Bull Environ Contam Toxicol (2011) 87:457–462
DOI 10.1007/s00128-011-0364-2

Comparative Tissue Distribution of Heavy Metals in House Sparrow (*Passer domesticus*, Aves) in Polluted and Reference Sites in Turkey

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Received: 11 April 2011 / Accepted: 1 July 2011 / Published online: 23 July 2011

Abstract Bioindicators are useful for environmental monitoring in ecosystems with pollution loads. We compared concentrations of selected 10 metals in 42 samples of House Sparrow in a polluted by thermal power plant and reference sites. We found mean tissue concentrations of some metals to be significantly higher in sparrows from the polluted area when compared to tissues from the reference site. In liver mean concentrations of Cu (35.85 ± 17.22 mg kg^{-1}) and Zn (101.76 ± 26.38 mg kg^{-1}) were significantly higher and concentration of Ni (0.43 ± 0.49 mg kg^{-1}) were significantly lower in sparrows from the polluted area ($p < 0.05$). The concentration of Cu was significantly higher in muscle and liver at the polluted site. Gender did not seem to influence residue levels, of the elements studied, among sparrows with the exception of kidney cobalt concentrations; which were higher in female sparrows than in males ($p < 0.05$, $t = -2.409$).

Keywords House Sparrow · *Passer domesticus* · Yatağan Thermal Power Plant
Tissue heavy metal levels · Bioindicator species

Some ecosystems have been heavily polluted as a consequence of urbanization and industrial processes. Heavy metals are ubiquitous elements present in environment through geological cycles (erosion from ore-bearing rock, volcanic activity, oceanic processes, wind-blown dust, etc.) and various anthropogenic activities (industrialization, fuel combustion, smelting processes, roadway traffic, etc.). Toxic and persistent, metals are introduced into the environment by natural and anthropogenic processes mainly in relationship with fossil fuels utlization, industrial activities, and different kinds of transportation emissions (Alleva et al. 2006).

The impact of metals on the environment can be a serious threat for ecosystem health and eventually for human health. Animals at the top of the food chain may bioaccumulate higher amounts of metals in their tissues, depending on age, size and feeding habits (Eens et al. 1999; Alleva et al. 2006).

Control of global atmospheric pollution is the main action for reducing metals and other toxic substances in the ecosystems and hence decreasing bioaccumulation (Feng and Qiu 2008). Birds are good bioindicators in polluted ecosystems, especially in territories adjacent to pollution sources due to their position in the terrestrial food web (Lebedeva 1997; Burger et al. 2004). Other advantages for preference of birds in ecotoxicology studies are abundance, wide distribution an dispersal, longer lifespan, sensitivity and being the first target of atmospheric pollution, occupying a top level in the food web and tendency for bioaccumulation in tissues enabling detection of sub-lethal and chronic effects (Eens et al. 1999; Alleva et al. 2006).

The House Sparrow, *Passer domesticus* one of the most widely distributed bird species in the world, is one of the most successful animals in adaptation to urban life as habitat and is the preferred bioindicator species (Anderson 2006; Deng et al. 2007). Sparrows are distributed to most of Europe and Central Asia, and are introduced nearly in all continents.

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Metal pollution poses important threats to biodiversity and environmental quality such as: Negative impacts on reproduction, egg hatchability, and hatching success (Ek et al. 2004; Deng et al. 2007).

We measured metal concentrations in selected tissues of the House Sparrow, *P. domesticus* in sites polluted by thermal power plant (Yatağan, Muğla) and reference sites (Antalya). Our objectives were to (1) assess the status of metal accumulation in these two sites, (2) quantify the distribution of metals in different sparrow tissues, (3) examine the effects of location and gender on variations in metal accumulation, (4) determine if House Sparrow is threatened by metal pollution at the study sites.

Materials and Methods

During April and June 2010, 42 specimens of sparrows were trapped by mist nets. Of these, 20 (8 males, 12 females) were caught from a polluted site affected by the Yatağan Thermal Power Plant (YTPP) which uses coal to produce electric energy in Yatağan town (Muğla, 37°20′03″ N, 28°07′21″ E) and 22 (12 males, 10 females) were collected from a reference site known to be "clean" in terms of thermal power plant type pollution in a small village, Çığlık (Antalya, 37°02′35″ N, 30°35′06″ E). Maximum distance between the two sampling sites was approximately 230 km (distance between Antalya and Yatağan). The SDU ET- 09.03.2010-05 protocol for using sparrow in the experiments was reviewed and approved by Süleyman Demirel University Local Ethical Committee on Animal Experiments regulations. Guiding principles for experimental procedures found in the Süleyman Demirel University Experimental Animals Ethical Council and Declaration of Helsinki of the World Medical Association regarding animal experimentation were followed in the study.

