Bull Environ Contam Toxicol (2012) 89:1082–1086
DOI 10.1007/s00128-012-0798-1

Comparison of the Metal Concentrations in the Feathers of Three Bird Species from Southern Iran

Mohsen Norouzi · Borhan Mansouri · Amir Hossein Hamidian · Tahereh Ebrahimi · Fakher Kardoni

Received: 30 April 2012 / Accepted: 16 August 2012 / Published online: 30 August 2012

Abstract This study was conducted to determine the concentration of metals, namely cadmium, lead, cobalt and copper, in the feathers of chukar (*Alectoris chukar*), see–see partridge (*Ammoperdix griseogularis*) and rock dove (*Columba livia*) in order to: examine the species, gender and age related variations in trace metal accumulation, and identify any relationships between species. Bird samples were collected in February 2012 from the Hormod protected area, southern Iran and the concentration of metals were measured using a Shimadzu AA 660 flame atomic absorption spectrophotometer. The concentrations in all three species were copper > lead > cadmium > cobalt. The average cadmium concentrations were 2.0, 1.9, and 1.9 μg/g for *A. chukar*, *A. griseogularis*, and *C. livia*, respectively. The average lead concentrations were 8.0, 5.4, and 7.7 μg/g for *A. chukar*, *A. griseogularis*, and *C. livia*, respectively. The results showed that in all three species, the highest metal concentrations were observed in female/adult birds and the lowest concentrations were found in female/juvenile birds (except lead in *A. chukar* and copper in *C. livia*).

Keywords Hormod protected area · Chukar · Rock Dove · Cadmium · Lead

M. Norouzi (✉)
Young Researchers Club, Larestan Branch, Islamic Azad University, Lar, Iran
e-mail: mohsenepa2010@gmail.com; mohsennorouzi@yahoo.com

B. Mansouri (✉)
Young Researchers Club, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran
e-mail: borhanmansouri@yahoo.com

A. H. Hamidian
Department of Environment, Faculty of Natural Resources, University of Tehran, Karaj, Iran
e-mail: a.hamidian@ut.ac.ir

T. Ebrahimi
Department of Environment, Faculty of Natural Resources, University of Shahid Beheshti, Tehran, Iran

F. Kardoni
Young Researchers Club, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran

Protected areas play an important role in the preservation of biodiversity through the protection of endangered species and ecosystems. They also serve as reservoirs of plant and animal species that can repopulate the devastated ecosystems. Hormod protected area, with a surface area of about 151,284 hectares is located in Larestan city, Fars Province, south of Iran (26°40′ to 27°N and 55°21′ to 55°52′E). Protected areas such as Hormod play an important role in protection of plant and animal species. The dense vegetation in the Hormod protected area, with a high diversity of plant species provides diverse habitats for birds like chukar, pigeon, lark and plover. In this paper, the concentrations of cadmium, lead, cobalt and copper in the kidney, liver and pectoral muscle of three species of wild birds in Hormod protected area, namely chukar (*Alectoris chukar*), see–see partridge (*Ammoperdix griseogularis*) and rock dove (*Columba livia*) are reported. These species are permanent resident birds in Iran. Although these bird species are protected by the Iranian Department of Environment, they are consumed by the local people.

Birds have been extensively used in the past as bioindicators of metal contamination in the environment (Burger 1994; Kim and Koo 2007; Mansouri et al. 2011). They are situated high on the food chain, can yield information over a large area around each sampling site, not only on

bioavailability of contaminants but also on how, where, and when they are transferred within the food chain (Battaglia et al. 2005). Burger (1995) reported that birds can accumulate metals into their feathers, making feathers useful for biomonitoring of metals in the environment. Birds sequester metals in their feathers, where the proportion of the body burden is relatively constant for each metal (Barbieri et al. 2009). Although seabirds and shorebirds have been used in many studies, their characteristics of wandering and feeding over a large area make it difficult to determine where they have acquired the metals. Recently, some researchers explored the potential of monitoring metal pollution using wild species such as doves (e.g., *Columba livia*), pigeons (*Forma urbana*), and great tits (*Parus major*) (Janiga and Zemberyová 1998; Nam et al. 2004; Hoff Brait and Antoniosi Filho 2011). These species are ideal bioindicators because they are common and widely distributed and have fast metabolic rates. Hence, our study aimed to further investigate the concentrations of cadmium, lead, cobalt and copper in the feathers of chukar (*A. chukar*), see–see partridge (*A. griseogularis*) and rock dove (*C. livia*). The research was also to examine the species, gender and age-related variations in trace metal accumulation.

