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Full Length Research

AVIAN FEATHERS AS BIOINDICATOR OF HEAVY METAL POLLUTION IN URBAN DEGRADED WOODLAND

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ABSTRACT

This study examined the level of three potentially toxic heavy metals; Cadmium (Cd), Lead (Pb) and Nickel (Ni) in the tail feathers samples collected from 16 avian species in urban degraded woodland in Jos, Plateau State, Nigeria. The bird species were trapped with the use of mist-nets placed randomly across the different habitat types in the reserve to trap four feeding guilds passerines representing insectivores, granivores, omnivores and nectrivores. Before the feather samples from each species collected were analyzed using Atomic Adsorption Spectrophotometer (AAS), it was heated to clarity, purified and diluted appropriately using distilled water. The results obtained for the Cd, Pb and Ni were in the range 0.231-1.745, 0.125-2.838 and 0.001-1.221 mg/kg respectively. The average concentration of Pb was notably higher in the insectivores, granivores and omnivores, while Cd accumulated in tail feathers of the nectrivores. The significantly high level of these heavy metals noted in the bird feathers provides a useful indication that they can be used to monitor level of contamination in the environment.

Keywords: Avian Feathers, Heavy metals, Bioindicator, Degraded Woodland

INTRODUCTION

Woodlands are of specific importance because they provide critical resource for avian life activities such as breeding, reproduction, shelter, protection etc. Because this study was carried out in a degraded savanna woodland habitat type in an urban environment surrounded by human settlement, the vegetation is at immense risk of all kinds of anthropogenic activities such as refuse dump and wash off from neighbouring community may consequently result in pollution by heavy metals. The degradation of this habitat can have harmful impact on the avian community and other organisms inhabiting the ecosystem, including humans. Therefore, understanding how birds respond to living in a polluted environment is crucial. Heavy metals can have profound effects on the ecosystem, as their presence in high concentrations could result in unhealthy avian community as an indication of detrimental conditions for other wildlife and for humans living in that environment. The effects of these contaminants on avian immunity are of particular interest, as exposure to them may increase vulnerability to diseases through suppression of the immune system (Grasman, 2002). For example, organisms that are higher in the food chain are especially susceptible to bio-accumulative effects

(Winter and Streit, 1992; Ibemenuga, 2013). The natural environment has been gradually contaminated by various forms of pollution, mainly as a consequence of urbanization and the increasing use of fuels by households, vehicles and industry (Swaileh and Sansur, 2006). A serious group of pollutants are heavy metals that pose ample threat on all living organisms, with lead (Pb) being especially considered as highly toxic (Roux and Marra, 2007). Similarly, Cadmium (Cd) and Mercury (Hg) are heavy metals with unknown roles in living organisms and are known to be toxic even at low concentrations (Vashishat and Kler, 2014). The source of environmental exposure to Cd is traced to electronics, plastics, batteries, contaminated water, and when ingested causes irritation of lungs and gastrointestinal track, kidney damage, abnormality of the skeletal systems and cancer of the lungs and prostate (UNEP, 2016). Kasprzak *et al.* (2003) reported the global input of Nickel (Ni) to be approximately 150 metric tonnes from natural sources and 180 metric tonnes from anthropogenic sources in a year. Substantial quantity of the Ni from the environment when ingested find their way into the bone, lung, kidney, liver, brain and endocrine gland, also detected in breast milk, saliva, nails hair. The literature has brought evidences that some Ni compounds are carcinogens to human with the mechanism of Ni-induced carcinogenesis still unclear (Duda-Chodak and Blaszczyk, 2008). This study is aimed at examining the potentials of avian wings feathers as a bio-indicator of heavy metal exposure in the environment.

MATERIALS AND METHODS

Materials:

All reagents used were of analytical grade. These includes; concentrated HNO_3 (Merck, Germany), HCl (Sigma-Aldrich) and Acetone (Standard grade, Sigma-Aldrich). The glassware and plastic containers used were washed with liquid soap, rinsed with clean water then soaked in 10% HNO_3 for 24hrs before rinsing them with distilled water. All other reagents needed were prepared by diluting with distilled water.

