Bull. Environm. Contam. Toxicol. 29, 544–549 (1982)

Mercury Concentration in Liver and Muscle of Cod (*Gadus morhua*) as an Evidence of Migration Between Waters with Different Levels of Mercury

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Fish accumulate mercury directly from the surrounding water as well as from the food. Methylmercury is the predominant form of mercury in aquatic pollution (JERNELÖV & LANN 1971) and of the mercury compounds studied, it is most readily accumulated in the tissues of fish (HANNERZ 1968; WESTÖÖ & RYDÄLV 1969; LUTEN et al. 1980). The concentrations of total mercury seem to be affected markedly by the age of the fish, and freshwater species as well as marine species respond to different mercury levels in the surrounding waters (JOHNELS et al. 1967; SCOTT & ARMSTRONG 1972; OLAFSEN et al. 1973; SCOTT et al. 1978; TOPPING & GRAHAM 1978). In order to establish an estimate as to the age relation the fish have to be in equilibrium with the surrounding water, Fish migrating between areas of approximately similar concentration levels in the water, such as cod caught off the Norwegian coast or in the Barents Sea, will usually show a tendency to comply with this requirement (OLAFSEN et al. 1973). Fish migrating between areas of different mercury levels usually may be in different states of accumulation or depletion, and for these groups an estimate may be difficult. Thus the use of cod as an indicator organism for mercury contamination needs careful evaluation of the results with consideration of geographical as well as biological factors. To gain some information on the biological problems involved, the present study was undertaken to establish the accumulation rate of $HgCl_2$ and CH_3HgCl given orally to the cod as measured by the subsequent distribution of mercury in muscle and liver tissue. The results of these experiments have been applied to the evaluation of mercury in cod migrating between moderatly contaminated waters and areas with different levels of mercury contamination.

MATERIALS AND METHODS

Experimental procedures. Cod, weighing between 100 and 300 g, were caught by closing net in Masfjord north of Bergen during May 1980. They were transferred to a sheltered 25 m^3 tank supplied with running sea water at 8°C and 35 o/oo salinity. The photoperiod was automatically regulated to 12 h light and 12 h dark, and the fish were acclimatized to the experimental conditions for 6 weeks. Whole capelin (*Mallotus villosus*) were ground and fed daily *ad libitum* during the acclimatization period.

Trial 1: Accumulation period. 150 fish randomly divided into three

0007-4861/82/0029-0544 $01.20

groups. Each group were twice daily fed moist pellets consisting of minced whole capelin, added vitamins, and dextrin as a binding agent. In the experimental period the control group received the same diet. The experimental groups received the pellets with addition of mercury (2 mg kg feed) as inorganic and methylmercury iodide, respectively. The water temperature was recorded daily and showed minor variations, 8.0 ± 1.0°C. At 8, 16 and 32 days, 6 fish were randomly sampled from each group. No mortality was recorded during the experimental period.

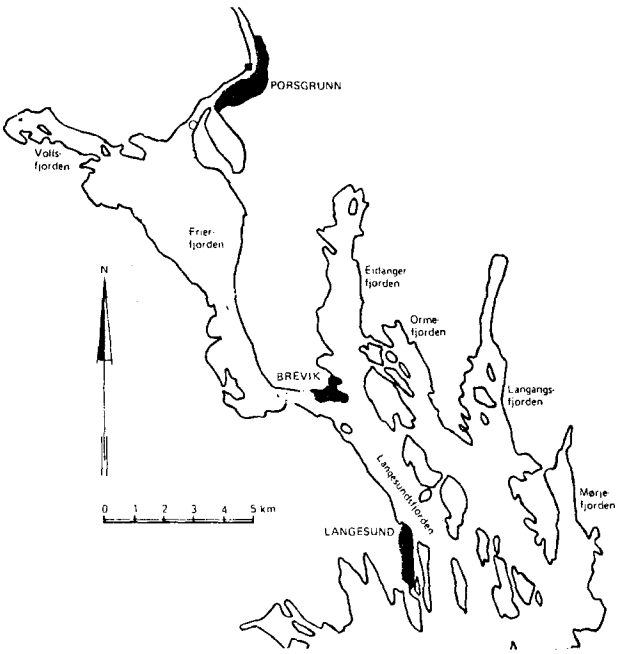

FIGURE 1. Map showing the location of the Frierfjord in relation to the Grenlandfjord area.

