Chapter 16 MINAMATA BAY

1. An Outline

In 1932, Nippon Chisso Hiryo K.K. (NCH) started to operate the acetaldehyde compound acetic acid facilities using mercury as a catalyst, at the bayside of Minamata facing toward the Yatsushiro Sea (Shiranui Sea). After that, those facilities had been operated for 36 years, exhausting waste liquid actually with no treatment. The contaminant, especially methyl mercury turned Minamata Bay to a sea of death. A lot of years had been spent, however, for people understand those facts. Instead, many victims suffered a pollution-induced disease, Minamata Disease, during those years.

An official recognition of Minamata Disease was first issued in 1956. Then, in 1968, the year in which the facilities suspended operation, Ministry of Japan officially set forth the methyl mercury in the waste liquid from the facilities as a cause of Minamata Disease. In 1977, a dividing net was set up to trap contaminated fishes within the Bay as well as the sludge disposal project effectuated.

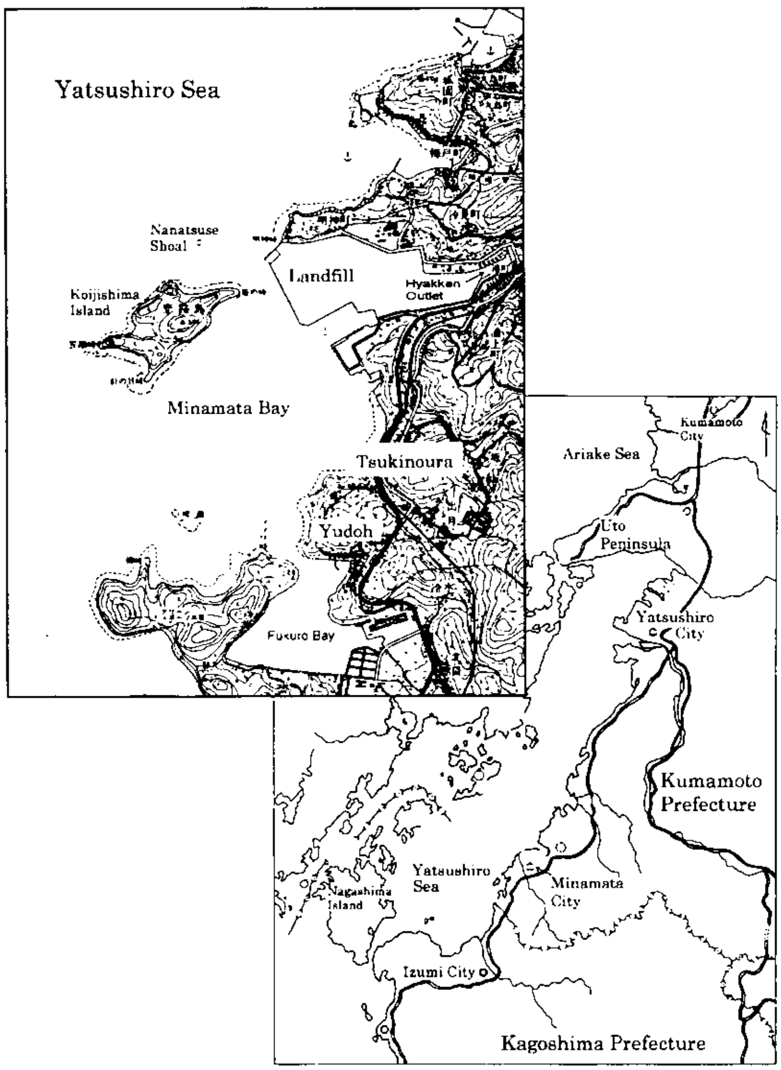

Fig. 16-1. Yatsushiro Sea and Minamata Bay

The sludge disposal program, however, remained to be suspended until 1980, when a guarantee of protection from secondary pollution was admitted by the residents.

The dredging program was completed in 1988, the Hyakken Port in which most high level pollution was found, had been reclaimed. And then, the dividing net, which was regarded as a symbol of Minamata Disease incident, had been completely removed in September 1997. The mercury pollution, called as an origin of the environmental pollution, is coming to an end. The reclaimed land was made as a modern looking park, and then the topography and the scenery of Minamata Bay have changed drastically.

2. Minamata Bay before the cause of Minamata Disease

Yatsushiro Sea spreads with 1,200 km^2, depth of which is 20~50 m. The deepest record is about 70 m at the south end called Nagashima Channel. Through this channel, largest tidal current is observed (Fig 16-1).

Minamata Bay is divided off by Nishinoura peninsula, in the southern end, surrounding a tiny inlet, Fukuro Bay. Myoujin Point and Koijishima Islet (Fig 16-1) make the northern boundary. The long axis of the Bay is 2.6 km long from northeast to Southwest, the short axis is 1.3 km from northwest to southeast, with an ellipse shape, and the spread of it is about 3 km^2. The interval from Koijishima islet and Nishinoura peninsula, about 1.1 km distance, opens to Yatsushiro Sea. This region is deepest as about 20 m, the bottom incline slowly to the outside. On the other side, the interval between Koijishima islet and Myoujin point had a distance of 370 m (at present that shortened to 190 m by a bank protection), the bottom slants gently to the Yatsushiro Sea.

Minamata Bay had once provided a spawning ground for the migratory fishes, and had been especially abundant of fish and shellfish. This is shown by many of materials and Tele by residents. That abundance makes residents depend their life on the flesh fish and shellfish which can be caught quite easily in the neighboring sea, rather than the rice which had to be purchased.

The population of Minamata Village at the beginning (1889) was more than 12,000. The area of Minamata Village locates in between mountains behind and sea in front, and is narrow place providing only a limited farmland. Therefore, the key industry before Meiji Era were a production of nuts of wax tree as a land tax instead of rice, or a production of salt in the salt pan. That salt was valued highly because of the good taste, which is a specialty of Shiranui Sea. Along the estuary of Minamata River, there was a fishing village, fish and shellfish, which were abundant as described above, were eaten as a basic food.

