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A survey of the mercury problem in Sweden with special reference to fish

Hans Ackefors
Institute of Marine Research, Lysekil, Sweden

Since the beginning of nineteen fifties the mercury problem has been observed in Sweden. The first observed sign of poisoning was decreasing bird populations.[34] In Japan the problem was noticed in connection with the Minimata catastrophe.[32] During 1953-1960 111 persons, living in the Minimata bay, were killed or seriously disabled. They were poisoned by fish and shellfish with elevated mercury concentrations. The mercury was discharged by a vinyl chloride and acetaldehyde plant.

The mercury problem was given special attention in Sweden in the end of 1965 when a great scientific conference was held in Stockholm.[2] The scientific research, which had started some 10 years before, was strongly increased and encouraged after this conference. Now many institutions are busy with the mercury problem from the technical, agricultural, genetic, ecological and medical point of view.

The most serious mercury problem in Sweden is the high concentration of mercury in fish. Especially the fish from freshwater (lakes and rivers) have been reported to have high levels of mercury but even fish from coastal areas, e.g. from Öresund (between Sweden and Denmark). Fish from a certain number of lakes and a few coastal areas at the Swedish east and west coasts are now forbidden for sale in Sweden.

Mercury compounds

Mercury is written with the chemical symbol Hg. The different types of compounds are:

A. Inorganic compounds; metallic Hg (Hg^0) or salts (Hg^{2+}), e.g. $HgCl_2$ which has industrical and medical use. From about 1920 and a few years on inorganic Hg was used for seed dressing.[4]

B. Organic compounds; (The anionic parts of the molecules are of minor importance, since in biological systems exchanges of the type $RHgX+Y^- \rightleftharpoons RHgY+X^-$ will take place).

1. Alkyl-Hg-X, e.g. methyl-Hg dicyanodiamide ($CH_3Hg\ H_2N\text{-}C(NH)\text{-}N\text{-}CN$). This type of of Hg compounds was introduced in the 1940's as seed dressing agents in Swedish agriculture. Since about 1950 it dominated the field until February 1, 1966, when it was banned from use as a seed dressing agent.[52]

2. Aryl-Hg-X, e.g. phenyl-Hg acetate ($C_6H_5Hg\text{-}OCOCH_3$). About 1946 pulp industry began to use phenyl-Hg acetate. The use of it in paper mills was stopped in June 1965.[28] Still there are a few pulp plants which use mercury. Phenyl-Hg was earlier (the 1920's and 1930's) used for seed dressing, but was later replaced by other mercury compounds e.g. alkyl-Hg (see above).[4]

3. Alkoxyalkyl-Hg-X, e.g. methoxyethyl-Hg acetate ($CH_3O\text{-}CH_2\text{-}Hg\text{-}OCOCH_3$). This type of compounds has probably been used in most of the European countries for seed dressing. In Sweden it was used in the 1920's and 1930's[4] but was later replaced by other mercury compounds (see above). Since 1966 it is the only mercury compound permitted in Sweden for this purpose. (A decision by the National Poisons and Pesticides Board, "Giftnämnden" in November, 1965.)

The main sources of contamination are:

1. The use of Hg-compounds as fungicides in agriculture.
2. The use of Hg-compounds as fungicides in mechanical pulp and paper mills.
3. The loss of mercury from the chlorine-alkani industry.
4. Electrical installations using mercury in rectifiers, relays, etc.
5. The heating of ores and clays with traces of Hg in industry.
6. Burning of oil and coal containing small amounts of mercury.
7. Burnings of paper and other sweepings containing mercury.
8. Wastes from dental clinics and hospitals.
9. Many industrial activities not yet identified as mercury sources.

Mercury is brought to soil, water and air due to the above mentioned activities. The occurrence of Hg in water, air etc. was noticed already in the 1930's by Stock.[42]

Official toxicological evaluations and measure units.

