Ethiopian Journal of Environmental Studies & Management 13(5): 522 – 534, 2020.
ISSN:1998-0507 doi: https://ejesm.org/doi/v13i5.1
Submitted: February 19, 2020 Accepted: August 20, 2020

ASSESSMENT OF HEAVY METAL CONTAMINATION IN PLANT SAMPLES OF OLD OYO NATIONAL PARK, SOUTHWEST, NIGERIA: A BASELINE STUDY

ADETUGA, A.T.,[1] OMONONA, A.O.[1] AND *JUBRIL, A.J.[2]
[1]Department of Wildlife and Ecotourism Management, University of Ibadan, Nigeria
[2]Department of Veterinary Pathology, University of Ibadan, Nigeria
*Corresponding author: afusatjagun@gmail.com

Abstract

Heavy metal contamination may alter the chemical composition of plants with consequent effect on their growth and possible transmission of potential toxic metals to animals and humans along the food chain. The study was carried out to quantitatively assess the levels of heavy metals in plant species in Old Oyo National Park, Southwest, Nigeria. The Segmented Transect Belt Method was adopted for matured plant (leaves) sampling in Marguba, Tede and Oyo-Ile ranges of Old Oyo National Park, purposively selected based on the observed anthropogenic activities by the surrounding local communities. Sampling was done within four seasons during the wet and dry seasons for two consecutive years (between 2017 and 2018). Heavy metals such as copper, zinc, lead, chromium, cadmium, nickel, iron and manganese were analysed in the samples using standard methods. Data collected were subjected to descriptive and inferential (ANOVA) statistics with statistical significance set at $\alpha_{0.05}$. The result showed that the mean concentrations of cadmium (except dry season, 2017), iron (during wet season, 2017) and chromium (during wet season, 2017) levels in the plants were above the comparable recommended limit while the mean concentrations of copper, zinc, lead, nickel and manganese across the four seasons of sampling were below comparable recommended limits. The sampled plant species were more contaminated with heavy metals during the wet season than the dry season. Statistically, there were significant differences in the values of all the analysed heavy metals in the plant samples across the four seasons at $P \leq 0.05$. There is need for continuous monitoring of heavy metal deposition, accumulation and contamination in the park.

Key Words: *Heavy metals, Plant samples, Wildlife, Old Oyo National Park*

Introduction

Heavy metal contamination of the environment is a worldwide phenomenon that is continuously gaining a great deal of attention (Idowu *et al*., 2014). Since the onset of industrial revolution and urbanization, the availability of toxic metals has increased considerably within the biota (Senwo and Tazisong, 2004). It is well-known that the most important sources of anthropogenic major and trace element emissions are industrial production, the combustion of fossil fuels in vehicular traffic and energy production, sewage sludge dispersal and fertilizer production (Dulama *et al*., 2012). Despite the fact that some metals such as iron and manganese play a role in metabolic activity and are required for growth, development and body maintenance, their high concentrations in the body have consequent adverse health effects on the body system (Rehman *et al*., 2018). On the other hand, metals such as lead has no role in metabolic activities of organisms but possess the potential to cause toxicity on different tissues of most living organisms even at low concentrations (Li *et al*., 2018). Generally, the threat that heavy metals pose to human and animal health is often aggravated by their long-term persistence in the environment (Yoon *et al*., 2006).

Biological indicators have been used for many years to detect the deposition, accumulation and distribution of heavy metal contamination or pollution within the environment (Ojekunle *et al*., 2014). Plants are being used intensively as biological indicators and biomonitors of heavy metal contamination in the environment due to their suitability (Hlail, 2019). They have been noted to be extremely sensitive to environmental conditions and are able to accumulate heavy metals in their tissues (Tangahu *et al*., 2011). Metal accumulation in plants have been reported to vary depending on the texture of soil or media on which they grow; species, part and nature of the plant as well as the type and nature of the metal itself (Sawidis *et al*., 2011; Serbula *et al*., 2012). Different parts of the plant contain different amounts of heavy metals with the highest concentrations of metals mostly found in roots, stems, and leaves (Mirecki *et al*., 2015).

The Old Oyo National Park is being threatened by human activities through the emergence and encroachment by surrounding communities (Oladeji *et al.,* 2012). These activities such as inorganic agriculture, mining, coal combustion, sewage, industrial effluents automobile exhaust, amongst others are potential sources of heavy metals. Several metals that are well-thought-out as essential nutrients in lower concentration (like Iron, Copper, Zinc and Manganese) can be considered harmful for the growing plant if the levels of these elements in soil and atmosphere are increased (Olowoyo *et al*., 2010; Stihi *et al*., 2011). Monitoring of heavy metals in the environment is therefore crucial to identifying the current state of the environment (Zolfaghari *et al.*, 2018). Due to their very high potential toxicity to animals and humans, accurate quantitative analysis of the residual levels of heavy metals in wild or medicinal plants is quite imperative (Vaikosen and Alade, 2011). It is highly pertinent to note that most of the plant species within the national park may serve as medicinal plants used for remedies, and as such, the guiding principles for assessing safety of wild plants with respect to contaminants (including heavy metals) and their residues are based on the provisional tolerable intake (PTI) of individual contaminant (or sum of similar group of contaminants) and maximum residual or permissible limits of these contaminants (Vaikosen and Alade, 2017). So, it is important to consider the levels of heavy metals to inhibit the potential hazards of these metals in the environment (Kharkan *et al*., 2019). This study was therefore to assess the levels of heavy metals concentration in soil of Old Oyo National Park, Southwest, Nigeria.