In 1908, nine years after the official designation of Minamata Village upon nationwide adoption of the Village system, Nippon Carbide Co. began manufacturing in this solitary village. Right after that, Sogi Electric Co. (located at Okuchi village in Kagoshima Prefecture), which had been supplying electricity to Minamata Village, merged with Nippon Carbide to form Nippon Chisso Hiryo K.K. (NCH) in August 20th. The NCH much contributed to the re-designation of the Village as Minamata Town in 1912, since the manufacture such as lime nitrogen production grew smoothly assisted in part by a kind of good luck.

As the factory advances, the fishing village around the estuary of Minamata River disappeared by the beginning of Showa Era. On the other hand, Immigrant from Amakusa Islands the opposite bank of Minamata settled the southern area near the boundary with Kagoshima Prefecture, making other fishing village named Yudo, Dezuki, Fukuro, Modo and so on[1]. Including those people, residents in Minamata area favored to earn the cash income by working in NCH rather than fishery. That could be why many of the fishermen came from periphery and opposite bank to Minamata Bay to engage in fishery[1]. The fishes from around Minamata Bay were important source of protein for the people living in the widespread area of Minamata region including the remote place in mountain. This fact was a specific reason of wide spread destruction caused when the mercury pollution of fish and shellfish arose by exhaust liquid.

3. Detail of mercury pollution in Minamata Bay

NCH was expected a great deal of an important role as a key of organic chemical industry during dawn of modern Japan. Moreover, assisted by the electricity provided with the abundant water resource and the low labor cost, and depend on a social situation such as playing a role as the munitions industry, NCH developed abruptly.

NCH started to operate acetaldehyde compound acetic acid facilities in 1932, in this year the history of mercury pollution in Minamata Bay originated. This production facilities are called as first stage (of operations), followed expansion of second to fifth stage in 1933, 34, 35 and 37 (Fig. 16-2). Only those preliminary plants were sufficient for producing 50% of acetic acid of whole in Japan in those early periods. The production of acetaldehyde, in those period, aroused up to over 9,000 t / year maximum, though, since the plant bared devastating destruction by the bombing done just before the end of World War II, resulted to stop operation temporarily in 1945. But after only a half of year from the cessation, the operation resumed. The first and second stages were carried on to 1955, the third and fourth stages to 1949, and the fifth had lasted until 1956, then that was taken over by the new fifth stage of operation. During those period, especially from 1950 when NCH changed its name to Shin-Nippon Chisso Hiryo K.K. (SNCH), in accordance with the industrial restoration of postwar Japan, the production of the Minamata factory abruptly enlarged through a repeated improvement of production facility. Those growth resulted in production exceed the maximum level in pre-war period during 1954 to 55. In those periods, the sixth stage had started its operation in 1953, and the seventh in 1959, both were expected as the latest facility (Fig. 16-2). As a result of those abrupt growth, especially during the term of scrap and build, amount of exhaust could became huge which extremely exceeds those in the usual operation. It is, therefore, thought that unexpected amount of mercury containing exhaust liquid flew out into Minamata Bay due to such an abrupt improvement (see below)[2].

By the way, NCH had started to produce vinyl chloride for the first time in Japan in 1941, which grew the another mainstay of the company later. That facility included the acetylene method using mercury as a catalyst also. In that facility also After NCH resumed to produce vinyl chloride in 1949, this plant had also increased production expanding the facilities supplying the expanding demand in those post-war periods.

SNCH renamed as Chisso Corporation (Chisso) in 1965. Then, when Chisso closed the acetaldehyde compound acetic acid facility in 1968, the maximum output (62,925 t/year) had been recorded. That facility came to an end by switching over to petrochemical plant in 1971. In duration of producing vinyl chloride, methyl-mercury containing exhaust liquid was also flown out into Minamata Bay. The amount of total mercury was less than that from acetaldehyde producing facility, however, that could be 30.6 t[2] as a whole loss of mercury used.

In 1958, SNCH had switched the outlet of drainage canal of acetaldehyde compound acetic acid facilities from Minamata Bay to the estuary of Minamata River, which flew out the pollution enlarging over the Yatsushiro Sea, and resulted to increase victims. Such line of

Fig. 16-2 Change of Acetaldehyde compound facility and production amount[2)]

Year	Production Results of Acetaldehyde (t)	Stage of Acetardehyde Compound Facility (Period of Operation ⟷)]	2nd	3rd	4th	5th	New 5th	6th	7th	Notes
1932	209.763	May								Start to exhaust effluent into Minamata Bay
1933	1297.41		Apr							
1934	2583.18			Oct						Start to produce acetic angydride, cellulose acetate
1935	3628.33				Sep					
1936	5133.75									Start to produce acetone
1937	6252.12					Sep				Start to produce acetic acid rayon
1938	7386.13									
1939	9063.108									Start to produce vinyl acetate, acetate staple fiber (both 1st in Japan), and ethyl acetate
1940	9159.187									
1941	8700.148									Start to produce vinyl chloride (1st in Japan)
1942	8480.196									
1943	7469.934									
1944	7295.541									
1945	2263.815									Interrupted by bombing in Aug
1946	2252.83									Resumed in Feb
1947	2362.703									
1948	3326.256									
1949	4391.208			Apr	Apr					
1950	4484.016									
1951	6248.467									Changed promoter from MnO2 to FeO
1952	6147.777									Start to produce octanohl (1st in Japan)
1953	6592.261							Aug		
1954	9059.14									
1955	10632.776	Sep	Sep							
1956	15919.042					May Dslv	May			May->Minamata Disease recognized first Dslv:dissolve
1957	18085.091									
1958	19191.351									Feb->Facility for continuous oxidation of reaction mixture completed Sep->drain rout changed to Minamata River
1959	31921.222								Nov	
1960	45244.79									
1961	42287.97									
1962	26500									
1963	38500									
〃	41029*									
1964	26581*									
1965	17960*									
1966	16115*									
1967	11961*								May	
1968	783*						May	May		May->Acetaldehyde production came to an end
	*Amount in every fiscal year	Normal pressure fractional distillation					Reduced pressure fractional distillation			

drainage canal was again changed to flow out into Minamata Bay in September of the next year.