The following measure units are used:

1 ppm = 1 mg/kg = 1000ng/g

1000 ppb = 1000 ng/g = 1 ppm

LD_{50} = the amount of a compound, expressed in mg/kg body-weight, which kills 50 % of the test animals.

"A no-effect level has not been demonstrated for mercury. The level of 0.1 ppm, equivalent 0.005 mg/kg body-weight per day, produced a slight effect in the rat. Even if this figure were to be adopted as a maximum no-effect level and the customary saftely factor applied this would give an acceptable daily intake (=ADI) for man of 0.00005 mg/kg body weight".[15]

ADI has earlier been estimated to 0.00005 mg/kg body-weight.[14]

For food FAO/WHO have proposed as practical residue limits (temporary);

0.02 - 0.05 ppm = 0.02 - 0.05 mg Hg/kg food = 20 - 50 ng/g.[16]

The practical residue limits and ADI have been estimated with respect to phenyl-mercury acetate. An ADI of 0.00005 mg Hg/kg body-weight is equivalent to 0.003 mg Hg/day for a person weighing 60 kg.

When it became evident that Swedish freshwater fish contain evevated methylmercury concentrations, the National Institute of Public Health proposed a temporary limit of 1 mg Hg/kg for fish (= 1000 ng/g).[5]

All figures in this paper are given in mg Hg/kg (or ng/g) wet weight.

The official Swedish residue limit of 1 mg Hg/kg for fish (1000 ng/g) which is 20 times higher than the limit of FAO/WHO, has been widely critized by many scientific authors. It included also mistakes when the calculations were made. The values of mercury contents of shellfish from Minamata were given in relation to dry weight,[32] whereas concentrations in Swedish fish are expressed in relation to wet weight. The error caused a misinterpretation of the original data by at least a factor of 2.5; Probably the value should be divided by a factor of 5 due to the high content of water in shellfish. This yields a limit of 0.4 - 0.2 mg Hg/kg food instead of 1 mg Hg/kg food.

Mercury concentrations in terrestrial wildlife and food.

Since the middle of the nineteen-fifties, mercury analyses have been performed at the State Veterinary Medical Institute in Stockholm.[9] The chemical analyses have comprised about 1275 wild animals (table 1).

Table 1; Mercury residues which were found in 50 % of the animals (liver and kidney)[9];

Animals found dead

Pheasants and partiridges	20-140 mg/kg	Finches	11-136 mg/kg
Pigeons	8- 45 mg/kg	Eagles, buzzards, hawks, falcons	6-100 mg/kg
Corvine birds	29-110 mg/kg	Owls	4-270 mg/kg

Animals killed for analysis

Mercury residues which were found in 50 % of the animals (liver):

Pheasants, partridges, pigeons	1.0-39	mg/kg
Goshawks	6.0-53	mg/kg
Common Buzzards	2.1- 6.5	mg/kg

In Swedish agricultural products mercury contents are as a rule relatively high as compared to those of other European countries.[54,59] (See table 2).

Table 2. Mercury contents in eggs and meat products from Sweden, Denmark and Norway.[54,59]

Type of food	Mean values mg Hg/kg	Extreme values
Swedish eggs	0,029	1,60[1)]
Norwegian eggs	0,020	
Danish eggs	0,004	
Swedish pork chops	0,030	0,130
Danish " "	0,003	0,007
Swedish pig's liver	0,060	0,183
Danish " "	0,009	0,020
Swedish beef	0,012	0,074
Danish "	0,003	0,004

1) Not included in average values.

Since the ban of alkyl-Hg as seed disinfectant mercury concentrations in Swedish eggs have decreased (table 3).[58] The mercurial seed dressing was restricted already in 1965. The Swedish authorities then decided to use "adapted" dressing, that is lower dosage or no dressing at all depending on the degree of infection.[9] Before 1965-1966 certain farmers probably used dressed seed left over after the sowing as food for fowls.

