POLLUTION PROBLEMS OF THE SETO INLAND SEA

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ABSTRACT

The present state of the pollution of the Seto Inland Sea is described as an example of pollution of a confined aquatic environment. A more detailed water quality survey on each organic pollutant should be carried out regularly to clarify the dispersion pattern. This is also necessary to ascertain the assimilation capacity of this aquatic environment and to clarify the permissible limits of the use of industrial chemicals*. The development of methods of forecasting how discharged pollutants will diffuse, change, accumulate in the environment and affect the ecosystem of the area is a very important task.

The Seto Inland Sea has an area of 22400 km^2 and as many as 3000 islands. The Sea is surrounded by the most important industrial districts of Japan, and is divided into the Kii Channel, Osaka Bay, Harima Sound, Bisan Channel, Bingo Sound, Hiuchi Sound, Aki Sound, Hiroshima Bay, Iyo Sound, Suo Sound, Bungo Channel and Kammon Strait. The Inland Sea is also important for fishing; about one-fourth of the total production of coastal fishing in Japan comes from the Inland Sea.

The depth of the Sea is generally under 50 m. The warm Kuroshio Current branches at the Bungo and Kii Channels, and the waters from both channels meet in the Bingo Sound. Thus, the Seto Inland Sea exchanges only slightly its water with that of the Pacific Ocean.

GENERAL FEATURES OF THE SETO INLAND SEA

In 1972 Japanese Government carried out four comprehensive water quality survey projects[1]. A total of 716 survey spots in the Seto Inland Sea were designated and records were gathered at all spots during the same day on each item of water temperature, salinity, transparency, pH values, dissolved oxygen (DO), turbidity, chemical oxygen demand (COD), nutrient salts and plankton samples. The results of the first round of surveying (22 May 1972) are as follows.

The surface distribution of COD is shown in *Figure 1*. Water areas showing COD values of 3 p.p.m. and over include Osaka Bay, the central part of Harima Sound and all industrial and city sea-fronts.

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* In Japan The Chemical Substances Control Bill was presented to the Diet in 1973, and all new chemicals will be checked in advance for possible toxicological effects on environment and human health. Continuous surveillance (production, use pattern, accumulation in environment, etc.) and repeated checks on toxicological safety will be carried out even after the advance check has been carried out.

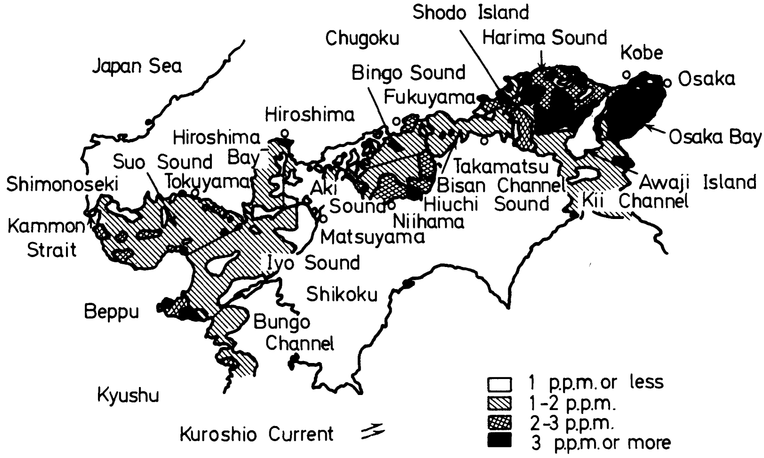

Figure 1. COD level of surface water (May 1972).

Water transparency is shown in *Figure 2.* The lowest transparency, 4 m or below, was found in littoral industrial and city sea-fronts, Harima Sound and Osaka Bay.

For the river water quality and industrial effluent survey sampling sites were set up along 123 river sections at 620 factory and workshop drainage places, and records were kept on temperature, pH values, COD and nutrient salts.

