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Analysis and Estimated Daily Dose Intake of Toxic Metals in Commonly Used Building Materials and Its Health Impacts on the Society in Lagos, Southwest Nigeria

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***Abstract**: Toxic metals are persistent in our environment, and building materials are not left over from the contaminations of these metals. These toxic metals posed a great threat to human health. Some of these heavy metals such as lead have been identified as a potential human carcinogen, causing lung cancer. This study is on commonly used building materials and identifications of selected toxic metals present therein and their health implications to our society. The most commonly used building materials are asbestos, red bricks, pasters of paris (POP) and paints from major manufacturers. The samples of these building materials were collected from point of sales and toxic metals such as: Pb, Zn, Cu and Co were identified and quantified. Using Atomic Absorption Spectrophotometer (AAS) model S4 series, Model (GBC 906) (USA) for the analysis of the samples. The Estimated Daily Dose Intake (EDDI) of the detected toxic metals was computed. EDDI from POP due to Pb, Cu and Zn are 1.390x10^{-5}, 1.812 x10^{-6} and 1.482 x10^{-5} mg/Kg/day respectively. For the paints, EDDI from paints are for Pb, Cu and Co are 9.900 x10^{-5}, -1.156 x10^{-5} and 3.990 x10^{-5} mg/kg/day respectively. However; in red bricks the EDDI obtained are Pb, Cu and Zn are 1.844 x10^{-5}, 8.711 x10^{-6}, and 3.159 x10^{-5} mg/kg/day respectively. The EDDI from the Asbestos due to Cu was 1.578 x10^{-6} and 4.061 x10^{-5} mg/kg/day. EDDI in POP are as follows Pb, Cu and Zn, 1.396 x10^{-5}, 2.990 x10^{-5} and 9.519 x10^{-6} mg/kg/day respectively. The ICRP has a set minimum permissible daily dose for each of the heavy metals however, the results so obtained in this study show that the Pb EDDI in Paints is 1.567 x10^{-4} mg/kg/day.*

Keywords: Toxic metals, Building materials, radiation effect, Radiation dose, Cancer, Radiation Exposure

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1.0 Introduction

Metallic elements are of particular toxicological importance. Many metallic elements play an essential role in the function of living organisms; they constitute a nutritional requirement and fulfill a physiological role. However, the overabundance of the essential trace elements and particularly their substitution by non-essential ones, such as Co, Pb, Cr, Ni, Zn, Cu, etc., can cause toxicity symptoms or death. Most human exposure to heavy metals is from both natural sources and man-made sources. Man-made sources (such as agrochemicals (fertilizers, fungicides, etc), industrial waste, the plume from industries and automobiles, and waste from the locality) of heavy metals (e.g. Co, Pb, Cr, Ni, Zn, Cu) released into our environment have been identified by various research works. Heavy metal ions pollution from man-made sources can easily create local conditions of elevated metal presence, which could lead to disastrous effects; and thus affects several individuals worldwide posing a serious threat to the health of millions of people. The environmental impact of heavy metals contaminations has been largely documented around the world (Tchounwou *et al*., 2018). The presence of radionuclides in the environment is partially due to natural processes and anthropogenic sources (Fernandes et al., 2000; Beavington et al., 2004), but is mostly the result of accumulated industrial wastes (Khillare et al., 2004; Al-Masri et al., 2006) . Heavy metal contaminated building materials could aggravate human health risks when inhaled or ingested into the human body. In addition to building materials health risks, there is also the risk of potential levels of heavy metals entering the food chain via absorption by crops from contaminated soil and water. Also, ingestions of radioactive heavy metals by cattle grazing on contaminated soil and plants may aggravate human health risks when beef from these cattle find their way to market. Several numbers of research works have suggested that there is a higher probability that heavy metals contaminations in building materials may accumulate in humans, either directly or indirectly by inhalation, ingestion as a result of hand-to mouth activity or via dermal contact absorption (Al-Rahji, et al., 1996; Molhave et al., 2002). Children can easily ingest soil or dust particles from building materials unintentionally since they spend most of their time outdoors and much of this time is spent in contact with floors, engaging in mouthing of hands, toys and other objects, or the consumption of food contaminated by hands (MohdTahir et al., 2007)

