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Assessment of heavy metals concentration in water, soil sediment and biological tissues of the lesser flamingos in four eastern rift valley lakes

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The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic at low concentrations. This study was conducted in four eastern Rift Valley lakes which included Lakes Oloidien, Crater, Elementaita and Nakuru, to determine the presence and levels of lead, arsenic, cadmium and chromium concentration in water, soil sediments and biological tissues of the Lesser Flamingos (Phoeniconaias minor) and compare with the set standards. As these lakes catchments fall directly within a combination of agricultural and industrial regions, the run-offs and the resulting effluents will make the waters highly prone to chemical contamination. The methodology involved collection of water samples (n=40), sediments samples (n=51) and the Lesser Flamingos (live n= 6; dead n=2) for qualitative and quantitative toxicological analysis. The analysis was done using Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS) model-Specter AA-10 Varian. Lead and arsenic were found to be in high concentration in soil sediments in all four lakes while chromium and cadmium were in low concentration. Soil sediments analysed from the inflow of the Nakuru sewerage drain (1754±22.81 ppb) and rivers to Lake Nakuru (1129±107 ppb) had the highest mean ± SD lead concentration. Arsenic, cadmium, chromium and lead were also observed in bird tissues. Metals in the Lesser Flamingo tissues were below the toxicological levels that are reported in literature to be harmful, except lead which was above the level recommended by the US Environmental Protection Agency.

Key words: Heavy metals, lesser flamingo, environment.

INTRODUCTION

Kenya is located in Africa and lies along the equator. It has a number of lakes located in the Rift Valley region which are known to host a vast number of migratory birds during their stop over. Some of these lakes include

Elementaita, Nakuru, Oloidien and Crater all located in Nakuru County, Kenya. They host a significant number of water birds species which include Lesser Flamingo (Phoeniconaias minor).The Lesser Flamingo contributes significantly to ecotourism which, in turn, contributes substantially to the Kenya's Gross domestic Product (GDP). Tourism is regarded as the second largest sector of country's economy and is estimated at contributing about 10% of the GDP. It is Kenya's leading foreign exchange earner, generating around 654 million US dollars in 2007 (Udoto, 2012). Recently there have been massive die-offs of Lesser Flamingo population; the most recent occurred towards the end of 2013. These mass deaths have been attributed to a number of diverse causes that either relate to the availability of food for flamingos or having a negative impact directly on the flamingos. As these lakes catchments fall directly within a combination of agricultural and industrial regions, the run-offs and the resulting effluents makes the waters highly prone to chemical contamination. It is possible that the Lesser Flamingos (*Phoeniconaias minor*) can take in the metals as they feed in the lakes or drink water from the nearby rivers. It is therefore important to regularly monitor the levels of the heavy metals in the Kenyan Eastern Rift Valley lakes in order to safeguard the flamingos. However, the potential impacts of the agricultural and industrial pollutants on the health of birds in the lakes are not well documented. The lifespan of Lesser Flamingo is over 50 years and their bodies can accumulate heavy metals to a harmful level. It is therefore recommended that close monitoring on the levels of these metals should be done regularly in order to safeguard the birds' lives.

MATERIALS AND METHODS

Study area

The study was conducted in Nakuru County, northwest of the capital city Nairobi, Kenya (Figure 1), during the month of December, 2013. The samples were collected from Lakes Oloidien, Nakuru, Elementaita, Crater, rivers and sewage discharging to Lake Nakuru. The four lakes under study host a significant number of the Lesser Flamingos during their stop over.

Sample collection and laboratory analysis

Water sampling sites were chosen purposively depending on the discharge points into the lake and six further sites were done randomly at least 100 metres from discharge points. Water samples were collected in sterilised polyethylene plastic containers. About 300 mg of sediments was scooped from the lake and river bed and also packed separately in labelled sterile polyethylene plastic containers. Water sampling sites were chosen purposively depending on the discharge points into the lake and six further sites were done randomly at least 100 metres from discharge points. Birds sampling was done opportunistically. The birds were trapped from the lakes by making use of a noose carpet or those that were too weak were caught by hand. The noose carpet is a 1m x 1m grid covered in wire mesh onto which nylon nooses are fixed. The noose carpet was submerged in shallow water in the region the birds were feeding. The birds were released from the nooses and placed inside a cloth bag with suitable aeration. Birds that were found to be in very poor physical condition were euthanized by use of sodium thiopental, by injection directly into the heart. The birds were carried away from the lake shore where they were dissected on a disinfected plastic table and the tissues removed aseptically.

