IOSR Journal of Applied Chemistry (IOSR-JAC)
e-ISSN: 2278-5736.Volume 16, Issue 12 Ser. I (December 2023), PP 14-20
www.iosrjournals.org

Determination Of Toxic And Essential Mineral Elements In Geophagic Material Obtained In The Northern And Central Senatorial Districts Of Cross River State, Nigeria And The Estimation Of Potential Risks From Its Consumption

Idim, V. D.
Chemistry Department, University Of Cross River State, Calabar, Nigeria

ABSTRACT
The mineral element content of fifty five (55) samples of geophagic materials from the Northern and central senatorial districts of Cross River State, Nigeria, were determined by atomic absorption spectrophotometry. It was also set to determined if there is any significant difference in the presence of the mineral element in the same geophagic material samples. Independent sample t-test was used to test the hypothesis at 0.05 level of significance. The study revealed that there is statistically significant differences among most mineral elements determined in the geophagic materials obtained in both the Northern and Central Senatorial districts. The result of the mineral elements were also compared with the recommended dietary intake as well as the target hazard quotients (THQs) on consumption of about 80 g (normal consumption) or 300 g (addicts consumption)ofgeophagic material. Thus, the presence of cadmium, lead and iron of toxicological implication above the total target hazard quotient recommended safe limit on consumption of geophagic materials in the Northern and Central Senatorial districts of Cross River State, Nigeria calls for concern.

Key words: *Geophagic material, senatorial district, mineral elements, consumption.*

Date of Submission: 28-11-2023 Date of Acceptance: 08-12-2023

I. INTRODUCTION

Mineral elements are those essential and non-essential elements which occurs naturally in the earths crust. However, soil being a very dynamic component and displays variable, physico-chemical, mineralogical and geochemical properties may consequently affect the mean composition of the mineral elements present, since the amount and the nature of the mineral elements present varies based on locations (Kumari and Mohan, 2021). Thus, geophagic materials (soil, clay, calabash chalk etc) is a naturally occurring materials, essentially composed of fossilized seashells (Chinko*et al.,* 2022). The act of eating this geophagic material, including soil and clay is termed geophagy (Bonglaisin*et al.,* 2022). It is often found in rural areas or preindustrtial societies mostly among children and pregnant women for the purpose of preventing or managing morning sickness such as vomiting, over salivation and nausea (Ekosse*et al.,* 2021) it is found in different parts of the world, diverse names has been ascribed to it, such as La-craie or Argile, Nzu, Ndom, Mubele, Eko, Ebumba, Poto and Ulo (Abrahams *et al.,* 2013)/ these materials have been used for various purposes, such as facial masks, soaps, toothpaste, ceramics, light bulbs consmetic, barrier creams, paint, adsorbent in water and wastewater treatment (Alorabi*et al.,* 2021).

Furthermore, due to the desirable physical and chemical properties of clay minerals, clay have also been used in pharmaceutical formulations, lubricants, dessicants, disintegrants, diluents, binders, adsorption (Nyanksone*t al.,* 2020). Pigments, opacifiers and other vital uses such as emulsifying, thickening, isotonic and anticaking agents as well as catalyst, ion exchanges (Zou *et al.,* 2021) and decolorizing agents (Nyanksone*t al.,* 2020). The mean composition as well as the target hazard quotients of the mineral elements in geophagic materials had been reported by different authors Thus: Ghana (Abdul *et al.,* 2020), Mozambique (Bernar-do *et al.,* 2022).

Most of the studies showed that kaolin-based type of clay is another common geophagic material mostly consumed by pregnant women (Cellier*et al.,* 2023) and it contains numerous vital mineral elements for biological activities. There are little or no literature documentation on geophagic materials obtained from the Northern and Central Senatorial districts of Cross River State, Nigeria. Hence, this work aim at ascertaining the presence of toxic and essential mineral elements (potassium, lead, magnesium, iron and cadmium) and thehealth

risk (target hazard quotients) (THQ) associated with the consumption of geophagic materials from some of the selected markets from the Northern and Central Senatorial districts of Cross River State, Nigeria.

II. RESULTS

The data presented in table 1, 2 and figure 1 below show the results of the mineral elements determination in geophagic material samples obtained from the Northern and Central Senatorial districts of Cross River State, Nigeria.

