DOI: 10.2428/ecea.2014.21(4)36 ECOL CHEM ENG A. 2014;21(4):453-460

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EFFECT OF ROOK FAECES ON HEAVY METALS CONTENT IN SOIL AT NESTLING SITES

WPŁYW KOLONII LĘGOWYCH GAWRONA NA ZAWARTOŚĆ METALI CIĘŻKICH W GLEBIE

Abstract: The content of Cu, Fe, Zn, Cd and Pb in rook faeces from two colonies roosting in urban parks in Eastern Poland (Siedlce and Biala Podlaska) and the effect of the colonies upon the metals content in soil were analyzed. The analysis was carried out by comparing the chemical composition of soils at the nestling sites and at the control sites. Differences showed in metals content in the faeces depended on the localization of colonies. The colony from the former site significantly contributed to the content of Cu, Fe, Zn and Cd in soil. Neither of the rook colonies affected soil Pb levels. The chemical composition of rook faeces reflected the quality of the environment in which rooks feed. Our study findings show that the rook is particularly sensitive to local changes in metals content in the environment.

Keywords: rook, breeding colonies, faeces, soil, heavy metals, contamination, bioindicators

Introduction

Birds are used as bioindicators of heavy metal pollution of the environment, for which purpose both feathers [1–4] and bird eggs [5–7] and tissues (liver, lung, kidney, muscle and bone) [8–10] are examined. Numerous reports also recognize the potential of bird faeces as indicators of environmental contamination with trace metals [3, 11–15]. Bioindicative studies frequently use colonial birds. It must be emphasized that birds living in large colonies contribute towards the changes of soil properties caused by deposited bird excrement [4, 12, 14, 15].

There are relatively numerous data regarding water bird colonies contaminating soil with heavy metals [4, 7, 11, 12, 15]. Urban synanthropic birds, however, have been

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examined much more rarely [1, 2]. Among land birds, the rook (*Corvus frugilegus*) is often found roosting in urban parks. In spite of nesting in bigger villages and towns, the rook is strongly associated with open farmland, especially in Eastern Poland [16]. It is an omnivorous, opportunistic feeder with a broad diet and varied nutrient proportions mainly based on *Coleoptera* and cereal grains that are found in the arable fields [17, 18]. The decrease in the rook population in Europe could be the effect of the environment contamination with pesticides and heavy metals [19]. There are few reports concerning the impact of environment contamination on the rook and, on the other hand, the influence of the rook colonies on soil composition. Some authors dealt with the influence of *Corvus frugilegus* on organic matter and N and P contents in soils [20]. The latest study regarding the accumulation of metals in the tissues of the rook nesting in Eastern Poland (Siedlce and its vicinity) was carried out by Orłowski et al. [9, 10] and it indicated that high level of Cd and Pb in the rook tissues may result from its diet. The quality of the bird diet is also reflected in the chemical content of its faeces [11, 15].

Our studies focused on two rook colonies roosting in agricultural region of Eastern Poland: in Siedlce and Biala Podlaska. We analysed the concentrations of Fe, Cu, Zn, Cd and Pb in the rook faeces and determined the influence of the colonies on heavy metals contents in nestling soil samples. We hypothesized that the impact of the rook colonies on the quality of soils and the content of heavy metals in them is alike, irrespective of nests location.

Material and methods

Study area

The study area is situated in the macroregion of the South Podlasie Lowland in eastern Poland. The research included two breeding colonies of the rook inhabiting two urban parks in Biala Podlaska (52°02″N, 23°02″E) and Siedlce (52°10″N, 22°18″E). Both towns lay in an agricultural region within about 70 km of each other. The total area of Biala Podlaska equals 49.4 km^2 and its population is 58 000. Siedlce covers the area of 32 km^2 and its population is 77 000. In Siedlce there are some large industrial plants specializing in metal sector (*eg* a galvanizing plant), whereas no similar ones operate in Biala Podlaska. An international arterial road E2 (Berlin–Moscow) and a major railway route are located in the close vicinity of the two towns.

The urban park in Biala Podlaska is located at the area of about 6 ha. The research focused on its southern part where 224 nests of the rook were found. The tree stand in the park, mainly represented by maple tree (*Acer platanoides*), European ash (*Fraxinus Excelsior*), horse-chestnut (*Asculus hippocastanum*), common alder (*Alnus glutinosa*) and common hornbeam (*Carpinus betulus*), comprises about 60 % of the park area. The park undergrowth comprises about 10 % and the lawns about 30 % of the whole area. In the studied north-eastern part of the park in Siedlce (with the total area of about 11 ha) there were 736 rook nests found. About 80 % of the terrain is covered with the tree stand mainly represented by white elm (*Ulmu leavis*), horse-chestnut (*Asculus hippocastanum*), European ash (*Fraxinus Excelsior)* and small-leaf line (*Tilia cordata*).