Table 3. Mercury content in Swedish eggs sampled March 1964 - Sept. 1967.[58]

Sample period	Mean value mg Hg/kg
March 1964 - April 1966	0,029
April 1966 - Nov. 1966	0,019
April 1967 - Sept. 1967	0,010

The analyses from 1966 and 1967 performed by the National Institute of Public Health have shown that most of the mercury (c. 90 %) in eggs is methyl-Hg. This was predicted already in 1965 by a few authors.[37]

Tejning has investigated the mercury contents in pheasants from an area where methyl-Hg dressed seed-grain was used.[44] The analyses of mercury in muscles, liver, kidney, feathers and claws showed the distribution in different parts of the body. A few examples are given in Table 4.

Table 4. Mercury contents of some pheasants collected in an area where seed was treated with methyl-Hg (mg Hg/kg).[44]

Pheasant	1	2	3	4
young/old	young	old	old	old
weight	1225	1370	1560	1635
Musculature	0.29	2.7	0.71	0.93
Liver	1.0	4.8	2.0	1.5
Kidneys	0.75	4.0	1.8	1.6
Plumage	79.4	29.5	13.5	8.3
Claws	6.8	56.4	13.7	19.9

Sources of mercury in terrestrial wildlife and in agricultural products

The widespread use of the most noxious type of Hg-compound, alkyl-Hg, for seed dressing must be the reason why Swedish eggs and other agricultural products have elevated mercury levels.[56, 58,59] Hg contents in birds, especially birds of prey and birds feeding directly on seeds, have been investigated by taking feathers from birds collected in nature as well as in various Swedish museums. The Hg-values found in the feathers of the birds from the period 1840 - 1940 were low in comparison with those after 1940. Berg et al.[4] correlated the mercury contents of the feathers to the use of alkyl-Hg in agriculture. (The use of these mercury compounds as seed dressing agents started in the 1940's; see above).

The restrictions in the use of alkyl-Hg in Sweden (after 1965-1966) have caused a decrease in mercury residues in wood--pigeons.[52] In pigeons shot during 1966 the Hg levels in liver were lower than those from 1964. (Cf. the decrease of mercury in Swedish eggs; see above.)

Mercury concentrations in fish and aquatic organisms

Already in 1965 it was evident that fish and aquatic organisms from lakes and rivers had very high concentrations of mercury.[2] Now we have more detailed reports available.[29,33,55-57,60] The highest contents have been recorded in freshwater fishes such as pike, perch, and pike-perch, but even salt water fishes, taken in coastal areas, have in many cases high mercury contents. Thus, in Öresund (between Denmark and Sweden) various species, for example plaice, cod, eel etc., have been reported to have rather high mercury contents (table 5).[21]

Table 5. The range of mercury concentrations in fish (muscles) from the Öresund.[21]

Type of fish	Range of mercury contents ng/g
Flounder (Pleuronectes flesus)	50 - 860
Plaice (Pleuronectes platessa)	71 - 3100
Cod (Gadus morhua)	245 - 2700
Perch (Perca fluviatilis)	1430 - 4160
Eel (Anguilla anguilla) blank	52 - 175
" " " yellow	810 - 2030
Pike-perch (Lucioperca sandra)	51 - 80

The main part (70-100 %) of the mercury isolated from fish (freshwater, the Baltic and the Atlantic) is methyl-Hg.[33,55,56,60]

In general, water organisms have higher "natural" contents of Hg than terrestrial wildlife. As elevated are considered levels higher than 200 ng Hg/g.[28] In sea fish in the thirties and forties Stock and Cucuel[43] found values in the range of 25-110 ng/g and Raeder and Snekvik[38,39] the range of 44-155 ng/g. Most of the investigated fishes from freshwater and coastal areas in Sweden have concentrations in the range of 200-1000 ng Hg/g. In about 1 % of the waters investigated in Sweden the fish have more than 1000 ng Hg/g. Fish from certain lakes and a few coastal areas are now banned from the market (where analyses of investigated samples show higher levels than 1 mg/kg = 1000 ng/g). The highest mercury concentration yet recorded is9800 ng/g and originated from a pike (Esox lucius) caught in the archipelago just outside Stockholm (the Baltic proper). Hitherto only few analyses have been made to estimate the concentrations of mercury in real sea fish.

