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Chapter

Occurrence and Impact of Heavy Metals on Some Water, Land, Flora and Fauna Resources across Southwestern Nigeria

Olufemi Akinnifesi, Femi Adesina, Germaine Ogunwole and Sylvanus Abiya

Abstract

Rapid urbanization and industrialization in communities of Nigeria contribute significantly to environmental pollution. Amongst the diversity of these environmental contaminants are heavy metals, a rarely biodegradable and toxic class of metals. Heavy metals are known to be harmful to plants, aquatic species, and subsequently endanger human health through bioaccumulation or biomagnification. Even at low concentrations, heavy metals may affect key soil microbial processes; inhibit plant metabolism and growth. Toxic metals in groundwater affect water quality and potability, and their presence in aquatic systems also facilitate the production of reactive oxygen species that can damage physiological processes in fishes and other aquatic organisms. This chapter highlights the occurrence and impact of heavy metals in different environmental matrices and organisms sampled across some Southwestern states in Nigeria. Various studies including those of the authors found varying levels of heavy metals, especially in concentrations that can imperil ecosystem functions. While results of studies included in this chapter may suggest heavy metal introduction through anthropogenic-urbanization means, the lack of proper implementation of environmental monitoring laws in Nigeria also clearly exist. As such, the mitigation of heavy metals amongst other pollutants demands better home-grown decentralized technologies.

Keywords: heavy metals, groundwater, lead, freshwater, bioaccumulation, mercury, food chain

1. Introduction

Nigeria is a developing and populous country in the Africa continent, with an estimated population of 200 million people making it the most populous country in the continent. It lies between latitudes 4° and 14° N, and longitudes 2° and 15° E. There are about 36 states and a Federal Capital Territory aggregated into six geopolitical zones. Southwest of Nigeria, which is one of these zones, comprise of six states (Ekiti, Lagos, Ogun, Ondo, Osun, Oyo). **Figure 1**, in which two (Lagos and Oyo) are among the five most populated states in Nigeria. Southwestern Nigeria has two distinct weather seasons; the dry season-from November to March; and the



Figure 1.
Map of Nigeria showing the Southwestern region and its states.

raining season-which ranges from April to October [1]. The region has an annual temperature range of 21 to 29°C, with relatively high humidity. The annual rainfall varies from 1150 mm in the northern part and 2000 mm in the southern areas [2].

Southwestern Nigeria holds major economic hub of the country, where most of the country's factories are located. The region is also endowed with rich mineral and agricultural resources that often encourage mining and farming activities. These increasing industrialization, migration, urban development, agricultural practices and human activities continue to expose southwestern Nigeria to environmental pollution. Solid waste, landfills, and inefficient urban runoff and sewage management systems are not uncommon in the region and this can further create hazards associated with heavy metal pollution in the region [3]. More so, the major cities of the region is often associated with very high vehicular activities. Automobiles are known to introduce a number of heavy metals from exhaust fumes, and in lubricants of faulty engines, which are consequently deposited on roadsides [4, 5]. or incorporated into dust particles in size range as small as 10^{-9} and 10^{-6} m [6].

Heavy metals are metallic, naturally occurring compounds with a very high density greater than 5 g/cm³ [7]. Heavy metal classification also includes some basic metals, metalloids, transition metals, lanthanides and actinides and groups III to V metals of the periodic table e.g. As, Pb, Hg, Cd, Cr, Co, Ni, Cu, Zn, Se, Al, Cs, Mn, Mo, Sr, U, Be and Bi [8]. Given that heavy metals are not usually biodegradable, they are often transported and accumulated into plants and animal tissues from soil and water matrices, which predispose long term deleterious effects on the receiving species. The inherent capacity of species to react differently to heavy metals does exist; hence, some species are more tolerant and resistant to heavy metals while others are not [9]. More so, the recalcitrant nature of heavy metals makes them persist in the environment for years and thus may pose threats to man and other organisms. With these characteristics of heavy metals and increasing pollution trends in our environment, it suffices to suggest that heavy metal is a serious threat [10].

