Bull. Environ. Contam. Toxicol. (2003) 70:792–799

DOI: 10.1007/s00128-003-0052-y

Bulletin of Environmental Contamination and Toxicology

Trace Metals in the Contour Feathers of Marabou Stork (*Leptoptilos crumeniferus*) from Kampala City and Its Surrounding Areas

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Received: 13 December 2001/Accepted: 7 December 2002

It has been known that human activities can markedly change the concentration of certain heavy metals in local environments. This contamination may be widespread and often has deleterious effects on the health of local population. Increasing exposure of man and his environment to toxic concentrations of heavy metals has produced a requirement for simple monitoring systems. Using bioindicators for pollution studies is therefore, an attractive and in some respects an essential aspect of long term effects of heavy metal concentration. In a survey of the heavy metal contaminations in Kampala, (Nyangababo 1987) it was suggested that the accumulation of heavy metals in linchens could be used to provide a reasonably accurate estimation of Cd, Pb, Fe and Ni concentration in rural, suburban and urban areas of Kampala. Considerable information has been published on the concentrations of heavy metals in birds from a wide range of ecosystems. For example Grananiello et al (2001) reported the concentrations of Zn, Cd, Pb and Cu in liver and kidney of sparrows. Thomson (2001) has indicated that migratory bird species potentially afford the opportunity to investigate heavy metal exposure without the need to sample tissues. The *L. Crumeniferus* is common around human habitations, garbage dumps, and abattoirs in Uganda, and since such environments are likely to contain higher concentrations of heavy metals a special survey of metals was carried out in these birds. The food of the Marabou is almost anything organic. According to Brown et al (1982), it will feed on virtually any animal matter from termites to a dead elephant. Their diet of wild carrion has been largely replaced in many areas by man-made carrion from garbage, fish scraps, and abattoir. Another entry of heavy metals into Marabous is via respiration of air contaminated by emissions from local sources and metals can diffuse through the exposed parts of the body. Ecological niche of *L. Crumeniferus* is characterized by interaction with anthropogenic environment and garbage.

Marabou can hence be used for estimation of environmental contamination by heavy metals. In order to use Marabou in the environmental survey, it would be ideal if very little physiological interference existed in the parts used and that fixed proportions of chemical elements ingested, inhaled or otherwise absorbed by the Marabou body were deposited and retained by the body parts. The use of Marabou feathers as bioindicators meets these requirements. Some metals that concentrate in the feathers such as cadmium, lead, copper, iron, manganese,

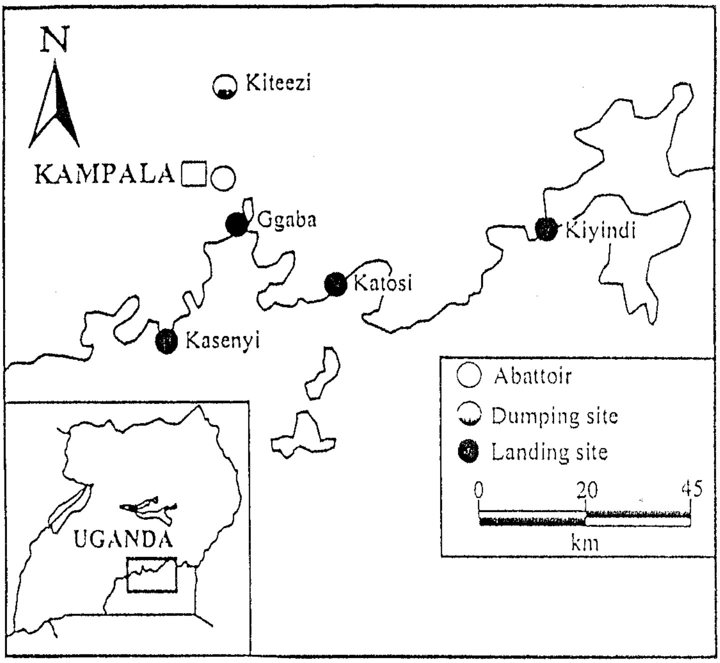

Figure 1. Sampling sites.

chromium and cobalt, are known to be toxic and their environmental concentration may be elevated as a result of the industry, traffic and poor disposal of domestic wastes. The rapidly changing environment and the feeding attendant exposure of the Marabous to new things may significantly change the general behaviour and dietary habits that may affect the trace metal concentration in the feathers. Marabous are an exceptionally suitable bioindicator of heavy metal contamination since they are long lived, up to 30 years and thus may accumulate metals over a long time (Pomeroy 1975b). The purpose of this paper is to report on a survey of the distribution of Zn, Cd, Pb, Cu, Fe, Mn, Cr, and Co in feathers from widely divergent areas and to evaluate the relationship between concentrations of these elements in Marabou feathers from various sites of different contamination status. This survey covered selected heavy metals as these are associated with vehicular traffic, industries and with the disposed garbage which could both be significant sources of pollution within the central region of Uganda.