The pollution load imposed upon the Inland Sea included 1600 ton/day in COD (670 ton/day from rivers and 930 ton/day from littoral industries), 470 ton/day in total nitrogen (200 ton/day from rivers and 270 ton/day

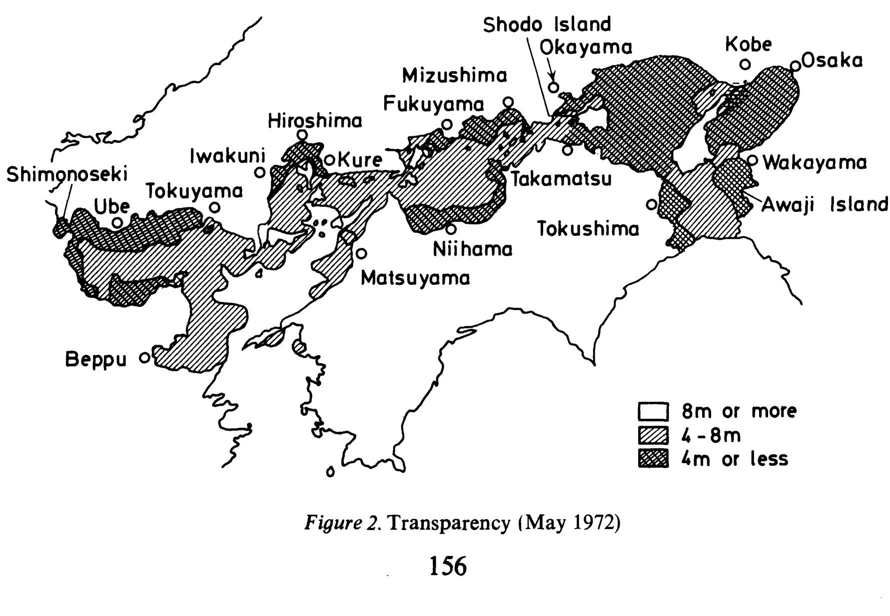

Figure 2. Transparency (May 1972)

from littoral industries) and 32 ton/day in total phosphorus (16 ton/day from rivers and 16 ton/day from littoral industries). The inflow to each water area is shown in *Figure 3*.

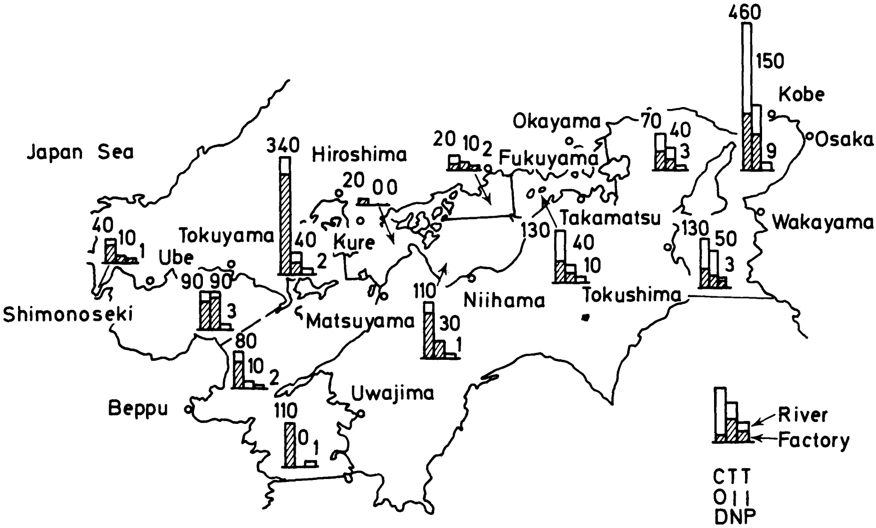

Figure 3. Pollution load on sea-water (financial year 1972, ton/day)

As regards the concentration of total nitrogen, water areas such as Bungo Channel and Kii Strait, which mix extensively with the nutrient-poor Kuroshio Current, had values of 4 μg/l or lower. In Osaka Bay, Bisan Channel and Aki Sound, high readings of 10 μg/l were noted, but the central Inland Sea had low values (2 μg/l) (*Figure 4*)[2].

Figure 4. Distribution of total nitrogen (August 1971, μg/l).

Thus, even though littoral industry effluent and water in rivers feeding the Inland Sea have a high nitrogen content, the fact that most readings were on a par with that of the nutrient-poor Kuroshio Current indicates that the waste water diffuses widely and also that much nitrogen may well be directly utilized by planktons as a nutrient salt.

The distribution of phosphorus in phosphate form is shown in *Figure 5*[2]. The pattern was very similar to that of total nitrogen.

Figure 5. Distribution of phosphate-phosphorus (August, 1971, μg/l).

