Corrected Original Research Article

Cancer Implications of Heavy Metals in Swampy Agricultural Soils Across Kokona, Nasarawa State, Nigeria.

Abstract

Elements that pose major threat to human health that are commonly found in contaminated soils are Lead (Pb), Chromium (Cr), Arsenic (As), Zinc (Zn), Cadmium (Cd), Copper (Cu), and Nickel (Ni).Soils are the major sink for heavy metals emission into the environment, as such; their total concentration in soils persists for a long time after their introduction. This study aimed at evaluating the carcinogenic and non-carcinogenic risk of the study area using X-Ray fluoroscopy. The results show that the mean concentration levels of heavy metals in some swampy agricultural soil from Nasarawa State, Nigeria varied significantly and decreased in the order of Cd(524.5) > Zn(502.8) > Ni(462.1) > Cu(314.1) > Pb(295.5) > Cr(278.1) > As(13.5). The Hazard Quotient (HQ) for both adults and children in terms of ingestion, inhalation and dermal contact pathways were all recorded to be lower than unity. The Total Risk and the Hazard Index (HI) were also recorded to be 1.1 x 10^{-2} and 1.4 x 10^{-1} respectively, values less than unity. This makes non-carcinogenic effects insignificant to the population and may not poses serious non-carcinogenic effects in the area under study.

Keywords: Heavy metals, Cancer, swampy, agricultural, soils, rain-fed rice, risk exposure.

Introduction

Elements that pose major threat to human health that are commonly found in contaminated soils are Lead (Pb), Chromium (Cr), Arsenic (As), Zinc (Zn), Cadmium (Cd), Copper (Cu), and Nickel (Ni).Soils are the major sink for heavy metals emission into the environment, as such; their total concentration in soils persists for a long time after their introduction [3, 4]. Changes in their chemical forms (speciation) and bioavailability are however possible. The presence of heavy metals in soils can severely inhibit the biodegradation of organic contaminants [1].

Heavy metals contaminants in soils may pose risk and harmful effects on human being and the environment through contact with contaminated soil or direct ingestion, drinking of contaminated ground water, the food chain. The Standard Organization of Nigeria (SON), Department of Petroleum Resources of Nigeria (DPR), United State Food and Agricultural Organization (USFAO), European Union Environmental Protection Agency (EUEPA) and the World Health Organization (WHO) characterize chemical properties of environmental phenomena, specifically on food chain [2]. While soil characterization will provide an insight into heavy metals bioavailability and speciation, an attempt to remediate heavy metals contaminated soils will entail knowledge of the source of contamination, basic chemistry, associated health and environmental effects (risks) of these heavy metals. Risk assessment will go a long way as an effective scientific tool which enables decision makers (government and stake holders) to manage site so contaminated in a cost effective way and manner while preserving the ecosystem and public health [3].

The adequate protection and restoration of soil ecosystems contaminated by heavy metals require their characterization and remediation. Contemporary legislation respecting environmental protection and public health, at both national and international levels, are based on data that characterize chemical properties of environmental phenomena, especially those that reside in our food chain [4]. While soil characterization would provide an insight into heavy metal speciation and bioavailability, attempt at remediation of heavy metal contaminated soils would entail knowledge of the source of contamination, basic chemistry, and environmental and associated health effects (risks) of these heavy metals. Risk assessment is an effective scientific tool which enables decision makers to manage sites so contaminated in a cost-effective manner while preserving public and ecosystem health [5]. Immobilization, soil washing, and phyto-remediation techniques are frequently listed among the best demonstrated available technologies (BDATs) for remediation of heavy metal-contaminated sites [6]. In spite of their cost effectiveness and environment friendliness, field applications of these technologies have only been reported in developed countries. In most developing countries, these are yet to become commercially available technologies possibly due to the inadequate awareness of their inherent advantages and principles of operation. With greater awareness by the governments and the public of the implications of contaminated soils on human and animal health, there has been increasing interest amongst the scientific community in the development of technologies to remediate contaminated sites [7].