The total intakes and uptakes of lead expected from all sources are 29.5 and 12.5 mg/d, respectively, for children and 63.7 and 6.7 mg/d, respectively, for adults in urban areas (WHO report 1987) . The relative contribution of water to average intake is estimated to be 9.8% and 11.3% for children and adults, respectively. Lead can be absorbed by the body through inhalation, ingestion, dermal contact (mainly as a result of occupational exposure), or transfer via the placenta. In adults, approximately 10% of ingested lead is absorbed into the body. Young children absorb from 40% to 53% of lead ingested from food. Once the lead is absorbed, it enters either a ”rapid turnover” biological pool with distribution to the soft tissues (blood, liver, lung, spleen, kidney, and bone marrow) or a “slow turnover” pool with distribution mainly to the skeleton(Rabinowitz et al., 1976) . The symptoms of acute lead poisoning are headache, irritability, abdominal pain and various symptoms related to the nervous system. Lead encephalopathy is characterized by sleeplessness and restlessness. The various health effects of heavy metal contaminations in the human metabolic system vary from one heavy metal to another and the amount of bioaccumulation of these metals. Highly poisonous arsenic is widely distributed in nature and occurs in the form of inorganic or organic compounds. Uranium occurs in the mammalian body in soluble form only as tetravalent uranium or hexavalent uranium in uranyl complexes. Both hexavalent and tetravalent uranium form complexes with carbonate ions and proteins in the body. Oxidation of tetravalent uranium to hexavalent uranium is likely to occur in the organism. Absorption of uranium salts may occur by inhalation or by ingestion; 95% of uranium retained in the body is deposited in bone. Excretion is mainly via the kidney. As all uranium isotopes are radioactive, the hazards of a high intake of uranium are twofold: chemical toxicity and radiological damage. There is no evidence that uranium has any metabolic function in the mammalian organism. The acute oral lethal dose of cadmium for humans has not been established; it has been estimated to be several hundred milligrams(Gleason., 1969) . Doses low as 15 – 30 mg from acidic foodstuffs stored in cadmium-lined containers have resulted in acute gastroenteritis (WHO report., 1974)]. The consumption of fluids containing 13–15 mg of cadmium per liter by humans has caused vomiting and gastrointestinal cramps. Acute cadmium poisoning has occurred following exposure to fumes during the melting or pouring of cadmium metal (WHO report., 1974) . Dose limits for radiation exposure, from artificial sources, for the public have been issued by the International Commission on Radiological Protection (ICRP), and have been set at 1 mSv per year.

2.0 Materials and Methods

In Lagos, southwest of Nigeria, most of the building materials were mostly imported with few locally made ones. There are several building material sales points, but the major markets; apart from the local manufacturer can be located in Mushin, Idi-Magbo area and Oshodi. Therefore these locations were selected randomly for the sample collections. For the red bricks we have to contact the major red bricks maker locally in their respective locations around the South-west of Nigeria.

Samples of the selected building materials of interest were collected; and were transferred into sterile sample bottles, labeled and kept for digestion. Digestion of samples was done using aqua-regia solution. Each sample weighing 1g, each of the wet samples were transferred into a beaker of 100ml high pressure vessel. Agua-ragia of ratio 1ml of HNO_3 and 3ml HCL was added to the sample in the beaker cleaned with 10% HNO_3 and rinsed with deionized water. The mixture was heated to 100℃ on a hot plate until the solute dissolved completely. A brownish poisonous gas is released during the process. The solution is heated until it gets to a 5 ml point on the beaker. The solution is allowed to cool. The solutions were filtered through Whitman No.1 filter papers into a pre-cleaned beaker to remove the particulates in the solution. The solution is then transferred into a 50 ml volumetric flask and diluted with distilled water to make up different concentrations. The concentrations of the selected heavy metals were determined by atomic absorption spectrometry (AAS) with a detection limit of 0.001ppm. The values of the heavy metal concentrations in the samples were calculated on dry weights. Measurement was performed for each of the triplicates of building material samples. The accuracy of the instrumental methods and the precision of the results of the sample were checked by measuring triplicate. The average mean concentration of each sample was calculated by using an appropriate graph.

