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Research Article

Heavy Metal Distribution in Soils and Health Implications: An Appraisal of Umuahia Metropolis, Nigeria.

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ABSTRACT

The distribution of heavy metals in soils of Umuahia metropolis was investigated. This became necessary as the total content of heavy metals informs the available or extractable content, which is of interest to man's health safety. The distribution of total lead (Pb), nickel (Ni), copper (Cu), iron (Fe) and manganese (Mn) in five representative surface soil samples in the metropolis was studied.

The total contents of Pb and Mn were found to range from 30 to 580ppm and 199.8 to 792.9ppm respectively in the samples investigated. Cu and Fe were found to range from 213 to 411ppm and 34,100 to 45,416ppm respectively. No Ni was detected in the samples analyzed.

Comparison of the data obtained to those recorded in literature showed that the levels of lead and Copper were very high and exceeded the reported ranges. But Mn and Fe, although high, fell within the range reported in literature. Comparison was also done on safe levels to ascertain the extent of contamination or heavy metal status of the metropolis.

This is because the use of soil archives or data provides the opportunity to retrospectively analyze changes in soil properties and heavy metal status[1]; and also present the short and long term health implications arising from the contamination of plants, the food chain, ground water and ultimately man.
A review of the potential health risks of these metals in soils was done.

INTRODUCTION

Umuahia metropolis is the capital of Abia State, Nigeria. It is an ancient town replete with fast growing commercial and industrial enterprises. The composition of geological deposits determines the texture of the soil, while weathering and biological processes of soil formation determine how much of the original endowment of rocks remains in the soil that is formed. The geology of Umuahia metropolis is described as coastal plain sand. The site is 122m above sea level and the soils derived from semi-consolidated sand and sandy deposits[2].

Soil is the loose, broken up material on which plants grow. Soils derived from recent geological formation and sedimentations consist of an earlier cycle of weathering. The coastal plain areas have been developed from transported parent materials that were low in some element as a result of previous weathering. The coastal plain sands are coastal lowland soil formed on sandy sediments. They are strongly weathered[3].

Heavy metals are elements having a density greater than $5kg/m^3$ in their elemental form and comprise some 38 elements. However, the term usually refers to 12 elements which are used and discharged by industries. These are Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sn and Zn. Heavy metals mostly find specific adsorption sites in the soil where they are retained very strongly either on the inorganic or organic colloids[3, 4]. "Heavy metals" are chemical elements with a specific gravity that is at least 5 times the specific gravity of water. The specific gravity of water is 1 at 4°C (39°F). Simply stated, specific gravity is a measure of density of a given amount of a solid substance when it is compared to an equal amount of water. Some well-known toxic metallic elements with a specific gravity that is 5 or more times that of water are arsenic, 5.7; cadmium, 8.65; iron, 7.9; lead, 11.34; and mercury, 13.546[4].

Heavy metals are widely distributed in the environment, in soils, in plants and animal tissues. The concentration of individual metals in living tissues is ordinarily very low and must be maintained with narrow limit to permit the optimum biological performances of most organisms. Some heavy metals are essential in trace amounts viz Co, Cu. Fe, Mn, Mo, Zn for plants and in addition, Cr, Ni, Sn, for animals. Cd, Hg and Pb have not been found essential for either plants or animals. Heavy metals are present in all uncontaminated soils as the result of weathering from their parent materials (Table 2).

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Heavy metals tend to accumulate on the surface soils as these metals are readily bound by organic matter which is concentrated in surface or top soils. Organic – matter – bound heavy metals are readily available to plants. These pose a possible threat, with severe health implications to organisms in the food chain, especially man. There is a possible existence of a definite bearing between total and available contents[3, 4].This would constitute a great health safety indicator to safeguard against disastrous unleashing of heavy metals on man.

A lot of factors promote the concentration of heavy metals in surface or top soils. Heavy metal pollution can affect all environments but its effects are most long lasting in soils due to relatively strong adsorption of many metals onto the humic and clay colloids. The duration of contamination may be for hundreds or thousands of years in many cases depending on the soil type and their physical and chemical parameters[3,5].