Hypothesis 1: There is no significant difference in the presence of the mineral elements between the Northern and Central Senatorial districts of Cross River State.

Independent t-test was applied in testing these hypotheses at 0.05 level of significance. The results are presented in table 1.

Table 1: Mineral elements concentration in geophagic material from areas in Northern and Central senatorial districts of Cross River State, Nigeria (mg/kg) means; standard deviation

Elements	Ogoja	Yala	Bekwara	Obudu	Obanliku	Boki	Ikom	Etung	Obubra	Yakurr	Abi
Cadmium (Cd)	0.01±0.001	0.010±0.003	0.009±0.004	0.003±0.003	-0.004±0.002	-0.005±0.003	-0.007±0.002	-0.010±0.001	-0.013±0.001	-0.012±0.002	0.228±0.033
Lead (Pb)	0.021±0.002	0.018±0.004	0.019±0.002	0.012±0.002	0.009±0.003	0.007±0.003	0.012±0.006	0.011±0.005	0.008±0.003	0.008±0.004	0.066±0.004
Iron (Fe)	0.425±0.016	0.391±0.095	0.298±0.162	0.266±0.042	0.393±0.069	0.473±0.133	0.330±0.100	0.474±0.097	0.413±0.146	0.577±0.008	0.660±0.039
Potassium (K)	1.349±0.043	1.331±0.176	1.412±0.361	1.425±0.102	1.104±0.051	1.302±0.185	1.486±0.087	1.071±0.304	1.112±0.351	0.433±0.301	1.515±0.063
Magnesium (Mg)	0.278±0.107	0.357±0.263	0.367±0.129	0.283±0.038	0.335±0.110	0.272±0.138	0.365±0.094	0.290±0.073	0.546±0.513	0.361±0.350	0.158±0.028
Calcium (Ca)	0.003±0.001	0.003±0.001	0.003±0.000	0.003±0.001	0.003±0.001	0.008±0.003	0.001±0.001	0.005±0.001	0.001±0.003	0.001±0.001	0.002±0.001

Mean ± Standard deviation

Table 2: Independent t-text analysis of difference in geophagic materials between the Northern and Central senatorial districts of Cross River State, Nigeria

Metal	Senatorial district	Means	Std. Dev.	t-value	p-value
Cadmium (Cd)	Northern senatorial district	1.388	0.201	2.246	0.029
	Central senatorial district	1.174	0.440		
Lead (Pb)	Northern senatorial district	0.355	0.120	-4.010*	0.000
	Central senatorial district	0.498	0.141		
Iron (Fe)	Northern senatorial district	0.003	0.001	-4.684*	0.000
	Central senatorial district	0.006	0.003		
Potassium (K)	Northern senatorial district	0.324	0.127	-0.602	0.550
	Central senatorial district	0.365	0.322		
Magnesium (Mg)	Northern senatorial district	0.006	0.007	1.302	0.198
	Central senatorial district	0.001	0.021		
Calcium (Ca)	Northern senatorial district	0.016	0.006	-0.664	0.509
	Central senatorial district	0.019	0.022		

* Significant at 0.05 ($p<0.05$)

