Corrected Original Research Article

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

Abstract

Heavy metals are divided according to their need for different organisms. Risks of heavy metal contamination in Soil-Pant System through the application of copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) are essential to plants, animals and humans and Selenium (Se) are essential only to animals and humans, while chromium (Cr) and nickel (Ni) are essential to humans and plants. This study aimed at evaluating the carcinogenic and non-carcinogenic risk of the study area using X-Ray fluoroscopy. The results show that, mean concentration levels of heavy metals in soil from Nasarawa State varied significantly and decreased in 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

Heavy metals can be divided according to their need for different organisms. Risks of heavy metal contamination in Soil-Pant System through the application of copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn) are essential to plants, animals and humans [1]. Selenium (Se) is essential only to animals and humans, while chromium (Cr) and nickel (Ni) are essential to humans and plants, respectively. The researchers also stated that arsenic (As), cadmium (Cd) and lead (Pb) are not essential to any of these organisms. On the other hand, As, Cd, Pb and Hg are not essential to humans but in excess can also cause toxicity [2]. People exposed to Pb or Hg develop neurological disorders, while exposure to Cd is associated with kidney damage and fragile bones, and various forms of cancer can occur due to the ingestion of food or water contaminated with As [3]. [4] Identified Cd as the metal with greatest potential to contaminate plants and subsequently to be transferred to animals and humans that eat these contaminated plants or part of them. This statement is based on the fact that (i) Cd poses animal and human health risks in plant tissue concentrations that are not generally phytotoxic and (ii) Cd concentrations in agricultural soils are increasing in many parts of world due to Cd inadvertent additions through the use of fertilizers, sewage sludge and soil amendments [5]. Due to the high risk of contaminating the food chain, the risk of Cd to cause toxicity is considered to be high as well. Despite increased concern with Cd, the toxicity risk of other heavy metals should not be neglected [6]. The toxicity of heavy metals in living organisms is a phenomenon somewhat complex. Toxic effects of a metal depend on a number of factors that often include rate, exposure time, tolerance of the organism and environmental conditions. In recent years, the effect of the interaction between heavy metals, animals and plants on the expression of toxicity has been considered very intensely. As a result of the interaction, a given metal may increase or decrease the negative effects of other metal in the organism [7]. Despite the complexity, the toxicity of heavy metals in plants and in animals and humans that eat contaminated plants is primarily associated with previous environmental contamination. Soils may be contaminated with such hazardous elements by the use of sewage sludge. High concentrations of metals in the sludge increase the risks of contamination and therefore the toxicity. Thus, it is important to know the chemical composition of sewage sludge [8]. 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:

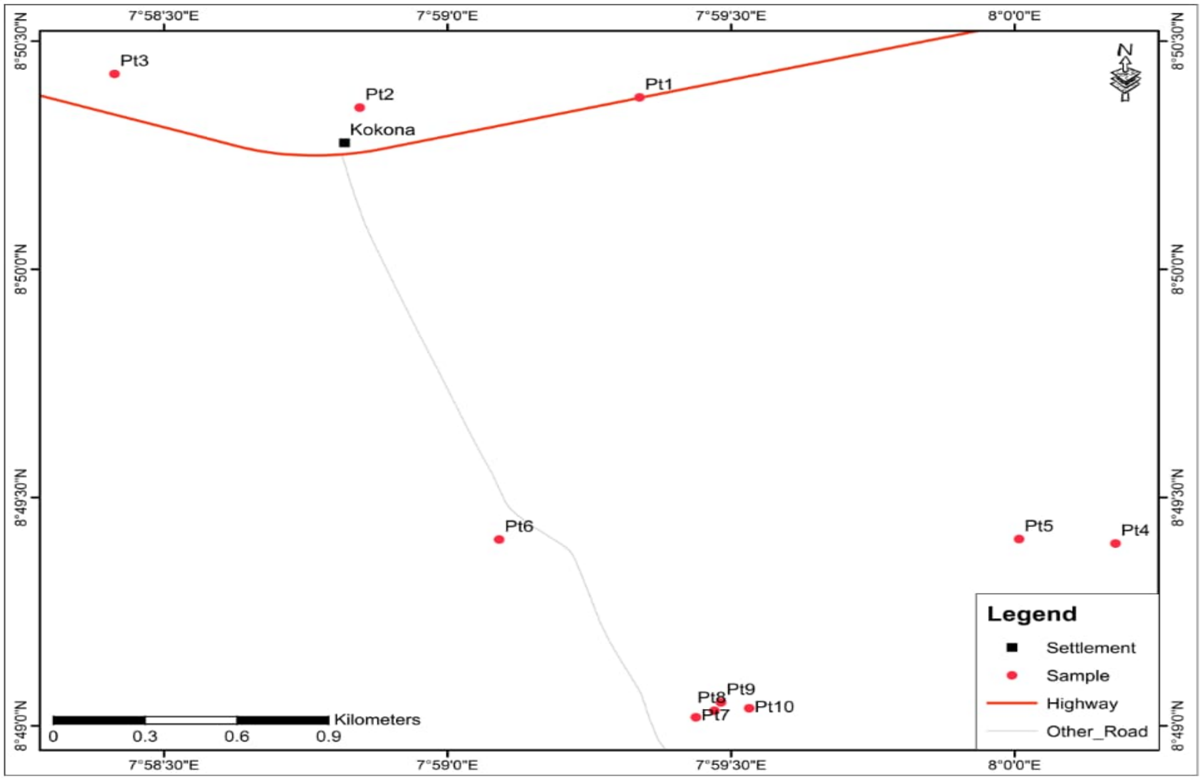

Figure 1: Map of the Study Area.

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 [9]:

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

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

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

$$RiskPathway = \sum_{k=1}^{n} MDI_{K} CSK_{K} \quad 4$$

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

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

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

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	[10]
Exposure Frequency (EF)	Days	350	350	[10]
Exposure Duration (ED)	Years	6	30	[10]
Ingestion Rate (IR)	mg/day	200	100	[10]
Inhalation Rate (IR air)	m^3/day	10	20	[10]
Skin Surface Area (SA)	cm^2	2100	5800	[10]
Soil Adherence Factor (AF)	mg/cm^2	0.2	0.07	[10]
Dermal Absorption Factor (ABS)	None	0.1	0.1	[10]
Dermal Exposure Ratio (FE)	None	0.61	0.61	[10]
Particulate Emission Factor (PEF)	m^3/kg	1.3×10^9	1.3×10^9	[10]
Conversion Factor (CF)	mg/kg	10^{-6}	10^{-6}	[10]
Average Time (AT)				[10]
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 x 10	1.5 x 10	1.5 x 10	[11]
Cd	5.0×10^{-4}	5.0×10^{-4}	5.7×10^{-5}	NA	NA	6.3 x 10	[11]
Cr	3.0×10^{-3}	NA	3.0×10^{-5}	5.0×10^{-1}	NA	4.1 x 10	[11]
Ni	2.0×10^{-2}	5.6×10^{-3}	NA	NA	NA	NA	[11]
Cu	3.7×10^{-2}	2.4×10^{-2}	NA	NA	NA	NA	[11]
Zn	3.0×10^{-1}	7.5×10^{-2}	NA	NA	NA	NA	[11]

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. in mg/kg.

