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Health Risk Assessment of Heavy Metals in Swampy Agricultural Soils in Nasarawa West, Nigeria

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Abstract
In this study, the health risk caused by heavy metals in swampy agricultural soil of Nasarawa west was assessed. A total of 50 soil samples from five local government of Nasarawa west (10 from each) were collected and analyzed for Asernic (As), Lead (Pb), Cadmium (Cd), Nikel (Ni) and Zinc (Zn) present in the samples using XRF Spectrometry at Center for Energy Research and Development (CERD) in Obafemi Awolowo University, Ile lfe. Osun State, Nigeria. Measured concentrations of these heavy metals were then used to calculate the health risk for adults and children. The result show that the concentrations are in the order of Ni> Cd> Zn>Pb>As which are all below the permissible level except for As which appear to be higher than the permissible levels. The Hazard Index (HI) of all the pathways for adults and children were found to be 1.55 and 12.19 respectively. These values are greater than 1 which is the tolerance level for both adults and children. These makes non- carcinogenic effects significant to the adult's population and pose serious non- carcinogenic effect on children in those areas. The carcinogenic risk values were found to be both higher than acceptable values. This implies that there is a probability that 1 adult in about 10,000 may be affected.

Keywords: XRF spectrometry, heavy metals, average daily intake, carcinogenic risk, non-carcinogenic risk.

INTRODUCTION
The accumulation of heavy metals in swampy agricultural soils is of increasing concern because of food safety issues, potential health risks, and its detrimental effects on soil ecosystem (Cui *et al.*, 2004). Hg, Pb, Cd and Cr are of great concern due to their toxicity to human health and other organism, whereas Zn and Cu are essential elements for plants and human (Na et *al*., 2007; Musa *et al,* 2017). Heavy metals can accumulate in the soil at toxic levels due to the long-term application of wastewater. Heavy metals are extremely persistent in the environment which is non -biodegradable and non-thermo degradable, thus they readily accumulate to toxic levels (Rajesh *et al*., 2007).

Vegetable plants take up Hg, Pb, Cd, Zn, and Cu and accumulate them in their edible and inedible parts with various concentrations. One important dietary uptake pathway could be through crops irrigated with contaminated waste, when the capacity of the soil to retain heavy metals is reduced due to repeated use of wastewater, soil can release heavy metals into the ground water or soil solution available for plant uptake (Rajesh *et al*., 2007). Rajesh *et al*. (2007) identified important sources of heavy metals in wastewater as urban and industrial effluents, deterioration of sewage pipe and treatment works, and the wear of household plumbing fixtures while Mapanda *et al*., (2005) identified other sources of contamination of agricultural soil as sewage sludge, fertilizers, and pesticides. Rajesh *et al*., (2006) further

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stated that the concentrations of heavy metals in soil, crops and water are compared with established safe limits. This provides a basis for guiding further activities aimed at preventing excessive exposure of toxic substances (heavy metals) to human beings. This can be done through monitoring and control of irrigation water and/or amelioration of uptake by crops (Musa *et al*., 2017).

Some metals are essential to life and play irreplaceable roles as sources of vitamins, and minerals in the functioning of body organs. All living organisms require varying amounts of metals, but become toxic at higher concentrations (Lane & Morel, 2009). Other metals have no useful role in the human physiology. Examples of such elements are arsenic, lead and mercury. They may be toxic even at low levels of exposure. Once absorbed by the body, heavy metals continue to accumulate in vital organs like the brain, liver, bones, and kidneys, for years or decades causing serious health consequences (Katata, 2011). Arsenic, lead and mercury are the first, second and third hazards on the priority list of heavy metal pollutants as designated by the United States Agency for Toxic Substances and Disease Registry (Agency for Toxic Substances and Disease Registry, 2007).

Arsenic, for instance, is regarded a human carcinogen from extremely low levels of exposure (Agency for Toxic Substances and Disease Registry, 1999).

Acute exposure to arsenic compounds may cause nausea, vomiting, abdominal pain, muscle cramps and diarrhoea (National Research Council, 1999) while chronic exposure is associated with peripheral nerve damage causing diabetes (United Nation Environmental Programme, 2002). Pb on the other hand, is regarded as a human mutagen and probable carcinogen (Podsiki, 2008). It induces renal tumours, and also disturbs the normal functioning of kidneys, joints, reproductive and nervous systems (Ogwuegbu & Muhanga, 2005).