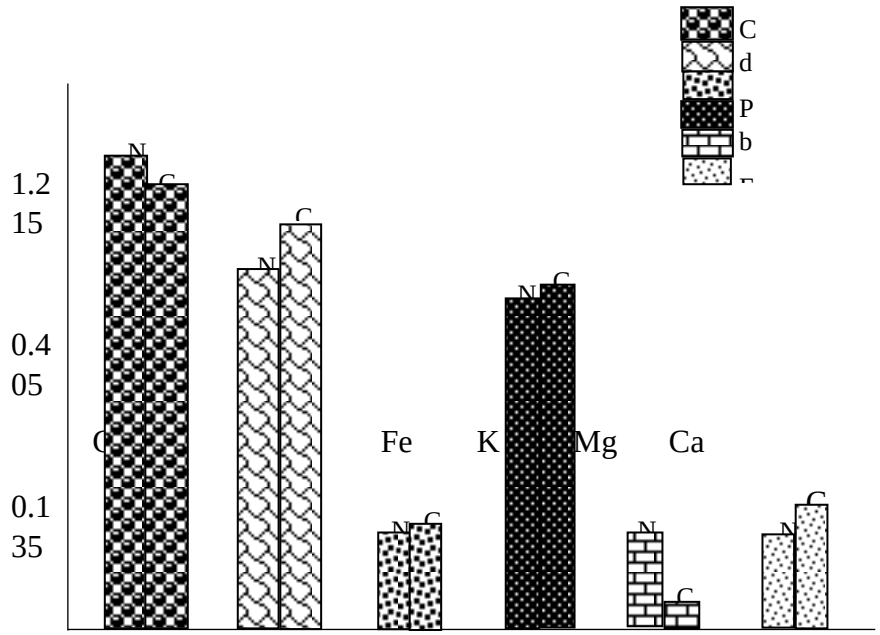

Figure 1: Mean metal concentrations (mg/kg) of geophagic material in Northern (N) and Central (C) Senatorial districts of Cross River State, Nigeria

The results of the independent t-test comparison of the mineral elements in geophagic materials between the Northern and Central Senatorial districts of Cross River State, Nigeria is presented in table 2. However, this study is to determine if there is any significant difference in these mineral elements in geophagic material between the senatorial districts (Northern and Central Senatorial districts).

III. DISCUSSION

The results obtained from the determination of mineral elements in geophagic material samples from the Northern and Central Senatorial districts of Cross River State, Nigeria as shown in table 2 showed that the mean concentration of cadmium in geophagic material samples from the Northern Senatorial district (1.388) is higher than that of the Central Senatorial district (1.174). The p-value of 0.029 is less than the chosen level of significance (0.05). Thus, the null hypothesis was rejected. This means that there is a significant difference in the presence of cadmium between the two senatorial districts.

It terms of lead (Pb), independent t-test was used to test the hypothesis at 0.05 level of significance. The result showed that the p-value (0.000) associated with the computed t-value (-4.010) is less than the chosen level of significance (0.05), hence, the null hypothesis was rejected; meaning that the presence of lead (Pb) mineral differs significantly between the two senatorial districts.

In terms of potassium (K), the p-value (0.550) is greater than the chosen level of significance (0.05). Hence, the null hypothesis was retained; meaning that potassium presence is not significantly different between the two senatorial districts.

Independent t-test analysis of difference in the presence of iron (Fe) between the Northern and Central Senatorial districts of Cross River State showed that the p-value (0.000) associated with the computed t-value (-4.684) is less than the chosen level of significant (0.05). Therefore, the null hypothesis is rejected. This implies that iron (Fe) presence differs significantly between the two Senatorial districts.

The results of the t-test analysis of difference in the presence of magnesium showed that the p-value (0.198) is greater than the chosen level of significance (0.05). Thus, the null hypothesis is retained. This means that there is no significant difference in the presence of magnesium between the two senatorial districts.

The mean concentration of calcium in geophagic, material samples from the central senatorial district (0.019) is higher than that of the Northern Senatorial district (0.016) as depicted in figure 1. The p-value associated with the computed t-value (-0.664) is less than the chosen level of significance (0.05), hence, the null hypothesis was rejected; meaning that the presence of calcium (Ca) mineral differs significantly between the two senatorial districts (Northern and Central Senatorial districts).

Cadmium (Cd) is highly toxic non-essential mineral element to physiological and biochemical functions (Genchi*et al.,* 2020). It is accumulated in environment by industrial pollution which is responsible for soil contamination. Therefore, soil consumed by pregnant women contains substances that are toxins (Bonglaisin*et al.,* 2022). Thus, the toxicity of non-essential heavy metals depends on factors such as absorbed dose, the route of exposure and duration of exposure. In other words, in acute or chronic condition, non-essential mineral elements consumed by pregnant women may possibly affect the intelligence quotient (IQ) of the foetus (Guo*et al.,* 2020). It was further reported that, clay contained pathogenic micro-organisms which can cause gastrointestinal infections, cancer etc so may not be safe for consumption (Kortei*et al.,* 2019). Similarly, it was reported that the consumption of geophagic material can potentially reduce the absorption of already bioavailable nutrients (Nnorom, 2016). However, the mean concentration of cadmium in the two senatorial districts already mentioned above were higher than the recommended daily intake of 0.0001 mg/day by regulatory agency for toxic substances and disease (Wong *et al.,*2022).