Trial II: Depletion period. The remaining cods received the control diet *ad libitum* for a period of 32 days. During this depletion period, 6 fish were randomly sampled from each group after 8, 16 and 32 days.

Field sampling. Wild cod (*Gadus morhua*) were caught during the month of December 1978 and 1979 in the Frierfjord at the south coast of Norway (Figure 1), a branch of the Grenland fjord. Immediately upon the catch the fish were killed by a blow on the head and frozen. The frozen samples were brought to the Central Laboratory, Directorate of Fisheries, Bergen, where the fish were weighed and the dorsal muscle and liver from each fish homogenized. The samples were brought to our institute for further preparation.

Methods of analysis. Samples of dorsal muscle and liver from each

fish were analyzed. The muscle samples were freezedried to a constant weight, homogenized and kept in tightly closed bottles until analysis, whereas the fatty liver samples were homogenized and kept frozen until analysis. Samples for mercury determination were digested by using nitric acid/perchloric acid (9:1) and further analysed according to the procedure described elsewhere (EGAAS & JULSHAMN 1978).

Mercury was measured by cold vapour technique in a gas cuvette utilizing a Perkin-Elmer Mercury Analysis System. EDL was used as light source. The overall reproducibility of the procedure (including sample preparation and acid digestion) was estimated by carrying out ten replicate analyses on a cod muscle sample. An average concentration of 0.25 mg kg^{-1} and a relative standard deviation of 4% was obtained. In order to evaluate the accuracy of the nitric acid/perchloric acid digestion two NBS materials and a cod muscle sample were analyzed. The latter had previously been tested by the method of Egaas and Julshamn (1978). The results summarized in Table 1, show a good accuracy. The detection limit was estimated to 10 µg kg^{-1} dry matter.

Table 1. Comparative analyses of mercury by using two different digestion procedures (values are given in mg kg^{-1}, n = 4).

Sample	$HNO_3/HClO_4$	$HNO_3/H_2SO_4/V_2O_5$ [a)]	NBS. value
SRM 1566 Oyster tissue	0.062±0.020	0.065±0.015	0.057±0.015
SRM 1577 Bovine liver	0.030±0.01	0.03 ±0.01	0.016±0.002
Cod muscle	0.24 ±0.03	0.28 ±0.02	

a) EGAAS & JULSHAMN 1978

RESULTS AND DISCUSSION

The experimental results are summarized in Fig. 2 and 3. Fish fed inorganic mercury (2 mg/kg feed) showed the highest uptake during the first 8 days, but only a small part of the intake was retained. As would be expected, the liver showed the highest uptake, whereas the muscle showed a slower but steady accumulation. After 32 days the mercury level in the liver had increased from 0.020 to 0.090 mg/kg, correspondingly the level in the muscle increased from 0.037 to 0.056 mg/kg. In the depletion period mercury continued to accumulate in the liver for 2 weeks, probably as a result of a redistribution. The final two weeks the levels in the liver and muscle both showed a steady decline.

