https://doi.org/10.52973/rcfcv-e34319 Revista Científica, FCV-LUZ / Vol. XXXIV, rcfcv-e34319

Evaluation of heavy metal (As, Hg, Zn, Cu and Se) levels in wild birds of prey and aquatic habitats

Evaluación de los niveles de metales pesados (As, Hg, Zn, Cu y Se) en aves rapaces silvestres y hábitats acuáticos

Zozan Garip*, Reşat Ektiren, Füsun Temamoğulları, Anıl Karakaş

Harran University, Faculty of Veterinary Medicine, Department of Pharmacology and Toxicology. Sanlıurfa, Türkiye.
**Corresponding author: garipzozan@gmail.com*

ABSTRACT

Birds are used as bioindicators to determine the negative effects of environmental pollution on human, animal, and environmental health. Among the terrestrial bird species in the study are: the common buzzard (*Buteo buteo*); black kite (*Milvus migrans*), common kestrel (*Falco tinnunculus*); among the aquatic bird species, marsh harrier (*Circus aeruginosus*), white stork (*Ciconia ciconia*), gray heron (*Ardea cinerea*) were used. Heavy metals As, Hg, Zn, Cu, and Se were analysed in blood samples by inductively coupled plasma mass spectrometry (ICP–MS). In the study, Hg and Se concentrations were generally higher and As concentrations were generally lower than those reported in the literature. In black kites, which are vulnerable to environmental contamination and pollution has serious effects on population numbers, it was observed that heavy metals other than As metal were generally higher than the values determined in the studies. Pollutants in nature need to be evaluated by taking into account species–specific differences, age, gender, habitats, migration periods, biomass and feeding habits.

Key words: Wild bird; indicator; metal; ICP–MS

RESUMEN

Las aves se utilizan como bioindicadores para determinar los efectos negativos de la contaminación ambiental en la salud humana, animal y ambiental. Entre las especies de aves terrestres en estudio se encuentran: ratonero común (*Buteo buteo*); milano negro (*Milvus migrans*), cernícalo común (*Falco tinnunculus*); entre las especies de aves acuáticas se utilizaron el aguilucho lagunero (*Circus aeruginosus*), la cigüeña blanca (*Ciconia ciconia*) y la garza real (*Ardea cinerea*). Los metales pesados As, Hg, Zn, Cu y Se fueron analizados a partir de muestras de sangre, mediante espectrometría de masas con plasma acoplado inductivamente (ICP–MS). En el estudio, las concentraciones de Hg y Se fueron en general más elevadas y las de As, más bajas que las señaladas en la bibliografía. En los milanos negros, que son vulnerables a la contaminación ambiental y la polución tiene graves efectos en el número de sus poblaciones, se observó que los metales pesados distintos del As eran en general superiores a los valores determinados en los estudios. Los contaminantes presentes en la naturaleza deben evaluarse teniendo en cuenta las diferencias propias de cada especie, la edad, el sexo, los hábitats, los periodos de migración, la biomasa y los hábitos alimentarios.

Palabras clave: Ave silvestre; indicador; metal; ICP–MS

Received: 08/09/2023 Accepted: 20/12/2023 Published: 22/02/2024

INTRODUCTION

The use of animals as bioindicators in understanding the extent of environmental pollution is extremely important in early detection of adverse effects on ecological health [1, 2, 3]. Birds are considered to be ideal bioindicators in figuring out the true extent of environmental pollution due to their wide geographical distribution, long life span, and being at the top of the food pyramid due to their correlation with the food chain [2, 3, 4, 5, 6, 7].

Wild birds are chronically exposed to toxic agents through air, water, and food. As predatory birds are at the top of the food chain, detection of environmental pollutants in predatory birds provides information on many points such as the type, amount, bioavailability, chemical properties, and environmental persistence of the toxic substance [4, 7, 8, 9]. Environmental pollution causes functional disorders in the nervous, reproductive, developmental (embryo death, malformation, growth retardation), and immune and endocrine systems [8]. This has become particularly important for bird species that are under threat of extinction Worldwide [3, 10].

Numerous studies have utilised feather, eggshell, blood, and tissue samples as pollution monitoring tools [2, 11, 12, 13, 14]. Determining concentrations of environmental pollutants in blood is important for determining real-time exposure by contact with the tissues where the chemicals are stored. Also, environmental pollution can be monitored even in small amounts with easy access to blood samples [2, 4]. The ubiquitous presence of heavy metals-one of the environmental pollutants-their inability to break down in nature, their accumulation, and the problems they may bring about on animal and human health raise global concerns [15].

Heavy metals are divided into two groups: essential heavy metals such as zinc (Zn), copper (Cu), and selenium (Se) and non-essential heavy metals such as arsenic (As) and mercury (Hg) [16]. Zn, Cu, and Se, which must be present in the living organism and cause various problems in deficiency and excess, are trace elements with a narrow tolerance range [17]. Zn is distributed to the environment as a consequence of anthropogenic and natural activities. It is toxic at high concentrations, especially in aquatic ecosystems [18]. In birds, toxic concentrations of Zn have been correlated with degenerative deformations of the liver and pancreas, as well as reproductive and teratogenic effects [19]. Cu accumulates directly in the soil, surface water, and groundwater after metal melting processes [20]. In, an increase in the amount of Cu affects the immune system of mammals [21]. Se in soils, rocks, and water can contaminate the food chain through plants and cause environmental pollution through industrial activities such as coal consumption, melting, and fertilizer production [22]. High levels of Se entering eggs through the diet and blood leads to poisoning and reduced survival rates in chicks and adults.

