Chapter 12 COUNTERMEASURES FOR WATER POLLUTION IN THE SETO INLAND SEA

1. Introduction

The Seto Inland Sea (S.I.S.) blessed with gentle climate and marine resources had been deeply connected with human life and culture and offered the natural grace to our nation since old time. The beautiful landscape combined with many small islands and beach lines called "white sand and blue pine" makes people's minds refreshing and wealthy, which is designated as the first national park in our country in 1934.

However, the shallow coastal areas with tidal flat, sand beach and sea weed bed were buried on large scale and coastal water pollution got serious with the expansion of industrial production during postwar high economic development period. Oil smell fishes or malformed fishes were often found in coastal areas near industrial effluent and large scale red tides or fishery damages due to aquatic eutrophication had used to break out in the summer season. For this reason, national government decided to introduce a special law to take countermeasure against the water pollution in the S.I.S. in 1973 except for general environmental laws. As the result, partial water pollution in coastal area strongly affected by industrial effluent and numbers of red tide outbreaks were improved, but overall water pollution in the S.I.S. shows no improvement in spite of the various measurements.

In this chapter, outlines of the countermeasures and changes of water quality in the S.I.S. are explained focusing the period after 1970 when the water pollution got serious.

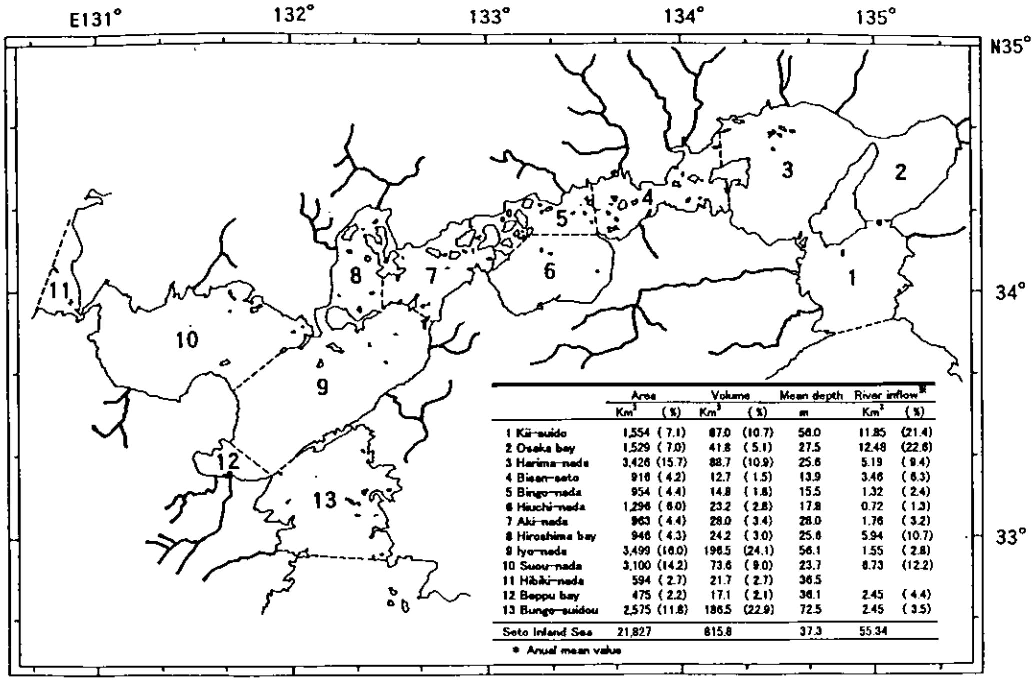
2. Overview of the Seto Inland Sea

2.1. General characteristics

The chain of Japan islands was constructed by separation from the Asiatic Continent due to earth crust change. It's said the present shape of the S.I.S. was almost formed about 10 thousand years ago.[1]

The Seto Inland Sea surround by three large islands, Honshu, Kyushu and Shikoku is a long shape enclosed sea, 15~55km wide from north to south and 450km long from east to west, and about 22,000km^2 area with mean depth of 37m. The average temperature of 15℃ with average annual precipitation of 1,000~1,600mm makes it mild climate. It is dotted with about 700 large or small islands and has total coastline of 6,800km. There are 662 rivers in the basin and total annual flow rate from rivers is about 55 billion tons (Fig.12-1).