The toxic effects of heavy metals on living organisms, especially when consumed above the recommended limits set by various regulatory bodies, are far reaching [11, 12]. Elements like arsenic, mercury and lead might be toxic even at low levels of exposure. Once consumed by humans, heavy metals continue to concentrate in vital organs like the brain, liver, bones, and kidneys, for years causing

damaging health consequences [13]. Many serious health conditions may also arise from the direct intake of heavy metal contaminated food. Heavy metal intakes have often been linked with health problems such as immunological compromise, intrauterine growth defect, impaired psycho-social behavior, and nutritional defect and many more [14].

Heavy metals contamination raises serious concern, however, governments of developed countries, through various regulatory agencies continues to introduce possible methods for heavy metal pollution prevention and remediation [15, 16]. Unlike these developed economies, Nigeria still faces waste management crises. Large introduction of heavy metals into the environment is yet inevitable, especially due to the dearth of infrastructures and weak environmental laws to cater for the 25 million tonnes of municipal waste generated annually [17].

2. Heavy metals accumulation in soil

The soil is a critically essential component for all living organisms. Especially for plants, soil serves as nutrient media for the growth of plants and other microflora. However, these life-supporting functions, which include carbon cycling, essential nutrients provision, water filtering and storage, atmospheric regulation [7], predispose soil matrixes to heavy metal occurrence. Heavy metals can occur naturally in soil environment via the pedogenetic weathering of parent materials viz. weathering of minerals, erosion and volcanic activity. More significantly, the anthropogenic introduction of heavy metals in soil arise from activities such as mining, smelting, electroplating, effluent discharge, as well through bio-solids (livestock manures, composts), waste incineration, vehicle exhausts [18–20]. Contamination of soils by heavy metals through anthropogenic activities from industrial areas has been reported in Southwest of Nigeria (**Table 1**) [22, 23, 26, 27, 29, 31].

Owing to the soil adsorption processes which binds inorganic and organic pollutant, soil has long been recognized as a sink for many pollutants [32]. A number of studies have reported that topsoil and roadside soil in close proximity to urban areas with heavy traffic are susceptible to heavy metal contamination from atmospheric deposition and adsorption [33, 34]. In heavily commuted cities such as in Southwest Nigeria, metals deposit such as Cd, Cu, Pb and Zn are good indicators of contaminations from automobiles as they appear in gasoline, oil lubricants, car component and industrial incinerator emissions [32]. Numerous studies conducted in recent years found high levels of heavy metals as street dust contaminants near traffic routes in Southwest Nigeria [24, 35, 36]. The re-suspension of metal-laden road dust may also be identified as the main source of road pollution, especially along roads with intense traffic and high vehicular emission. These have made ecological risk assessment of heavy metals in polluted soils to gain more attention in recent years [37–39].

Mining is another means of heavy metal pollution in the soil. There is preponderance of artisanal gold and gemstone mining in Southwestern Nigeria. Most of these mines are found in deep reserved locations not readily accessible by regulatory agencies, thus, make illegal mining practices to continue unchecked [22]. With lack of rules guiding artisanal mining, this have significantly contributed to soil-heavy metal pollution in the region. Very recently, the increased government interest in the mining and extractive industries may also heighten the challenges associated with heavy metal pollution, especially if environmental protection is not given top priority. Some proponents have stated that ecological risk assessment can reveal the possibility of soil being polluted, and even determine the ecological functions that may likely be altered by concerned heavy metals [40]. However, in contrast, [41]