The literature includes a limited number of studies in which Se concentration was determined [23]. Hg is a highly hazardous toxic heavy metal that has raised global concerns about the environment and human health through the aquatic food chain. Birds are highly susceptible to Hg poisoning and are at risk. Hg toxicity in birds leads to reproductive problems such as deformed embryos, reduced number of eggs, decreased number of chicks (*Gallus gallus domesticus*), retarded growth, and even lower survival rates [24]. As contaminates drinking water due to its abundance in geological regions, spreads through melting processes caused by mining activities, and threatens the environment. As inactivates enzymes, depletes antioxidants, and causes carcinogenic and genotoxic effects [25].

Heavy metal use and quantities in the environment are gradually rising with each passing day. Therefore, pollution monitoring should be carried out with long-lived bird species that can allow toomonitor the amount of chemical substances at accurate intervals in the assessment of environmental health [9]. Common buzzards (*Buteo buteo*) (regional or short-distance migratory), black kites (*Milvus migrans*) (migratory), and common kestrels (*Falco tinnunculus*) (partly migratory and partly regional) are long-lived predatory birds that live in terrestrial habitats (such as forests, agricultural and mountainous areas) and have a broad diversity of prey (mice (*Mus musculus*), rabbits (*Lepus europaeus*), insects, lizards (*Lacertidae*), reptiles (*Reptilia*), small mammals, and carrion). Since they are suitable bioindicator species owing to these characteristics, they were preferred in the study [4, 5, 7, 23]. Marsh harrier (*Circus aeruginosus*) (migratory and regional), grey heron (*Ardea cinerea*) (migratory and mostly regional), and white stork (*Ciconia ciconia*) (migratory and some colonies regional) are predatory birds that feed on a mixed diet (fish, crayfish, amphibians, insects, reptiles, small mammals) in wetland habitats (rivers, lakes, ponds, wetlands, and marshes), agricultural lands and meadows. They are one of the preferred species for monitoring environmental pollution in large-scale studies [17, 23, 26, 27, 28].

This study aims to evaluate the exposure of bird species from different Regions of Turkey to heavy metals (As, Hg, Zn, Cu, and Se) and environmental pollution.

MATERIALS AND METHODS

Ethical statement

The Animal Experiments Local Ethics Committee of Harran University approved the study with the decision dated 27/11/2019 (Approval no: 28328). Permission was obtained from the General Directorate of Nature Conservation and National Parks with the number 21264211-288.04-E.377151 dated 01.31.2020.

Twenty-four predatory birds of different ages and sexes were utilized for their blood samples of common buzzard (n=4), black kite (n=4), common kestrel (n=4), marsh harrier (n=4), grey heron (n=4), and white stork (n=4), which were injured for several reasons (falling from the nest, malnutrition, struck by a vehicle, electric shock, and unknown causes) between 2016 and 2022 at Gölpınar Wildlife Rescue and Rehabilitation Centre.

A 2.5-3 mL blood sample was drawn from the tibial and brachial veins of the birds. Blood samples were stored in a deep freezer (New Brunswick / U410-86, England) at -80°C until analysis. Blood samples were pre-treated and gradually incinerated in a microwave oven (Milestone Systems / Start D 260, Denmark) as described by Ütme and Temamoğullari [11]. After adding 8 mL of nitric acid and 2 mL of hydrogen peroxide to 1 mL of blood sample taken into a porcelain crucible, the incineration process was carried out. Combustion was carried out gradually in a microwave oven (10 min at 130°C, 5 min at 150°C, and 10 min at 180°C). The samples were filled to 50 mL with distilled water and filtered.

The heavy metals As, Hg, Zn, Cu, and Se (ppb, $\mu l \cdot L^{-1}$) were analysed from the samples through inductively coupled plasma-mass spectrometry (ICP-MS, Agilent Technologies / 7700X, USA). In this study, standard 1 ppm internal standard (Agilent 5188-6525) samples were analysed according to EPA 6020 method (TABLE I.). The limit of detection (LOD) and limit of quantification (LOQ) values were calculated separately for each element and average values were given by repeating each sample three times. LOD and LOQ values (ppb) of the metals were determined as 0.03255, and 0.107415 for As; 0.7285, and 2.40405 for Se; 0.02888, and 0.095304 for Hg; 0.4574, and 1.50942 for Zn; and 0.04684, and 0.154572 for Cu. ND, no concentration detected, < LOQ, If the sample measurement value is measured as zero, zero is deleted and < LOQ, i.e. ND is written instead.

