Health Sciences Research
2017; 4(5): 29-40
http://www.aascit.org/journal/hsr
ISSN: 2375-379X

AASCIT American Association for Science and Technology

Keywords
Heavy Metal,
Pollution,
Public Health,
Unsafe Regions

Received: May 26, 2017
Accepted: July 20, 2017
Published: September 26, 2017

The Unsafe Regions and Health Implications of the Deposition of Heavy Metals in Nigeria 'A Systematic Review Focusing on Lead and Cadmium'

Ibrahim Kaa Lezeya Christopher[1], Nzelibe Humphrey Chukwuemeka[2], Tatah Verwiyeh Silas[3]

[1]Department of Family Health, Federal Ministry of Health, Abuja, Nigeria
[2]Department of Biochemistry, Faculty of Science, Ahmadu Bello University, Zaria, Nigeria
[3]Department of Biochemistry, Faculty of Pure and Applied Science, Federal University Wukari, Wukari, Nigeria

Email address
chrisb54life@gmail.com (I. K. L. Christopher)

Citation
Ibrahim Kaa Lezeya Christopher, Nzelibe Humphrey Chukwuemeka, Tatah Verwiyeh Silas. The Unsafe Regions and Health Implications of the Deposition of Heavy Metals in Nigeria 'A Systematic Review Focusing on Lead and Cadmium'. *Health Sciences Research.* Vol. 4, No. 5, 2017, pp. 29-40.

Abstract
Pollution of the environment with heavy metals is a great problem to public health. Heavy metal contamination from industries, fertilizer, liming materials and agrochemicals has been a significant issue. Water bodies and soil used by humans and animals are been polluted with these metals and these results to health challenges mostly in developing countries like Nigeria where there are little or no measures to control environmental pollution as well as waste management. Rapid increase in population growth and industrialization with inadequate waste treatment and disposal is a great challenge in developing world. Lead and cadmium deposition is a major public health issue because they are harmful when ingested at low concentration. A systematic literature review approach was carried out and a total of nine studies were obtained, all related to heavy metals in Nigeria with cadmium, lead or cadmium and lead included in each study. The result from this study shows the concentration of lead and cadmium above the tolerance limit set by the World Health Organization (WHO) in samples analyzed from each of the study which ranged from soil, water, pediatric syrups, cosmetics, meat and battery manufacturing plant in Nigeria. Contributing factors to these are the lack of treatment and quality monitoring of industrial wastewater, improper disposal of wastewater, lack of public awareness and site for industrial activities which are close to residential areas. Results obtained from this study imply that heavy metal pollution in Nigeria is a major challenge as such government and non-governmental bodies need to provide measures in other to control the deposition of toxic metals and other waste in the country.

1. Introduction

Environmental pollution is one of many health challenges in the world today. Increasing yearly and causing irreparable damage globally. There has been rise in universal public health concern over the last thirty years attributed to pollution of the

environment [1]. 12.6 million Deaths have been estimated in the year 2012 due to working or living in poor environment, this is about 1 in 4 of deaths worldwide [1]. The World Health Organization estimates risk factors from the environment such as water, air, chemical exposure, soil pollution metals, climate change and ultraviolet radiation as a contributory factor to more than 100 injuries and diseases [2].

Heavy metal, one of the environmental pollutants is any chemical element with high density and is toxic or harmful at a very low concentration [3]. The use of liming materials, fertilizers, agrochemicals, atmospheric deposition and also organic amendments such as wastewater and sewage sludge cause contamination of the soil on a large scale with heavy metals [4, 5]. In recent times, a great concern has been indicated over issues of water and soil contamination with toxic metals due to rapid urbanization and industrialization. Pollution of the environment with heavy metals has become a significant problem in the last twenty years [6]. This is because the metals will accumulate in the crops grown and when consumed by humans it eventually transfers into the body [7, 8].

For several years, African continent was considered to be safe from heavy metal contamination [9]. However, rapid growth in population and high rates of urbanization resulting to recent development in cities with lack of adequate planning and without proper disposal waste facilities has led to increase in pollution. Consequently, Rotich *et al.* [10] confirmed that management of solid waste is a crucial problem in many developing countries like Nigeria, as the production of waste surpasses capacities for collection and also the disposal by the local authorities. As noticed by the United Nations Centre for Human Settlements [11], only one-third of generated solid waste is collected in the urban areas of Africa, and of the one-third collected only 2% is recycled. Furthermore, the use of leaded gasoline Nabulo *et al.* [12], toxic waste burning, indiscriminate dumping; burning of cadmium/nickel-based batteries, due to non-functioning pollution legislation has intensify contamination of the continent with heavy metal [13, 14].

Nigeria, a West African country shares a land border with Cameroon and Chad in the east, in the west with Republic of Benin, Niger in the northern part of the country and its southern coast in the Gulf of Guinea which is on the Atlantic Ocean. The population of the country is over one hundred and sixty million people with a growth rate of 1.9%, a birth rate of 36.0/1000, 92.9/1000 infant mortality rate and 50.2 years life expectancy based on the census conducted in 2006. WHO, Pointed out in a comprehensive study of Environmental Burden of Disease (EBD) that each year 2.97 million people die as a result of environmental risk factor in Nigeria and 46 countries in Africa combined. Almost all the deaths are avoidable because they are related with water and air quality, hygiene and sanitation. Ineffective urban run-off facilities, solid waste, accumulation of dumpsites are main features of many cities in Nigeria. Solid waste and open air waste creates problem related to environmental pollution [15].

Diverse activities generate heavy metals deposition. The principal way is industrial activities, with several waste generated such as toxic waste, chemical solvent, metals and solid waste [16]. Innumerable serious health issues arise when heavy metals are absorbed into the body through water and food, some of which include decline in immunological defenses' retardation in intrauterine growth, impairment in psycho-social behavior, as well as disabilities related to malnutrition are just some of the many health issues [17].

Heavy metal pollution has become a great problem in many Nigerian cities. Contamination of water, soil and air has been a main factor in heavy metal introduction, such as mercury, cadmium and lead in foodstuff. Toxic metals may arise as a result of industrial growth, improvement in agricultural chemicals and other urban activities of humans [15]. Olaifa and Ayodele [18] assert that technological advancement, industrialization and developmental processes have led to hazardous chemical introduction to the country. They include herbicides, agrochemicals, polycyclic hydrocarbon, pesticides and food activities. They further showed that in Nigeria, the rapid industrialization rate is leading to deterioration and contamination of the environment. The major issues however are the lack of preparations towards protecting the environment.

2. Materials and Method

2.1. Study Approach

This study aimed at determining the impact of deposition of the heavy metals cadmium and lead in Nigeria, focusing on regions with toxic metal limits above tolerance level, routes of exposure and public health impacts. The most appropriate option considered was a systematic review. Mulrow, [19] explored the idea that, with systematic review, enormous numbers of studies are improved to good information; furthermore, redundant and insignificant literatures are separated from relevant and critical studies. Furthermore, primary studies have several limitations such as misinterpretation, bias, methodological flaws, time factor, context dependency as well as conflicting conclusion. Study methodology and designs might be the cause of these limitations. In this case the appropriate method for the improvement of accuracy and reliability of conclusions as well as limiting bias is systematic review [19].