The acute ingestion of inorganic Hg potentially causes gastrointestinal disorders, diarrhoea, and haemorrhage (United Nation Environmental Programme, 2002). Repeated and prolonged exposure may seriously affect the kidneys, liver and skin. Cd is known to be toxic even at low concentrations and is also regarded as a probablecarcinogen. Severe exposure to Cd may result in pulmonary effects such as bronchiolitis, emphysema, and alveolitis (Kabata, 2011). Cd can also result in bone fracture, kidney dysfunction, hypertension and even cancer (Khan *et al*, 2013). Arthritis, diabetes, anaemia, cardiovascular disease, cirrhosis, reduced fertility, headaches and strokes are some of its odd long term effects.

Whereas chromium (III) is an essential element, chromium (VI) compounds are known to be mutagenic and carcinogenic. Breathing high levels of chromium (VI) may cause asthma and shortness of breath. Long term exposure may cause damage to the liver and kidneys (Caspah, 2016). Ni on the other hand is known to cause cancer, both oral and intestinal. It also causes depression, heart attacks, haemorrhages and kidney problems (National Research Council, 1999). Excessive intake of Zn and Cu may cause non-carcinogenic effects on human health, even though they are essential to human life (Cao *et al*., 2010). Cu surplus had been associated with liver damage while Zn may cause impairment of growth and reproduction (Nolan, 2003; Caspah, 2016).

The aim of this study is to assess the health risk of heavy metals in swampy agricultural soil of Nasarawa west, Nigeria. This was achieved by comparing the concentration of heavy metals in the swampy soil with WHO guideline and hence estimate the carcinogenic and non-carcinogenic risk for both adults and children in the areas.

MATERIALS AND METHOD

Study Area

This research work centered on Nasarawa West which consist of five Local Government Areas, Karu, Keffi, Kokona, Nasarawa and Toto. In Nasarawa West, soils are found along the flood plains which are always swampy in nature due to availability of water all the year round. The forest soils are rich in humus and laterite soils. They are found in most parts of the state and very good for crop production. Nasarawa West has arable land for commercial farming, fishery development, wild life and forestry conservation. Agriculture therefore, is the backbone of the economy because majority of the populace are involved in subsistence farming.

