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TOTAL MERCURY CONCENTRATION IN KIDNEYS OF BIRDS OF PREY FROM DIFFERENT PART OF POLAND - SOME INTERSPECIES AND GEOGRAPHICAL DIFFERENCES

STĘŻENIA RTĘCI W NERKACH PTAKÓW DRAPIEŻNYCH Z RÓŻNYCH OBSZARÓW POLSKI - ZRÓŻNICOWANIE MIĘDZYGATUNKOWE I GEOGRAFICZNE

Abstract: Mercury concentration levels in kidneys of 46 individuals of 13 species of birds of prey have been determined. The greatest mean concentration of mercury in kidneys was found in White-tailed Eagle *Haliaeetus albicilla* 1.54 mg/kg d.m. however the maximum concentration of mercury in kidney was determined in a Eurasian Buzzards *Buteo buteo*: 4.54 mg/kg d.m. The level of mercury concentration in kidneys of young individuals of raptors was lesser than in adults. In the light of research carried out birds of prey feeding and hunting birds accumulated less mercury in their kidneys in comparison with species whose diet was based on small mammals. Birds of prey bound with the agricultural landscape of north-east Poland seem to accumulate more mercury in kidneys as compared with raptors who originate from other parts of Poland.

Keywords: mercury, raptors, owls, Poland, kidneys, agriculture

Mercury and its compounds are included among the most toxic substances found in the ecosystems [1]. However only after the Minamata tragedy (Japan, 1953-1960) interest in the processes of accumulation of mercury in different compartments of ecosystems began to increase [1, 2]. Simultaneously it is necessary to bear in mind that mercury not

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only takes part in a number of complex environmental cycles in aquatic environment but also in atmospheric ones [1, 3].

In Poland for years, significant quantities of mercury were emitted into the environment by coal fired power plants. In addition to this, in areas of intense agricultural growth significant amounts of fungicidal seed dressings based on organomercury compounds were used. In the past in Poland five organomercury compounds were used for dressing of seeds. Agrotechnical use of organomercury compounds was estimated on 6,000÷30,000 kg yearly in 1970-1975 [4]. And even at present, Poland occupies the second position in the total anthropogenic mercury emission ranking in the EU [5]. The above - mentioned reasons showed that monitoring of accumulation levels of mercury is necessary not only in aquatic organisms, but also among organisms populating other habitats. For many years good models in researching the accumulation of different metallic pollutants have been key organs of avian top predators, particularly the kidneys. Moreover, metallic pollutants, such as mercury, cause organ damage as well as metabolic and behavioural disorders in vertebrates [6-8].

The aim of this research was to determine the concentration levels of mercury in kidneys in 13 species of diurnal and nocturnal raptors from different parts of Poland which have different habitat and trophy collection preferences.

Methods

Kidneys used in this research came from birds which were wounded during the breeding season, and were delivered to veterinary clinics or rehabilitation centers close to their nesting place in the years 2005-2007 (with the exception of one specimen of Great Spotted Eagle, *Aquila clanga*, found during autumnal migration).

Table 1

Concentration of mercury in kidney [mg/kg] of 46 individuals of studied birds of prey: N - number of samples, Std. dev. - standard deviation of measurement, ad. - adult, juv. - juvenile. In the case of maximum concentration levels in kidneys of adult individuals the upper index indicates the area of origin: NE Poland, CE Poland and SE Poland

Species	N	Mean	Std. dev.	Median	Max	Min.
		[mg/kg]				
Great-spotted Eagle *Aquila clanga ad.*	1	0.510	-	-	-	-
Lesser-spotted Eagle *Aquila pomarina ad*.	2	0.982	0.431	0.982	1.413 ^{NE}	0.550
Common Kestrel *Falco tinunnculus ad.*	4	0.300	0.234	0.099	0.998 ^{CE}	0.001
Eurasian Buzzard *Buteo buteo ad.*	10	0.595	0.451	0.020	4.539 ^{NE}	0.001
Honey Buzzard *Pernis apivorus ad.*	1	0.337	-	-	-	-
Eurasian Marsh Harier *Circus aeruginosus juv.*	2	0.0015	0.0003	0.0015	0.0025	0.0004
Sparrowhawk *Accipiter nisus ad.*	10	0.180	0.096	0.017	0.961 ^{NE}	0.0005
Goshawk *Accipiter gentilis ad*.	1	0.078	-	-	-	-
Goshawk *Accipiter gentilis juv*.	1	0.0037	-	-	-	-
White-tailed Eagle *Haliaeetus albicilla ad*.	4	1.542	0.917	0.742	4.285 ^{NE}	0.401
Common Barn Owl *Tyto alba ad.*	2	0.372	0.078	0.372	0.450 ^{NE}	0.294
Long-eared owl *Asio otus ad.*	2	0.148	0.148	0.148	0.296 ^{NE}	0.001
Tawny Owl *Strix aluco ad.*	4	0.193	0.083	0.187	0.395 ^{NE}	0.001
Ural Owl *Strix uralensis ad.*	2	0.184	0.183	0.185	0.367 ^{SE}	0.001