Westöö has investigated frozen fillets taken from fishes caught outside the northern coast of Denmark and the Norwegian west coast.[57] The concentration range was 16-110 ng/g and the mean value 44 ng/g. The mercury concentrations in fish analysed in Sweden up till 1967 were summarized by Birke et al. (Table 6).[7]

Table 6. Mercury contents in fish (muscles) analysed in Sweden, 1965-1967.[7]

Area	Range of Hg concentrations mg Hg/kg	Type of fish
The West Coast	0,03 - 0,2	Pike, perch, pike-perch vendace
The Baltic	0,02 - 2,5	" "
Lakes	0,05 -10,0	Only pike
Off the coast in the Baltic and the Atlantic	0,016 - 0,110	Various saltwater fishes

A few analyses of saltwater fish (other than those mentioned in Reference 57) caught in the sea have shown low values. Cod from the Baltic as well as from the west coast of Sweden has mercury concentrations in the range of 32-90, whereas plaice has 31-76 ng Hg/g. In certain coastal areas, however, such as "Lundåkrabukten" in the Öresund the mercury concentrations are much higher as stated above.

Mercury in pike and other aquatic organisms in Sweden in relation to the contamination of the environment.

Johnels et al.[28] have chosen pike (Esox lucius L.) and some aquatic invertebrates as indicators of mercury contamination in the

environment. They found that pike was especially suitable because of (1) stationary habits, which provide definite geographic information; (2) life span of several years which will serve to integrate temporal variations in the occurrence of accumulative substances in the environment; and (3) wide distribution that permits comparative studies over extensive geographical areas."

Samples have been taken of the axial muscle of fish and investigated by activation analysis.[11,41,53]

The distribution of mercury in the different organs of the pike is given in Table 7. The axial muscle and the heart muscle of pike from moderately contaminated waters exhibit higher levels of mercury than liver and kidney. (Cf. the short-term studies in laboratory which are mentioned below).

Table 7. Mercury content of organs of a pike, weight 3120 g.[28]

Organ	Hg ng/g
heart muscle	1000
axial muscle	850
liver	780
kidney	640
intestine	610
ovary	560
epidermal finrays	390
gill	300.
brain	290
spleen	280
scales	104

The concentration of mercury in pikes increases with age and weight.[28,29] At low levels (less than 200 ng Hg/g, however, there is no measurable increase with age. At high mean levels (more than 1000 ng/g) especially at localities which are heavily contaminated by waste water, there is no relation between mercury content and age. In most cases Johnels et al. have recalculated the analyses to a "1 kg standard pike" to make possible comparisons between different geographic areas.[28,29]

There is definite evidence that mercury is accumulated along the food chain.[29] The concentration factor from water to pike is in the order of 3000,[28] although there are large variations between different localities. Johnels et al.[21] found in various lakes with the same mercury contents lower levels of mercury in the organisms living in eutrophical waters, and it seems that oligotrophical lakes are more sensitive to mercury contamination than eutrophical lakes.

Sources of mercury in aquatic organisms.

Pollution of water and air with mercury (see above) has for obvious reasons more seriously affected water organisms living in lakes, rivers and coastal waters than those living in the open sea far off the coast. Johnels et al.[30] noticed increased mercury concentration in feathers of recently living ospreys as compared to those from earlier times (Pandion haliateus), and they could correlate the rise of mercury content with the time of early industrilization. (Ospreys feed on fish to nearly 100 percent.)

Johnels et al.[28] have shown that organisms living in streams below paper mills have elevated mercury levels in comparison with those from localities above the paper mills. A few examples are given in Table 8.