Fish fed methylmercury showed a much higher uptake, but also a different distribution pattern between the two organs. Again the uptake was strongest in the liver, but a maximum of 0.58 mg/kg was obtained after 8 days, and this level was maintained during the rest of the experimental period. The muscle, however, showed

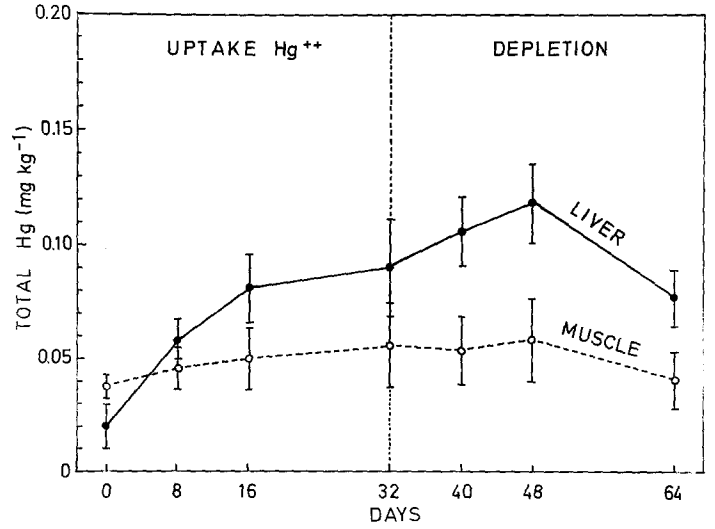

FIGURE 2. Uptake of mercury in the muscle and liver of cod fed inorganic mercury and the effect of a subsequent depletion period.

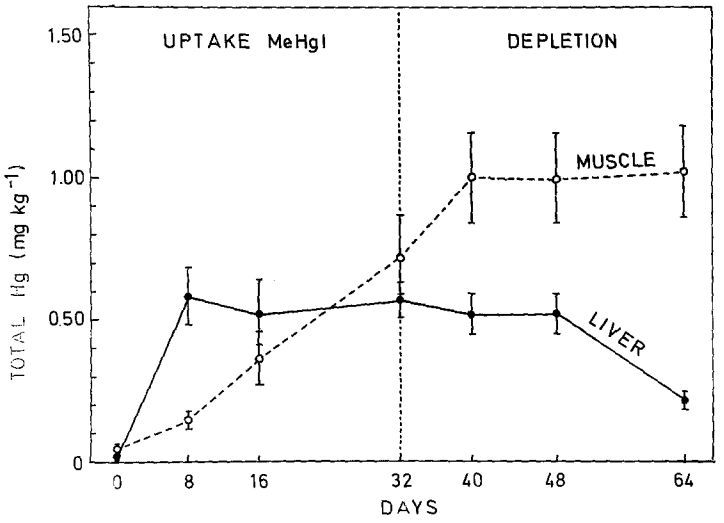

FIGURE 3. Uptake of mercury in the muscle and liver of cod fed methylmercury and the effect of a subsequent depletion period.

continuous uptake for the whole 32 days feeding period, and showed a higher concentration at 32 days than the corresponding liver sample. In the depletion period the liver showed a decrease, which was most pronounced the last two weeks. The muscle on the other hand showed a strong increase the first week of depletion

reaching a level as high as 1.0 mg/kg, and retaining this level during the last part of the experiment. This finding expresses an internal redistribution of methylmercury and that the muscle tissue has a higher storage capacity than the liver.

No estimate could be given for the biological halftimes for the muscle, whereas a value of 24 days could be calculated for the liver concentration. PENTREATH (1976) studied the uptake and depletion of inorganic mercury and methylmercury by feeding labelled compounds to plaice (*Pleuronectes platessa L*). He gave the percentage distribution between different organs, and although a direct comparison with the present results can not be made, the trend for liver and muscle seemed to be the same in both species.