Methodology

Study Area

The Old Oyo National Park (OONP) earlier existed as two contiguous forest reserves; Upper Ogun and Oyo-Ile and gazetted in 1936 and 1941, respectively. It is one of the seven national parks in Nigeria and was upgraded from game reserve to a national park status in 1991 by decree number 36 which was later substituted with Act No. 46 of 1999. The park has a total land mass area of 2,512 km^2 making it the fourth largest national park in Nigeria. The park is divided into five administrative units (hereafter termed "Ranges"): Oyo Ile (476 km^2), Marguba (617 km^2), Tede (422 km^2), Sepeteri (607 km^2) and Yemoso (390 km^2). It is located between latitudes 8° 15′ to 9° 05′ N and longitudes 3° 35′ to 4° 42′ E, and centered on North latitude 8° 36′ 00″ and East longitude 3° 57′ 05″ (Akinyemi and Kayode, 2010). The Old Oyo National Park is drained mainly by River Ogun, and its network of tributaries that cover the entire Southern part of the park. River Tessi is the main source of water to the wild animals in the Northern part of the park while several tributaries notably Iwa, Oopo, Iwawa, Oowe, Owu, Ayinta, Sooro, Iweke and so on exist in the park. The park is rich in both flora and fauna species of ecological as well as touristic importance.

Sample Site Selection

The study was carried out within three (3) ranges of Old Oyo National Park. The ranges include Oyo-Ile, Tede, and Marguba. These ranges were purposively selected based on the presence of perennial waterholes, representativeness of the park and dominant anthropogenic activities by the surrounding local communities such as agriculture, charcoal production, illegal mining and grazing sequel to a thorough reconnaissance survey of the park.

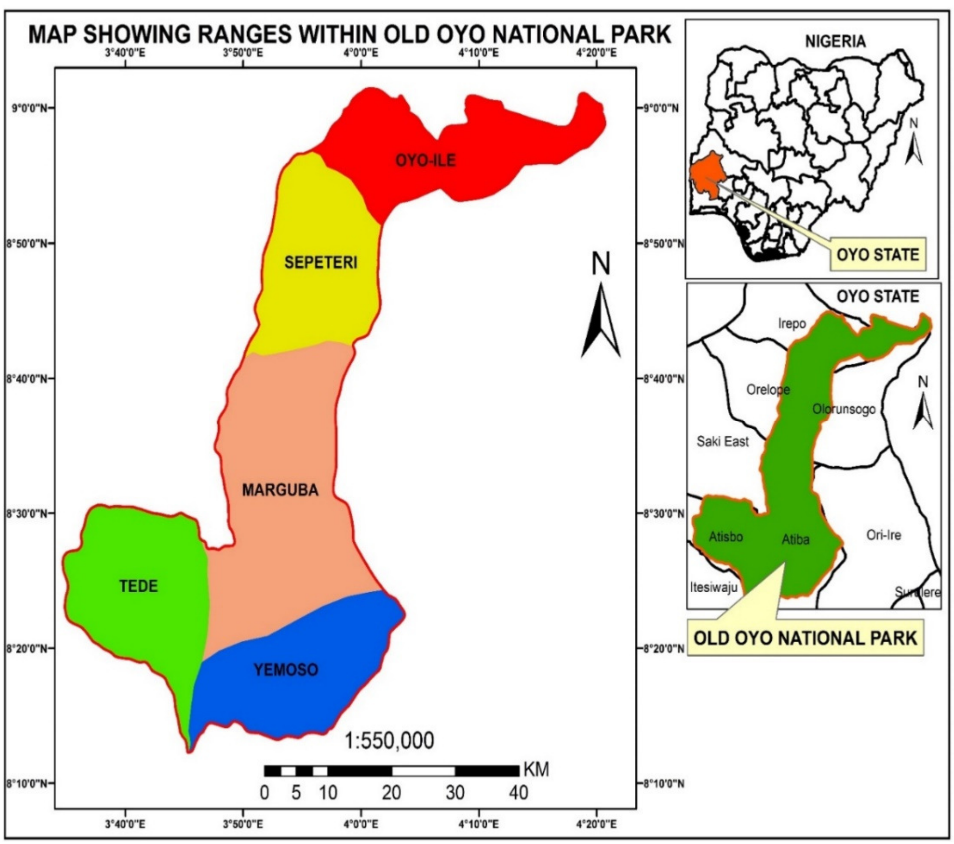

Fig. 1: Map of Old Oyo National Park showing the ranges

Collection of Samples and Sampling Technique

The Segmented Transect Belt Method (STBM) was adopted for plant sampling (Alarape, 2002). Transect lines of 1.2 km in length were chosen randomly in Marguba, Oyo-Ile and Tede ranges of Old Oyo National Park. On each transect, at about 100 m sampling intervals, four matured plant (leaves) samples were randomly collected. The plant species sampled were the ones that are thought (sequel to reconnaissance survey) to be most preferred by herbivores in each of the chosen ranges. As such, plant species in Marguba (*Blighia sapida*, *Terminalia glaucescens*, *Kigelia africana* and *Pterocarpus erinaceus*), Oyo-Ile (*Vitellaria paradoxa*, *Khaya grandifoliola*, *Afzelia africana* and *Daniella oliverii*) and Tede (*Anogeissus leiocapus*, *Brachystegia euryloma*, *Isoberlinia doka* and *Burkea africana*) ranges were collected, properly labeled and assessed for heavy metals. The plant species were identified on the field with the help of rangers and later confirmed using a field guide. A total of four (Marguba range), four (Oyo-Ile range) and four (Tede range) plant samples were collected per season of sampling. In all, forty-eight (48) plant samples were collected throughout the period of sampling. Sampling was done within four seasons during the rain (April-October) and dry (November-March) seasons for two consecutive years (between 2017 and 2018).