Sulphides have dangerous effects on benthos, and the compounds are produced from sulphate ion in sea-water, as organic compounds are oxidized under anaerobic conditions. The distribution of total sulphur in the bottom deposit of the Seto Inland Sea is given in *Figure 6*[2]. The areas of more than 0.5 mg sulphur/g dry deposit were often observed in Osaka Bay, Bingo Sound, Hiroshima Bay and Suo Sound. In these areas benthos are usually not observed.

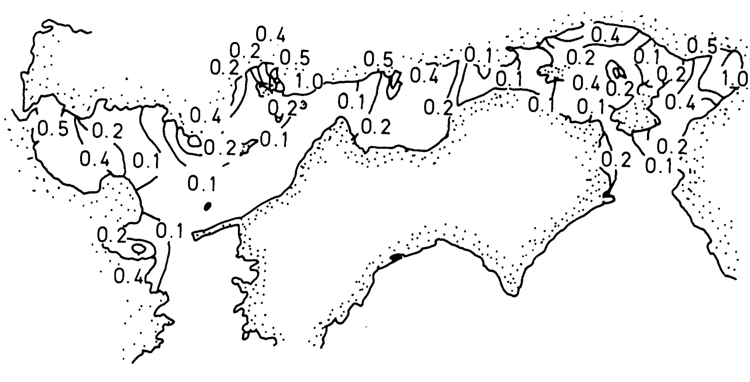

Figure 6. Concentration of total sulphur in the bottom deposit (August 1971, p.p.m. dry sample)

RED TIDE

Red tide is a phenomenon whereby the colour of the sea changes as a result of a rapid and unusual increase of certain types of plankton. Until the late 1950s the region where this red tide occurred was limited to places such as Osaka Bay, Hiuchi Sound and Suo Sound. However, the region began to increase during the 1960s. In this period industrial complexes were built at various places along the coast of the Seto Inland Sea.

Figure 7 shows regions where the red tide occurred in 1960 and 1972[1].

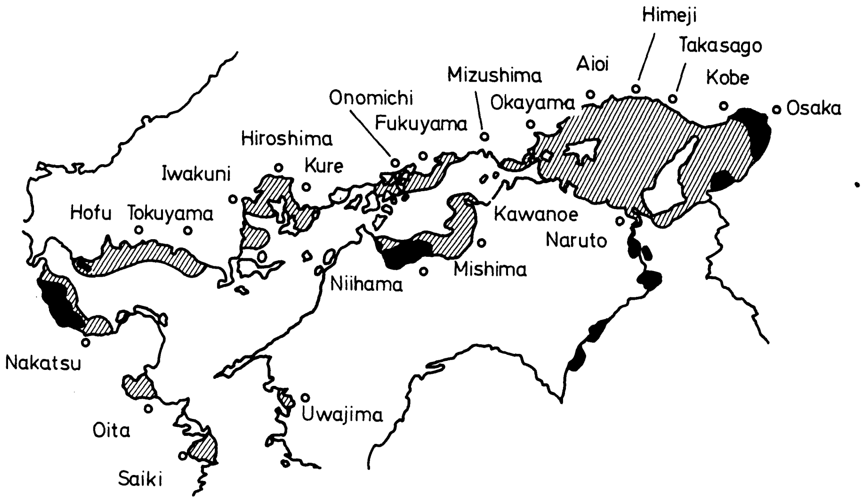

Figure 7. The occurrence of red tide in 1960 (■) and 1972 (▨).

Comparing the COD distribution in *Figure 1* with this figure, it is found that they tally very well. The results of four rounds of surveying definitely showed that the COD values were greatly indebted to the presence of planktons in the sea-water.

The occurrence mechanism of red tide is still unknown[3,4]. The large-scale occurrence of red tide is thought to originate in the stagnancy of the sea-water, excess nutritiousness, sufficient sunshine, growth stimulants such as organic matters, metals and vitamins and a fall in salinity. The acceleration of spore reproduction due to decreased DO conditions in the deep sea-water is also attributable to the occurrence of red tide. Eutrophication is a condition for the occurrence of red tide, and for the red tide not to occur, it is necessary for the inorganic nitrogen to be under 0.1 p.p.m. and inorganic phosphorus under 0.015 p.p.m.[5].