TABLE I
ICP–MS Working conditions

Instrument	Agilent 7700× ICP–MS
RF matching	2.1 V
RF power	1550 W
Sample uptake rate	0.1 mL·min^{-1}
Sample depth	8.0 mm
Plasma gas flow rate	15 L·min^{-1}
Auxiliary gas flow rate	1.0 L·min^{-1}
He gas flow fate	4.3 mL·min^{-1}
Carrier gas flow rate	0.95 L·min^{-1}
Number of replicates	3
Spray chamber	Soft double pass–type
Spray chamber temp.	2°C
Torch	Quartz glass torch

RESULTS AND DISCUSSION

TABLE II shows the concentrations of heavy metals (As, Hg, Zn, Cu, and Se) in wild birds inhabiting aquatic and terrestrial habitats. When the species in the study were compared, it was observed that the highest As concentration in blood was determined as 25.44 ppb in white stork, while the Hg, Zn, Cu, and Se were 7,920.84 ppb; 64,739.32 ppb; 1,207.70 ppb and 3,219.44 ppb at the highest concentrations in grey heron. TABLE III shows the heavy metal concentrations in the blood of common buzzard, black kite, marsh harrier, grey heron, and white stork species determined in various studies in the literature.

In the study, Hg and Se concentrations were generally higher and As concentrations were generally lower than those reported in the literature. In black kites, a species vulnerable to environmental contamination and for which pollution has serious effects on population size, concentrations of heavy metals other than As were found to be higher than those reported in the literature, except in one case. Since no heavy metal (As, Hg, Zn, Cu, and Se) blood concentrations causing acute or chronic poisoning concentrations in wild birds were found in the literature reviews, it is unknown whether it causes ecotoxicological concerns. It has been stated that a blood Hg level of 7,000 ppb reduces hatchling success by 10% in terrestrial birds [29]. 48,000 ppb blood Se levels have been reported to be the temporal threshold for reproductive and survival effects [30].

The concentration of As in common buzzards blood samples was below the detection limit in three samples (0.107415) and 9.86 ppb in one sample. The As concentrations in the study were lower than the concentration determined by Carneiro *et al.* [4] in Spain (14.89 ± 14.57 ppb). In the study, the As concentration of black kites

TABLE II
Heavy metal (As. Hg. Zn. Cu and Se. ppb. µl·L^{-1}. mean) concentrations of wild birds of prey and aquatic habitats

Common name	Scientific name	As	Hg	Zn	Cu	Se
Common buzzard	*Buteo buteo*	9.86	478.98	9947.60	645.03	475.93
		ND	32.87	9230.43	391.23	615.34
		ND	399.53	19698.93	359.45	753.72
		ND	445.38	18229.28	653.19	759.68
		2.03	27.81	17681.35	978.31	564.37
	Mean	2.37	276.91	14957.52	605.44	633.81
Black kite	*Milvus migrans*	ND	215.59	23721.84	1077.07	550.27
		ND	2563.61	16965.47	551.61	518.90
		ND	1152.91	13579.91	1030.24	626.48
	Mean	ND	1310.70	18089.07	886.31	565.21
Common kestrel	*Falco tinnunculus*	ND	43.55	12176.38	435.36	524.78
		ND	17.05	9316.16	773.24	529.67
		ND	21.84	5918.87	608.50	765.33
		ND	29.16	10586.59	870.09	647.15
	Mean	ND	27.90	9499.50	671.80	616.73
Marsh harrier	*Circus aeruginosus*	ND	368.11	38631.71	612.80	1942.39
		ND	149.22	15102.48	779.88	505.17
		ND	319.86	78594.65	1123.96	965.65
		ND	65.55	14858.10	770.92	1063.34
	Mean	ND	225.68	36796.74	821.89	1119.13
Gray heron	*Ardea cinerea*	ND	817.71	5812.27	915.94	1281.68
		ND	4402.27	64739.32	715.32	3219.44
		0.18	310.21	520.26	46.48	45.15
		2.82	7920.84	11814.60	1207.70	1202.04
		ND	106.70	11030.88	869.71	433.13
	Mean	0.6	2711.55	18783.47	751.03	1236.29
White stork	*Ciconia ciconia*	25.44	44.46	10896.28	700.12	367.34
		4.44	393.07	12616.42	879.37	699.61
		ND	94.64	12145.72	679.30	478.35
	Mean	9.96	177.39	11886.14	752.93	515.10

ND. no concentration detected. < LOQ

was found to be below the detection limit in three samples and 2.03 ppb in one sample. Compared to many studies (8–262.36 ± 469.87ppb) conducted in Spain between 1998 and 2012 to determine the amount of As in the blood of black kites, the amount of As in the study was found to be lower [3, 7, 21, 26, 33]. Since there is no study in which heavy metal levels were determined from blood samples in common kestrel, it was compared with the common buzzard, which has similar feeding habits. In this study, the concentration of As in blood was found to be below LOD in four samples and lower than the concentration found in the study conducted in common buzzard in Spain [4]. This study compared the marsh harrier with a grey heron with a similar feeding habit. The concentration of As was found to be below LOD in four samples of marsh harrier and two samples of grey heron; the concentration in two samples of the grey heron was 0.18–2.82 ppb, lower than the concentration (6 ppb) found in the study conducted by Vega Benito *et al*. [26] in Spain. In the study, the As concentration of white stork was below LOD in two samples, 4.44–25.44 ppb in two samples, and higher than that in one sample in the As concentrations (9.81 ± 2.09–31.68 ± 48.72 ppb) in the studies carried out in Spain between 1998–2008, but similar to that in one sample [3, 17, 21, 26, 32, 33]. When the As levels in this study were analysed by considering the previous information, it was found to be lower in the other samples except for one sample in the white stork which was similar. Heavy metal pollution varies according to factors such as environment (industrial development in the sampling sites), substance (chemical properties, duration of exposure, amount), and organisms (species, age, sex, habitat, varying dietary characteristics, behavior, and biomass) [2, 23, 32, 33].