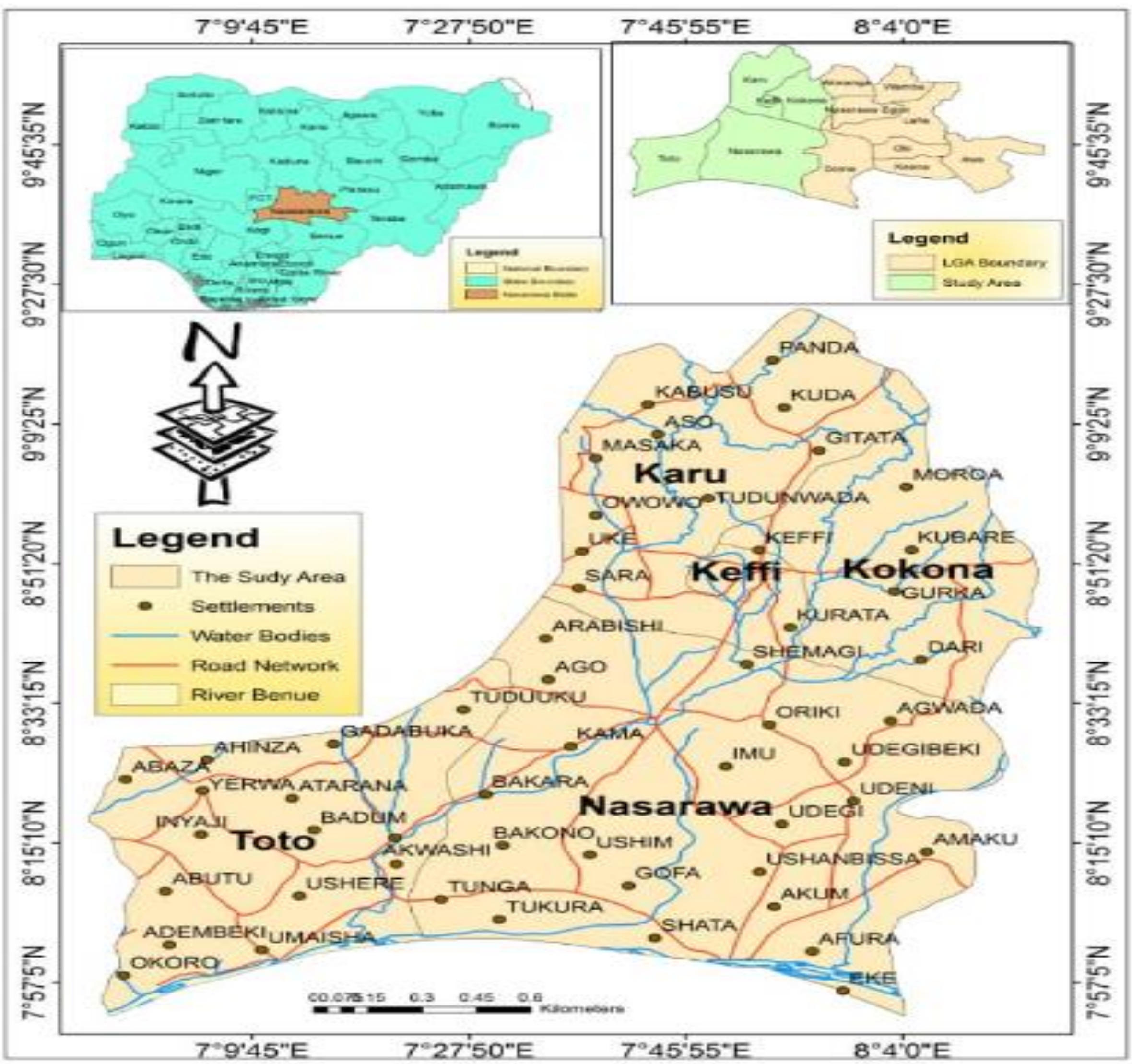

Figure 1. Study Area

Soil Samples Preparation

The swampy agricultural soil samples collected from rice plantation across Nasarawa west were air dried under ambient temperature, grinded, using agate pestle and mortar, and allowed to pass through 2.0mm sieved, packaged properly in a paper bag and labeled with code numbers for easy identification. The soil samples were then taken to Center for Energy Research and Development, Obafemi Awolowo University, Ile lfe. Osun State, Nigeria for XRF elemental analyses.

Method of Data Analysis

Concentrations of elements as analyzed by the X-Ray Florescence Spectrometric Analysis which has its unit in weight percent (w.t.%) were coded in an excel software package in other to generate the result in $mg.kg^{-1}$. The unit of the raw data in weight percent (wt%) were converted into milligram per kilogram ($mg.kg^{-1}$)by multiplying the values in wt% by 10,000 (1ppm or $1mg.kg^{-1}$ = 10,000 wt%)as the world standard acceptable unit for soil analysis (WHO, 2000).

HEALTH RISK ASSESEMENT

The potential exposure pathways for heavy metals in contaminated soils are calculated based on recommendations by several U.S Environmental protection Agency (U.S.EPA, 2015). ADI (mg/kg-day) for the different pathways were calculated using the following exposure Equations (1)–(3) as prescribed by (U.S. EPA, 1989)

The ingestion of Heavy Metals through Soil (ADI_{ing}), Inhalation of Heavy Metals via Soil Particulates (ADI_{inh}), and Dermal Contact with Soil (ADI_{dems}) are given in equation (1), (2), and (3) respectively.

$$ADI_{ing} = \frac{CxIRxEFxEDxCF}{BWxAT} \quad (1)$$

where ADI_{ing} is the average daily intake of heavy metals ingested from soil in mg/kg-day, C is the concentration of heavy metal in mg/kg for soil. IR in mg/day is the ingestion rate, EF in days/year is the exposure frequency, ED is the exposure duration in years, BW is the body weight of the exposed individual in kg, AT is the time period over which the dose is averaged in days. CF is the conversion factor in kg/mg.

$$ADI_{inh} = \frac{C_s xIR_{air} xEFxED}{BWxATxPEF} \quad (2)$$

where $ADI_{inh}$is the average daily intake of heavy metals inhaled from soil in mg/kg-day, CS is the concentration of heavy metal in soil in mg/kg, IR_{air} is the inhalation rate in m^3/day, PEF, is the particulate emission factor in m^3/kg. EF, ED, BW and AT are as defined earlier in Equation (1).