The birds, despite intensive treatment in veterinary clinics and rehabilitation centers either died or upon determining that they were untreatable, were put down to relieve them from unnecessary suffering by humane methods (lethal injection) by qualified and certified veterinary doctors. The time of stay of the bird in the veterinary clinic or rehabilitation centres up until the moment of the death never exceeded seven days. All kidneys examined came from adult individuals (marked as *adultus* = *ad.*) with the exception of two ones, Eurasian Marsh harrier *Circus aeruginosus* and one individual of Goshawk *Accipiter gentilis*, who were juveniles (the first year birds, marked as *juvenis* = *juv.*) (see Table 1).

The names of locations in which birds were found are given below; number of specimens was also given. The upper index labeled the region of Poland from which the specimen came, in the form of letters: CE - central-east Poland, NE - north-east Poland, SW - southwest Poland, NW - northwest Poland. Kidney of the following diurnal birds of prey were examined: Great Spotted Eagle: Garwolin^{CE} - 1 *ad*., Lesser Spotted Eagle *Aquila pomarina*: Łomża^{CE} - 1 *ad*., Olsztyn^{NE} - 1 *ad*., Eurasian Buzzard *Buteo buteo*: Lublin^{SE} - 5 *ad*., Świdnik^{SE}, - 1 *ad*., Olsztyn^{NE} - 1 *ad*., Wichrowo^{NE} - 1 *ad*., Suwałki^{NE} - 1 *ad*., Warsaw^{CE} - 1 *ad*., Honey Buzzard *Pernis apivorus*: Mikołów^{SW} - 1 *ad*., Eurasian Marsh Harrier: Kock^{SE} - 2 *juv*., Sparrowhawk *Accipiter nisus*: Barciany^{NE} - 1 *ad*., Lublin^{SE} - 1 *ad.*, Łomża^{CE} - 1 *ad*., Świdnik^{SE} - 1 *ad.*, Krutyń^{NE} - 2 *ad.*, Suwałki^{NE} - 2 *ad*., Wyszków^{CE} - 1 *ad.*, Warsaw^{CE} - 1 *ad*., Goshawk: Sobibór^{SE} - 1 *ad*., Lublin^{SE} - 1 *juv*., White-tailed Eagle *Haliaeetus albicilla*: Drawsko Pomorskie^{NW} - 1 *ad.*, Garwolin^{CE} - 1 *ad.*, Gościeradów^{SE} 1 *ad.*, Olsztyn^{NE} - 1 *ad*. All specimens of Common Kestrel *Falco tinnunculus*, from which kidneys were taken, came from cities: Warsaw^{CE} - 3 *ad.* and Lublin^{SE} - 1 *ad.*

In addition, a similar analysis of kidneys of owls, was carried out: Common Barn Owl *Tyto alba*: Padlewo^{NE} - 1 *ad*., Niemsty^{NE} - 1 *ad*., Long-eared owl *Asio otus* Białystok^{CE} - 1 *ad*., Giżycko^{NE} - 1 *ad*., Tawny Owl *Strix aluco*: Garwolin^{CE} - 1 *ad.*, Mrągowo^{NE} - 1 *ad*., Olsztyn^{NE} - 1*ad*., Pisz^{NE} - 1 *ad*. and Ural Owl *Strix uralensis*: Sanok^{SE} - 1 *ad*., Oświęcim^{SW} - 1 *ad*.