2.2. Inclusion and Exclusion Criteria

2.2.1. Inclusion Criteria

1) Studies conducted within 2000 and 2016 in Nigeria by primary research.
2) Studies which involved heavy metals and includes lead, cadmium or cadmium and lead.
3) Studies that have investigated the impact heavy metals have upon health
4) Studies conducted in Nigeria and published in English language

2.2.2. Exclusion Criteria

1) Studies conducted by means of secondary research were excluded regardless of the location and the year it was conducted.
2) Studies on non-heavy metals were excluded.
3) Studies published before 2000 and conducted outside Nigeria
4) Studies not published in English language but published in other languages were excluded.

2.3. Search Strategy

The databases searched for the review include PubMed that comprises of about 4600 journals. It was selected taking into consideration the number of academic and peered reviewed articles that it provides in healthcare area. In addition CINAHL database which has recorded over 420,000 articles from 1982 with approximately 1200 journals in the area of healthcare [48]. Additional databases used include Medline, web of science, Cochrane library and Amed database. Numerous databases were used because all publications cannot be obtained using only one database. Furthermore keywords were used as explained by Haynes [21] that a qualitative search strategy require use of key words that enhance the search of suitable materials relevant to the systematic review topic in adequate quantity through the use of logical method. Advance search was conducted using different combination of key words with Boolean operators 'AND' and 'OR' in each of the data bases. The key words used are: cadmium, lead, heavy metals, health implications, metal deposition, Nigeria, Zamfara, north, south, contaminate. The search was narrowed to articles published between 2000 and 2016. The combination is as follows: deposition OR contaminat* OR wast* OR 'soil pollutant' AND Nigeria OR Lagos OR north* OR south* OR east* OR west* OR Zamfara OR 'niger delta' AND health OR cancer OR kidney* OR fertility OR pregnancy AND 'heavy metals' OR metals OR lead OR cadmium. Furthermore to the search explained above, more searches were conducted from reference list and citations of relevant articles, Google and Google scholar were also checked in order to obtain additional articles for this review and to enable global coverage of findings and resourceful materials.

2.4. Screening Strategy

The articles were first screened by title and abstract to assess whether they meet the criteria and followed by the full text screening for elaborate information. The inclusion and exclusion criteria were used to select the articles for the review which was described in this part of the methodology. Gerrish and Lacey [22] maintained that title and abstract screening is necessary for quick evaluation and reading of an article which will help improve the quality of the search strategy. Providing guide and focus to search involves systematic search [23]. Title and abstract screening was the first phase of the screening process while full text screening was the second phase of the screening process. Medline, CINAHL, PubMed, Cochrane Library, web of science and Amed databases were checked individually and 478 articles identified after removing duplicates using endnotes and applying limiters (exclusion criteria). Other searches used such as Google and Google scholar identified 13 articles. A total of 491 articles were identified. Secondly duplicated were removed from articles identified and a total of 354 articles were left for further screening. Titles of the articles were screened and 158 journal articles were excluded with 196 remaining. The abstract screening was the next phase of the strategy which excluded 124 articles as a result of their objectives not meeting the study criteria. The remaining 72 articles were fully screened in detail and 9 articles were finally selected because they met the exclusion and inclusion criteria.

2.5. Quality Appraisal

Quality appraisal of each of the selected articles was done using an adapted checklist developed by Guyatt *et al., [*24]. The checklist contains 11 items which assessed the sample/population studied, the measurement used, type of sampling, how data or samples were collected, result presentation as well as clear statement of the findings and also assessing whether the result can be generalized. The final question of the tool presents a general comment as such was not included in the appraisal. Answers to questions were scored 0 (for No) and 1 (for yes) [24]. Each of the study selected was rated by summing up the scores from the various items in the checklist. A study that scores 8 and above was considered good, 5-7 was considered to be moderate, and any study that scored less than 5 was evaluated to be poor. In total, all the 9 articles used in this review were with moderate and good validity and were considered for the review.

2.6. Data Analysis

As a result of the diverse nature of the data and results of this review, the most appropriate method considered was the narrative approach which was used for analyzing and synthesizing the data used in the review. Popay *et al.* [25] and Hart [26] proposed that narrative synthesis is an approach that depends on use of words to give a summary of the findings and results from different studies as such there is rigorous and in-depth discussion when using narrative analysis. The narrative method for this review was based on critically summarizing the result of the selected articles structurally, as a result critically appraising the data extracted from the individual studies.

3. Results

SUMMARY OF CADMIUM AND LEAD LEVELS IN WATER SAMPLES OF SOUTH-SOUTH AND NORTHWEST REGION IN NIGERIA

Hassan *et al.* [27] and Nduka *et al.* [28] investigated the concentration of cadmium and lead in water samples of some creeks and rivers in Delta state, wells and boreholes in

Zamfara state respectively. Table 1 below shows the summary of cadmium and lead pollution in water samples reported by Hassan *et al.* [27] and Nduka *et al.* [28].

Table 1. *Levels of lead and cadmium in Delta state (south-south) and Zamfara state (North-west) water samples.*

Regions	Cadmium (mg/l)		Lead (mg/l)	
	Dry season	Raining season	Dry season	Raining season
Delta state				
Ijala creek	0.60 ± 0.04	0.52 ± 0.02	0.10 ± 0.00	0.09 ± 0.00
Ubeeji creek	0.70 ± 0.02	0.64 ± 0.01	0.30 ± 0.02	0.22 ± 0.01
Jeddo river	1.10 ± 0.03	0.86 ± 0.01	0.60 ± 0.02	0.48 ± 0.01
Ekpan River	1.00 ± 0.04	0.85 ± 0.01	0.40 ± 0.01	0.36 ± 0.01
Ekurede creek	0.50 ± 0.04	0.46 ±0.02	1.00 ± 0.04	0.87 ± 0.02
Ughelli river	0.02 ± 0.01	0.17 ± 0.01	0.80 ± 0.03	0.72 ± 0.01

Zamfara State	Lead (mg/l)
Topeki village (wws)	0.065 ± 0.019
Dareta Village (wws)	0.121 ± 0.014
Topeki village (bws)	0.039 ± 0.027
Dareta village (bws)	0.165 ± 0.034

Note: wws = well water sample; bws = borehole water sample.

Cadmium and Lead concentrations in Rivers, Bayelsa (South-South) and Kano state (North-West) Nigeria Danazumi and Bichi [29], Nduka and Orisakwe [28].

Two reaches designation as upstream, station A and station G, downstream down the river were chosen. Station A is an end, upstream before wastewater from Challawa industries starts contaminating the river and station G, downstream, is another end point where one old water works draws in its raw water.