Though it was said exchange characteristic of the sea was bad by the reason for the typical enclosed shape, the mean residence time turned out to be about 15 months from recent researches [2].



	Area		Volume		Mean depth	River inflow*	
	Km²	(%)	Km³	(%)	m	Km³	(%)
1 Kii-suido	1,554	(7.1)	87.0	(10.7)	58.0	11.85	(21.4)
2 Osaka bay	1,529	(7.0)	41.8	(5.1)	27.5	12.48	(22.6)
3 Harima-nada	3,426	(15.7)	88.7	(10.9)	25.6	5.19	(9.4)
4 Bisan-seto	916	(4.2)	12.7	(1.5)	13.9	3.46	(6.3)
5 Bingo-nada	954	(4.4)	14.8	(1.8)	15.5	1.32	(2.4)
6 Hiuchi-nada	1,296	(6.0)	23.2	(2.8)	17.8	0.72	(1.3)
7 Aki-nada	963	(4.4)	28.0	(3.4)	28.0	1.76	(3.2)
8 Hiroshima bay	946	(4.3)	24.2	(3.0)	25.6	5.94	(10.7)
9 Iyo-nada	3,499	(16.0)	196.5	(24.1)	56.1	1.55	(2.8)
10 Suou-nada	3,100	(14.2)	73.6	(9.0)	23.7	6.73	(12.2)
11 Hibiki-nada	594	(2.7)	21.7	(2.7)	36.5		
12 Beppu bay	475	(2.2)	17.1	(2.1)	36.1	2.45	(4.4)
13 Bungo-suidou	2,575	(11.8)	186.5	(22.9)	72.5	2.45	(3.5)
Seto Inland Sea	21,827		815.8		37.3	55.34	

* Anual mean value

Fig.12-1 Overview of the Seto Inland Sea

2.2. Fishery resources

There are about 500 species in seaweed, 3,000 species in animal and 600 species in fish, about 100 species of which are associated with fishery resources. Annual fishery catches were under 150 thousand ton before the world war II but increased over 250 thousand ton after the war. Then the amounts continued to increase from the middle of 1960 and reached to 450 thousand ton. However, after the peak, it decreased under 300 thousand ton in 1993 [3,4](Fig.12-2).

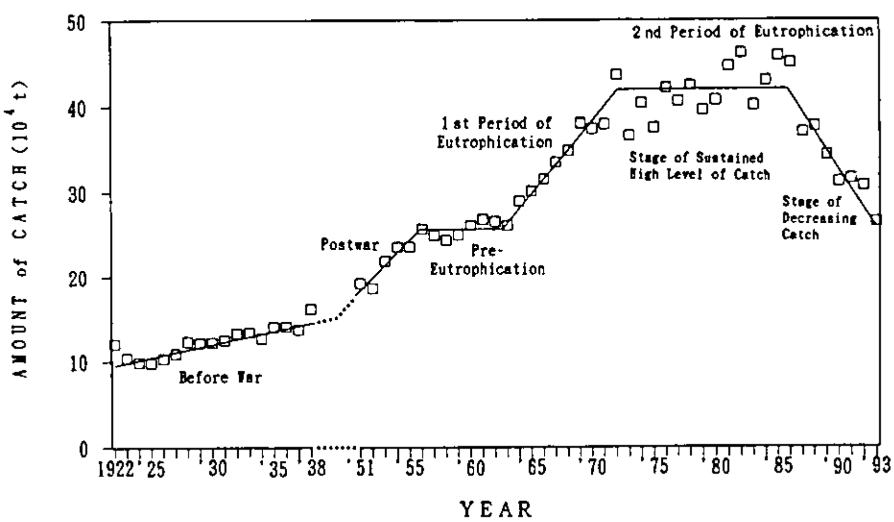


Fig.12-2 Shifts in fish catch amount

The expansion period of the caches after 1965 corresponds to the period of high economic development, when reclamation of coastal area suitable for fishery and environmental pollution has been advanced rapidly. Never the less, fishery production increased due to development and rationalization of fishery technology. However, high price species like sea bream decreased in this period, although low price species like anchovy, cutlass fish, sand eel and Shirasu etc. increased. Recently, sea bream maintained the amounts due to the artificial seed release but low price species tend to decrease by the reason for reckless fishing.