It was not until the Minamata Disease Medical Study Group in Kumamoto University Medical School had struggled along to mercury as a cause of the disease in 1959, that the evidence of mercury pollution in Minamata Bay had been uncovered. In that year, Kitamura et al. had first investigated the pollution of Minamata Bay, the data of which is quite valuable today to study the situation of mercury pollution over the Bay[4] (Fig 16-3). According to them, on the sludge pollution, maximum was 2010 ppm per wet weight at the outlet of drainage from the factory in the deep end of Bay, then decreased as went to outer sea.

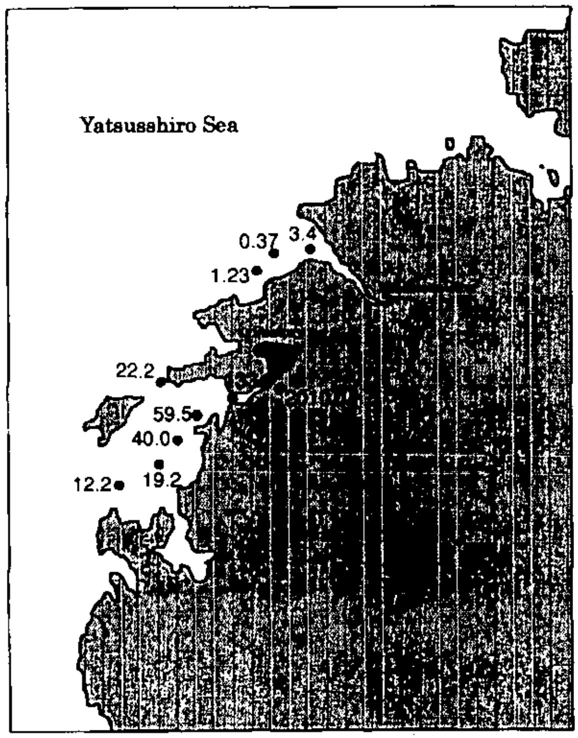

Fig. 16-3. Mercury concentration in the sludge of Minamata Bay (ppm wet weight)[4]

Measurement of total mercury content at sixteen fixed points within the Bay in every 1963, 1969, 1970 and 1971[4], the averaged concentrations were 146.3 ± 173.5, 141.6 ± 214.6, 67.2 ± 65.1 and 129.6 ± 147.3 ppm dry weight, respectively. The sludge made by the accumulation of mercury containing waste in Minamata Bay showed its maximum depth of 4 m. According to the inspection conducted by Kumamoto Prefecture prior to the beginning of sludge disposal in 1974, the sludge containing over 25 ppm of mercury distributed throughout the Bay. It was deeper at the inner end of the Bay, which indicated maximum

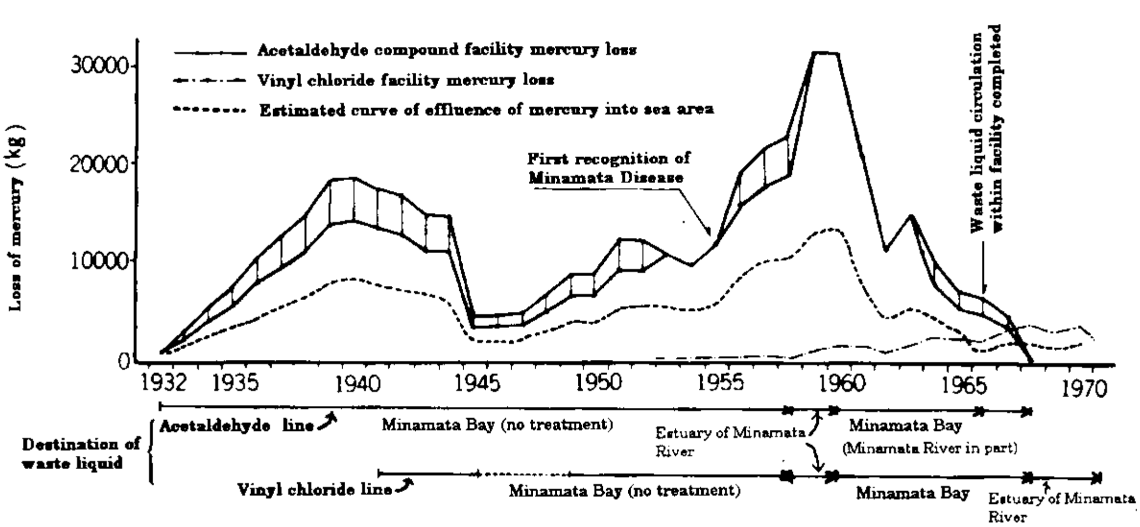

Fig. 16-4. Annual change of mercury loss amount from acetaldehyde compound facility[2]

2,700 ppm per dry weight, decreased with going through out the Bay. Total amount of such a contaminated sludge is announced as 1.5 million cubic meter. On the methyl-mercury, however, the concentration was 0.03 ppm per dry weight as a maximum, and majority of other points was under the minimum limit of detection. Thereafter, disposal of sludge including more than 25 ppm total mercury had been completed by 1990 as described below. In the inspection post-dredging project, the maximum mercury concentration had decreased to around 12 ppm that is much lower than the provisional regulatory standard.

Then, how much mercury had been exhausted into the sea? It is impossible to reply that question because we have a limited data available for figuring out an exact value, but only we can estimate those using such an operation diary recorded in the factory. According to the official announcement by Kumamoto Prefecture or by Minamata City, the whole amount of sediment could be Minamata Bay is 150 t or more. On the other hand, There were a few investigators who performed those calculations more accurately. One of those results is indicated in Fig. 16-4 as an annual transition of mercury loss from the acetaldehyde