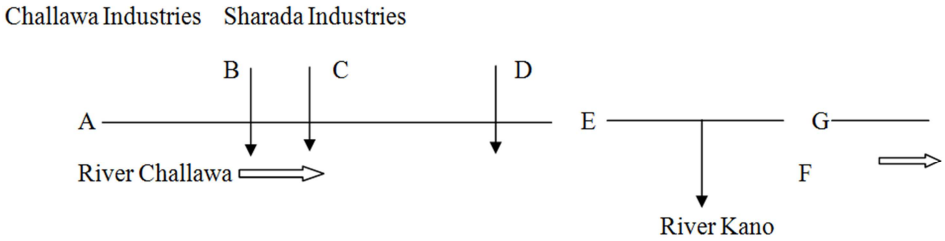

Figure 1. *Schematic outline of Challawa River, effluents discharged points and confluence with Kano, North Western Nigeria 'Danazumi and Bichi [29].*

Table 2 below shows the summary of cadmium and lead pollution in water samples reported by Danazumi and Bichi [29] and Nduka and Orisakwe [28]

Table 2. *Levels of lead and cadmium in Rivers, Bayelsa state (South-South) and Kano state (North-West) water samples.*

Regions	Cadmium (mg/l)		Lead (mg/l)	
Dry season	Raining season	Dry season	Raining season	
Rivers state				
Okiriki river	0.16 ± 0.04	0.13 ± 0.02	0.59 ± 0.03	0.52 ± 0.02
Ndmbia river	0.20 ± 0.02	0.16 ± 0.00	0.56 ± 0.02	0.48 ± 0.01
Iwofe river	0.14 ± 0.03	0.13 ± 0.02	0.50 ± 0.04	0.43 ± 0.02
Bayelsa state				
Akipai stream	0.01 ± 0.00	0.01 ± 0.00	ND	ND
Nembe creek	ND	ND	ND	ND

Kano State	Lead (mg/l)	
Points of sample collection	Dry season	Raining season
A	0.190	0.111
E	0.840	0.459
G	0.523	0.285

Note: ND = Not detected

SUMMARY OF CADMIUM AND LEAD LEVELS IN SOIL SAMPLES OF SOUTH-SOUTH REGION IN NIGERIA

Elevated soil heavy metals level in the Niger Delta and its human health effects Olawoyin *et al.* [30].

Olawoyin *et al.* [30] quantified soil samples at variable depth (0 – 15cm) in Niger Delta in four different areas (Eriemu = ERSS, Bonny = BNSS, Ughelli = OGSS, Odidi = ODSS). The median concentration of cadmium in BNSS (2.018mg/kg), OGSS (1.403mg/kg), ERSS (1.570mg/kg) and ODSS (0.571mg/kg) while the median concentration of lead in all the four soil samples are BNSS (918.845mg/kg), OGSS (709.666mg/kg), ERSS (1005.320mg/kg) and ODSS (911.360mg/kg).

Table 3. *Total cadmium and lead concentrations in mg/kg in soils of Niger delta.*

Sample ID	Cadmium		Lead	
	Median	StDev	Median	StDev
BNSS	2.018	0.867	918.845	406.620
OGSS	1.403	0.811	709.666	296.721
ERSS	1.570	1.396	1005.320	537.884
ODSS	0.571	0.047	911.360	51.573
Total	1.307	1.041	895.05	423.93

*Note: Bonny = BNSS, Eriemu = ERSS, Odidi = ODSS, and Ughelli = OGSS

CADMIUM AND LEAD CONCENTRATION IN PRODUCTS USE IN NIGERIA

Contamination of Heavy Metal in ready to use herbal remedies in South Eastern Nigeria, Nwoko and Mgbeahuruike [31].

Nwoko and Mgbeahuruike [31] conducted a study to determine the concentration of heavy metals in herbal remedies in the urban areas of South-Eastern part of Nigeria comprising of Owerri, Aba, Onitsha, Enugu and Abakiliki.

The study revealed that some of the places herbal remedies where sold were commercial, industrial and residential areas with either low or high traffic situations. The range and mean metal content of herbal remedies are presented in table 4 below.

Table 4. *Mean and range of cadmium and lead concentrations of herbal remedies in South-Eastern Nigeria.*

South-East	Cadmium (µg/g)		Lead (µg/g)	
	Mean Content	Range	Mean Content	Range
Owerri	5.3	0.83 - 6.5	6.1	2.6 - 10.3
Abakiliki	4.8	0.89 - 10.6	35.7	18 - 46
Enugu	4.2	1.1 - 9.7	23.1	12.7 - 34.7
Abia	3.0	0.97 - 1.4	16.3	10.8 - 23
Onitsha	5.1	1.0 - 8.4	40.5	34 - 48

Owerri had the maximum mean concentration of cadmium with 5.3µg/g while Abia had 3.0µg/g the lowest amongst the cities. Maximum Lead concentration of 35.7µg/g was reported in Abakiliki while 6.1µg/g in Owerri been the lowest. Some herbal medicines recorded highest concentration for lead and cadmium as shown in table 5 below.

Table 5. *Lead and cadmium concentrations in herbal medicines.*

State/City	Herbal Medicines	Concentration	
		Cadmium (µg/g)	Lead (µg/g)
Owerri	C-cysta	6.5 ± 1.3	
	C-candi		10.3 ± 2.5
Abakiliki	H-Nal	10.6 ± 1.5	46 ± 16.3
Abia	Rinbacin	7.3 ± 0.43	
	Koso Powder		23.5 ± 1.4
Onitsha	Virgyvirgy		
	Worm expeller	8.4 ± 1.1	
	Sekim powder		48 ± 17.8

Cadmium and Lead levels of commonly administered pediatric syrups in Nigeria: A public health concern? Orisakwe *et al.* [32].

Fifty samples of paediatric syrup were analysed by Orisakwe *et al.* [32]. The samples were purchased from pharmaceutical shops and patent medicine stores in Akwa, the capital of Anambra state, Nigeria. The syrups were separated into two groups of imported and Nigerian made. The levels of lead of the locally produced syrups ranged from 0.01mg/l in chloroquine to 1.08 mg/l in magcid suspension. Magcid suspension had the highest concentration of cadmium with 2.45mg/l while emzolyn and colipan had the lowest with a concentration of 0.01 mg/l.

The levels of lead were detected in about 58.8% of the syrups produced in Nigeria while levels of cadmium were detected in all the syrups. Cadmium and lead levels in imported syrups ranged between 0.01mg/l in cadiphen which was manufacture in Dhilka, India to 0.09mg/l in maxiquine manufactured in England. The levels of lead were detected in about 31.2% of the syrups imported. Zentelalbendazole and chloramphenicol syrups had 0.88mg/l and 0.60mg/l of cadmium respectively. The lowest level of cadmium was seen in Bellis cough syrup with a concentration of 0.01mg/l. Erythromycin suspension was the only syrup with no detectable level of cadmium representing 6.3% of the imported syrup. Lower concentrations of cadmium and lead were observed in imported syrups as compared to the Nigerian made syrups.

The result of this investigation showed the presence of cadmium in 98% and lead in 60% of the sample size most of which exceeded limits set by the National Agency for Food and Drug Administration (NAFDAC) and the world Health Organisation (WHO).

Evaluation of the concentration of Toxic Metals in cosmetic products in Nigeria‘Adepoju-Bello *et al.* [33].

Adepoju-Bello *et al.* [33] analysed the concentration of heavy metals in fifty cosmetic products such as lip glosses, lipsticks, skin whitening creams (in bottles, cups and tubes). They were obtained from different shops in various locations in Lagos, Nigeria. They digested the samples and prepared standard solutions to analyse the concentrations using AAS. The concentrations of metals were analysed in duplicates and average value was statistically analysed. The metals had an average concentration of 0.023 – 0.203 ppm for cadmium and 0.017 – 0.090 ppm for lead.

