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HEAVY METALS CONCENTRATIONS AND THEIR HEALTH RISK ASSESSMENT IN SOIL FROM BOKO HARAM'S AFFECTED AREAS OF GOMBE STATE, NIGERIA

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ABSTRACT

The research was aimed to evaluate the concentration of some heavy metals and their health risk assessment in the soil samples from Boko Haram attacked areas of Gombe State. The samples were collected from the affected sites (Gombe division, Quarter guard, Kwadon police Station, D/Kowa Park, K/mata, Timber Market and Gombe Main market in Gombe Metropolis, Nafada Police Station and Nafada Mosques in Nafada, Bajoga Police Station, Ashaka Junction, GRA, and Union Bank in Bajoga Town) and the metals concentrations were determined using Energy Dispersive X-Ray Fluorescence (EDXRF) Spectrometry. The results indicated that the mean concentrations of the metals in the study area ranged as follows; Cr=19.6-58.3Mg/kg; Ni=2.76-12.6Mg/kg; Cu=17.5-60.1Mg/kg; Zn=6.08-1,460Mg/kg; As=1.75-30.20Mg/kg; and Pb=3.57-196Mg/kg. All the metals investigated in all the samples were found to be below their Maximum Permissible Limits, (MPL) set by WHO except Zn (300Mg/kg) in Gombe Division, D/Kowa Park and Timber Market, Pb (100Mg/kg) in D/Kowa Park and As (20Mg/kg) in Quarter guard. Risk characterization which predicts the potential non-carcinogenic and carcinogenic health risk on populace in the study area was carried out by integrating all the information gathered to arrive at quantitative estimates of hazard and cancer risk indices. The Hazard index, HI which represent the potential non-carcinogenic risk posed by more than one metal ranged from 0.0171-0.9621. This indicates that all the samples had HI values <1 and hence, the exposed population is unlikely to experience adverse health effects. The incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen, called the Risk Index, RI indicates that all the sites had RI values >1.0E-4 except K. police Station, K/Mata, BJ Police station, Ashaka Junction and GRA sites. This shows pollution that may pose cancer risk to the adult populace. Therefore, most Boko Haram attacked sites in the study area were found to be polluted by heavy metals as shown by the risk indices values and comparison of the metal's concentration in the affected sites and that of the control samples where there were no attacks.

Keywords: Heavy metals, Health Risk, Boko Haram, Hazard Index, Risk Index

INTRODUCTION

During Boko Haram insurgency, bombs, explosions and landmines are mounted in various locations and many casualties were recorded. The devastation to the environment and civilian population caused by cluster bombs will be a lingering and insidious nightmare against the environment and people. The bombs detonated have chemical by-products. Chemicals supporting war activities, such as Herbicides or chemical weapons, have effects that are seen for generations (Abdhesh, 2003).

The release of heavy metals in soils are of great concern to humans and the environment, due to their toxicity, bio-accumulative potentiality, and recalcitrant nature. Some metals are essential for life, playing an irreplaceable role as sources of vitamins and minerals for human organs to function. All living organisms require varying amounts of metals, but at higher concentrations they become toxic (Adesuyi *et al*., 2015). What is more, some metals do not play any useful role in human physiology and might be toxic even at low rates of exposure. They might continuously get accumulated in vital organs such as the brain, the liver, bones, and kidneys, for years or decades, in turn causing serious health problems (Aluko *et al.,* 2018).

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 (ATSDR, 2015).

Arsenic is regarded a human carcinogen from extremely low levels of exposure. Acute exposure to Arsenic compounds may cause nausea, vomiting, abdominal pain, muscle cramps and diarrhoea while chronic exposure is associated with peripheral nerve damage causing diabetes (Thouin *et al.,* 2016).

Lead is regarded as a human mutagen and probable carcinogen. It induces renal tumours, and also disturbs the normal functioning of kidneys, joints, reproductive and nervous systems (Kamunda *et al.*, 2016).

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 (Abdullahi *et al.,* 2019).

Nickel is known to cause cancer, both oral and intestinal. It also causes depression, heart attacks, haemorrhages and kidney problems (Kamunda *et al.*, 2016)

Excessive intake of Zn and Cu may cause non-carcinogenic effects on human health, even though they are essential to human life. Zn surplus may cause impairment of growth and reproduction (Kamunda *et al.*, 2016).

The Maximum Allowable Limit of Concentrations of some Heavy Metals in Soil mg/kg from some literatures are summarized below.

