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# INVESTIGATION ON THE DISTRIBUTION OF MERCURY IN TISSUES AND ORGANS OF WILD BIRDS OBTAINED FROM THE AREA COVERED BY GREATER WARSAW

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**Abstract**

The material for investigations was composed of samples of tissues and internal organs of 20 birds. The aim of the work was to analyze the mercury distribution in tissues and organs of wild birds. The following body organs were sampled: chest muscles, femoral muscles, heart muscle, bones, intestines, liver, kidney, lungs, gizzard, the mucosa of the stomach and brain. The content of mercury in the samples was determined by the method of atomic absorption spectrometry (AAS). Based on the results and supported by the relevant literature, certain regularities emerged in the distribution of mercury in tissues and organs of wild birds. The organs with the highest accumulation of mercury were the kidney, liver, cardiac muscle and skeletal muscles. The smallest concentration of mercury appeared in the lungs, bones and the brain. The distribution of mercury depended on the tissue, indicating that the alimentary tract is the main gate through which mercury penetrated into birds' organisms, in a way corresponding to their eating prefences. The highest concentrations of this element were ascertained in the little grebe feeding on aquatic organisms and small fish. The lowest concentrations of mercury appeared in town-dwelling pigeons.

**Key words**: mercury, wild birds, contamination, tissues, organs.

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# INTRODUCTION

Rapid development of civilisation which ignores the principles of sustainable development has contributed to the creation of technologies devoid of the so-called clean and zero-waste production. The consequence is environmental pollution with chemical substances on both the local and global scale.

Mercury is an extremely toxic element, although cases of mercury poisoning are only sporadically reported. In the past, it was used in the past as an active ingredient in ointments, parasiticidals, antiseptics, disinfectants, diuretics and fungicides. Mercury can be a source of environmental contamination when present in seed dressing fungicides, anti-slime fungicides in the pulp and paper industries, by-products of burning coal, mine tailings and waste from chlorine and alkali industries

Mercury compounds which are able to migrate to all elements of the natural environment, including terrestrial and aquatic food chains, are the most dangerous. The use of mercury fungicides in agriculture has contributed to the accumulation of mercury in soils. Seed dressing enriched soils with *ca* 10 g Hg $ha^{-1}$. Plant contamination with mercury in croplands was small. Seed-eating birds are occasionally affected by toxic mercury after feeding on mercury fungicide treated seed. Contamination of granivorous food chain was first noticed in the 1950s in Sweden, when various bird species had disappeared: pigeons, pheasants, partridges and others (BORG 1958, LINDBERG, ODSJÖ 1983).

The second link in this terrestrial food chain was composed of diurnal and nocturnal birds of prey like e.g.: the kestrel, white-tailed eagle, peregrine falcon, goshawk and the eagle owl. Birds of these and other species died or lost reproductive abilities due to the thinning of egg shells and breaking eggs by nesting birds. In many regions of Sweden, kestrels were almost extinct and the number of peregrine falcons and goshawks markedly declined (BORG et al. 1970). During the period when alkyl mercury was used in agriculture in Sweden (1940-1966), elevated mercury levels were reported among many of the common prey species of the peregrine. Samples of pigeons, i.e. wood pigeons, feral pigeons and stock dove (*Columba oenas*), from 1956-63 averaged 10.6 ppm w.w. in mixed kidney-liver tissues, corresponding to a level of about 3.5 ppm w.w. in muscles assuming the ratio between muscles and liver kidney of 0.3 (BORG et al. 1970).

Mercury levels in food webs in southern Sweden were at least 25 times higher during that period compared with residues in 1976-1977. Corresponding high levels were also found in peregrines and the concentrations were probably so high that they lowered both reproduction and survival (LINDBERG, ODSJÖ 1983). The sex of a bird can, in principle, affect exposure to and accumulation of mercury.

One conventional explanation for the sex differences in mercury burden suggests that female birds should have lower concentrations than conspecific males, because breeding females can depurate methylmercury to their eggs. It is true that eggs of several birds from aqueous reservoirs should not be eaten by sensitive humans due to high levels of mercury (EICHLER 1982, BURGER et al. 1997).

Mercury, which is eliminated from the female via egg laying, has been reported to cause abnormal egg laying behaviour, impaired reproduction, slowed duckling growth and altered duckling behaviour in mallard ducks (KHERA 1979, WOLFE et al. 1998, HEINZ, HOFFMAN 2003, BURGESS, MEYER 2008) Ingested mercury is rapidly absorbed by the intestinal tract and stored in the kidney and liver. A similar situation was also observed in other areas (LINDBERG, ODSJÖ 1983).