Five grams (5 g) of wet tissue from the flamingo organs/ tissue (liver, heart, kidney, lungs, bone and muscle) was individually digested with 20ml of concentrated nitric acid and complete digestion done by adding hydrogen peroxide followed by filtration. Two and a half grams of dry sediment was digested with 20ml concentrated nitric acid. Fifty millilitres of the water sample was digested with 5 ml of concentrated nitric acid and topped up with distilled water.Aliquots of filtrate was analyzed by Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS) model-Specter AA-10 Varian.

Data obtained were analyzed using "Instat +" computer statistical package. Descriptive statistics; the mean, standard deviation, and two-way ANOVA was used to determined the significant difference ($p<0.05$) of statistical means of heavy metals in Lesser Flamingos, water and soil sediments samples.

RESULTS

The mean concentration of lead, chromium, cadmium and arsenic collected from water of the four lakes, rivers and sewage discharge in Nakuru County, Kenya are shown in Table 1. Lake Elementaita had the highest mean concentration of lead (14.24 ± 8.86 ppb) followed by Lake Nakuru (12 ± 14.24 ppb). There were no detectable levels of lead from Lake Oloidien and the Crater Lake. Rivers discharging to Lake Nakuru and sewage drain had the least lead concentrations. Chromium mean concentration from the highest to the lowest was; Lake Nakuru (5.25 ± 5.67 ppb) followed by Lake Elementaita (3.42 ± 4.16 ppb) and Crater Lake (0.21 ± 0.26 ppb). The concentration of arsenic was highest in Lake Oloidien with a mean of 11.37 ± 11.21 ppb and it was the only metal detected in Lake Oloidien water. Lake Nakuru had the lowest mean concentration of arsenic (2.34 ± 3.1 ppb). In general, it was observed that Lake Nakuru and Lake Elementaita had high concentrations of the four heavy metals.

All the metals under study were found in soil sediments of the four lakes except cadmium which was not

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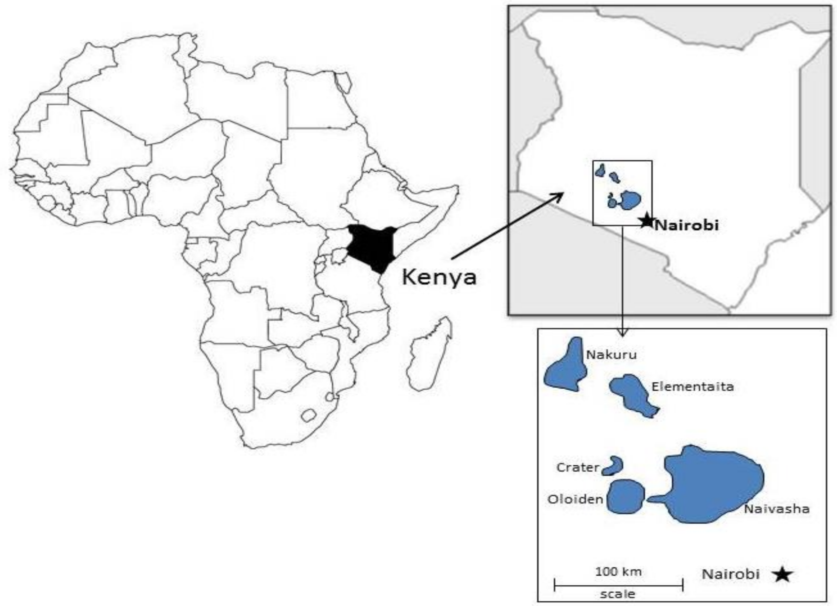

Figure 1. Location of Kenya in Africa and lakes Nakuru, Elementaita, Crater and Oloidien in Nakuru County, Kenya.