Study area:

The Jos Wildlife Park is located within the Jos Plateau of Plateau State, North-central Nigeria (09°53'N and 08°58'E). Plateau State has a landmass of approximately 250 km by 150 km above 1000m in Nigeria. This forms a unique vegetation unit, within the Guineo-Congolian/Sudanian Regional Transition Zone. It Comprise of high plains with scattered rock outcrops ranging from 1120 to 1450 m above sea level and a number of granite hill ranges rising to 1,781 m. Jos-Plateau has an average rainfall of 1,411 mm per year. The Park was established in 1972, and is located to the south west of Jos, Plateau State, Nigeria, at Latitude 09°52' and Longitude 08°53' covering an area of 12 km^2. It is characterized by savanna woodlands, gallery forests with seasonal streams, gentle hills and rocky outcrops and some exotic plant species.

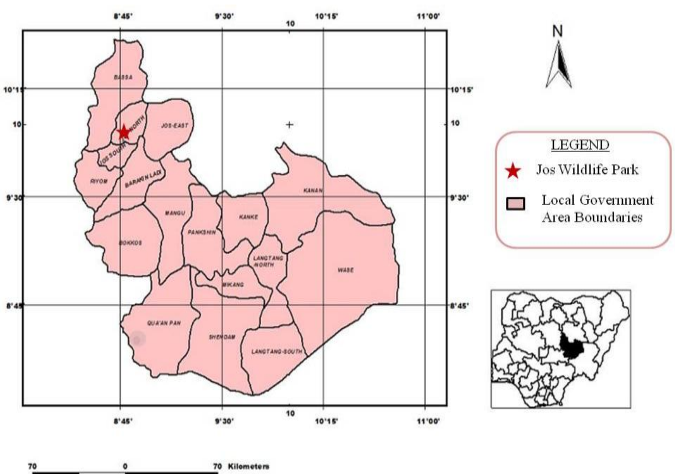

Figure 1. Map of Plateau State (with Map of Nigeria Inset) Showing the Approximate Location of the Study Area (Source: Ministry of Lands and Survey, Plateau State).

Sample collection

Five 9 m long mist-nets were placed randomly in the reserve to trap passerines, early in the morning between 6 am to 11 am. Mounted mist nets were sporadically checked for possible catch after every 20 minutes. This technique was carried out for a period of fourteen days during the dry season. The feathers collected were the tail feathers, from the birds captured which includes; insectivorous (birds that feed on insects), omnivorous (feed on insects, fruits, nectar, cereal or grains), granivorous (grain or cereal eating birds) and nectarivorous (feed on nectar of flowers or plants in general). Ringing and morphometric measurements were not taken so as to avoid unnecessary stress on captured birds. To further avoid unnecessary stress on captured birds, only two (2) feathers were collected from each bird then immediately released, making this a non-destructive bio-indicator for pollution monitoring.

Sample treatment and analysis

After collecting the tail feathers from the birds, it was washed by alternating distilled water and acetone three times to remove any external contaminants. The samples were then air-dried before regulating the drying in an oven at 105 °C for 2-3 h. Stainless steel scissors was used to cut the feathers into very tiny pieces to allow for easy digestion with the acid. The acid digestion mixture was prepared by mixing concentrated hydrochloric acid (HCl) and nitric acid (HNO_3) in a 3:1 ratio by volume (*aqua regia*). 0.5 g of the samples were completely digested then filtered and diluted with 50 mL of distilled water. It was then stored at 20 °C in sample bottles and finally analyzed using an Atomic Adsorption Spectrophotometer (PerkinElmer, Model 3000).