MATERIALS AND METHODS

Three study areas were chosen on the basis of industries, traffic densities, the abattoir (urban), garbage dump (semi-rural), and fish landing (rural) centres. The abattoir, garbage dump and fish landing centers (Figure 1 and Table 1) were selected for study and these areas had average daily traffic densities of 22,000, 12,000 and 3,000 vehicles per 24 hours respectively. A total of 12 birds from urban area, 12 from semi-rural areas and 13 from rural area were sampled. The contour feathers were preferred because they are on the surface hence exposed to

Table 1. Areas investigated.

Area sampled	District	Possible sources of heavy metals		
		Garbage Dump	Industry	Traffic Density
Katosi	Mukono	Light	No	Low
Kasenyi	Wakiso	Light	No	Low
Katebo	Mpigi	Light	No	Low
Kiyindi	Mukono	Light	No	Low
Kiteezi	Mpigi	Heavy	No	Medium
PortBell Road	Kampala	Light	Yes	High
Ggaba	Kampala	Light	No	Medium

the environment and were easily accessible. Contour feathers were sampled from the birds in all areas by using meat or fish pieces as baits. Once the bird was in reach, it was caught and carefully handled to avoid the partially open bill. Then six feathers were plucked off, placed in labeled polyethene bags and returned to the laboratory with minimum contamination. In the laboratory, the feather samples were washed thoroughly with 2M NH4-EDTA solution , rinsed at least five times with double distilled water and then oven dried at 40°C for 24 hours. The dry feathers were then placed in a dissicator for 2 hours to equilibrate with ambient room temperature (ca 25°C). This was to avoid re-absorption of water from the atmosphere (Thompson 2001). The washed dried feathers were trimmed of barbs and these were used in the analytical procedure.

Briefly the barb sample portions (0.50g) were wet ashed using a mixture of 6.0 ml fuming nitric acid (90%) and 3.0ml perchloric acid (70%) in Uniseal digestion bomb. The digestion vessel with its contents was placed in an oven at 140°C for 3 hours and then cooled to ambient temperature. In this procedure, organic matter in the samples is destroyed by nitric acid and perchloric acid. Thus a relatively concentrated solution is provided having little matrix interference for atomic absorption analysis. The digest solutions were each transferred to a 50ml volumetric flask and the volumes adjusted to the mark and stored in polystyrene containers. Blanks of nitric and perchloric acids were taken through the same procedure. All standards were formulated to contain 2.0% nitric acid 1.0% perchloric acid (70%) per 50 ml because this is the prototypic matrix for the unknown samples. Some samples were spiked in the bomb before the digestion, to obtain recovery values and to check such factors as loses by volatalization, adsorption on the walls of the teflon container, or transference errors as well as unsuspected interferences. Manganese, cobalt, copper, zinc, cadmium, chromium and lead were analyzed by direct aspiration of the sample solution into atomic absorption spectrophotometer. In the analysis of iron in all samples, a dilution factor of 20 was necessary. The analysis was then accomplished using a Perkin-Elmer model 2380 spectrophotomer, with detection limits and recoveries found to fall with 0.01-0.1 $\mu g\ ml^{-1}$ and 93-103% respectively. The data obtained for these three different types of sites are listed in table 2 to 4 (all data are quoted in $\mu g\ g^{-1}$ of dry weight sample).

Table 2. Heavy metal levels for rural feather sites.