Kidneys, after being obtained from the bodies of birds, were stored in freezers up until their analysis, and finally air - dried. Mercury content in samples prepared in such a way was determined using a not-flame atomic spectrometry absorption technique (mercury analyzer: AMA 254, Altec, Czech Republic). During analysis in the AMA 254, kidney samples were predried (at 120°) in the internal oven of the analyzer and burned in oxygen (of 99.999% purity) at 550°. The decomposition products were further carried by oxygen flow to an Au-amalgamator for selective mercury trapping. A short heat-up of amalgamator caused the release of mercury and measured it by a cold vapour AAS technique at λ = 253.65 nm in dual-path length (long and short) cuvette. Hence the same quantity of mercury was measured twice at different sensitivities, resulting in a dynamic range enabling mercury determination in the range from 0.05 to 600 ng in single measurement [9]. The detection limit was 10^{-5} mg/kg. The values of calibration made by producer were controlled regularly by the calibration standard mercury solution (AccuTrace single Element standard; AccuStandard Inc., New Haven, CT, USA). Both kidneys of one bird were considered as one sample to be analyzed (no division between right and left kidney were carried out).

Results

As it is seen from Table 1, in spite of the fact that the largest average concentration of mercury among studied birds was shown in White tailed-eagles: 1.542 mg/kg d.m., the maximum value: 4.539 mg/kg d.m. was determined in an individual species of Eurasian Buzzard, found wounded after crash with high tension wire lines near Olsztyn (NE Poland). It was also ascertained that the average concentration of mercury in ten Eurasian Buzzards studied showed relatively high values: 0.595 mg/kg d.m., losing out only to average concentrations in White-tailed Eagles and Lesser Spotted Eagles (Tab. 1). In spite of the fact that samples of only single specimens of Great-spotted Eagle and Honey Buzzard were subjected to analysis, the concentrations of mercury were comparable with the concentrations found in kidneys of Eurasian Buzzards (Tab. 1). Particular attention needs to be paid to the concentration levels of one deadly wounded Honey Buzzard found in the region of Mikołów, which was the only insectivorous species of raptor in our study (Tab. 1). Observed levels of concentration were high (but not the highest), which may be explained by the fact that this sample came from strongly industrialized areas of Upper Silesia. The level of mercury was also analyzed in four kidney samples of adult individuals of Common Kestrel which coming from urban area exclusively. However, the level of mercury in those samples was twice lower than those found in Eurasian Buzzards (Tab. 1).

During the study ten samples from four species of owls were analyzed. Among these, both average mercury concentration as well as the highest concentration levels was found in Barn Owls (Tab. 1). Moreover, average concentration levels in kidneys of Long-eared owls were 2.5 times lower than those shown in Barn Owls (Tab. 1). In the case of Tawny Owls and Ural Owl a great similarity was determined in average mercury concentration levels as well as median concentrations in both species (Tab. 1). Only three samples of juvenile raptors were accessible. Determined mercury concentration in these samples turned out to be many times lower than those found in adult birds. In the case of a young Goshawk the concentration levels were as much as 26.5 times lower than those of adult specimen, in which the concentration level of mercury was at 0.078 mg/kg d.m. (Tab. 1). A broad range of data was not available for us to show the levels of mercury concentration in kidneys of adult Eurasian Marsh Harriers. One can however compare the determined mercury concentration levels with data received from other diurnal birds of prey. It turns out that the average concentration level for both juvenile specimens of Eurasian Marsh Harriers was as much as 52 times lower in comparison with the level shown by an adult Goshawk. The last mentioned species showed the lowest level of mercury concentration among all adult specimen samples analyzed by us (Tab. 1).

Among the nine studied species of raptors, for whom data of the level of mercury concentration in kidneys was available from at least two adult samples, from at least two different regions of Poland and from non-urban areas, the maximum concentration levels in seven cases were shown by kidneys of birds originating from NE Poland (Tab. 1). The concentration levels of mercury in the kidneys of specimens from areas of NE Poland, dominated by agriculture landscape belonging to extensive area farming, most often former monocultured state-owned farms, turned out to be many times larger in comparison with specimens from other parts of Poland. This is the best illustrated by data of

concentration levels presented in particular places, shown in Figures 1 and 2, in relation to samples of Sparrowhawk and Common Buzzard.