Table 1. Mean metal concentrations ± SD (ppb) in water and sediment from the four Rift Valley lakes in Nakuru County, Kenya.

Locality	metals in water					metals in sediment				
	N	Pb	Ca	Cr	As	N	Pb	Ca	Cr	As
Crater	4	ND	ND	0.21 ± 0.26	4.35 ± 3.81	6	212.5 ± 44.29	36.2 ± 39.7	136.4 ± 48.4	409.3 ± 243.9
Elementaita	8	14.24± 8.86	ND	3.42 ± 4.16	9.68 ± 3.36	12	567.3 ± 46.12	64.8 ± 40.47	64.85 ± 18.73	512 ± 66.96
Nakuru	12	12 ± 14.24	ND	5.25 ± 5.67	2.34 ± 3.1	15	430.1 ± 122.1	76.69 ± 48.31	57.85 ± 17.29	354.4 ± 294.9
Oloidien	4	ND	ND	ND	11.37 ± 11.21	6	273.7 ± 67.12	0.4673 ± 0.52	50.27 ± 3.98	265.5 ± 290.8
River Nakuru	8	1.2 ± 2.23	ND	18.55 ± 19.92	0.77 ± 1.36	9	1129 ± 107	82.88 ± 17.83	99.72 ± 24.38	198.4 ± 49.87
Sewage Nakuru	4	1.52 ± 1.76	ND	4.47 ± 0.96	0.50 ± 0.44	3	1754 ± 22.81	ND	91.3 ± 6.26	ND
Benchmark levels*		8.1	9.3	50	36		21000	1000	8100	6000

*Benchmark levels for water concentrations (µg/L) for Pb from US EPA (1999) and for Ca, Cr and As from US EPA (1987). For sediment benchmark levels (µg/kg): Pb and Cd from MacDonald (1993), Cr from Long et al. (1995), As from Persaud et al. (1993). ND not detected.

Table 2. Mean metal concentrations ±SD (ppb) in birds tissue samples collected from the four Rift Valley lakes in Nakuru County, Kenya.

	Muscle	bone	brain	heart	Kidney	liver	lungs
Lead * 25							
Crater Lake(n=2)	32±45.25	111.5±17.68	0.21±0.29	47±18.38	70.5±14.85	21.5±4.95	20.5±4.95
Oloidien(n=5)	4.94±9.61	162±31.14	2.94±1.6	7.17±12.28	7.74±13.13	17.1±9.15	13.6±8.08
Elementaita(n=1)	ND	100	ND	9	17	4.9	2.2
Nakuru	None	none	none	none	None	none	none
Cumulative mean	11.09±22.69	141.6±37.45	1.89±1.89	17.36±21.67	24.59±30.79	16.68±8.83	13.9±8.54
Cadmium *1450							
Crater (n=2)	ND	ND	ND	ND	62.7±1.27	27.3±15.98	ND
Oloidien(n=5)	ND	ND	ND	ND	37.46±47.32	64.96±28.72	ND
Elementaita(n=1)	ND	ND	ND	ND	71.8	78.9	ND
Nakuru	None	none	none	none	None	none	none
Cumulative mean	ND	ND	ND	ND	48.06±38.76	57.29±29.56	ND
Chromium*1000							
Crater (n=2)	0.82±0.97	10.65±8.98	10±8.49	10.16±8.29	27.4±4.38	8.08±4	7.3±3.11
Oloidien(n=5)	1.29 ±1.82	10.94±6.38	10.52±6.55	8.26±3.52	255.2±329	21.96±19.35	7.76±3.53
Elementaita(n=1)	1.1	11.9	12.6	9.3	23.7	21	5.94
Nakuru	None	none	none	none	None	none	none
Cumulative mean	1.15±1.44	10.99±5.91	10.65±5.96	8.87±4.2	169.3±276.1	18.37±16.02	7.42±2.98
Arsenic*2460							
Crater (n=2)	11.37±4.15	7.65±4.88	5.35±0.92	13.3±5.24	19.45±8.27	11.18±3.29	8.14±1.29
Oloidien(n=5)	9.65±2.75	7.23±1.23	5.17±2.97	10.02±1.99	17.67±2.78	19.18±6.29	14.7±2.90
Elementaita(n=1)	10.6	3.07	5.4	6.77	25.7	17.1	9.84
Nakuru	None	none	none	none	None	none	None
Cumulative mean	10.2±2.72	6.82±2.57	5.24±2.27	10.43±3.25	19.12±4.68	16.92±6.1	12.45±3.87