Table1: Maximum Allowable Limit of Concentrations of some Heavy Metals in Soil mg/kg

Organisation	As	Pb	Hg	Cd	Cr	Cu	Zn	Co	Ni	Reference
FAO/WHO Guidelines mg/kg	20	100	n.a.	3	100	100	300	50	50	Chiroma *et al*., (2014)
EU Guidelines mg/kg	n.a.	300	n.a.	3	150	140	300	n.a.	75	Kamunda *et al*., 2016
South Africa mg/kg	5.8	20	0.93	7.5	6.5	16	240	300	91	DEA (2010)

n.a= Not available

MATERIAS AND METHODS

Sampling Area

Soil Samples were collected from Bajoga, Nafada and Gombe metropolis and environs all in Funakaye, Nafada, and Gombe Local Government Areas of Gombe State. Samples were taken only from places with recorded Boko Haram's explosion activities. A control sample for each study area was taken from an area that has no record of Boko Haram attacks.

Soil Sampling

Soil sampling was carried out according to the method described by Aluko *et al.,* (2018). From each sampling location, five replicate samples were collected. These were thoroughly mixed to give a homogenous sample, out of which 500g was packaged in

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tagged polythene bags. Control samples were obtained 1km off the sampling sites. All collected samples were properly tagged and identified by their sampling locations. The collected soil samples were taken to the laboratory for analysis.

Sample treatment and Analysis

Soil samples collected were analyzed using Energy dispersive X-ray Fluorescence spectrophotometry. The samples were first grounded into a homogenous powder approximately 100-200 mesh, and then about 5g of each sample was weighed into 32mm sample cups with a polypropylene X-ray film of 4µm thickness and were hydraulically pressed. Sample heights were measured in millimeters and sample cups were capped. The EDXRF analysis was performed using a Rigaku NEX DE EDXRF spectrometer equipped with a fifteen-place sample changer with spin function using slow and steady spinning mode. EDXRF measurements were carried out under helium (He) atmosphere using a palladium (Pd) X-ray tube at a voltage of 60 kV and current 10µA with 10 mm beam spot size, and silicon (Si) drift detector comprised of Peltier electronic circuit cooling system. Standard less calibration was employed using Fundamental Parameters (FP) methods software (Rigaku RPF-SQX) to allow for elemental quantification of completely unknown.

Health Risk Assessment (HRA) of heavy metals in the soil samples

Health risk assessment for carcinogenic and non- carcinogenic risk assessment model used in the study is based on the method described by (Abdullahi *et al.,* 2019). The daily intake doses of heavy metals in soil are usually through three main paths namely ingestion, inhalation and dermal contact. These were calculated using the following equations:

Ingestion: $$AD_{ing}\ (mgkg^{-1}day^{-1}) = \frac{CS \times IRing \times EF \times FI \times ED \times CF}{BW \times AT} \quad \text{......} \quad 1$$

Inhalation: $$AD_{inh}\ (mgKg^{-1}day^{-1}) = \frac{CS \times IRinh \times EF \times FI \times ED}{PEF \times BW \times AT} \quad \text{......} \quad 2$$

Dermal: $$AD_{Der}\ (mgKg^{-1}day^{-1}) = \frac{CS \times SA \times AF \times ABS \times ED \times CF}{BW \times AT} \quad \text{......} \quad 3$$

Where AD ($mgKg^{-1}day^{-1}$) is the absorbed dose of exposure to metals through ingestion (AD_{ing}), inhalation (AD_{inh}) and dermal contact (AD_{der});

CS = Chemical concentration of the metal in soil mg/kg (obtained from this study);

IR_{ing}= Ingestion rate (mg soil/day) = 100 mg/day ((USEPA, 1989; USEPA, 2011; Abdullahi *et al.,* 2019).;

IR_{inh} = Inhalation rate (m^3/h) = 20m^3/h for adult (USEPA, 1989).;

FI = Fraction ingested from contaminated Source = 1 at reasonable maximum exposure (USEPA, 2001).;

EF = Exposure frequency = 350 days a year (USEPA, 2011; Abdullahi *et al*., 2019).;

ED = Exposure duration (years) = 30 years for non-carcinogenic effect (USEPA, 2011; Abdullahi *et al., 2019*).;

SA = Exposure skin area = 5700cm^2 (USEPA, 2011; Abdullahi *et al.,* 2019).;

AF = Soil to skin adherence factor (mg/cm^2) = 0.07mg/cm^2 (USEPA, 2011; Abdullahi *et al.,* 2019).;

ABS = Absorption factor = 0.03(As), 0.001 (other metals) (USEPA, 2011; Abdullahi *et al.,* 2019).;

BW = Body weight (Kg) = 70 Kg for adult average (USEPA, 1989).;

PEF = Particle emission factor = $1.36\times10^{9}m^{3}Kg^{-1}$ (USEPA, 2004; Abdullahi *et al.,* 2019).;

AT = averaging time = 365×ED for non-carcinogenic effect and 365×70 for carcinogenic effect (USEPA, 2011; Abdullahi *et al.,* 2019).;

CF = Conversion factor (10^{-6}).