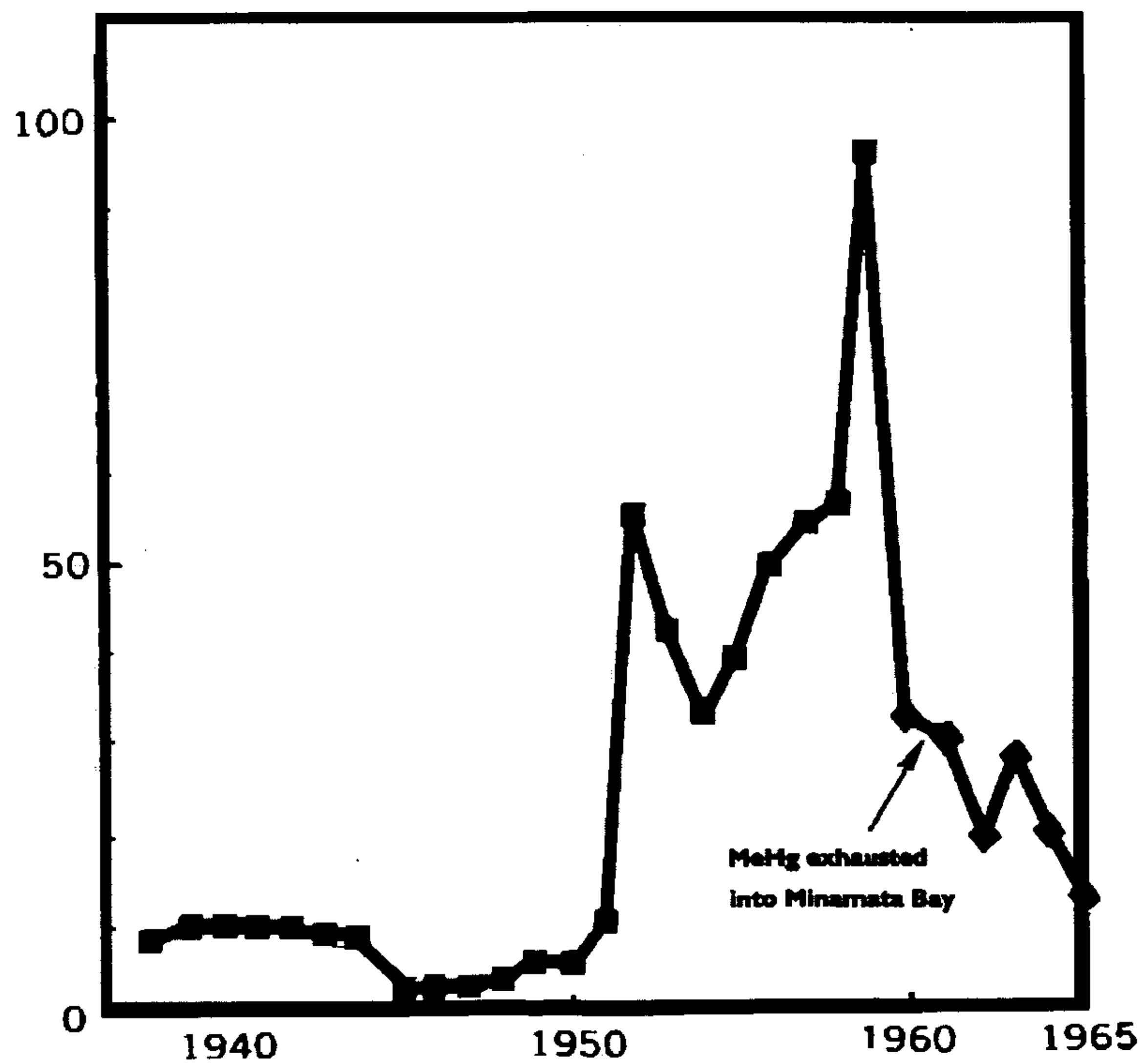

Fig. 16-5 Annual change of MeHg exhaustion amount into Minamata Bay[3)]

production process[2]. As shown in that figure, from 1956 when Minamata Disease was recognized officially, the amount of mercury loss had increased abruptly till 1960, the year when a kind of liquid-waste treatment facility named cyclator-sedifloater (named by SNCH) started to work in SNCH. The period of mercury loss peak coincides with the term of the innovation of facility described above, as well as with the period when acute patients of Minamata Disease had been discovered one after another. There is another dull peak around 1939 in Fig 16-4, which indicates the amount of mercury loss increased in accordance with the growth of acetaldehyde manufacturing process from the start in 1932, and decreased along the deterioration of war situation.

Oxidized mercury, catalyst, forms methyl mercury within the mother liquor of acetaldehyde production[5]. The efficiency of methyl mercury formation is unexpectedly as high as 75% or more of added mercury in the last exhaustion liquid. However, the victims of Minamata Disease were mainly reported during the term of the later peak, but scarcely in the former peak of pre-war period. The reason of which is unknown, but recently Nishimura[3] has shown that NCH first used manganese + oxidized iron as a sub-catalyst for reducing deterioration rate of oxidized mercury, which by chance reduced the formation of methyl mercury, but later (from 1951) SNCH had changed the sub-catalyst to oxidized iron[6]. His report infers such change increased the rate of methyl mercury formation. He also indicated that SNCH used a crude iron (III) oxide derived from a sulfuric acid production process instead of purified ferric sulfate, which caused the repeated bumping accident by reacting with nitric acid included in the mother liquor. Those accidents extraordinary increased the exhaust of methyl mercury into the Minamata Bay. The other primary factor for increasing methyl mercury formation was also disclosed by those researchers that SNCH used seawater in part for the industrial purpose. The chloride ion in the seawater contributed to turn methyl mercury ion into methyl mercury chloride, volatile form, which easily contaminate into the exhaust liquid within the rectifying column. This could be one of the main causes why only the SNCH out of 7 factories using mercury in that period brought about such an devastating public hazards. As a conclusion, they have figured out the annual change of methyl mercury amount exhausted from SNCH Minamata factory, such as 50 kg/year as an average between 1951 to '60, and 95 kg as a peak in 1959. On the other hand, in the term before 1951 and after 1960, the average could be lower than 10 kg/year (see Fig 16-5).

Table 16-1. Changes of mercury concentration in shell fish[5]

(μg/g per wet wt.)