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, (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 in (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 $\times 10^{-5}$	1.50	57	32	51	55	30	34	260.50
Ingestion	Adult $\times 10^{-5}$	0.78	31	17	27	30	16	18	139.78
Inhalation	Child $\times 10^{-9}$	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 in (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	2.5×10^{-3}	
	Ingestion/Adult	2.8×10^{-3}	
	Inhalation/Child	0.012×10^{-3}	1.1×10^{-2}
	Inhalation/Adult	0.026×10^{-3}	
	Dermal/ Child	0.51×10^{-3}	
	Dermal/Adult	5.4×10^{-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	8.6×10^{-2}	
	Ingestion / Adult	0.36×10^{-2}	
	Inhalation / Child	0.3×10^{-2}	
	Inhalation / Adult	0.0013×10^{-2}	1.4×10^{-1}
	Dermal / Child	3.5×10^{-2}	
	Dermal / Adult	0.75×10^{-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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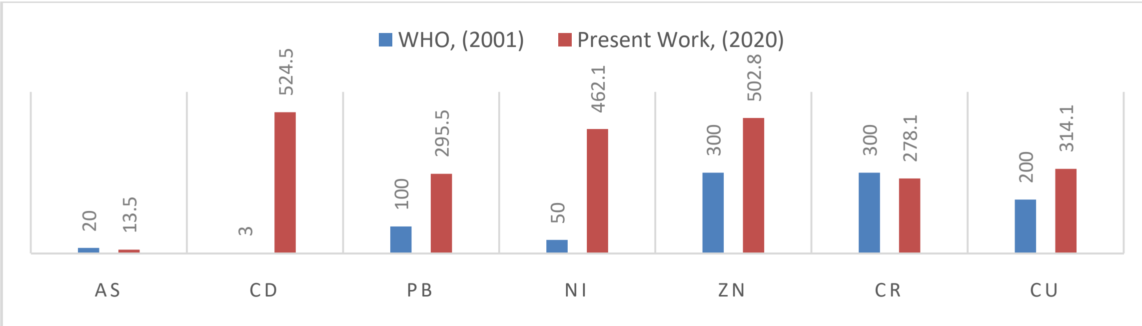