Materials and Methods

Bird samples were collected in February 2012 from the Hormod protected area. A total number of 45 bird samples of three bird species (15 of each species) were analyzed for cadmium, lead, cobalt and copper concentrations in their feathers. Breast feathers were selected because they are representatives of the plumage and are less influenced by the molt compared to flight feathers (Burger and Gochfeld 2000). The bird samples included chukar (*A. chukar*) (n = 15), see–see partridge (*A. griseogularis*) (n = 15), and rock dove (*C. livia*) (n = 15) with average weight (±SE) of 451 (±94), 268 (±91), and 367 (±115) g, respectively. The individuals were killed, weighed, stored in plastic bags, and kept at −20°C until dissection and chemical analysis. The feather samples were digested in a (2:1) nitric acid (HNO_3) and perchloric acid ($HClO_4$) solution (Merk, Germany). The feather tissues were then accurately weighed into 150-mL Erlenmeyer flasks, and 10 mL nitric acid (65 %) was added to each flask, and the samples were left overnight to be slowly digested (Mansouri et al. 2012); thereafter, 5 mL perchloric acid (70 %) was added to each sample. Digestion was continued on a hot plate (sand bath) at 200°C. After that, the digested samples were diluted by 25 mL deionized water. The concentrations of heavy metals were measured using a Shimadzu AA 680 flame atomic absorption spectrophotometer. The detection limits of metals were: cadmium (0.038 μg/g), lead (0.042 μg/g), cobalt (0.049 μg/g), and copper (0.038 μg/g). The mean recovery percentages of cadmium, lead, cobalt and copper were 98 %, 99 %, 103 %, and 97 %, respectively.

Statistical analyses were performed using the statistical package SPSS (version 16; SPSS, Chicago, IL). The concentrations of metals were compared in the feathers of chukar, see–see partridge, and rock dove species using two-way analysis of variance (ANOVA). We used a two-way ANOVA to study the metal concentrations and sex, age [sex × age] interactions. Data were log transformed to achieve normal distribution that satisfied the homogeneity of variance required by ANOVA. The concentrations of metals in feather tissues were expressed as microgram per gram dry weight (dw). Values are given in means ± standard errors (SE).

Results and Discussion

The mean concentrations of cadmium and lead in the feathers of *A. chukar*, *A. griseogularis*, and *C. livia*, collected from Hormod protected area in south of Iran are presented in Tables 1, 2, 3 and 4. The average cadmium concentrations were 2.0, 1.9, and 1.9 μg/g for *A. chukar*, *A. griseogularis*, and *C. livia*, respectively. The average lead concentrations were 8.0, 5.4, and 7.7 μg/g for *A. chukar*, *A. griseogularis*, and *C. livia*, respectively. No significant difference was observed between the average concentrations of cadmium and lead in the feathers of these three species (one-way ANOVA, $p > 0.05$). Among these three species, the highest cadmium concentration was found in the feathers of female/adult birds and the lowest cadmium concentration was observed in the feathers of female/juvenile birds. The highest lead concentration was measured in female/adult birds and the lowest lead concentration was found in male/juvenile birds (except *A. chukar*). Overall, the concentrations of cadmium and lead in adult birds were higher than in juveniles. The concentrations of cadmium were higher in females than in males.

Cadmium and lead are very toxic and common in the environment. Elevated cadmium concentrations in the feathers were strongly correlated with reduced growth rates of bone (Spahn and Sherry 1999) but not mass (Custer and Mulhern 1983) in wild birds. Cadmium and lead concentrations in the feathers of these three bird species were higher than those in great tits and robins in central Portugal (Costa et al. 2011), and little owls and common buzzards in northern Italy (Battaglia et al. 2005). Several studies have suggested that lead in feathers can be partially due to direct external contamination onto the feather surface (Burger 1993; Dauwe et al. 2002a). Goede and de Voogt (1985)

Table 1 Mean (±SE) metal concentrations (μg/g dry weight) in the feathers of *Alectoris chukar* in Hermoud protected area in southern Iran