Bird number	Concentration of heavy metals, μg g^{-1}							
	Zn	Cd	Pb	Cu	Fe	Mn	Cr	Co
1	56.3	1.30	11	24.1	27	16.1	8.0	0.40
2	61.2	1.33	12	27.2	51	18.2	7.0	0.38
3	54.0	1.79	15	20.1	36	16.5	8.1	0.45
4	55.6	1.21	14	21.4	28	17.4	9.1	0.39
5	71.0	1.17	10	24.5	27	15.4	6.8	0.46
6	60.5	1.36	11	19.8	18	13.3	7.7	0.14
7	54.4	1.41	13	20.3	37	15.6	1.4	0.38
8	56.7	1.78	12	28.7	45	16.6	8.0	0.43
9	40.4	1.0	13	21.6	31	16.2	1.4	0.41
10	70.1	2.06	10	20.8	60	15.7	1.5	0.56
11	63.5	2.04	18	24.7	34	16.1	7.9	0.50
12	54.8	2.02	14	24.4	57	15.8	8.0	0.48
Average	58.2	1.55	12.8	23.1	37.6	16.1	6.2	0.44

Table 3. Heavy metal levels for semi-rural feather sites.

Bird Number	Concentration of heavy metals, μg g^{-1}							
	Zn	Cd	Pb	Cu	Fe	Mn	Cr	Co
13	103	2.8	21.1	55	94	50	14.4	11
14	110	1.5	22.5	66	104	48	14.8	11
15	98	3.6	20.8	63	97	42	14.5	19
16	10	1.7	20.9	58	90	51	15.0	10
17	112	2.1	21.3	58	98	54	14.1	12
18	115	2.4	23.5	60	95	48	14.7	11
19	155	1.9	26.6	123	106	42	18.2	39
20	110	1.8	24.4	111	100	75	17.0	38
21	134	2.6	25.1	123	98	64	17.7	29
22	142	2.0	24.7	106	112	78	16.9	31
23	129	1.9	24.9	117	97	65	17.0	31
24	134	1.8	25.0	105	97	60	17.1	28
Average	121	2.2	23.4	87.1	99.0	53.9	16.0	23

RESULTS AND DISCUSSION

For the experimental procedure, which was adopted, it was necessary to determine the degree to which the species of interest could be recovered from the digestion mixture. Recoveries were checked for all elements tested and showed good spike recovery data. This indicates the efficiency of the recovery for the

The average concentrations in feathers collected at sampling site 32 were about 8 times higher than the average concentrations in feathers collected from site 9. The

Table 4. Heavy metal levels for urban feather sites.

Bird number	Concentration of heavy metals, µg g^{-1}							
	Zn	Cd	Pb	Cu	Fe	Mn	Cr	Co
25	290	30	152	146	131	86	64	79
26	220	29	161	143	140	80	62	77
27	270	22	158	151	138	89	64	80
28	304	24	153	147	132	83	60	82
29	287	20	157	149	144	85	59	77
30	257	18	164	142	132	87	57	74
31	389	19	160	152	137	82	61	70
32	304	21	152	155	142	81	63	81
33	297	20	146	150	137	88	58	79
34	268	22	162	149	134	83	59	82
35	291	22	155	146	139	87	60	84
36	294	19	153	147	139	87	64	78
37	288	17	150	152	143	80	58	81
Average	281	21.8	156	148	138	85	61	79

areas investigated (Table 1 Figure 1) were selected to provide a range of human influence. Kiteezi, Portbell road, and Gaba are subjected to considerable human influences; all receive traffic emissions and in Kiteezi, there is a large garbage disposal site on which Marabous make their living. The study sites in the rural area are outside the influence of heavy traffic and industry. As anticipated from the start, the heavy metal figures of concentration decline rapidly from urban area through semi-rural to rural area. This decline pattern of heavy metal levels clearly point to common sources of these pollutants road traffic, industry and garbage. The source of Pb, for instance, is well documented, it being added to petrol at a rate of 0.45 g/liter as an anti-knock agent (Muskett et al 1980). Cadmium has been reported as a constituent of car tyres (David et al 1975) and others are added to fuel oils as a lubricant (Lagerwerff, 1967). The garbage contaminated with heavy metals is also a considerable source of these pollutants.Reference to Table 5 it can be seen that the heavy metal concentration figures exhibit a trend of increasing levels in the following order: Rural < Semi-rural < urban and within each class of locality,

Rural : Zn>Fe>Cu>Mn>Pb>Cr>Cd>Co
Semi rural : Zn>Fe>Mn>Pb>Cr>Cu>Cd
Urban : Zn>Pb>Cu>Fe>Mn>Co>Cr>Cd