Authors	Sites	State	Heavy metals (mg/kg)									
			Pb	Zn	Ni	Cd	CCu	Fe	As	Hg	Cr	Mn
[21]	T Trailer T Terminal	Ogun	0.20–9.60	1.60–64.55	0.65–1.65	0.20–1.40	0.76–3.13	0.65–5.46	12.0–65.0*	0.80–43.25*	0.20–0.25	
[22]	Mining Site	Ekiti	0.1	4.95	0.17	1.53	2.71	54.7	0.01			
[23]	Mining Site A	Osun	0.216	0.7	0.08	0.13	0.629		0.09			
	Mining Site B	Osun	0.278	0.628	0.081	0.09	0.629		0.051			
[24]	Dumpsite	Ondo	18.6	148.7	17.7	1.2	17.8				45.5	
[25]	Mining site	Ogun	0.296	0.116	0.027	0.595			0.535	0.291	0.225	
[26]	Roadside	Lagos	5.57–69.20	25.87–198.32	0.94–42.73			403–1528.30			1.58–347*	3.72–953.52
[27]	Dumpsite	Ondo	0.1	2.92			0.76	4.59				
	Induced soil	Ondo	0.20–0.70	2.04–7.09			0.07–0.39	8–12.80				
[28]	Dumpsite	Oyo	4273.8*			258.38*		7910				
[29]	Roadside	Osun	72.7									
[30]	Industrial areas	Oyo	3.5–363.9*		0.7–19.1	5.6–22.9*	0.0–163.5*	0.3–2.9			77.6–84.9	50.5–1685.0
WHO/FAO			100	300	50	3	100	50,000	20	4	100	2000

*Above maximum allowable limits.

Table 1.
Heavy Metals occurrence in soil reported from southwest Nigeria.

has stated that more studies and practices have shown that such results from risk assessment have little capability to reveal the real degree of the potential toxic effects of metals without primary empirical research.

The result of the baseline heavy metal content in mined soil (in Ijero Ekiti, Ekiti State, Nigeria) by [22] showed mined soil have significant amount of cadmium (1.530 ppm), chromium (0.810 ppm), iron (54.700 ppm), arsenic (0.010 ppm), zinc (4.950 ppm), lead (0.100 ppm) and nickel (0.170 ppm), except copper (2.710 ppm) which is not significant ($p > 0.05$) to control soil. Similarly, [23] studied mined soil of different depth (0–15 cm and 15–30 cm) at Ijana in Osun state, Nigeria and high levels of Zn, Cd, Pb and Cu were detected in the soil from mine site. Heavy metals in mined soil were consistently higher than in the control soil. Which also aligns with earlier studies by [42–44]. Following the submission of [23] a continuously exploited mining site would lead to increased soil degradation, higher soil acidity levels and eventual increase in heavy metals solubility in the soil of the mine site.

Also, in a study conducted by [45] who examined an illegal dumpsite in Lagos State, Nigeria, a high level of Zn, 25.48 mg/L was reported, followed by Fe, 15.63 mg/L. Cu, Mn, Pb and Cd found in soil samples were 2.11, 1.04, 0.22 and 0.09 mg/L respectively. Except Ni (0.01 mg/L) found at the lowest concentration and mercury (Hg) which was below detectable levels, all metals detected were above the permissible limits of the Nigerian Standard for Drinking Water Quality (NSDWQ), World Health Organization (WHO), and United State Environmental Protection Agency (USEPA).

Similarly, in Ibadan (Oyo State), Pb and Cd concentrations detected in top-soil of battery waste dumpsite exceeded the environmental quality standards set by National Environmental Standards and Regulations Enforcement Agency (NESREA) for soils in Nigeria [28]. Street dumpsite soil samples in Osogbo, Osun state was also examined by [29] and the highest Lead concentration detected was 72.7 mg/kg. This value for lead is comparable to that recorded in other states such as Ondo, Oyo and Lagos States. Heavy metal contents in soils varied significantly from location to location in Lagos State. Mn content in soils ranged from 3.72–953.52 mg/kg, Ni ranged from 0.94–42.73 mg/kg, Pb ranged from 5.57–69.20 mg/kg, Cr ranged from 1.58–347 mg/kg, Zn ranged from 25.87–198.32 mg/kg and Fe ranged from 403 to 1528.30 mg/kg [26].

In 2017, [27] examined soils of a cocoa industry dumpsite in Akure, Ondo State and heavy metal contents detected were Fe (4.59 mg/kg), Pb (0.10 mg/kg), Zn (2.92 mg/kg) and Cu (0.76 mg/kg). Induced soil with different concentration of spent engine oil, also contained Fe (8.00–12.80 mg/kg), Pb (0.20–0.70 mg/kg), Zinc (2.04–7.09 mg/kg) and Cu (0.07–0.39). Likewise, [24] reported the contamination indices and the potential ecological risks of toxic metals contents of soil from municipal waste in Ondo. Though the contamination index recorded was 2.8, depicting a low degree of contamination, the total ecological risk index was 285.5, which portray the site as high risk. Also, the heavy metals contamination of soils at Ogere trailer terminal along the busy Ibadan-Lagos express road in Ogun State revealed significant heavy metal presence [21].