Mercury also enters aquatic food chains with industrial waste waters and surface runoff from fields. It accumulates in subsequent links of food chains leading to a situation when its concentration in tissues of piscivorous birds goes up to a level that would be lethal to granivorous field birds (SCHEUHAMMER et al. 2009).

Most of the mercury in birds is in the form of methylmercury and comes from the diet. Although the consumption of fish is the main pathway for methylmercury in humans, for there are few people who eat piscivorous birds, such as fish-eating seabirds and ducks (e.g., mergansers), this is a potentially significant source of mercury exposure. Granivorous game birds such as doves, quail and pheasants tend to have low mercury levels and pose a small threat to a human consumer (SCHEUHAMMER 1987, WOLFE et al. 1998, BRASSO, CRISTOL 2008, SCHEUHAMMER et al. 2009)

Even doves that have fed on hazardous waste sites, such as the contaminated lakebed of Par Pond, a Superfund site in South Carolina, have accumulated little mercury (BURGER et al. 1997).

This study was aimed at determining the distribution of mercury in tissues and internal organs of wild birds. It was part of a study on mercury transformation in birds and on critical accumulation of mercury in these animals. The study will facilitae an assessment of the environmental loading by this heavy metal because of the direct dependence of wild birds on local food resources.

## MATERIAL AND METHODS

The material consisted of samples of tissues and internal organs of 20 birds. The birds died when crashed against the walls of the Palace of Culture (16 individuals) or were found dead in other places of Warsaw (4 individuals). Collected individuals represented the following species: the song thrush *Turdus philomelos* Brehm 1831(6 birds), the woodcock *Scolopax rusticola* Linnaeus, 1758 (3 birds), the kestrel *Falco tinnunculus* Linnaeus, 1758

(3 birds including one chick), the blackbird *Turdus merula* Linnaeus, 1758 (2 birds). The great spotted woodpecker *Dendrocopus major* Linnaeus, 1758, the feral pigeon *Columbia livia* forma *urbana*, Gmelin, 1789, the icterine warbler *Hippolais icterina* Vieillot, 1817, the crow *Corvus corone* Linnaeus, 1758, the skylark *Alauda arvensis* Linnaeus, 1758, and the little grebe *Tachybeptus ruficollis* Pallas, 1764, were represented by one bird each. Pectoral muscles, femoral muscles, heart, bones, intestines, liver, kidney, lungs, gizzard, stomach mucus and brain were taken for analyses. Until analyses, the material was stored in a refrigerator at -21°C.

The content of mercury in studied samples was analysed with atomic absorption spectrophotometry (AAS) using an automatic mercury analyser AMA-254 made by the Czech firm Altec. The apparatus works on the basis of atomic absorption spectrophotometry and is controlled by the AMA computer software. The method consists in measurements of the absorption spectrum of a lamp with a mercury cathode. The sensitivity is 0.01 ng Hg and the measurement range is from 0.05 to 600 ng. The maximum weight of a sample should not exceed 300 mg.

Concentrations of mercury in analysed samples are given in mg per 1 kg of tissue mass. Each analysis was triplicated and the result is a mean of three measurements. The apparatus was calibrated with the solution of polarographically pure mercury in 2% $HNO_3$. Arithmetic mean, standard deviation, minimum and maximum values were calculated and obtained results were statistically processed using Statgraphic 4 + computer package.

## RESULTS AND DISCUSSION

Concentrations of mercury in samples of tissues and organs varied substantially both across tissues and bird species (Table 1) and were related to the feeding habits of birds. High standard deviation from the mean was mainly the result of extremely high mercury concentrations noted in practically all tissues and organs of the little grebe.

Irrespective of the bird species, concentrations of mercury in analysed tissues decreased in the following order: kidneys, liver, heart muscle, pectoral muscles, intestines, femoral muscles, gizzard, lungs, brain, bones and stomach mucus (Table 1).

Absolute amounts of mercury depend on a bird's feeding habit, but within the distinguished groups there were interspecific differences. The lowest mercury concentrations were found in omnivorous birds, which, due to specific urban conditions, included also the feral pigeon, a granivorous bird when feeding in the wild. Relatively low mercury concentrations were noted in the birds of prey represented here by three kestrels (including one chick). Low tissue contamination by mercury in these birds is understood since they all were relatively young (adult kestrels were no more than one year old).