Analytical Procedure for Heavy Metal Determination in Plant Samples

Plant samples were oven-dried and pulverized. Then, about 1.0 g plant samples were appropriately digested using 12 mL concentrated acid mixture (69% HNO_3: 70% $HClO_4$; 3:1 v/v). The mixture was heated over a sand bath in a fume hood until it became clear. After the digested samples were cooled, they were filtered and transferred into a 100 mL volumetric flask and the volume was made to the mark with 5% HNO_3 acid. The concentration of metals in the samples were subsequently determined using Buck scientific VGP Atomic Absorption Spectrophotometer. Analyses were carried out at the Soil Chemistry Laboratory, Department of Agronomy, University of Ibadan, Ibadan, Nigeria.

Heavy Metals Analysed

For the heavy metals assayed, Zinc (Zn), Cadmium (Cd), Nickel (Ni), Copper (Cu), Lead (Pb), Chromium (Cr), Iron (Fe) and Manganese (Mn) were analyzed in the plant samples. These heavy metals were purposively selected because they constitute part of the eleven heavy metal elements of utmost wildlife protection concern (Beyersmann and Hartwig, 2008) and also based on the observed anthropogenic activities around the study area such as agriculture, charcoal production, illegal mining and vehicular emissions even within the park especially at Oyo-Ile range.

Statistical Analysis

Data collected were subjected to descriptive (mean, standard deviation) and inferential (ANOVA) statistics. Post-hoc test (LSD) was used to determine significant differences in the mean concentrations of heavy metals across the seasons of sampling with statistical significance set at $\alpha_{0.05}$.

Results

The heavy metal concentration in plant samples from Old Oyo National Park collected for two years (2017 and 2018) are presented in Table 1 to Table 4. The result from the dry season of 2017 showed that Pb, Ni and Cd were all below detection limit in all the plants sampled while Cr (2.88 ± 0.02) in *Afzelia africana* was above WHO recommended level (Table 1). In the wet season of 2017, Cr levels in all the sampled plants (except *Blighia sapida*, *Kigelia africana*, *Khaya grandifoliola*, *Daniella oliverii*), Cd (in *Pterocarpus erinaceus*, *Vitellaria paradoxa*, *Anogeissus leiocarpus*, *Isoberlinia* spp) and Fe (in all the sampled plants) were above recommended levels as shown in Table 2. Furthermore, in the dry season of 2018, Cr (in *Terminalia glaucescens, Vitellaria paradoxa, Burkea africana*), Cd (in all sampled plants except *Blighia sapida*, *Khaya grandifoliola*, *Daniella oliverii*) and Fe (except *Terminalia glaucescens, Pterocarpus erinaceus, Khaya grandifoliola, Afzelia africana, Daniella oliverii, Brachystegia euryloma*) were above recommended levels as shown in Table 3. During the wet season of 2018, levels of Cr (in *Vitellaria paradoxa, Afzelia africana, Anogeissus leiocarpus*), Cd (*Kigelia africana, Pterocarpus erinaceus, Afzelia africana, Anogeissus leiocarpus, Isoberlinia* spp) and Fe (*Terminalia glaucescens, Kigelia africana, Vitellaria paradoxa, Afzelia africana, Isoberlinia* spp*)* were above the recommended level as shown in Table 4. The sampled plant species were more contaminated with heavy metals during the wet season. The mean values of heavy metal in the plant samples across all the four seasons revealed that Cr (wet season, 2017), Cd were above recommended levels (Table 5). Statistically, there were significant differences in the values of all the analysed heavy metals in the plant samples across the four seasons at $P \leq 0.05$ (Table 6).

Table 1: Heavy metals concentration of plant samples in Old Oyo National Park [Dry Season, 2017]