Impact of environmental lead and cadmium on quality of

goat meat in Nigeria 'Okoye and Ugwu [34].

Okoye and Ugwu [34] evaluated the concentration of lead, cadmium and some heavy metals in the edible offal's and muscle of goat bred from Nigeria. Thirteen samples *(Kano brown breed/Red sokoto)* each comprising of liver, muscle, heart and kidney were obtained from the abbatoir as shown in table 6 below:

Table 6. *Mean concentrations of cadmium and lead ($mgkg^{-1}$) in the kidney, muscle, liver and heart of goat.*

Metal	Liver	Kidney	Heart	Muscle
Cadmium				
Range	Nd-1.15	0.07-3.08	Nd-2.04	0.09-1.26
Mean ± SD	0.35 ± 0.36	*0.83 ± 0.73	*0.34 ± 0.57	0.69 ± 0.42
Lead				
Range	Nd- 0.65	Nd-0.63	Nd-1.11	Nd-1.18
Mean ± SD	0.65	*0.53 ± 0.14	*0.20 ± 0.37	0.47 ± 0.50

Nd = not detectable; SD = standard deviation, *correlation significant at $p < 0.01$

Impact of effluents from a car battery manufacturing plant in Nigeria on soil, water, and food qualities 'Orisakwe *et al.* [32].

Orisakwe *et al.* [32] collected soil, water and food samples for heavy metal determination from a car battery production plant in Nnewi, Nigeria. Four (4) samples were analyzed from a 30cm depth. Sample A collected from within the manufacturing yard, and B, C and D, from farmlands adjacent and outside the factory. Eleven samples were used for the study as shown in table 7 below:

Table 7. *Metals levels (ppm) in soil samples.*

Soil sample					
Analyte (ppm)	**A**	**B**	**C**	**D**	**Control**
Pb^{2+}	38.0	12,102	97	5,738	4.54
Cd^{2+}	0.02	5.00	0.02	0.02	2.20

High concentrations of lead (21 and 19ppm) were detected in the dried cassava tuber and edible fruit respectively, whereas 2.0ppm was detected in the dried cassava tuber from the control site. 0.02ppm of cadmium was detected in the fruit sample and the cassava as shown in table 8 below.

Table 8. *Metals levels (ppm) in Water and Food Samples.*

	Water sample		Food sample	
Analyte (ppm)	**Tap water**	**Cassava water**	**Cassava**	**Fruit**
Pb^{2+}	0.20	0.02	21.00	19.00
	(<0.01)	(0.04)	(2.0)	(NA)
Cd^{2+}	0.20	0.02	0.02	0.02
	(<0.001)	(<0.001)	(<0.001)	(NA)

*Notes: NA = not analyzed. Numbers in parenthesis indicate control values.

This investigation revealed high concentration of lead and cadmium in soil and water as well as cassava and fruit consumed by the public.

4. Discussion

The availability of portable water supply has been a major concern that has affected Nigeria, especially the oil producing states located in the Niger Delta region. This challenge has been as a result of environmental pollution and degradation, which has led to efforts and resources being put to source for water, that may end up being of questionable quality. Great deals of literature have reported the pollution of water bodies in Nigeria from anthropogenic and industrial activities [28, 30, 32]. Consequently, inspection of water quality to guarantee health security is a critical public health task carried out globally particularly in developing countries like Nigeria. The issue of water pollution in the Niger Delta region in Nigeria cannot be overemphasized, and this has most times being linked to industrial activities in the region. Nduka and Orisakwe [28] reported hazardous levels of cadmium, lead and other heavy metal all through the various open water ways found along creeks or coastal areas of Bayelsa, Rivers and Delta States located in the Niger Delta region of Nigeria (Table 1). These water bodies are the main sources of water supply for consumption and other domestic activities to the local communities of these regions. The outcomes from their study from the articles selected systematically demonstrates that the levels of cadmium and lead in the surface water surpassed their threshold limit of 0.01mg/L and 0.003mg/L respectively, which is the standard as set by the WHO for drinking water. This is dangerous to the environment and proves to be a health hazard to the local communities, since these water bodies do serve as the main source of water for consumption and domestic activities [35].

Olawoyin *et al.* [30] also agreed with Nduka *et al.* [28] and confirmed that several petrochemical activities in the Niger Delta region has led to incidences of oil spillages, gas flaring, waste discharges and the release of chemical into the environment. The disposal of these toxic by-products has affected the quality of soil in this region and in the long run posing several health issues to the ecosystem and local population. Olawoyin *et al.* [30] analysed soil samples from the Niger Delta region in order to test the concentration levels of heavy metals in those soils. The findings shows that there was a high level of Lead (Pb) and Cadmium (Cd) in the samples of soil collected (Table 3) in contrast with the recommended and standard values reported from some past studies [36]. The concentrations of cadmium and lead in the soil samples were not safe as presented in Table 3 and are considered to be reasons of the increased cancer prevalence among children and adults because of accidental ingestion and/or inhalation of soils in the region [30]. The soil analysis carried out by Olawoyin *et al.* [30] on soil samples from the area affirmed the causal association between having high

levels Cadmium and Lead in soils and developing cancer. Investigations by Iwegue *et al.* [36], Nduka and Orisakwe [28] and Olawoyin *et al.* [30] showed that the Niger Delta region of Nigeria is polluted with cadmium, lead and some heavy metals above the tolerance limit set by the World health Organizations and other international bodies and also reveals crude oil exploration as the main route of exposure to cadmium and lead in the Niger-delta region or the South-South region of Nigeria which contaminates the soil and water used by the public in this region.

In the North-western region of Nigeria, over three hundred (300) lives, mostly that of children have been lost due to the negative effects of the unlawful mining activities in Zamfara, North-West Nigeria in 2010 [36]. Yahaya [37] pointed out that extensive lead poisoning in some villages in the North-western Nigeria claimed the lives of about 355 children and about an estimated 1500 children were reported to be exposed to lead poisoning [38]. This was connected with Lead (Pb) poisoning or high Lead fixation in the blood as a result of widespread pollution in the towns. There was an incidence of acute Lead (Pb) poisoning that occurred in Bagega and its environs in Zamfara State. This was as a result of artisanal gold mining in the region and Hassan *et al.* [27] reported cases of water population from Lead accumulation. The results from the water analysis conducted showed Lead (Pb) concentration above the WHO threshold limit. The Lead concentration in the local well water was roughly 9 times above the WHO set limit, with the borehole water and surface water in the district recording about 10 times and 74 times above the minimum limit respectively as set by WHO. Hassan *et al.* [27] reported that blood Lead concentration increases by around 1 μg/dl per 0.005 ppm of Lead in water is ingested; as a result, 0.5 ppm of lead in water ingested will lead to 10μg/dl of Lead in blood. The findings from this study were similar with a different investigation carried out by Biney *et al.* [9] on blood samples of children. The result showed that the blood Lead (Pb) levels (BLLs) surpassed 10 μg/dl (the international standard limit for Blood Lead (Pb) Level). The borehole water in the study region with the exception of Topeki borehole water is likely to contribute to an abnormally high blood Lead concentration greater than 10μg/dl. Yusuf *et al.* [39] also confirmed Hassan *et al.* [27] report and found that farmlands and several water sources within the North-western cities were contaminated with Lead above the threshold limits. These investigations proved that the North Western part of the country involved in mining and other industrial activities have a high concentration of lead and cadmium in their soil and water bodies.