Year, Month		1960			1961			1962	1963	1965	1966		1967				
Place	Species	1	4	8	1	4	12	1	10	5	10	12	4	6	8	10	12
Midori	Mussel*	85	50	31	56	30	9	12	12			8					
Midori	Asari clam								28	33	84		8	15	26	24	20
Myoujin	Asari clam							28	12	16	21		7	8	3	16	13
Koijishima	Asari clam							43	40		81		60	19	48	32	14
Oosaki	Asari clam							5	5	5			6	3	6	5	9

Year, Month		1968				1969					1970				1971	
Place	Species	3	6	7	8	2	6	8	10	12	2	6	8	12	2	3
Midori	Mussel*															
Midori	Asari clam	12	8	9	4	4	2	1	1	1	2	1	16	3	18	3
Myoujin	Asari clam	9	10	12	2	6	7	3	4	6	5	14	2	6	3	4
Koijishima	Asari clam	45	30		5	2	12	16	4	2	10	7	7	4	4	4
Oosaki	Asari clam	4	3	1	0.7	1	0.6	0.3	0.4	0.5	0.4	0.3	0.4	0.6	0.3	0.7

* Hormomya mutabilis

On fish and shellfish, the level of mercury pollution has attracted the attention since Minamata Disease caused by eating them. For such subject, however, the earliest data is also those taken by Kitamura et al. in 1959. According to their inspection, total mercury concentrations in a bivalve *Hormomya mutabilis* obtained inside of the Bay were 11.4-39.0 ppm wet weight, and those outside of the Bay were 2.4-20.4 ppm. For other species in wet

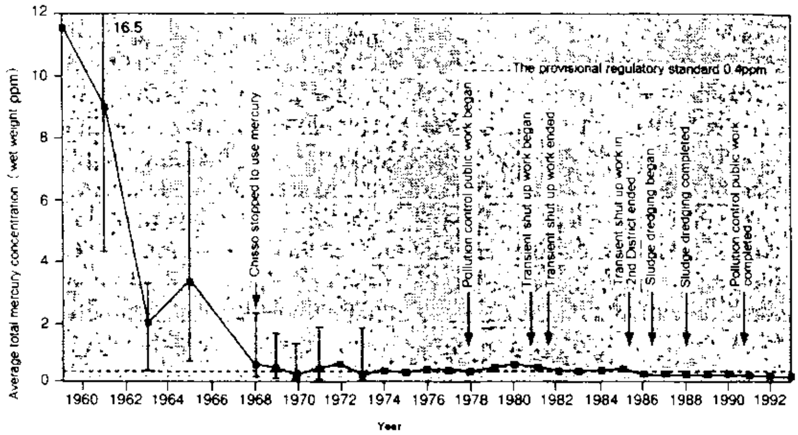

Fig. 16-6. Changes of mercury concentration in fishes of Minamata Bay[7]

weight, small sized crabs 35.7 ppm, croaker fishes 14.9 ppm, short-necked clams 24.1 ppm, black porgies 24.1 ppm and so on. Those values correspond about 40 to 100 times of the provisional regulatory standard 0.4 ppm wet weight provided in the Food Sanitation Low in 1974, that indicate the extraordinary pollution of Minamata Bay in those periods.

The change of mercury concentration in fish and shellfish of Minamata Bay after the inspection described above can be realized from the data of a fixed-point survey performed by Irukayama et al. between 1960 and 1971[4] (Table 16-1). For the initial two years from 1960, we can obtain data only for *Hormomya mutabilis* (mentioned as mussels in the report) collected at Midori seashore (Tsukinoura region); those decreased from 85 ppm dry weight to 12 ppm in October 1963. On the short-necked clams at the same place, the change is from about 30 ppm during 1963-65, which increased to 84 ppm in 1966, then decreased to less than 20 ppm after 1970. Those changes tell that mercury level in those zoobenthos is hard to decrease. On the other hand, on the mercury level changes in fish and shellfish after 1971 there is a huge pile of data produced by Kumamoto Prefecture[7] (Fig. 16-6). Reading the change by average of whole species of fishes inspected between 1961-74, the mercury level rapidly decreased from 9 ppm wet weight in 1961 to the level of 0.5 ppm in 1969, then transit around 0.5 ppm for several years. Except 1980 and 1981 when temporal increase of mercury level was observed, the level decreased little by little, finally after 1986 when Sludge Dredging Project started, the level was below the provisional standard value 0.4 ppm. Unfortunately, however, there were 16 species with higher level than 0.4 ppm in Minamata Bay after the Dredging Project completed, such as greenlings, scorpion fishes, striped grunts, nibblers, porgies, smelts, flounders and so on. For this reason, Kumamoto Prefecture enforced capture and disposal of the fishes inside of the separate nets bordering Minamata Bay at a periodic interval in order to exterminate the polluted fishes. As a result, there is no fish with the level over the standard value after 1994.

4. Process of inquiry into the cause of Minamata Disease, and situation around Minamata Bay

The severe neurological illness (called, afterwards, Minamata Disease), that actually had been found since 1953 or before in Minamata area, was officially recognized in May 1956. Such an illness had been called as a strange disease of Minamata in those days, and was initially thought a kind of infectious disease. Even after the possibility of infections was denied, a lot of candidates for the cause of the illness were taken up for discussion, such as selenium, tallium or manganese. In August 1956, a study group was organized in Kumamoto University Medical School. The members of that group announced an opinion that the cause of the disease was some material contaminated in fish and shellfish in Minamata Bay, and the source of contamination could be the exhaust liquid from SNCH Minamata Factory, as early as in the next year. The opinion, however, had been obscure among the complicated arguments mentioned above.

Cats in Minamata area had been known to show the same neurological disorder of movement as Minamata Disease before the disease was recognized officially. That forced some researchers to design the experiment of fish administration to cats. Itoh et al. showed the cat given shellfish derived from Minamata Bay developed the symptom of Minamata Disease on 7-48th day of administration in 1957[8]. In other case, Sera et al. had committed fishermen live in Minamata area to keep cats derived from outside of Minamata area[9]. All eight cats in that experiment had shown symptom in 32-65 days. In a case, for example, a cat given 40 dried fries (about 10 g) three times a day developed symptom in 51st day of administration.