The dominant species of planktons which caused red tide in the Seto Inland Sea are shown in *Figure 8*[2]. The occurrence of red tide due to flagellatates is increasing yearly. The tide caused by flagellatates was killing fishes and shells and inflicting other damage on the fishing industry. In the summer

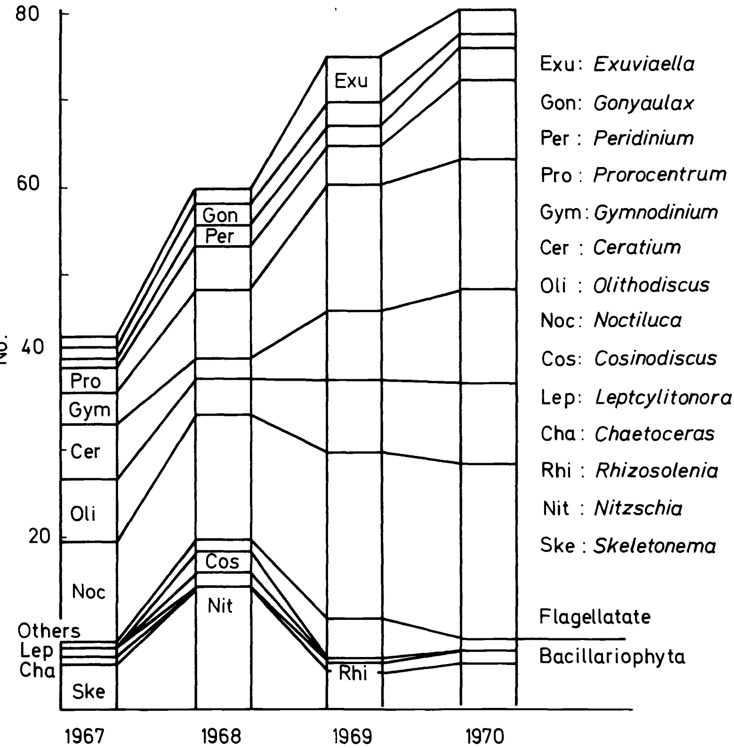

Figure 8. Predominant species of planktons in red tide occurrence.

of 1972 the red tide occurred in Harima Sound (main species: *Eutreptiella*), killed 14 million heads of cultured yellowtails and caused damage amounting to 25 million dollars.

HEAVY METALS IN THE SEA DEPOSITS

Much work has been carried out on the analysis of metals in the bottom deposit of the Seto Inland Sea. A few examples of the distribution patterns of metals will be mentioned here. *Figure 9* shows the distribution of total mercury concentrations in the bottom deposits of Osaka Bay[2]. The concentrations decrease from the inside to the outside of Osaka Bay. Other metals (Cr, Zn, Pb, Cu, Cd, Fe) showed similar patterns to this. It is well known that there exists a linearity between the concentrations of each metal and the areas of the given concentrations, when a sea current has little effect on the dispersion of pollutants. This is the case in Osaka Bay, Bingo Sound and Hiuchu Sound (for Osaka Bay, see *Figure 10*)[2].

Another example is the distribution of chromium in the bottom deposit of Harima Sound. The concentrations of chromium are lower near the Akashi Channel (the sea current is rapid) and higher off the Island of Awaji (the sea

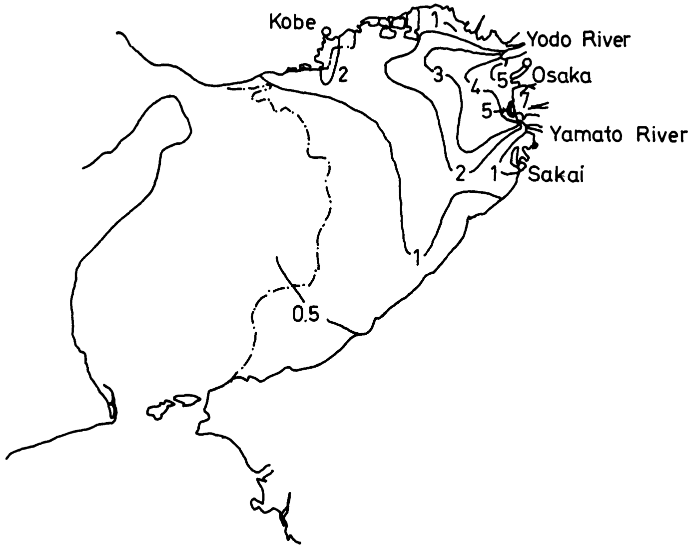

Figure 9. Mercury concentration of the bottom deposit of Osaka Bay (total Hg, p.p.m. dry sample).