In the study conducted by Carneiro *et al*. [4] on common buzzards blood samples in Spain, the Hg concentration (209.40 ± 267.28 ppb) was similar and higher than the concentrations of 399.53, 445.38, 478.98 ppb in three samples in this study, while it was 32.87 ppb lower than one sample in this study. Hg concentrations were determined as (99.4 and 74.93 ± 84.64 ppb) in studies conducted by Alvárez *et al.* [23] and Carneiro *et al.* [31] in Spain with black kites blood samples. In the present study, the concentrations determined as 27.81–2,563.61 ppb were lower in one sample and higher in three samples compared to the studies conducted in Spain. The Hg concentration (209.40 ± 267.28 ppb) in the study conducted by Carneiro *et al*. [4] in the common buzzard in Spain was found to be 17.05–43.55 ppb higher than the concentration in the common kestrel.

The Hg concentration (43.2 ppb) in marsh harrier determined by Alvárez *et al*. [23] in Spain was lower than the present study (65.55–368.11 ppb). In the study, the Hg concentration in grey heron was 310.21–7,920.84 ppb, lower than the concentrations determined by Alvárez *et al*. [23] in Spain (288 ppb). This study revealed the Hg concentration in white stork as 44.46–393.07 ppb; while the concentration in one sample was lower than the concentrations determined in the studies conducted in Spain (16.48 ± 1.94—153.20 ± 123 ppb), three values were determined at higher concentrations than the studies [23, 28, 34]. The Hg concentration in the present study was found to be generally higher in species other than common kestrels compared to previous studies. Since there was no study in which Hg levels were determined from blood samples in common kestrel, it was compared with the common buzzard, with a similar feeding habit. It is considered that this difference may be attributed to the variation between the species. Birds inhabiting aquatic habitats increase microbial conversion of inorganic Hg to methyl Hg, in wetland and marsh habitats; therefore, Hg concentrations increase in these birds [34]. High Hg concentrations in aquatic birds are consistent with other studies, as fish and *zooplankton* have higher Hg concentrations [35]. Aquatic birds are at higher risk for Hg because they feed in aquatic habitats [34]. The elevated Hg concentrations in predatory birds have been associated with the consumption of Hg-containing pesticides and fungicides by rodents [6]. Hg concentrations should be monitored continuously to avoid toxicological concerns.

In the study, the Zn concentrations were determined as 9,230.43–19,698.93; 13,579.91–23,721.84, and 5,918.87–12,176.38 ppb in common buzzard, black kite, and common kestrel, respectively. When the concentrations in common buzzards and common kestrels were compared with black kites, it was found that Zn concentrations in black kites in Spain (3,300–5,370 ± 990 ppb) were lower in common kestrels except for one sample [3, 7, 21, 26]. While the Zn concentrations in marsh harrier and grey heron were determined as 14,858.10–78,594.65, 520.26–64,739.32 ppb, respectively, in the present study; the study by Benito *et al*. [26] in grey heron in Spain was found to be higher than the concentration (2,200 ppb) in one sample for grey heron, lower than three samples and lower than four samples for marsh harrier. It was observed that Zn concentrations of 10,896.28–12,616.42 ppb in white storks were compatible with Zn concentrations (1,900–11,218 ± 6,016ppb) in studies conducted in Spain [3, 17, 21, 26, 32].

It was observed in the present study that Cu values of 359.45–653.19; 551.61–1,077.07, and 435.36–870.09 ppb in common buzzard, black kite, and common kestrel, respectively, were compatible with and higher than Cu concentrations (211–368.65 ± 72.78 ppb) in studies conducted in Spain [3, 7, 21, 26]. In the study, Cu concentrations were 612.80–1,123.96 and 46.48–1,207.70 ppb in marsh harrier and grey heron, respectively, and higher than the concentration (352 ppb) in the study conducted by Benito *et al*. [26] in grey heron in Spain except for one sample in grey heron. The Cu concentration in white storks was 679.30–879.37 ppb in the study, which was compatible with the concentrations found in studies conducted in Spain (319.74 ± 88.34—10,880 ± 1,100 ppb) [3, 17, 21, 26, 32]. White storks are susceptible to the accumulation of various pollutants such as metals and pesticides [2]. It has been reported that Cu and Zn concentrations rise in white storks in areas where copper enterprises are located and pollution is intense [17, 33]. Technological advances and metal melting processes resulted in more accumulation of Cu in soil, surface water, and groundwater, which would be dangerous for the environment [20].