Table 16-2. Mercury concentration in cats (ppm)[4]

	liver	kidney	brain	hair	blood
Cats suffering from spontaneous Minamata disease	54.0	30.0	–	–	–
	37.0	17.2	–	–	–
	58.5	–	–	–	–
	101.1	–	–	–	–
	54.5	12.2	8.08	52.0	10.6
	68.0	–	10.4	39.8	15.8
Cats suffering from experimental Minamata disease	66.0	–	–	–	–
	105.6	–	–	–	–
	145.5	–	18.1	–	–
	53.5	–	8.05	–	–
	57.5	36.1	–	–	–
	78.3	12.8	–	–	–
	62.0	–	18.6	–	–
	47.6	15.6	10.0	70.0	–
	52.5	15.9	9.14	21.5	–
Healthy cats in the control district	0.9	0.7	–	–	–
	3.66	0.52	–	–	–
	3.01	–	–	–	–
	1.18	0.82	0.05	2.2	–
	1.28	0.09	0.05	0.51	0.13
	1.56	0.28	0.12	3.34	–
	1.64	0.55	0.13	3.45	–
	0.99	0.25	0.09	1.91	–
	1.25	0.16	0.04	3.05	0.08
	0.64	0.28	0.02	0.8	0.06
	–	–	–	–	0.26
	1.7	–	–	9.0	–
	2.7	–	–	0.16	0.05
	6.58	0.05	0.12	29.2	0.68

Kitamura et al. had confirmed an extraordinary high level of mercury contamination in the sludge or the bivalve *Hormomya mutabilis* derived from Minamata Bay after analyzing various toxic metals in 1959[3]. They, further, measured mercury content in the major organs of cats shown symptom after taking seafood from the Bay, and the cats living along Shiranui Sea. They confirmed that those organs contain significantly high level of mercury comparing the control cats[3] (Table 16-2). In addition, on the victim died after showed symptom, the mercury level was remarkably higher than the autopsy died due to another disease. The earlier, in particular, the victim died after symptom appearance, the higher the level of mercury (Table 16-3). In the inspection of mercury content in hair of the patient, the content was extremely high[3] (140.1 ± 188.7).

Based on those results, the Minamata Disease Study Group officially announced that for the candidate of toxic material contaminated in the fish and shellfish of Minamata Bay, mercury was thought with great deal in September 1959. Thereafter, the group extracted and crystallized methyl mercury compound from *Hormomya mutabilis,* short-necked clams and sludge in the factory, one after another. Also, the group succeeded to show symptom in the experimental animals administered the extracted and crystallized material[10][11]. Acetaldehyde is produced by a water addition reaction of acetylene under blowing acetylene into the solution containing sulfuric acid and inorganic mercury, and is separated through a distillation apparatus. Because methyl mercury was separated as crystal out of the sludge obtained from the distillation apparatus for the acetaldehyde-acetic acid production facilities; it was uncovered that methyl mercury was formed as a by-product from inorganic mercury within the acetaldehyde manufacturing process. That was a great result the Study Group performed.

Table 16-3. Mercury concentration in human organs[4)]

Autopsy cases of Minamata disease				Autopsy cases of other diseases		
Approximate days from suffering to death	Liver	Kidney	Brain	Liver	Kidney	Brain
20	70.5	144.0	9.60	0.18	–	–
25	38.2	47.5	15.4	–	–	0.11
50	34.6	99.0	7.80	0.84	–	–
50	39.5	40.5	8.95	0.45	–	–
60	42.1	106.0	21.3	0.2	–	–
60	38.8	68.2	24.8	0.38	–	–
60	34.7	64.2	7.8	1.06	–	–
90	–	–	9.45	1.02	3.02	–
90	36.2	21.2	4.85	–	0.37	0.11
95	30.0	22.6	4.63	–	0.25	0.08
100	22.0	42.0	2.6	–	1.08	0.12
550	26.0	37.4	5.32	0.07	10.7*	0.05
860	6.35	12.8	1.30	–	0.53	0.09
1000	2.05	3.11	0.09	0.60	2.04	0.47
1470	5.44	5.9	2.22	0.97	1.01	1.54

*: The patient had been treated with a mercury-containing drug.

Emission of waste liquid from the acetaldehyde-acetic acid production facilities into Minamata Bay had not been abolished until the drainage facility was switched to the complete circulatory system in 1965 owing to the outbreak of another Minamata Disease in Niigata Prefecture. Acetaldehyde production came to end in May 1968. And then, in September of the same year, Japan Government announced that Minamata Disease in Kumamoto was caused by the methyl mercury formed within the acetaldehyde-acetic acid production facilities in SNCH Minamata Factory, which make Minamata Disease recognized as a pollution induced disease.

Afterwards, the Minamata Disease patients has been certified one another by Kumamoto Prefecture and Kagoshima Prefecture, resulted 1,770 patients among 13,408 applicants for certification in 1994 were certified as Minamata Disease patients and are receiving compensation, such as medical care expenses, from Chisso Corporation (Fig. 16-7). The history of patient certification, which originated with the enforcement of "Relief Law" (exactly, the Law Concerning Special Measures for the Relief of Pollution Related Patients, effective February 1st 1970), is that of conflict, that is, many of lawsuit had been started. In Fig. 16-7, which displays the annual change of certified patient number, remarkable change of data can be seen in several columns, reflecting some transition of social situation or opinion of the judiciary at each point of time. For example, in 1971, the year when Environment Agency established, a notification concerning the certification of Minamata Disease based on the Special Measures Law (Relief Law) was given by the Agency, by which the criterion for certification became not only clearer but also acquiring its publicity.

Moreover, in September of the same year, the Niigata District court decided in accuser's favor, which is a first pollution litigation in Japan. Those situations can be thought to influence on the increase of number of application (see Fig. 16-7). In the meantime, in 1986 court ruled in favor of accusers in the Minamata Disease Certification Suit. This implied the tendency that opinion of the judiciary acknowledges responsibility on government concerning the elongation of conflict. Government, on the other hand, worked out a policy, which included a variety of means such as the Special Medical Project. The Special Medical Project was a measure to provide people who can not be certified as Minamata Disease with a certain medical compensation in order to reduce or get rid of the anxiety for health due to the mercury pollution. That measure was further expanded as the Comprehensive Measures for Minamata Disease in 1992. Finally, in July 1995, Three ruling coalition parties submitted a solution for problem of Minamata Disease based on the Comprehensive Measures for Minamata Disease. The outline of the agreement is that "any conflict should be early, finally and totally settled under the framework that 1) the enterprise (Chisso Co. Ltd.) should pay 2.6 million yen to people who should be relieved, 2) the Prime Minister and the Governor of Kumamoto Prefecture should express regrets, 3) people who will be relieved by this solution should end the conflicts completely, for example, by withdrawing the suits. In the event of the end of suits and conflicts, the government and the prefectures concerned have to continue the financial support to the program of the Comprehensive Measures of Minamata Disease. They also have to resume to accept applications for that program, and should take measures to support Chisso Co., Ltd. financially, and to recover and promote the region affected by Minamata Disease"[11]. Since most of the victim's organizations had accepted that solution, conflicts concerning Minamata Disease extended over a long period of time turn to settle promptly. Kumamoto Prefecture organized the certification Board based on the Comprehensive Measures, applied to its work of screening for the lump-sum compensation, and recognized 10,329 people by March 1997.