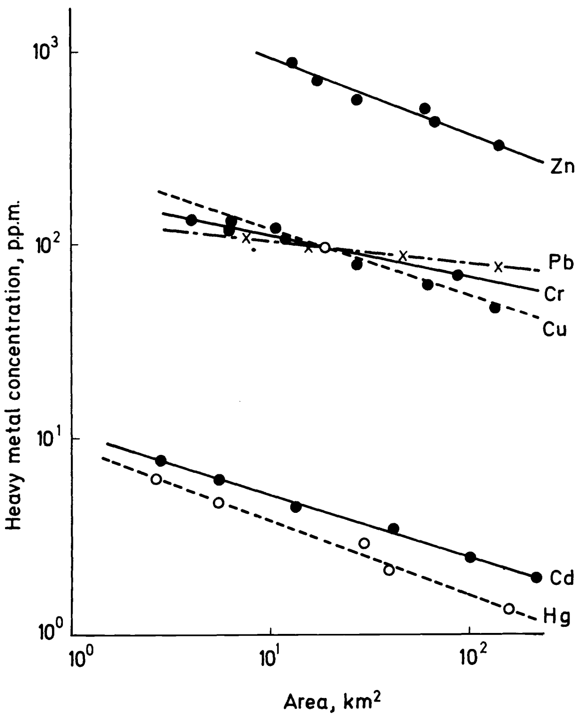

Figure 10. Relationship between heavy metal concentrations in the bottom deposit and their area (Osaka Bay).

current is slow) (*Figure 11*)[2]. It was shown that there exists a linearity between the chromium concentrations and particle sizes (in percentage of the particles less than 50 μm), as shown in *Figure 12*[2]. This dispersion tendency is usually observable in a bay, where a sea current shows a complicated pattern.

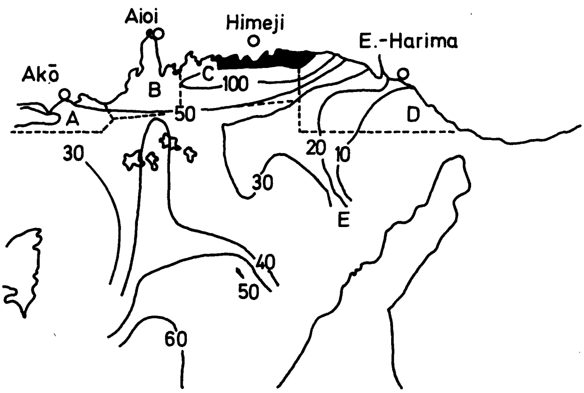

Figure 11. Chromium concentration of the bottom deposit of Harima Sound (p.p.m. dry sample).

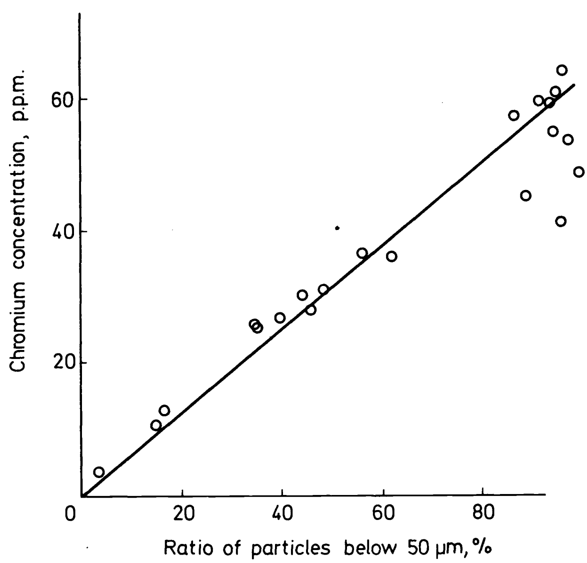

Figure 12. Relationship between chromium concentration and particle size (Harima Sound).

PCB CONTAMINATION AND THE SETO INLAND SEA

Nationwide surveys on the concentration of PCB in human milk in Japan covering 671 lactating women in 52 prefectures and cities were undertaken in 1972 (and 1973)[3,4]. The subjects of the study were women who were within 4 months but at least 1 month after delivery and classified into four groups by their dwelling conditions, such as urban area, agricultural area, fishery area and the area which contains factories suspected of emitting PCB. A few samples from a mining area were also examined as a reference. PCB residues were detected in all the samples examined, and the concentration of PCB in the samples from agricultural areas was lower than those of urban areas. The group which showed the highest concentration of PCB was that of the fishery area (for average values, see *Table 1*).