In developing countries with great population density and scarce funds available for environmental restoration, low cost and ecologically sustainable remedial options are required to restore contaminated lands so as to reduce the associated risks, make the land resource available for agricultural production, enhance food security, and scale down land tenure problems [7].

This work centered on some swampy agricultural soils where food crops like rice, vegetables, sugar cane, etc. are cultivated. These crops followed food chain by deriving their nutrients from the plants, the plants derive their nutrients from the soil and the soil may probably contain heavy metals as the case may be. This study aimed at evaluating the carcinogenic and non-carcinogenic risk of the study area and will serve as a baseline data for ecological integrity and human wellbeing in Kokona, Nasarawa State, Nigeria.

2. Materials and Methods

2.1 Materials

Table 1: The materials used for this research work

S/N	Materials	Quantity	Specifications
1	Small Trowel	1	Metal Type
2	Permanent Marker	1	Plastic Type
3	Field Work Book	1	Paper Type
4	A Hand Held Global Positioning System	1	URIC. Type
5	Agate Pestle and Mortar	1	Ceramic Type
6	Sieve (2.0mm)	5	Plastic Type
7	Masking Tape	1 Roll	Paper Type
8	Hand Gloves	1Pkt	Polythene
9	Safety Boot	1Pair	Rubber Type
10	Nose Mask	1Pkt	Cotton
11	Laboratory Coat	2	Cotton
12	Meter Rule	1	Plastic Type
13	Mentholated Spirit	10 Bottles	Emzo Brand
14	Paper Bag/Brown Envelope	5 Dozens	Paper Type
15	X-Ray Fluorescence Machine	1	XR-100CR

2.2. Methods

2.2.1. Sample Size

Ten (10) random soil samples were collected from Kokona Local Government Areas in order to conduct this elemental analysis.

2.2.2. Sample Techniques

Consideration was employed by randomly collecting the soil samples from each of the area under investigation and the soil samples were collected at thirty centimeter (30cm) depth from the top soil so as to obtain the desired standard result.

2.2.3. Study Area

This research work centered on Kokona Local Government Area of Nasarawa State. The sample points are abbreviated as PT1, PT2, PT3, PT4, PT5, PT6, PT7, PT8, PT9 and finally, PT10, located at $8^0$50′22.62″N and $7^0$58′80.33″E, $8^0$50′21.28″N and $7^0$58′50.72″E, $8^0$50′25.71″N and $7^0$58′24.78″E, $8^0$49′23.98″N and $7^0$59′70.68″E, $8^0$49′24.558″N and $7^0$59′60.48″E, $8^0$49′24.47″N and $7^0$59′5.478″E, $8^0$49′1.128″N and $7^0$59′26.28″E, $8^0$49′1.998″N and $7^0$59′28.24″E, $8^0$49′3.078″N and $7^0$59′28.94″E and finally, $8^0$49′2.322″N and $7^0$59′31.92″E

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Rice was cultivated in all the ten sample points as represented in Fig. 1:

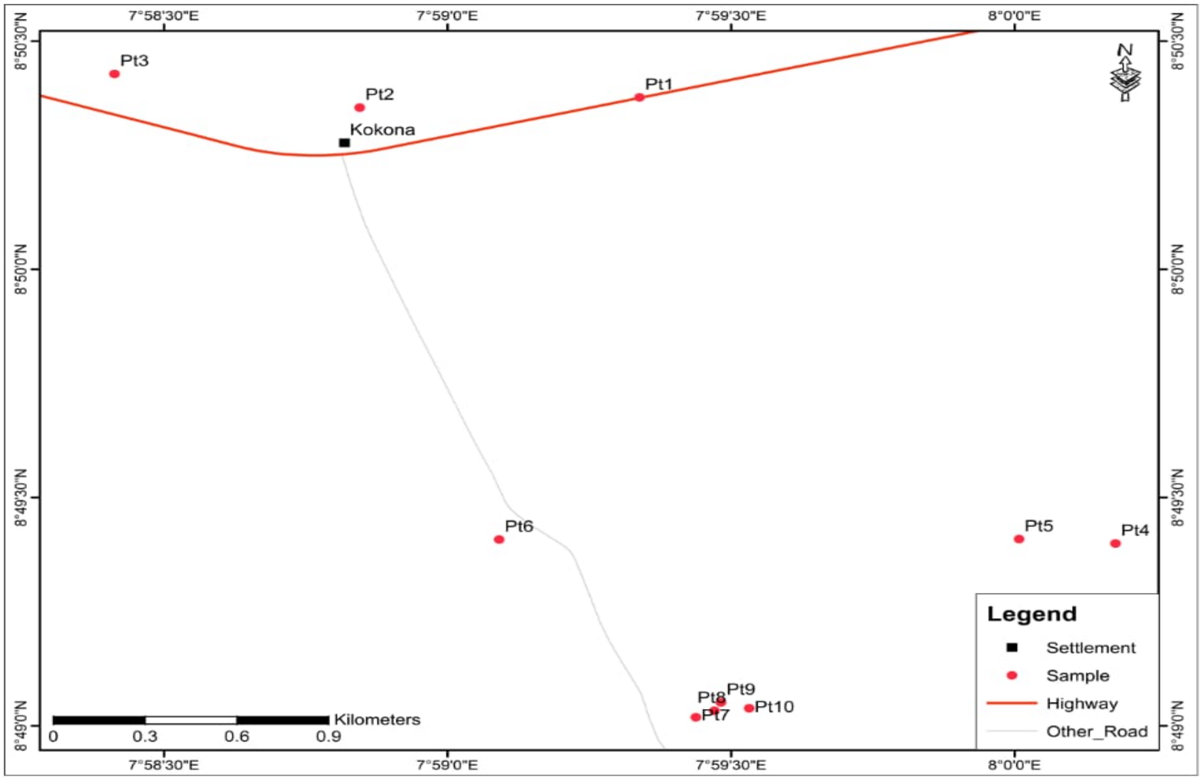

Figure 1: Map of the Study Area.

2.2.4. Samples Preparation

The soil samples were collected between 30th October, 2019 and 11tth November, 2019. The collected swampy agricultural soil samples were air dried under ambient temperature, pulverized, using agate pestle and mortar, and allowed to pass through 2.0mm meshed sieved, packaged properly in paper bags 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 for analyses.

2.2.5 Method of Sample Analyses

X- Ray Fluorescence (XRF) Spectrometry analysis is used for routine, non- destructive spectrometric determination of food, rocks, soils, minerals and liquid samples with little or no pre-treatment needed. It enables chemical composition to be determined in seconds. It involves mass analysis and every component in the irradiated substance is included. However, X.R.F. cannot generally make analysis at the small spot sizes (2-5microns). It is typically used for bulk analysis of larger fractions of geological materials. The relative ease, low sample preparation and the stability and ease of use of X-Ray Spectrometers make it one of the most widely used methods for analysis of major and trace elements in rocks, soil, water, mineral sediment etc.

When an X-ray emission from a radioactive source strikes a sample, the x-ray can either be absorbed by an atom or scattered through the material after absorption. The atom becomes exited and gives off a characteristics x-ray whose energy level is unique to the element impacted by the incident x-ray. The emission of this characteristics x-ray is called X-Ray Florescence. Measurement of the number of emitted x-ray provides a quantitative indication of the concentration of the metal present in the sample.

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2.2.6. Data Analysis

In other to compute the analyzed result for the carcinogenic and non-carcinogenic health risk assessment (that is ingestion of heavy metals through soil, inhalation of heavy metals through soil and dermal contact of heavy metals with soil), the following methods and formulas were used as pointed out by [8]:

$$MDI_{ing} = \frac{c_S*IR*EF*ED*CF}{BW*AT} \quad (1)$$

$$MDI_{inh} = \frac{C_S*IR_{air}*EF*ED}{BW*AT*PEF} \quad (2)$$

$$MDI_{derm} = \frac{C_{S}*SA*FE*AF*ABS*EF*ED*CF}{BW*AT} \quad (3)$$

$$RiskPathway = \sum_{k=1}^{n} MDI_K CSK_K \quad (4)$$

$$Risk_{(total)} = Risk_{(inj)} + Risk_{(inh)} + Risk_{(derm)} \quad (5)$$

$$HQ = \frac{MDI}{RfD} \quad (6)$$

$$HI = \sum_{k=1}^{n} HQ_k = \sum_{k=1}^{n} \frac{MDI_k}{RfD_k} \quad (7)$$

Where MDI_{ing}, MDI_{inh}, and MDI_{derm} are the Mean Daily Intake for the Exposure Dose via ingestion, inhalation and dermal contact in mg/kg/day respectively. HQ, HI, RfD and CSK are the hazard quotients, hazard index, reference dose and cancer slope factor respectively. C_s is the concentration of heavy metal in soil in mg/kg. The abbreviated parameters in equation (1), (2) and (3) are explain in Table 2. Also, the values for the conversion factors in equation (4), (5), (6) and (7) are presented in Table 3. Equation (4) and (5) are the equations for the carcinogenic risk assessments while (6) and (7) are the non-carcinogenic risk assessments.

Table 2: Exposure Parameters Used for the Health Risk Assessment Through Different Exposure Pathways for Soil.

Parameter	Unit	Children	Adults	References
Body Weight (BW)	Kg	15	70	[9]
Exposure Frequency (EF)	Days	350	350	[9]
Exposure Duration (ED)	Years	6	30	[9]
Ingestion Rate (IR)	mg/day	200	100	[9]
Inhalation Rate (IR air)	m^3/day	10	20	[9]
Skin Surface Area (SA)	cm^2	2100	5800	[9]
Soil Adherence Factor (AF)	mg/cm^2	0.2	0.07	[9]
Dermal Absorption Factor (ABS)	None	0.1	0.1	[9]
Dermal Exposure Ratio (FE)	None	0.61	0.61	[9]
Particulate Emission Factor (PEF)	m^3/kg	1.3×10^9	1.3×10^9	[9]
Conversion Factor (CF)	mg/kg	10^{-6}	10^{-6}	[9]
Average Time (AT)				[9]
For Carcinogens	Days	365 x 70	365 x 70	
For Non- Carcinogens	Days	365 x ED	365 x ED	

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Table 3: Reference Doses (RfD) and Cancer Slope Factors (CSF) for different Heavy Metals.

Heavy Metal	Oral RfD	Dermal RfD	Inhalation RfD	Oral CSF	Dermal CSF	Inhalation CSF	References
As	3.0×10^{-4}	3.0×10^{-4}	3.0×10^{-4}	0.15×10	1.5×10	1.5×10	[10]
Cd	5.0×10^{-4}	5.0×10^{-4}	5.7×10^{-5}	NA	NA	6.3×10	[10]
Cr	3.0×10^{-3}	NA	3.0×10^{-5}	5.0×10^{-1}	NA	4.1×10	[10]
Ni	2.0×10^{-2}	5.6×10^{-3}	NA	NA	NA	NA	[10]
Cu	3.7×10^{-2}	2.4×10^{-2}	NA	NA	NA	NA	[10]
Zn	3.0×10^{-1}	7.5×10^{-2}	NA	NA	NA	NA	[10]

NA = Not Available

If the (HI) value is less than one (<1), the exposed population is unlikely to experience adverse health effects. However, if the (HI) value exceeds one (>1), then there may be concern for potential non-carcinogenic effects.

3. Results and Discussion

3.1. Results

The data collected from different Swampy Agricultural Soils from Kokona L.G.A were analyzed using X- Ray Fluorescence (XRF) Spectrometry. The results of the analysis were obtained and presented in Table 4, which are the Concentration Level of Heavy Metals such as Chromium (Cr), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Cadmium (Cd) and Lead (Pb). Further evaluations were made for the carcinogenic and non-carcinogenic risk assessments such as Mean Daily Intake (MDI), Hazard Quotients (HQ), Hazard Index (HI), Risk Pathway and Total Rick, and are presented in Table 5, 6, 7 and 8.

Table 4: Concentration Levels of Elements in some Swampy Agricultural Soils from Kokona L.G.A.

