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REDUCTION OF MERCURY POLLUTION IN THE VICINITY OF A CAUSTIC SODA PLANT IN THAILAND

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Abstract. Fish samples collected near the caustic soda factory of TACSCO in Thailand during November and December 1978 were found to contain 0.10 to 1.38 ppm Hg in flesh (on wet weight basis), whereas those of the control areas contained 0.01 to 0.30 ppm. The Hg content of the fish in the TACSCO area had decreased by more than half from the first investigation which took place during 1975–76. This decrease is obviously a result of the functioning of the waste-water-treatment system built by the factory in 1974. The bottom mud collected near the factory in 1978 contained 8.39 to 57.95 ppm Hg (on dry weight basis) as compared with the mean of 0.03 ppm in samples taken from the control area. The Hg content in fish-eating birds were low, 0.04 to 0.44 ppm in the muscles and 0.05 to 1.32 ppm in the livers (on wet weight basis).

1. Introduction

There has been an increase in westernized industrial techniques which have contributed to environmental pollution in the developing countries (Siam Rat Daily, 1978 a, b; Anon., 1978). Flesh samples of a predatory-fish species, *Ophicephalus striatus* (Bloch), collected from the channel in front of the factory of the Thai Asashi Caustic Soda Co. Ltd. (TACSCO) during 1975–76, contained 0.32 to 3.6 ppm Hg (on wet weight basis) (Suckcharoen *et al.*, 1978). The elevated Hg contents have caused concern because fish is the major source of animal protein for the rural population and the poor.

The TACSCO factory has reduced the release of mercury by constructing a waste-water-purification system. The system started functioning in 1974 and gradually reached a high efficiency according to the information presented to us by Igata (1978).

The Hg content of the bottom mud as well as in fish-eating birds near the TACSCO factory has been investigated to determine the amount of Hg pollution since the factory has been controlling the Hg output.

2. Materials and Methods

2.1. FISH SAMPLES

Fifty four commercial fish were caught by gill nets from the following localities:

2.1.1. From the channel lying in front of the TACSCO factory along Suksawad Road at Samut Prakarn Province in Thailand. This channel meets the Tha Kwien and Song Pri Nong canals at about equal distance of 500 m towards north and south from the factory, respectively. The two canals are then connected with the Chao Phraya River which passes behind the factory. In addition, many other factories are also located in the

vicinity of the TACSCO area. Samples were collected during November and December 1978.

2.1.2. From a marshland behind the Kobe Battery Mill. The collecting locality was at a distance of about 2.5 km from the TACSCO factory. Samples were collected during January and March 1978.

2.1.3. From the canal system near the Dah Yang Chemical Co. Ltd., also in Samut Prakarn Province but at some distance from the TACSO area. Samples were collected in March 1978.

About 6 g of the side musculature from each fish were taken and deep frozen in glass tubes.

2.2. BOTTOM-MUD SAMPLES

Mud samples were collected from the same locality as the fish samples (locality 1). The samples of surface mud were taken to the depth of 15 cm and were collected by a hand-operated scoop at distances of 5, 10, 20 and 45 m from the exit of the factory towards the south. At each point, 5 mud samples were taken. In addition, 12 control samples were collected from an unpolluted canal, 30 km north of Bangkok in the Bangkhen District. All the mud samples were collected in December 1978 and deep frozen in plastic bags.

2.3. BIRD SAMPLES

Nineteen specimens of six species of piscivorous birds were obtained by shooting. The collecting locality was at a distance of about 2 km from the TACSCO factory. The samples were taken from the pectoral muscles and livers and deep frozen in glass tubes. The samples were collected in December 1978.

2.4. MERCURY ANALYSIS

All the samples of fish, mud and birds were packed in a dry-ice box for transport to Finland by air. Before being processed for analysis, the mud samples were thawed, then oven-dried at 100°C for 3 days. Gravel in the mud samples was removed by screening.

For the analyses of Hg in fish the method of Kivalo *et al.* (1974) was used. While for the mud and bird samples the method of Särkkä *et al.* (1978b) with a slight modification (4 ml of conc. H₂SO₄ and 1 ml of conc. HNO₃) was used. The Hg content of the digest was measured by Mercury Analyzer Coleman MAS-50.