Non-carcinogenic Risk Assessment

The hazard quotient (HQ) represents the potential non- carcinogenic risk for an individual heavy metal. HQ is a unitless number that is expressed a probability of an individual suffering an adverse effect. The HQ is defined as the ratio of ADI (Mg/kg/day) to the reference dose (RfD, Mg/kg/day) and is an estimation of daily exposure to the human population that is not likely to represent an appreciable risk of deleterious effects during a lifetime (USEPA, 2010; Abdullahi *et al.,* 2019).

HQ = $\frac{ADI}{\mathrm{RfD}}$ ………………………………..4

Hazard index

Hazard Index (HI) indicates the potential non-carcinogenic risk pose by more than one metal. 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.

HI = ∑HQi = $\sum\frac{ADIi}{\mathrm{RfDi}}$ ………………………5

Total Hazard Index refers to the sum of more than one HI for multiple pathways.

$HI_T = HI_{ing} + HI_{inh} + HI_{derm}$ …………………6

Where i corresponds to different heavy meals.

HI ≤ 1 indicates no adverse health effects and HI > 1 indicates likely adverse health effects (Abdullahi *et al.*., 2019).

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:

$Risk\ pathways = \sum_{k=1}^{n} ADIkxCSFk$ ……..7

Where Risk is a unit less probability of an individual developing cancer over a life time. ADI_k (Mg/kg/day) and CSF_k (Mg/kg/day) are the average daily intake and the cancer slope factor, respectively for the k^{th} 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 (Kamunda *et al.*, 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) = $Risk_{ing} + Risk_{inh} + Risk_{derm.}$ ……8

where $Risk_{ing}$, $Risk_{inh}$, and $Risk_{derm}$ are risks contributions through ingestion, inhalation and dermal pathways.

Both non-carcinogenic and carcinogenic risk assessment of heavy metals are calculated using RfD and CSF values derived largely from the Department of Environmental Affairs (South Africa) and USEPA as shown in Table 2.

Table 2: Reference doses (RfD) in (Mg/kg/day) and Cancer Slope Factors (CSF) for the different heavy metals in soil

Heavy metal	Oral RfD	Dermal RfD	Inhalation RfD	Oral CSF	Dermal CSF	Inhalation CSF
As	3.00E-04	3.00E-04	3.00E-04	1.50E+00	1.50E+00	1.50E+01
Pb	3.60E-03	-	-	8.5E-03	-	4.20E-02
Hg	3.00E-04	3.00E-04	8.60E-05	-	-	-
Cd	5.00E-04	5.00E-04	5.70E-05	-	-	6.30E+00
Cr	3.00E-03	-	3.00E-05	5.00E-01	-	4.10E+01
Co	2.00E-02	5.70E-06	5.70E-06	-	-	9.80E+00
Ni	2.00E-02	5.60E-03	-	-	-	-
Cu	3.70E-02	2.40E-02	-	-	-	-
Zn	3.00E-01	7.50E-02	-	-	-	-

Source: (USEPA, 1991)

RESULT AND DISCUSSION

The concentrations of heavy metals: Cr, Ni, Cu, Zn, As and Pb in the soil from different Boko Haram's explosion sites in Gombe state were investigated and the results are presented in Table 3 below.