Transfer coefficients, concentration of metal in the aerial portion of the plant relative to total concentration in the soil, are convenient ways of quantifying the relative differences in bioavailability of metals to plants. This is based on root uptake of metals. Foliar adsorption of atmospheric deposits on plant leaves also takes place. Cd, Tl and Zn have the highest transfer coefficients, which is a reflection of their relative low sorption in the soil. In contrast, Cu, Co, Cr and Pb have low coefficients because they are usually strongly bound to the soil colloids[6]. Flooded soils show higher bioavailability than well-aerated soils. Very acidic soils that are poorly drained often supply toxic quantities of Fe and Mn.

All metals except Mo are most soluble and bio-available at low pH and toxicity problems are likely to be more severe in acid environments. In the case of pollution by particles of sulfide ore minerals, the weathering of the sulfide exacerbates the problem by increasing the acidity of the soil.

In agricultural soils, the concentration of heavy metals may be significantly increased in many ways. The use of agricultural chemicals like fertilizers which are intended to fortify the soil for crops incidentally may add heavy metals to the soil. Compounds used to supply these elements (N,P,K) contain trace amounts of heavy metals as impurities which after continued fertilizer application may signicantly increase their content in the soil. Sludge is a useful and cheap source of N P K and may also improve the physical conditions of the soils, most times it contains some heavy metals which will accumulate in soils over the years especially when sludge from industrial areas is applied. Aerial emission from combustion of leaded petrol and application of farm slurries, especially those from piggery (because of $CuSO_4$ supplement) are other sources of heavy metal contamination of soils.

Comprehensive data on the levels of heavy metals in soils of Umuahia metropolis are not available. These data are useful for comparison with data from areas suspected to be contaminated

In this study effort was made to determine the level of some selected heavy metals in the metropolis. A comparison of the data obtained with other works done elsewhere and other information on safe levels of these metals was done to ascertain the heavy metal status of the metropolis[7, 8, 9,10, 11, 12]. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. Heavy metals may enter the human body through food, water, air, or absorption through the skin when they come in contact with humans in agriculture and in manufacturing, pharmaceutical, industrial, or residential settings. Industrial exposure accounts for a common route of exposure for adults. Ingestion is the most common route of exposure in children. Children may develop toxic levels from the normal hand-to-mouth activity of small children who come in contact with contaminated soil or by actually eating objects that are not food (dirt or paint chips). Less common routes of exposure are during a radiological procedure, from inappropriate dosing or monitoring during intravenous (parenteral) nutrition, from a broken thermometer, or from a suicide or homicide attempt[13, 14]. As a rule, acute poisoning is more likely to result from inhalation or skin contact of dust, fumes or vapors, or materials in the workplace. However, lesser levels of contamination may occur in residential settings, particularly in older homes with lead paint or old plumbing[13]. Heavy metal toxicity can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs. Long-term exposure may result in slowly progressing physical, muscular, and neurological degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis. Allergies are not uncommon and repeated long-term contact with some metals or their compounds may even cause cancer[13]. For some heavy metals, toxic levels can be just above the background concentrations naturally found in nature. Therefore, it is important for us to inform ourselves about the heavy metals and to take protective measures against excessive exposure. If unrecognized or inappropriately treated, toxicity can result in significant illness and reduced quality of life. For persons who suspect that they or someone in their household might have heavy metal toxicity, testing is essential. Appropriate conventional and natural medical procedures may need to be pursued.[14] The association of symptoms indicative of acute toxicity is not difficult to recognize because the symptoms are usually severe, rapid in onset, and associated with a known exposure or ingestion: cramping, nausea, and vomiting; pain; sweating; headaches; difficulty breathing; impaired cognitive, motor, and language skills; mania; and convulsions. The symptoms of toxicity resulting from chronic exposure (impaired cognitive, motor, and language skills; learning difficulties; nervousness and emotional instability; and insomnia, nausea, lethargy, and feeling ill) are also easily recognized; however, they are much more difficult to associate with their cause.