3. Results and Discussion

3.1. FISH

Fish samples from the TACSO area (locality 1) showed a Hg content ranging from 0.10 to 1.38 ppm, while those of the control area (localities 2, 3) contained 0.01 to 0.30 ppm (Table I). *O. striatus* from the caustic soda factory area had 6 times as high mean Hg as

TABLE I

Mean and ranges of Hg content (on wet weight basis) in flesh of fish in the TACSCO area (locality 1) and in control areas (localities 2, 3).

Species	Locality	No. of fish analyzed	Weight range (g)	Length range (cm)	Hg content (ppm)
<i>Ophicephalus striatus</i> (Bloch)	1	11	60–150	12.5–25.5	0.67 (0.10–1.38)
<i>Ophicephalus striatus</i> (Bloch)	2	17	40–520	15.5–40	0.12 (0.01–0.30)
<i>Anabas testudineus</i> (Bloch)	3	3	40–80	13.5–16.5	0.47 (0.36–0.64)
<i>Trichogaster microlepis</i> (Günther)	1	1	—	—	0.72
<i>T. trichopterus</i> (Pallas)	1	3	20–50	7.0–11.5	0.10 (0.10–0.11)
<i>Clarias macrocephalus</i> (Günther)	1	1	40	18	0.10
<i>Clarias macrocephalus</i> (Günther)	2	5	60–160	18.5–26.5	0.09 (0.02–0.14)
<i>Mugil</i> sp.	3	13	20–40	11–14.5	0.03 (0.01–0.06)

that found at locality 2. A significant difference in the mean Hg content of *O. striatus* was found between the years 1975–76 compared with the year 1978 ($t=2.382$, $P < 0.05$). The mean Hg content in 1978 has decreased by more than half from the results of the years 1975–76 (Figure 1). Obviously, this had occurred as a result of waste-water treatment constructed by TACSCO. The decrease in the Hg content is considerable

Fig. 1. Mercury content (on wet weight basis) in the flesh of *Ophicephalus striatus* in Thailand. Data for 1975–76 after Suckcharoen *et al.* (1978).

when compared with the slow rate of Hg elimination in Swedish and Finnish waters (Nuorteva *et al.*, 1975; Olsson, 1976 a, b).

The climbing perch (*A. testudineus*) and *T. microlepis* also accumulated Hg. Earlier observations by Huschenbeth and Harms (1975) in the Ayuthaya area in Thailand showed only a very low Hg content in the climbing perch (less than 0.01 ppm on average). This is probably the natural background Hg value for this fish.

The Hg content of the fish in this study as well as those from previous studies represented a low degree baseline contamination which is characteristic for Thai fish. The only exception was found in those fish near the TACSCO area (Huschenbeth and Harms, 1975; Menasveta and Sawangwong, 1977; Suckcharoen *et al.*, 1978). Although numerous samples have been collected near other Thai factories, the Hg content has not risen above the baseline. Based on the available data, it seems that a localized pocket of Hg pollution occurred near the TACSCO factory. Although this is not the case when we consider the environmental effects of caustic soda factories in Finland, Sweden, Canada and Japan (Häsänen and Sjöblom, 1968; Johnels and Westermarck, 1968; Fimreite and Reynolds, 1973; D'Itri and D'Itri, 1977).

Obviously, the Thai environment has a rather good capability for eliminating Hg pollution. This capability is possibly related to the low baseline Hg contamination of the biota as well as to its variety and profusion.

3.2. BOTTOM MUD

The Hg content of the mud samples was found to increase positively in relation to the distances from the factory (Table II). Unfortunately, the extent of the samples was restricted to 45 m. It showed, however, that the most effective sedimentation of Hg does not occur at very short distances, but at a distance more than 45 m. Similar delayed Hg fall-out was also observed in grass, *Sporobolus virginicus*, growing near the TACSCO area (Suckcharoen, 1979b).

Compared with the control area, the mud samples from the TACSCO area had Hg contents which were 280 to 1932 times greater. It should be stressed that the actual values of Hg will be higher than those obtained in this study since it is generally known that soils or sediments will lose some Hg when they are oven-dried.