Sample collection

Soil samples were collected at the end of October 2009. In each park 10 nestling and 10 control sites were chosen at random. At each site the surface of about 100 × 100 cm was marked off, followed by removing dead leaves and plants. Soil samples were collected at the depth of 20 cm from the surface. From each site three samples were collected, put into plastic bags and thoroughly mixed up. Altogether, 40 samples were collected.

Faecal samples, including fresh dropping samples, were taken from four sites in each colony of *Corvus frugilegus* during April 10–30, 2009. The bird faeces were collected into plastic boxes from the sites located under the rook nests.

Sample preparation and analysis

The soil and faecal samples were air dried in the clean laboratory. The soil samples were sieved through a sieve of 2 mm mesh size and 1 g samples were mineralized in mixture of HNO_3 (68 %) and H_2O_2 (30 %) in a microwave mineralizer concentrated nitric acid enriched in oxide hydrogen (3 : 2 cm^3). After mineralization the samples were transferred quantitatively to 25 cm^3 flasks and topped up with distilled water. Faecal samples were dried to constant mass at a temperature 60 ^oC. The samples were homogenized in an agate mortar. Subsamples of 0.5 g weight were mineralized alike the soil samples. The contents of iron, copper, zinc, lead, cadmium in soil and faeces samples were marked with the use of AAS technique (an apparatus manufactured by Carl Zeiss Jena), using acetylene-air flame for analysis: Fe, Cu, Zn, Pb. The content of Cd in samples was determined by means of a graphite cell used as an excitation source. Standard solutions within concentration ranges [$\mu g \cdot cm^{-3}$]: Fe: 50–300, Cu: 0.005–0.100, Zn: 0.5–10.0, Pb: 0.2–4.0 and Cd: 0.001–0.100 were used for the determination of individual metals. In cases of high metals content in the samples, exceeding the concentration range of standard solutions, the examined samples were diluted. Each analysis was repeated twice. Simultaneously, the analyses for the blank test were carried out [21].

On the basis of the results achieved, the mean values of studied parameters for both control points and contaminated sites were calculated. The normal distribution was checked with the use of Shapiro-Wilk's test. Differences between the mean content of individual metals in control points and at contaminated sites were tested with the use of Student's t-test. The content of metals in the rook faeces collected in the two towns was analysed with χ^2 test. All the calculations were done with the use of "Statistica, ver. 10.0."

Results

Out of the five metals examined: Fe, Cu, Zn, Cd and Pb, iron was found in the rook faeces in the highest concentrations (over 1000 $mg \cdot kg^{-1}$) while Cu and Cd concentrations were the lowest (below 1 $mg \cdot kg^{-1}$). The average iron content in the

rook faeces collected in Biala Podlaska was 1149.5 ± 208.9 mg · kg^{-1}, which was over twice lower than in Siedlce. (2659.3 ± 479.2 mg · kg^{-1}) (χ^2 = 7941.0 df = 3, p < 0.001). Mean values of lead in faeces measured for Siedlce (6.9 ± 2.15 mg/kg^{-1}) did not differ from those measured for Biala Podlaska (7.4 ± 1.70 mg/kg^{-1}, χ^2 = 2.39, df = 3, p = 0.496). However, the content of cadmium in rook faeces from Siedlce (0.94 ± 0.224 mg · kg^{-1}) was four times higher than in Biala Podlaska samples (0.26 ± 0.104 mg · kg^{-1}, χ^2 = 7.47, df = 3, p = 0.058). Also zinc content in rook faeces from Siedlce (41.05 ± 5.07 mg · kg^{-1}) was significantly higher than in the samples collected in Biala Podlaska (30.92 ± 2.69 mg · kg^{-1}, χ^2 = 14.12, df = 3, p = 0.003). However, copper content in the rook faeces collected in both towns was not statistically significant (χ^2 = 0.22, df = 3, p = 0.974) and it was estimated at 0.735 ± 0.128 mg · kg^{-1} in Biala Podlaska and 0.581 ± 0.062 mg · kg^{-1} in Siedlce.

In both towns the concentrations of Fe, Cu, Zn, Pb and Cd were higher at nestling sites than at controls, but in Siedlce the differences for Fe, Cu, Zn and Cd between the two sites were even more apparent (Table 1).

