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Levels of Selenium in Relation to Levels of Mercury in Fish from Mjøsa, a Freshwater Lake in Southeastern Norway

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Mjøsa (365 km^2) is the largest freshwater lake in Norway. Several species of fish from this lake are used for human consumption. The lake is, however, contaminated with mercury, and large specimens of pike, burbot, perch and brown trout occasionally contain mercury in amounts exceeding the general guideline limits for human consumption (Sandlund et al. 1981).

In addition to its role as a micro nutrient, selenium exerts an antagonistic effect in mercury poisoning (Spallholz et al. 1981). The levels of selenium in fish from water systems contaminated with mercury are therefore of great interest. This is especially so in Norway, a country known as a low-selenium area. The present paper reports levels of selenium and their relationship to mercury accumulation in the flesh of fish from Mjøsa. For comparison, fish from five lakes in the surrounding area were also included in the investigation.

MATERIAL AND METHODS

Specimens of six species of fish were collected at three different sites in Mjøsa (Furnesfjorden, Ringsakerfjorden, Minnesund) in 1979-80. The material consisted of cisco, *Coregonus albula* (20), brown trout, *Salmo trutta* (18), smelt, *Osmerus eperlanus* (20), burbot, *Lota lota* (25), pike, *Esox lucius* (40) and perch, *Perca fluviatilis* (52). Additional specimens of perch were collected from five minor lakes in the same water system: Sillongen (13), Ottsjøen (20), Hersjøen (20), Matfartjern (20) and Losna (20). The situation of these lakes in relation to Mjøsa is shown in Fig. 1. The weights and the lengths of the fish were recorded, and their ages determined by examination of otholiths, operculum, scales or cleithrum. Samples of the dorsal muscles were collected and frozen at -20°C till analysed. Mercury content in the samples was determined by atomic absorption, cold vapor technique

(Hatch and Ott 1968) using a Coleman MAS 50 instrument. Selenium was determined by a spectrofluorimetric method (Ihnat 1974) after wet digestion with nitric and perchloric acid (Norheim and Nymoen 1981). The results are expressed as ppm (ug/g) on a wet weight basis.

RESULTS AND DISCUSSION

The results of the selenium and mercury analyses are presented i Table 1. The mean values of selenium in fish from Mjøsa varied from 0.21 ppm in pike to 0.30 ppm in perch, with a total range of 0.15-0.80 ppm. The differences between the species were statistically significant ($P<0.001$, f-test). In pike and perch from Mjøsa, small, but significant differences were found between the three catching sites. The highest mean values were found in fish from Ringsakerfjorden, 0.22 ppm in pike and 0.36 ppm in perch, while the lowest levels were found in fish from Minnesund, 0.17 ppm in pike and 0.26 ppm in perch. The average levels of selenium in perch from other lakes varied from 0.23 ppm in Sillongen to 0.64 ppm and 0.66 ppm in Hersjøen and Ottsjøen, respectively. The differences between the lakes were statistically significant ($P<0.001$).

Levels of mercury showed considerable more variation than selenium levels, with mean values from 0.21 ppm in cisco to 1.3 ppm in brown trout. The highest single value measured was 4.85 ppm in a 16 year old perch. The total age range in perch was up to 19 years. A

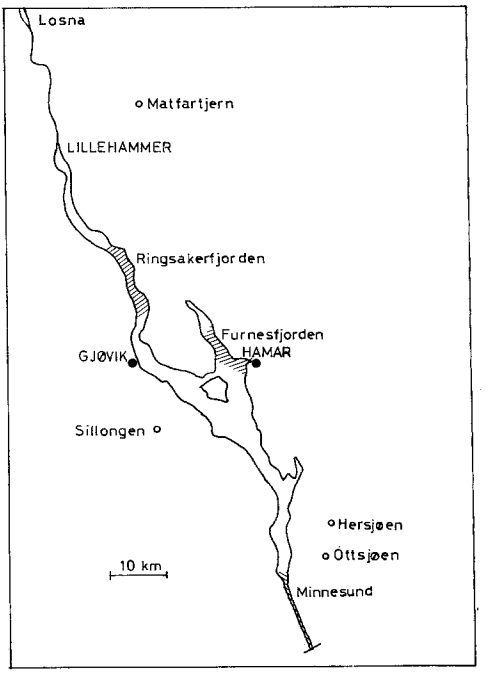

Figure 1. The location of the sites of collection in Mjøsa and the situation of the five surrounding lakes in relation to Mjøsa.