Another significant problem of environmental concern, confronting the Kano city in Northwest Nigeria, is that of growing indiscriminate release of industrial waste into Jakara River basin that is being eventually channeled into the Kano River and River Challawa. Danazumi and Bichi [29], assessed the impact of heavy metals disposal from industrial wastes on River Challawa in Kano (Figure 1). The river is used for diverse purposes including fishing, irrigation and water supply. Samples of water were collected during the wet and dry season in September and May respectively. Their findings revealed that the mean concentrations of Lead and Cadmium released into the stream during both seasons and at different points during the course of each seasons surpassed the threshold limits as set by the Federal Environmental Protection Agency of Nigeria (FEPA) and WHO. This may most likely be attributed to the high volume of industrial and economic activities within the city due to the high number of people living in the City. Abdul *et al.* [40] further confirmed cadmium and lead contamination in North-western city of Nigeria. Abdul *et al.* [40] reported the incidence of cadmium contamination of agricultural products like vegetables and its related health impact resulting from the use of this polluted wastewater for irrigation in Kano. This leads to the bioaccumulation of heavy metals within the internal systems of humans and animals at the point when these agricultural product are continually consumed, which will eventually result in toxicity [40, 41].

Reports by WHO has suggested that herbal medicines are being used globally as natural prescriptions by approximately 80% of the total populace [42, 43]. This occurs more in developing nations like Nigeria, and can be linked to its acceptability due to the belief that they are more effective and less harmful to the body. Nwoko and Mgbeahuruike [31] found high levels of cadmium and lead in herbal remedies (HR) sold in major cities of South-East Nigeria, including Onitsha, Abakiliki, Aba, Owerri and Enugu. These herbal remedies are largely consumed by the northerners in Nigeria and is believed to cure several infections. Consequently, the consumption of these herbal remedies mostly by the North western people of Nigeria leads to high concentration of cadmium and lead in the blood [43]. The investigations by Abdul *et al.* [40], Kroll and Shaw [42], Nwoko and Mgbeauruike [31], Prasad and Freitas [41] and Caldas and Machado [43] have shown that the northern part of the country most especially the North-western region is contaminated with cadmium and lead.

The existence of chemical contaminants in consumables is a significant health concern that calls for immediate attention in Nigeria. A study was conducted to analyze the levels of heavy metals such as cadmium and lead in paediatric syrups sold in Nigerian markets. Orisakwe and Nduka [44] randomly selected fifty different paediatric syrups from patent medical stores and pharmaceutical shops inside Awka, in Anambra State South-East Nigeria between November 2007 and May 2008. Findings of their investigation revealed a concentration of Cadmium and Lead that contributes around 60% and 98% of the individual contaminants, which are above the threshold limit set by WHO and NAFDAC, therefore making the syrups hazardous as a result of the possible bioaccumulation of heavy metal and the resultant general health issues particularly in children. The investigation by Orisakwe and Nduka [44] is of great public health concern in northern Nigeria as confirmed by Ishola *et al.* [45] that there is high use of paediatric syrup in Kano state, North Western part of Nigeria where most children are

infected with several diseases such as malaria, anaemia, fever, as a result of lack of education and awareness of the mothers and the general public in that region as compared to the south western part of the country. The increase in the use of paediatric syrup in the North western part of the country results to high concentration of cadmium and lead in children of this region.

Adepoju-Bello *et al.* [33] reported the increasing concern towards the effect of toxic metals on human physiology and behavior. For example, the toxic effect of Lead and Cadmium at high concentrations of exposure. But recent evidence shows that even reduced exposure or low concentrations of these metals such as contact through cosmetic products can also have an adverse effect on the health [46]. Beautifying products are presently regarded as one of the potential sources of dangerous levels of cadmium and lead that negatively affect the human body. Hence, it was important to find out the concentrations of these heavy metals in some frequently utilized cosmetic product in Nigeria, as a result of the likelihood of skin sensitivity and contact dermatitis that may occur more often because of the increased presence of heavy metals in beauty care products. In their study, Adepoju-Bello *et al.* [33] surveyed the levels of toxic metals in various cosmetic products sold in various beauty and body care shops in Lagos, Nigeria. The cosmetic products included thirty creams and twenty lipsticks and lip sparkles. These products were randomly bought from different shops at various areas in Lagos. The heavy metals discovered in the products analyzed were classified as inadvertent contaminants. These metals are inadvertently added during the preparation of the product and had no particular function in the mixture. Though there were trace amounts of Cadmium and Lead in the products analyzed, it could still pose a serious health risk as a result of the slow release of trace volumes of these heavy metal when they are allowed to accumulate over time due to their long shelve-life [33]. The European Union (EU) law for cosmetic had banned the use of cadmium, lead and heavy metals in beauty care products in 1976, therefore, the strict adherence to this quality control is vital in guaranteeing that the Lead and Cadmium contamination in cosmetic is maintained [47].

Okoye and Ugwu [34] assessed the levels of lead, cadmium and other heavy metals in the muscle and edible internal organs of goat reared in Nigeria. The mean value of estimated levels of Cadmium in all the meat parts (Table 6) were higher than those reported in calves from a contaminated industrialized zone of Northern Spain and other rural towns Miranda *et al.* [48]. All the mean concentrations of cadmium retrieved (table 6) in the study were additionally higher than that reported by Falandysz *et al.* [50] in poultry liver from a polluted region in Poland. However, Garco-Rico *et al.* [49] reported low values in swine kidney from Sonora. The levels of Lead concentration in this study were higher than that of the kidney, liver and muscles reported by Miranda *et al.* [48]. Samples of muscle (4), heart (1), kidney (1) and liver (1) all exceeded the Codex standard (2001) for muscle and offal of cattle and the Pearson's correlation gave strong significant correlations at $p< 0.01$ for Lead and Cadmium in heart and kidney, thus signifying same source of pollution and a negative effect of the environmental pollution on the quality of meat [34]. This has several health effect in most part of northern Nigeria as reported by Adeyinka and Mohammed [51] that the northern part of the country consume large amount of meat especially goat meat. The investigation by Okoye and Ugwu [34] on the quality of meat has revealed high cadmium and lead contamination in Nigerian meat which has more health effect on the northern part of the country where there is high consumption of meat.

Furthermore, a study by Orisakwe *et al.* [52] examined the impact of effluents on water, soils and foods quality from a car battery manufacturing Plant in Nnewi, Nigeria. The authors investigated the levels of lead, cadmium and others heavy metals in tap and cassava water, dried cassava tuber, soil, and edible fruit samples from the company. Findings revealed that lead had the highest concentration in all the samples tested; with the soil samples having the highest lead concentration (12–38 ppm) and the water samples having the lowest (0.02 – 0.20 ppm). The study reveals soil Pb levels to be very high, an observation similar to findings by Orisakwe *et al.* [32]. This reflects the tendencies of the toxic metals to accumulate at diverse pollution sites in the food chain. This could possibly account for the high concentrations of lead and other metals in these sampling sites, which suggest that there is an indiscriminate battery effluents discharge both within and outside the factory yard. Lead contents in the soil and food samples as shown in the investigation were found to be very high with passion fruit, cassava tuber and soil sample B having values of 19mg/l, 21mg/l and 12,102ppm respectively. This high concentration is more likely due to absorbed lead rather than surface contamination, in as much as passion fruit grows aerially, it still had high lead level. Orisakwe *et al.* [52] reported factory workers poisoning from misuse or the overuse of lead compounds which are highly toxic to body organs. Lead poisoning majorly arises from cumulative inhalation of dust as well as consumption of organo-lead compounds. Orisakwe *et al.* [32] further confirmed lead pollution from food and drinks which amounts to 200 – 400mg, of which about 10% is absorbed. Geophagia or clay eating is a common practice, especially among children and pregnant women in the semi-urban town of Nnewi. Hence soil lead levels found in this area has an adverse health impact to the inhabitants.