Table 8. Mercury content of water organisms living in a stream below and above a paper mill located at the stream.[28]

Material	Locality	Hg ng/g
Trichoptera	15 km above mill	52
"	6 " below "	10,700
Asellus aquaticus	1 " above "	65
"	20 " below "	1,900
Pike (male) 490 g	8 " above "	1,200
" (female) 4040 g	4 " " "	1,680
" (male) 725 g	8 " below "	5,650
" (female) 1575 g	8 " " "	8,000

Mercury contents in water, bottom sediments, and soil.

Earlier analyses (1934) of water from various places have given the following results: sea water 0,03, river water 0,1 (Rhine), rainwater 0,05-0,5 ng Hg/g.[43] Sillén has reported a concentration of $1,5 \times 10^{-10}$ M in the sea.[40] Snow on a lake in Sweden (Dec. 1965) contained 0,07 ng Hg/g in the surface layer and 0,21 ng Hg/g in a deeper layer.[28]

Bottom sediments in the Öresund outside the town of Landskrona contain very high levels of Hg. The highest value reported until date is about 20000 ng Hg/g (dry weight).[20] Normal values are considered to be 100-200 ng Hg/g (dry weight). It is therefore not surprising that fish from the "Lundåkrabukten" in the neighbourhood of Landskrona exhibit very high levels of mercury. Outside the river "Göta älv" on the Swedish west coast the mercury concentration of bottom sediments was between 1000-1500 ng/g.[3]

Until the beginning of 1966, 50 samples have been taken in Swedish soils (topsoils).[1] The results of the analyses are given in Table 9.

Table 9. Mercury content in Swedish soil.[1]

Moraine soils	125-250	ng Hg/g
Clay soils	80-150	"
Sandy and silty soils	50-350	"
Organic soils	300-510	"

Late when about 200 samples had been analysed the range of the Hg-content was reported to vary between 20 ng/g and 920 ng/g, with an average value of 70 ng/g.[1]

Experimental investigations of the accumulation of mercury in water organisms.

Mercury compounds and their influence on fishes has been studied in aquarium experiments. With the aid of labelled compounds Hannerz[19] made experiments in ponds, tanks and aquaria in order to study the accumulation and up-take of mercury. Water plants, various invertebrates and various fish-species have been studied. The highest concentrations in fish were found in kidney and liver, medium-high concentrations in heart muscles, spleen, gills and brain and the lowest concentrations in muscles and bone (Cf. the analyses of pikes from natural waters).

Methyl-Hg had the greatest concentration factor in comparison with other compounds such as methoxyethyl-Hg and inorganic Hg compounds. For pike, the factor pertaining to freshwater was in

the order of 2000 (muscles) - 9000 (kidneys). There was, however, a considerable variation in the uptake in different specimens of the same species, and there were considerable differences between uptake in brackish and salt water. In brackish water there was a lower uptake of methyl-Hg and especially of methoxyethyl-Hg. The concentration of electrolytes of the water seems to be the reason for these differences.

The experiments performed by means of whole body autoradiography of fish and other animals have revealed a great difference between inorganic and organic compounds when they are accumulated in the body.[10] When water was contaminated with inorganic compounds the highest values were found in the gills and the skin. When injected or given with the food the greatest accumulation occurred in the kidneys, the liver, and the spleen. Organic Hg compounds were accumulated to higher concentrations in the skeletal muscles, although the highest concentrations were found in liver and kidneys. A very interesting observation was made when fish were given phenyl-mercury acetate. A green discoloration of the liver and the muscles was observed. This has been noticed earlier by fishermen. The author has observed the phenomenon in the Baltic proper. Histological examination of the liver revealed that there was a strong bile production but no sign of pathological changes in the liver could be detected.

Animal experiments on mercury effects.

A large number of animal tests have been reported in recent years. Only a few Swedish papers will be mentioned here. Ramel[36] and collaborators have studied the genetic effects of mercury.

