International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133, Print ISSN: 2664-7125, Impact Factor: RJIF 5.28
Received: 08-02-2021, Accepted: 11-03-2021, Published: 05-04-2021
Volume 3, Issue 2, 2021, Page No. 10-15

Human health and ecological risk assessment of heavy metals in water, biota and sediment in Nigeria: A scholarly review of literature

Obed-Ndukwu[1*], Ihuoma C[2]
[1] PhD, Student in Faculty of Environmental Management, Institute of Geosciences and Space Technology, Rivers State University Nkpolu-Oroworukwo, Port Harcourt, Rivers, Nigeria
[2] PhD, Institute of Geosciences and Space Technology, Rivers State University Nkpolu-Oroworukwo Port Harcourt, Rivers, Nigeria

Abstract
It is a common knowledge that heavy metals possess considerable human and ecological risk in water, biota and sediment. Notably, the human health risk assessment models includes; estimated daily intakes of the heavy metals (EDI), Target Hazard Quotient (THQ) and Hazard Index (HI) of Heavy Metals as well as the carcinogenic and non-carcinogenic risks due to the exposure on adults, children to heavy metals in water, biota and the sediments. In accessing the ecological risk of heavy metals in water sediments and the biota; Bioaccumulation Factors, Pollution Load Index (PLI), modified contamination degree (MCD), Geo-accumulation Index (GI) and Anthropogenicity are usually employed. Consequently, the objective of this research is to perform a scholarly review of empirical literature on the human and ecological risk from heavy metals in water, biota and sediment. Documentary data with regards to the research were obtained from various journal publications and other secondary sources and were studied and reviewed accordingly. Findings of this study revealed that the risk of heavy metals human and the ecology have been exhaustively reported. However, studies on risk of heavy metals human and the ecology in Nigeria have been minimal. Furthermore, methodologies adopted in most of the studies were not clearly defined. The study recommends that more research should be performed to ascertain the human and ecological of heavy metals in Nigeria and the methodologies adopted should be appropriately and clearly defined.

Keywords: heavy metals, human health, ecological risk, water, biota, sediment, Nigeria

Introduction

Heavy metal pollution of the environment is a serious concern because of the hazardous effects they pose to various ecosystem and human receptors (Ryams-Keller *et al*., 1998; Ho & Hui, 2001; Yilmaz, 2005) [22, 29]. Among environmental pollutants, heavy metals are of particular concern because they are known for their persistent behaviour in the environment and are harmful, because of their ability to bioaccumulate in the environment and cause damage to plants and animal tissues. (Zweig *et al*., 1999; Censi *et al*., 2006; Babalola, 2010; Zheng *et al*., 2013) [31, 3, 2, 30]. Some metals, including chromium, lead, cadmium, arsenic and mercury are known to be highly toxic to humans and aquatic life. They act as human mutagens and carcinogens and are associated with various human ailments such as causing liver and kidney problems, cardiovascular, nervous system, blood and bone diseases, kidney failure, gingivitis, and tremors, genotoxic carcinogens among others (Nguyen *et al*., 2005; Rashed, 2008; Sun *et al*., 2014) [12, 21, 26]. The human health risk assessment models usually employed includes; estimated daily intakes of the heavy metals (EDI), Target Hazard Quotient (THQ) and Hazard Index (HI) of Heavy Metals as well as the carcinogenic and non-carcinogenic risks.

Ecological risk assessment (ERA) is a process of collecting, organizing and analyzing environmental exposure and effect data to estimate the risk of contamination to ecosystems (Niemeyer *et al*., 2015) [14].

Increasing human development, industrialization and population growth have exerted alarming and diverse pressures on the quality, quantity and access to water resources. Consequently, Heavy metals contamination of water is a global environmental concern because of their indestructible and harmful effects on aquatic organisms, soil and biota. The most commonly found heavy metals in water include arsenic, cadmium, chromium, copper, lead, nickel, and zinc, all of which cause risks for human health and the environment (Lambert *et al*., 2000) [10].

Fishes are major faunal components of aquatic environments and are usually used as excellent environmental biomarkers of the health of aquatic systems (Stiassny, 1996) [25]. Fishes are continuously exposed to waterborne and particulate heavy metals due to continuous flow of water through gills and through food sources. Metals bioaccumulate in different tissues follow different patterns of bioaccumulation factors (Fatima & Usmani, 2013) [8].

