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Mercury content of common frogs (Rana temporaria L.) and common toads (Bufo bufo L.) collected in southern Finland

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In the southern Finnish rural municipality of Tuulos, which has a low environmental mercury load, the mean mercury contents of the common frog's (*Rana temporaria*) liver, kidney, muscle, lung and eggs ranged from 0.03 to 0.08 mgHg/kg fresh weight. In two sample localities within the cities of Helsinki and Porvoo the range of the corresponding means was somewhat wider, viz. 0.03-0.19 mgHg/kg fresh weight, but statistically significant differences were found only between the mean mercury content of the liver in the frogs from Tuulos and those of the frogs from both Helsinki and Porvoo. In Lake Kirkkojärvi in Hämeenkyrö, which is badly polluted by phenyl mercury compounds from a paper mill, only a minimal mercury load (less than 0.05 mgHg/ fresh weight) was recorded in the few small specimens studied. In the common toad (*Bufo bufo*) from the unpolluted Tuulos area the mean mercury content was highest in liver (0.12 ppmHg/kg fresh weight) and lowest in muscle tissue (0.03 ppmHg/kg fresh weight).

It was noted that the mean mercury content in the liver of southern Finnish frogs and toads was 3-10 times lower than in that of the same species from unpolluted areas of Yugoslavia and was as much as 110-420 times lower than in those from the mercury mining area of Idrija in Yugoslavia. With regard to the other tissues (kidney, muscle and lung), the corresponding differences were somewhat smaller.

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1. Introduction

During the past ten years much data has been published in Finland on the occurrence of mercury in plant and animal species representing different trophic levels and life forms in terrestrial and aquatic ecosystems (see e.g. Suckcharoen 1980). The tailless amphibians (Anura) have not been studied in this respect, although they form an important link between the food chains of aquatic and terrestrial ecosystems; their eggs and tadpoles develop in water but after metamorphosis the young become terrestrial and shift to prey on insects and other terrestrial invertebrates. In the following we report some preliminary data on the mercury contents of *Rana temporaria* and *Bufo bufo* collected in different parts of southern Finland. The purpose of our observations was not only to fill a gap in the Finnish data, but also to compare the mercury content in Finnish frogs and toads to that in the same species in Yugoslavia, where the background level of mercury is considerably higher than in Finland. The mercury contents of Yugoslavian amphibians has been studied by Byrne et al. (1975).

2. Sample sites and methods

The frogs and toads analysed originated from areas of southern Finland with unequal levels of environmental mercury, and most of them were captured at spawning time (Fig. 1, Appendix 1). The *Rana* individuals from the completely rural municipality of Tuulos were collected from cultivated fields and ditches in the vicinity of a farmhouse (Taipale) by Lake Oksjärvi. The *Bufo* individuals from this municipality were caught in a small (about 0.2 km^2) polyhumic pond called Okslampi. There are three small cultivated fields with ditches leading to the pond and one summer cottage close to the shore of Okslampi. Mixed forests comprise about 40 % of the shore line, the other 60 % being

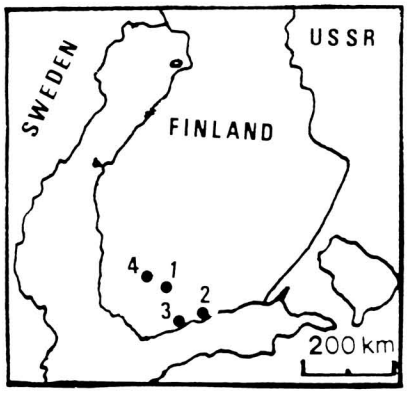

Fig. 1. Sample localities. 1. Tuulos, Oksjärvi/Okslampi. 2. Porvoo, Ruskis. 3. Helsinki, Pornaistenniemi. 4. Hämeenkyrö, Kirkkojärvi.

covered with peat-bog vegetation (*Sphagnum, Carex, Drosera* spp., *Phragmites, Myrica* and *Betula*).