Table 1

Mean values of studied parameters in soils and the calculated values of Student's t-test

Metal	Location	Site	Mean ± SD [mg · kg^{-1}]	Min-max [mg · kg^{-1}]	t	p
Fe	BP	n	3347.5 ± 1310.0	1688.3–5978.0	0.15	0.884
		c	3281.2 ± 541.2	2453.7–4523.0		
	S	n	5013.8 ± 1422.0	2917.3–7299.4	**2.80**	**0.012**
		c	3350.3 ± 1224.3	1526.0–5198.4		
Cu	BP	n	0.477 ± 0.227	0.210–0.990	1.54	0.140
		c	0.365 ± 0.057	0.280–0.450		
	S	n	0.526 ± 0.158	0.340–0.892	**3.63**	**0.002**
		c	0.289 ± 0.135	0.136–0.631		
Zn	BP	n	68.12 ± 56.35	10.66–238.7	0.40	0.690
		c	37.85 ± 11.90	17.76–54.47		
	S	n	60.51 ± 24.32	34.80–110.7	**2.47**	**0.024**
		c	39.37 ± 21.62	15.63–93.36		
Pb	BP	n	23.85 ± 21.88	6.42–75.65	0.37	0.716
		c	21.11 ± 8.42	11.92–40.30		
	S	n	15.63 ± 4.95	8.59–23.34	0.33	0.745
		c	14.92 ± 4.64	9.57–24.61		
Cd	BP	n	0.12 ± 0.10	0.020–0.410	1.60	0.127
		c	0.07 ± 0.04	0.010–0.180		
	S	n	0.20 ± 0.16	0.014–0.461	**2.81**	**0.012**
		c	0.05 ± 0.04	0.006–0.127		

* BP – Biala Podlaska, S – Siedlce, n – nestling sites, c – control sites.

Discussion

Environmental research indicates that birds, on the one hand, contribute to the changes of soil properties caused by deposited faeces [4, 12, 14, 20], and, on the other hand, they are used as bioindicators of environmental contamination by heavy metals [1, 2, 4, 7, 8, 11, 12, 15]. Depending on the type of food consumed and its sources, birds contribute to soil contamination with certain elements. This holds particularly true for colonial birds such as the rook, which was indicated in the present study.

In both towns metal concentrations in the soil were higher at the nestling sites than at the controls. Statistically significant differences in metals content (Fe, Cu, Zn and Cd) between the nestling sites and the controls were observed in Siedlce. Also Fe, Zn and Cd concentrations in the rook faeces in Siedlce were higher than those in Biala Podlaska. Elevated levels of metals in rook faeces sampled in Siedlce, as opposed to those from Biala Podlaska, may indicate higher concentrations of these elements in the former environment, in which the birds fed. Numerous reports point out the fact that birds are sensitive to variation in food available [22–24]. The species under discussion employs a gregarious feeding strategy based on probing the ground [16, 25]. Greater metal values in the rook faeces in Siedlce and a strong influence of the colony of *Corvus frugilegus* roosting in Siedlce upon elevated levels of iron, copper, zinc and cadmium may indicate that environmental levels of these metals are higher around Siedlce than around Biala Podlaska.

During the past years researches on metals concentrations in soil samples taken at random points throughout Siedlce and Biala Podlaska have shown similar lead concentrations in both towns, estimated at 22.6 mg · kg^{-1} [26] and 23.9 mg · kg^{-1} [27] respectively, almost twice greater values of soil iron in Siedlce (2817.0 mg · kg^{-1}) than in Biala Podlaska (1501.7 mg · kg^{-1}), also two times higher concentrations of Cd (0.31 mg · kg^{-1}) and Cu (6.87 mg · kg^{-1}) in Siedlce [26] than in Biala Podlaska (0.15 mgCd · kg^{-1} and 3.70 mgCu · kg^{-1}) [28]. In Siedlce zinc was present in soil at a higher concentration estimated at 43.2 mg · kg^{-1} than in Biala Podlaska (30.1 mg · kg^{-1}). Increased Cd and Zn concentrations in soil in Siedlce, as opposed to Biala Podlaska, may be the result of the local emission of these metals from the galvanizing plant in the former. This was pointed out in the study by Krolak et al [28], in which the dust monitoring results for Siedlce were reported.

The results seem to prove the usefulness of rook faeces as an indicator of metal levels in the environment in which birds feed.

Metals content in bird faeces is determined by a number of factors including the type of bird food, the behaviour and physiological features of birds as well as environmental quality [12, 15]. Metals concentration values in rook faeces sampled in Siedlce and in Biala Podlaska either fell within the range reported for other bird species or were lower (Table 2). The levels of Cd and Pb content in rook faeces in the research area roughly corresponded with those estimated by Spahn and Sherry [13] in the faeces of the blue heron chicks (*Egretta caerulea*) in south Louisiana wetlands.