$$ADI_{dems} = \frac{C_S xSAxFExAFxABSxEFxEDxCF}{BWxAT} \quad (3)$$

Where ADI_{dems} is the exposure dose via dermal contact in mg/kg/day. CSis the concentration of heavy metal in soil in mg/kg, SA is exposed skin area in cm^2, FE is the fraction of the dermal exposure ratio to soil, AF is the soil adherence factor in mg/cm^2, ABS is the fraction of the applied dose absorbed across the skin. EF, ED, BW, CF and AT are as defined earlier in

Equation (1). Table 1 shows the exposure parameters used for the health risk assessment for standard residential exposure scenario through different exposure pathways.

Table 1. Exposure parameter used for the health risk assessment through different exposure pathways for soil (DEA, 2010).

Parameter	Unit	Child	Adult
Body weight (BW)	Kg	15	70
Exposure frequency (EF)	Days/ years	350	350
Exposure duration (ED)	Years	6	30
Ingestion rate (IR)	mg/ day	200	100
Inhalation rate (IR_{air})	m^3/ day	10	20
Skin surface area (SA)	cm^2	2100	5800
Soil adherence factor (AF)	mg/ cm^2	0.2	0.07
Dermal absorption factor (ABS)	None	0.1	0.1
Dermal exposure ratio (FE)	None	0.61	0.61
Particulate emission factor (PEF)	m^3/ kg	1.3×10^9	1.3×10^9
Conversion factor (CF)	kg/ mg	10^{-6}	10^{-6}
Average time (AT) for carcinogens	Days	365 x 70	365 x 70
Average time (AT) for non- carcinogens	Days	365 x ED	365 x ED

Non- Carcinogenic Risk Assessment

Non-carcinogenic hazards are characterized by a term called hazard quotient (HQ). HQ is a unitless number that is expressed as the probability of an individual suffering an adverse effect. It is defined as the quotient of ADI or dose divided by the toxicity threshold value, which is referred to as the chronic reference dose (RfD) in mg/kg-day of a specific heavy metal as shown in Equation (4);

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

For n number of heavy metals, the non-carcinogenic effect to the population is as a result of the summation of all the HQs due to individual heavy metals. This is considered to be another term called the Hazard Index (HI) as described by USEPA document (U.S. EPA, 1989; Caspah, 2016). Equation (5) shows the mathematical representation of this parameter:

$$HI = \sum_{k=1}^{n} HQ_k = \sum_{k=1}^{n} \frac{ADI_k}{RfD_k} \quad (5)$$

where HQ_k,$ADI_k$and $RfD_k$are values of heavy metal k. If the HI value is less than one, the exposed population is unlikely to experience adverse health effects. If the HI value exceeds one, then there may be concern for potential non-carcinogenic effects (U.S. EPA, 1989; Caspah, 2016).

Carcinogenic Risk Assessment

For carcinogens, the risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. The equation for calculating the excess lifetime cancer risk is:

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

where Risk is a unitless probability of an individual developing cancer over a lifetime. ADI_k

(mg/kg/day) and CSF_k(mg/kg/day)$^{-1}$are the average daily intake and the cancer slope factor, respectively for the kth heavy metal, for n number of heavy metals. The slope factor converts the estimated daily intake of the heavy metal averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer(U.S. Environmental Protection Agency, 1989; Caspah, 2016).

The total excess lifetime cancer risk for an individual is finally calculated from the average contribution of the individual heavy metals for all the pathways using the following equation:

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

where $Risk_{(ing)}$, $Risk_{(inh)}$, and $Risk_{(dermal)}$are risks contributions through ingestion, inhalation and dermal pathways.
Both non-carcinogenic and carcinogenic risk assessment of heavy metals are calculated using RfDand CSF values derived largely from the Department of Environmental Affairs (South Africa) and USEPA as shown in Table 2.

Table 2. Reference doses (RfD) and Cancer Slope Factors (CSF) for the different heavy metals (Caspah, 2016; DEA, 2010 & U.S.EPA, 1991).