3. Heavy metal accumulation in plants

Owing to the fact that decayed and composted wastes enhance soil fertility, it is a common practice in Nigeria that dumpsites and previously cleared landfills in urban regions are converted to farming sites [55]. Most of these wastes sites and associated soils often contain heavy metal remains in various forms and at

different contamination levels [46], which can be transferred into plants parts and their produce. Heavy metals are some of the known form of contamination in food supply, especially vegetables [47]. Their uptake by plants from the soil depends on different factors, including agrochemical applications, solubility of heavy metals, soil pH, soil type, plant species and soil-to-plant translocation factors (TFs) of the metals [48, 49]. Regardless of which factor is more dominant, crops planted directly on municipal waste sites can absorb heavy metals through their roots as soluble ions present in the soil, or absorption by leaves. These absorbed metals can get transferred and bioaccumulated in the storage and vegetative plant parts. Although micronutrients such as Fe, Mn, Cu, Zn, Mo are essential for normal metabolic processes in plants, excessive quantities can be quite harmful to plants [50].

It has also been established that high heavy metal pollution causes adverse effects on the physiological processes of agricultural plants. These often caused reductions in plant growth and dry matter accumulation. Furthermore, excessive heavy metal accumulation in agricultural soils frequently leads to high heavy metal uptake by crops, and thus affects food quality and safety [51]. The direct intake of heavy metal contaminated foods by humans make heavy metals persist in the food chain [52]. Heavy metal presence in the human systems can deplete some essential nutrients in the body, tinker immunological defenses, impair psychosocial faculties, trigger malnutrition, and most often incites the prevalence of gastrointestinal disorder and cancer.

The uptake, metabolism, and effects of most heavy metals on different plant species in South-west Nigeria have been documented in literature (**Table 2**). Adesina and Akinnifesi [53] revealed that heavy metals from crude oil contamination were absorbed by tomato plant roots and translocated to other parts of the plants, thereby storing them in the tissues. The experiment also showed that fruits were also reduced in sizes compare to tomato fruit on uncontaminated soil. *Chromolena odorata* plants growing around gold mining site in Ijana, Osun State were found to contain heavy metals although within the permissible limits [23]. In a greenhouse experiment, maize seeds were planted on a mined soil from Ijero-Ekiti, Ekiti State, plant growth parameters were retarded as the soil, roots and shoots from the mine soil have higher heavy metals content than in the control soil [22].

Accumulation of heavy metals in plants was also proven by [28] where high levels of Pb, Cd and Fe in maize roots, stems, leaves, and grains were recorded. This was attributed to contaminated battery waste soil on which the maize plants were grown in Ibadan, Oyo State. Also, 30 edible plants belonging to species of *Celosia argentea*, *Corchorus olitorius* (Jute), *Colocasia esculenta* (Cocoyam), *Musa sp.* (Banana) and *Saccharum officinarum* (Sugar cane) growing on mining soil at Ewekoro, Ogun State were examined by [54]. The mean concentrations of heavy metals in plants studied were Cu (26.32 mg/kg), Pb (15.46 mg/kg), Zn (213.94 mg/kg), Cr (30.62 mg/kg), Co (0.45 mg/kg) and Ni (3.77 mg/kg). These levels detected in all the plants were all above international limits and $Zn > Cr > Cu > Pb > Ni > Co$. In 2018, [56] used moss plant (*Dicranum scoparium*) as bioindicator to evaluate heavy metals from different locations in Yaba College of Technology Campus, Lagos State. The presence of Zn (8.63 mg/l), Pb (1.12 mg/l), Cu (0.51 mg/l), Ni (0.43 mg/l) and Cd (0.026 mg/l) reflect 80.46%, 10.49%, 4.78%, 4.03% and 0.24% respectively. The highest amount of Zinc was attributed to emission of zinc from paint chips from the walls of buildings, use of cosmetics including perfumes, pigments, corrosion of galvanized safety fence and wearing of iron.