RESULTS AND DISCUSSION

In this study, the heavy metals have been detected in wing feathers of avian species from the degraded savanna woodland habitat (The Jos Wildlife Park) of Plateau State (Figure1). The heavy metals of interest in this work which includes; Nickel (Ni), Lead (Pb) and Cadmium (Cd) were detected in various samples of avian tail feathers shown in Table 1. These metals were considered in this research because they are widely reported to be potentially toxic on living tissues (Duruibe*et al*., 2007). The average concentrations range of the heavy metals in the avian feathers as indicated in Figure 2 are; 0.0006 – 1.2206 mg/kg, 0.2392-1.7465 mg/kg and 0.1254-1.8915 mg/kg for Ni, Cd and Pb respectively. Pb was the highest followed by Cd, which can be harmful to the birds even at low concentrations when ingested over a long period of time. This goes on to provide an indication as to how other environmental matrices could also be affected.

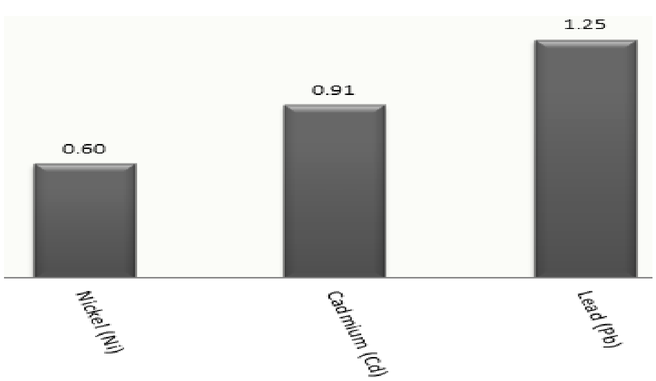

Figure 2: Average concentration (mg/kg) of heavy metals in 28 avian species wing feathers

Although Ni has the least concentration among the heavy metals detected, it is high enough to harm vulnerable bird species and other life forms in the environment (Table 1 and Figure 3). It is reported to affect the respiratory system of birds, causing asthma, as well as birth defects, vomiting, and damage to DNA (Van *et al*., 2001). This was not detected (ND) in a few of the feathers which might be attributed to either low sensitivity of the instrumentation used or the absence of these metals in the samples. In any case, the metals were detected in most of the samples with concentrations exceeding the maximum permissible limits (MPL) of 0.67 mg/kg for Ni set by FOA/WHO (2001) in food (cereals) as indicated in Table 1. With this, the work recommends the need to investigate the sources of this metal in the degraded wood land with a view to proposing remediation measures that will eventually enhance the quality of the environment.

Table 1: Heavy metal concentrations (mg/Kg) detected in avian tail feathers of Avian species.

S/N	Common Name	Scientific name	Ni	Cd	Pb
1	African Pygmy Kingfisher	*Ceyx pictus*	0.57	0.56	0.74
2	Common Bulbul	*Pycnonotus barbatus*	0.86	0.48	0.64
3	Common Wattle Eye	*Platysteira cyanea*	0.57	0.79	0.44
4	Laughing dove	*Streptopelia senegalensis*	0.48	ND	1.69
5	Northern Black Flycatcher	*Melaenornis edolioides*	0.28	1.75	ND
6	Red Billed Fire Finch	*Lagonosticta senegala*	0.56	0.53	2.81
7	Speckled-fronted Weaver	*Sporopipes frontalis*	0.88	ND	2.41
8	Scarlet-chested Sunbird	*Chalcomitra senegalensis*	0.25	1.20	0.57
9	Variable Sunbird	*Cinnyris venustus*	0.88	1.15	0.45
10	Yellow-Fronted Tinker Bird	*Pogoniulus chrysoconus*	0.61	0.68	1.36
11	Northern Grey-headed Sparrow	*Passer griseus griseus*	0.63	1.32	1.16
12	Pied Flycatcher	*Ficedula hypoleuca*	0.85	0.86	2.23
13	Red-checked Cordon Blue	*Uraeginthus bengalus*	0.73	0.70	0.28
14	Snowy-Crowned Robin Chat	*Cossypha niveicapilla*	0.63	0.87	2.03
15	Pale Flycatcher	*Melaenoinis pallidus*	0.62	0.70	1.24
16	Viteline Masked Weaver	*Ploceus velatus*	0.20	1.48	1.11
FAO/WHO- Maximum Permissible Limits (MPL) in food (cereals)			0.67	0.20	0.30

From the concentration of the heavy metals based on the feeding guilds of the birds species from where the feathers were obtained, Ni has the lowest concentration in the entire samples but has the highest concentration for insectivores with average concentration of 0.66 mg/kg which is quite low when compared to a similar work reported for Cattle Egret (*Bubulcus ibis*) with 12.51 mg/kg detected in the faecal matter (Kler *et al.,* 2014). The concentrations detected gave a useful hint to the level of Ni within the study area which may serve as baseline reference data for further research.