Heavy metal	OraRfD	Dermal RfD	Inhalation RfD	Oral CSF	Dermal CSF	Inhalation CSF
As	$3.0x10^{-4}$	$3.0x10^{-4}$	$3.0x10^{-4}$	1.5	1.5	15
Pb	$3.6x10^{-3}$	-	-	$8.5x10^{-3}$	-	4.2 x 10-2
Cd	$5.0x10^{-4}$	$5.0x10^{-4}$	$5.7x10^{-5}$	-	-	6.3
Ni	$2.0x10^{-2}$	$5.6x10^{-3}$	-	-	-	-
Zn	$3.0x10^{-1}$	$7.5x10^{-2}$	-	-	-	-

RESULTS AND DISCUSSION

Concentrations of Heavy Metals in Swampy Soil of Nasarawa west.

Average concentrations of heavy metals in mg.kg^{-1} from swampy soil of Nasarawa west area are presented in Table 3. The Average Daily Intake (ADI) for carcinogenic and non-carcinogenic risk assessment was calculated from the values of concentrations of heavy metals in swampy agricultural soil.

The presented results showed that the mean concentrations of the heavy metals in swampy soil from Nasarawa west varied significantly and decreased in the order of Ni>Cd> Zn>Pb> As. The average ranges were as follows; Ni (342.20- 555.10mgkg^{-1}); Cd (260.90- 524.50mgkg^{-1}); Zn (243.60- 502.80mgkg^{-1}); Pb (167.80- 336.60mgkg^{-1}); and As (7.40- 20.33mgkg^{-1}) respectively. It was also discovered that the minimum concentration of Zn (615.60mgkg^{-1}) was recorded in Nasarawa (NS) and maximum of 502.80mgkg^{-1} from Kokona (KK) of Nasarawa west. On the other hand, Ni recorded a minimum concentration of 342.20mg.kg^{-1} in Toto (TT), while a maximum of 555.10mgkg^{-1} was recorded in Keffi (KF).

Table 3. Mean concentration of heavy metals in swampy agricultural soil from Nasarawa west.

Location	Geo- Points	No. of Samples	Mean Concentrations of Heavy Metals in different Locations ($mgkg^{-1}$)				
			As	Cd	Pb	Ni	Zn
KR	$8^0 53^1 58.906''$N $7^0 50^1 46.444''$E	10	7.40	345.40	291.00	555.10	426.70
KF	$8^0 52^1 16.506''$N $7^0 52^1 22.801''$E	10	23.60	260.90	323.90	525.00	367.60
KK	$8^0 50^1 22.62''$N $7^0 58^1 80.33''$E	10	16.88	524.50	328.30	462.10	502.80
NS	$8^0 40^1 26.084''$N $7^0 48^1 35.844''$E	10	16.75	387.30	167.80	352.20	243.60
TT	$8^0 30^1 1.566''$N $7^0 31^1 19.116''$E	10	37.00	331.00	336.60	342.20	339.10
Average			20.33	369.82	289.52	447.32	375.96
Minimum			7.40	260.90	167.80	342.20	243.60
Maximum			20.33	524.50	336.60	555.10	502.80

Comparison of the mean concentration of heavy metals from Nasarawa west as shown in Table 3and maximum allowable limit of heavy metals concentrations in soil for different countries and FAO/WHO guidelines as shown in Table 4, the concentration of Cd, Pb, Ni, Zn , were higher than the maximum allowable limits set by FAO/ WHO for other countries like Germany, Poland, china and South Africa but lower for some countries guideline like Australia, UK, and Taiwan.

Table 4. Maximum allowable limit of heavy metals concentrations in soil for different countries (Caspah, 2016).

Country	Maximum permissible Limit of Concentrations of Heavy metals for different Countries ($mgkg^{-1}$)				
	As	Pb	Cd	Zn	Ni
Germany	50	70.0	1.0	150	50.0
Poland	n.a	100	3	300	100
UK	32	450	10	n.a.	130
Australia	20	300	3	200	60
Taiwan	60	300	5	600	200
Bulagaria	10	26	0.4	88	46
Canada	20	200	3	500	100
China	30	80	0.5	250	50
Tazania	1	200	1	150	100
FAO/ WHO Guidelines	20	100	3	300	50
EU Guidelines	n.a	300	3	300	75
South Africa	5.8	20	7.5	240	91

NOTE: n.a.= Not Available

Carcinogenic Risk of Heavy Metals for Adults and Children

The excess lifetime cancer risks for adults and children are calculated separately from the mean contribution of the individual heavy metals in soil for all the pathways using Equation (6) and (7). The result of the excess lifetime cancer risk values are presented in Figure 1 and 2 based on the carcinogenic risk values of the calculated ADI values presented in Table 5.