In the North-Western part of Nigeria, illegal mining activities in recent times killed hundreds of people in Zamfara state which are mostly children [3]. This was as a result of artisanal gold mining activities which led to high lead concentration in the soil resulting to lead poisoning. There was wide spread contamination of lead in the villages and towns where gold ore are being processed. The ore contains lead as impurity and hence it was deposited in the community during processing. Hassan *et al.* [27] reports that high deposition of lead and cadmium in northern Nigerian has led to absorption of these metals by crops as well as translocation of the metals from the shoot to the

grain. Stalk and leaves of most plants are consumed by livestock in Nigeria. Hence cadmium and lead accumulation are transferred to animals and as such contaminate the food chain. Hassan *et al.* [27] added that deposits from underground water movement and dust from landfills that are not well protected could also lead to accumulation of heavy metals and this contaminates and pose health impacts to humans.

There are several health implications of cadmium and lead as identified in the articles that met the inclusion criteria for this systematic review. Several metals have been flagged as environmental and toxicological hazards with public health implications. Lead and cadmium are two main heavy metals of toxicological significance that are extensively disperse in the environment. Activities of humans have played a great role in altering the natural distributions of these heavy metals. The occurrence of lead and cadmium in drinking water is known as a vital and critical pathway of exposure to toxicity. Exposure to lead and cadmium in soil, drinking water and food is of major interest because of the toxicological effects which include kidney disease, cancer, impaired cognitive functions [53].

According to the World Health Organization, cadmium and Lead are one of the most toxic heavy metals with toxicological health effects. These metals interfere with the function of vital nutrients of similar features such as zinc (Zn^{2+}) and calcium (Ca^{2+}). Lead because of its charge similarities and size can be deposited in the bone by replacing calcium (Ca^{2+}) [54]. However it can be displaced when the concentration of cadmium is elevated and this expose the system to lead resulting to neurotoxicity, nephrotoxicity and hypertension. The ability of lead to undergo metathesis reactions with zinc and calcium metalloproteins which results in loss of metabolic functions in the body continues to be a critical issue of public health concern detrimental to lead exposure [55]. Cadmium, one of the most toxic heavy metals has several health impacts. It is capable of causing hepatic, renal and testicular injury. It interferes with the metallothionein's ability to moderate copper and zinc levels in the blood. Metallothionein, a protein binds to excess metals in the body to render them unavailable [54]. Cadmium triggers metallothionein activities which binds to zinc and copper, as a result interfere with homeostasis as well as metabolic activities in the body [56]. Long-time exposure to cadmium interferes with the re-absorption activities in the tubules of the kidney leading to lung cancer and disorders in the skeletal systems [57]. Sarosiek *et al.* [58] demonstrated the ability of toxic metal ions such as cadmium and lead to distort the motility parameters of spermatozoa and reduce the fertilizing capacity of cyprinuscarpio [59].

Olawoyin *et al.* [30] analyzed heavy metal concentration in soils from various locations in Niger Delta, Southern Nigeria and reported that they add to significant life-time cancer-causing hazard on the health of the populace because of unintentional/accidental ingestion and/or inhalation of dust from polluted soils. From their outcomes, the probability of having high risk of cancer occurrence in this region is clear, with Cadmium and Lead being the characteristic heavy metals with high odds of causing cancer to the inhabitants in the area. Adepoju-Bello *et al.* [33] additionally reported that cancerous breast cells showed higher accumulation of Lead and Cadmium than non-carcinogenic biopsies. They reported that many heavy metals act as oestrogen within some breast cancer cells. Lead, although a toxic metal, it is also known as a neurotoxin which has been connected to learning, dialect and behavioral issues. It has likewise been associated with miscarriages, hormonal changes, reduced fertility in men and women, menstrual irregularities and delays in onset of puberty among girls [33]. At puberty, development of secondary sexual characteristics like testes may be affected in boys as a result of Lead poisoning. Pregnant women and young children are additionally vulnerable due to the possibility of Lead crossing the placenta, which become concentrated in brains of the foetus [60].

5. Conclusion

Findings obtained from this systematic review showed the contamination of soil and water with cadmium and lead in the Niger-Delta or south-south region of the country where there is exploration of crude oil. Furthermore, the review identified heavy metal contamination in the North- Western part of the country where there are mining activities, considerable amount of lead where reported in the water samples which was above tolerance limit set by WHO. In addition, Kano State River had heavy metal limits which exceeded the maximum permissible limits due to industrial activities in the north western state. This confirms cadmium and lead pollution in the regions as reported by the articles selected systematically with the aid of the inclusion and exclusion criteria. The study indicates that pollution with cadmium, lead and other toxic metals varies in routes of exposure and concentration levels within the regions of the country.

Acknowledgements

My most heartfelt gratitude goes to God almighty for keeping me alive throughout my study period and also for the gift of knowledge, wisdom and understanding leading to the completion of this research work. I also want to recognise the importance of my family and friend Mr Silas V. Tatah for their contribution to the success of the research.

References

[1] United Nations Environment Program (2007) *'Global Environment Outlook (GEO)—4, Summary for decision makers',* [Online] Available at: http://www.unep.org/geo/geo4/media/GEO4%20SDM_launch.pdf

[2] World Health Organisation (2016) *'Environmental pollution',* [Online] Available at: http://www.who.int/topics/environmental_health/en/

[3] Nourbakhsh, M., Sag, Y., Ozer, D., Aksu, Z. and Caglar, A. (1994) 'A comparative study of various biosorbents for removal of chromium (VI) ions from industrial waste waters', *Process Biochemistry*, 29 pp. 1-5.

[4] Senesi, G. S., Baldassarre, G., Senesi, N. and Radina, B. (1999) 'Trace element inputs into soils by anthropogenic activities and implications for human health', *Chemosphere*, 39 (2), pp. 343-377.

[5] Singh, R. P. and Agrawal, M. (2010) 'Variations in heavy metal accumulation, growth and yield of rice plants grown at different sewage sludge amendment rates', *Ecotoxicology and Environmental Safety*, 73, pp. 632-641.

[6] Wei, B. G. and Yang, L. S. (2010) 'A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China', *Microchemical Journal*, 94, pp. 99-107.

[7] Cheng, Z., Lee, L., Dayan, S., Grinshtein, M. and Shaw, R. (2011) 'Speciation of heavy metals in garden soils: evidences from selective and sequential chemical leaching', *Journal of Soils and Sediments*, 11, pp. 628-638.