2.3. Changes of social condition in the basin

The changes of social condition are briefly mentioned here as basic data associated with pollutant loading (Table 12-1).

Many heavy and chemical industrial complexes were constructed around the coastal areas in high economic development period since 1955, because it has various advantages in aquatic transportation and many shallow areas for reclamation of industrial adjustment. Though the production amounts had once occupied one half of all our country in steel, petrochemical and chemical industries and one third in food, textile and paper & pulp industries, the rates is decreasing little by little at present. Overall industrial production in the area occupied 38% in our country in 1960 but decreased to 28% in 1993. To compare the production amounts among industries, the rates decrease in primary and secondary industries, and increase in tertiary industry.

The population in the basin increased by 1.2 million during these 20 years and reached to 30.1 million in 1993. On the other hand, the population treated by sewerage system increased from 7.92 to 14.8 million, and the popularization percentages became from about 30 to 50%. The pollution treated with combined type and single type private sewage also increased from 1.78 to 2.08 million, from 4.65 to 5.31 million, respectively. So, population treated by some systems increased nearly by 8 million on the whole.

The numbers of farm animals bred in the basin are 604 thousand, 974 thousand, 1.22 thousand and 175 million in cattle, pig, horse and chicken. The percentages of them to total number in our country are 10, 10, 5, 25 %, respectively.

The area of forest in the basin is 4.64 million ha, 20% in all forest areas in Japan. It increased by 0.21 million ha during these two decades.

Table12-1 Sensus data in the Seto Inland Sea baisin

Year		1970	1975	1980	1985	1990	1993
Population (million)		26.2 *1	28.0 *1	29.0	29.6	29.9	30.1
Population in sewerage system (million)		6.73 *2	9.44 *2	9.52	10.9	13.3	14.8
Sewerage percentage (%)		25.7 *2	33.7 *2	32.8	36.7	44.4	49.2
Population in private sewage system (million)				1.78	2.12	2.08	2.08
Population in combined sewage systen (million)				4.65	5.27	5.29	5.31
Industrial production amount (¥trillion)		23.4	42.5	67.8	78	89.5	86.4
Production amount	Primary (¥trillion)	0.963	1.58	1.66	1.73	1.71	1.57
	Secondary (¥trillion)	10.2	17.6	27.3	32.7	44.9	45.1
	Tertiary (¥trillion)	12.8	27.6	46.1	61.6	80.7	87.2
Number of farm animal	Cattle (thousand)	699	576	632	659	621	604
	Pig (thousand)	927	967	1,190	1,230	1,110	974
	Horse (thousand)	4.13	1.21	0.63	1.53	1.49	1.22
	Chicken (million)	77.5	70.6	75.5	74.2	95.5	175
Area of forest (thousand ha)		4,430	4,440	4,640	4,640	4,640	

Note: Data except for population and sewerage% indicate total values in 13 prefecture around the S.I.S.
Population data (* 1) in the basin are got by converting total values in 13 prefectures into vasin values on the basis of the value in 1980 considering population expantion rate during 1970～1980.
Sewerage percentage(* 2) are estimaated on the assumption that sewerage area% are equal to sewerage population %.

2.4. Reclamation of coastal line

Reclamation area in the S.I.S. amounts to 26,400ha during 70 years between 1900 and 1970, whose 33% has been buried during only 5 years after 1965. The reclamation condition after 1965 is shown in Fig.12-3. As the restriction against reclamation was enforced by two special laws, "Law concerning provisional measures for conservation of environment of the S.I.S.(LCPMCE)" in 1973 and " Law concerning special measures for conservation of the environment of the S.I.S. (LCSMCE)" in 1978, the rate decreased after 1974.

However 41,900ha of shallow areas have been lost by reclamation between 1900 and 1993. About 50% in all coastal lines, 6,800km have been covered with artificial concrete instead of natural shore-line, only 38% of which remain in the basin [3] (Fig.10-4).