Table 5. Mean daily intake (ADI) values for adult and children in swampy soil from Nasarawa west for carcinogenic risk calculations.

Receptor	Pathway	Average Daily Intake (ADI) values for Heavy Metals ($mgkg^{-1}$)					Total
		As	Cd	Pb	Ni	Zn	
Ingestion	Child	2.22E-05	4.05E-04	3.17E-04	4.90E-04	4.12E-04	1.65E-03
	Adult	1.19E-05	2.17E-04	1.70E-04	2.63E-04	2.21E-04	8.83E-04
Inhalation	Child	8.57E-10	1.56E-08	1.22E-08	1.89E-08	1.58E-08	6.34E-08
	Adult	1.84E-09	3.34E-08	2.61E-08	4.04E-08	3.39E-08	1.36E-07
Dermal	Child	2.85E-06	5.19E-05	4.06E-05	6.28E-05	5.28E-05	2.11E-04
	Adult	2.96E-06	5.38E-05	4.21E-05	6.50E-05	5.47E-05	2.19E-04

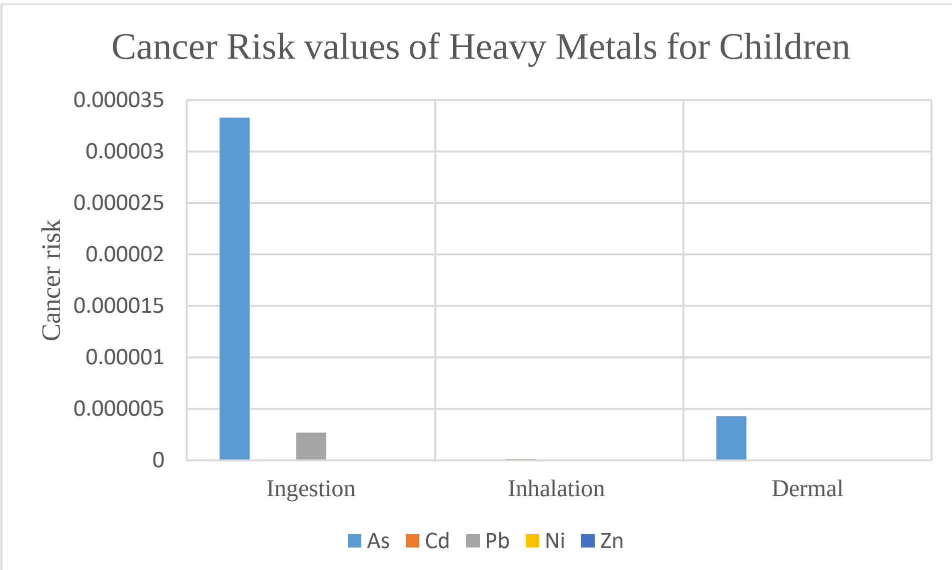

Figure 2. Cancer risk values of heavy metals for children in swampy soils from Nasarawa west.