Soil Pollution by heavy metal just like aquatic pollution equally occurs due to industrial wastes, application of fertilizer, corrosion of sheeting, wires, pipes, and burning of coal and wood (Nwankwoala & Ekpewerechi, 2017). The effects of prolonged exposure of various fauna and flora species to heavy metals have been reported by several studies (Chibuike & Obiora, 2014; Fayiga *et al*., 2004; Migliorini *et al*., 2004; Sethy & Ghosh, 2013) [4, 9, 11, 23]. The ecological risk assessment models usually employed includes; Bioaccumulation Factors, Pollution Load Index (PLI), modified contamination degree (MCD), Geo-accumulation Index (GI) and Anthropogenicity. In Nigeria, there is equally a growing body of research into the human and ecological risk assessment of heavy metals in water, biota and sediment. The purpose of this paper is to review empirical literature on environmental impact of heavy metals on human and the ecology given the detrimental risk heavy metal possess on human beings and also ecology-water, sediments and biota.

This paper is structured as follows: The introductory part is followed by the methodology section. Section three is a review of empirical literature on the human and environmental risk assessment of heavy metals. Section four discusses the paper and the final section concludes the paper.

Methodology

The research is an archival type where the outline of the study is basically a review of empirical literature on the on the human and ecological risk from heavy metals in water, biota and sediment. Thus the methodology employed in collecting the required data was based on secondary sources of data obtained from academic journals, articles conference papers, textbooks and the Internet.

Empirical literature on the human and ecological risk assessment of heavy metals in water, biota and sediment

Ogunkunle and Fatoba (2012) study aimed to assess the concentrations and potential ecological risk of heavy metals around a mega cement factory in southwest Nigeria. Cement production is noted for particulate pollution of the environment because of high dust emissions and heavy metals that later deposited in soils, serving as a sink. Soil samples were randomly collected in the eastern, western, and southern axes of the factory. The samples were subjected to Nitric-perchloric acid digestion, and an atomic absorption spectrophotometer was used to determine the concentrations of Pb, Cu, Cd, Cr, and Zn. Data were analyzed with ANOVA and Duncan Multiple Range Test. The results showed that the mean concentrations of Pb, Cu, Cd, and Cr (666.1 mg/kg, 613.4 mg/kg, 547.9 mg/kg, and 188.5 mg/kg, respectively) were above the international standard limits. Nemerow pollution indices, according to the axes, indicated serious pollution with heavy metals. The Single Potential Ecological Risk Index (PERI) showed that soil contamination from Cd in the 3 axes had very high potential ecological risk, which translated into the high value of Comprehensive Potential Ecological Risk (RI) value (11,488.3) for the entire study area. Among the recommendations include; an intensive study to determine the actual route of Cd introduction to the soil, due to the high contributing factor of Cd to the potential ecological risk of the area; discouragement of farming activities should be within a radius of 10 kilometers of the vicinity of the factory because there is every possibility of great uptake of these heavy metals by crops planted, which will eventually reach up the food chain to humans, bioremediation of some metal contents of the soils, especially Cd, to reduce ecotoxicological problems, Monitoring and environmental audit of production by the designated authority in charge of the environment should spring into action to boast the environmental quality of this area, finally, further research should be carried out to determine the potential risk of these heavy metals to crops and humans in this area.

Ogbuagu and (2014) [16] study investigated the levels, index of accumulation and recovery capacity of heavy metals (Pb, Cd, Cu, Ni, Zn, Fe, Mn) in sand mine ponds of the Otamiri River in Owerri, Nigeria during the wet season of 2012. Water (WC) and sediment samples (SD) were collected from six sampling points, with WC 1-WC 3 and SD 1-SD 3 located within a derelict mine pond and WC 4-WC 6 and SD 4-SD 6 located within an actively mined pond. The pH was determined *in situ* and levels of heavy metals measured with the atomic absorption spectrophotometer. The student's t-test, index of geoaccumulation (Igeo), accumulation factor (AF) and pond recovery capacity (PRC) were computed for the ponds. There was significant spatial heterogeneity in mean levels of the heavy metals in sediments (sig. t=0.029) at $P<0.05$, with higher levels of metals also recorded in sediments than water columns. The order of Igeo was Fe (5.959) > Zn (4.932)> Cu (4.743) > Mn (4.326) > Pb (3.214) > Ni (2.483) > Cd (1.649), AF was Zn (1.513) > Cd (1.179) > Fe (1.082) > Ni (1.048) > Mn (1.042) > Cu (1.032) > Pb (0.987) and PRC was Zn (33.891) > Cd (15.165) > Fe (7.604) > Ni (4.608) > Mn (4.047) > Cu (3.052) > Pb (-1.373). Active mining led to extreme contamination of the ponds with Fe, strong to extreme contaminations with Cu, Zn and Mn, strong contamination with Pb, moderate to strong contamination with Ni and moderate contamination with Cd. However, Pb showed deficit recovery capacity and this could portend unfavourable ecological consequences on resident biota and raises public health concerns among resource dependants of the river. Strict enforcement of regulations on in-stream sand mining should be applied.