S/N	Sample Points	Cr	Ni	Cu	Zn	As	Cd	Pb
1.	PT1	127	325	046	389	389	261	985
2.	PT2	201	628	43	723	N.D	853	634
3.	PT3	208	545	438	343	13	592	142
4.	PT4	154	506	326	653	25	345	N.D
5.	PT5	211	616	454	505	15	390	543
6.	PT6	189	178	804	745	16	342	250
7.	PT7	483	680	322	607	14	23	549
8.	PT8	302	592	535	681	18	433	319
9.	PT9	203	473	135	279	N.D	938	106
10.	PT10	703	78	38	103	10	344	24
11.	**Mean**	**278.1**	**462.1**	**314.1**	**502.8**	**13.5**	**524.5**	**295.5**
12.	**WHO/USFAO, (2001)**	**300.0**	**50.0**	**200.0**	**300.0**	**20.0**	**3.000**	**100.0**

ND = Not Detected

Table 5: Mean Daily Intake (MDI) Values of Heavy Metals for Carcinogenic Risk Assessment (mg/kg/day)

Receptor	Pathway	Mean Daily Intake (MDI) Values for Heavy Metals in Soils							Total
		As	Cd	Pb	Ni	Zn	Cr	Cu	
Ingestion	Child $x10^{-5}$	1.50	57	32	51	55	30	34	260.50
Ingestion	Adult $x10^{-5}$	0.78	31	17	27	30	16	18	139.78
Inhalation	Child $x10^{-9}$	0.57	22	12	19	21	12	13	99.570

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Inhalation	Adult x10^{-9}	1.20	47	27	42	45	25	28	215.20
Dermal	Child x10^{-5}	0.19	7.3	4.1	6.5	7.0	3.9	4.4	33.390
Dermal	Adult x10^{-5}	0.20	7.9	4.4	6.9	7.5	4.2	4.7	35.800
Mean x10^{-5}		**0.45**	**17**	**9.7**	**15**	**17**	**9.0**	**10**	**78.150**
WHO (2001) x 10^{-5}		**1.30**	**0.2**	**6.6**	**89**	**19**	**19**	**40**	**186.80**

Table 6. Mean Daily Intake (MDI) Values of Heavy Metals for Non-Carcinogenic Risk Assessment (mg/kg/day)

Receptor	**Pathway**	**Mean Daily Intake (MDI) Values for Heavy Metals in Soils**							**Total**
		As	**Cd**	**Pb**	**Ni**	**Zn**	**Cr**	**Cu**	
Ingestion	Child x10^{-3}	0.180	6.80	3.80	6.00	6.50	3.60	4.10	30.980
Ingestion	Adult x10^{-3}	0.007	0.29	0.16	0.25	0.28	0.15	0.17	1.3070
Inhalation	Child x10^{-7}	0.066	2.60	1.50	2.30	2.50	1.40	1.50	11.870
Inhalation	Adult x10^{-7}	0.029	1.10	0.63	0.98	1.10	0.59	0.67	5.0990
Dermal	Child x10^{-4}	0.220	8.40	4.70	7.40	8.00	4.40	5.00	38.120
Dermal	Adult x10^{-4}	0.046	1.80	1.00	1.60	1.70	0.95	1.10	8.1960
Mean x10^{-4}		**0.360**	**1.40**	**7.60**	**72.0**	**13.0**	**7.10**	**8.10**	**109.56**
WHO (2001) x10^{-4}		**1.1**	**0.16**	**5.3**	**2.7**	**16**	**16**	**11**	**52.26**

Table 7: Carcinogenic Risk Assessment.

Location	**Pathways**	**Cancer Risk**	**Risk Total**
Kokona	Ingestion/Child	2.5 x 10^{-3}	
	Ingestion/Adult	2.8 x 10^{-3}	
	Inhalation/Child	0.012 x 10^{-3}	1.1 x10^{-2}
	Inhalation/Adult	0.026 x 10^{-3}	
	Dermal/ Child	0.51 x 10^{-3}	
	Dermal/Adult	5.4 x 10^{-3}	
WHO (2001)		**1.000**	**1.000**

Table 8: Non Carcinogenic Risk Assessment.