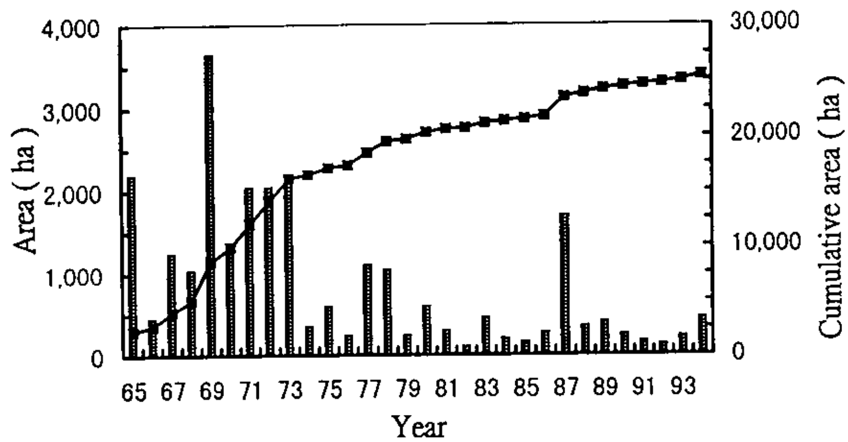


Fig.12-3 Yearly change in reclamation areas in the S.I.S.

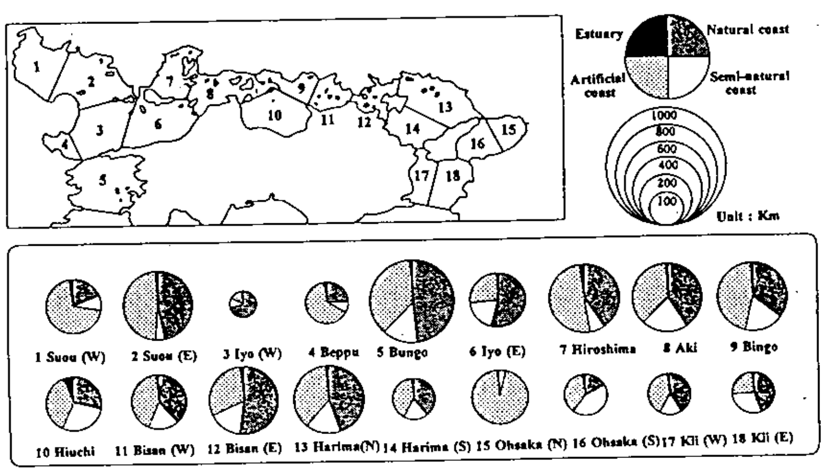


Fig.12-4 Present circumstance in natural coast line

2.5. Oil pollution

The numbers of oil spill affairs after 1970 are shown in Fig. 12-5. Maximum numbers of 874 are recorded in 1972. In 1974, there was a large scale of oil spill from oil tanks at Mizushima combination in Okayama prefecture by accident. Heavy oil of 43,000kl exhausted from tanks, 7,500~9,000kl of which flowed into coastal sea. It was the largest oil pollution at that time in our country and the damage had amounted to over 16 billion yen [2,7]. Oil spill numbers in the S.I.S. showed a peak between 1971 and 74, and decreased. However, the numbers even now amount to 101 affairs and occupy about 30% in our country.

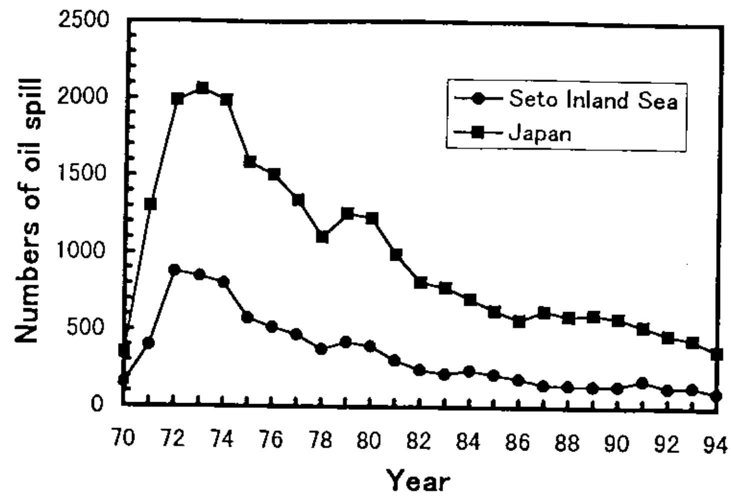


Fig.12-5 Yearly change in oil spill affairs in the sea.