3.0 Results and Discussion

The results obtained were analyzed for each of the different heavy metals in the selected building materials. The motivation for the selection of these building materials was because they are commonly used in and around Lagos Metropolis. The asbestos is used commonly as roofing plate and both internally and externally in the majority of the buildings (residential, offices and workplaces) in Lagos where the majority of the citizens spend most of their time every day. Mean Pb estimated daily dose intake (EDDI) from the two types of Asbestos are 4.562 $x10^{-7}$ mg/kg/day and $5.141x10^{-5}$; Cu the mean EDDI was detected as 1.578 $x10^{-5}$ and 4.061 $x10^{-5}$ mg/kg/day and the mean EDDI obtained or Zn is 2.185 $x10^{-4}$ mg/kg/day respectively. The Zn mean EDDI is the highest in the Asbestos while the Pb mean EDDI is the lowest in this material. However, the comparisons between EDDI in each of the heavy metals in the Asbestos have been obtained. Fig. 1 shows the results as obtained for the asbestos.

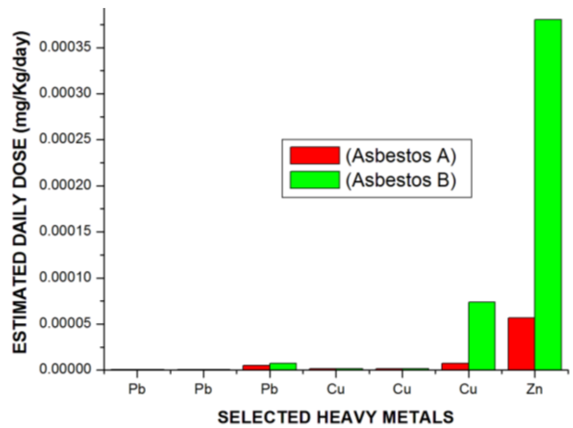

Fig. 1: Estimated daily dose from Asbestos of different make.

Asbestos type B has EDDI of about 3.805 $x10^{-4}$ mg/kg/day from the Zn while type A EDDI is 5.657 $x10^{-7}$ mg/kg/day. The Cu daily dose intake of type B is of about 7.401 $x10^{-5}$ mg/kg/day. The Pb daily dose level is very low compared to that of the other heavy metals.

Red bricks samples were collected from the two major Red bricks (S and B) producers in Lagos and the mean EDDI have been obtained as follows from producer A for Pb, Cu and Zn 1.844 $x10^{-5}$, 8.711 $x10^{-6}$, 3.159 $x10^{-5}$mg/kg/day respectively while for producer B 1.651 $x10^{-5}$, 4.325 $x10^{-6}$ and 1.359 $x10^{-9}$ mg/kg/day for Pb, Cu and Zn respectively.

The estimated daily dose intake has been computed and compared from these producers. The EDDI obtained from the two Red bricks producers is has illustrated in Fig 2, producer A contains the highest EDDI from Pb, Cu and Zn which are 1.844 $x10^{-4}$, 8.711 $x10^{-6}$ and 3.156 $x10^{-5}$ mg/kg/day respectively while that obtained from producer B Red bricks are $1.651x10^{-5}$, $4.325x10^{-6}$ and 1.358 $x10^{-5}$ mg/kg/day for Pb, Cu and Zn respectively as shown in Fig. 2.