Lead (Pb) is also regarded as toxic trace element which is not essential for both human and animal health (He *et al.,* 2020). However, the mean concentration of lead (Pb) was higher in central senatorial district (0.498±0.141 mg/kg) than Northern Senatorial district with corresponding value of 0.355±0.120 mg/kg. However, the mean concentration of lead (Pb) in the two senatorial districts were higher than the recommended daily intake of 0.00016 mg/kg by Food and drug administration (Wong *et al.,* 2022), but below the values 3.0±0.8 mg/kg reported by Nnorom (2016). Toxic mineral elements has deleterious effects even at low concentration (Demir*et al.,* 2020). Furthermore, there is no threshold value for the level of lead (Pb) present in the blood which its concentration can be consideredsafe, this is because, even at a lower level of lead (Pb), once ingested has the potential to bioaccumulate in tissues and organs of the body thereby preventing biochemical processes in that body (Yebpella*et al.,* 2017). Therefore, elevated levels of lead (Pb) in pregnancy have been associated with gestational hypertension, spontaneous abortion, low birth weight and impaired neurodevelopment (Olajide-kayode*et al.,* 2023).

Nevertheless, chronic exposure to lead (Pb) can pose various negative health effects including mental retardation, paralysis, muscular weakness, brain damage, kidney damage and even death (Lar *et al.,*2015).

Iron (Fe) is one of the vital elements for the maintenance of healthy life, for example, it's a component of haemoglobin in blood which help in transporting oxygen from the lungs to different parts of the body and it

helps in storing of oxygen in muscle cell in myoglobin. It is also essential for growth, healing, immune function and synthesis of DNA (Puig*et al.,* 2017). However, the mean content of iron (Fe) in the two senatorial districts were below the value of 18 mg/day recommended by the food and drug administration (Koubova*et al.,* 2018). Nevertheless, the result of iron (Fe) content indicated that this mineral elements in the two senatorial districts compared to the recommended daily intake (RDI) can be of health benefit.

Furthermore, the result of Potassium (K) concentration showed that the mean concentration of Potassium (K) was higher in geophagic materials samples obtained from the central senatorial district (0.365±0.322mg/kg) than that of Northern senatorial district with corresponding value of 0.324±0.127 mg/kg.

Potassium (K) is a very important element for the proper functioning of all cells, tissues and organs in the body. Its promote normal rate of heart beat and also maintains fluid and electrolyte balance in the body. Potassium also plays an important role in keeping the body hydrated and work with sodium to support cellular function with the body system (Adrogue and Madias, 2014).

A deficiency in potassium can lead to muscle cramps, fatigue, constipation, weight gain, irritability, blood pressure problems, nausea, arthritis etc. (O'shaughnessy, 2006). The current recommended dietary intake for male and female adults is 4,700 mg/day (Cogswell *et al.,* 2012).

However, based on the Food and Nutrition center of the institute of medicine, the recommended daily intake of potassium is: infants 0-12 months: 400-700 mg/day, children 1-8 years 3060-3,800 mg/day, Teenager 9-18 years: 4,500-4,700 mg/day, Adults: 19 years and above, men and women: 4,700 mg/day, pregnant women/nursing mothers 5,100 mg/day (Perazella, 2000).

According to the above recommended dietary intake of potassium by the food and nutrition center of the institute of medicine, the result of the potassium content as highlighted implies that, this mineral elements in geophagic materials from the two senatorial districts will serve as vital element for the proper functioning of the cells, tissues and organs in human body. Magnesium content of the two senatorial districts were also determined. However, the results showed that the Northern senatorial district have the higher mean concentration of 0.006±0.007 mg/kg while the central senatorial district have 0.001±0.021 mg/kg. Magnesium is also one of the essential mineral elements which have several important functions to include, the regulation of blood pressure and blood glucose, protein synthesis, muscle and nerve function (Rude *et al.,* 2010). Deficiency of magnesium causes loss of appetite, nausea, fatigue, weakness, numbness, muscle contractions and cramps, scizures, abnormal heart rhythms etc (Rude *et al.,* 2010). However, the recommended dietary intake of magnesium is: 1-3 years 80 mg/day, 4-8 years 130 mg/day, 9-13 years 240 mg/day, 14-18 (men) 410 mg/day, 360 mg/day (female), 400 mg/day (pregnant mothers), 360 mg/day (nursing mothers), Adults:19-30 years (men) 400 mg/day, 19-30 years (female) 310 mg/day, 30 years and above, men 420 mg/day, women 320 mg/day, pregnant women 19-30 years 350 mg/day, nursing mothers 19-30 years 310 mg/day, pregnant women 30 years and above 360 mg/day, nursing mothers 30 years and above 320 mg/day (Food and Drug Administration, 2016). The result of magnesium content in the geophagic material samples obtained from the two senatorial districts can be of health benefit.