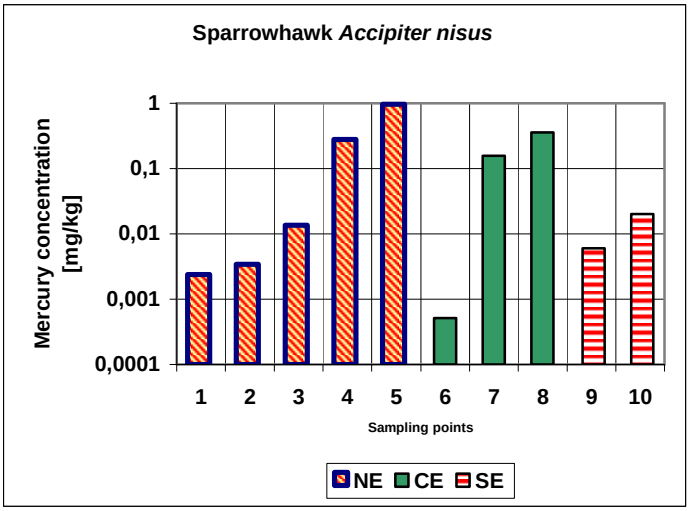

Fig. 1. Average mercury concentration in kidneys of Sparrowhawk *Accipiter nisus* [mg/kg] coming from North-eastern (NE), Central-eastern (CE) and South-eastern (SE) Poland. Places of collecting birds: 1 and 3 - Krutyń, 2 and 4 - Suwałki, 5 - Barciany, 6 - Warsaw, 7 - Łomża, 8 - Wyszków, 9 - Lublin, 10 - Świdnik

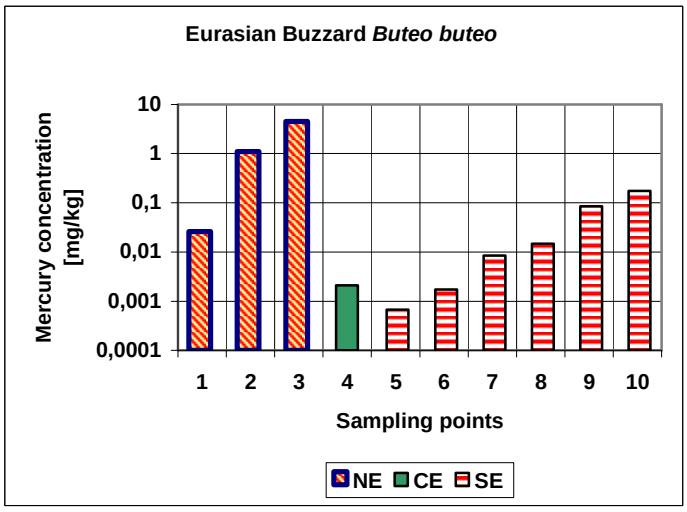

Fig. 2. Average mercury concentration in kidneys of Eurasian Buzzard *Buteo buteo* [mg/kg] coming from North-eastern (NE), Central-eastern (CE) and South-eastern (SE) Poland. Places of collecting birds: 1 - Wichrowo, 2 - Wigry, 3 - Olsztyn, 4 - Warsaw, 5, 6, 7, 9 and 10 - Lublin, 8 - Świdnik

Discussion

The highest concentration levels of birds studied were found in White tailed-eagles. In this way, the highest levels of mercury concentration in kidneys of picivorous birds observed by other authors were confirmed in relation to other trophic groups of birds [2, 10-12]. This is caused by the fact that in aquatic environments mercury compounds are transformed by microorganisms to highly toxic metaloorganic compound - methylmercury. This is a lipophilic compound and bioaccumulates in the aquatic food webs. Therefore, predators related to aquatic food webs are exposed to higher mercury levels compared with terrestrial food web [1, 2, 10-12]. The most important data from Poland on renal mercury concentration in White-tailed Eagles originates from research in the early 90's by the Falandysz team [13]. These authors analyzed the renal mercury concentration levels in ten specimens, arriving at an arithmetic mean of 52.0 ± 16.0 mg/kg dry mass (at a range of 1.4÷220 mg/kg). However, two of Eagle individuals, originated from breeding sites at the Baltic coast, analyzed by the Falandysz team, revealed the mercury concentration in kidneys at extremely high levels of 190÷220 mg/kg d.m. and in the case of three other individuals' mercury concentration was found in levels ranging between 22÷49 mg/kg d.m. However, a half of the studied specimens of the Baltic White-tailed Eagles had mercury concentration levels of 1.4÷7.3 mg/kg d.m., the data which corresponds with results received by us in average and maximum concentration levels in kidneys of Eagles. Studying the scope of mercury concentration levels we have to realize that White-tailed Eagles are birds which were in no way connected with coastal areas and their diet in large part is based on other birds [14].