Location	**Pathways**	**Hazard Quotient (HQ)**	**Hazard Index (HI) = Sum of (HQs)**
Kokona	Ingestion / Child	8.6 x 10^{-2}	
	Ingestion / Adult	0.36 x 10^{-2}	
	Inhalation / Child	0.3 x 10^{-2}	
	Inhalation / Adult	0.0013 x 10^{-2}	1.4 x 10^{-1}
	Dermal / Child	3.5 x 10^{-2}	
	Dermal / Adult	0.75 x 10^{-2}	
WHO (2001)		**1.000**	**1.000**

3.1.1. Result Analysis

In order to analyze the results obtained and presented in Table 1, charts were plotted and comparison was made with World Health Organization for all the Carcinogenic and Non-Carcinogenic Risk Assessment.

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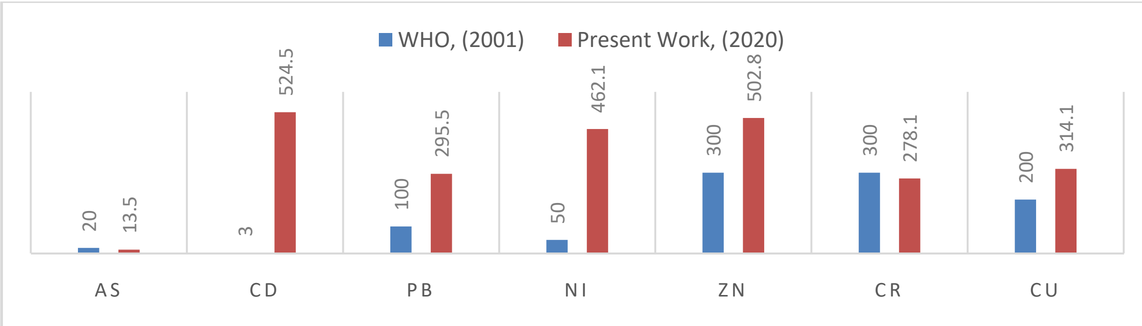