Table 1

No. of samples (Year)	671 (1972)	5.95 (1973)
1. Agricultural area	0.028 p.p.m.	0.027 p.p.m.[a]
2. Urban area	0.038	0.031
3. Fishing area	0.045	0.039
4. Area around factories	0.040	0.044
Mean	0.035 (max. 0.2)	0.032 (max. 0.2)

[a] On a whole milk basis.

This observation may suggest that the major route responsible for accumulation of PCB in the human body is ingestion of an increased amount of fish. The results of the epidemiological survey of PCB in human milk are given in *Figure 13*.

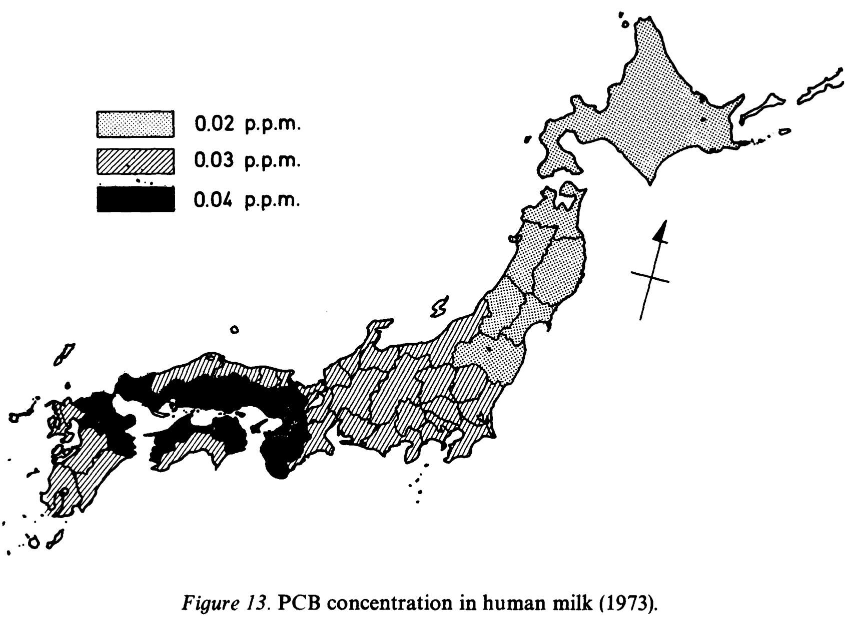

Figure 13. PCB concentration in human milk (1973).

In Japan temporarily accepted limits for the PCB residues of foods and animal feeds were announced in 1972. These provisional limits (in p.p.m.) are as listed in *Table 2*.

Table 2

Fish and shellfish		Powdered milk for infants	0.2
ocean and coastal products (edible portion)	0.5	Meat	0.5
inland water products (edible portion)	3.0	Eggs	0.2
Milk	0.1	Containers and wrapping	5.0
Dairy products	1.0	Compound feeds	0.5

A nationwide survey covering 110 water bodies and 2826 fishes and shellfish was carried out from May 1972 through June 1973. The pollution by PCB in the aquatic environment in Japan is lower in the northern part of Japan and higher in the southern part as reflected in the levels in the fish. PCB levels higher than 3 p.p.m. (provisional limit) were reported mainly in the fish from the Şeto Inland Sea, including Osaka Bay. *Figure 14* shows the