[8] Liu, P., Zhao, H., Wang, L., Liu, Z., Wei, J., Wang, Y., Jiang, L., Dong, L. and Zhang, Y. (2011) 'Analysis of heavy metal sources for vegetable soils from Shandong Province, China, *Agricultural Sciences in China,* 10 (1), pp. 109-119.

[9] Biney, C., Amuzu, A. T., Calamari, D., Kaba, N., Mbome, I. L., Naeve, H., Ochumba, P. B. O., Osibanjo, O., Radegonde, V. and Saad, M. A. (1994) 'Review of heavy metals in the African aquatic environment', *Ecotoxicology Environmental Safety,* 28, pp. 134-159.

[10] Rotich, K., Zhao Yongsheng, H. and Jun, D. (2006) 'Municipal solid waste management challenges in developing countries—Kenyan case study', *Waste Manage,* 26, pp. 92-100.

[11] United Nations Centre for Human Settlements (2001) '*State of the World's Cities. In: UNEP. 2002. Global Environment Outlook: GEO-3. State of the Environment and Policy Retrospective: 1972–2002',* [Online] Available at: http://www.unep.org/geo/geo3/english/pdfs/%20chapter2-8_urban.pdf.

[12] Nabulo, G., Oryem, O. H. and Diamond, M. (2006) 'Assessment of lead, cadmium and zinc contamination of roadside soils, surface films and vegetables in Kampala city, Uganda', *EnvironmentalResources*101, pp. 42-52.

[13] Fianko, J. R., Osae, S., Adomako, D., Adotey, D. K. and Serfor- Armah, Y. (2007) 'Assessment of heavy metal pollution of the Iture Estuary in the central region of Ghana', *EnvironmentalMonitoring and Assessment* 131, pp. 467-473.

[14] Dimari, G. A., Hati, S. S., Waziri, M. and Maitera, O. N. (2008) 'Pollution synergy from particulate matter sources: the Harmattan, fugitive dust and combustion emissions in Maiduguri Metropolis, Nigeria', *European Journal of Science Resource* 23, pp. 465-473.

[15] World Health Organisation (2014) *'Quantifying environmental health impacts: data and statistics',* [Online] Available at http://www.who.int/quantifying_ehimpacts/en/

[16] Meagher, R. B. (2000) 'Phytoremediation of toxic elemental and organic pollutants', *Current Opinion in Plant Biology*3 (2) pp. 153-162.

[17] Nweke, O. C. and Sanders, W. H. (2009) 'Modern environmental health hazards: a public health issue of increasing significance in Africa', *Environmental Health Perspectives* 117 (6), pp. 863-870.

[18] Olaifa, F. E. and Ayodele, I. A. (2004) 'Presence of hydrocarbon and heavy metals in some fish species in the cross river, Nigeria', *African Journal of Livestock Extension,* 3, pp. 90-95.

[19] Mulrow, C. D. (1994) 'Rationale for systematic review', *British Medical Journal,* 309 (6954), pp. 597-599, *Pubmed* [Online]. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2541393/

[20] Polit, D., F. and Beck, C., T. (2014) '*Essentials of nursing research: Appraising evidence for nursing practice*', 8th edn. Philadelphia: Lippincott Williams and Wilkins. [Online] Available at: https://books.google.co.uk/books?hl=en&lr=&id=N4TpwETZYPQC&oi=fnd&pg=PT4&dq=Polit,+D.,+F.+and+Beck,+C.,+T.+(2014)+%E2%80%98Essentials+of+nursing+research:+Appraising+evidence+for+nursing+practice%E2%80%99,+8th+edn.+Philadelphia:+Lippincott+Williams+and+Wilkins.&ots=3EJpkW8WkC&sig=kU2H0fAqVSjcwE_wmx1UOL7QCgY#v=onepage&q&f=false

[21] Haynes, R. B (1994) 'Developing optimal search strategies for detecting clinical sound studies in MEDLINE', *Journal of American Medical Informatics Association,* 1 (6), pp. 447-458.

[22] Gerrish, K. and Lacey, A. (2010) '*the research process in nursing,* 6th edn. Chichester: Wiley-Blackwell.

[23] Aveyard, H. (2010) '*Doing a literature review in health and social care: a practical guide*', 2nd edn. London: Open University Press. [Online] Available at: https://books.google.co.uk/books?hl=en&lr=&id=qYdFBgAAQBAJ&oi=fnd&pg=PP1&dq=Aveyard,+H.+(2010)+%E2%80%98Doing+a+literature+review+in+health+and+social+care:+a+practical+guide%E2%80%99,+2nd+edn.+London:+Open+University+Press.&ots=aP9Z2FGal4&sig=q0gMtiGrmGFHhYJF4PpoqxsH96o#v=onepage&q&f=false

[24] Guyatt, G. H., Sackett, D. L., and Cook, D. J. (1994) 'Users' guides to the medical literature. II. How to use an article about therapy or prevention', *JAMA,* 271 (1): pp. 59-63.

[25] Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., Britten, N., Roen, K. and Duffy, S. (2006) '*Guidance onthe conduct of narrative synthesis in systematic reviews: a productfrom the ESRC methods programme.* Available at: http://www.lancaster.ac.uk/shm/research/nssr/research/dissemination/publications/NS_Synthesis_Guidance_v1.pdf

[26] Hart, C. (1998) *Doing a Literature Review: Releasing the Social Science Research Imagination*. *Sage* [online]. Available at: http://s3.amazonaws.com/academia.edu.documents/35996527/Doing_a_L_review.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1474463791&Signature=l%2Fde0cu%2F3DOriWUOQn9tyVfE0sc%3D&response-content-disposition=inline%3B%20filename%3DDoing_a_Literature_Review_Releasing_the.pdf

[27] Hassan, M. M., Nuhu, A. A., Sallau, M. S., Majiya, H. M. and Mohammed, A. K. (2015) 'Zamfara lead poisoning saga: comparison of lead contamination level of water samples and lead poisoning in Bagega Artisanal gold mining district, Nigeria', *Journal of chemical and pharmaceutical research*, 7 (3), pp. 7-12.

[28] Nduka, J. K. and Orisakwe, E. O. (2011) 'water-quality issues in the Niger Delta of Nigeria: a look at heavy metal levels and some physiochemical properties *'Environmental Science Pollution Research*, 18, pp. 237-246.

[29] Dan'azumi, S. and Bichi, M. H. (2010) 'Industrial pollution and heavy metals profile of Challawa river in Kano, Nigeria', *Journal of applied sciences in environmental sanitation*, 5, pp. 23-29.

[30] Olawoyin, R., Oyewole, S. A. and Grayson, R. L. (2012) 'Potential risk effect from elevated levels of soil heavy metals on human health in the Niger delta' *Ecotoxicology and environmental safety*, 85, pp. 120-130.

[31] Nwoko, C. O and Mgbeahuruike, L. (2011) 'Heavy metal contamination of ready-to-use herbal remedies in South Eastern Nigeria' *Pakistan Journal of Nutrition*, 10 (10), pp. 959-964.

[32] Orisakwe, O. E., Obi, E., Afonne, O. J., Dioka, C. E., Akumka, D. and IIlondu, N. A. (2001) 'Ecotoxicological study of the Niger-Delta area of the River Niger', *Bulletin of Environmental Contamination and Toxicology*, 66, pp. 548-552.