In the study, the Se concentrations were found to be 475.93–759.68, 518.90–626.48, and 524.78–765.33 ppb in common buzzard, black kite, and common kestrel, respectively, higher than the concentration (359 ppb) in the study conducted in Spain by Alvárez *et al.* [23] in black kites. In the study, the Se value was found to be 505.17–1,942.39 ppb in marsh harrier and higher than the concentration (299 ppb) in the study conducted by Alvárez *et al.* [23] in Spain. The Se concentrations in grey heron and white stork were 45.15–3,219.44 and 367.34–699.61 ppb, respectively; higher than one sample and lower than three samples in grey heron, and higher than all samples except one in white stork, for the concentrations in the studies conducted in white storks in Spain (382– 461.00 ±70.40 ppb) [23, 34]. No studies were found in which the amount of Se was determined by blood samples in common buzzards, common kestrels, and grey herons. For this reason, since the common kestrel was compared with the black kite and the grey heron was compared with the white stork, it is thought that this difference may be due to the difference between the species. The Se concentrations of bird species were generally higher than the values reported in the literature [22]. 48,000 ppb blood Se levels have been reported to be the temporal threshold for reproductive and survival effects [30]. However, the levels seen in this study are below the threshold for adverse reproductive outcomes. In Turkey, studies conducted by Temamoğullari and Dinçoğlu [36] in well water in Şanlıurfa, by Tokatli [37] in drinking water in the Ergene River basin, and by Yabanli and Tay [38] with fish muscle tissues in Muğla reported that selenium ratios were high. This confirmed that the high levels of Se in the present study were ingested by birds through soil, water, or food.

Especially young, sick, and small black kites are vulnerable to environmental contamination. Also, pollution has serious effects on the population size of black teal [7]. Researchers have reported that an elevation in toxic metal levels is associated with decreased fertility and a higher mortality rate [8]. Since black kites breed in

TABLE III
Heavy metal concentrations in the blood of common buzzard, black kite, marsh harrier, grey heron, and white stork species determined in various studies in the literature (mean± standard deviation, minimum–maximum range, ppb, µL·L⁻¹)

Common name	Scientific name	Location	Device	Year	As	Hg	Zn	Cu	Se	Reference
Common buzzard	*Buteo buteo*	Spain	ICP–MS	2007–2012	14.89±14.57	209.40±267.2	–	–	–	Carneiro *et al.*[4]
Black kite	*Milvus migrans*	Spain	AAS	1998	8 (6–35)	–	3300 (2300–4500)	211 (120–303)	–	Benito *et al.* [26]
			AAS	1999	262.36±469.8 (ND–1.5)	–	5150±910 (3340–7470)	356.42±48.35 (252–471)	–	Baos *et al.* [3]
			CVAAS–ICP–MS	1999–2000	–	99.4 (45.0–194)	–	–	359 (354–364)	Alvárez *et al.* [23]
			AAS	2000	28.68±56.20 (ND–298.7)	–	5280±1020 (2250–7510)	368.65±72.78 (236–561)	–	Baos *et al.* [3]
			AAS	2001	15.50±18.43 (ND–97)	–	5210±560 (4000–6600)	357.47±125.10 (200–737)	–	Baos *et al.* [3]
			AAS	2002	40.22±47.88 (ND–165)	–	4760±600 2950–6090)	312.91±41.97 (230–381)	–	Baos *et al.* [3]
			AAS	1999	124.48±260.0 (9–1,559)	–	4820±940 (3340–9580)	364.23±59.20 (252–495)	–	Baos *et al.* [21]
			AAS	2001	41.25±63.49 (0.10–288)	–	5370±990 (3560–8630)	320±70 (190–550)	–	Blanco *et al.* [7]
			ICP–MS	2009–2012	15.66±7.53 (ND–22)	ND	–	–	–	Carneiro *et al.* [31]
			ICP–MS	2009–2012	45.21±56.95 (ND–225)	74.93±84.64 (ND–313.4)	–	–	–	Carneiro *et al.* [31]
Marsh harrier	*Circus aeruginosus*	Spain	CVAAS– ICP–MS	1999–2000	–	43.2 (19.3–78.3)	–	–	299 (132–487)	Alvárez *et al.* [23]
Grey Heron	*Ardea cinerea*	Spain	AAS	1998	6	–	2200	352	–	Benito *et al.* [26]
			CVAAS– ICP–MS	1999–2000	–	288 269–342)	–	–	ND	Alvárez *et al.* [23]
White stork	*Ciconia ciconia*	Spain	AAS	1998	19 (6–121)	–	1900 (800–2800)	586 (180–1530)	–	Benito *et al.* [26]
			AAS	1999	29.14±22.88 (ND–104)	–	3260±960 (1240–5250)	424.34±84.30 (279–776)	–	Baos *et al.* [3]
			CVAAS– ICP–MS	1999–2000	–	121 (99.9–146)	–	–	382 (328– 445)	Alvárez *et al.* [23]
			AAS	2000	31.68±48.72 (ND–248)	–	2670±460 (1500–3700)	351.69±52.6 (236–503)	–	Baos *et al.* [3]
			AAS	1999	28.38±22.64 (ND–104)	–	3300±960 (1240–5250)	425.67±82.79 (279–776)	–	Baos *et al.* [21]
			AAS	2003	18.03±7.42 (6–36)	–	3290±370 (2660–4500)	319.74±88.34 (180–570)	–	Baos *et al.* [21]
			ICP–MS	2006–2008	27.07±48.86 (ND–259)	153.20±123 (5.97–457.40)	2340±250.70 (1817–2808)	558.40±141.00 (364–934)	461.00±70 (292–988)	Maia *et al.* [32]
			AAS	2006	–	–	9660±60 (9220–10150)	10880±1100 (1420–16490)	–	Kamiński *et al.* [33]
			AAS	2006	–	–	6870±1150 (430–11010)	7610±810 (4820–13710)	–	Kamiński *et al.* [33]
			AAS	2005–2007	–	–	11218±6016	9866±3402	–	Kamiński *et al.* [17]
			AAS	2005–2007	–	–	10037±5036	7424±2717.5	–	Kamiński *et al.* [33]
			ICP–MS	2013	9.81±2.09 (2.87–94)	16.48±1.94 2.65–63.25	–	–	–	Pérez–López *et al.* [28]