Table 1. Selenium and mercury levels (ppm wet weight), and the correlation between selenium and mercury (correlation coefficients) in fish from Mjøsa and five surrounding lakes in south-eastern Norway

	Lake	n	Se	Hg	r
Cisco *Coregonus albula*	Mjøsa	20	0.26±0.03	0.21±0.08	0.12
Brown trout *Salmo trutta*	Mjøsa	18	0.25±0.04	1.29±0.44	0.10
Smelt *Osmerus eperlanus*	Mjøsa	20	0.23±0.03	0.30±0.18	-0.31
Burbot *Lota lota*	Mjøsa	25	0.27±0.05	1.07±0.53	-0.12
Pike *Esox lucius*	Mjøsa	40	0.21±0.03	1.12±0.54	0.25
Perch *Perca fluviatilis*	Mjøsa	52	0.30±0.06	0.81±0.89	0.51
	Sillongen	13	0.23±0.03	0.23±0.08	0.06
	Ottsjøen	20	0.66±0.13	0.43±0.19	-0.43
	Hersjøen	20	0.64±0.12	0.45±0.22	0.30
	Matfartjern	20	0.35±0.03	0.25±0.12	-0.04
	Losna	20	0.40±0.09	0.23±0.25	0.79
Perch (total)		145	0.41±0.16	0.50±0.61	0.00

comprehensive report of mercury levels and the relationship to fish age has been given elsewhere (Sandlund et al. 1981).

Unlike mercury, selenium levels did not correlate with the age of the fish. Nor was there any overall correlation between selenium and mercury, samples high in mercury not having correspondingly high selenium levels. Though positive correlations were observed between mercury and selenium in perch from Mjøsa, and more so from Losna, a weak, inverse relationship seemed to exist in perch from Ottsjøen. These findings are illustrated in Fig. 2. Judging from the figure, it seems reasonable to suggest that the apparent correlation found in Losna and Ottsjøen is in fact due to a combination of a limited number of samples, and the narrow range exhibited by the mercury and selenium levels. The correlation observed in Mjøsa is due mainly to the large range in mercury concentrations. The overall correlation between mercury and selenium in perch from all localities was close to zero.

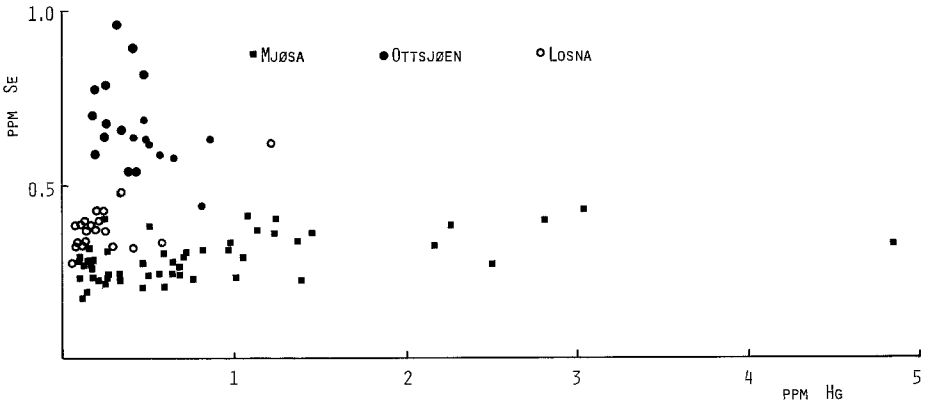

Figure 2. The relation between the levels of mercury and selenium in perch from the lakes Mjøsa, Ottsjøen and Losna.