In total, 42 samples from the reference and polluted sites were analysed for muscle, kidney and liver. Tissue samples were dried for about 24 h in a Christ LDC-1 freeze dryer.(muscle liver and kidney samples of the birds were freeze-dried for approximately 24 h to a final pressure of 0.05 mbar at −50°C, using a CHRIST LDC-1 freeze dryer). The final pressure and theoretical temperature for the freeze-drying were 0.04 mbar and −50°C, respectively. For digestion, a microwave closed system (Milestone Mega MLS-1200, Bergamo, Italy) was used. Each sample (100–500 mg) was digested with 5 mL of nitric acid (65% HNO_3) and 1 mL hyrogen peroxide (30% H_2O_2) in the digestion system for 30 min and diluted with deionized water to a final volume of 25 mL. A blank digest was processed in the same way. Exactly the same procedure was applied to the blank samples (replacing the amount of tissue with 1 mL deionised water), spiked samples (using certified 10.00 mg L^{-1} stock solutions of metals provided by Fisher Chemicals) and for samples of liver and muscle reference material (National Institute of Standards and Technology, NIST).

The accuracy of the analytical procedures was checked against the National Institute of Standards and Technology (NIST) for bovine liver 1577A (Cd, Cu, Hg, and Zn) and dogfish muscle DOLM-1 (As, Cd, Cu, Hg and Zn).

Copper, lead, cobalt, mercury, arsenic, zinc, cadmium, chromium, manganese, nickel concentrations (Cu, Pb, Co, Hg, As, Zn, Cd, Cr, Mn, Ni) in the samples were analysed by an inductively coupled plasma optical emission spectrometry system (ICP-OES, Perkin-Elmer, 5300 DV). Each analysis was carried out in duplicate. Standard reference materials were analysed concurrently with the samples. All values were within certified limits. Metal concentrations are given as mg kg^{-1} dry weight tissue. Values of wavelength, limits of quantification and limits of detection of the analyses are depicted in Table 1. Samples below the detection limits were repeated the analysis to fortify at the level of detection.

Values of metal concentrations were routinely checked for normal distributions using Q–Q plots. Metal concentrations showed skewed distributions which were normalized by applying a logarithmic transformation. Comparisons between sexes, sampling sites, tissues (muscle, liver, and kidney) were made using the *t*-test statistic for independent samples on the log-transformed values for metal concentrations. Pearson correlation coefficient was used to assess the relationship between metal concentrations and tissues using log transformed values of metal concentrations. The level of significance was set at 0.05. Mean and standard deviation of the mean (SD) using original values are presented together as mean ± SD. SPSS for windows 11.1 was used for statistical analysis.

Table 1 Values of wavelength, detection limits, limits of quantification and limits of detection of analyses

	Wavelength (nm)	Limits of quantification (mg kg^{-1})	Limits of detection (mg kg^{-1})
Cu	327.393	0.01	0.003
Zn	206.200	0.01	0.003
Mn	257.610	0.01	0.003
Co	228.616	0.01	0.003
Ni	231.604	0.02	0.007
Cr	267.716	0.02	0.007
Cd	228.802	0.01	0.003
Pb	220.353	0.06	0.02
Hg	253.652	0.09	0.03
As	188.979	0.17	0.05

Each sample below the detection limits was assigned a value of one-half the detection limit and included in the data set for statistical treatment, a technique which minimizes nominal type I error rates. If the number of samples below the detection limits were greater than 70% of total sample size, they were not included for statistical treatment; but their data evaluated on a case-by-case basis.

Results and Discussion

This study compares tissue heavy metal level of House Sparrows from a reference (Antalya, Turkey) and polluted (under threat from a thermal power plant in Muğla Province, Turkey). Several metals (Cu, Zn, Mn, Co, Ni, Cr, Cd, Pb, Hg) and the metalloid (As) concentrations in selected tissues of sparrows were determined on the basis of their dry weight. Muscle, liver and kidney concentrations of Cd, Pb, and Hg were frequently found to be less than detection limits for these elements with the methodology used (Table 1). All of tissues As concentrations (42 of 42 samples) were less than the detection limit (0.05 mg kg^{-1}).