Plant Samples	Cu (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Ni (mg/kg)	Cd (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
Blighia sapida	6.43 ± 0.02	29.10 ± 0.07	BDL	BDL	BDL	BDL	12.81 ± 0.24	1.22 ± 0.79
Terminalia glaucescens	5.28 ± 0.03	8.48 ± 0.08	BDL	BDL	BDL	BDL	14.66 ± 0.71	1.10 ± 0.35
Kigelia africana	3.03 ± 0.03	7.60 ± 0.08	BDL	BDL	BDL	BDL	9.21 ± 0.11	2.23 ± 0.29
Pterocarpus erinaceus	4.15 ± 0.02	14.60 ± 0.03	BDL	BDL	BDL	BDL	11.72 ± 0.26	0.87 ± 0.12
Vitellaria paradoxa	0.96 ± 0.06	10.20 ± 0.09	BDL	BDL	BDL	BDL	12.04± 0.98	1.34 ± 0.31
Khaya grandifoliola	4.18 ± 0.01	11.80 ± 0.09	BDL	BDL	BDL	BDL	13.45 ± 0.60	2.79 ± 0.03
Afzelia africana	6.00 ± 0.04	20.10 ± 1.02	2.88 ± 0.02	BDL	BDL	BDL	11.12 ± 0.83	3.32 ± 0.42
Daniellia oliveri	6.53 ± 0.11	14.00 ± 0.87	BDL	BDL	BDL	BDL	9.56 ± 0.44	2.41 ± 0.18
Anogeissus leiocapus	3.71 ± 0.41	5.88 ± 0.01	BDL	BDL	BDL	BDL	10.53 ± 0.77	6.10 ± 0.22
Brachystegia euryloma	0.35 ± 0.03	2.94 ± 1.72	BDL	BDL	BDL	BDL	9.98 ± 0.23	4.07 ± 0.01
Isoberlinia sp.	2.62 ± 0.78	4.21 ± 0.85	0.92 ± 0.03	BDL	BDL	BDL	12.24 ± 0.16	3.86 ± 0.37
Burkea africana	1.20 ± 0.33	5.34 ± 0.27	0.27 ± 0.34	BDL	0.16 ± 0.87	BDL	7.37 ± 0.94	2.82 ± 0.05

Note: BDL - Below detection limit

Table 2: Heavy metals concentration of plant samples in Old Oyo National Park [Wet Season, 2017]

Plant Samples	Cu (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Ni (mg/kg)	Cd (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
Blighia sapida	9.23 ± 0.14	36.06 ± 0.10	0.24 ± 0.03	BDL	BDL	BDL	34.54 ± 0.12	7.22 ± 0.21
Terminalia glaucescens	3.71 ± 0.41	5.88 ± 0.01	2.85 ± 0.04	BDL	BDL	BDL	24.8 ± 0.09	9.10 ± 0.27
Kigelia africana	5.28 ± 0.02	8.48 ± 0.06	1.12 ± 0.58	BDL	BDL	BDL	41.24 ± 0.78	7.04 ± 0.11
Pterocarpus erinaceus	3.07 ± 0.32	9.43 ± 0.05	2.23 ± 0.07	1.08 ± 0.08	1.16 ± 0.04	0.79 ± 0.04	24.20 ± 0.17	5.17 ± 0.15
Vitellaria paradoxa	4.15 ± 0.02	16.60 ± 0.02	1.92 ± 0.33	0.52 ± 0.53	0.88 ± 0.32	0.28 ± 0.28	31.84 ± 0.89	3.02 ± 0.91
Khaya grandifoliola	1.82 ± 0.07	10.20 ± 0.09	0.92 ± 0.49	BDL	BDL	BDL	36.06 ± 1.12	3.76 ± 0.33
Afzelia africana	5.12 ± 0.10	11.80 ± 0.09	3.70 ± 0.03	1.81 ± 0.04	0.75 ± 0.07	BDL	33.93 ± 0.50	6.73 ± 0.05
Daniellia oliveri	6.00 ± 0.04	20.10 ± 1.02	0.87 ± 0.02	BDL	BDL	BDL	26.44 ± 0.21	4.32 ± 0.46
Anogeissus leiocapus	6.53 ± 0.11	14.00 ± 0.87	1.88 ± 0.06	1.00 ± 0.03	1.36 ± 0.09	0.43 ± 0.02	26.02 ± 0.20	4.43 ± 0.14
Brachystegia euryloma	4.14 ± 0.08	10.14 ± 0.32	3.28 ± 0.12	BDL	0.66 ± 0.03	BDL	32.1 ± 1.32	6.50 ± 0.03
Isoberlinia sp.	4.36 ± 0.24	9.15 ± 0.15	5.22 ± 0.06	1.28 ± 0.04	1.07 ± 0.06	0.54 ± 0.14	37.67 ± 0.51	6.17 ± 0.05
Burkea africana	4.31 ± 0.09	4.23 ± 0.11	5.28 ± 0.13	BDL	0.22 ± 0.24	BDL	22.21 ± 0.67	3.12 ± 0.04

Note: BDL - Below detection limit

Table 3: Heavy metals concentration of plant samples in Old Oyo National Park [Dry Season, 2018]