Enuneku, *et al*., (2018) [7] studied the evaluation of the potential health risks of heavy metal pollution in sediment and selected benthic fauna (Chrysichthys auratus and Tympanotonus fuscatus) of Benin River, Southern Nigeria. Three sampling sites associated with heavy anthropogenic activities along the course of the river were sampled. Heavy metals concentrations were determined in the samples using atomic absorption spectrophotometer (Model 210 VGP, Buck Scientific). In all sediment samples, only Pb exceeded the threshold/probable effect level (TEL). Very high contamination degrees (CD > 24) 181.74, 50.11, and 101.96) for stations 1, 2, and 3, respectively, were observed indicating serious anthropogenic pollution. Geoaccumulation index (igeo) showed slight pollution with Pb and Cd and severely to extremely Polluted with Fe across the stations. Cd exhibited moderate individual potential risk (Eir), and the other heavy metals showed low Eir. Potential ecological risk index (RI) showed low risk of contamination for heavy metals in sediment. Human health risk assessment for Co, Cd, Cu, Zn, Mn, Fe, and Ni in C. auratus and Co, Zn, Mn, Fe, and Ni in T. fuscatus indicated no obvious health risk from these heavy metals over a lifetime of exposure. However, hazard quotient (HQ) values for Pb in C. auratus and Cd, Cu, and Pb in T. fuscatus indicated significant health risk. The hazard index (HI) values for both C. auratus and T. fuscatus were > 1 indicating significant adverse health risk of non-carcinogenic effect. Therefore, the consumption of these contaminated fish and shellfish by the people of Koko portends risks of the health of the public. The industries operating in this community should adopt more sustainable and eco-innovative management options in order to attenuate potential ecological and human health risk of metal pollution.

Tesleem *et al*., (2018) [27] examined heavy metal contamination and ecological risk assessment in soils and sediments of an industrial area in southwestern Nigeria. The Mineralogical composition of the media and their heavy metals concentrations were determined using X-ray diffractometry and inductively coupled plasma-mass spectrometry methods, respectively.

Ecological risk assessment was carried out using single (contamination factor, geo-accumulation index, enrichment factor) and multi-elemental (contamination degree, pollution index and modified pollution index) standard indices. Results indicate that the average heavy metal concentrations in soils and sediments followed the order magnesium (Mn) > chromium (Cr) > lead (Pb) > copper (Cu) > cadmium (Cd) > cobalt (Co) > nickel (Ni), with corresponding values for soils and sediments of 324.3, 79.9, 66.1, 40.7, 14.3, 9.1, 6.8 mg kg^{-1} and 266.8, 78.6, 40.6, 39.8, 12.9, 8.4, 4.6 mg kg-1, respectively. Principal component (PC) analysis of the results indicated three main sources of metals (industrial, vehicular activities and geogenic input). Evaluated contamination factor (Cf), enrichment factor (Ef) and geoaccumulation index (Igeo) revealed very high contamination for Pb, Cd and Cu in all of the samples, with calculated pollution index (PI) and modified pollution index (MPI) revealing that all the samples were severely polluted. Calculated potential ecological risk factor (ERi) within the industrial area demonstrated a strong potential ecological risk for Cd, Pb and Cu. The study concluded that activities in the industrial area have affected the quality of the analyzed environmental media, with possible detrimental health consequences. Regular environmental monitoring of the industrial area and the formulation of appropriate policies that support reduction of contamination are strongly recommended. However, due to the limitations of comparing site samples with a single control sample in this work, further study is recommended to compliment this preliminary study.