Key: ND – not detected, none- no sample collected. ***Benchmarkslevels for birds concentration µg/kg BW-day for Pb from Kendall and Scanlon (1982),Ca from White and Finley,(1978),Cr from Heseltine et al. (1985) and As from U.S. Fish and Wildlife Service,(1969).

detectable in sewage drain soil sediment in Lake Nakuru. Heart, lungs, brain, liver, kidney, bone and muscle tissues were sampled. All the metals were detected in tissues of Lesser Flamingo except cadmium which was detected only in the liver and kidney (Table 2)

DISCUSSION

Lake Oloidien had the highest levels of arsenic which could be as a result of wash off from the surrounding flower farms. It is also possible that the arsenic leaches from the volcanic soils to the water hence the high concentration. In general, it was observed that Lake Nakuru and Lake Elementaita had the highest levels of the four heavy metals. This suggests that the rivers flowing in and the sewage drain to Lake Nakuru contribute to the levels of these metals apart from those leaching naturally from the ground. Analysis of variance (ANOVA) for metal in water revealed that the mean concentration of all the metals varied significantly ($p<0.05$) with Lake Nakuru levels being significantly higher. There is much inflow from the rivers which flood the lake and this could be the possible cause of the higher variation in Lake Nakuru.

The levels of cadmium, chromium and arsenic in the four lakes under study were below the benchmark levels recommended by the US Environmental Protection Agency (Table 1) except for lead levels in Lake Elementaita (14.24 ± 8.86 ppb) and Lake Nakuru (12 ± 14.24 ppb).

Lead, cadmium, chromium and arsenic were found in soil sediments of the four lakes; however cadmium and arsenic were not detected in sewage drain to Lake Nakuru. Sewage drain and the rivers draining to Lake Nakuru had a high mean concentration of lead (1754

±22.81 ppb) and (1129 ± 107 ppb) respectively and they were the possible causes of lead detected in Lake Nakuru. Comparing the present average levels of chromium (57.85ppb) and lead (430.1ppb) detected in soil sediments in Lake Nakuru with the previous findings by Nelson et al. (1998), (average levels of chromium 67 ppb and lead 22 ppb) chromium current levels are slightly lower while lead levels for the current study are very high. The present higher average levels of lead in Lake Nakuru compared to the other lakes can be attributed to accumulation, since the lake has no out-flow but has many inflows. Another contributing factor could be due to increase in the number of industries and population which in turn increases effluent and sewage discharge respectively. The levels of all the metals under study were below the benchmark levels of the marine soil sediments (Table 1).

Heart, lungs, brain, liver, kidney, bone and muscle tissues were sampled. All the metals were detected in tissues of Lesser Flamingo except cadmium which was detected only in the liver and kidney (Table 2) which agrees with studies done by Schafer, *et al*.,(1999) that the liver and kidney accumulates cadmium. The highest mean concentration of cadmium was 58 µg/kg which is almost 40 times higher than what was found out by Kairu, 1996 (1.3 µg/kg) and Koeman et al., 1972 (1.35 µg/kg). This can be attributed to bioaccumulation since the Lesser Flamingo can live for about 50 years. The Lesser Flamingos are filter feeders,they feed through stiring up the lake sediments then filtering out their food and in the process can take in the metals in the lake sediments.There is also possibility that the Lesser Flamingos consumes the heavy metals from the rivers that are discharging to the lakes.

Conclusion

Metals were detected in water and soil sediments but they were below the benchmark levels except lead in Lake Elementaita and Lake Nakuru waters. Levels of lead were above the recommended in the birds tissues.

Conflict of interests

The author has not declared any conflict of interests.

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