Plant Samples	Cu (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Ni (mg/kg)	Cd (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
Blighia sapida	5.37 ± 0.16	30.05 ± 0.03	BDL	BDL	BDL	BDL	21.63 ± 0.38	2.89 ± 0.35
Terminalia glaucescens	1.41 ± 0.09	2.40 ± 0.10	1.69 ± 0.04	1.21 ± 0.11	0.50 ± 0.08	0.65 ± 0.02	20.00 ± 0.10	8.00 ± 0.06
Kigelia africana	1.69 ± 0.12	2.19 ± 0.09	0.98 ± 0.05	1.30 ± 0.10	0.40 ± 0.11	0.70 ± 0.17	22.00 ± 0.07	10.20 ± 0.02
Pterocarpus erinaceus	2.10 ± 0.18	7.22 ± 0.16	1.23 ± 0.11	0.92 ± 0.03	1.02 ± 0.13	0.44 ± 0.02	16.10 ± 0.19	3.04 ± 0.07
Vitellaria paradoxa	1.50 ± 0.06	2.53 ± 0.13	1.75 ± 0.10	1.24 ± 0.12	0.58 ± 0.14	0.68 ± 0.07	20.81 ± 0.26	8.30 ± 0.02
Khaya grandifoliola	0.85 ± 0.01	7.12 ± 0.05	0.71 ± 0.41	BDL	BDL	BDL	17.01 ± 0.21	1.53 ± 0.13
Afzelia africana	3.98 ± 0.08	8.98 ± 0.28	1.04 ± 0.31	1.62 ± 0.06	0.43 ± 0.12	0.47 ± 0.01	18.50 ± 0.16	2.67 ± 0.03
Daniellia oliveri	4.07 ± 0.01	9.18 ± 0.82	0.36 ± 0.09	BDL	BDL	BDL	11.08 ± 0.12	1.96 ± 0.14
Anogeissus leiocapus	1.70 ± 0.17	2.30 ± 0.21	1.21 ± 0.12	1.33 ± 0.04	0.46 ± 0.13	0.74 ± 0.19	22.10 ± 0.16	10.25± 0.06
Brachystegia euryloma	0.73 ± 0.01	1.44 ± 0.14	1.20 ± 0.05	0.84 ± 0.04	0.22 ± 0.05	0.31 ± 0.02	13.10 ± 0.27	3.10 ± 0.13
Isoberlinia sp.	1.69 ± 0.23	2.19 ± 0.18	1.19 ± 0.10	1.30 ± 0.03	0.40 ± 0.08	0.68 ± 0.11	21.50 ± 0.16	10.00 ±0.11
Burkea africana	1.48 ± 0.02	2.48 ± 0.19	1.70 ± 0.05	1.21 ± 0.12	0.52 ± 0.11	0.66 ± 0.03	20.10 ± 0.13	8.10 ± 0.04

Note: BDL - Below detection limit

Table 4: Heavy metals concentration of plant samples in Old Oyo National Park [Wet Season, 2018]

Plant Samples	Cu (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Ni (mg/kg)	Cd (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
Blighia sapida	6.82 ± 0.64	18.02 ± 0.67	0.29 ± 0.13	BDL	BDL	BDL	17.08 ± 0.91	9.54 ± 0.55
Terminalia glaucescens	3.04 ± 0.81	7.24 ± 0.28	0.79 ± 0.08	BDL	0.21 ± 0.09	BDL	22.13 ± 0.83	12.16 ± 0.69
Kigelia africana	3.52 ± 0.19	4.66 ± 0.33	0.83 ± 0.27	0.32 ± 0.16	0.32 ± 0.15	0.62 ± 0.18	31.25 ± 1.02	5.51 ± 0.36
Pterocarpus erinaceus	3.07 ± 0.32	8.31 ± 0.45	1.14 ± 0.18	0.28 ± 0.13	1.19 ± 0.54	0.36 ± 0.21	18.44 ± 0.94	2.88 ± 0.22
Vitellaria paradoxa	5.78 ± 0.73	18.11 ± 0.96	1.96 ± 0.49	1.26 ± 0.83	0.62 ± 0.14	BDL	25.19 ± 0.85	6.41 ± 0.73
Khaya grandifoliola	1.26 ± 0.16	12.58 ± 0.63	BDL	BDL	BDL	BDL	13.56 ± 1.30	4.21 ± 0.66
Afzelia africana	2.48 ± 0.27	6.40 ± 0.12	3.70 ± 0.03	1.17 ± 0.35	0.47 ± 0.16	0.29 ± 0.13	26.17 ± 1.82	5.92 ± 0.46
Daniellia oliveri	3.91 ± 0.44	12.70 ± 0.89	BDL	BDL	BDL	BDL	18.90 ± 1.64	3.14 ± 0.62
Anogeissus leiocapus	4.23 ± 0.18	9.33 ± 0.61	1.62 ± 0.88	0.82 ± 0.31	0.38 ± 0.12	0.58 ± 0.24	14.57 ± 0.92	7.25 ± 0.39
Brachystegia euryloma	2.97 ± 0.88	6.61 ± 0.71	0.44 ± 0.10	BDL	0.41 ± 0.81	BDL	18.11 ± 0.72	4.42 ± 0.47
Isoberlinia sp.	3.61 ± 0.42	2.51 ± 0.39	0.74 ± 0.23	1.06 ± 0.12	0.52 ± 0.11	0.41 ± 0.32	22.13 ± 0.69	5.61 ± 0.72
Burkea africana	6.56 ± 0.77	7.41 ± 0.52	1.32 ± 0.55	BDL	0.46 ± 0.71	BDL	12.50 ± 0.18	6.43 ± 0.56