3. Red tide and fishery damage

Red tide by *Noctiluca* and *Skeltonema* had been seen in the S.I.S. since old time. However, they were on small scales and not serious until *Gymnodinum* red tide with fishery damage happened in Tokuyama Bay in 1957. After that, red tides and fishery damages by Diatom and Dinophyceae had used to happen every year and expanded the scales[8~10]. Red tides and fishery damages since 1962 are shown in Table 12-2 [3].

Table 12-2 Damages to fisheries by red tide in the S.I.S.

Year	Location	Case species	Damage to fisheries	Fish mortalities	Damage (¥millions)
1970	Hiroshima Pref. Coast	*Chattonella*	Young yellowtail	500,000	620
1972	Harima-Nada	*Chattonella*	Young yellowtail	14,000,000	7,100
1975	Harima-Nada	*Prorocentrum*	Young yellowtail	35,000	Unknown
1977	Harima-Nada etc.	*Chattonella etc.*	Young yellowtail etc.	3,560,000	2,940
1978	Harima-Nada etc.	*Chattonella etc.*	Young yellowtail	2,830,000	3,320
1979	Harima-Nada etc.	*Chattonella etc.*	Young yellowtail etc.	1,820,000	1,110
1980	Bungo-Suido etc.	*Photogonyaulax*	Young yellowtail etc.	523,000	390
1983	Kii-Suido etc.	*Chattonella etc.*	Young yellowtail etc.	286,000	281
1985	Suo-Nada, Bungo-Suidou	*Gymnodinium*	Young yellowtail etc.	Unknown	10,210
1987	Harima-Nada etc.	*Chattonella etc.*	Young yellowtail	1,900,000	2,400
1991	Hiroshima Bay etc.	*Gymnodinium*	Sea bream etc.	2,050,000	1,500
1995	Bungo-Suido etc.	*Gonyolux*	Sea bream etc.	5,500,000	1,270

In 1972, an unprecedented large scale red tide by *Chattonella* happened in Harima-Nada and many fishes in artificial rafts were killed by the red tide. By this affair, eutrophication and red tide became a social issue in the sea, and national government decided to enact the special law "LCPMCE" to cope with water pollution in the S.I.S. Yearly change in breakout numbers of red tide is shown in Fig.12-6. The red tides tend to decrease after the peak in 1976.

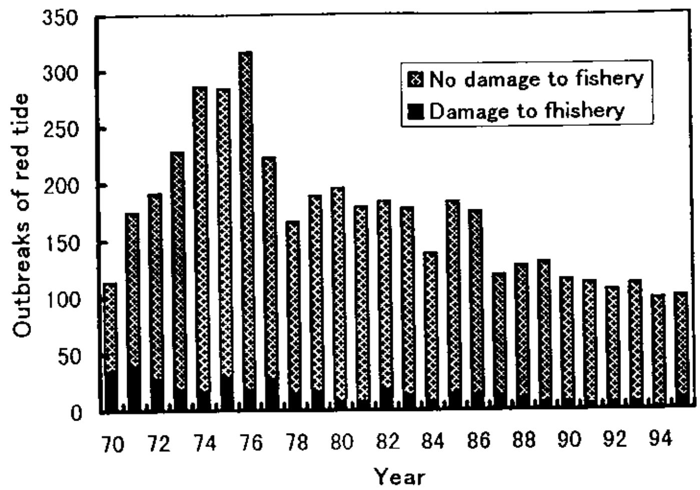


Fig.12-6 Yearly changes in red tide outbreaks

The fishery damage by red tide is largely divided into two, one is due to toxin of plankton and the other due to oxygen deficit. There are various harmful species in plankton. *Shattonella* and *Gymnodinum* are representative species to kill fishes by their toxin.

Recently, red tide by Dinophyceae (*Alexandrium*) which is one of the species of paralytic shellfish toxin such as gonyautoxin or saxitoxin has often happened in the area. The shellfish uptaking this plankton sometimes shows paralytic toxin to human beings.