Ogunola and Falaye (2018) [18] carried out a study on ecological risk assessment of trace metals from industrial effluents in the Okrika estuary (Niger-delta region) of Nigeria. Concentrations of heavy metals Aluminium (Al), Chromium (Cr), Copper (Cu), Iron (Fe), Nickel (Ni), Vanadium (V) and Zinc (Zn) were analyzed in the tissues of two estuarine fish species; Tilapia (Sarotherodon melanotheron) and silver catfish (Chrysichthys nigrodigitatus) from Okrika estuary in the Niger Delta area of Nigeria. The sampling was conveyed in two seasons, October/November, 2015 and January/February, 2016, representing the climax of both wet and dry seasons respectively. The levels of the metals in the fish species were analyzed by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES). The sequence of the metal accumulations in Tilapia was; Fe > Al > Zn > Cu > Cr > V > Ni, in silver catfish; Fe > Al > Zn > Cu > Cr >Ni > V. Levels of the metals in the fish species were higher than the international permissible limits based on the criteria or application of relevant pollution indices. This indicates that the two fish species were not fit for human consumption. A two way analysis of variance (ANOVA) was used to test the difference in metal concentrations in the fish tissues. Mean differences were separated by the use of t-test. In comparison of the metal accumulations in the tissues of the fish species from oil impacted creeks (Ekerekana, Okari and Ogoloma) and none or less oil impacted counterpart (control site), higher levels ($p<0.05$) of the metals were observed in the impacted than the non-impacted creek. For most of the metals, Sarotherodon melanotheron had higher concentrations than the Chrysichthys nigrodigitatus. Seasonal variations reflected that there was higher accumulation of the metals in the two fish species in the rainy season than the dry season. Pearson Correlation Analysis and the use Vanadium/Nickel ratio were used to confirm the source of the metals in the fish from oil pollution. Therefore, it is mandatory and expedient to ensure regular monitoring of the trace element loadings in these creeks and to take appropriate measures to alleviate the incidence in order to safeguard the health of the public.

Enitan, *et al*., (2018) [6] human health risk assessment of trace metals in surface water due to Leachate from the Municipal Dumpsite by Pollution Index: A Case Study from Ndawuse River, Abuja, Nigeria The study assessed the level of heavy metals in surface water across Ndawuse River near the dumpsite at Phase 1 District of the Federal Capital Territory (FCT), Abuja, Nigeria. The results indicated that oxygen demand, turbidity and heavy metals were above the standard limits set for drinking water. Multivariate analysis using principal component analysis and hierarchical cluster analysis revealed natural and anthropogenic activities as sources of heavy metal contamination. The estimated non-carcinogenic effects using hazard quotient toxicity potential, cumulative hazard index and daily human exposure dose of surface water through ingestion pathway were less than a unity. The estimated carcinogenic risks (CRing) exceeded the suggested potential risk limits, with lead (Pb) having the highest CRing value for all age groups. However, children were found to be more susceptible to heavy metals over a period of time according to the estimated values. The concentration of heavy metals in the investigated river could pose an adverse health risk to several communities that rely on this receiving water bodies for domestic purposes. Therefore, there is need for strict enforcement of environmental laws to protect aquatic ecosystem and to avoid long term cumulative exposure risk that heavy metals may pose on human health.

Otene and Alfred-Ockiya (2019) [19] carried out an experimental study on the human and ecological risk assessment of heavy metals in water and sediment from Elechi creek, Port Harcourt, Nigeria. The concentration of heavy metals such as Cadmium (Cd), Chromium (Cr), lead (Pb) and Copper (Cu) in water and sediment were investigated using Atomic Absorption Spectrophotomer. Results indicate that Cd, Cr, Pb and Cu a mean concentrations (mg/l) of (0.0036 ± 0.277), (0.0042 ± 0.196), (0.00387 ± 0.136) and (0.0068 ± 0.217), respectively in water while that of sediment (mg/kg) were (0.00494 ± 0.203), ($0.00457 + 0.172$), (0.00468 ± 0.205) and (0.00731 ± 0.204) respectively. Apart from Cd which exceeded the TSE – 266 and WPCC limit and Pb which exceeded the criterion continuous concentration (CCC) other metals studied were within the TSE – 266, WPCl, CIW and EC water guideline. The order or magnitude of heavy metal concentration in water is Cu > Cr > Pb > Cd while that of sediment is Cu > Cd > Pb > Cr with Cu having the highest concentration in both media. The contamination factor (CF) and pollution load index (PLI) were all less than unity showing that there was little pollution in the area. The concluded reached was that Elechi Creek is contaminated-though without potential danger for now. However, agriculture and further anthropogenic activities in the area may increase the pollution risk.