The *Rana* individuals from Porvoo, Ruskis, were captured in spawning pools close to the mouth of the River Porvoonjoki. In Helsinki, Pornaistenniemi, we could only capture young frogs which had recently left their wintering sites at the mouth of the River Vantaanjoki. Both of these rivers carry considerable amounts of agricultural, industrial and urban wastes.

The mercury contents of the liver, kidney, hind-leg muscles, lung and eggs of the *Rana* and *Bufo* individuals from the above-mentioned areas were analysed by digesting the corresponding tissues with 10 ml of concentrated sulphuric and nitric acids (4:1) in a hot (+75 °C) aluminium block for four hours. The mercury contents were measured with cold vapour atomic absorption spectrophotometry (Coleman MAS-50).

In addition, we had some *Rana* specimens from the mercury-polluted Lake Kirkkojärvi in Hämeenkyrö. The degree of mercury contamination in the biota of this area has been described by Nuorteva et al. (1975). Our frogs from Kirkkojärvi were collected in 1976 and comprised 10 recently metamorphosed individuals (mean weight 0.7 g, length 2.2–2.8 cm), one young frog (1.7 g, 3.2 cm) which had undoubtedly metamorphosed in 1975, and one adult frog (24 g, 6.1 cm). The 10 youngest frogs were analysed together; the other two frogs were studied separately. All the samples from Hämeenkyrö were analysed by neutron activation analysis as described by Häsänen (1970).

For the primary data of the frog and toad individuals analysed see Appendix 1.

3. Results and discussion

Table 1 shows that the rate of mercury bioaccumulation in *Rana* and *Bufo* individuals has been low within the four Finnish sample areas. Considering all our *Rana* individuals, the mercury load was highest in the liver (mean ± S.E. = 0.11 ± 0.01 mgHg/kg fresh weight) and lowest in the hind-leg muscle tissue (0.05 ± 0.01 mgHg/kg fresh wt.). We could find no significant correlation between the fresh weight of *Rana* individuals and the mercury content of their tissues (liver, kidney, lung and muscle) either separately in the three areas (Tuulos, Porvoo and Helsinki) or if all the samples were pooled.

In *Rana* individuals from the Tuulos area the mean mercury contents of liver, kidney, lung and muscle did not differ significantly from each other, but, compared to the corresponding values in specimens from Helsinki and Porvoo, the amount of mercury in the liver of the Tuulos specimens was significantly lower than in the speciments from the two latter areas ($P_{\text{Tuulos x Helsinki}} \approx 0.05$, $P_{\text{Tuulos x Porvoo}} < 0.001$, t_{Cochran}-test). No significant differences could be detected with regard to the other tissues.

In Yugoslavian *Rana temporaria* and *Bufo bufo* individuals the mean mercury load was 6–9 times higher in liver than in muscle tissue (Table 1). Moreover, in the Idrija area, which is contaminated with mercury, the total mercury content of the liver in *Rana* and *Bufo* was up to 25.9 and 25.5 mgHg/kg fresh weight, respectively. However, in uncontaminated areas the corresponding values did not exceed 1.5 mgHg/kg fresh wt. (Byrne et al. 1975). Comparing the data in Table 1 we can conclude that the mercury load in the liver of Finnish frogs is about 3–10 times lower than in the unpolluted areas of Yugoslavia and 110–420 times lower than in the polluted Yugoslavian areas. The corresponding values are 6 and 180 times lower for the common toad in Finland than for the Yugoslavian specimens. With respect to the other tissues (kidney, lung, muscle and eggs) the differences are also very prominent, though somewhat smaller.

On the southern coast of Finland (Helsinki and Porvoo), the mercury load from atmospheric pollution is about 0.261 ± 0.066 mgHg/kg dry weight (mean ± SD) of the epiphytic lichen *Hypogymnia physodes* used as biological indicator (Lodenius 1981a), and in the surface soil there is 0.05–0.1 ppmHg/kg (Soveri 1977). For the Tuulos area the corresponding figures are 0.192 ± 0.059 ppmHg/kg in lichens and 0.03–0.08 ppmHg/kg in the surface soil. We can conclude that the mercury loads in *Rana* and *Bufo* individuals from Tuulos, Helsinki and Porvoo correspond well to the normal baseline mercury concentrations of the environments.