Table 3: Mean concentrations of Heavy Metals in the soils from different Boko Haram's explosion sites in Gombe State

Sample's location	Concentrations of metals mg/kg					
	Cr	Ni	Cu	Zn	As	Pb
Gombe division	28.4±9.62	8.85±1.74	39.9±12.50	435±208	17.2±1.63	42.8±6.90
Quarter guard	29.7±10.20	8.3±3.12	39.4±8.42	176±15.41	30.2±4.31	15.7±4.42
K/Police station	ND	6.07±1.65	19.7±8.20	72.9±18.88	ND	15.6±2.33
D/kowa Park	ND	8.19±2.06	60.1±8.74	317±103	10.2±1.66	196±87.42
K/mata	ND	4.1±0.88	21.9±2.13	124±17.55	ND	21.7±2.50
Timber Market	ND	ND	31.4±5.69	1460±238	17±1.96	69.3±5.28
Main market	58.3±6.92	10±2.01	30.9±5.73	80±11.92	15.2±1.71	3.57±1.22
GMControl	**45.6±6.12**	**11±3.32**	**26.1±3.16**	**93.6±11.45**	**ND**	**15.5±1.40**
N/Police station	19.6±2.22	2.76±0.74	18.5±1.62	9.9±1.33	1.02±0.72	12.6±1.04
NFD Mosque	20.1±1.97	8.59±1.03	24.9±2.08	19.9±2.11	ND	15.8±2.22
NFControl	**39.9±5.12**	**12.6±3.76**	**25.6±2.52**	**30.4±4.81**	**1.48±0.44**	**26.5±7.52**
BJ Pol. Station	ND	6.11±1.09	17.5±1.38	16.6±2.01	ND	20.2±2.61
Ashaka Junct.	ND	3.33±0.42	22±3.10	6.08±0.96	ND	42.2±5.73
GRA	ND	7.25±1.31	18±2.89	29±2.64	1.21±0.94	25.7±10.2
Union Bank	27.2±2.88	12.1±1.52	22.3±3.27	30.6±5.02	ND	25.8±3.32
BJControl	**ND**	**7.93**±1.20	**19.2**±4.41	**21.2**±6.15	**ND**	**25.1**±3.11

The distribution of Chromium in the soil samples of Boko Haram's explosion sites in Gombe metropolis and environs was shown in Figure 1. The Chromium was not detected in soils from Kwadon police station, D/kowa park, Timber market and K/mata. The concentrations observed in these sites were below that observed in the control sample (45.6Mg/kg) except in Main market soil. In Nafada soil samples, the concentrations of Chromium were found to be 19.6 and 20.1Mg/kg at Nafada police station and Nafada mosque respectively. These concentrations were below that observed in the NF-control which was 45.6Mg/kg.as shown in figure 3. Chromium was not detected in all the samples collected from Bajoga except in Union bank soil (27.2Mg/kg). The maximum allowable limits of Chromium in soil as given by FAO/WHO

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was 100Mg/kg, EU guidelines present a maximum of 150Mg/kg while south Africa peg it at 6.5Mg/kg as indicated in Table 1. This indicates that the sampling points has Chromium concentration within the limits of FAO/WHO and EU guidelines but were all above the south African guideline.