Calcium is a very important element for proper regulation of muscle contractions and heart beat, its helps in building strong bones and teeth. However, lack of calcium causes rickets in children and osteomalacia or osteoporosis in later life (Chibuzor*et al.,* 2020).

The acceptable dietary daily intake of calcium is: infant 0-6 months (breastfed) approximately 210 mg/day, infant 0-6 months (formula fed) 350 mg/day, 7-12 months 270 mg/day, 1-3 years 500 mg/day, 4-8 years 700 mg/day, 9-11 years 1,000 mg/day, 12-18 years 1,300 mg/day, women 19-50 years 1,000 mg/day, 51-70 years 1,300 mg/day, while men 19-70 years 1,000 mg/day, 71 years and above 1,300 mg/day (Food and Nutrition Board, 1997). The result of calcium content compared to the recommended dietary intake showed that this mineral element in the calabash chalk samples from the two senatorial districts can equally be of health benefit.

POTENTIAL RISKS FROM CONSUMPTION OF GEOPHAGIC MATERIAL

The associated risks posed by heavy metals on consumption of calabash chalk was assessed by calculating the target hazard quotient (THOs). The result showed that on the consumption of about 80 g of geophagic material obtained from Northern senatorial district, Cadmium (Cd) (1.59) and Iron (Fe) (4.90) were higher than the World Health Organization (W.H.O) safe limit of 1 for food. Similarly, on the consumption of about 80 g of geophagic material obtained from the Central senatorial district, Cadmium (Cd) was (1.34) and Iron (Fe) (9.80). These were also above the limit of 1, which are therefore considered not safe for human health. While Lead (Pb) from Northern senatorial district is (0.12) and that of Central senatorial districts is (0.16) which is below the permissible limit of 1, indicating little or no health risk for consumers of a maximum of 80 g of geophagic material. However, for those who are addicts of geophagic material in the Northern senatorial district, who consumes up to 300 g, the Target Harzard Quotients (THQ) of Cadmium (Cd) is (5.95) and Iron (Fe) is (1.84), signified potential health risks. And for those who are addicts of geophagic material in Central senatorial

district, who consume up to 300 g, the THQ of Cadmium (Cd) is (5.03) and Iron (Fe) is (3.67) which also signified potential health risks. While Lead (Pb) from Northern senatorial district is (0.44) and Central senatorial district is (0.61), that is below the WHO acceptable limit of 1, indicating little or no health risks for consumers. The above information showed that, total target hazard quotient (TTHQ) for both normal and addicted consumers of geophagic material from both the Northern and Central senatorial districts can be of adverse health effect because of the presence of these heavy metals which have the potential tobioaccumlate in essential organs in human body like kidney, liver, blood and bones as well as other animals once ingested it (Yebpella*et al.,* 2017). Concequently, this may also causes physiological, biochemical and abnormal behaviour in humans (Matoric*et al.,* 2015).

IV. CONCLUSION

The results of this study showed that geophagic materials obtained from both the Northern and Central senatorial distracts of Cross River State Nigeria, could be good sources of essential mineral elements (K, Mg, Fe and Ca) analyzed, which are naturally occurring inorganic elements required as essential nutrients by organisms to maintain optimal health. However, the presence of the toxic elements (Cd and Pb) with the mean concentrations higher than the FAO/WHO safe limit for food is a cause for concern. Furthermore, the TTHQ signified health threat to both normal and addicted consumers of geophagic material from the Northern and Central senatorial districts because the toxic elements have the potential to bioaccumulate in vital organs in the body like kidney, liver, bones and blood which consequently pose adverse health effect. However, this will be a means of advice in other to educate the public on the health implications of geophagic material consumption and also this result could serve as a database or basis to which future research work could be compared.