Ngwoke, *et al*., (2019) [13] carried out an Assessment of heavy metal pollution in marine sediments receiving produced water, Delta State, Nigeria. This research focuses on the environmental assessment of heavy metal pollution on marine sediments receiving treated produced water in Delta state, Nigeria. Sediment samples were obtained from produced water discharge area at various distances from the disposal point. Heavy metals

(Cadmium, Zinc, Iron, Lead, Chromium, Vanadium, Barium, Nickel and Manganese) concentrations in the sediment were analyzed using Atomic Absorption Spectrophotometry method. In the sediment, manganese, nickel, chromium, lead, cadmium and zinc were detected in all the locations and showed no significant difference across the various locations. Barium and vanadium were detected in some location although no statistical difference was established across the locations. Iron concentration showed significant difference across the various locations. The results of heavy metals contamination factor in marine sediments ranged from low contamination to very high contamination (CF<1; 3 ≤ CF ≥ 6). High contamination values were recorded for vanadium (Location SD16, 21 and 22) and barium locations (SD8 and 21). The pollution load index ranged from no pollution (PL1 <1) under both background scenarios, to moderate pollution (1< PLI< 2), heavy pollution (2< PLI< 3), and extremely heavy pollution (3<PLI) in location SD21. The variation showed that the level of pollution in the different locations are not similar suggesting varying man made pollution source on the sediment. The enrichment factor of heavy metals ranged from minimal to moderate, significant and very high enrichment. Barium, Nickel and Manganese showed the highest variation in enrichment factor. Other than cadmium and barium that showed moderate risk (40 ≤ Er <80) and very high risk (Er ≥ 320) at some locations respectively, the Ecological Risk Index of heavy metals based on the criteria for risk assessment showed low risk (Er<40) for most of the locations.

Dibofori-Orji, *et al*., (2019) [5] paper titled "spatial and temporal distribution and contamination assessment of heavy metal in Woji Creek was designed to assess spatial and temporal variation of selected heavymetals and level of pollution in Woji Creek. The study was carried out in the months of August, September and October 2018.Water samples were collected from five stations along the creek over a 3.2 km stretch. Water was collected to be analysed for Heavy metals (Nickel, Cadmium, Copper, Lead and Iron).Results were subjected to ANOVA and heavy metal pollution index (HPI) was calculated using aquatic toxicity reference values (TRV) as threshold values. Heavy metal dominance in Woji was in the order of Pb>Ni>Fe>Cd>Cu. In the river, Ni had mean values ranging from0.379±0.259mgl^{-1} in August to 0.545±0.369 in October, while Pb with the highest concentration had mean values ranging from0.229±0.333mg l^{-1} in October to 1.534±0.103mg l^{-1} in September. Concentrations of metals analysed were high than the TRV. Temporal analysis of HPI calculated for the study was above the critical heavymetal pollution index (100) (August=329.358, September =361.796, October = 112.715). A correlation was observed between heavy metals analysed during the study. Spatial analysis of HPI showed higher pollution level at Station 3 with the highest anthropogenic activity along the creek. Cu showed a negative correlation to other metals analysed. Sources of pollution on this creek was identified to be both natural and majorly anthropogenic sources. This study, therefore, points out the need for proper environmental management as regards commercial activities around the waterways.