The concentration of Hg in the mud and fish samples in the TACSCO area was

TABLE II
Mercury content in the bottom-mud samples (on dry weight basis)
in the TASCOS area and the control area.

Distance from the factory, m	Control area	
	mean $\pm$ S.D.	mean $\pm$ S.D.
5	8.39 $\pm$ 0.11	0.03 $\pm$ 0.02
10	8.52 $\pm$ 0.08	
20	14.28 $\pm$ 0.09	
45	57.95 $\pm$ 0.46	

similar to that of a polluted area of the Coatzacoalcos River in Mexico (Báez and Nullman, 1975). The low Hg content in the Thai control area, ranging from 0.008 to 0.06 ppm represented normal background values of unpolluted sediments and is similar in value to those reported by other countries (Alhonen *et al.*, 1972; Konrad, 1972; Taylor, 1976; Håkanson, 1977; Särkkä *et al.*, 1978a).

Bed sediments are known to be the sources for most of the Hg found in the aquatic biota and the Hg is also transferred to fish after formation of methyl-mercury proteinate at a suitably low pH (Tsai *et al.*, 1975; Kudo, 1976; Miller and Akagi, 1979; Akagi *et al.*, 1979). The high Hg contents of the muds in the TACSCO area are positively related to the elevated Hg levels found in fish, aquatic plants and freshwater shrimps (Suckcharoen *et al.*, 1978; Suckcharoen, 1978, 1979a,b,c).

3.3. BIRDS

Bird samples had a low Hg content ranging from 0.04 to 0.44 ppm (average 0.19 ppm) in the muscles and 0.05 to 1.32 ppm (average 0.48 ppm) in the livers (Table III). The Hg levels in the muscles were of the same magnitude as the study by Suckcharoen *et al.* (1978) and in the uncontaminated fish-eating birds of other countries (Vermeer *et al.*,

TABLE III
Mean and ranges of Hg (on wet weight basis) in the muscles and livers of birds in Thailand.

Species	No. of birds analyzed	Hg content, ppm	
		muscles	livers
<i>Ardeola raloides</i>	5	0.15 (0.08–0.20)	0.28 (0.14–0.41)
<i>Halcyon smyrnensis</i>	2	0.26 (0.08–0.44)	0.53 (0.12–0.94)
<i>H. chloris</i>	4	0.23 (0.13–0.30)	0.73 (0.41–0.94)
<i>Sterna sumatrana</i>	2	0.06 (0.04–0.07)	0.20 (0.05–0.35)
<i>Larus brunnicephalus</i>	3	0.31 (0.15–0.39)	0.82 (0.56–1.32)
<i>Alcedo atthis</i>	3	0.13 (0.10–0.25)	0.31 (0.11–0.65)

1973; Fimreite, 1974; Turner *et al.*, 1978). The Hg content of the birds was low in spite of the fact that the materials were collected at a distance of only 2 km from the TACSCO area. As mentioned above, the Hg content of fish is also low at a distance of 2 km.

In conclusion, the present investigation showed that the Hg content in fish from the TACSCO area decreased sharply after the waste-water system was built. This decrease as well as the localized pocket of Hg pollution indicate that Hg is easily sedimented or excreted from the aquatic birds. In spite of this fact, the fish in the TACSCO area still have Hg levels which are above the tolerance levels accepted in other countries (0.5 ppm in North America and 1 ppm in Scandinavian countries). Therefore, eating a large amount of fish from this area is a risk. The degree of this risk is aggravated by the fact that some edible aquatic and terrestrial plants near the factory are also loaded with Hg

(Suckcharoen, 1978, 1979b; Paasivirta *et al.*, 1979). Thus, the local inhabitants may receive Hg-contaminated food from several sources.

Although the Hg in the fish is decreasing, there exists no evidence for the decrease of Hg fall-out in terrestrial plants (Suckcharoen, 1979b). This may be the major pathway for the release of Hg into the Thai environment and may increase the baseline Hg load, and consequently deteriorate the Hg eliminating capacity of the natural environment. This has already happened in the industrialized countries where caustic soda factories have distributed Hg over large areas to the detriment of the environment.

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