Fig. 2. Comparison of Mean Concentration Level for Present Study with WHO

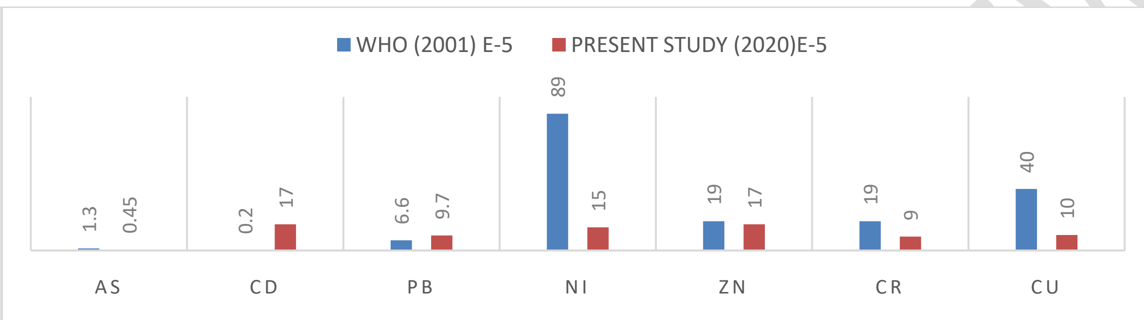

Fig. 3. Comparison of Carcinogenic Mean Daily Intake for Present Study with WHO

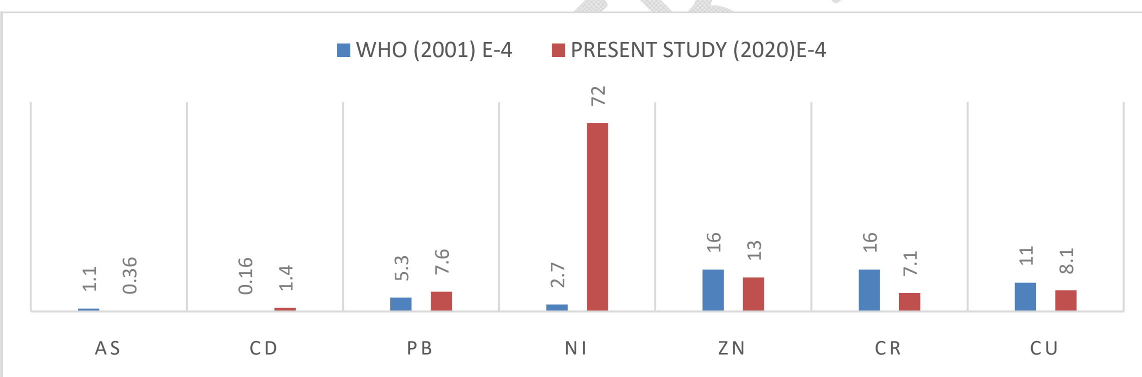

Fig. 4. Comparison of Non-Carcinogenic Mean Daily Intake for Present Study with WHO

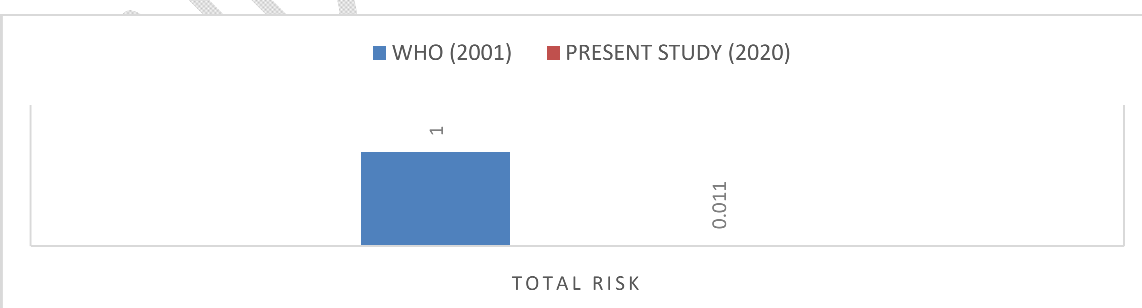

Fig. 5. Comparison of Carcinogenic Risk Assessment for Present Study with WHO

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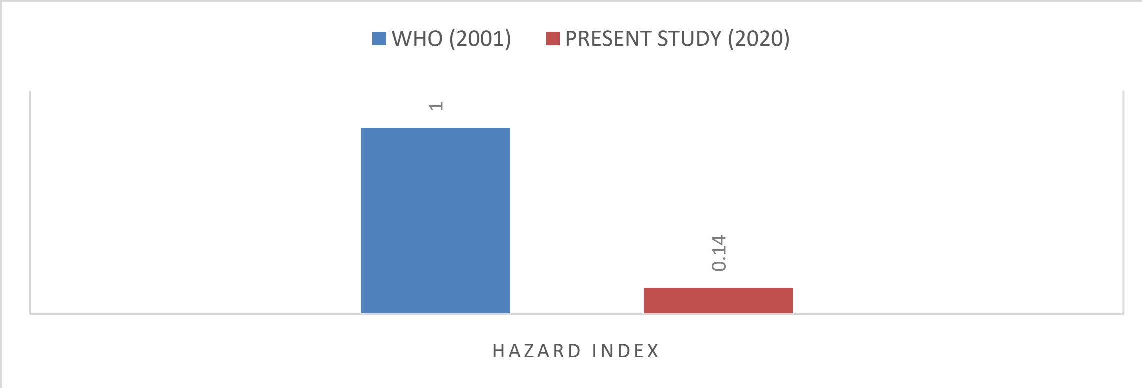

Fig. 6. Comparison of Non-Carcinogenic Risk Assessment for Present Study with WHO

3.2. Discussion

Concentration Level (Table 4 and Figure 2)

The results of the Heavy metal contamination in swampy agricultural soils of Kokona, Nasarawa State, Nigeria using X- Ray Fluorescence (XRF) Spectrometry have been presented. The mean concentration of various heavy metals found in the soil samples are presented in Table 4 in mg/kg. Seven heavy metals along with their respective concentrations in mg/kg (Cr (278.1), Ni (462.1), Cu (314.1), Zn (502.8), As (13.5), Cd (524.5) and Pb (295.5)) were found in the soil samples.