Anyanwu, *et al*., (2020) [1] Application of Pollution Indices and Health Risk Assessment of Heavy Metals in the waters of a South-eastern Nigeria River. The study on the heavy metal content of a local drinking water source in South-east Nigeria was carried out in 3 sampling stations between May 2019 and October 2019. Pollution indices and health risk assessment for non-carcinogenic were used to check the water's suitability for human consumption. The indices were heavy metal pollution index (HPI) and Contamination Index (Cd). Eight metals were evaluated with standard methods and compared with Nigerian and WHO drinking water standards. Some metals like iron, lead and cadmium exceeded the recommended limits. The stations Heavy Metal Pollution Index ranged between 511.4 and 512.4 while the monthly values ranged between 279.8 and 547.6; all exceeding the threshold value of 100. Contamination Index ranged between 3.12 and 3.32 (stations) and -0.80 to 4.80 (month) indicating high contamination potential and low to high contamination potentials respectively. All the hazard indices also exceeded one (1). Stations 1 and 2 were higher in all the indices. All the indices were linked the high values of iron, lead and cadmium, influenced by sand mining activities. The pollution indices and Health Risk Assessment converged to show that the waters of Iyiakwu River are not fit for human consumption. The children are more vulnerable since it the main source of drinking water in the area.

Stephen and Glory (2020) [24] studied the level and ecological risk assessment of heavy metals in old landfill in Bayelsa state, Nigeria. The study assessed the ecological fate of heavy metals within the vicinity of an area formally used as dump site in Igbogene, Bayelsa state. Soil auger was used to collect samples at 0 - 20 cm depth at 50, 100 and 150 m distances from the four cardinal points *viz*: North east and west and south east and west. The soil samples were sieved, ashed, digested and analyzed using atomic adsorption spectrometry. The heavy metals results ranged from 646.73 to 715.33 mg/kg (iron), 59.30 to 73.05 mg/kg (manganese), 83.20 to 114.18 mg/kg (zinc), 10.67 to 15.95 mg/kg (copper), 7.70 to 9.64 mg/kg (chromium), 11.56 to 14.48 mg/kg (cadmium), 10.09 to 13.86 mg/kg (lead), 4.57 to 6.33 mg/kg (nickel) and 3.52 to 4.92 mg/kg (vanadium). Statistically there was no significant variation (p>0.05) across the various distances for each of the metals studied, but apparent decline in values exist as the distance away from the landfill increased. In addition, each of the metals showed positive significant correlation with each other at p<0.01. Cluster analysis revealed two main clusters. These are samples from each of the latitude directions, southern direction (east and west) and northern direction (east and west). Pollution indices were higher in sample obtained from the southern direction (west and east) compared to northern area (west and east) but generally it ranged from no pollution to moderate pollution. Positive quantification of contamination indicates that pollution due to anthropogenic activities occurred in few instances. The ecological risk index showed low risk/fate of the heavy metals studied area.

Yahaya, *et al*., (2021) [28] studied the ecological risk assessment of heavy metal-contaminated soils of selected villages in Zamfara State, Nigeria. This study evaluated the incidence of heavy metal contamination in five (5) villages (Bagega, Dareta, Sunke, Tunga, and Abare) in Zamfara State, northern Nigeria, due to artisanal mining in some villages. In each of the five villages, three sites (3) were identified as a mining site, processing site, and village making a total of sixteen (16) sites. Bulked soil samples were collected in triplicate and analyzed for iron, lead, cadmium, chromium, zinc, and nickel using flame atomic absorption spectrophotometry. Measured concentrations of the heavy metals in soils were then used to calculate the pollution and ecological risk pose by heavy metals. Their concentrations were in the order Fe > Pb > Cr > Zn > Cd > Ni, with Pb and Cd having a concentration higher than permissible levels for soils and accounted for 98.64% of the total potential ecological risk. Also, all the different pollution indices examined showed that all the sites were polluted with Cd, and all the processing sites were polluted with Pb. This reveals that processing sites pose more risk to heavy metal contamination. Correlation analysis showed a highly significant ($p < 0.001$) positive correlation between Pb and Zn, Cr and Ni, and a significant ($p < 0.01$) positive correlation between Fe and Pb, Zn and Cr. The principal component analysis suggested that Pb, Zn, Cr, and Ni likely originated from the same source, i.e., mining activities, and Fe and Cd originated from the abundant parent material in the study area The results of this research revealed that processing sites pose more risk to heavy metal contamination as compared to mining sites and the farmlands around the villages, this is due to the grinding of the metal ores that releases the metals into the environment. It also revealed that Pb and Cd have the highest enrichment with most of the values greater than the maximum allowable limits set by different countries, and they virtually accounted (98.64%) of all the total potential ecological risk in the study areas. This quantitative evidence demonstrates the critical need to put in place mining regulations to protect the environment and residents, especially children, from heavy metal pollution in the area, and remediation of the contaminated areas is highly recommended.