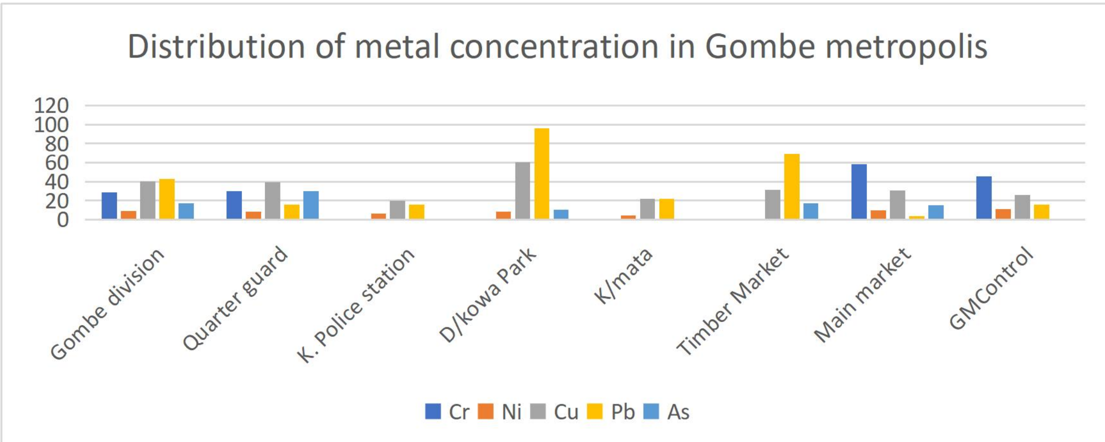

Figure 1: Distribution of some heavy metals in samples from Gombe metropolis

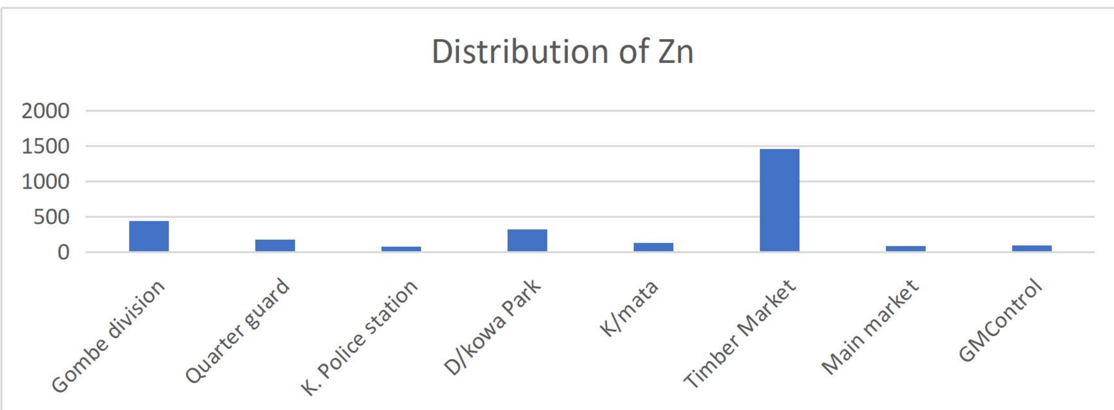

Figure 2: Distribution of Zn and Ba in soil samples from Gombe metropolis

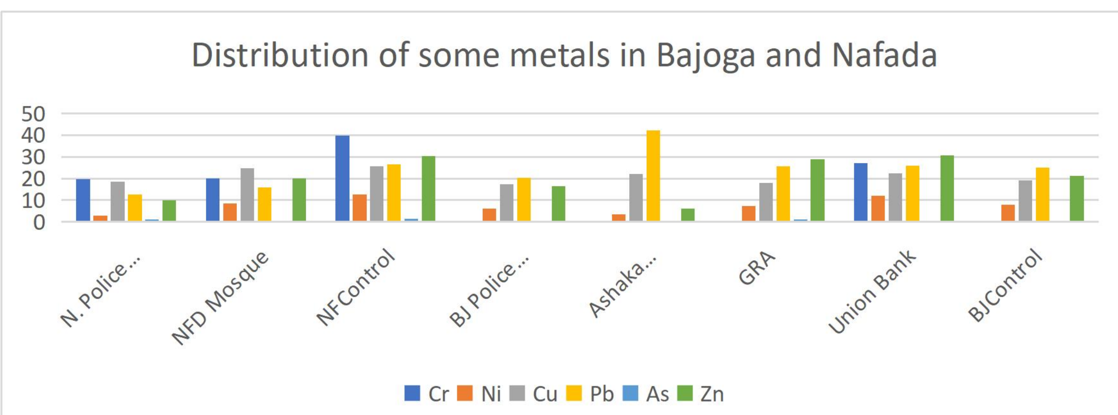

Figure 3: Distribution of some metals in Samples from Bajoga and Nafada

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In Gombe metropolis and environs, the soil sample from k/mata recorded lowest concentration of Nickel (4.1Mg/kg) and the largest was observed in sample from main market (10.0Mg/kg). All the concentrations from these sites were below the concentration recorded in the control (Figure 1). This indicates that there may likely be no Nickel contamination due to Boko Haram's activity in these sites. Soil samples from Nafada recorded smaller concentration than that in NF-control sample (39.9Mg/kg). All the samples from Bajoga had Nickel concentrations lower than BJG-control (7.93Mg/kg) except Union bank soil (12.1Mg/kg) as seen in figure 3.

In a similar study to investigate the impact of world war on soils of Saipun, Denton *et al.,* (2016) reported Nickel concentration of 19-96Mg/kg in soil and sediment of dumpsites in Saipun which were far higher than the concentrations documented in this study (2.6-12.1Mg/kg). Also, in assessing the heavy metal pollution in soils after mine clearance and disposal through controlled explosions in dugout pits during demining operations at two hotspot areas, in the Halgurd-Sakran National Park, Nickel was found to range between 296.55 – 328Mg/kg (Hamad *et al.,*2019).

The concentrations of Nickel in this study were all below the maximum permissible limits of Nickel concentration in soil set by FAO/WHO (50Mg/kg), EU guidelines (75Mg/kg) and South African guideline (91Mg/kg).