[33] Adepoju-Bello, A., Oguntibeju, O. O., Adebisi, R. A., Okpala, N. And Coker, H. A. B. (2012) 'Evaluation of the concentration of toxic metals in cosmetic products in Nigeria', *African Journal of Biotechnology*, 11 (97), pp. 16360-16364.

[34] Okoye, C. O. B and Ugwu J. N (2010) 'Impact of environmental cadmium, lead, copper and zinc on quality of goat meat in Nigeria', *Bulletin of the Chemical Society of Ethiopia*, 24, pp. 133-138.

[35] World Health Organization (2001) *'Guidelines for drinking water quality',* 2nd edn, vol 1. Geneva, pp 49–50 [Online] Available at: http://www.who.int/water_sanitation_health/dwq/gdwq2v1/en/

[36] Iwegue, C. M. A., Arimoro, F. O. and Nwozo, S. O. (2007) 'Study of Heavy Metal Speciation in Sediments Impacted with Crude Oil in the Niger delta. Nigeria', *AnnalidiChimica,* 97, pp. 1143.

[37] Yahaya, S. (2010) *'Lead poisoning from mining kills 163 in Nigeria',* Thomson Reuters, [Online] Available at: http://www.reuters.com/article/us-nigeria-poisoning-idUSTRE6534JE20100604

[38] Me´decins Sans Frontie`res (2012) *'Lead Poisoning Crisis in Zamfara State, Northern Nigeria: MSF Briefing Paper, 2012',* [Online] Available at: www.msf.org

[39] Yusuf, A. A., Abdu, N. and Tanimu, B. (2011) 'Assessment of lead contamination of farmlands in Abare village, Zamfara State', *In Mobilizing Agricultural Research Towards Attaining Food Security and Industrial Growth in Nigeria. Proceedings of the 45th Annual Conference of the Agricultural Society of Nigeria,* pp. 487-491.

[40] Abdul, N., Abdulkadir, A., Agbenin, J. O., Buerkert, A. (2011) 'Vertical distribution of heavy metals in wastewater irrigated-vegetable garden soils of three West African cities', *Nutrient Cycling in Agro ecosystems,* 89 (3), pp. 387-397.

[41] Prasad, M. N. V. and Freitas, H. M. O. (2003) 'Metal hyperaccumulation in plants: Biodiversity prospecting for phytoremediation technology', *Electronic Journal of Biotechnology,* 6 (3), pp. 286-321.

[42] Kroll, D. J. and Shaw, H. S. (2003) 'Complementary and alternative medicine (CAM): relevance to laboratory medicine', *Clinical Laboratory International,* pp 14-17.

[43] Caldas, E. D. and Machado, L. L (2004) 'Cadmium, mercury and lead in medicinal herbs in Brazil', *Food and Chemical Toxicology,* 42 (4), pp. 599-603.

[44] Orisakwe, O. E. and Nduka, J. K. (2009) 'Lead and Cadmium levels of commonly administered paediatric syrups in Nigeria: A public health concern? *Science of the total environment*, 407 (23) pp. 5993-5996.

[45] Ishola I. O., Oreagba, I. A., Olayemi, S. O and Gbadamosi, R (2011) 'Assessment of treatment pattern of uncomplicated malaria in paediatric patients attending a teaching hospital in north-western Nigeria', *Journal of Applied Pharmaceutical Science',* 05, pp. 177-181.

[46] Koller, K., Brown, T., Spurgeon, A. and Levy, L. (2004) 'Recent developments in low-level lead exposure and intellectual impairment in children', *Environmental Health Perspectives,* pp. 987-994.

[47] Amit, S. C., Bhadauria, R., Singh, A. K., Lodhi, S. S., Chaturvedi, D. K. and Tomar, V. S. (2010) 'Determination of lead and cadmium in cosmetic products', *Journal of Chemical and PharmaceuticalResearch,* 2 (6), pp. 92-97.

[48] Miranda, M., López-Alonso, M., Castillo, C., Hernádez, J. and Benedito, J. L. (2005) 'Effectsof moderate pollution on toxic and trace metal levels in calves from a polluted area ofnorthernspain', *Environmental International,* 31 (4), pp. 543-548.

[49] Garco-Rico, L., Felix, C. F., Burgueño, R. R. and Marini, M. J. (2002) 'Determination of cadmium and zinc and its relationship to metallothionein levels in swine kidney', *RevistaInternacional de ContaminaciónAmbiental,* 18 (4), pp. 157-162.

[50] Falandysz, J., Kotecka, W., Kannan, K., (1994) 'Mercury, lead, cadmium, manganese, copper, iron and zinc concentrations in poultry, rabbit and sheep from the northern part of Poland', *Science Total Environment,* 141 (1-3), pp. 51-57.

[51] Adeyinka, I. A. and Mohammed, I. D. (2006) 'Consumption pattern of two breeds of Goats in Northern Nigeria', *Journal of Animal and Veterinary Advances* 5 (11), pp. 705-716.

[52] Orisakwe, O. E., Asomugha, R., Afonne, O. J., Anisi, C. N., Obi, E. and Dioka, C. E. (2004) 'Impact of effluents from a car battery manufacturing plant in Nigeria on water, soil, and food qualities', *Archives of environmental health: An international Journal,* 59, pp. 31-36.

[53] Mushak, P. and Crocetti, A. (1996) '*The nature and extent of lead poisoning in children of the US: Report to Congress',* Upland, CA: Diane Publishing.

[54] Osmond, D. L., Line, D. E., Gale, J. A., Gannon, R. W., knott, C. B., Barthenhagen, K. A., Turner, M. H., Coffey, S. W., Spooner, J., Wells, J. and Walker, J. C. (1995) 'WATERSHEDSS: Water, Soil and Hydro-Environmental Decision Support System.

[55] Lewis, J. A. and Cohen, S. M. (2004) 'Addressing lead toxicity: Complexation of lead (II) with thiopyrone and hydroxypyridinethione O, S-mixed chelators', *Inorganic Chemistry*, 43 (21), pp. 6534-6536.

[56] Kennish, M. J. (1992) *'Ecology of estuaries, Anthropogenic Effects',* vol 2, CRC, Boca Raton

[57] Jacubowski, M. (1997) 'Exposure to chemical factors in the work environment, In: Jacubowski, M. (ed) Biological monitoring', *Nofer Institute of Occupational Medicine, Lodz,* pp. 165-177.

[58] Sarosiek, B., Pietrusewicz, M., Radziwoniuk, J. and Glogowski, J. (2009) 'The effect of copper, zinc, mercury and cadmium on some sperm enzyme activities in the common carp (Cyprinuscarpio L.)', *Reproductive Biology,* 9 (3), pp. 295-301.

[59] Das, K. K. and Banerjee, S. K. (1980) 'Cadmium toxicity in fish', *Hydrobiology*, 75, pp. 117-121.

[60] Horowitz, Y., Greenberg, D., Ling, G. and Lifshitz, M. (2002) 'Acrodynia: a case report of two siblings', *Archives of Disease in Childhood,* 86 (6) pp. 453 - 453. [Online] Available at: http://adc.bmj.com/content/86/6/453.1.full.pdf (Accessed: 01 November, 2016).