REFERENCES

[1]. Abdul, Rasheed, M., Arhim, Emmanuel And Arihin Jnr, Atta A. (2021). Mineralogy And Geochemistry Of Geophagic Materials At Mfensi-Adankwame In The Ashanti Region Of Ghana And Possible Health Implications, Geology, Ecology And Landscapes Doi:10.1080/24739508.2021.1952775.

[2]. Abrahams, Peter W., Davies, Theo C., Solomon, Abive O., Trow, Amanda J. And Wraggtoanna (2013). Human Geophagia, Calabash Chalk And Undongo: Mineral Element Nutritional Implications 8(1):E53304 Doi:10.1371/Journal.Pane.0053304.

[3]. Adroque, H. J. And Madias, N. E. (2014). The Impacts Of Sodium And Potassium On Hypertension Risk. Seminnephro. 34(3):257-272.

[4]. Alorabi, Ali O., Hassan, Mallickshamshi., Alam, Mohammad Manboob., Zabin, Sami A., Alsenani, Nawaf I. And Baghdadi, Neazaressam (2021). Natural Clay As A Low-Cost Adsorbent For Crystal Violet Dye Removal And Antimicrobial Activity. Nanomaterials (Baset). 11(11):2789 Doi:10.3390/Nano11112789

[5]. Bernardo, Bernardino., Candeias Carla And Rocha, Fernando (2022). Geophagic Materials Characterization And Potential Impact On Human Health: The Case Study Of Maputo City (Mozambique). Environmental Geochemistry And Medical Geology, 12(10):4832 Https://Doi.Org/10.3390/App12104832.

[6]. Bonglaisin, Julius Nsawir., Kunsoan, Noellabajia., Bonny, Patience., Matchawe, Chelea., Tata, Bridget Ndakoh., Nkeunen, Gerard And Mbofung Carl Moses (2022). Geophagin: Benefits And Potential Toxicity To Human – A Review. Front Public Health 10:893831 Doi:10.3389/Fpubh.2022.89381

[7]. Cellier, Morgane; Lecot, Jeremy; Morin, Emilie; Deguigne, Marie; Lelievre, Benedicte(2023). Risk Of Addictive Clay Or Kaolin Consumption In Pregnant Women: Three Cases Reports. Toxicologiesanalytique Et Clinique, 35(3):249-254. Doi:10.16/J-Totac.2022.12.004chal-04228360.

[8]. Chibuzor, M. T., Graham-Kalio, D., Osaji, J. O. And Meremikwu, M. M. (2020). Vitamin D, Calcium For The Treatment Of Nutritional Rickets In Children. Cochrane Database Syst Rev. 17:4(4):Cd012581. Doi:10.1002/14651858.Cd012581.Pub2.

[9]. Chinko, Bruno C., Amah-Tariah, Fortunes., Ekenna, Ifeoma And Okpa, Oghomena A. (2022). Evaluation Of The Effects Of Calabash Chalk On The Haematological Profile Of Wistar Rats 14(3). Doi: Https://Doi.Org/10.55779/Nsb14311281

[10]. Cogswell, M. C., Zhang, Z., Cariquiry, A. I. (2012). Sodium And Potassium Intakes Among Us Adults: Nhanes 2003-2008. Am. J. Clin. Nur. 96(3):647-657.

[11]. Demir, Funda., Kipcak, Azmiseyhun., Ozdemir, Ozguldere And Derun, Emekmoroydor (2020). Determination Of Essential And Non-Essential Element Concentrations And Health Risk Assessment Of Some Commercial Fruit Juices In Turkey. Journal Food Science Technol, 57(12):4432-4442 Doi:10.1007/S13197-020-04480-9.

[12]. Ekosse, Georges-Ivo., Nkeng, George Elambo; Bukalo, Nenita And Oyebanjo, Olaomipekun (2021). Geophagic Clays From Cameroon: Prevenance, Metal Contamination And Health Risk Assessment. Int. J. Environ. Res Public Health, 18(16):8315 Doi:10.3390/Ijerph18168315.