All the soil samples in Gombe metropolis had higher Copper concentration than the control sample except K. police station and k/mata soils as shown in figure 1. The concentration ranged from 19.7-60.1Mg/kg. There may be possible Copper contamination by Boko Haram's activity in the sampling sites in Gombe metropolis as the control sample recorded lesser concentration of the Copper. The concentrations of copper in Nafada were all below that recorded by control sample (25.6Mg/kg). Ashaka junction and Union bank's soil samples had Copper concentrations of 22.0 and 22.3Mg/kg which were both above the Copper concentration in the BJ-control (19.2Mg/kg) as seen in figure 3. This indicates possible contamination from the Boko Haram's activity. The maximum permissible limit of copper concentration in soil as given by FAO/WHO was 100Mg/kg, EU Guideline set it at 140Mg/kg while south African guideline set it at 16Mg/kg. This shows that all the samples in the Boko Haram's explosion sites within the study area were above the maximum limit set by south African and below the others.

The distribution of Zinc in the soil samples from Boko Haram's explosion sites from Gombe metropolis as shown in figure 2 indicates that; with the exception of K. police station and main market, all the samples had concentrations higher than that recorded by control sample (93.6Mg/kg). This shows possible Zn contamination from Boko Haram's activity. Analysis of Zinc in the soil of explosion sites in Bajoga reveals a concentration of 6.08, 16.6, 29.0 and 30.6Mg/kg in Ashaka junction, BJ police station, GRA and Union Bank respectively. The maximum permissible value of Zinc in soil set by FAO/WHO and EU guidelines were 300Mg/kg. This indicates that Gombe division, D/kowa park and Timber market soil had concentrations of Zinc above the maximum permissible limits.

Arsenic analysis in the soil from explosion sites in Gombe metropolis indicates a range of 10.2 – 17.2Mg/kg as shown in figure 1. All the concentrations in Gombe metropolis samples were above the control indicating

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possible contaminations. The control sample from Nafada had higher Arsenic concentration than that in the sites investigated. It was not detected in all the samples from Bajoga including the BJ control except in GRA soil. All the Arsenic concentration observed are below the maximum permissible limit set by FAO/WHO (20Mg/kg) except in Quarter guard sample which recorded a concentration of 30.2Mg/kg.

Lesser concentration of Arsenic (0.8 – 10Mg/kg) was reported by Bordeleau *et al.,* (2008) while assessing the impacts of training activities on heavy metal concentration at an air weapon range. High Arsenic pollution was observed in the analysis of soil polluted by destruction of Arsenic containing shells from the great war. The concentration of Arsenic was reported to be 1,937 – 72,820Mg/kg (Thouin *et al.*, 2016).

The concentration of Lead in soil samples in Gombe metropolis is shown in Table 1. All the Lead concentrations were found to exceed that of the GM control (15.5Mg/kg) except Main market sample (3.57Mg/kg). In Nafada soil samples, the concentration of Lead in N. police station (12.6Mg/kg) and NFD mosques (15.8Mg/kg) were less than the concentration in NF control (26.5Mg/kg). Soil samples from Bajoga had Lead concentrations higher than that in the BJ control (25.1Mg/kg) except BJ police station soil (20.2Mg/kg) which was lower. According to FAO/WHO guidelines, the maximum permissible limit of Lead in soil was 100Mg/kg. This indicates Lead pollution in D/kowa park's soil with a concentration of 196Mg/kg.

The daily intake doses of heavy metals in soils of Boko Haram's explosion site in the study area through three main paths namely: ingestion, inhalation and dermal contact were calculated for both carcinogenic and non-carcinogenic risk assessment models.

The HQ is defined as the ratio of ADI (Mg/kg/day) to the reference dose (RfD, Mg/kg/day) and is an estimation of daily exposure to the human population that is not likely to represent an appreciable risk of deleterious effects during a lifetime (USEPA, 2010).

For a 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.

The hazard index, HI via different pathways for the soil samples from Boko Haram's explosion sites in the study area were calculated and presented on Table 4.

The result indicates that the site with the highest HI value was Quarter guard (0.9621) while the least was observed in Ashaka junction with HI value of 1.1E-02. The HI value for the ingestion pathway was found to be higher than the dermal and inhalation pathways in all the samples investigated.

The Total Hazard Index, HI_T for the three exposure routes for all the analysed metals in all the sampling stations are below the safe level of 1. When HQ and HI values exceed one, there may be concern for potential non-carcinogenic effects. The calculated values of HQ and HI were less than one in all the samples investigated. This indicates that Soil samples from Boko Haram's explosion sites in this study does not pose major non-carcinogenic adverse health effect.