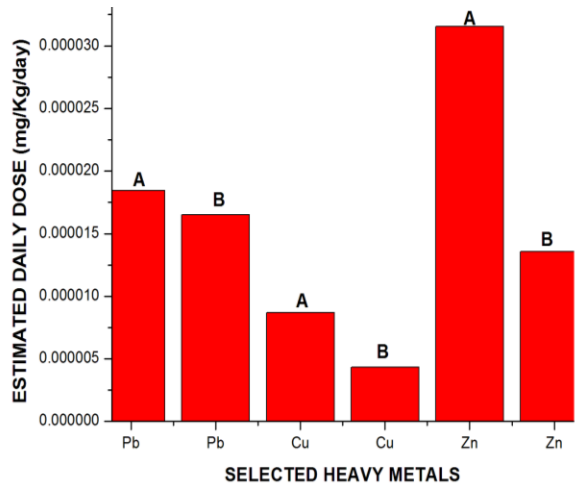

Fig. 2: EDDI from Red Bricks of producer A and B

There were many paints producers in Lagos but paints samples were collected from the two major paints producers in Lagos for both the commercial and residential uses and these paint samples were grouped according to the producers as S or B. However, the paints used in this research study are Gloss and Emulsion paints are commonly used. The EDDI from producer B obtained are as follows for Pb, Cu and Co are 9.900 $x10^{-5}$, -1.156 $x10^{-5}$ and 3.990 $x10^{-6}$ mg/kg/day respectively. While for the second producer S, obtained mean EDDI were for Pb, Cu and Co are 3.044 $x10^{-5}$, -7.116 $x10^{-6}$ and 3.331 $x10^{-6}$ mg/kg/day. From producer B, Gloss has the highest EDDI in Pb while both Emulsion and Gloss have the lowest EDDI from both Gloss and Emulsion from producer B of the paints. Cu was found to be below the detectable limit of the equipment used for analyzes see Fig. 3.

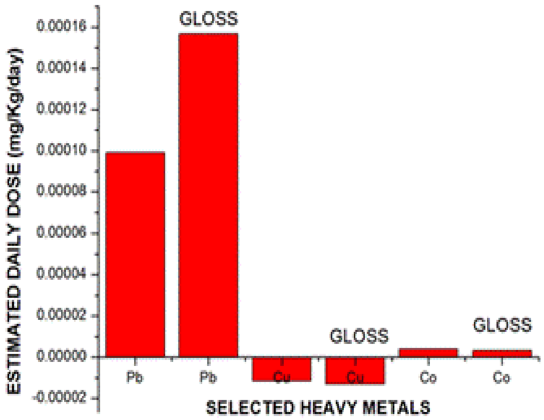

Fig. 3: EDDI obtained from the two major types of paints produced.

Producer S has the highest EDDI obtained from Co and the second highest from the Pb both from the paint type Gloss from this producer. Emulsion has obtained EDDI lower than that of the Gloss from this paints producer S. In comparing the EDDI from this two major paints producer S and B obtained results is as illustrated in Fig. 4.

Plaster of Paris (POP) is usually imported to the country and the manufacturers are from several companies from different countries, nevertheless, these materials found its way to a common marketing point in and around Lagos. Plaster of Paris are generally used for both the residential and work place buildings, therefore it's of interest for this study. The heavy metal EDDI in POP are as follows Pb, Cu and Zn, 1.396 x10^{-5}, 2.990 x10^{-6} and 9.519 x10^{-6} mg/kg/day respectively. Therefore, the EDDI from POP due to Pb, Cu and Zn are 1.390 x10^{-5}, 1.812 x10^{-6} and 1.482 x10^{-5} mg/Kg/day respectively and the second samples of POP from the second points of sales have the EDDI results as for Pb, Cu and Zn are 1.079E-05, 2.990 x10^{-6} and 9.518 x10^{-6} mg/kg/day.

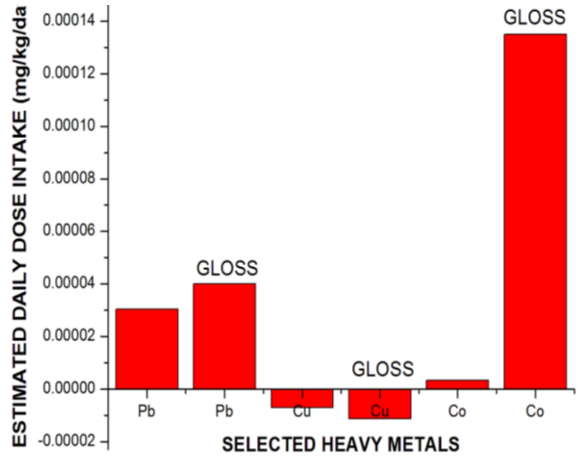

Fig. 4: Comparing the EDDI obtained from the two major types of paints produced.