Many Bioaccumulation factor (hereafter BAF) and translocation factor (hereafter TF) experiments have helped evaluate phytoremediation potentials of some plant Eqs. (1) and (2) [60]. While BAF is a calculated value that indicates the ability of

Authors	Plants	Sites	State	Heavy metals (mg/kg)					
				Lead	Zn	Ni	Cd	Cu	Cr
[53]	Tomato	Crude oil	Ondo	0.01–0.06	—	0.01–0.46	0.01–0.06	0.02–0.28	0.01–0.22
[23]	<i>Chromolena odorata</i>	Mining	Osun	0.13–0.20	1.02–1.21	0.08–0.09	0.01–0.02	0.59–0.60	0.12
[22]	Maize	Mining	Ekiti	Nd	0.02–0.64	0.04–0.08	0.02–0.04	0.01–0.08	Nd
[54]	30 edible plants	Mining	Ogun	0.66–109*	14.9 – 252*	0.66–29.10	—	2.59–305.6*	1.20 – 343*
[55]	<i>Amaranthus cruentis</i>	Landfill	Oyo	110.5–678.5*	—	—	2.01 - 3.20*	—	—
[56]	Moss plant (mg/L)	within college	Lagos	0.57–1.61	3.62–10.18	0.08–1.52	0.0001–0.06	0.0001–2.38	—
[57]	Basil	Industrial Dumpsite	Lagos	1.85–2.54	—	—	0.99–1.41	—	—
[58]	5 plants	Farm	Ekiti	—	247.6–784.2*	—	147.8 - 366.5*	—	—
[59]	Fruit and vegetables	Market	Lagos	0.07–1.93	0.03–0.13	0.05–0.29	0.004–0.09	0.01–0.07	—
WHO/ FAO				0.3	100	67	0.1	73	1.3

*Above maximum allowable limits, nd – not detected.

Table 2.
Heavy Metals occurrence in some plants reported in southwest Nigeria.

plants to remove metal compounds from the soil/substrate, the translocation factor indicates the ability of the absorbed compound to be transferred from plant roots to other plant organs [61].

$$\text{BAF} = \frac{\text{Metal concentration in stem or leaves}}{\text{Metal concentration in soil}} \quad (1)$$

$$\text{TF} = \frac{\text{Metal concentration in stem or leaves}}{\text{Metal concentration in root}} \text{ or } \frac{\text{BAF in stem or leaves}}{\text{BAF in root}} \quad (2)$$

Plants that have BAF and TF >1 can be used as bioaccumulators [62].

Also, plants can be deployed as phytostabilizers if they have BAF >1 and TF <1; and as phytoextractors if they have BAF <1 and TF >1 [63]. The knowledge of these values also help as guides when planting crops in areas of possible heavy metal contaminations.

4. Heavy metal accumulation in surface and groundwater

One of the targets of Millennium Development Goals (MGDs) is to globally achieve clean water before 2030. Most livelihood activities depend on the availability of water for drinking, irrigation, and industrial processes or recreational purposes. The availability of quality water depends on the physical, chemical, and biological properties surrounding the water [9]. In Southwest Nigeria, fresh surface water is usually available throughout the year, but in abundant quantities during the rainy season, which almost last for 7 months. While most rural communities are served by surface water, urban communities in Southwestern Nigeria depend largely on groundwater abstraction to meet their water need. Achieving quality water in this region has continued to be major concern, giving the spate of pollution to both surface and groundwater in the region. High industrial use, agricultural activities, poor sewage management, urban runoff and overall poor environmental monitoring has increased the pollution menace on water resources in the Southwest.