Discussions

Most of the studies focused on the human health and ecological risk of heavy metals in several locations in Nigeria. The heavy metals mostly identified using atomic absorption spectrophotometry were; iron, lead, cadmium, chromium, zinc, and nickel Findings from various researches using various human health and ecological risk assessment models revealed the considerable level of contamination from heavy metals in many of the locations. Anthropogenic and industrial activities were identified as the major sources of heavy metal contamination in Nigeria.

Conclusion

In conclusion, heavy metals possess significant human and ecological risk in water, biota and sediment in Nigeria. The most commonly found heavy metals in water, sediments and biota include; arsenic, cadmium, chromium, and copper, lead, nickel, and zinc, all of which cause risks for human health and the environment. The review shows anthropogenic activities as sources of heavy metal contamination in Nigeria. Therefore, there is need for strict enforcement of environmental laws to protect aquatic ecosystem and to avoid long term cumulative exposure risk that heavy metals may pose on human health. Suitable approaches in mitigating the heavy metal pollution should be adopted for a given study in order to narrow the literature gap on the subject matter.

References

1. Anyanwu ED, Adetunji OG, Nwachukwu ED. Application of Pollution Indices and Health Risk Assessment of Heavy Metals in the waters of a South-eastern Nigeria River; Pollution,2020:6(4)1-15.
2. Babalola OO. Beneficial bacteria of agricultural importance. Biotechnology Letters,2010:32(11):1559-1570.
3. Censi P, Spoto SE, Saiano F, Sprovieri M, Mazzola S, Nardone G *et al*. Heavy metals in coastal water systems. A case study from the northwestern Gulf of Thailand. Chemosphere,2006:64(7):1167-1176.
4. Chibuike GU, Obiora SC. Heavy Metal Polluted Soils: Effect on Plants and Bioremediation Methods [Review Article]. Applied and Environmental Soil Science; Hindawi, 2014. https://doi.org/10.1155/2014/752708
5. Dibofori-Orji1 AN, Ihunwo OC, Udo KS, Shahabinia AR, Onyema MO, Mmom PC. Spatial and temporal distribution and contamination assessment of heavy metal in Woji Creek; Environ. Res. Commun,2019:1:1-11.
6. Enitan IT, Enitan, Odiyo JO, Alhassan MM. Human Health Risk Assessment of Trace Metals in Surface Water Due to Leachate from the Municipal Dumpsite by Pollution Index: A Case Study from Ndawuse River, Abuja, Nigeria; Open Chem,2018:16:214-227
7. Enuneku A, Omoruyi O, Tongo I, Ogbomida E, • Ogbeide O, Ezemonye L. Evaluating the potential health risks of heavy metal pollution in sediment and selected benthic fauna of Benin River, Southern Nigeria; Applied Water Science,2018:8:224
8. Fatima M, Usmani N. Histopathology and bioaccumulation of heavy metals (Cr, Ni and Pb) in fish (Channa striatus and Heteropneustes fossilis) tissue: A study for toxicity and ecological impacts. Pakistan J Biol Sci,2013:16:412-420.
9. Fayiga AO, Ma LQ, Cao X, Rathinasabapathi B. Effects of heavy metals on growth and arsenic accumulation in the arsenic hyperaccumulator Pteris vittata L. Environmental Pollution,2004:132(2):289-296.
10. Lambert M, Leven BA, Green RM. New methods of cleaning up heavy metal in soils and water. Environmental Science and Technology Briefs for Citizens. Kansas State University, Manhattan, KS, 2000.
11. Migliorini M, Pigino G, Bianchi N, Bernini F, Leonzio C. The effects of heavy metal contamination on the soil arthropod community of a shooting range. Environmental Pollution,2004:129(2):331-340.
12. Nguyen HL, Leer makers M, Osán J, Török S, Baeyens W. Heavy metals in Lake Balaton: Water column, suspended matter, sediment and biota. Science of the Total Environment,2005:340(1-3):213-230.
13. Ngwoke M, Igwe O, Ozioko OH. Assessment of heavy metal pollution in marine sediments receiving produced water, Delta State, Nigeria; International Journal of Physical Sciences,2019:14(14):152-170,
14. Niemeyer JC, Moreira-Santos M, Ribeiro R, Rutgers M, Nogueira MA, da Silva EM *et al*. Ecological Risk Assessment of a Metal-Contaminated Area in the Tropics. Tier II: Detailed Assessment. PLoS ONE, 2015, 10(11). https://doi.org/10.1371/journal.pone.0141772
15. Nwankwoala H, Ememu A. Contamination Indices and Heavy Metal Concentrations in Soils in Okpoko and Environs, Southeastern Nigeria. Journal of Environmental Science and Public Health,2018:2(2):77-95.
16. Ogbuagu DH, Samuel CB. Accumulation and recovery capacity of heavy metals in sand mine ponds of the Otamiri