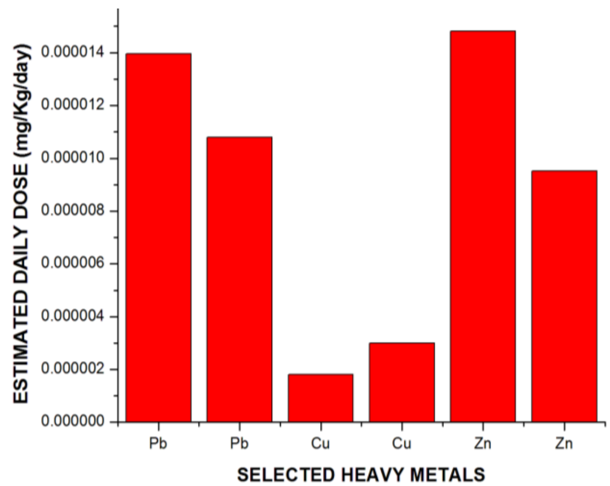

Fig. 5: Estimated daily dose intake from the use of Plaster of Paris.

The health Impacts of Pb, Co, Zn, and Cu on our society today our very enormous as reported by various studies on toxic metals around the world by the scientific community. Lead absorption may be influenced by factors such as age and physiological status, nevertheless; the greatest percentage of lead is taken into the kidney, followed by the liver and the other soft tissues such as the heart and brain, and the skeleton represents the major body fraction (Flora *et al*., 2006). The nervous system is the most vulnerable target of lead poisoning.

Headache, poor attention span, irritability, loss of memory and dullness are the early symptoms of the effects of lead exposure on the central nervous system (CDC report, 2001). Lead is the most systemic toxicant that affects several organs in the body including the kidneys, liver, central nervous system, hematopoietic system, endocrine system, and reproductive system (ATSDR report., 1999) . Lead exposure usually results from lead in deteriorating household paints, lead in the workplace, lead in crystals and ceramic containers that leach into water and food, lead use in hobbies, and lead use in some traditional medicines and cosmetics (CDC report., 1991). The carcinogenic potential of cobalt and its compounds were evaluated by IARC in 1991, which concluded that there was inadequate evidence for carcinogenicity in humans (lung cancer) but sufficient evidence in experimental animals(Lison et al., 2001) .

Copper intake varies greatly for individuals depending on food choices and dietary customs, as well as environmental factors. Most diets contain enough Cu (1-5 mg) to prevent a deficiency and not enough to cause toxicity. It can result in brain damage, liver failure, or death if it is not treated. Normally, your liver gets rid of extra copper by sending it out in bile. Disruptions in the homeostasis of Cu is associated with tissue damage and several diseases(Bleackley et al., 2011) Chronic Cu toxicity in the form of liver cirrhosis and damage to other organs is seen in genetic abnormality of Cu metabolism (Wilson’s disease) and the presumed environmental disorder Indian Childhood Cirrhosis (ICC) (Pandit et al., 1996). Cu has also been implicated in the pathogenesis of such common neurodegenerative diseases Alzheimer's, Parkinson’ and Huntington’s diseases as well as amyotrophic lateral sclerosis.