Species	Sex/age	No.	Metals			
			Cadmium	Lead	Cobalt	Copper
Alectoris chukar						
	Male/adult	5	2.0 ± 0.2	8.6 ± 0.7	1.3 ± 0.2	8.8 ± 0.7
	Male/juvenile	4	1.8 ± 0.3	5.4 ± 0.8	0.9 ± 0.2	10.4 ± 1.1
	Female/adult	3	2.8 ± 0.5	10.8 ± 0.3	1.8 ± 0.5	12.1 ± 1.7
	Female/juvenile	3	1.6 ± 0.4	7.3 ± 0.9	0.7 ± 0.2	8.7 ± 1.8
	Min–max		0.84–3.68	3.2–11.6	0.3–2.6	6.1–14.3
	Overall mean		2.0	8.0	1.2	9.8
	p value sex*		NS	0.02	NS	NS
	p value age*		NS	0.001	0.04	NS

[a] *p* value for 2-way ANOVA

[b] *NS* not significant at $p > 0.05$

Table 2 Mean (±SE) metal concentrations (μg/g dry weight) in the feathers of *Ammoperdix griseogularis* in Hermoud protected area in southern Iran

Species	Sex/age	No.	Metals			
			Cadmium	Lead	Cobalt	Copper
Ammoperdix griseogularis						
	Male/adult	3	1.9 ± 0.5	10.4 ± 1.1	1.6 ± 0.3	10.4 ± 1.5
	Male/juvenile	4	1.5 ± 0.3	5.1 ± 1.5	1.4 ± 0.3	8.4 ± 1.4
	Female/adult	5	2.7 ± 0.2	9.6 ± 0.8	1.7 ± 0.2	11.7 ± 0.8
	Female/juvenile	3	1.2 ± 0.2	5.9 ± 0.3	1.0 ± 0.2	8.3 ± 1.1
	Min–max		0.8–3.2	2.9–12.6	0.7–2.6	6.2–14.5
	Overall mean		1.9	5.4	1.5	9.7
	p value sex*		NS	NS	NS	NS
	p value age*		0.03	0.01	NS	0.04

[a] *p* value for 2-way ANOVA

[b] *NS* not significant at $p > 0.05$

Table 3 Mean (±SE) metal concentrations (μg/g dry weight) in the feathers of *Columba livia* in Hermoud protected area in southern Iran

Species	Sex/age	No.	Metals			
			Cadmium	Lead	Cobalt	Copper
Columba livia						
	Male/adult	6	1.9 ± 0.3	7.5 ± 1.2	1.3 ± 0.2	10.8 ± 0.6
	Male/juvenile	2	1.9 ± 0.6	5.2 ± 1.2	0.8 ± 0.2	7.4 ± 0.9
	Female/adult	4	2.1 ± 0.4	10.1 ± 0.5	1.8 ± 0.1	12.8 ± 0.7
	Female/juvenile	3	1.6 ± 0.2	6.9 ± 2.1	0.8 ± 0.2	8.3 ± 0.9
	Min–max		0.9–3.1	2.5–11.1	0.5–2.1	6.5–14.3
	Overall mean		1.9	7.7	1.3	10.4
	p value sex*		NS	NS	NS	NS
	p value age*		NS	NS	0.01	0.001

[a] *p* value for 2-way ANOVA

[b] *NS* not significant at $p > 0.05$

Table 4 The analysis of variance (ANOVA) of the data among species

Elements	*F*	*p*
Cadmium	0.01	NS
Lead	0.01	NS
Cobalt	0.94	NS
Copper	0.28	NS

NS not significant at $p > 0.05$

reported lead concentrations of 1.0–32.0 μg/g dry weight in feathers of the Wadden Sea's shorebirds. Lead concentrations of 4 μg/g dry weight in feathers are known to cause sublethal and reproductive effects (Kim and Koo 2008). In this study, lead concentrations were greater than 5 μg/g in the feathers of the three species. The high concentrations of lead in the feathers indicate that the environment is highly polluted with lead. As with other studies, this research suggests that feathers could be used to indicate local atmospheric contamination (Almansour 2007; Dauwe et al.

2002a). Lead as an ubiquitous pollutant is transported into the sea by industrial wastewater, produced by industries such as printing, dyeing, and oil refineries (Lakshmanan et al. 2009; Newbury 1979).