Data are shown as x̄±SD, Atomic absorption spectrophotometry (AAS), Cold Vapor Atomic Absorption Spectroscopy (CVAAS), and Inductively Coupled Plasma Mass Spectrometry (ICP–MS) areas with high agricultural, industrial, and urban pollution and due to their life history characteristics, it is important to monitor the extent of pollution [7, 23]. Pollutants may be associated with environmental factors and the level of pollutant accumulation varies according to sampling sites, chemical properties, quantity, and the species (species, age, sex, habitat, exposure time, varying feeding characteristics, behavior, and biomass). Heavy metals should be assessed by considering species–specific reference values [2, 23, 34, 35]. Reference values for poisoning were not found in the literature reviews.

CONCLUSIONS

In conclusion, this study is a preliminary study for future studies as it is a study to determine heavy metal (As, Hg, Zn, Cu and Se) levels in birds of prey and bird species living in aquatic habitats with blood samples in Turkey. Necessary measures should be taken to mitigate the threats that predatory birds in terrestrial and aquatic habitats would be exposed to with toxicological studies to be carried out at temporal and spatial scales. It is important to monitor the persistent effects of toxic substances on wild birds, their effects on wild animal populations, and the trends in pollutant concentrations to understand the extent of heavy metal pollution and to protect the ecosystem and human health. When developing pollution monitoring plans, species–specific differences should be taken into account. A perspective for environmental biomonitoring and toxicological risk assessment should be established.

Conflict of interest

The authors declare that have no conflicts of interest.

BIBLIOGRAPHIC REFERENCES

[1] Baos R, Blas J, Bortolotti GR, Marchant, TA, Hiraldo F. Adrenocortical response to stress and thyroid hormone status in free–living nestling white storks (*Ciconia ciconia*) exposed to heavy metal and arsenic contamination. Environ. Health Perspect. [Internet]. 2006; 114(10):1497–1501. doi: https://doi.org/cwqz77

[2] de la Casa–Resino I, Hernández–Moreno D, Castellano A, Soler–Rodríguez F, Pérez–López M. Biomarkers of oxidative status associated with metal pollution in the blood of the white stork (*Ciconia ciconia*) in Spain. Toxicol. Environ. Chem. [Internet]. 2015; 97(5):588–598. doi: https://doi.org/mg34

[3] Baos R, Jovani R, Pastor N, Tella JL, Begona J, Gomez G, Gonzalez MJ, Hiraldo, F. Evaluation of genotoxic effects of heavy metals and arsenic in wild nestling white storks (*Ciconia ciconia*) and black kites (*Milvus migrans*) from southwestern Spain after a mining accident. Environ. Toxicol. Chem. [Internet]. 2006; 25(10):2794–2803. doi: https://doi.org/d48bh2

[4] Carneiro M, Colaço B, Brandão R, Ferreira C, Santos N, Soeiro V, Colaço A, Pires MJ, Oliveira PA, Lavín S. Biomonitoring of heavy metals (Cd, Hg, and Pb) and metalloid (As) with the Portuguese common buzzard (*Buteo buteo*). Environ. Monit. Assess. [Internet]. 2014; 186(11):7011–7021. doi: https://doi.org/f6kzv3

[5] Manzano J, Méndez–Fernández P, Gil–Jiménez E, Romero D, Ferrer M. Temporal trends of inorganic elements in a common kestrel (*Falco tinnunculus*) population from southwest Spain. Environ. Pollut. [Internet]. 2021; 274:116447. doi: https://doi.org/mg36

[6] Kitowski I, Kowalski R, Komosa A, Sujak A. Total mercury concentration in the kidneys of birds from Poland. Turk. J. Zool. [Internet]. 2015; 39(4):693–701. doi: https://doi.org/mg37

[7] Blanco G, Frías O, Jiménez B, Gómez G. Factors influencing variability and potential uptake routes of heavy metals in black kites exposed to emissions from a solid–waste incinerator. Environ. Toxicol. Chem. [Internet]. 2003; 22(11):2711–2718. doi: https://doi.org/dgr7z7

[8] Fox GA. Wildlife as Sentinels of Human Health Effects in the Great Lakes. St. Lawrence Basin. Environ. Health Perspect. [Internet]. 2001; 109(6):853–861. doi: https://doi.org/d4xpjv

[9] Pérez–López M, Hermoso de M. M, López–Beceiro A, Soler–Rodríguez F. Heavy metal (Cd, Pb, Zn) and metalloid (As) content in raptor species from Galicia (NW Spain). Ecotoxicol. Environ. Saf. [Internet]. 2008; 70(1):154–162. doi: https://doi.org/bksxfr