On a molecular basis the Hg:Se ratios of the means varied from 2.1 in brown trout and pike from Mjøsa, the two species most heavily contaminated with mercury, to 0.2-0.4 in perch from the other lakes. Perch from Mjøsa, with an intermediary mercury load, had a ratio of 1.1.

Analysis of edible muscles of fish from Mjøsa, and some surrounding lakes, did not show up the presence of the same extremely low levels of selenium in fish, as have been found in grain and forages grown in the same part of the country (Frøslie et al. 1980). Fish supply significant amounts of selenium as compared with other foodstuffs. Bearing in mind the antagonistic effect of selenium, there is no reason to evaluate mercury contamination in fish as presenting a greater health risk than implied by present general recommendations.

Luten et al. (1980) reported mean values of selenium in pike, perch and pike-perch, from the Netherlands of 0.13, 0.24 and 0.26 ppm, respectively. Cappon and Smith (1981) reported similar levels in perch (0.17 ppm) and slightly higher levels in northern pike (0.35-0.44 ppm) from USA, while Speyer (1980) reported levels from <0.20-0.62 ppm in northern pike from a lake in Canada and 1.3-3.0 ppm in pike from another lake. Slightly higher levels (up to 2 ppm) were also reported in homogenized freshwater fish from Upper Austria (Teherani et al. 1979). Similar levels of selenium have also been reported in marine fish (Egaas and Brækkan 1977; Luten et al. 1980; Cappon and Smith 1981, 1982).

Quite divergent results have been reported in the literature concerning the relationship between selenium and mercury in fish. Koeman et al. (1975) reported a molar Hg:Se ratio of 1:16 (0.06) in marine fish and a ratio of 1:1, with an almost perfect linear correlation, in marine mammals. Similar ratios (0.68-2.08) were found by Kari and Kauranen (1978) in muscles of seals heavily contaminated with mercury. Fish from the same freshwater and brackish areas were moderately loaded with mercury and had molar Hg:Se ratios between 0.11 and 1.8. Freeman et al. (1978) reported a non-linear correlation between mercury and selenium in swordfish. In swordfish, with mercury levels below 10 umol/kg (2 ppm), the molar concentration of selenium exceeded that of mercury. Luten et al. (1980) and Leonzio et al. (1982) also reported a correlation between mercury and selenium in fish. Luten et al. (1980) found the stoichiometric Hg:Se ratio to be less than one in marine fish and more than one in freshwater fish. Leonzio et al. (1982) found accumulation of both mercury and selenium to be related to the age of the fish, the best correlation being obtained between the age of the fish and the molar sum of selenium and mercury. In contrast, Cappon and Smith (1981, 1982) found that muscle selenium in marine and freshwater fish did not correlate with the corresponding mercury content. Speyer (1980), who examined selenium and mercury levels in northern pike, found that fish from the lake with the lowest mercury contamination had the highest levels of selenium, and vice versa. In the mercury loaded fish he found accumulation to be related to the size of the fish. No relation between selenium levels and age was found. It seems that the mechanisms at play in the interaction between selenium and mercury in fish is far from being completely understood.

The differences found between the lakes in the present investigation as regards selenium levels in fish can hardly be explained from differences in environmental pollution. With the possible exception of air-borne pollution, the two lakes in which fish showed the highest levels of selenium are quite unaffected by contamination resulting from human activities. The differences found were therefore most probably a reflection of basic geochemical variation. Stream sediments in the area around Mjøsa have been found to contain generally low levels of mercury (Bølviken pers. comm.). At present, there is, however, no available data on selenium concentrations. The differences in mercury levels between the different fish species in Mjøsa, and also between the levels in fish from the different lakes may perhaps be partly explained by differences in contamination patterns in the lakes as well as the trophic level of the species concerned.

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