Essential elements, such as copper (Cu) and cobalt (Co) are necessary for the metabolism but can cause adverse effects when their concentrations in the organism become excessive. Cobalt as part of vitamin B_{12} is associated with nitrogen assimilation, and synthesis of hemoglobin and muscle protein. In addition, cobalt influences certain enzymes (Roginski and Mertz, 1977). However, excessive intake of cobalt by organisms results in toxic effects. The highest cobalt concentrations in these three species were measured in female/adult birds and the lowest concentrations were found in female/juvenile birds. Idem, in the three species, the highest copper concentrations were measured in female/adults and the lowest concentrations were observed in male/juveniles (except *C. livia*). The average concentrations of cobalt and copper were 1.2 and 9.8 μg/g, 1.5 and 9.7 μg/g, and 1.3 and 10.4 μg/g dry weight in *A. chukar*, *A. griseogularis*, and *C. livia*, respectively. Copper concentrations found in this study were similar to those in great tits (Llacuna et al. 1995) and great and blue tits in Antwerp, Belgium (Dauwe et al. 2002b). In general, birds retain a small portion of copper and other metals ingested (Bryan and Langston 1992). Breteler (1984) reported that copper is one of the major threats to ecosystem health relative to other heavy metals. According to Schmitt-Jansen et al. (2008), the sublethal effects of copper on birds include growth retardation, suppression of egg production, thinner egg shells, and changes in behavior.

Several studies have examined the effects of gender and age on the accumulation of metals in feathers and other tissues (Burger 1995; Zamani-Ahmadmahmoodi et al. 2009; Mansouri et al. 2011). Few studies reported no significant differences in metal content of feathers between male and female birds (Hutton 1981; Zamani-Ahmadmahmoodi et al. 2009). Similarly, in this study no significant differences found between the concentrations of metals in male and female birds except lead in *A. chukar* (two-way ANOVA, $p > 0.05$), suggesting that different sexes utilize similar foraging strategies in these species (Hindell et al. 1999). However, females can sequester metals in eggs (Tom et al. 1999) which provides them with a unique route of elimination, not available to males (Burger 1993). On the other hand, significant differences were observed between the concentrations of lead and cobalt in *A. chukar*; cadmium, lead and copper in *A. griseogularis*; and cobalt and copper in *C. livi*a; in adult and juvenile birds. Mansouri et al. (2011) found that the concentrations of cadmium and lead were higher in the feathers of adults than in juveniles of *Egretta gularis* and *Larus heuglini*. According to Furness and Monaghan (1987), cadmium concentration is always higher in the adults, because of bioaccumulation. Adults have had several years to bioaccumulate metals in their internal tissues, and this can be mobilized into the blood and deposited in feathers during their formation (Burger 1994).

References

Almansour MI (2007) Inter-species differences between lead concentration in the feathers of *Pycnonotus leucogenys* and *Streptopelia seneglenses* from different cities of Saudi Arabia. Inter J Zool Res 3:200–206

Barbieri E, Andrade Passos ED, Filippini A, Souza dos Santos I, Borges Garcia CA (2009) Assessment of trace metal concentration in feathers of seabird (Larus dominicanus) sampled in the Florianópolis, SC, Brazilian coast. Environ Monit Assess. doi: 10.1007/s10661-009-1202-4

Battaglia A, Ghidini S, Campanini G, Spaggiari R (2005) Heavy metal contamination in little owl (*Athene noctua*) and common buzzard (*Buteo buteo*) from northern Italy. Ecotoxicol Environ Safe 60:61–66

Breteler RJ (1984) Chemical pollution of the Hudson-Raritan Estuary. NOAA Tech Memo NOS/OMA 7

Bryan GW, Langston WJ (1992) Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: a review. Environ Pollut 76:89–131

Burger J (1993) Metals in avian feathers: bioindicators of environmental pollution. Rev Environ Toxicol 5:203–311

Burger J (1994) Metals in avian feathers: bioindicators of environmental pollution. Rev Environ Toxicol 5:203–311

Burger J (1995) Heavy metals and selenium in feathers of Herring gulls (*Larus argentatus*): differences due to year, gender, and age at Captree, Long Island. Environ Monit Assess 38:37–50

Burger J, Gochfeld M (2000) Metals in Laysan Albatrosses from Midway Atoll. Arch Environ Contamin Toxicol 38:254–259

Costa RA, Petronilho JMS, Soares AMVM, Vingada JV (2011) The use of passerine feathers to evaluate heavy metal pollution in central Portugal. Bull Environ Contam Toxicol 86:352–356

Custer TW, Mulhern BL (1983) Heavy metal residues in prefledging Black-crowned Night Herons from three Atlantic coast colonies. Bull Environ Contam Toxicol 30:178–185