[13]. Food And Drug Administration (Fda) (2016). Revision Of The Nutrition And Supplement Facts Labels. Fda, Hhs. Fed Rest. Pmid:27236871

[14]. Genchi, Giuseppe., Sinicropi, Maria Stefania., Lauria, Graziantonio., Carocci, Alessia And Cataiang, Alessia (2020). The Effects Of Cadmium Toxicity.Int. J. Environ. Res. Public Health, 17(11):3782 Https:Doi.Org/10.3390/Ijerph17113782

[15]. Guo, J., Wu, C., Zhang, J., Qi, X, Lv, S., Jiang, S., Zhou T., Lu, D., Feng, C., Chang, X., Zhang, Y., Cao, Y., Wang, G. And Zhou, Z. (2020). Prenatal Exposure To Mixture Of Heavy Metals, Pesticides And Phenols And Iq In Children At 7 Years Of Age: The Smbcs Study. Environment International 139:105692 Doi: 10.1016/J.Envint.2020.105692.

[16]. He, Honghua., Wang, Xio., Wu, Miaomiao., Guo, Lei., Fan, Chenbin And Peng, Qi. (20200. Cadmium And Lead Affect The Status Of Mineral Nutrients In Alfalfa Grown On A Calcareous Soil. Soil Science And Plant Nutrition 66(3):506-514. Https://Doi.Org/10.1080/00390768.2020.1747362.
[17]. Institute Of Medicine. Dietary Reference Intakes For Calcium, Phosphorus, Magnesium, Vitamin D And Fluoride. Food And Nutrition Board, National Academy Of Sciences; The National Academy Press; Washington Dc, Usa: 1997.
[18]. Kortei, N. K., Annor, I. A., Aboagye, G., Manaphraim, N. Y. B., Koryo-Debrah, A., Essuman, E. K., Alidu, H. W., Tettey, C. O. And Awadzi, B. (2019). Elemental Minerals And Michrobial Compositions As Well As Knowledge And Perceptions Regarding Kaolin (Clay) Consumption By Pregnant Women In The Ho Municipality Of Ghana. Pan African Med. J. 34(113). Doi:10.11604/Pan:2019,34.17394.
[19]. Kumar, Neeraj And Mohan, Chandra (2021). Basics Of Clay Minerals And Their Characteristic Open Access Peer-Reviewed Chapter
Doi:10.5772/Intechopen.97672.
[20]. Koubova, E., Sumczynski, D., Senkarova, L., Orsavova, J. And Fisera, M. (2018). Dietary Intakes Of Minerals, Essential And Toxic Trace Elements For Adults From Enagrostis Ref L.: A Nutritional Assessment Nutrients. 10(4):479. Doi:10.3390/Nu10040479.
[21]. Lar, U. A., Agene, J. I., Umar, A. I. (2015). Geophagic Clay Materials From Nigeria: A Potential Source Of Heavy Metals And Human Health Implications In Mostly Women And Children Who Practice It. Environ. Geochem. Health. Environmental Geochemistry And Health, 37, 363.
[22]. Matovic, V. A., Buha, D. D. And Bulat, Z. (2015). Insight Into The Oxidative Stress Induced By Lead And/Or Cadmium In Blood, Liver And Kidney. "Food And Chemical Toxicology", 78:130-140.
[23]. Nnorom, I. C. (2016). Major And Minor Elements Of Calabash Chalk (Nzu) From Abia State, Nigeria: Evaluation Of Potential Intake Benefits And Risks. Toxicological Environmental Chemistry, 98(2):149-166.
[24]. Nyankson, Emmanuel; Mensah, R. Q., Kumafle, L., Gblerkpor, W. N., Aboagye, S. O., Asimeng, B. O. And Tiburu, E. K., Alshamaileh, E. (Reviewing Editor) (2020). Dual Application Of Natural Clay Material-Blue Dye, Cogent Chemistry 6:1 Doi: 10.1080/23312009.2020.1788291,
[25]. O' Shaughnessy, K. M. (2006). Role Of Diet In Hypertension Management. Curr. Hypertens Rep. 8(4):292-7.