In the 1960s and 1970s Lake Kirkkojärvi and some other lakes along the watercourse of Hämeenkyrö were reported to be among the most polluted areas in Finland with respect to

Table 1. The mercury content of liver, kidney, lung and muscle tissues (mgHg/ kg fresh weight) in the common frog (*Rana temporaria*) and the common toad (*Bufo bufo*) collected in Finland and Yugoslavia. The Yugoslavian data are taken from Byrne et al. (1975).

	Liver		Kidney		Lung		Muscle		Eggs	
	n	Mean ± SE	n	Mean ± SE	n	Mean ± SE	n	Mean ± SE	n	Mean ± SE
Finland										
Rana temporaria										
Tuulos	9	0.06 ± 0.01	7	0.08 ± 0.03	9	0.07 ± 0.01	9	0.03 ± 0.00	3	0.02 ± 0.01
Porvoo	12	0.13 ± 0.04	10	0.05 ± 0.01	12	0.07 ± 0.02	12	0.06 ± 0.02	-	-
Helsinki	4	0.19 ± 0.04	1	0.03	4	0.08 ± 0.03	4	0.07 ± 0.03	-	-
Hämeenkyrö	1	0.05	-	-	-	-	1	0.04	-	-
—"—	1	specimen analysed *in toto*: 0.01								
—"—	10	specimens analysed *in toto*: 0.01								
Bufo bufo										
Tuulos	4	0.12 ± 0.02	3	0.08 ± 0.01	4	0.06 ± 0.01	4	0.04 ± 0.01	-	-
Yugoslavia										
Rana temporaria										
Background areas	1	0.48	-	-	-	-	-	-		
Contaminated area	2	21.05 ± 4.85	1	16.2	1	1.54	1	3.44	1	1.25
Bufo bufo										
Background areas	5	0.74 ± 0.22	4	0.68 ± 0.22	4	0.11 ± 0.03	4	0.12 ± 0.03	-	-
Contaminated area	4	21.75 ± 2.07	3	22.77 ± 0.91	3	1.47 ± 0.18	3	2.33 ± 0.47	2	2.23 ± 0.08

mercury (Nuorteva et al. 1975). This was due to the phenylmercury compounds used as slimicides by the pulp and paper industry. In the 1970s the environmental mercury load of the area decreased as a result of the mercury ban accepted by the Finnish paper industry at the end of the 1960s. In Lake Kirkkojärvi in 1974-76 there was about 1.7 mgHg/kg fresh weight, and in 1977-79 about 1.4 mgHg/kg fresh weight in pike (*Esox lucius*) weighing 4 kg and in 1976-79 about 0.43 mgHg/kg fresh weight in *Abramis farenus* (= *A. ballerus*), a cyprinid fish, weighing about 0.25 kg (Nuorteva et al. 1979). Our frog specimens from Kirkkojärvi in 1976, though few, indicate that the mercury content of *Rana temporaria* was low there.

According to Itämies & Koskela (1970) Finnish *Rana temporaria* individuals mainly consume insects, in particular coleopterans and flies, as well as terrestrial snails. Some plant material may be present in the gut, too. Nuorteva & Nuorteva (1982) pointed out that some sarcosaprophagous flies and staphylinid beetles have excretory mechanisms which enable them to inhibit high rates of mercury bioaccumulation. This is also true of many dipterous larvae feeding on macrofungi (Lodenius 1981b). Accordingly, the mercury content of many important prey animals of the frog may be low. This is also suggested by the mercury analysis of the gut content of the adult *Rana temporaria* from Lake Kirkkojärvi: the snails they had consumed contained only 0.03 mgHg/kg fresh weight. It seems that in Kirkkojärvi the frogs, though representating a rather high trophic level, are not an important pathway for the transfer of mercury along the food chains of aquatic and terrestrial ecosystems. The verification for this hypothesis still requires further study, especially of specimens from waters polluted with mercury.