There are three major routes of entry for zinc into the human body; by inhalation, through the skin, or by ingestion (Toxicological Profile for Zinc, 2005) . Inhalation of zinc-containing smoke generally originates from industrial processes like galvanization, primarily affecting manufacturing workers. Ingestion was caused by the moderately acidic nature of the food or drink, enabling the removal of sufficient zinc from the galvanized coating. The resulting symptoms included nausea and vomiting, epigastric pain, abdominal cramps, and diarrhea (Brown *et al*., 1964). The obtained results of the Estimated Daily Dose Intake (EDDI) from the samples of the selected building materials and the detectable heavy metals shows that the EDDI from POP due to Pb, Cu and Zn are $1.390x10^{-5}$, $1.812x10^{-6}$ and $1.482x10^{-5}$ mg/kg/day respectively for the first sample while for the second samples of POP (different manufacturer) have the EDDI results as for Pb, Cu and Zn are 1.079 $x10^{-5}$, 2.990 $x10^{-6}$ and 9.518 $x10^{-6}$ mg/kg/day. For the paint type, EDDI from producer B obtained are as follows for Pb, Cu and Co are 9.900 $x10^{-5}$, -1.156 $x10^{-5}$ and 3.990 $x10^{-6}$ mg/kg/day respectively. While for the second paint producer S, obtained EDDI for Pb, Cu and Co are 3.044 $x10^{-5}$, -7.116 $x10^{-6}$ and $3.331x10^{-6}$ mg/kg/day respectively. From producer B of paint type; Gloss has the highest EDDI in Pb while both paints type Emulsion and Gloss have the lowest EDDI from producer B of the paints. Cu was found to be below the detectable limit of the equipment used for analyzes. But for the Red bricks samples collected from the two major Red bricks (S and B) producers in Lagos, the EDDI obtained from producer A for Pb, Cu and Zn are 1.844 $x10^{-5}$, 8.711 $x10^{-6}$, 3.159 $x10^{-5}$ mg/kg/day respectively, while for producer B 1.651E-05, 4.325 $x10^{-6}$ and 1.359 $x10^{-9}$ mg/kg/day for Pb, Cu and Zn respectively. The EDDI from producer A contains the highest EDDI from Pb, Cu and Zn which are 1.844 $x10^{-6}$, 8.711 $x10^{-6}$ and 3.156 $x10^{-5}$ mg/kg/day respectively while that obtained from producer B Red bricks are 1.651 $x10^{-5}$, 4.325 $x10^{-6}$ and 1.358 $x10^{-5}$ mg/kg/day for Pb, Cu and Zn respectively.

5.0 Conclusion

Zn is required by the human body system, However, excessive concentration of zinc in the human body becomes very dangerous. Zinc Recommended Dietary Allowance (RDA) for adults is 11 mg/day for men and 8 mg for women. Pregnancy and lactation require slightly more at 11 mg and 12 mg, respectively. The Tolerable Upper Intake Level is the maximum daily intake unlikely to cause harmful effects on health www.hsph.harvard.edu.) . Pb estimated daily dose intake (EDDI) from the two types of Asbestos are 4.562 $x10^{-7}$ mg/kg/day and 5.141 $x10^{-7}$; while Cu the EDDI detected was 1.578 $x10^{-6}$ and 4.061 $x10^{-5}$ mg/kg/day then; the EDDI obtained or Zn is 2.185 $x10^{-4}$ mg/kg/day respectively. The Zn as heavy has EDDI the highest in the Asbestos while the Pb EDDI is the lowest in this material. Copper Recommended Dietary Allowance for median intake of copper from food in the United States is approximately 1.0 to 1.6 mg/day for adult men and women. The Tolerable Upper Intake Level for adults is 10 mg/day, a value based on protection from liver damage as the critical adverse effect (www.ncbi.nlm.nih.gov/books). In the case of lead, FDA recommended Dietary Allowance for RDA is 3µg per day and 12.5 µg per day for children and adults respectively; while cobalt the RDA is 5 - 50 µg/day for men and women. However; ICRP has a set minimum permissible daily dose for each of the heavy metals however, the results so obtained in this study show that the Pb EDDI in Paints is $1.567x10^{-4}$ mg/kg/day. The bio-cumulative effects at this level of EDDI per year are very dangerous. Also from the other samples, Zn is 3.804 $x10^{-4}$ mg/kg/day.

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Consent for publication

Not Applicable.

Availability of data and materials

The publisher has the right to make the data public.

Competing interests

The authors declared no conflict of interest. This work was carried out in collaboration among all authors.

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Authors' contributions

Dr. Ogungbemi did sampling, data collection and analysis and draft of the paper. Dr. Adedokun did data analysis. Dr. Ibitoye did data collection and first prove reading, while Dr Oyebola carried out prove reading of the paper and Prof. Ojo finalized the paper corrections. Dr. Owoade carried out sampling treatment and data collection.