Symptoms of chronic exposure are very similar to symptoms of other health conditions and often develop slowly over months or even years. Sometimes the symptoms of chronic exposure actually abate from time to time, leading the person to postpone seeking treatment, thinking the symptoms are related to something else.[15]

In small quantities, certain heavy metals are nutritionally essential for a healthy life. Some of these are referred to as the trace elements (e.g., iron, copper, manganese, and zinc). These elements, or some form of them, are commonly found naturally in foodstuffs, in fruits and vegetables, and in commercially available multivitamin products[13]. Diagnostic medical applications include direct injection of gallium during radiological procedures, dosing with chromium in parenteral nutrition mixtures, and the use of lead as a radiation shield around x-ray equipment[16]. Heavy metals are also common in industrial applications such as in the manufacture of pesticides, batteries, alloys, electroplated metal parts, textile dyes, steel, and so forth[13]. Many of these products are in our homes and actually add to our quality of life when properly used. Lead accounts for most of the cases of pediatric heavy metal poisoning. It is a very soft metal and was used in pipes, drains, and soldering materials for many years. Millions of homes built before 1940 still contain lead (e.g., in painted surfaces), leading to chronic exposure from weathering, flaking, chalking, and dust. Every year, industry produces about 2.5 million tons of lead throughout the world. Most of this lead is used for batteries. The remainder is used for cable coverings, plumbing, ammunition, and fuel additives. Other uses are as paint pigments and in PVC plastics, x-ray shielding, crystal glass production, and pesticides. Target organs are the bones, brain, blood, kidneys, and thyroid gland[13, 16, 17]. Acute exposure to lead is also more likely to occur in the workplace, particularly in manufacturing processes that include the use of lead (e.g., where batteries are manufactured or lead is recycled). Even printing ink, gasoline, and fertilizer contain lead. Symptoms include abdominal pain, convulsions, hypertension, renal dysfunction, loss of appetite, fatigue, and sleeplessness. Other symptoms are hallucinations, headache, numbness, arthritis, and vertigo. Chronic exposure to lead may result in birth defects, mental retardation, autism, psychosis, allergies, dyslexia, hyperactivity, weight loss, shaky hands, muscular weakness, and paralysis (beginning in the forearms). Children are particularly sensitive to lead (absorbing as much as 50% of the ingested dose) and are prone to ingesting lead because they chew on painted surfaces and eat products not intended for human consumption (e.g., hobby paints, cosmetics, hair colorings with lead-based pigments, and even playground dirt). In addition to the symptoms found in acute lead exposure, symptoms of chronic lead exposure could be allergies, arthritis, autism, colic, hyperactivity, mood swings, nausea, numbness, lack of concentration, seizures, and weight loss. Ingestion accounts for most of the toxic effects of iron because iron is absorbed rapidly in the gastrointestinal tract. The corrosive nature of iron seems to further increase the absorption. Most overdoses appear to be the result of children mistaking red-coated ferrous sulfate tablets or adult multivitamin preparations for candy. (Fatalities from overdoses have decreased significantly with the introduction of child-proof packaging. In recent years, blister packaging and the requirement that containers with 250 mg or more of iron have child-proof bottle caps have helped reduce accidental ingestion and overdose of iron tablets by children.) Other sources of iron are drinking water, iron pipes, and cookware. Target organs are the liver, cardiovascular system, and kidneys[16]. It is very important to note that treatment regimens vary significantly and are tailored to each specific individual's medical condition and the circumstance of their exposure. Providing a complete history of the person, including their occupation, hobbies, recreational activities, and environment, is critical in diagnosing heavy metal toxicity. A possible history of ingestion often facilitates a diagnosis, particularly in children. Findings from physical examinations vary with the age of the person, health status of the person, amount or form of the substance, and time since exposure (absorption rate)[15]. Allopathic (conventional) and alternative medicine practitioners (and naturopathic practitioners to a lesser extent) treat heavy metal toxicity. Once toxicity is confirmed, all cases (even suspected) of heavy metal toxicity should be brought to the attention of a professional who is experienced in diagnosing and treating poisoning. Often professionals consult with regional poison control centers or medical toxicologists for added expertise. Emergency room personnel and first responders are trained in recognizing symptoms and in proper handling, decontamination, and treatment techniques in acute exposure cases[18]. Conventional and alternative medical treatment includes chelation therapy, supportive care (intravecsnous fluids, cardiac stabilization, exchange transfusion, dialysis), and decontamination (charcoal, catharti, emesis, gastric lavage, surgery). These procedures typically require hospitalization or treatment in a health care or clinical setting. Follow-up is required with laboratory testing until reference levels are within and remain in the normal range, particularly when the exposure was acute or if the person continues to have symptoms after treatment[18]. Additionally, if there is a suspected homicidal or suicidal association, proper medical and legal resources should be involved. Medical personnel should report exposures to the appropriate agency to prevent additional public health risks either in the workplace or in the home[13, 18].