The studies presented on White-tailed Eagles reflected and confirm a current decline of environmental mercury concentration in animals related to water habitats perhaps due to a ban of organomercury seed dressing. This may answer in part the occurrence of lower concentration levels in kidneys of White-tailed Eagles from the 90's in comparison with those from the 60's of twentieth century [15]. The second of the species of aquatic environment studied by us were the Great Spotted Eagles. The concentration levels in the specimen turned out to be however as much as three times lower in comparison with White-tailed Eagles (Tab. 1), which may be accounted for by different feeding preferences of both species of raptors found in wetland areas. Great Spotted Eagles diet consists in large part in water animals, such as water birds and amphibians [16].

The remaining diurnal birds of prey and owls studied by us are the species which are nesting in terrestrial habitats. The highest renal mercury concentration levels were found in Lesser Spotted Eagle. We do not have comparative data of concentration levels in this species. In considering mercury concentration levels in kidneys of Lesser Spotted Eagle and Eurasian Buzzards in Poland, particular attention should be paid to the fact that in most feeding areas and important part of their diet is food gathered in wetlands which consists mainly of amphibian *Amphibia* and molluscs [17-19]. From the literature data it is apparent that amphibians play an important role in the retention of mercury in aquatic and terrestrial habitats [1]. On the other hand, in many areas, an important component of food for Lesser Spotted Eagle and Eurasian Buzzards are voles *Microtus* sp. [17, 18, 20**]**.

In Golden Eagles *Aquila chrysaetos* from the Alps the mean renal mercury concentration was 0.016 mg/kg wet mass (ranged from ND to 0.039 mg/kg) [21], which is a decidedly lower value than that determined from eagles of the *Aquila* genus, studied by

us. This, on the one hand, shows that a diet based on medium size mammals, birds and carrion, especially during the winter season flatters the birds [21, 22], and, on the other hand, shows relatively low level of mercury from anthropogenic sources in the alpine area.

Kidneys analyzed by us, derived from adult species of Eurasian Common Buzzards (ten specimens) in eastern Poland, accumulated on average 0.595 mg/kg d.m. of mercury. The same numbers of samples from Eurasian Common Buzzards nesting in Central parts of Moravia (Czech Republic) were also analyzed by Houserova et al [2, 3]. The mercury concentration levels in kidneys found in those species was higher on average 2.0 ± 0.15 mg/kg d.m, and the range narrowed than that received by us, ie 1.09÷2.65 mg/kg d.m. (Tab. 1). This can be accounted for by the decidedly smaller area from which samples came in comparison with birds studied by Houserova et al [2, 3]. However, the maximum mercury concentration level determined by us in a wounded specimen of Eurasian Buzzards from the vicinity of Olsztyn (Tab. 1) is decidedly higher than maximal level found in kidneys of Buzzards from Czech Republic. Despite high mortality rates and ease of obtaining sample materials, studies on mercury concentrations in kidneys of owls are very rare. Horai et al [12] gives average value of mercury concentration levels in Ural Owl from industrial vicinity of Tokyo (Japan) at 3.18 ± 4.99 mg/kg (ranged from 0.039 to 15.5 mg/kg). The lower threshold level of mercury accumulation turned out to be comparable with data received by us. During the studies of kidneys of owls we ascertained that the highest level is connected with Barn Owls. Such synanthropic owls, like Barn Owls, nest in areas of human habitation, in many cases near large warehousing facilities, barns and other buildings where seed were dressed with mercury compounds and sowing seeds were stored. A detailed study of the feeding habits of Barn Owls points to a high rate of synanthropic small mammals in their diet [23]. For this reason Barn Owls have more opportunities to accumulate mercury pollutants in comparison with typically wood habitat species, such as the Ural and Tawny Owls.

The affirmed accumulation of mercury levels in kidneys ascertained by us in juvenile birds was many times lower than that found in adult birds. In studies of other birds it was also shown, that mercury concentration levels in kidneys of adults birds were higher than those in juveniles and chicks [3, 10]. However, we should be aware that mercury accumulation with growth may not be important in some birds since much of the body burden of mercury is removed through moulting [10].