Finding of this study have revealed that the mean Concentration of the analyzed heavy metals in the all soil samples for all points arranged in decreasing order is Cd > Zn >Ni > Cu >Pb > Cr >As. These values were found to be higher than the safe limit recommended by World Health Organization except for Chromium (Cr) and Arsenic (As) which are found to be lower. This implies that the mean concentration level of heavy metals in those areas is significantly high and may cause immediate radiological hazard to the populace of the study area.

Mean Daily Intake (Table 5, 6 and Figure 3 and 4).

The results of Mean Daily Intake of Heavy Metal for both carcinogenic and non-carcinogenic risk in swampy agricultural soils of Kokona, Nasarawa State, Nigeria, have been presented in Table 5 and 6. Seven heavy metals along with their respective Mean Daily Intake for both carcinogenic and non-carcinogenic risk in mg/kg/day (Cr(9.0 x 10^{-5} and 7.1 x 10^{-4}), Ni(15 x 10^{-5} and 72 x 10^{-4}), Cu(10 x 10^{-5} and 8.1 x 10^{-4}), Zn(17 x 10^{-5} and 13 x 10^{-4}), As(0.45 x 10^{-5} and 0.36 x 10^{-4}), Cd(17 x 10^{-5} and 1.4 x 10^{-4}) and Pb (9.7 x 10^{-5} and 7.6 x 10^{-4} respectively)) were evaluated for the soil samples.

Finding of this study revealed that the carcinogenic mean daily intake values were found to be lower than the safe limit recommended by World Health Organization except cadmium (Cd) and lead (Pb) which is found to be higher. The non-carcinogenic mean daily intake values were also found to be lower than the safe limit recommended by World Health Organization except (Cd), lead (Pb) and nickel (Ni) which is found to be higher. This implies that the carcinogenic and non-carcinogenic mean daily intake of heavy metals in those areas is partially high and may or may not cause immediate radiological hazard to the populace of the study area.

Carcinogenic Risk Assessments (Table 7 and Figure 5)

It was observed from Table 7 and Figure 5 that, the cancer risk for both adults and children in terms of ingestion, inhalation and dermal contact pathways were all recorded to be higher than unity and the total cancer risk was found to be (1.1 x 10^{-2}), a value less than unity, indicating that the cancer risk is negligible according to [4].

Non- Carcinogenic Risk Assessments (Table 8 and Figure 6)

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It was observed from Table 8 and Figure 6 that, the Hazard Quotient (HQ) for both adults and children in terms of ingestion, inhalation and dermal contact pathways were all recorded to be higher than unity. The Hazard Index (HI) was also recorded to be (1.4×10^{-1}) a value less than unity, indicating that the areas under study are safe according to [4].

4. Conclusion and Recommendations

4.1 Conclusion

The results show that the mean concentration levels of heavy metals in some swampy agricultural soil from Nasarawa State, Nigeria varied significantly and decreased in the order of Cd(524.5) > Zn(502.8) > Ni(462.1) > Cu(314.1) > Pb(295.5) > Cr(278.1) > As(13.5). The high values for some of the heavy metals could be attributed to the geological strata and the pollution of the studied area. The Hazard Quotient (HQ) for both adults and children in terms of ingestion, inhalation and dermal contact pathways were all recorded to be lower than unity. The Total Risk and the Hazard Index (HI) were also recorded to be 1.1×10^{-2} and 1.4×10^{-1} respectively, values less than unity. This makes non-carcinogenic effects insignificant to the population and may not poses serious non-carcinogenic effects in the area under study.

4.2 Recommendations

Even though the values are much lower than that which could cause health effects to the populace, remediation techniques are important in order to control the human adverse health effects in contaminated swampy agricultural soils. To achieve that, regular monitoring and evaluation of the soils and the crops cultivated at the sample locations should be carried out to check the elevated concentrations of these harmful metals. The data from this assessment could serve as an index in which remediation variables in modeling could be anchored.

5. References

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