Note: BDL - Below detection limit

Table 5: Mean values of heavy metals in plant samples of Old Oyo National Park

Heavy metals	Mean Values ± Standard Deviation				Recommended Level (in medicinal plant)	References
	Dry Season (2017)	Wet Season (2017)	Dry Season (2018)	Wet Season (2018)		
Cu (mg/kg)	3.70 ± 2.14^{abc}	4.81 ± 1.88^{acd}	2.21 ± 1.45^{bce}	3.94 ± 1.67^{cde}	10	WHO, 2005
Zn (mg/kg)	11.19 ± 7.51^{ad}	13.00 ± 8.47^{bce}	6.51 ± 7.97^{abde}	9.49 ± 4.93^{c}	50	Khan *et al*., 2008
Cr (mg/kg)	1.36 ± 1.36^{ab}	2.46 ± 1.66^{ac}	1.19 ± 0.43^{ab}	1.28 ± 0.99^{ac}	1.50	WHO, 1998
Pb (mg/kg)	BDL	1.14 ± 0.47^{ab}	1.22 ± 0.23^{abc}	0.81 ± 0.43^{ac}	2.0	WHO, 1998
Ni (mg/kg)	0.16 ± 0.00^{abd}	0.87 ± 0.38^{abc}	0.50 ± 0.22^{ace}	0.51 ± 0.28^{ade}	1.5	WHO, 2005
Cd (mg/kg)	BDL	0.51 ± 0.21^{ab}	0.59 ± 0.15^{abc}	0.45 ± 0.14^{ac}	0.3	WHO, 2005
Fe (mg/kg)	11.22 ± 2.02^{ab}	30.92 ± 6.07^{ac}	18.66 ± 3.64^{abc}	20.00 ± 5.59^{a}	20	WHO, 1998
Mn (mg/kg)	2.68 ± 1.52^{abcd}	5.55 ± 1.88^{ab}	5.84 ± 3.56^{ac}	6.12 ± 2.63^{ad}	200	WHO, 1998

Note: BDL- Below detection limit; Means with the same alphabets are significantly different at P≤0.05

Table 6: ANOVA of the heavy metals in the sampled plants of Old Oyo National Park

		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	125.700	3	41.900	13.687	.000
Cu	Within Groups	428.590	140	3.061		
	Total	554.290	143			
	Between Groups	824.387	3	274.796	5.399	.002
Zn	Within Groups	7125.735	140	50.898		
	Total	7950.122	143			
	Between Groups	84.602	3	28.201	24.928	.000
Cr	Within Groups	158.378	140	1.131		
	Total	242.980	143			
	Between Groups	15.127	3	5.042	20.750	.000
Pb	Within Groups	34.021	140	.243		
	Total	49.148	143			
	Between Groups	7.691	3	2.564	8.562	.000
Ni	Within Groups	41.920	140	.299		
	Total	49.611	143			
	Between Groups	3.623	3	1.208	22.793	.000
Cd	Within Groups	7.419	140	.053		
	Total	11.042	143			
	Between Groups	7124.755	3	2374.918	117.902	.000
Fe	Within Groups	2820.045	140	20.143		
	Total	9944.801	143			
	Between Groups	275.326	3	91.775	15.313	.000
Mn	Within Groups	839.071	140	5.993		
	Total	1114.396	143			

Discussion

Heavy metals contamination is a global challenge as heavy metals are not destructible and majority have impacts on life forms especially when permissible limits are exceeded (Emmanuel *et al.,* 2014). Trace metals accumulation in plants from anthropogenic sources has been reported to have drawn greater attention to inorganic pollution, and established plants as passive bio-monitors, since plants respond directly to the state of soil and air (Divan *et al*., 2009). Plants growing in polluted areas show symptoms of accumulation of heavy metals in different parts of them (Kulshreshtha *et al*., 2010) though some plants have the ability to absorb heavy elements in different plant tissues more than others (Aksoy *et al*., 2012). The larger portion of the concentration of iron (highest) obtained from the study may have been obtained from the soil. Stihi *et al*. (2011) reported that increased soil heavy metal levels have proportional influence on the concentration absorbed by plants while Adefemi *et al.* (2007) earlier posited that iron (Fe) occurs at high concentrations in Nigeria soils. Parzych (2014) noted that the specific sensitivity of some plant species to the presence of heavy metals in soil allows for the determination of the degree, range and structure of environmental changes. The implication of this high iron level is that there is availability of Fe for the plant species uptake to maintain normal cellular activities such as DNA replication, nitrogen fixation, reactive oxygen species (ROS) scavenging and chlorophyll biosynthesis (Yruela, 2013). Even though cadmium (Cd) had the lowest mean concentration in the plant samples across the seasons of sampling, it is of ecotoxicological concern. When biomagnified in animal tissues, cadmium possesses inhibitory capabilities, that is, it can block calcium channels or metabolism thereby disrupting the electrolyte balance and causing the excretion of calcium, which can lead to brittle bones (Larison, 2001). In mammals, cadmium has been reported to induce not only acute renal and liver failures but also pneumonitis and pulmonary oedema in mammals (Annabi *et al.,* 2013). The high values of Zn obtained from the study may be from effluents eliciting from human activities such as illegal metal smelting and mining from outside the boundaries of the park. Huseyinova *et al.* (2009) asserted that heavy metals spread as a result of human activities, leading to an excess accumulation that exceeds the permissible limits causing serious environmental disaster. Specifically, very high concentration of Zinc can cause injury to the pancreas and distort metabolism of protein, and leading to arteriosclerosis when bioaccumulated in animals or humans (Sinha *et al.,* 2010). Despite the fact that the concentrations of copper, lead, nickel and manganese obtained in this study were relatively low when compared with the recommended levels, their bioaccumulative tendencies and biomagnification potential along the food chain cannot be jettisoned. This is because the intensity of heavy metal uptake can change the overall elemental composition of the plants in its entirety (Vaikosen and Alade, 2017). Also, consumption of medicinal or wild plant and their products contaminated with toxic substances like these heavy metals, have been reported to elicit deleterious health effects on living organisms (Sethy and Ghosh, 2013). The plant samples of Old Oyo National Park on the average, were more contaminated with heavy metals during the wet season compared to the dry season. This may be accredited to run-off as averred by Jung (2001) and atmospheric deposition. Barbes *et al.* (2014) also opined that the concentrations of major and trace metals in plants depend on root uptake as well as accumulation of dry and wet deposition on outer plant organs, such as leaves or bark. The presence of these heavy metals and their toxicity may have an inhibitory impact on the growth of plant species, photosynthetic activity, enzymatic activity, and build-up of other nutrient elements, as well as disrupting the root system (Gune *et al*., 2004) since certain plants have the ability to uptake and accumulate metallic contaminants via the root system and store them in various plant compartments (Tangahu *et al.,* 2011).