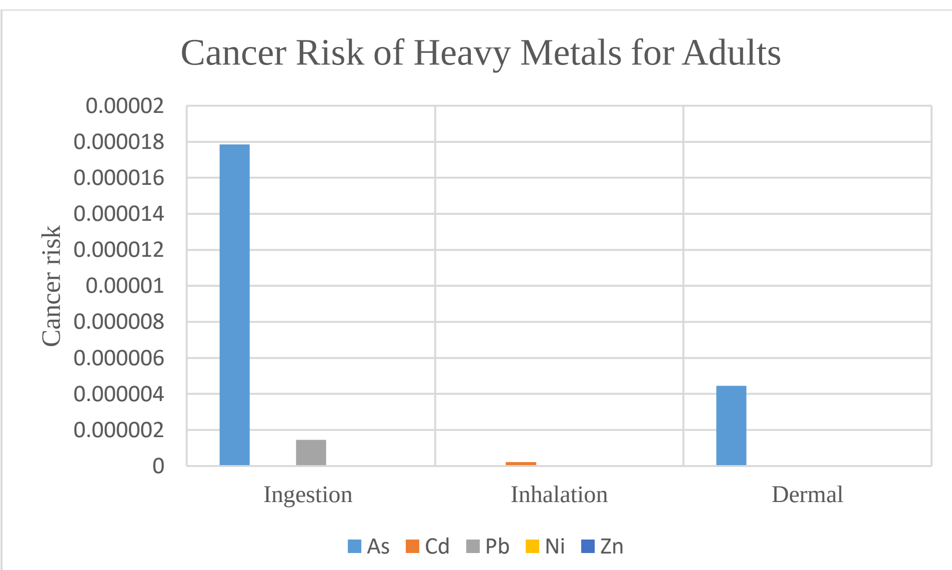

Figure 3. Cancer risk values of heavy metals for adults in swampy soils from Nasarawa west.

The carcinogenic risk was calculated for As, Pb, Cd, Ni and Zn. As was found to be the highest contributor to the cancer risk. The acceptable range for cancer risk by the US Environmental Protection Agency is 1x10-6 to $1x10^{-4}$ and for South Africa is $5x10^{-6}$(U.S. Environmental Protection Agency, 2004; Lee & Lee, 2011). The ingestion pathway is the major contributor to excess lifetime cancer risk followed by dermal.

Non- Carcinogenic risk of Heavy Metals for Adults and Children

Non carcinogenic risk for adults and children were calculated based RfD values as presented in Table 3 and ADI values in Table 6. These results for the ingestion, inhalation and dermal pathways are all presented in terms of Hazard Quotients (HQs) as shown in Figure 3 and 4.

Table 6. Mean daily intake (ADI) values for adult and children in swampy soil from Nasarawa west for non-carcinogenic risk calculations.

Receptor	**Pathway**	**Average Daily Intake (ADI) values for Heavy Metals (mgkg^{-1})**					**Total**
		As	Cd	Pb	Ni	Zn	
Ingestion	Child	2.60E-04	4.73E-03	3.70E-04	5.72E-03	4.81E-03	1.59E-02
	Adult	2.78E-05	5.07E-04	3.97E-04	6.13E-04	5.15E-04	2.06E-03
Inhalation	Child	9.99E-09	1.82E-07	1.42E-07	2.20E-07	1.85E-07	7.39E-07
	Adult	4.28E-09	7.79E-08	6.10E-08	9.43E-08	7.92E-08	3.17E-07
Dermal	Child	3.321E-05	6.06E-04	4.74E-04	7.33E-04	6.16E-04	2.46E-03
	Adult	6.89E-06	1.25E-04	9.82E-05	1.52E-04	1.28E-04	5.10E-04

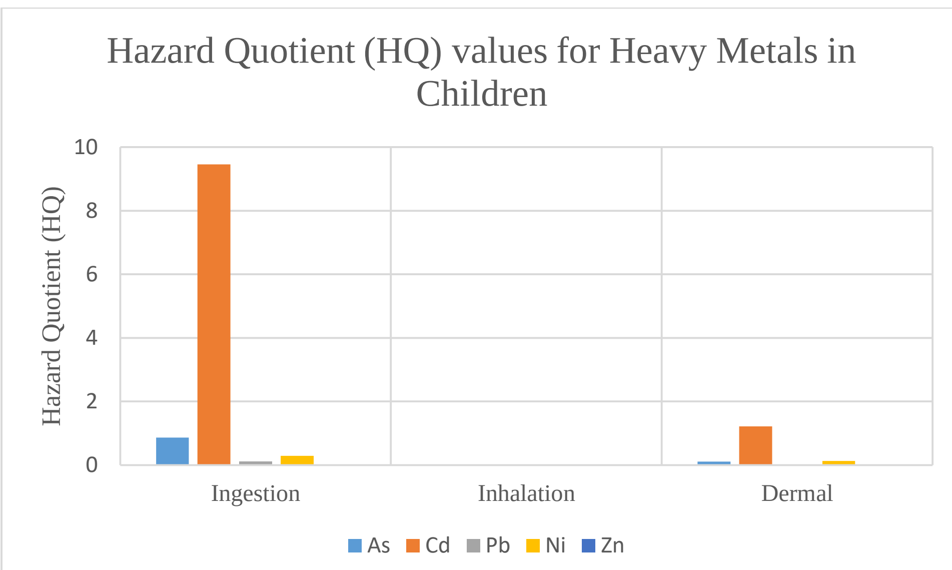

Figure 4. Hazard Quotient (HQ) values for heavy metals in Children for swampy soils from Nasarawa west.