The mean values (arithmetic) are given for the rural sampling sites, Table 2 for semi-rural sampling sites Table 3, and Table 4 for the Urban sites. The tables are arranged according to rural, semi-rural and urban total metal content. The order reveals the complicated character of accumulation and distribution of heavy metals in feathers of Marabou stork. In all the study areas (rural, semi-rural, urban) examined, Zn predominated. This was followed by Fe in the case of rural and Semi-rural areas and Pb in the case of urban area. The predominance and distribution of metals in feathers are not well understood. Some researchers (Nyangababo and Ichikuni 1986) have stipulated that this may be due to different

Table 5. Comparison of mean heavy metal levels different types of site (feathers).

Metal	Site type			Pearson comparison-levels of significance		
	Rural	Semi-rural	Urban	Rural/ semi rural	Rural/ urban	Semi-rural/ Urban
Zn x	60.2	12.40	287			
δ	0.78	0.22	0.32			
n	17	16	21	-0.06	-32	0.16
Cd x	1.58	12.10	24.30			
δ	0.24	0.18	0.22			
n	22	16	18	-0.07	-0.19	0.08
Pb x	14.50	22.15	158			
δ	0.23		0.25			
n	16		18	0.16	-0.28	0.01
Fe x	24.70	87.60	152			
δ	0.20	0.17	0.12			
n	20	22	16	0.21	0.08	0.50
Cu x	44.40	112.50	138			
δ	0.16	0.15	0.15			
n	15	18	21	-0.08	0.03	0.27
Mn x	15.85	54.70	84		-0.48	-0.14
δ	0.35	0.39	0.17			
n	19	24	18	0.07		
Cr x	7.84	15.14	63			
δ	0.28	0.20	0.13			
n	17	16	15	-0.62*	0.77**	-0.08
Co x	0.46	18.50	82	0.33	0.53	0.01
δ	0.28	0.27	0.16			
n	22	16	22			

$P < 0.01$**
$P < 0.05$ *

metal elements contained in different airborne particulates with different sizes and composition and therefore with different deposition characteristics. A similar distribution pattern has been observed in other studied animal species (Mathieson et al, 1995; Petuchov et al, 1983).

The differences in heavy metal distribution in feather were not investigated but judging by publications of other authors (Petuchov et al 1983), these differences could be due to biochemical and physiological properties of the heavy metals.
The Person's correlations were found among the metals in Marabou feathers of rural, semi-rural and urban areas (Table 5). In general these correlation coefficients are low. The weak relationship is thought to be due to difference in particle size of these elements; different source of emission of these elements and because of having no actual chemical association of these elements. In Table 6, a more comprehensive comparison is made on the four types of birds as a summary of this work. At first glance, the data show that there are distinct differences between

Table 6. Concentration levels (μ g g-1) of some metal elements found in biological materials of different species of birds.

Metal element	Type of bird	Biological material	Environment	Metal level	Ref
Zn	Sparrow	Liver	Rural Urban	154 205	Gragnaniello et (2001
		Kidney	Rural Urban	133 164	
Cd	Sparrow	Liver	Rural Urban	0.48 1.31	Gragnaniello et (2001
		Kidney	Rural Urban	3.92 10.8	
Pb	Sparrow	Liver	Rural Urban	2.71 42.0	
		Kidney	Rural Urban	92.7 74.9	
Hg	Bar-tailed Godwit	Feather	-	0.35-4.80	
Zn	Marbon Stock	Feather	Rural Urban	58.2 281	This work
Cd	Marabon Stork	Feather	Rural Urban	1.55 21.8	This work
Pb	Marabon Stork	Feather	Rural Urban	12.8 156	This work
Cu	Marabon Stork	Feather	Rural Urban	23.1 148	This work

them. Gragnaniello et al (2001) compared the data obtained in their study with the few data reported (Sawaicka-Kapusta et al, 1986) and warned that when comparing sedentary species with nesting and wintering ones, insectivores with granivores, and young with adult, caution must be exercised. The survey has shown that there are enhanced levels of heavy metals Zn, Cd, Pb, Cu, Fe, Mn Cr, and Co in the feathers of Marabou stor,mmk of Kampala city and the neighbouring areas. The evidence supports the hypothesis that these enhanced levels are due mainly to aerial contamination and waste dumps.

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