Dauwe T, Bervoetts L, Blust R, Eens M (2002a) Tissue levels of lead in experimentally dosed zebra finches (*Taeniopygia guttata*) with particular attention on the use of feathers as biomonitors. Arch Environ Contamin Toxicol 42:88–92

Dauwe T, Bervoetts L, Ellen J, Rianne P, Blust R, Eens M (2002b) Great and blue tit feathers as biomonitors for heavy metal pollution. Ecol Indica 1:227–234

Furness RW, Monaghan P (1987) Seabird ecology. Chapman & Hall, New York, p 164

Goede AA, de Voogt P (1985) Lead and cadmium in waders from the Dutch Wadden Sea. Environ Pollut 37:311–322

Hindell MA, Brothers N, Gales R (1999) Mercury and cadmium concentrations in the tissues of three species of southern albatrosses. Polar Biol 22:102–108

Hoff Brait CH, Antoniosi Filho NR (2011) Use of feathers of feral pigeons (Columba livia) as a technique for metal quantification and environmental monitoring. Environ Monit Assess. doi: 10.1007/s10661-010-1748-1

Hutton M (1981) Accumulation of heavy metals and selenium in three seabird species from the United Kingdom. Environ Pollut 26:129–145

Janiga M, Zemberyová M (1998) Lead concentration in the bones of the feral pigeons (*Columba livia*): sources of variation relating to body condition and death. Arch Environ Contamin Toxicol. doi:10.1007/s002449900351

Kim J, Koo TH (2007) The use of feathers to monitor heavy metal contamination in herons, Korea. Arch Environ Contamin Toxicol 53:435–441

Kim J, Koo TH (2008) Heavy metal concentration in feathers of Korean shorebirds. Arch Environ Contamin Toxicol 55:122–128

Lakshmanan R, Kesavan K, Vijayanand P, Rajaram V, Rajagopal S (2009) Heavy metals accumulation in five commercially important fishes of Parangipettai, Southeast Coast of India. Advan J Food Sci Technol 1:63–65

Llacuna S, Gorriz A, Sanperra C, Nadal J (1995) Metal accumulation in three species of passerine birds (*Emberiza cia*, *Parus major*, and *Turdus merula*) subjected to air pollution from a coal-fired power plant. Arch Environ Contam Toxicol 28:298–303

Mansouri B, Pourkhabbaz A, Babaei H, Houshyari E (2011) Heavy metal contamination in feathers of Western Reef Heron (Egretta gularis) and Siberian gull (Larus heuglini) from Hara biosphere reserve of Southern Iran. Environ Monit Assess. doi:10.1007/s10661-011-2408-9

Mansouri B, Pourkhabbaz A, Babaei H, Hoshyari E, Khodaparast SH, Mirzajani A (2012) Assessment of trace metal concentration in Western Reef Heron (*Egretta gularis*) and Siberian gull (*Larus heuglini*) from southern Iran. Arch Environ Contamin Toxicol 63:280–287

Nam DH, Lee DP, Koo TH (2004) Monitoring for lead pollution using feathers of Feral pigeons (*Columba livia*) from Korea. Environ Monit Assess. doi:10.1023/B:EMAS.0000029898.28393.30

Newbury TK (1979) Possible accumulation of heavy metals around offshore oil production facilities in the Beaufort Sea. Arctic 32:42–45

Roginski EE, Mertz W (1977) A biphasic response of rats to cobalt. J Nutrit 107:1537–1542

Schmitt-Jansen M, Veit U, Dudel G, Altenburger R (2008) An ecological perspective in aquatic ecotoxicology: approaches and challenges. Basic Appl Ecol 9:337–345

Spahn SA, Sherry TW (1999) Cadmium and lead exposure associated with reduced growth rates, poorer fledging success of Little Blue Heron chicks (*Egretta caerulea*). Arch Environ Contam Toxicol 37:377–384

Tom D, Bervoets L, Blust R, Pinxten R, Eens M (1999) Are eggshell and egg contents of great and blue tits suitable as indicators of heavy metal pollution? Belgian J Zool 129:439–447

Zamani-Ahmadmahmoodi R, Esmaili-Sari A, Savabieasfahani M, Ghasempouri SM (2009) Mercury in wetland birds of Iran and Iraq: contrasting resident Moorhen, Gallinula chloropus, and migratory common Teal, Anas crecca, life strategies. Bull Environ Contamin Toxicol 82:450–453