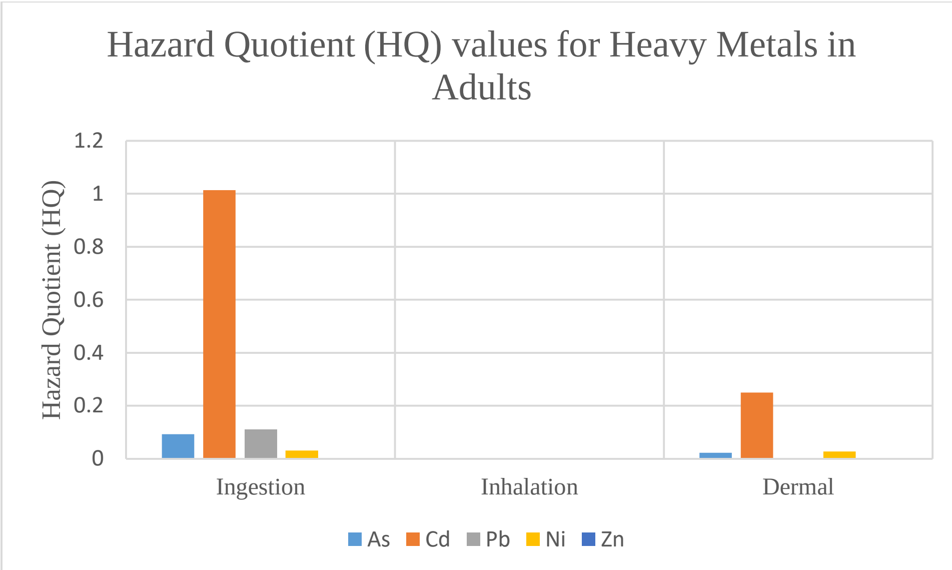

Figure 5. Hazard Quotient (HQ) values for heavy metals adult for swampy soils from Nasarawa west.

When Hazard Quotient (HQ) and Hazard Index (HI) values are less than 1, there is no obvious risk to the population, but if these values exceed one, there may be concern for potential non-carcinogenic effects (U.S. Environmental Protection Agency, 2004). For the adult population, calculated values of HQwere less than one in inhalation and dermal pathways but is slightly above 1 which is 1.014 for ingestion pathway. However, HI for all the pathways for adult was equal to 1.55 and children was 12.19, a value greater than one due to the ingestionpathway. This meant that the children and adult population are atrisk of non-carcinogenic effects. This high value indicated heavy metal pollution that may pose a very high non cancer health risk to children living around the swampy agricultural soil in Nasarawa west. The results also indicate that, in both adults and children, the ingestion pathway contributes the greatest to non-carcinogenic risk followed by the dermal pathway. Inhalation is the least contributor to the risk.

CONCLUSION

The heavy metals concentration levels of swampy agricultural soil in Nasarawa west were analysed and determined using XRF for elemental analysis. Result obtained indicated that the swampy agricultural soil contained considerable high level of heavy metals (As, Cd, Pb, Ni and Zn) which are higher than the acceptable limits of concentration by FOA/ WHO guideline and other countries limit except for As which is below the limit. Health risk assessment for carcinogenic and non- carcinogenic risk was calculated using the ADIs (for carcinogenic and non- carcinogenic risk) values, RfD (for non- carcinogenic risk) and CSF (for carcinogenic risk). The result obtained for non- carcinogenic risk indicate that for adult population, calculated values of HQ were less than one in inhalation and dermal pathways but was slightly above 1 which was 1.014 for ingestion pathway. However, HI for all the pathways for adult was equal to 1.55 and children was 12.19, a value greater than one due to the ingestion pathway. This meant that the children and adult population are at risk of non-carcinogenic effects. On the other hand, carcinogenic risk result shows that As was found to be the highest contributor to the cancer risk. The ingestion pathway is the major contributor to excess lifetime cancer risk followed by dermal. This quantitative evidence demonstrate the critical need to put in place majors that will protect the adults and children populace from pollution from the environment and crops planted on those soil.

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