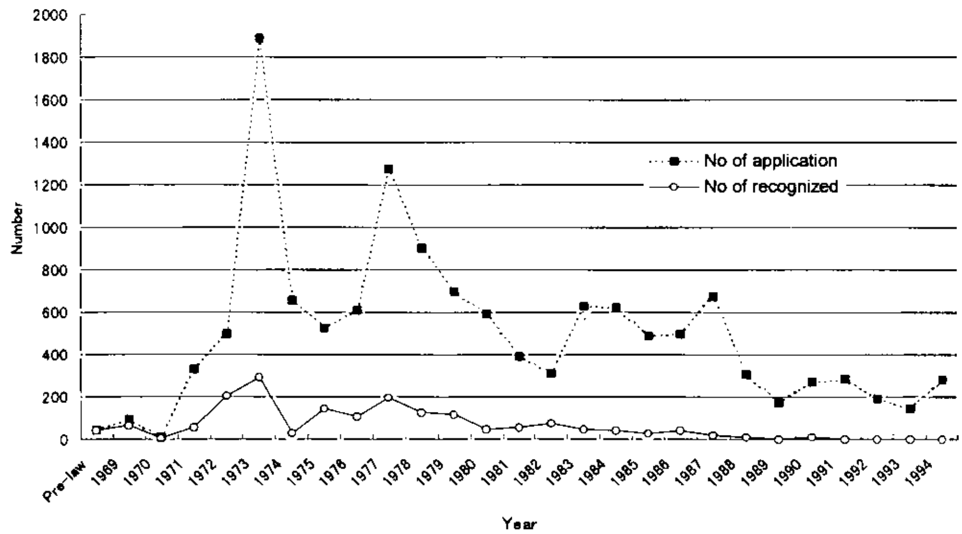

Fig. 16-7. Changes of number of application and recognized victims

5. Sludge Dredging from Minamata Bay

The mercury-contaminated sludge accumulated in Minamata Bay was thought to be inevitable to remove by resident and all classes of people. However, the project for sludge removal attracted attention from all over the world for a long term due to the problems such as bearing the expense, the method for preventing secondary pollution, and the regulatory standard.

Initially, a Sub-committee on Water Quality under the Central Council for Environmental Pollution Control, an advisory body of government, had submitted a report in June 1973 that the regulatory standard for sludge removal should be provisionally 25 ppm in Minamata Bay. Kumamoto Prefecture, being prompted by the government, introduced that value of standard and decided to process by drainage and reclamation of 1.5 million cubic meters of sludge, which contain more than 25 ppm of mercury. Kumamoto Prefecture and the government started the project with payment of 65% of total expense by the company responsible for the pollution and the remaining 35%. Prior to begin the project, various procedures for blocking the diffusion of contaminated materials were tried in order to avoid secondary pollution. Those included many things such as setting separation net with total 3.6 km length to confine the fishes within the Bay, using a cutter-less pump in dredging, setting a treatment apparatus for the exceed water, and mercury monitoring system for water and fish, which spent a long time and expense (Fig. 16-8).

On the procedure of calculating the regulation standard C (25 ppm), the factors on which the standard is based are as follows. 1) Permissible value of mercury contamination in the edible fish as 0.4 ppm reported as a provisional standard by Ministry of Health and Welfare, 2) elution index from sludge to sea water determined by experiment j, 3) the range of the tide □H, 4) concentration coefficient of mercury from sludge to fish (that was decided as 1,000 in Minamata's case), and 5) safety coefficient determined by considering the extent of utilizing fish as food S (that was considered as100 in Minamata). That means there should not be more than 25 ppm of mercury in sludge to prevent fish contamination over 0.4 ppm in Minamata Bay. Against this procedure, however, there have been some arguments. For example, the permissible standard of Ministry of Health and Welfare was figured out based on the biological half-life of methyl mercury, 70 days. Some researchers, however, think to need more consideration on that value, since the half life within the central nervous system is much longer as 230 days, and referring that the true nature of methyl mercury intoxication is the defect of central nervous system. On the concentration coefficient and safety coefficient, those were also thought as subjects to be considered in some cases. Anyway, those values are the 'provisional' standards for the situation of those days in Minamata Bay.

$$C = 0.18 \cdot \frac{\Delta H}{j} \cdot \frac{1}{S}$$

Sludge disposal was started as a preliminary construction to prevent secondary pollution in 1977, the transient shutting up work had then been done in 1980, and thereafter, the full-scaled dredging and reclamation work had barely started in 1981. It was 1990 when whole works had completed, concluding the dredging of Marushima Port and the drainage ditch where contaminated by waste liquid, as well as Minamata Bay. Those were a huge scaled project spending as long as 10 and several years and total expense of 48.5 billion yen. As a result, the sea of 58 ha which had been a fishing port was reclaimed and the pollution control public work of severely polluted Minamata Bay and surrounding sea has been completed. However, the mercury concentration of the fish in the Bay is not necessarily decrease to the background level within a short period. Even for judging the effect of that project, the monitoring of mercury level in fish and shellfish is important to continue, which has been performed by Kumamoto Prefecture and Fishery Agency.