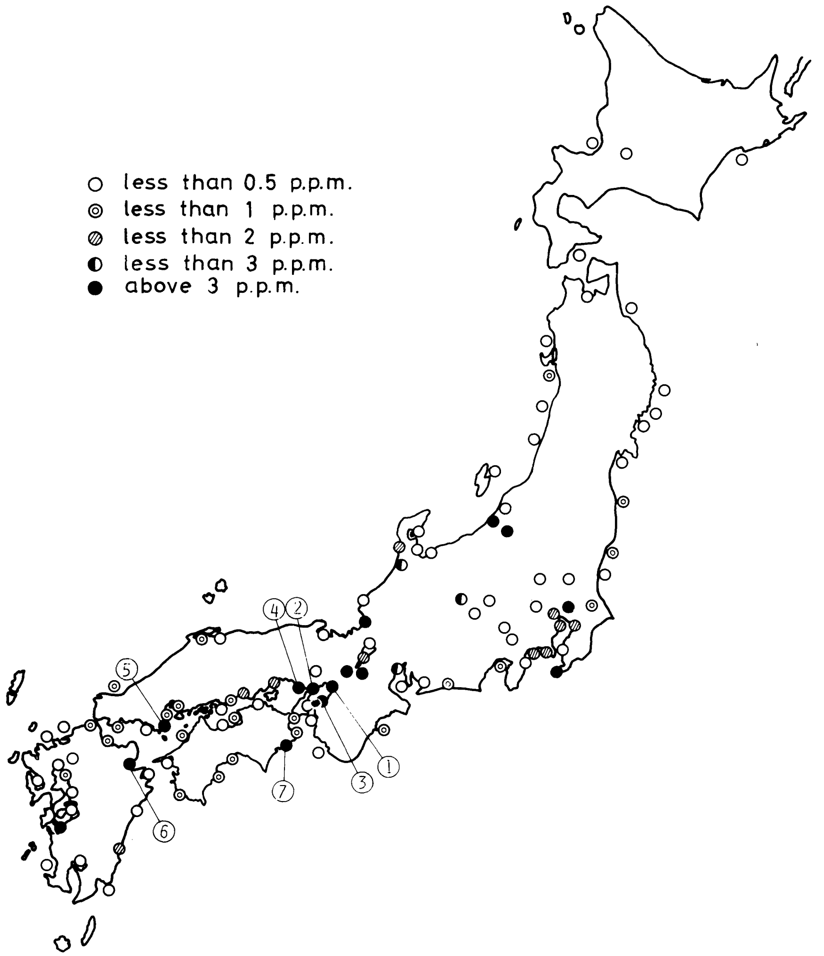

Figure 14. PCB residues in fish (1973)

results of the survey. The concentrations are given by the highest concentrations found in 20 per cent of the fish examined (for details, see ref. 6).

OIL POLLUTION

Of the 2283 cases of pollution reported in 1972, about 87% were due to oil[4]. By area, the waters fronting large cities and littoral industrial zones—where the flow of vessel traffic is greatest—showed the highest incidence of pollution, with the Seto Inland Sea, Tokyo Bay and Ise Bay accounting for 73 per cent of all pollution reported.

COUNTERMEASURES FOR SETO INLAND SEA POLLUTION

For environmental standards, fifty water areas have already been classified by water body category and environmental quality standards have been established. Supplementary effluent standards were also established under prefectural government. An example is given in *Table 3*.

Table 3

CN^-	Not detectable	As	<0.05 p.p.m.
Alkyl Hg	Not detectable	pH	7.8–8.3
Total Hg	Not detectable	COD	<2 p.p.m.
Organic phosphorus	Not detectable	DO	>7.5 p.p.m.
Cd	<0.01 p.p.m.	Oily matter	Not detectable
Pb	<0.1 p.p.m.	*Escherichia coli*	<1000 MPN/100 ml
Cr^{VI}	<0.05 p.p.m.		

For planned sewage treatment, the projected investment total affecting the Seto Inland Sea under the Third Five Year Sewage Plan is 2.6×10^9 dollars, about 30 per cent of the national total. Using a fund of 12 million dollars in the financial year 1972, dredging was carried out in six port areas starting with Tokyo Bay. By the end of the financial year 1972 facilities treating waste oil had been constructed at 71 sites in 46 ports and harbours.

The Maritime Safety Agency set up a Maritime Safety Research Center and a Marine Pollution Surveillance Center. New patrol boats and surveillance helicopters were added to the facilities, and infra-red monitors were provided to detect oil dumping at night. Arrests made for marine pollution crimes numbered 1 177 during 1972.

The complicated pattern of Seto Inland Sea pollution is a function of complex sea currents set up by the varying bottom topography. For the purpose of elucidating the pollution mechanisms, construction of a large-scale hydraulic model of the Inland Sea has been undertaken at a cost of 1.5×10^6 dollars in the financial year 1971 and 3.5×10^6 dollars in the financial year 1972.

A total ban on the dumping of human excrement in the Seto Inland Sea has been in force since 1 April 1973.

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