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Table 4: The hazard index, HI for the soil samples from Boko Haram explosion sites for different pathways

Location	HI_{ing}	$HI_{inh.}$	$HI_{derm.}$	HI_T
Gombe division	0.6712	2.0E-04	1.62E-04	0.6715
Quarter guard	0.9616	2.0E-04	2.83E-04	0.9621
K. Police station	0.0445	-	2.70E-07	0.0445
D/kowa Park	0.7523	6.7E-06	9.63E-05	0.7524
K/mata	0.0595	-	3.09E-07	0.0595
Timber Market	0.6710	1.1E-05	1.61E-04	0.6711
Main market	0.5975	3.9E-04	1.43E-04	0.5980
N. Police station	0.1159	1.3E-04	9.69E-06	0.1161
NFD Mosque	0.1008	1.3E-04	2.66E-07	0.1009
BJ Police Station	0.0530	-	1.91E-07	0.0530
Ashaka Junction	0.0171	-	1.49E-07	0.0171
GRA	0.0996	7.9E-07	1.16E-05	0.0996
Union Bank	0.1442	1.8E-04	3.28E-07	0.1444

For carcinogenic risk assessment, 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 excess lifetime cancer risk, RI for all the exposure pathways; ingestion, inhalation and dermal pathways as well as the total cancer risk were calculated and presented in Table 5 below.

Based on the carcinogenic risk values of the calculated ADI's, the excess lifetime cancer risks called the Risk Index, RI for different pathways were calculated and the result presented on Table 5. The RI represent the total excess lifetime cancer risks via the three pathways.

The highest excess life cancer risk value in the study area was observed in Quarter guard soil sample with an RI value of 4.96E-04 and lowest RI value of 1.09E-06 was obtained in K. police station. Union bank's soil recorded higher RI value of 1.14E-04 than all the soils of Bajoga, while the least was obtained in BJ police station (1.41E-06).

The ingestion route seems to be the major contributor to excess lifetime cancer risk followed by inhalation and the dermal pathways.

The US Environmental Protection Agency considers acceptable for regulatory purposes a cancer risk in the range of 1.0E-06 to 1.0E-04 (USEPA, 2004). On the other hand, South Africa, considers the Individual cancer risk limit to be 5.0E-06.

The cancer risk index in sample from Gombe metropolis were all found to be above the acceptable range except K. police station and K/mata samples which are within the acceptable limits. All the soil samples from explosion sites in Nafada and Bajoga had RI values within the acceptable limits except Union Bank soil which was slightly above the range. It can therefore be stated that soils from explosion sites: Gombe division, Quarter guard, D/kowa park, Timber market and main market are polluted by heavy metals which may pose risk to the adult populace.

Table 5: The excess lifetime cancer risk, RI in the soil samples from Boko Haram explosion sites for different pathways

Location	RI_{ing}	$RI_{inh.}$	$RI_{derm.}$	RI
Gombe division	3.32E-04	2.81E-07	7.25E-08	3.32E-04
Quarter guard	4.95E-04	3.29E-07	1.27E-07	4.96E-04
K. Police station	1.09E-06	1.29E-10	-	1.09E-06
D/kowa Park	1.39E-04	3.18E-08	4.30E-08	1.40E-04
K/mata	1.52E-06	1.80E-10	-	1.52E-06
Timber Market	2.14E-04	5.08E-08	7.17E-08	2.15E-04
Main market	4.27E-04	5.16E-07	6.41E-08	4.28E-04
N. Police station	9.40E-05	1.62E-07	4.30E-09	9.42E-05
NFD Mosque	8.37E-05	1.63E-07	0.00E+00	8.39E-05
BJ Police Station	1.41E-06	1.67E-10	-	1.41E-06
Ashaka Junction	2.95E-06	3.49E-10	-	2.95E-06
GRA	1.67E-05	3.79E-09	5.10E-09	1.67E-05
Union Bank	1.14E-04	2.20E-07	-	1.14E-04

CONCLUSION

It can be concluded that; since the calculated values of HQ and HI were less than one in all the samples investigated, the Soil samples from Boko Haram's explosion sites in this study does not pose major non-carcinogenic adverse health effect. But lifetime exposure to these metals shows that soils from explosion sites: Gombe division, Quarter guard, D/kowa park, Timber market and main market were polluted by heavy metals which may pose cancer risk to the adult populace.