MATERIALS AND METHODS

Perchloric acid ($HClO_4$) 72%, Hydrofluoric acid (HF) 48% concentrated Hydrochloric acid (HCl), concentrated Nitric acid (HNO_3); deionized water. Sieve (2mm & Imm). Agate mortar, Oven, Hot plate, Teflon crucible (100mI), Fume cupboard, weighing device, Atomic absorption spectrophotometer, etc

Soil samples were collected from surface soil (0 – 10cm) from randomly selected sites in the metropolis.

Soil Digestion for Total Content Analysis.

The representative soil samples collected were air-dried and stored in polythene bags. About 100g each of the air-dried soil samples was crushed and made to pass through a 2mm sieve. 20g of the soil was obtained from the sieved sample by crush sieving, mixing and quartering. This was made to pass through a 1mm sieve by grinding in an agate mortar. The sample was dried in an oven at 100^{o}c and then cooled in a desiccator.

0.5g of the oven-dried sample was accurately weighed into a 100ml Teflon crucible. The soil was then moistened with 1ml deionized water and 10ml of 48% HF acid and 5ml of concentrated HNO_3 acid were added. 3ml of 72% $HClO_4$ acid was added after about 5 minutes. The crucible and the contents were heated on a hot plate, in a fume cupboard, first at about 100^{0}c and then gradually to about 200^{0}c until excess HF and silica were driven off. Another 1ml of deionized water and 2 drops of $HCl0_4$ were added to ensure complete removal of the HF and silica. The content was then heated to dryness. The crucible was allowed to cool and then 5ml each of concentrated HCl acid and deionized water were added. The solution formed was brought to boiling and the clear solution obtained was cooled and transferred and made up to mark with de-ionized water in a 100ml flask or beaker.

Standard concentrations of the various elements intended for analysis were prepared – with digital atomic absorption spectrophotometer there is an internal mode calibration. The instrument was adjusted to zero with ionized water and later adjusted to read the concentration of the standard of the elements being determined. Thus, the concentration of Cu, Fe, Mn, Ni and Pb in each solution was analyzed with atomic absorption spectrophotometer[20, 21].

Table 1: Concentration is μgg^{-1} (ppm)

LOCATION	Cu	Fe	Mn	Pb	Ni
1	213.4	35,433	699.4	50	ND
2	253.4	34,100	792.8	220	ND
3	411.0	45,416	647.2	300	ND
4	404.4	36,633	485.6	580	ND
5	284.4	36,800	199.8	30	ND

RESULTS AND DISCUSSIONS

TOTAL COPPER

Total copper was found to range from 213.4 to 411.0ppm (Table 1) with an average of 313.3ppm.

A general range of 2 – 100ppm has been reported [22], 10 – 200ppm for mineral soils in USA[23], 11 – 175ppm with an average of 56ppm for West Indian soils[7] and 1.6 – 140ppm for soils of Western Nigeria. A comparison with values in Table 3 and Table 4 showed that the level of copper in the soils of the metropolis is high. This high value could be traceable to either high organic matter or high clay content prevalent in these soils. Copper found in soils occur mainly as the corresponding ion Cu^{2+} either adsorbed by clay mineral or tied up with organic matter. Furthermore, copper displays little mobility within the soil and hence tend to accumulate in the surface soil than in subsoil.