They found among other things that alkyl-Hg and phenyl-Hg in concentrations around $2.5 \cdot 10^{-7}$ mol/l or 0.05 ppm caused a disturbance of the spindle. This means that mercury compounds are effective at much lower concentrations than any other c-mitotic substances investigated. The corresponding value for colchine is almost a thousand times higher. Together with Frölén, Ramel has made experiments on inbred CBA mice.[36] Both males and females exhibited increased sterility in comparison with untreated animals when methyl-Hg was injected intraperitoneally (0.1 mg per mouse). Pregnant females showed a high frequency of resorbation of litters when they were given injections at the tenth day of pregnancy.

The difference in distribution, accumulation degradation, and excretion between alkyl-Hg and the other types of organic compounds is obvious from a number of experiments. In short term investigations alkyl-Hg is accumulated in the brain twentyfold as compared to other Hg compounds. Berlin and Ullberg[6] have shown with the help of autoradiographic methods that both the brain--blood barrier and the placenta acted as a barrier for phenyl--Hg compounds and inorganic mercury salts but not for alkyl-Hg. The tests were performed with mice. The acute toxicity (LD_{50} doses) for mouse and rat for alkyl-Hg compounds has been calculated to be in the range 20-30 mg/kg body weight. The animals were observed, however, for a period of time less than the latency period of the appearance of neurological disorders.

Japanese investigations show that rat is able to accumulate more mercury in the blood than man before neurological disorder may be noticed.[18]

Other Japanese investigations show that a daily intake of 0,4-1 mg Hg/kg body weight (methyl-Hg) gives rise to neurological effects in rabbits, dogs and cats.[23,31,50]

Effects of mercury intake in man.

The characteristic symtoms of methyl-Hg poisoning described in literature have been summarized by Kurland et al.[32] Neurotoxic effects appear only after a latency period even if the exposure of methyl-Hg is strong enough to give rise to serious poisoning. In severe cases the latient loses the ability to coordinate his motions and has difficulties to eat, speak, and hear. The visual field is concentrically constricted and the hearing is blurred. This is caused by the cerebellar atrophy of the granule cells and injuries in other cortical regions.

The mercury contents of blood and hair of people investigated in Sweden have been reported by Birke et al.[7] and Tejning.[45-47] The latter author has performed analyses of the mercury contents of blood corpuscles and blood plasma in a normal Swedish population (table 9).

Table 9. Mercury levels in blood of a normal Swedish population ($\pm$ standard deviation).[45]

Sex	Number of persons	Hg conc. ng/g blood corpuscles	plasma
male	58	9.87 $\pm$ 2.63	2.01 $\pm$ 0.82
female	25	10.48 $\pm$ 2.60	2.89 $\pm$ 1.35
mixed	83	10.06 $\pm$ 2.63	2.27 $\pm$ 1.08

Tejning states that values higher than 18 ng/g in blood corpuscles, 4.5 ng/g in plasma in males and 7 ng/g for females may be considered abnormal.

In the lake of Vänern (the largest lake in Sweden with important fishery amounting to 800-1000 metric tons a year, some species have been reported to have high Hg concentrations.

Mean values for pike were in the range 0,7-1,2 mg Hg/kg in various parts of the lake. Tejning[46] started a study of mercury contents in blood and hair of 51 extreme fish eaters from Lake Vänern area. The average intake of fish meals was 3,1 a week. With a calculated portion of 150 g of fish and a mean value of 0,870 mg Hg/kg fish the weekly intake of mercury was 0,39 mg or 20 mg Hg a year. The investigated population had 5-6 times higher mercury concentrations in erythrocytes and hair as compared to normal persons (see above). Table 10 gives a summary of the results from these analyses.