Table 1

The content of Hg in tissues and internal organs of wild birds (mg kg$^{-1}$ fresh weight)

| No. | Bird species | Pectoral muscles | Femoral muscles | Heart | Bone | Intestines | Liver | Kidney | Lungs | Gizzard | Stomach mucosus | Brain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ***Turdus philomelos*** *Turdus philomelos melos* | 0.004 | 0.003 | 0.006 | 0.005 | 0.010 | 0.018 | 0.019 | 0.004 | 0.003 | 0.002 | 0.004 |
| 2 | ***Turdus philomelos*** | 0.003 | 0.005 | 0.004 | 0.001 | 0.010 | 0.012 | 0.014 | 0.004 | 0.003 | 0.004 | 0.002 |
| 3 | ***Turdus philomelos*** | 0.005 | 0.009 | 0.016 | 0.003 | 0.014 | 0.015 | 0.029 | 0.002 | 0.003 | 0.013 | 0.008 |
| 4 | ***Turdus philomelos*** | 0.001 | 0.002 | 0.002 | 0.002 | 0.019 | 0.011 | 0.045 | 0.011 | 0.007 | 0.014 | 0.004 |
| 5 | ***Turdus philomelos*** | 0.002 | 0.004 | 0.013 | 0.004 | 0.006 | 0.050 | 0.053 | 0.009 | 0.007 | 0.009 | 0.014 |
| 6 | ***Turdus philomelos*** | 0.001 | 0.001 | 0.002 | 0.002 | 0.018 | 0.032 | 0.023 | 0.006 | 0.003 | 0.006 | 0.006 |
| 7 | ***Tachybeptus ruficolis*** | 0.704 | 0.454 | 1.331 | 0.088 | 0.783 | 1.094 | 1.498 | 0.619 | 0.992 | | |
| 8 | ***Falco tinnunculus*** | 0.016 | 0.011 | 0.010 | 0.004 | 0.033 | 0.052 | 0.022 | 0.019 | 0.012 | | 0.015 |
| 9 | ***Falco tinnunculus*** | 0.041 | 0.030 | 0.095 | 0.004 | 0.094 | 0.094 | | 0.056 | 0.001 | | 0.025 |
| 10 | ***Falco tinnunculus*** | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.002 | 0.001 | 0.001 | | 0.000 |
| 11 | ***Columbia livia*** | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | | 0.001 | | | |
| 12 | ***Hippolais icterina*** | 0.082 | 0.079 | 0.101 | 0.002 | 0.041 | 0.118 | 0.165 | 0.080 | 0.058 | 0.041 | 0.060 |
| 13 | ***Turdus merula*** | 0.004 | 0.003 | 0.007 | 0.003 | 0.006 | 0.021 | 0.053 | 0.003 | 0.010 | 0.006 | 0.004 |
| 14 | ***Turdus merula*** | 0.013 | 0.012 | 0.014 | 0.006 | 0.026 | 0.064 | 0.052 | 0.025 | 0.018 | 0.029 | |
| 15 | ***Corvus corone*** | 0.001 | 0.002 | 0.002 | 0.001 | 0.001 | 0.005 | 0.004 | 0.001 | 0.002 | 0.001 | |
| 16 | ***Dendrocopus major*** | 0.007 | 0.010 | 0.008 | 0.002 | 0.005 | 0.010 | 0.009 | | 0.006 | | |
| 17 | ***Alauda arvensis*** | 0.002 | 0.004 | 0.003 | 0.002 | 0.006 | 0.009 | 0.006 | 0.004 | 0.004 | | |
| 18 | ***Scolopax rusticola*** | 0.030 | 0.015 | 0.059 | | 0.125 | 1.377 | 0.141 | 0.055 | 0.043 | | |
| 19 | ***Scolopax rusticola*** | 0.427 | 0.483 | 0.421 | 0.022 | | | 0.958 | | | | 0.027 |
| 20 | ***Scolopax rusticola*** | 0.129 | 0.099 | 0.185 | 0.016 | 0.208 | 0.020 | 0.354 | 0.255 | | | 0.148 |
| | **Mean** | 0.074 | 0.061 | 0.114 | 0.009 | 0.078 | 0.158 | 0.192 | 0.064 | 0.069 | 0.013 | 0.024 |
| | **Standard deviation** | 0.177 | 0.142 | 0.303 | 0.020 | 0.184 | 0.384 | 0.398 | 0.151 | 0.238 | 0.013 | 0.041 |
| | **Maximum** | 0.704 | 0.483 | 1.331 | 0.088 | 0.783 | 1.377 | 1.498 | 0.619 | 0.992 | 0.041 | 0.148 |
| | **Minimum** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.001 | 0.001 | 0.001 | 0.000 |

Age has a limited effect on mercury concentrations in the birds' tissues. Mercury accumulated in internal tissues is excreted into the feathers and eliminated in the moult period. It is a way to remove mercury from a bird's body. However, most studies quoted by STEWART et al. (1997) found that mercury concentrations in adults were higher than in chicks or subadults.