What is interesting, exactly the same range of Pb content as measured by the authors was estimated by Yin et al [15] in the faeces of the Red-footed Booby (*Sula sula*).

However, considerably higher Zn concentrations, compared to rook faeces, were estimated in the faeces of the Red-footed Booby (*Sula sula*) by Yin et al [15], Caspian Gull (*Larus cachinnans*) by Otero [12], Great Tit (*Parus major*) and Blue Tit (*Parus caeruleus*) by Dauwe et al [3] (Table 2).

Table 2

Heavy metals in faeces of birds according to literature data

Species of birds	Metal [mg · kg^{-1}]					References
	Cu	Fe	Zn	Pb	Cd	
Parus major and *Parus caeruleus*	36.16		400.4–429.4	2.34 –80.4	5.72–16.8	[3]
Rissa tridactyla and *Larus hyperboreus*	5.7–65.0	716–517	63–261	17–32		[11]
Larus cachinnans	30.4–73.9		165.9–397.9	22.9–55.1	2.1–7.7	[12]
Egretta caerulea				1.45–1.59	0.11–0.34	[13]
Sula sula	21.1		419.4		6.34	[14]
	20.0		450	4.26–9.48		[15]
Corvus frugilegus	0.49–0.87	877–3041	27.8–47.0	4.26–9.48	0.14–1.22	Present paper

Contrary to the reports of Orlowski et al. [9, 10], our research shows no evidence that the rook roosting near Siedlce is exposed to excessive Cd and Pb. Based on Cd and Pb estimates in the rook tissues (liver, kidney, lung, bones and muscles), ranging from 17.0–17.2 mgCd · kg^{-1} and 5.0–6.2 mgPb · kg^{-1}, the Authors drew conclusions about acute cadmium contamination and an elevated level of lead in the environment. They reported particularly high levels of Cd, the concentrations of which in all examined tissues were almost identical and ranged between 17.0 and 17.2 mg · kg^{-1} d.m. Our findings show that soil cadmium levels near Siedlce and Biala Podlaska are at least 100 times (or by two orders of magnitude) lower than lead levels. According to Orlowski et al [9, 10], however, Cd concentration in rook tissues was about three times as high as Pb level. The level of cadmium in the tissues of the rook from Siedlce, as estimated by Orlowski et al [9, 10], is surprisingly high. When analyzing the data reported by Orlowski et al [9, 10], we were puzzled at the sample weights (liver, kidney, lung, bones and muscles) ranging between 5 and 151 mg. Sample weights as low as several milligrams are too small to permit accurate determination of trace amounts of cadmium. The cadmium estimates obtained by the Authors might therefore result from the fact that the metal was contained in the reagents used for analysis (so-called blind test).

According to Market [29], a bioindicator is an organism that contains information on the quality of the environment. The rook is particularly sensitive to local environmental contamination by heavy metals taken up with food. Therefore this species can be a good bioindicator of the quality of the environment.

Conclusions

The presence of the rook nestling sites influences the increase of heavy metals content (Zn, Cd, Cu and Fe) in soil.

The content of heavy metals in soil at nestling sites reflects the chemical composition of the rook faeces.

Heavy metals concentration in the rook faeces is determined by the metals content in the environment in which the rook feeds.

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WPŁYW KOLONII LĘGOWYCH GAWRONA NA ZAWARTOŚĆ METALI CIĘŻKICH W GLEBIE

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Abstrakt: Analizowano zawartość metali Cu, Fe, Zn, Cd i Pb w odchodach gawrona bytującego w dwóch koloniach zlokalizowanych w parkach miejskich na terenie wschodniej Polski (Siedlce i Biała Podlaska) oraz wpływ kolonii na zawartość tych metali w glebach. Analizy wpływu kolonii gawrona na zmiany właściwości gleb dokonano, porównując skład chemiczny gleb na stanowiskach pod gniazdami ptaków i na stanowiskach kontrolnych. Odnotowano statystycznie większą zawartość Fe, Zn i Cd w odchodach ptaków gniazdujących na terenie Siedlce niż w Białej Podlaskiej. Istotny, na zawartość Cu, Fe, Zn, Cd i Pb w glebie, okazał się wpływ siedleckiej kolonii gawronów. Nie wykazano wpływu kolonii gawrona na zmiany zawartości Pb w glebie. Skład chemiczny odchodów jest odzwierciedleniem jakości diety ptaków. Przeprowadzone badania wykazały, że gawron jest gatunkiem szczególnie wrażliwym na lokalne zmiany zawartości metali w środowisku.

Słowa kluczowe: gawron, kolonia lęgowa, odchody, gleba, metale ciężkie, zanieczyszczenie, bioindykacja