Table 10. Average mercury contents in blood corpuscles, blood plasma and hair of extreme fish eaters from different parts of the lake of Vänern (± the variance).[46]

Group	No. of persons	Age	Mercury concn. (ng/g) in erythrocytes	plasma	hair	Average meals with fish a week
1	14	49±3.8	37± 8.8	4,8±1.0	4716±1076	3.0±0.2
2	12	55±4.6	91±15.0	13.4±2.9	11720±2490	3.0±0.2
3	10	53±4.1	59±15.8	5.8±1.0	8225±1627	3.7±0.6
4	15	51±3.8	51± 6.6	6.4±0.8	7638±1125	3.0±0.2

A 60 year old fisherman at Lake Vänern had the highest mercury concentration: blood corpuscles 260 ng/g, hair 27600 ng/g and 46600 ng/g respectively. Daily he ate 3/4 kg fish, mainly pike and turbot. This is about 1/10 of the mercury values reported for a man in Niigata, Japan, who died in the Minamata disease.[22] The values correspond to a daily intake of fish with a level of 0.5 mg/kg. As a comparison the values of a 21 year olid boy may be mentioned, who never ate fish: blood corpuscles 4.6, plasma 0.8 and hair 920 ng/g.

Later, Tejning[47] investigated persons who consumed exclusively salt water fish. These persons lived in the Öresund area (table 11).

Table 11. Mercury concentrations (ng/g) in blood corpuscles and blood plasma in 21 persons eating 3 or more meals of commercial saltwater fish.[47]

ng Hg/g in blood corpuscles	No. of persons	Average mercury concn. in ng/g blood corpuscles	plasma	Average number of fish meals a week
10 - 18	4	14.8	2.5	3.8
19 - 30	5	23.8	4.6	4.0
31 - 550	5	41.0	6.6	4.3
51 - 100	4	71.3	8.4	3.8
101 - 230	3	194.3	17.7	3.8

With reference to the above mentioned investigations, Tejning has proposed that the highest permitted mercury concentration in fish for human consumption should be 0.2 mg Hg/kg. (The National Institute of Public Health now permits 1 mg Hg/kg; see above). Birke et al.[7] have calculated that the mercury concentration of 5-6 mg/kg in fish will give a lethal dose for a grown up person if the intake of fish is daily.

The biological half-life of methyl-Hg has been investigated by Åberg and collaborators.[12,13] Three males about 40 years old took a single oral dose of 3 µc isotope labelled methyl-Hg nitrate. Measurements of mercury concentrations were first made every day in different parts of the body and in blood, sperm, hair, urine and faeces. The main excretion

of methyl-Hg was via the faeces and very little via urine. The biological half-life of methyl-Hg calculated on a whole-body basis was 65-74 days for the three experimentees.

A weekly intake of 1 mg methyl-Hg during a year will give a mercury concentration of about 13 mg in the brain (mainly cerebellum).[61]

General conclusions

The intentional and unintentional pollution with mercury in Sweden has given rise to a serious problem which embraces hazards for all types of biological ecosystems. The recently reported information that all types of mercury compounds may end up as methyl-Hg in a natural system by action of unidentified micro-organisms forces us to look upon this problem as even more serious.[26,27] The fact that the mercury contained in fish is 70-100 % methyl-Hg is frightening. In about 1 % of the investigated waters in Sweden the mean value of mercury concentration in fish is higher than 1000 ng/g and therefore extremely unfit for general consumption. Such fish is now forbidden to market in Sweden.

Mercury residues have been reported in many types of agriculturally produced food and in wildlife. The mercury concentrations seem to be higher in kidney and liver than in muscles (meat) of terrestrial animals. There are, however, examples of very high concentrations in the flesh of pheasants. In contaminated water fish has generally higher concentrations in muscle than in liver and kidney.

The mercury problem may be more serious in Sweden than in other countries due to the widespred use of mercury in industry and agriculture, but there is every reason to believe that the

problem is of the same magnitude in other countries, especially with regards to aquatic organisms, the main difference being that the problem has not been observed there yet and this is because until now very few investigations have been made outside Japan and Sweden. From the recent point of view it is extremely important that all countries take interest in the problem and begin to restrict as far as possible mercury contamination of soil, water and air in order to prevent the great hazards for mankind which the increased mercury concentrations in nature imply.

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