The introduction of foreign contaminants into water bodies may either pollute the water or increase nutrients for aquatic biota [64]. Water is polluted or contaminated if its physicochemical properties are altered, and these alterations affect the aquatic lives adversely [65]. Heavy metal can be introduced into water matrices through anthropogenic activities like mining, crude oil spills, and untreated waste effluents containing metals. Surface water can be polluted by contaminants washed into it either from far polluted sites as non-point source pollution or through direct introduction into water bodies, as point source pollution [66]. Akinyemi et al. [9] sampled river water beside a cassava processing factory at Ibadan, Oyo State for heavy metals (**Table 3**) and reported the mean concentration of Cu at (0.035 mg/l), Cr (0.026 mg/l), Ni (0.036 mg/l), Cd (0.026 mg/l), Zn (0.075 mg/l) and Pb (0.032 mg/l). Though the heavy metals reported were within WHO permissible limits, the discharged from the cassava factory near the river was reported to contribute to the heavy metal contamination of the river.

Furthermore, the cross interaction of water at the surface water and groundwater interface may also contribute heavy metals to water especially in regions with high water table [68] investigated some shallow groundwater wells that were in close contact with polluted streams in.

Authors	Sites	State	Heavy Metals (mg/l)						
			Lead	Cd	Cr	Zn	Ni	Cu	Fe
[9]	River	Ogun	0.002–0.135*	0.009–0.085*	0.013 – 0.068*	0.026–0.214	0.018 – 0.076*	0.001–0.164	—
[45]	Leachate	Lagos	0.22*	0.09*	—	25.48*	0.01	2.11*	15.63*
	Groundwater		0.004– 0.009	0.002–0.009*	—	0.15 – 4.10	0.002–0.007	0.01–0.023	0.02–0.06
[28]	Stream	Oyo	0.024–0.275*	0.002 – 0.025*	—	—	—	—	0.262 – 2.038
[67]	Rivers	Osun	—	—	0–2100*	10–650*	—	0–1350*	—
[68]	Stream	Ondo	0.518*	0.252*	0.372*	—	—	—	—
	Groundwater		0.000– 0.079*	0.000– 0.820*	0.000– 0.079*	—	—	—	—
[69]	Lake	Oyo	0.015*	nd	nd	—	nd	—	0.0066
[70]	Lagoon	Lagos	—	—	—	0.4–0.54	0.1–0.60*	—	7.3 – 6.65*
[10]	River	Ekiti	0.16*	0.13*	—	4.65	—	0.84	5.87*
[71]	Water treatment facility	Oyo	0.07–0.36*	0.08 –0.10*	0.04–0.22*	—	—	—	—
	Tap water		0.12–0.65*	0.08 –0.11*	0.02–0.29	—	—	—	—
	Dam		0.03–0.15*	0.06 –0.08*	0.13–0.37*	—	—	—	—
[72]	Reservoir	Osun	3.05*	2.9*	3.88*	8.99*	7.26*	3.19*	176.22*
[73]	Coastal water	Ondo	0.00–0.01	0.00–0.01*	—	0.00 - 0.01	—	nd	0.06–0.43
WHO/FAO			0.01	0.003	0.05	5	0.02	2	3

*Above maximum allowable limits, nd – not detected.

Table 3.
Heavy Metals occurrence in Surface and Groundwater from Southwest Nigeria.

Ondo City, Ondo State. Highest level of aluminum, cadmium, lead, and chromium concentrations in well water at 1.632 mg/l, 0.820 mg/l, 0.079 mg/l and 0.079 mg/l recorded in the rainy season exceeded WHO recommendations.

Landfill leachates also contribute toxic metals to surface water and groundwater through percolation of the subsoil. Ogunwole et al. [45] investigated the impact of leachates on groundwater resources at varying horizontal distances from some dumpsites in Lagos State. Their findings showed high concentrations of Zn (25.48 mg/l), Fe (15.63 mg/l). Cu, Mn, Pb, Cd, Ni had a concentrations of 2.11, 1.04, 0.22, 0.09 mg/l and 0.01 respectively. For the groundwater, heavy metals level ranges as Cd (0.004–0.009 mg/L) and Zn (4.10 mg/L) detected in some of the wells exceeded the permissible level to be found in drinking water. Prohibitory levels of Cd found in the groundwater closest to the dumpsite were attributed to the low pH around the dumpsite area. Mobility of metals in soil column is often determined by the pH of the subsurface area. This mostly affects the sorption/desorption of metals, precipitation/dissolution, complex formation and oxidation/reduction reactions of metals [74]. Ten rivers were examined in Osun State by [67], while most of the parameters measured fell within the threshold values for drinking water, heavy metals like iron ($60\text{--}960\ \mu\text{g L}^{-1}$), chromium ($0\text{--}2100\ \mu\text{g L}^{-1}$), aluminium ($0\text{--}800\ \mu\text{g L}^{-1}$) and calcium ($6400\text{--}232,000\ \mu\text{g L}^{-1}$) exceeded at some locations. For public health concerns, individuals drinking from heavy metal contaminated water are highly liable to cancerous conditions. Hence, there is need to regulate heavy metal pollutant that is discharged into these water bodies.