In the vertebrate body the liver is known to play a detoxifying role, and through bile the liver eliminates heavy metals such as mercury, copper and zinc (Harper 1965). The importance of the liver in diminishing the bioaccumulation of mercury into living amphibian tissues is evidently indicated by the fact that the amphibians, unlike birds and mammals (see e.g. Nuorteva et al. 1975, Häkkinen & Häsänen 1980), cannot deposite mercury in the feathers or fur, as well as by the fact that the mercury values recorded in the liver were higher than those in the other tissues.

Almost all of the mercury in the muscles of the *Rana temporaria* and *Bufo bufo* individuals from Yugoslavia was in a methylated form, but in the liver and kidney there was less than 30 % methylmercury. As living organisms can excrete elementary mercury more quickly than organic mercury (Nuorteva & Nuorteva 1982), it is

astonishing that the Finnish frogs, in particular those from Lake Kirkkojärvi, have such low mercury contents, although in their environment the mercury is mainly in an organic form.

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Appendix 1. Sample site, date, fresh weight (g) and mercury contents (mgHg/ kg fresh weight) of liver, kidney, lung and muscle in the individuals of *Rana temporaria* and *Bufo bufo* analysed. In addition, the mercury contents of the eggs in the females indicated with asterisks were 0.02, 0.03 and 0.01 mgHg/ kg fresh weight, respectively.

	Fresh weight	Liver	Kidney	Lung	Muscle
Rana temporaria					
Tuulos, Oksjärvi, Taipale					
9.5.1981	36.2	0.07	0.07	0.06	0.04
—"—	39.6	0.06	0.08	0.04	0.02
—"—	34.7	0.07	0.05	0.06	0.03
16.5.1981	20.6	0.06	0.15	0.05	0.03
8.-9.8.1981	30.2*	0.07	0.00	0.07	0.02
—"—	19.0	0.04	-	0.07	0.02
—"—	27.4*	0.07	0.19	0.08	0.05
—"—	39.5*	0.04	-	0.15	0.03
—"—	24.0	0.04	0.02	0.06	0.02
Porvoo, Ruskis					
27.4.1983	44.0	0.14	0.14	0.09	0.06
—"—	37.5	0.15	-	0.08	0.05
—"—	41.4	0.11	-	0.06	0.05
—"—	49.5	0.24	0.00	0.10	0.07
—"—	26.8	0.21	0.10	0.09	0.07
—"—	45.2	0.11	0.05	0.06	0.05
—"—	56.3	0.12	0.04	0.06	0.06
—"—	44.7	0.08	0.03	0.06	0.03
—"—	42.9	0.12	0.05	0.02	0.05
—"—	34.0	0.11	0.04	0.05	0.08
—"—	22.4	0.05	0.00	0.00	0.03
—"—	36.8	0.13	0.04	0.11	0.07
Helsinki, Pornaistenniemi					
28.4.-3.5.1983	10.4	0.20	0.31	0.00	0.06
—"—	9.2	0.12	-	0.08	0.04
—"—	8.1	0.28	-	0.15	0.16
—"—	12.1	0.15	-	0.09	0.03
Hämeenkyrö, Kirkkojärvi					
24.8.1976	24.0	0.05	-	-	0.04
—"—	1.8	mercury content 0.01 ppm (analysed *in toto*)			
—"—	Mean = 0.7 (10 exx.)	mercury content 0.01 ppm (analysed *in toto*)			
Bufo bufo					
Tuulos, Okslampi					
17.5.1983	20.0	0.06	-	0.04	0.03
—"—	38.7	0.14	0.08	0.10	0.06
—"—	44.8	0.12	0.07	0.04	0.04
—"—	31.5	0.15	0.09	0.07	0.04

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