Distinct differences in mercury contamination were found among birds feeding on invertebrates. The lowest concentrations of Hg were found in the song thrush (*Turdus philomelos*) and the highest – in woodcocks (*Scolapax rusticola*). There were several reasons for such differences. First, the diet of the song thrush is composed mainly of insects and berry fruits while woodcocks feed mainly on earthworms and other soil invertebrates. The origin and age of a bird are also important. The woodcock most severely contaminated with mercury was an adult bird banded in France, where loads of chemicals in agriculture and industries (and hence the environmental contamination) are incomparably higher than in Poland.

In agreement with the current knowledge of mercury cycling and transformation in aquatic ecosystems, the highest concentrations of mercury were found in the little grebe (*Tachybeptus ruficollis*), a bird feeding on aquatic organisms including small fish. Mercury concentration in muscles, liver and kidneys of this bird were by two orders of magnitude higher than in birds from terrestrial ecosystems. Similarly high were mercury concentrations in other tissues and organs. It has been thus confirmed that mercury accumulates in a trophic chain and that mercury in food is the most important source of contamination by this metal in natural conditions (KHERA 1979, LINDBERG, ODSJÖ 1983, SCHEUHAMMER 1987, BURGESS, MEYER 2008). Fish selectively accumulating mercury in their muscles are the source of contamination for the little grebe.

A very strong correlation was affirmed between the concentrations of mercury in individual tissues and organs, except the accumulation of mercury in the osseous tissue, which was independent from the rigors of this element in soft tissues (Table 2)

Table 2

The correlation coefficients among mercury concentrations in tissues and organs

| Tissues, organs | Femoral muscles | Heart | Bones | Liver | Gizzard | Stomach mucosa | Intestine | Kidney | Lungs | Brain |
|---|---|---|---|---|---|---|---|---|---|---|
| Pectoral muscles | 0.99** | 0.99** | - 0.24 | 0.93** | 0.99** | 0.94** | 0.90** | 0.95** | 0.99** | 0.98** |
| Femoral muscles | - | 0.99** | - 0.25 | 0.93** | 0.98** | 0.95** | 0.90** | 0.94** | 0.98** | 0.98** |
| Heart | | - | - 0.18 | 0.94** | 0.98** | 0.95** | 0.87** | 0.95** | 0.97** | 0.99** |
| Bones | | | - | -0.13 | - 0.24 | - 0.36 | - 0.50 | - 0.19 | - 0.28 | -0.19 |
| Liver | | | | - | 0.93** | 0.87** | 0.79* | 0.93** | 0.94** | 0.97** |
| Gizzard | | | | | - | 0,85** | 0.87** | 0.98** | 0.99** | 0.98** |
| Stomach mucosa | | | | | | - | 0,95** | 0.95** | 0.96** | 0.95** |
| Intestine | | | | | | | - | 0.82* | 0.92** | 0.86** |
| Kidney | | | | | | | | - | 0.96** | 0.96** |
| Lungs | | | | | | | | | - | 0.98** |

**Explanations**: * correlation coefficient for two variables $r_{xy}$ significant at $p \leq 0.05$, ** correlation coefficient $r_{xy}$ significant at $p \leq 0.01$

Earlier studies on mercury contamination of the skin and feathers of wild birds led to a hypothesis that periodical shedding of feathers enables birds to remove mercury excess from the organism. Data relating Mg feather levels to hatchability are more scanty, but in some species reduced hatching was observed in the 5-10 ppm range, while in others the levels of 40-70 ppm in feathers were associated with lowered reproduction (Adley, Brown 1972, Eisler 1987). Using 5 ppm in feathers as a criterion level, Burger and Gochfeld (1997) reported that the common loons were at considerable risk with an average feather mercury level of 10 ppm

## CONCLUSIONS

Based on the results and literature data, some regularities may be seen in the distribution of mercury in tissues and organs of wild, free-living birds.

1. Kidneys, liver, heart and skeleton muscles are the organs of largest mercury accumulation.

2. The lowest mercury concentrations are characteristic of lungs, bones and brain.

3. Distribution of mercury in birds' tissues in relation to feeding behaviour indicates that the alimentary tract is the main port of entry for mercury into birds' organisms.

4. The piscivorous little grebe was the most severely contaminated with mercury, while the granivorous feral pigeon was the least affected.

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