According to the report of Fishery Agency in 1995, even in the scorpion fishes which always shows highest level of mercury concentration within the fishes in the Bay, the level was below 0.4 ppm. Kumamoto Prefecture declared the safety on the mercury level of the fishes in the Bay based on no fish has been found to exceed the standard level for the latest three years. Then, Kumamoto Prefecture had removed the dividing nets between August and September, after getting permission of the fishery cooperative and other organizations. Now, the landscape of Minamata Bay has changed seriously, and the Bay is acquiring a value of existence as a symbol for constructing the new Minamata City with a slogan of environmental conservation. Also, it is worth to notice how Minamata Bay, which has lost the value as fishing ground since the outbreak of Minamata Disease, restores under the measures on environmental restoration.

6. Concluding remarks

Minamata Bay, which experienced most disastrous mercury pollution on record, has been restored spending huge amounts of time and cost. Chisso Co. Ltd. has to continue to pay for various compensations based on the principle of the responsible company bearing the burden. Here, the government and Kumamoto Prefecture are under the pressure of necessity to sustain supporting Chisso from bankruptcy in being short of paying.

On the other hand, it is possible that the reason why the fish with the mercury level over the standard value has disappeared is due to the decrease of such fishes as an appearance. Because there is no fish other than the small sized (young) one as a result of the intensive catching operation of the polluted fish within the dividing nets. It is well known so far that most amount of mercury accumulated in fish is methyl mercury, however, methyl mercury concentration in sediment is as low as hard to detect. Moreover, total mercury

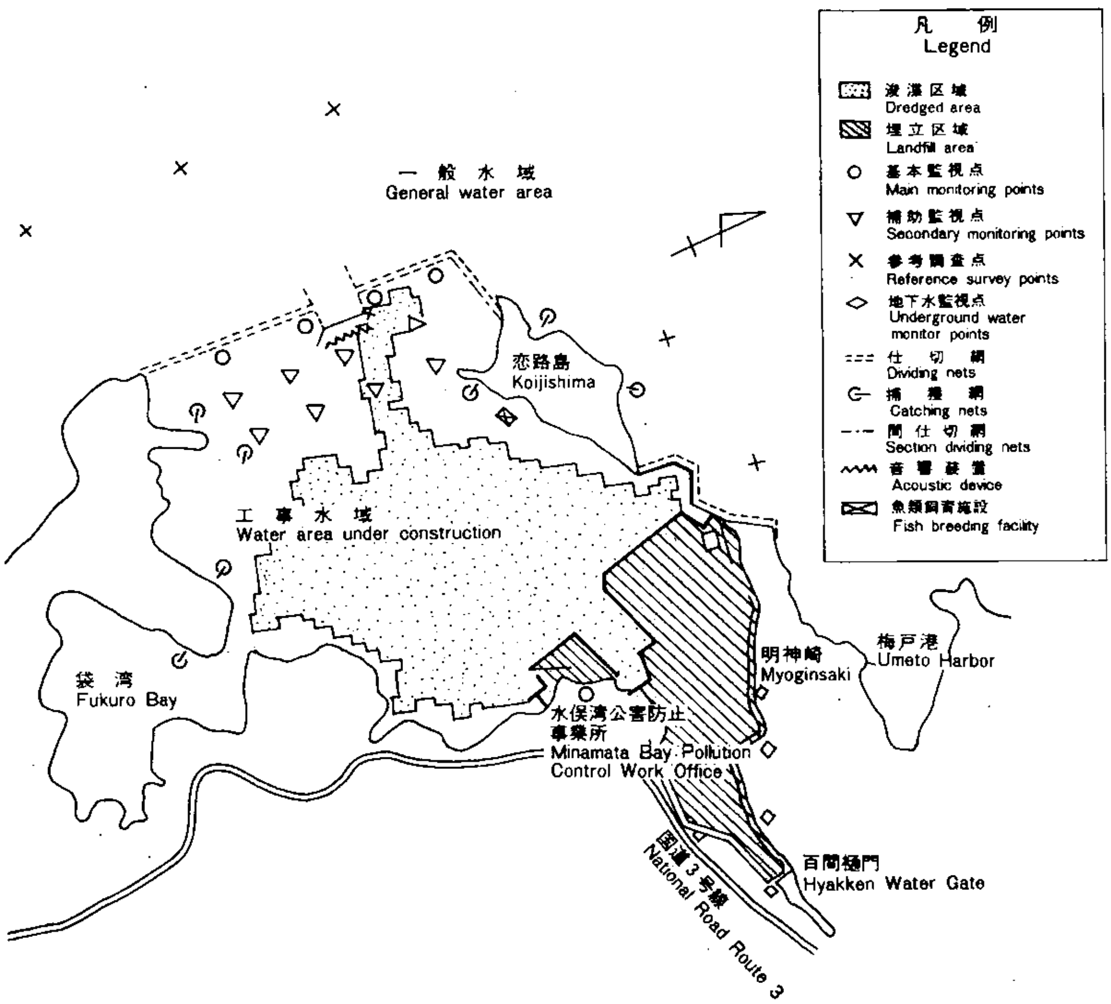

Fig. 16-8 Sludge removal project in Minamata Bay

concentration in seawater of Minamata Bay is also under the detection limit. Therefore, many problems are remaining to be studied on the mechanism of methyl mercury accumulation in fish and shellfish. The mercury level in Minamata Bay must be monitored from now on including whether no polluted fish appears or not.

References

1) Okamoto, T., Nishimura, H.: Gijutu to Ningen Dec. 1996 (in Japanese).
2) Arima, S.: Minamata Byou, Seirinsha, 1979 (in Japanese).
3) Nishimura, H.: Gendai Kagaku, Feb., 1998 (in Japanese).
4) Kitamura, S. et al.: Kumamoto medical Journal **34**, Supplement, 593-601, 1960 (in Japanese).
5) Irukayama, K. et al.: Japanese Journal of Hygiene **19**, 25-32, 1972 (in Japanese).
6) Irukayama, K. et al.: Kumamoto Medical Journal **43**, 946-957, 1969 (in Japanese).
7) Material issued by the Division of Environmental pollution in Kumamoto Prefecture, 1995. (in Japanese).
8) Itoh, H.: Kumamoto Medical Journal **31**, Supplement 2, 282-289, 1957 (in Japanese).
9) Inoue, T: Kumamoto Medical Journal **36**, 877-889, 1962 (in Japanese).
10) Uchida, M.: Seikagaku **35**, 430-439, 1963 (in Japanese).