In liver mean concentrations of Cu and Zn were significantly higher and concentration of Ni were significantly lower in sparrows from the polluted area (Table 2). In muscle, significant differences in Cu and Zn concentrations were found between the sites. The concentration of Cu was significantly higher in muscle and liver at the polluted site (Table 2). The concentrations of Zn and Cu were higher than the other trace elements for both sites (Table 2). However, Zn showed varied concentrations, such as; higher concentrations in liver and low concentration in kidney and muscle.

However, there were statistically significant differences in muscle Cu, liver Cu, Zn, Ni, and kidney Co in males and there were statistically significant differences in muscle Zn and liver Cu, Zn in females between the reference and polluted sites (Table 3). No statistically significant differences were found between genders, except for Cr in kidney at the reference site ($t = -2.409$, $p < 0.05$).

Mn was detected at highest levels in liver samples from the reference site; followed by kidney and muscle (Table 2). However, Mn concentrations were lowest in kidney samples from the polluted site than in muscle and liver.

Highest Cr concentration was in kidney and less in liver and muscle (Table 2) at the reference site. However, in polluted site Cr had the highest concentration in liver and the least in the kidney and muscle. Co burden was much higher in the kidney, and was lower in the liver and muscle (Table 2).

Mercury (Hg) concentrations were determined to be 69 mg kg^{-1} in muscle samples from the polluted site, and 65 mg kg^{-1} in the kidney samples from only one individual from the reference site. In polluted site, mean of Pb concentrations was found to be 0.28 mg kg^{-1} in the liver, however, Pb concentrations were below detection limits (<0.02 mg kg^{-1}) in kidney and muscle. In the reference site, Pb concentrations were below detection limits in all tissues. Concentrations of Cd were higher in kidney and liver samples than muscle in the reference site. In the polluted site; the mean Cd concentration in kidney sample was found only 1.93 mg kg^{-1}, the mean liver concentrations

Table 2 Mean ± SD values for several metals (Cu, Zn, Mn, Co, Ni, Cr) in tissues of sparrows compared by site (in mg kg^{-1} DW) in Turkey

		Reference site (ANT) Mean ± SD	Polluted site (YAT) Mean ± SD	*t*	*p*
Muscle	Cu	21.04 ± 5.47	25.07 ± 4.58	2.450	0.019
	Zn	19.90 ± 7.24	34.03 ± 17.25	2.126	0.04
	Mn	2.33 ± 2.07	3.29 ± 4.66		n.s.
	Co	0.34 ± 0.36	0.58 ± 0.54		n.s.
	Ni	0.58 ± 0.67	3.53 ± 9.92		n.s.
	Cr	0.35 ± 0.52	0.42 ± 0.73		n.s.
Liver	Cu	17.56 ± 6.22	35.85 ± 17.22	6.511	0.000
	Zn	43.18 ± 19.69	101.76 ± 26.38	8.353	0.000
	Mn	5.85 ± 11.02	5.50 ± 7.11		n.s.
	Co	0.87 ± 2.13	0.28 ± 0.58		n.s.
	Ni	0.61 ± 2.37	0.43 ± 0.49	2.216	0.032
	Cr	0.48 ± 0.66	6.02 ± 16.55		n.s
Kidney	Cu	14.00 ± 6.88	14.96 ± 10.67		n.s.
	Zn	19.72 ± 19.94	31.51 ± 25.80		n.s.
	Mn	3.87 ± 7.59	1.80 ± 1.37'		n.s.
	Co	3.52 ± 9.10	0.84 ± 1.71		n.s.
	Cr	34.94 ± 78.1	3.11 ± 4.28		n.s.