Concentration level determined by us in an adult Goshawk was lower in comparison with other studies carried out from the area of Japan [12], which were at 4.29 ± 12.0 mg/kg d.m. (12 samples), but still corresponds to the bottom threshold in the indicated work (the range of values were 0.075÷42.4 mg/kg d.m.). Comparative data from earlier studies on the subject of mercury levels in kidneys from Goshawks from Germany are available [24]. Birds studied there, both adult and juveniles (n = 61), accumulated mercury in their kidneys at levels of 0.066 mg/kg wet mass (median) at a range of ND ÷ 1.170 mg/kg wet mass, what is comparable to our results.

In the light of studies carried out, diurnal raptors which hunt on other birds, (Sparrowhawk and Goshawk) accumulated less mercury in their kidneys in comparison with species whose diet consisted of small mammals (rodents), for example Eurasian Buzzard. Above observation is in the contrast to results of studies from the period in which dress-

ing of seeds using on large scale mercury compounds were common practice in farming. At that time, species of birds *Accipiter* genus which preyed on other birds were found to accumulate the largest amount of mercury because they hunted birds for whom an important part of their diet were dressed seeds [25, 26]. The mobility of mercury in terrestrial environment and its potential impacts on raptors are largely undocumented phenomena. Although, based on trophic relationships, some studies showed a possibility of transfer of mercury through various compartments of the ecosystem to small mammals [27]. It may correspond with higher mercury concentration in Eurasian Buzzards kidneys than hawks from *Accipiter* genus. It was a possibility of comparing of mercury levels accumulated in kidneys in at least two adult birds from different regions of Poland in seven species of raptors studied by us. In all cases higher concentration levels pertained areas of northeast Poland. Additionally, relatively high levels of mercury concentration found in two samples of Barn Owls from agricultural areas of NE Poland, seem to confirm these results. In the case of NE Poland the presence of mercury observed in our study is in large surely a result of dressing of seeds and in this way mercury was introduced to local terrestrial and aquatic ecosystems. These areas were dominated by the huge former monocultured state-owned farms, which consumed enormous quantities of chemicals, including mercury based fungicides [28]. Fortunately, mercury and its alkylated forms have not been employed as fungicides for the dressing of seeds in Poland from early 70's. Even now, when mercury based fungicides are not used in agricultural practice for years, this metal is still present in elevated concentrations in areas of NE Poland [29, 30].

Conclusions

Our study shows that raptors found in water habitats exhibit higher levels of accumulated mercury concentration in kidneys. The species which had the highest mercury concentration level was the White-tailed Eagle *Haliaeetus albicilla*. Elevated levels of mercury accumulation were mainly exhibited by birds from NE Poland. Mass application of mercury based fungicides, particularly intensively used in dressing of seeds at former state-owned farms caused the presence of mercury in biotic components of habitats where intensive agricultural activity was carried out.

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STĘŻENIA RTĘCI W NERKACH PTAKÓW DRAPIEŻNYCH Z RÓŻNYCH OBSZARÓW POLSKI - ZRÓŻNICOWANIE MIĘDZYGATUNKOWE I GEOGRAFICZNE

Abstrakt: Zbadano poziomy stężeń rtęci w nerkach 46 osobników z 13 gatunków ptaków drapieżnych. Największe średnie stężenie rtęci, wynoszące 1,54 mg/kg suchej masy, oznaczono w nerkach bielika *Haliaeetus albicilla*. Natomiast maksymalne stężenie wynoszące 4,54 mg/kg suchej masy stwierdzono u myszołowa *Buteo buteo*. Wykazano również, że osobniki młode mają mniejsze koncentracje rtęci w nerkach w porównaniu z dorosłymi ptakami. Przeprowadzone badania pozwoliły ustalić, że drapieżniki polujące na ptaki kumulują w nerkach mniejsze ilości rtęci niż drapieżniki o diecie składającej się z drobnych ssaków. Drapieżniki związane z obszarami rolniczymi północno-wschodniej Polski kumulowały w nerkach większe ilości rtęci w porównaniu z ptakami z innych części Polski.

Słowa kluczowe: rtęć, ptaki drapieżne, Polska, nerki, rolnictwo