5. Heavy metals toxicity in freshwater fishes

Aquatic environment is one of the major receiving ends for pollutants, particularly heavy metals which are routed back into the food webs through bio-accumulation in aquatic macroinvertebrates, invertebrate fishes and finally biomagnified in human [10].

Heavy metals in aquatic ecosystems are usually found in water, sediments and associated biota [75]. They generally exist in low concentrations in water and attain considerable levels in sediment and biota. The adhesive property of sediments makes it possible to sink pollutants like pesticides and heavy metals; and also important for the remobilization of contaminants in aquatic systems [76]. The biota that inhabits contaminated sites is generally exposed to toxic concentrations of these metals because many of them process food from sediment. Most filter feeding fishes and macro-invertebrates take up heavy metals and bioaccumulate them. This can potentially threaten the health of these aquatic species and others across the food chain, especially birds, fish and humans [77].

The process by which metal accumulate in the tissues of living organisms via the food chain is called bioaccumulation, and are measured as either Bioaccumulation factor (BAF) and Bioconcentration factor (BCF). If BAF is high, it indicates that the bioaccumulation of heavy metals occurred in organisms. Bioaccumulation is often related to the fact that metals of different kind tend to accumulate differently in the tissue of aquatic species, considering the feeding, swimming, and metabolic activity of individual species. Previous documented studies reveal accumulated concentrations of heavy metals in various parts of the organism. Fish gill was reported to store the highest amount of Pb (15.5 mg/kg) and Mn (604.32 mg/kg), while liver tissue had the highest Cd (7.88 mg/kg) and Zn (11.80 mg/kg) level in fish species from Ogun River, Nigeria [78].

Olusola and Festus [79] during their study of coastal waters of Ondo state, noted that distribution of heavy metals in different fish parts were organ specific,

Authors	Species	Site	State	Heavy metals (mg/kg)						
				Lead	Cd	Zn	Fe	Ni	Cu	Cr
[78]	Fish	River	Ogun	8.69–15.5*	1.53 - 7.88*	6.78–11.80	—	15.9–24.80*	—	—
[69]	Fish	Lake	Oyo	0.053	0.064	—	7.43*	0.016	—	0.004
	Prawn			0.104	0.045	—	1.61*	0.019	—	0.001
[10]	<i>Clarias gariepinus</i>	River	Ekiti	0.09	0.04	0.95	1.09*	—	0.66	—
[79]	Fish	Coastal water	Ondo	1.14	3.18*	0.28 - 4.14	—	0.01	5.72*	3.41*
[82]	Catfish	Lake	Oyo	1.3–12.1*	0.3 - 4.2*	3.5–71.2	82.1 - 2303.8*	0.7–39.3*	1.3 - 40.1*	—
[83]	Fish	Lagoon	Lagos	3.19–5.88*	—	8.73 - 15.78	7.27–8.69*	—	2.04 - 3.31*	—
[73]	Shrimps	Costal water	Ondo	0.01–0.027	0.01	5.35–7.51	4.21–5.90*	—	1.86 - 3.06*	—
[70]	Tilapia	Lagoons	Lagos	—	—	0.16–1.30	0.10–8.02*	0.00 - 4.00*	—	—
	Catfish			—	—	0.25–1.95	0.21–8.40*	0.00 - 2.80*	—	—
[80]	Frozen fish	Storage facilities	Oyo	2.11–13.18*	0.59 - 2.18*	—	—	—	2.89 - 9.74*	—
WHO/FAO				2	0.5	30	0.5	0.02	3	0.05

*Above maximum allowable limits.