Table 3 Mean ± SD values for several metals (Cu, Zn, Mn, Co, Ni, Cr) in gender of sparrows compared by site (in mg kg^{-1} DW)

		Reference site		Poiluted site	
		Male Mean ± SD	Female Mean ± SD	Male Mean ± SD	Female Mean ± SD
Muscle	Cu[a]	20.75 ± 5.63	21.38 ± 5.55	27.38 ± 5.11	23.52 ± 3.62
	Zn[b]	18.48 ± 8.84	21.61 ± 4.55	31.22 ± 8.65	35.89 ± 21.38
	Mn	2.78 ± 2.66	1.78 ± 0.86	4.83 ± 7.19	2.26 ± 1.29
	Co	0.35 ± 0.38	0.33 ± 0.35	0.47 ± 0.29	0.65 ± 0.66
	Ni	0.62 ± 0.76	0.53 ± 0.57	6.49 ± 15.73	1.55 ± 1.35
	Cr	0.41 ± 0.58	0.29 ± 0.44	0.31 ± 0.43	0.49 ± 0.90
Liver	Cu[a, b]	17.35 ± 6.38	17.82 ± 6.37	35.11 ± 15.02	36.35 ± 19.19
	Zn[a, b]	46.40 ± 23.83	39.31 ± 13.42	97.89 ± 13.22	104.33 ± 32.75
	Mn	3.75 ± 2.30	8.38 ± 16.24	8.23 ± 10.98	3.68 ± 1.27
	Co	0.47 ± 1.10	1.35 ± 2.94	0.45 ± 0.81	0.17 ± 0.37
	Ni[a]	0.11 ± 0.29	1.22 ± 3.51	0.60 ± 0.65	0.32 ± 0.33
	Cr	0.50 ± 0.78	0.46 ± 0.52	1.97 ± 4.31	8.72 ± 21.01
Kidney	Cu	14.67 ± 7.83	13.21 ± 5.86	10.37 ± 7.58	18.02 ± 11.60
	Zn	17.70 ± 16.55	22.14 ± 24.10	19.74 ± 23.61	39.35 ± 25.04
	Mn	3.65 ± 5.83	4.15 ± 9.63	1.40 ± 1.50	2.07 ± 1.27
	Co[a, d]	1.21 ± 1.25	6.28 ± 13.26	0.11 ± 0.30	1.32 ± 2.09
	Cr[c, d]	20.17 ± 62.23	52.68 ± 94.19	1.33 ± 3.72	4.30 ± 4.36

[a] Statistical differentiation was found between reference site and polluted site males ($p < 0.05$)

[b] Statistical differentiation was found between reference site and polluted site females ($p < 0.05$)

[c] Statistical differentiation between gender was found in reference site ($p < 0.05$)

[d] Statistical differentiation between gender was found in polluted site ($p < 0.05$)

was determined as 21.21 mg kg^{-1} dry weight, muscle levels were below the detection limits (<0.003 mg kg^{-1}).

Cadmium (Cd) concentrations of the tissues studied were less than the detection limits (0.003 mg kg^{-1}). Namely 40 of muscle, 30 of liver, and 37 of kidney samples out of a total 42 samples were below the limits. In muscle, of the 2 samples that were greater than the detection limit, the mean concentration was 0.15 ± 0.16 mg kg^{-1} in reference site. In liver, of the 12 samples were greater than detection limit, the mean concentration was 36.14 ± 31.11 mg kg^{-1} (n = 3) in reference site and 21.21 ± 29.11 mg kg^{-1} (n = 9) in polluted site. In kidney, of the 5 samples were greater than detection limit, the mean concentration was 29.10 ± 15.11 mg kg^{-1} (n = 4) in reference site and 1.93 mg kg^{-1} (n = 1) in polluted site.

All or most of concentration of Pb (for muscle 42, for liver 36, and for kidney 42 of 42 samples) were below the detection limits (0.02 mg kg^{-1}). In liver, of the 12 samples were greater than detection limit, the mean concentration was 0.28 ± 0.23 mg kg^{-1} (n = 6) in polluted site. We did not detected Pb concentration in muscle and kidney.

All or most of concentration of Hg (for muscle 41, for liver 42, and for kidney 41 of 42 samples) were less than the detection limits (0.03 mg kg^{-1}). In muscle, only one samples exceeded the detection limit, with a concentration of 69.27 mg kg^{-1} in polluted site. Similarly, in kidney, the only sample exceeding the limit of detection was at a concentration of 65.48 mg kg^{-1} in the reference site. We did not detected any Hg residues in liver.

Most of kidney concentration of Ni (35 of 42 samples) were less than the detection limits (0.007 mg kg^{-1}). Of the seven samples that were greater than the detection limit, the mean concentrations were 26.09 ± 29.75 mg kg^{-1} (n = 3) in reference site and 3.87 ± 3.37 (n = 4) in the polluted site.