Mercury in fish is predominantly present as methylmercury (JERNELÖV & LANN 1977). From our experimental data, a muscle-liver ratio for mercury above 1 should indicate an equilibrium with the environment. Results from analyses of muscle and liver from 40 cods caught in the Barents Sea showed a muscle-liver ratio of 2.5 ± 1.5, indicating such an equilibrium. Similar ratio can also be seen from data reported by LUTEN (1980). On the other hand, other species show higher accumulation capacity in liver than in muscle (JOHNELS et al. 1967; OLSON et al. 1973; PENTREATH 1976). In Fig. 4 are plotted muscle-liver ratios for cod caught in the Frierfjord area. The samples were taken in December 1978 and 1979, and showed a muscle-liver ratio varying from 0.29 to 5.5 and 0.23 to 2.8, respectively. Less than half of the samples showed a ratio exceeding 1, indicating that the cod collected from this environment may migrate between waters of different degree of

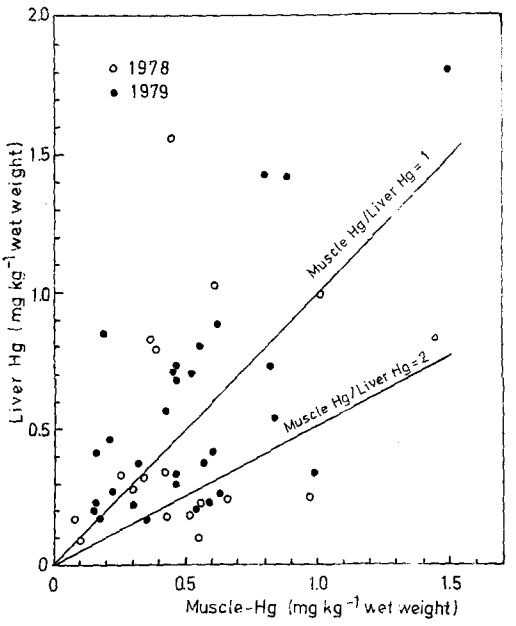

FIGURE 4. A correlation plot showing the distribution of the muscle-liver ratio in relation to curves expressing ratios of 1 and 2, respectively.

mercury contamination, and are not in an equilibrium with the surrounding water. It points out that the values can not be used to establish a correct relationship between mercury and age and further that the cod would not be suitable indicator organism in this environment.

REFERENCES

EGAAS, E. and K. JULSHAMN: At. Absorption Newsl. 17, 135 (1978).

HANNERZ, L.: Rep. Inst. Freshwater Res. Swed. 48, 120 (1968).

JERNELÖV, A. and H. LANN: Okios 22, 403 (1971).

JOHNELS, A.G., T. WESTERMARK, W. BERG, P.I. PERSSON and B. SJØSTRAND: Okios 18, 323 (1967).

JULSHAMN, K., O. RINGDAL, K-E. SLINNING and O.R. BRAEKKAN: Spectrochim. Acta, Part B in press (1982).

LUTEN, J.B., A. RUITER, T.M. RITSKES, A.B. RAUCHBAAR and G. RIEKWEL-BOOY: J. Food Sci. 45, 416 (1980).

MAGOS, L.: Br. J. Pharmacol. 56, 479 (1976).

OLAFSEN, J.A., N. LOSNEGARD and K. BAKKEN: Fisk. Dir. Skr. serie tekn. undersøkelser 5, 1 (1973).

OLSON, K.R., H.L. BERGMAN and P.O. FROMM: Fish Res. Board Can. 30, 1293 (1973).

PENTREATH, R.J.: J. Exp. Mar. Biol. Evol. 25, 51 (1976).

PHELPS, R.W., T.W. CLARKSON, T.G. KERSHAW and B. WHEATLEY: Arch. Environ. Health 35, 161 (1980).

SCOTT, D.P. and F.A.J. ARMSTRONG: Fish. Res. Board Can. 29, 1685, (1972).

SCOTT, D.P., G. SIROTA, J.F. UTHE and C.J. MUSIAL: International Council for the Exploration of the Sea C.M. 1978 /E: 16.

TOPPING, G. and W.C. Graham: International Council for the Exploration of the Sea C.M. 1978 /E: 34.

WESTÖÖ, G. and M. RYDÄLV: Vår Föda 21, 17 (1969).

Accepted September 9, 1982