Table 4.
Heavy Metals occurrence in aquatic animals from Southwest Nigeria.

as higher concentrations of metals were recorded in the gills and eyes compared to other organs. In contrast, [80] recorded highest concentration of Pd, Cd, Cu and Hg in liver than other parts of frozen fishes sold in storage facilities in Ibadan, Oyo State. Some of the concentrations recorded in these parts were considered to be above maximum acceptable limit by [81]. Severe exposure of aquatic animals to heavy metals through different sources could result in observable structural and/or functional changes. This could further cause mortality, and also loss of biodiversity. Leachates collected from dumpsite were investigated for toxicity on fishes (*C. gariepinus* and *O. niloticus*) and it was found out that the treatment (leachates) induces biochemical alterations in the organism, as well as mortality [45].

Several researchers have reported accumulation of heavy metals in aquatic animals in Southwest Nigeria (Table 4). Two lagoons (Epe and Badagry) in Lagos were investigated and found to contain Zn, Ni and Fe in both water and sediment [70]. The fishes dwelling inside these studied lagoons were further examined and similar metals were detected in various parts of the fishes (tilapia and catfish). While concentrations detected in the study were considered safe for consumption, the researchers still emphasized the need for continuous monitoring to prevent adverse human health effects [78, 84, 85], especially if heavy metals detected in fishes are in elevated concentrations.

6. Conclusion

Many of the heavy metals reported in this chapter exceed the maximum limit by WHO and FAO. Despite the massive and continued documented evidences on the occurrence and adverse effects of heavy metals in the South-west region and the larger Nigeria, little is been done in terms of control measures. Many domestic and industrial wastes in the South-western region of Nigeria are still discharged into water bodies untreated. This contributes a large intermix of heavy metals in many of the natural waters in the urban areas and endangers the quality and health of aquatic environment. Deploying advanced technologies for wastewater and sewage treatment have greatly reduced the menace of toxic metal pollution in developed countries. Developing a similar but strategic approach in Nigeria should lessen the impact of heavy metal pollution in the Southwestern Nigeria. More so, with efficient water and sanitary infrastructure, larger populace will have access to clean water supply and hygiene practices that will limit their use of contaminated water.

Most inhabitants in South-west Nigeria, especially in highly commuted cities, are still constantly predisposed to metal contamination through industrial and automobile emissions. Poor combustion engines add large quantities of lead and cadmium into the air and surfaces as particulate matters. Lead in human causes cardiovascular diseases, predispose renal, immunological and reproductive dysfunctions. Also, Cadmium is carcinogenic, neurotoxic and causes skeletal disorders, and disrupts a mineral balance in the body.

As a booming revenue generator, the hydrocarbon industries in the Southwest Nigeria also contribute immensely to heavy metal pollution in the region. Large deposits of crude oil spills and other hydrocarbon exploring technologies add metal contaminants into land, surface and groundwater. Likewise, the unguarded activities of artisanal miners of gold, copper, limestone etc. are another major heavy metal contributor in this region. These crude mining methods are implicated to not only unearth natural heavy metals, but introduces others forms of heavy metals through explosives and catalyst.

With research showing that heavy metals do accumulate in agricultural produce, edible fruits and seafood, it is evident that most local populace are constantly, but

insensibly taking in heavy metals through many food sources. More worrisome is that the concept of quality control of most food products in Nigeria is still very low. Hence, most people could be exposed to the long term health effect of heavy metals. The exposure to cadmium, lead, nickel and mercury compounds from consumption of contaminated plant, water and seafood is dangerous, especially during prenatal development and infancy, as it causes irreversible changes in the central nervous system.

From the reports in this chapter, and many other uncovered studies of heavy metals in south west region of Nigeria, there is enough empirical based need for urgent attention to control waste and activities that contribute heavy metals to the environment.

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Author details

Olufemi Akinnifesi*, Femi Adesina, Germaine Ogunwole and Sylvanus Abiya
Department of Biology, Federal University of Technology Akure, Ondo State,
Nigeria

*Address all correspondence to: olufemiakinnifesi@yahoo.com

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