REFERENCE

Abdhesh, G. (2003): "Landmines - Challenges to Humanity and Environment" organized by Indian Institute of Peace, Disarmament and Environmental Protection, Nagpur, India and Global Green Peace, Srinagar, Jammu & Kashmir, India at Srinagar, India. 20 April, 2003.

Abdullahi, A.O, Mohammed, A.B. and Maigari, A.U. (2019). Health risk assessment of heavy metals in kaolin Dust from a kaolin milling plant in Alkaleri, Bauchi State, Nigeria. *FUW Trends in science & Technology Journal.*2019 Vol. 4 No. 1 pp. 304-308.

Adesuyi, A.A., Njoku, K.L. and Akinola, M.O. (2015): "Assessment of Heavy metals pollution in soils and vegetation around selected Industries in Lagos, South western Nigeria." J GEP, 3: 11-19.

Aluko, T.S., Njoku, K.L., Adesuyi, A.A. and Akinola, M.O. (2018); "Health Risk Assessment of Heavy Metals in Soil from the Iron Mines of Itakpe and Agbaja, Kogi State, Nigeria." Pollution, 4(3): 527-538, Summer 2018.

Agency for Toxic Substances and Disease Registry. ATSDR (2015) Guidance for the Preparation of a Twenty First Set Toxicological Profile. 2015. Available online: http://www.atsdr.cdc.gov/toxprofiles/guidance/set_21_ guidance.pdf (accessed on 12 May 2021).

Bordeleau, G., Martel, R., Ampleman, G. and

Thiboutot, S. (2008) "Environmental impacts of training activities at an air weapons range," Journal of Environmental Quality, vol. 37, pp. 308–317, 2008.

Broomandi, P., Dabir, B., Bonakdarpour, B., Rashidi, Y. (2017) Identification of dust storm origin in South -West of Iran. J. Environ. Health Sci. Eng. 2017, 15, 16.

Chiroma, T.M., Ebewele, R.O., Hymore, K. (2014) Comparative assessment of heavy metal levels in soil, vegetables and urban grey waste water used for irrigation in Yola and Kano. Int. Ref. J. Eng. Sci. 2014, 3, 1–9.

Denton, G.R.W.; Emborski, C.A.; Hachero, A.A.B.; Masga, R.S.; Starmer, J.A. (2016) Impact of WWII dumpsites on Saipan (CNMI): Heavy metal status of soils and sediments. Environ. Sci. Pollut. Res. 2016, 23, 11339– 11348.

Department of Environmental Affairs, DEA (2010). The Framework for the Management of Contaminated Land, South Africa. 2010. Available online: http://sawic.environment.gov.za/documents/562.pdf (accessed on 5 February 2019).

Hamad, R., Balzter, H., and Kolo, K. (2019) "Assessment of heavy metal release into the soil after mine clearing in Halgurd-sakran National Park, Kurdistan, Iraq" Environmental Science and pollution Research, 26: 1517- 536.

Kamunda, C., Mathuthu, M. and Madhuku, M. (2016). "Health Risk Assessment of heavy metals in soils from Witwatersrand Gold mining basin, South Africa". International Journal of Environmental Research and Public Health 2016, 13, 663; doi:10.3390/ijerph13070663.

Thouin, H., LeForestier, L., Gautret, P., Hube, D., Laperche, V., Dupraz, S., Battaglia-Brunet, F. (2016) Characterization and mobility of Arsenic and heavy metals in soils polluted by the destruction of Arsenic-containing shells from the Great War. Sci. Total Environ. 2016, 550, 658–669.

USEPA (1989). Risk assessment guidance for superfund volume I. Human health evaluation manual (Part A) Interim Final. Office of emergency and remedial response. U.S. Environmental Protection Agency Washington, D.C. 20450. EPA/540/1-89/002.

USEPA (2001). Risk Assessment Guidance for Superfund: Volume III - Part A, Process for Conducting Probabilistic Risk Assessment Office of Emergency and Remedial Response U.S. Environmental Protection Agency Washington, DC 20460. EPA 540- R-02-002.

USEPA (2004) U.S. Environmental Protection Agency. Risk Assessment Guidance for Super fund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment); USEPA: Washington, DC, USA, 2004.

USEPA (2010) "Contaminated Site Clean-Up Information" Technology Innovation and Field Services Division, US Environmental Protection Agency, Washington, DC, USA, 2010.

USEPA (2011). Exposure factors handbook 2011 edition (Final). http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=23625.