River in Owerri, Nigeria; Rev. Ambient. Água,2014:9(1):1-9.
17. Ogunkunle CO, Fatoba O. Pollution Loads and the Ecological Risk Assessment of Soil Heavy Metals around a Mega Cement Factory in Southwest Nigeria Pol. J. Environ. Stud,2013:22(2):487-493
18. Oluniyi OS, Falaye EA. Ecological risk assessment of trace metals from industrial effluents in the Okrika estuary (Niger-delta region) of Nigeria; British Journal of Environmental Sciences,2018:6(4):1-32.
19. Otene BB, Alfred-Ockiya JF. Human and Ecological Risk Assessment of Heavy Metals in Water and Sediment of Elechi Creek, Port Harcourt, Nigeria; IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT),2019:13(3):01-07
20. Ramesh A, Kumar A, Aramandla MP, Nyanda AM. Polycyclic Aromatic Hydrocarbon Residues in Serum Samples of Autopsied Individuals from Tennessee. International Journal of Environmental Research and Public Health,2015:12(1):322-334. https://doi.org/10.3390/ijerph120100322
21. Rashed MN. Total and extractable heavy metals in indoor, outdoor and street dust from Aswan City, Egypt. CLEAN–Soil, Air, Water,2008:36(10-11):850-857.
22. Ryams-Keller A, Olson KE, Oray C, CarIson JO, Beaty BJ. Effects of heavy metals on Aedes aegypti (Diptera: Culicidea) Larvae. Ecotoxicol. Environ. Safety,1998:39:41-47.
23. Sethy SK, Ghosh S. Effect of heavy metals on germination of seeds. Journal of Natural Science, Biology, and Medicine, 2013:4(2):272.
24. Stephen UA, Glory R, Level and ecological risk assessment of heavy metals in old landfill in Bayelsa state, Nigeria; Journal of Environmental Chemistry and Ecotoxicology, 2020:12(1):32-44.
25. Stiassny ML. An overview of freshwater biodiversity: With some lessons from African fishes. Fisheries,1996:21(9):7-13.
26. Sun L, Liao X, Yan X, Zhu G, Ma D. Evaluation of heavy metal and polycyclic aromatic hydrocarbons accumulation in plants from typical industrial sites: Potential candidate in phytoremediation for co-contamination. Environmental Science and Pollution Research,2014:21(21):12494-12504.
27. Tesleem KO, Akinade OS, Mustapha JT, Olugbenga FT. Heavy Metal Contamination and Ecological Risk Assessment in Soils and Sediments of an Industrial Area in Southwestern Nigeria; Journal of Health & Pollution (JH&P),2018:8(19):2-17.
28. Yahaya SN, Abubakar F, •Abdu N. Ecological risk assessment of heavy metal-contaminated soils of selected villages in Zamfara State, Nigeria, SN Applied Sciences, Springer Nature Journal,2021:3(168):1-13.
29. YILMAZ AB. Comparison of heavy metal levels of grey mullet (Mugil cephalus L.) and sea bream (Sparus aurata L.) caught in Iskenderun Bay (Turkey). Turkish Journal of Veterinary and Animal Sciences,2005:29(2):257-262.
30. Zheng J, Chen K, Yan X, Chen S-J, Hu G-C, Peng X-W *et al*. Heavy metals in food, house dust, and water from an e-waste recycling area in South China and the potential risk to human health. Ecotoxicology and Environmental Safety,2013:96:205-212.
31. Zweig RD, Morton JD, Stewart MM. Source water quality for aquaculture: A guide for assessment. The World Bank, 1999.