Conclusion

The study documented a baseline quantitative information on the levels of heavy metals in plant (leaves) samples of Old Oyo National Park, Nigeria. The mean concentrations of cadmium (except dry season, 2017) iron (during wet season, 2017) and chromium (during wet season, 2017) levels in the plants were above the comparable recommended limit while the concentrations of copper, zinc, lead, nickel and manganese were below comparable recommended limits. These low concentrations are still of great concern since heavy metals have bioaccumulative tendencies and biomagnification potentials along the food chain. There is need for continuous monitoring of heavy metal deposition, accumulation and contamination in the park.

Conflict of Interest

The authors have not declared any conflict of interests.

Acknowledgement

The authors are grateful to the management of Old Oyo National Park for granting us the permission to carry out the research and also appreciate the critical evaluations of the anonymous reviewers.

References

Adefemi, O.S., Olaofe, D. and Asaolu, S.S. (2007). Seasonal variation in heavy metal distribution in the sediment of major dams in Ekiti-State. *Pakistan J. Nutrition*, 6(6): 705-707.

Akinyemi, A.F. and Kayode, I.B. (2010). Effects of Agricultural Practices on the Distribution of Western Hartebeest *(Alcelaphus buselaphus)* in Old Oyo National Park, Nigeria. *Journal of Environmental Issues and Agriculture in Developing Countries,* 2(1): 121-130.

Aksoy, A., Osma, E. and Leblebici, Z. (2012). Spreading Pellitory (*Parietaria judaica* L.): A Possible Biomonitor of Heavy Metal Pollution. *Pakistan Journal of Botany*, 44: 123-127.

Alarape, A. (2002). Culture and Conservation in and around Old Oyo National Park. Ph.D. Thesis Submitted to the Department of Wildlife and Fisheries, University of Ibadan.

Annabi, A., Said, K. and Messaoudi, I. (2013). Cadmium: bioaccumulation, histopathology and detoxifying mechanisms in fish. *American Journal of Research Communication*, 1(4): 60-79.

Barbeş, L., Bărbulescu, A., Rădulescu, C., Stihi, C. and Chelarescu, E.D. (2014). Determination of heavy metals in leaves and bark of *Populus nigra* L. by atomic absorption spectrometry. *Romanian Reports in Physics,* 66(3): 877-886.

Beyersmann, D. and Hartwig, A. (2008). Carcinogenic metal compounds: recent insight into molecular and cellular mechanisms. *Arch. Toxicol*. 82: 493-512.

Divan, A.M., Oliveira, P.L.D., Perry, C.T., Atz, V.L., Azzarini-Rostirola, L.N. and Raya-Rodriguez, M.T. (2009). Using Wild Plant Species as Indicators for the Accumulation of Emissions from a Thermal Power Plant, Candiota, South Brazil. *Ecol. Indic*. 9: 1156–1162.

Dulama, I., Popescu, I.V., Stihi, C., Radulescu, C., Cimpoca, G.V., Toma, L.G., Stirbescu, R. and Nitescu, O. (2012). Studies on accumulation of heavy metals in Acacia leaf by EDXRF, *Romanian Reports in Physics,* 64: 1063–1071.

Emmanuel, A., Cobbina, S.J., Adomako, D., Duwiejuah, A.B. and Asare, W. (2014). Assessment of heavy metals concentration in soils around oil filling and service stations in the Tamale Metropolis, Ghana. *Afr. J. Environ. Sci. Tech.*, 8(4): 256-266.

Gune, A., Alpasalan, M. and Inal, A. (2004). Plant growth and fertilizer. Ankara University of Agriculture publication. No: 1539, Ankara, Turkey

Hlail, S.H. (2019). Heavy Metals Accumulation in Trees Grown in

Urban and Rural Areas. *Journal of Geoscience and Environment Protection*, 7: 69-75.

Huseyinova, R., Kutbay, H.G., Bilgin, A., Kılıc, D., Horuz, A. and Kirmanoğlu, C. (2009). Sulphur and Some Heavy Metals Content in Foliage of *Corylus avellana* and Some Road Side Native Plants in Ordu Province, Turkey. *Ekoloji*, 70: 10-16.

Idowu, E.T., Amaeze, N.K., Adie, P.I. and Otubanjo, O.A. (2014). Heavy metal bioaccumulation and biomarkers of oxidative stress in the wild African tiger frog, *Hoplobatrachus occipitalis. African Journal of Environmental Science and Technology,* 8.1: 6-15.

Jung, M.C. (2001). Heavy metal contamination of soils and waters in and around the Imcheon Au–Ag mine, Korea. *Applied Geochemistry,* 16: 1369-1375.