Fig. 2. Comparison of Mean Concentration Level for Present Study with WHO

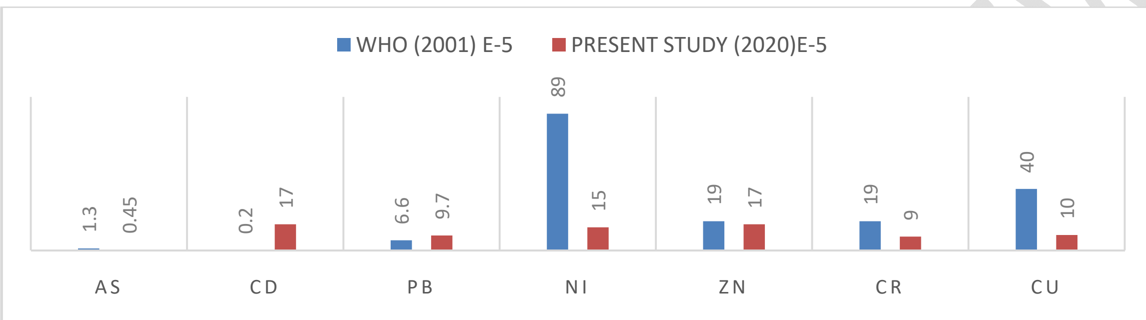

Fig. 3. Comparison of Carcinogenic Mean Daily Intake for Present Study with WHO

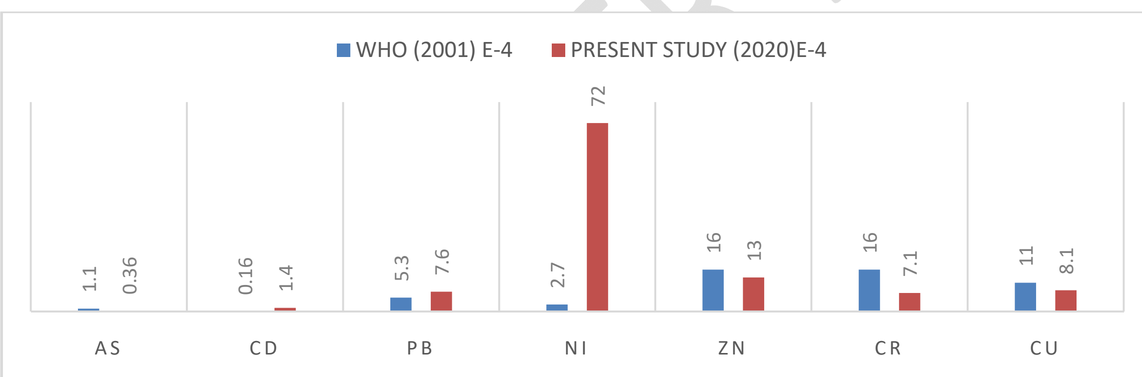

Fig. 4. Comparison of Non-Carcinogenic Mean Daily Intake for Present Study with WHO

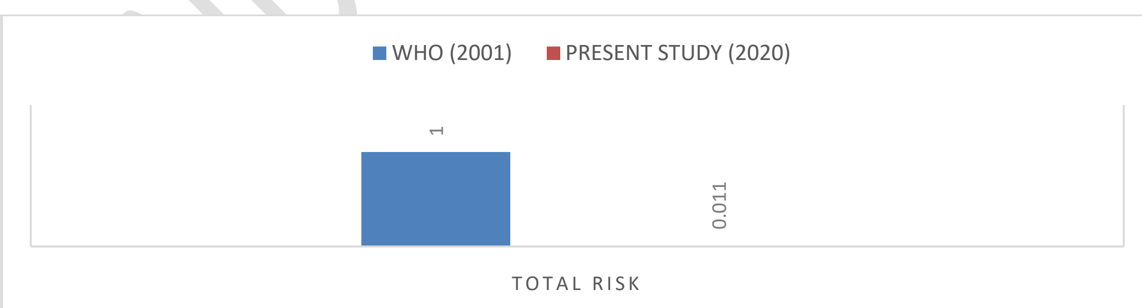

Fig. 5. Comparison of Carcinogenic Risk Assessment for Present Study with WHO

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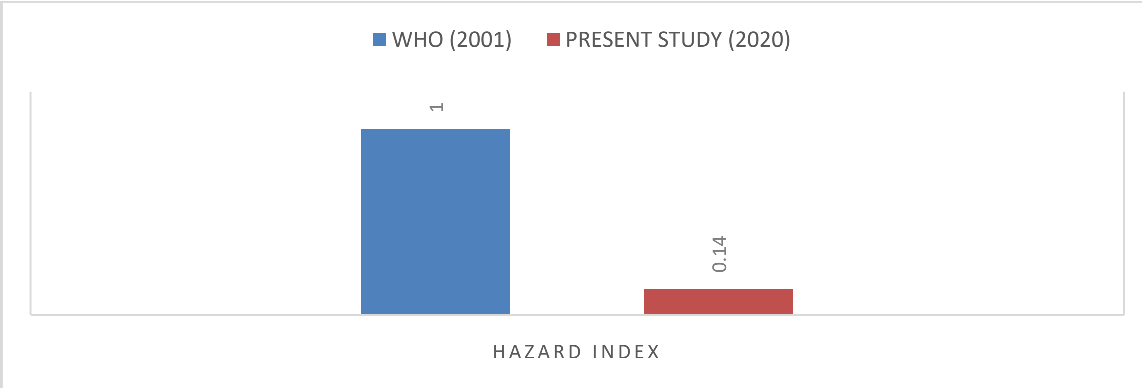

Fig. 6. Comparison of Non-Carcinogenic Risk Assessment for Present Study with WHO

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(9.0×10^{-5} and 7.1×10^{-4}), Ni(15×10^{-5} and 72×10^{-4}), Cu(10×10^{-5} and 8.1×10^{-4}), Zn(17×10^{-5} and 13×10^{-4}), As(0.45×10^{-5} and 0.36×10^{-4}), Cd(17×10^{-5} and 1.4×10^{-4}) and Pb (9.7×10^{-5} and 7.6×10^{-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 (1.1×10^{-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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