TOTAL IRON

Total iron was found to range from 34,100 – 45,416ppm with an average value of 37,676ppm. Reported ranges are 200 – 100,000ppm (typical), 8000 – 105,00ppm with an average of 41,000ppm in Western Nigerian basement complex. In most profiles the total Fe seemed to follow the same distribution pattern as the clay content with the profile[24]. The values obtained for Fe are high but compared favorably with literature[24].

TOTAL MANGANESE

Total Mn was found to range from 199.8-792,8ppm with an average of 564.ppm. The reported ranges are 60 – 1780 with an average of 550ppm in the basement complex of Western Nigeria[7],76- 1635ppm for alluvial soils of Southern Vietnam and Thailand[8]. Total Mn decreases with increasing depth down the soil profile.

TOTAL LEAD

Total Pb was found to range from 30 – 580ppm with an average of 236ppm. A comparison with tables I and 3 showed that these values exceeded test requirement. The low level recorded in sample 1 (Table 1) is traceable to erosion while the low values in sample 5 (Table 1) is traceable to the fact that it is a spare part market and what is predominant are discarded used metal parts. A Comparison with the values from Table 4 showed that the average value obtained for Pb was lower for agricultural, residential and industrial soils values. This means that these are not yet polluted[7, 8, 9, 10, 11, 12].

TOTAL NICKEL

This was not detected in the samples collected and analyzed. The reason for this seem elusive. As it is,it can be said that the soils of Umuahia metropolis is free of nickel.

CONCLUSION

Soils derived from recent geological formation and sedimentations consist of an earlier cycle of weathering. The coastal plain areas have been developed from transported parent materials that were low in some elements as a result of previous weathering. Thus the level of the total content of heavy metal in the soils of the metropolis ought to be low due to their heavily weathered state. But the contrary was the case, in most

Table 2[7, 8, 9, 10]: Concentration is μgg^{-1} (ppm)

METAL	LITHOSPHERE	TYPICAL	SOIL ORIGIN	PLANT
Cd	0.2	0.06	0.01-0.7	0.2-0.8
Co	40	8	1-40	0.05-0.5
Cr	200	100	5-3000	0.2-1.0
Cu	70	20	2-100	4-15
Fe	50000	38000	700-550000	140
Hg	0.5	0.03	0.01-0.3	0.015
Mn	1000	850	100-4,000	15-100
Mo	2.3	2	0.2-5	1-10
Ni	100	40	10-1000	1
Pb	60	10	2-200	1-10
Sn	40	10	2-200	0.3
Zn	80	50	10-200	8-100

of the cases. The high levels of total content of heavy metals in the sois of the metropolis, although within safe levels in most of the cases investigated, are indicative of the fact that heavy metal pollution is imminent or may result in the near future if not now.

Table 4[12]: Soil concentration reference in μgg^{-1} (ppm)

METAL	BACKGROUND	AGRICULTURAL	RESIDENTIAL	INDUSTRIAL
Cu	30	150	100	500
Ni	25	375	500	1000
Pb	20	150	100	500

In order to forestall the ugly consequence of heavy metals in the soils of the metropolis; there is need to define principles, establish strategies, set up of administrative procedures, enforce compliance and penalties for non-compliance using appropriate laws and proper waste management and disposal.

Furthermore, the land use policy should be such that areas suspected to be high in heavy metals be set apart for industrial sites and areas with far tolerable limits for agricultural and residential uses.

In conclusion, safety is the driving force for man's continued existence, if the soils are unsafe for plants and animals and ultimately man, then our existence is in jeopardy, and possible risk of impairment and un-bargained death may become rife. Heavy metal toxicity has been reported in many places with attendant great devastating effects. In order to guarantee health safety in the metropolis, a knowledge of the distribution of heavy metals is expedient. This will enable the control of factros that seem to promote the total and extractable contents of these soils and ultimately control the fraction that is ingested by man. This will raise awareness and stimulate acquisition of remedies and preparedness in handling cases of heavy metal contamination, toxicity and poisoning.

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Table 3[11]: Soil concentration reference in μgg^{-1} (ppm)

METAL	REFERENCE	TEST REQUIREMENTS	INTERVENTION VALUE	TARGETS FOR SOILS
Cu	50	100	500	36
Ni	50	100	500	35
Pb	50	150	600	85

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