Kharkan, J., Sayadi, M.H. and Rezaei, M.R. (2019). Investigation of heavy metals accumulation in the soil and pine trees. *Environmental Health Engineering and Management Journal,* 6(1): 17-25.

Kulshreshtha, S., Mathur, N. and Bhatnagar, P. (2010). Bioremediation of Industrial Waste through Mushroom Cultivation. *Journal of Environmental Biology*, 31: 441-444.

Larison, J.R. (2001). Poisoned Paradise. Living Bird, Autumn issue, pp. 19–23.

Li, R., Tang, C., Cao, Y., Jiang, T. and Chen, J. (2018). The distribution and partitioning of trace metals (Pb, Cd, Cu, and Zn) and metalloid (As) in the Beijiang River. *Environ Monit Assess*; 190(7): 399. doi: 10.1007/s10661-018-6789-x.

Mirecki, N., Agic, R., Sunic, L., Milenkovic, L. and Ilic ZS. (2015). Transfer factor as indicator of heavy metals content in plants. *Fresen Environ Bull*., 24(11c): 4212-9.

Ojekunle, Z.O., Adeboje, M., Taiwo, A.G., Sangowusi, R.O., Taiwo, A.M. and Ojekunle, V.O. (2014). Tree Leaves as Bioindicator of Heavy Metal Pollution in Mechanic Village, Ogun State. *J. Appli. Sci. Environ. Manage*. 18(4): 639 – 644.

Oladeji, S.O., Agbelusi, E.A. and Trevelyan, R. (2012). Anthropogenic activities threatening the Management of the Ecotourism resources in Old Oyo National Park, Nigeria. *Ethiopian Journal of Environmental Studies and Management,* 5(1): 100-111.

Olowoyo, J.O., van Heerden, E., Fischer, J.L. and Baker, C. (2010). Trace metals in soil and leaves of *Jacaranda mimosifolia* in Tshwane area. South Africa, *Atmospheric Environment*, 44: 1826–1830.

Parzych, A. (2014). The heavy metal content of soil and shoots of *Vaccinium myrtillus* L. in the Slowinski National Park. *Leśne Prace Badawcze (Forest Research Papers*), 75(3): 217–224.

Rehman, I.U., Ishaq, M., Ali, L., Khan, S., Ahmad, I., Din, I.U. and Ullah, H. (2018). Enrichment, spatial distribution of potential ecological and human health risk assessment via toxic metals in soil and surface water ingestion in the vicinity of Sewakht mines, district Chitral, Northern Pakistan. *Ecotoxicol Environ Saf.* 154: 127-36. doi: 10.1016/j.ecoenv.2018.02.033.

Sawidis, T., Breuste, J., Mitrovic, M., Pavlovic, P. and Tsigaridas, K. (2011). Trees as Bioindicator of Heavy Metal Pollution in three European Cities. *Environmental Pollution,* 159: 3560–3570.

Senwo, Z.N. and Tazisong, I.A. (2004). Metal contents in soils of Alabama. *Common Soil Sci. Plant Anal.,* 35: 2837-2848.

Serbula, S.M., Miljkovic, D.D., Kovacevic, R.M. and Ilic, A.A. (2012). Assessment of Airborne Heavy Metal Pollution Using Plant Parts and Topsoil. *Ecotoxicol. Environ. Saf*. 76: 209–214.

Sethy, S. K. and Ghosh, S. (2013). Effects of heavy metals on germination of seed. *J. Nat. Sc. Biol. Med.* 4(2): 272–275.

Sinha, S., Sinam, G., Mishra, K., Mallick, S. (2010). Metal accumulation, growth, antioxidants, and oil yield of *Brassica juncea* L. exposed to different metals. *Exoticol. Environ. Saf.* 73(6): 1352-1361.

Stihi, C., Radulescu, C., Busuioc, G., Popescu, I.V., Gheboianu, A. and Ene, A. (2011). Studies on accumulation of heavy metals from substrate to edible wild mushrooms, *Romanian Journal of Physics*, 56(1–2): 257–264.

Tangahu, B.V., Abdullah, S.R.S., Basri, H., Idris, M., Anuar, N., Mukhlisin, M. (2011). A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. *International Journal of Chemical Engineering,* 21: 1- 31.

Vaikosen, E.N. and Alade, G.O. (2011) Evaluation of pharmacognostical parameters and heavy metals in some locally manufactured herbal drugs. *J. Chem. Pharm. Res.* 3(2): 88-97.

Vaikosen, E.N. and Alade, G.O. (2017). Determination of heavy metals in medicinal plants from the wild and cultivated garden in Wilberforce Island, Niger Delta region, Nigeria. *Journal of Pharmacy and Pharmacognosy Research*, 5(2): 129 – 143.

Yoon, J., Cao, X., Zhou, Q. and Ma, L.Q. (2006). Accumulation of Pb, Cu, and Zn in Native Plants Growing on a Contaminated Florida Site. *Sci. Total Environ*. 368: 456–464.

Yruela, I. (2013). Transition metals in plant photosynthesis. *Metallomics,* 5: 1090–1109.

Zolfaghari, G., Atash, Z.A.S. and Sazgar, A. (2018). Baseline heavy metals in plant species from some industrial and rural areas: Carcinogenic and non-carcinogenic risk assessment. *MethodsX* 5: 43-60.