[10] Pérez–López M, Cid F, Oropesa AL, Fidalgo LE, López–Beceiro A, Soler F. Heavy metal and arsenic content in seabirds affected by the Prestige oil spill on the Galician coast (NW Spain). Sci. Total Environ. [Internet]. 2006; 359(1–3):209–220. doi: https://doi.org/fcwp8h

[11] Ütme Ö, Temamoğullari F. Analysis of some heavy metals (Cd and Pb) in the Şanlıurfa province using Feral pigeon blood samples. Turkish J. Vet. Anim. Sci. [Internet]. 2021; 45(2):311–317. doi: https://doi.org/mg38

[12] Grúz A, Mackle O, Bartha A, Szabó R, Déri J, Budai P, Lehel J. Biomonitoring of toxic metals in feathers of predatory birds from eastern regions of Hungary. Environ. Sci. Pollut. Res. [Internet]. 2019; 26(25):26324–26331. doi: https://doi.org/mg39

[13] Kitowski I, Jakubas D, Wiącek D, Sujak A, Pitucha G. Trace element concentrations in livers of Common Buzzards *Buteo buteo* from eastern Poland. Environ. Monit. Assess. [Internet]. 2017; 189(8):421. doi: https://doi.org/mg4b

[14] Ding J, Yang W, Yang Y, Ai S, Bai X, Zhang Y. Variations in tree sparrow (*Passer montanus*) egg characteristics under environmental metal pollution. Sci. Total Environ. [Internet]. 2019; 687:946–955. do: https://doi.org/mg4c

[15] Wu X, Cobbina SJ, Mao G, Xu H, Zhang Z, Yang L. A review of toxicity and mechanisms of individual and mixtures of heavy metals in the environment. Environ. Sci. Pollut. Res. [Internet]. 2016; 23(9):8244–8259. doi: https://doi.org/ghw7vj

[16] Malvandi H, Shamabadi MH. Use of Feathers from Birds that Collided with Vehicles to Monitor Heavy Metal Contamination in Western Khorasan Razavi, Iran. Bull. Environ. Contam. Toxicol. [Internet]. 2022; 109(3):495–501. doi: https://doi.org/mg4d

[17] Kamiński P, Kurhalyuk N, Kasprzak M, Jerzak L, Tkachenko H, Szady–Grad M, Klawe JJ, Koim B. The impact of element–element interactions on antioxidant enzymatic activity in the blood of white stork (*Ciconia ciconia*) chicks. Arch. Environ. Contam. Toxicol. [Internet]. 2009; 56(2):325–337. doi: https://doi.org/chgb7q

[18] Montañez JC, Arribére MA, Rizzo A, Arcagni M, Campbell L, Ribeiro–Guevara S. Zinc in an ultraoligotrophic lake food web. Environ. Sci. Pollut. Res. [Internet]. 2018; 25(16):15422–15435. doi: https://doi.org/gdwkc5

[19] Xu EG, Lin N, Cheong RS, Ridsdale C, Tahara R, Du TY, Das D, Zhu J, Silva LP, Azimzada A, Larsson HCE, Tufenkji N. Artificial turf infill associated with systematic toxicity in an amniote vertebrate. Proc. Natl. Acad. Sci. U.S.A. [Internet]. 2019; 116(50):25156–25161. doi: https://doi.org/gq2jf3

[20] Kierczak J, Potysz A, Pietranik A, Tyszka R, Modelska M, Néel C, Ettler V, Mihaljevič M. Environmental impact of the historical Cu smelting in the Rudawy Janowickie Mountains (south-western Poland). J. Geochem. Explor. [Internet]. 2013; 124:183–194. doi: https://doi.org/mg4f

[21] Baos R, Jovani R, Forero MG, Tella JL, Gómez G, Jiménez B, González MJ, Hiraldo F. Relationships between T-cell-mediated immune response and Pb, Zn, Cu, Cd, and as concentrations in blood of nestling white storks (*Ciconia ciconia*) and black kites (*Milvus migrans*) from Doñana (southwestern Spain) after the Aznalcóllar toxic spill. Environ. Toxicol. Chem. [Internet]. 2006; 25(4):1153–1159. doi: https://doi.org/bv267z

[22] Zhang HH, Wu ZF, Yang CL, Xia B, Xu DR, Yuan HX. Spatial Distributions and Potential Risk Analysis of Total Soil Selenium in Guangdong Province, China. J. Environ. Qual. [Internet]. 2008; 37(3):780–787. doi: https://doi.org/bc87gv

[23] Alvárez CR, Moreno MJ, Alonso LL, Gómara B, Bernardo FJG, Martín-Doimeadios RCR, González MJ. Mercury, methylmercury, and selenium in blood of bird species from Doñana National Park (Southwestern Spain) after a mining accident. Environ. Sci. Pollut. Res. [Internet]. 2013; 20(8):5361–5372. doi: https://doi.org/f5bjd3