The influence of sex on bioaccumulation levels of metals in House Sparrows are given in Table 3. Gender did not seem to influence metal concentrations among sparrows with the exception of kidney where Co which was higher in female sparrows than in males ($p < 0.05$, $t = -2.409$). Among gender differences, females had significantly higher mean residue concentrations of Co and Cr in kidney at the reference site and polluted site ($p < 0.05$, $t = -2.409$), whereas females bioaccumulated more Co and Cr ($p < 0.05$) at the polluted site (Table 3).

The availability of potentially toxic metals such as Cu, Zn, Cd, Pb in the impacted site was still higher than in the reference site and they were accumulated in the tissues of sparrow. In polluted site, Yatağan Thermal Power Plant has SO_2, NO_x and metals emissions as well as radioactive contaminants such as uranium (U), thorium (Th) and potassium (K) (Baba et al. 2003). Mercury pollution has also been reported in Yatağan, all of which affect living organisms (Baba et al. 2003; Burger et al. 2004; Bianchi et al. 2008).

Ni concentrations in the liver were higher in the reference site than the polluted site, could partially be explained by the effect of fertilizers, which load the waters and soils of the reference area with metals (Tovar-Sanchez et al. 2006).

The Antalya area is under pollution stress mainly due to fertilizers, agricultural applications, insecticides, industrial waste discharges and residues of automobile exhausts.

Statistically significant differences were found between the reference and polluted sites for Cu in muscle, liver, Zn in the liver, and Co in the kidney by males. In contrast, samples collected from females from the polluted site had higher Zn concentrations in muscle and Cu, Zn levels in liver than the same metals and tissues by reference site. This (gender) related variation in trace metal accumulation could be related to ecological or physiological factors.

Though we found that gender did not seem to influence elemental levels among sparrows with the exception of kidney Co and Cr which was higher in female sparrows than in males, gender differences in the small passer birds, *Parus major* and *Carduelis sinica* (Deng et al. 2007).

Although we did not find statistically significant differences between sexes for sparrows, in general, mean metal levels were higher in males than in females in this species. Generally speaking, the gender differences of these essential elements (Co, Fe, Zn, and Mo) may be associated with differences in the metabolic profile of metals involved in the activity of sexual hormones, the intake or uptake of metals, nutritional requirement or interactions between elements (Vahter et al. 2007). Metals excreted in eggs are the results of both stored body burdens and food choice of the female during egg formation (Ek et al. 2004).

Higher concentrations of Cu and Zn in the muscle; Cu, Zn, and Cd in the liver; Cu, Zn, Cr, and Cd were found in kidney. Other studies have shown similar body compartment specific distributions such as high concentrations of trace elements in the kidney, liver, and low concentrations in the muscle (Nam et al. 2005).

In polluted site, the present values of the samples analysed for Zn in liver were found to be within the range reported for similar samples by Deng et al. (2007) but in reference site, it was lover than the report. However, the Zn levels in liver were lower than those found Swaileh and Sansur (2006) but, the Zn levels in liver were higher when compared with those found by Chao et al. (2003).

The concentrations of Cd, Cr, Ni, Co and Cr in liver, kidney and muscle samples were higher than those found Deng et al. (2007) but, the Mn concentrations in muscle were higher than those detected in China (Deng et al. 2007). On the other hand, the Cr, Zn, Cd and Co concentrations in liver were higher than those detected in China (Chao et al. 2003).

Reports on the body distribution and monitoring data of some elements such as As, Hg and Pb in sparrows were rather limited in the open literature and reported in detail in the present study. The results showed that mean Pb levels in liver ranged between 0.27 and 0.28 $\mu g\ g^{-1}$. On the other hand, concentrations of Pb were clearly lower than those reported in the literature (Swaileh and Sansur 2006; Deng et al. 2007), possibly due to banning of leaded fuel in industrialized countries some time ago and recently Turkey steadily reduced lead in gasoline (mostly between 1998 and 2005). The results presented in this study not only indicated that mean tissue concentrations of some metals to be significantly higher in sparrows from the polluted area when compared to tissues from reference site but birds can be used as a reliable bioindicator species for monitoring programs, as they can act as adequate local monitors of contaminant levels.

Acknowledgments The research was supported by Mehmet Akif Ersoy University (BAP 0093-NAP-10). We are grateful to H. Kuleaşan and H. Tunçmen who helped with the analyses of the bird samples. We thank Işıl and Deniz Albayrak for their efforts in the field work.

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