Lead (Pb), with environmental exposure linked to emissions and waste from industries, vehicles, paint, burning, plastics papers, etc., is known to cause impairment of neurological development, suppression of haematological system and kidney failure in human (UNEP, 2016). It accumulates more in all the feeding guilds, except for the nectarivorous species, which is the lowest. The insectivorous species have the highest concentration of Pb throughout the samples which implies that the insectivorous species feeds on insects from environmental sources where Pb pollution is likely to be high. The positive part of this is that the concentration of Pb detected in all samples analyzed in this work (Table 1)shows no sign of danger because it is below the 4 mg/kg adverse effect thresh hold limit for Pb in birds (Tsipora *et al.,* 2008). An earlier study observed that Pb levels of 4 mg/kg in bird feathers are associated with negative effects such as delayed parental and siblings recognition, impaired thermoregulation, locomotion, depth perception, abnormal feeding behaviour and lowered nestling survival (Burger and Gochfield, 2000). Pb and Cd have no documented positive role in most living organisms, it is rather associated with breeding failure, decreased body weight and reproduction impairment in some egret and heron species (Burger, 1993; Hashmi *et al*., 2013).

Cd is listed in the "most dangerous trace element category" and is present in both the environment and food with long persistence and high toxicity. It had an average concentration of 0.95 mg/kg in all the feeding guilds (Figure 3). This indicates how high the level of Cd contamination across the feeding guilds was when compared to the threshold limits of 0.2 mg/kg for a potential threat in avian population (Burgar and Gochfeld, 2000) and reported work of 0.22, 0.32 and 0.11 mg/kg detected in feather samples of accipitridae, falconidae and strigidae species respectively (Nighat *et al.,* 2013).

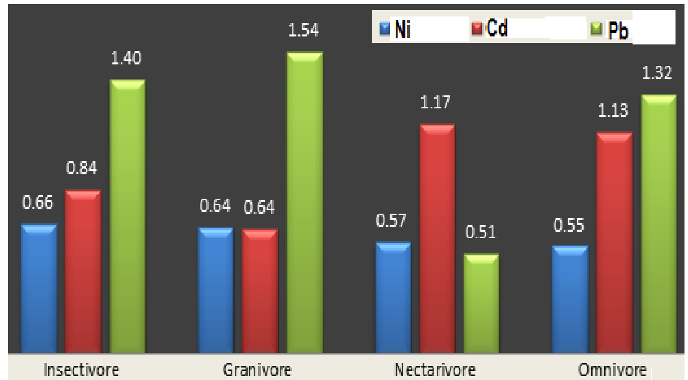

Figure 3: Average concentration (mg/kg) across four avian feeding guilds.

This goes on to provide an indication on the extent of involvement of the avian populations with emissions and releases from man-made activities such as erosion of surface deposits of minerals containing Cd, ores purifications from smelters/mines and commercial products such batteries, paints, coatings on metals devices and plasticizers (Qadir *et al.,* 2008; Malik *et al.,* 2010) around the study areas covered by the bird species. High concentration of Cd detected will make the avian species vulnerable apart from affecting other environmental elements, which necessitates the need to manage properly and control pollutant in the environment.

CONCLUSION

This finding shows the presence of heavy metals in tail feathers of all the sixteen (16) bird species, and will serve as a suitable indicator for the assessment of heavy metal contamination in avian species and the environment. Variations in heavy metal concentration among the species throw light to the fact that there are significant fluctuations in the level of contamination of the environment where these birds lives and feeds. The feeding guilds of these birds will provide a useful guide in determining the sources of the pollutants in the environment.

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CONFLICT OF INTEREST

None declared.

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