[24] Ackerman JT, Herzog MP, Evers DC, Cristol DA, Kenow KP, Heinz, G. H., Lavoie, RA, Brasso, RL, Mallory, ML, Provencher, JF, Braune, BM, Matz A, Schmutz JA, Eagles-Smith CA, Savoy LJ, Meyer MW, Hartman CA. Synthesis of Maternal Transfer of Mercury in Birds: Implications for Altered Toxicity Risk. Environ. Sci. Technol. [Internet]. 2020; 54(5):2878–2891. doi: https://doi.org/ghkcg9

[25] He C, Su T, Liu S, Jiang A, Goodale E, Qiu G.Heavy Metal, Arsenic, and Selenium Concentrations in Bird Feathers from a Region in Southern China Impacted by Intensive Mining of Nonferrous Metals. Environ. Toxicol. Chem. [Internet]. 2020; 39(2):371–380. doi: https://doi.org/mg4g

[26] Benito V, Devesa V, Muñoz O, Suñer MA, Montoro R, Baos R, Hiraldo F, Ferrer M, Fernández MA, González MJ. Trace elements in blood collected from birds feeding in the area around Donana National Park affected by the toxic spill from the Aznalcollar mine. Sci. Total Environ. [Internet]. 1999; 242(1-3):309–323. doi: https://doi.org/dj7w8z

[27] Bjedov D, Mikuška A, Velki M, Lončarić Z, Mikuška T. The first analysis of heavy metals in the Grey Heron *Ardea cinerea* feathers from the Croatian colonies. Larus-Hrvat. Akad. Znan. i Umjet. [Internet]. 2020; 55(1):7–25. doi: https://doi.org/mg4j

[28] Pérez-López M, De la Casa-Resino I, Hernández-Moreno D, Galeano J, Míguez-Santiyán MP, de Castro-Lorenzo A, Otero-Filgueiras M, Rivas-López O, Soler F. Concentrations of Metals, Metalloids, and Chlorinated Pollutants in Blood and Plasma of White Stork (*Ciconia ciconia*) Nestlings From Spain. Arch. Environ. Contam. Toxicol. [Internet]. 2016; 71(3):313–321. doi: https://doi.org/f83989

[29] Jackson AK, Evers DC, Etterson MA, Condon AM, Folsom SB, Detweiler J, Schmerfeld J, Cristol DA. Mercury Exposure Affects the Reproductive Success of a Free-Living Terrestrial Songbird, the Carolina Wren (*Thryothorus ludovicianus*). The Auk. 2011; 128(4):759–769. doi: https://doi.org/fh32h6

[30] Beyer WN, Meador JP, editors. Environmental Contaminants in Biota: Interpreting Tissue Concentrations. 2nd. ed. Boca Raton, Florida, USA: CRC Press. 2011. p. 669-696

[31] Carneiro M, Oliveira P, Brandão R, Soeiro V, Pires MJ, Lavin S, Colaço B. Assessment of the exposure to heavy metals and arsenic in captive and free-living black kites (*Milvus migrans*) nesting in Portugal. Ecotoxicol. Environ. Saf. [Internet]. 2018; 160(6):191–196. doi: https://doi.org/mg5k

[32] Maia AR, Soler-Rodriguez F, Pérez-López M. Concentration of 12 Metals and Metalloids in the Blood of White Stork (*Ciconia ciconia*): Basal Values and Influence of Age and Gender. Arch. Environ. Contam. Toxicol. [Internet]. 2017; 73(4):522–532. doi: https://doi.org/mg5m

[33] Kamiński P, Kurhalyuk N, Jerzak L, Kasprzak M, Tkachenko H, Klawe JJ, Szady-Grad M, Koim B, Wiśniewska E. Ecophysiological determinations of antioxidant enzymes and lipoperoxidation in the blood of White Stork *Ciconia ciconia* from Poland. Environ. Res. [Internet]. 2009; 109(1):29–39. doi: https://doi.org/bzc36v

[34] Eagles-Smith CA, Ackerman JT, De La Cruz SEW, Takekawa JY. Mercury bioaccumulation and risk to three waterbird foraging guilds is influenced by foraging ecology and breeding stage. Environ. Pollut. [Internet]. 2009; 157(7):1993–2002. doi: https://doi.org/cd6db8

[35] Borgå K, Campbell L, Gabrielsen GW, Norstrom RJ, Muir DCG, Fisk AT. Regional and species specific bioaccumulation of major and trace elements in Arctic seabirds. Environ. Toxicol. Chem. [Internet]. 2006; 25(11):2927–2936. doi: https://doi.org/dhvhf4

[36] Temamoğullari F, Dinçoğlu AH. Şanlıurfa ve Çevresindeki Kuyu Sularında Çinko ve Selenyum Düzeyleri. *Kafkas* Univ. *Vet. Fak. Derg*. [Internet]. 2020; 16(2):199–203. doi: https://doi.org/mg5p

[37] Tokatli C. Drinking water quality assessment of ergene river basin (Turkey) by water quality index: Essential and toxic elements. Sains Malays. [Internet]. 2019; 48(10):2071–2081. doi: https://doi.org/mg5q

[38] Yabanli M, Tay S. Selenium and mercury balance in sea bream obtained from different living environments in Turkey: a risk assessment for the consumer health. Environ. Sci. Pollut. Res. [Internet]. 2021; 28(27):36069–36075. doi: https://doi.org/gmpnk7