The reason why fishery damages by red tide happen frequently is that artificial fishery is popular in our country and that fishes bred in raft can't get away from red tide. Though basic countermeasure for these damages is to reduce eutrophic level in the sea, following devices are adapted in this area at present; 1) Establishment of monitoring systems of red tide, 2) Movement of fish raft in the early stage of red tide outbreak, 3) Descent of feed amounts which is one of the causes of red tide outbreaks.

4. Restriction and countermeasure against water pollution

Effluent and environmental standard are defined by "Water Pollution Control Law (WPCL)", and monitored and restricted by local governments in our country. However, as the effect on improvement in the environment pollution by only this law is assumed to be low, two special laws, " LCPMCE" and " LCSMCE" were introduced to the S. I.S. The outlinesof two special laws are introduced here.

4.1. " LCPMCE"

As red tide and fishery damage had often happened on large scales in the S.I.S., provisional law, "LCPMCE" was enacted urgently to cope with these issues in 1973 under the limit of 5 years legislation at the instance of House members and succeeded automatically by formal law, " LCSMCE" in 1978. Though the content is almost same with "LCSMCE", following two are peculiar in this law.

1) An express statement of early introduction of mass emission restriction system against pollutant effluent.
2) 50% reduction of COD load during 5 years.

As the system for pollutant load restrictions was not one by total mass emission, but by concentration in 1973, national government declared the necessity of early introduction of the mass emission restriction system and also decided a 50% reduction for COD load in 1972 until 1976 in this law, considering that the countermeasure need to be emergency and that it will fairy contribute to water quality improvement in the sea, although there was no evidence for scientific basis [12,13].

4.2. "LCSMCE"

As mass emission regulation system was introduced in the " WPCL" in 1978 according to the law "LCPMCE" and the system was applied to the S.I.S. besides Tokyo Bay and Ise Bay. For this reason, mass emission regulation system for COD load and guidance for nutrient load reduction were incorporated in this law.

Each prefecture made regional plan for environmental protection according to the basic plan by national government.

⟨View point of the basic plan⟩

Local governments must make the effective plans for environmental protection according to the idea that all people will accept equally the values of beautiful scenery and abundant resources, and succeed them to descendants.

⟨Contents of the regional plan ⟩

1) Restriction of settlement of effluent source called "specific facility".

The settlement of specific facility is notification system in " WPCL " ,but permission system in this law. New settlement of specific facility is under an obligation to carry out environmental assessment.

2) Enforcement of total mass emission restriction for COD load.

National government plans the goal of total mass reduction for COD load in the whole Inland Sea and local governments carry out the plan. The reduction goal of COD is decided every 5 years in the range of technical realization. The goal is shown in Table 12-3.

Table 12-3 Reducing plan for COD and nutrient loads in the S.I.S.

Stage	Final year	Goal in COD load		Designated
		Reduction %	Actual %	substance
I	1984	7.4	10.9	P
II	1989	6.1	6.8	P
III	1994	9.1	10.9	P
IV	1999	3.9		N and P

3) Reducing guidance for designated substance (nutrient) load.

Only phosphorus had been designated as reducing guidance substance between 1~3 stages (Table 12-3), because nitrogen can be fixed in the sea by bacteria or algae, and the treatment technology for nitrogen had not yet established sufficiently. However nitrogen was also designated the reducing guidance substance from the forth stage because of following two reasons.[15]

① Phosphorus is not always a limiting element of nutrients for algal growth because the N/P ratios show the variation in each season and region in the S.I.S.

② Large shift of N/P ratio from natural values will not be favorable for environmental ecosystems.

Local governments make the plan for reducing guidance of nutrient load considering regional features. The main countermeasures for reducing guidance are as follows;

① Countermeasures for industrial load.

- Restriction of nutrient load by effluent standard
- Improvement of sub-materials containing nitrogen and phosphorus
- Convert to phosphorus-free detergent
- Appropriate maintenance of treatment facility
- Introduction of effective treatment system

② Countermeasures for domestic load

- Promotion and proper maintenance of municipal sewerage, treatment facility in agricultural area, raw sewage treatment plant and private sewage system, etc.
- Convert to phosphorus-free detergent
- Education and public relation to enlighten citizen's consciousness for domestic effluent load

③ Countermeasures for the other load

- Livestock farming: Appropriate treatment of animal discharge and the effective utilization
- Agriculture: Observance of proper usage of fertilizer
- Fish culture: Observance of proper feeding
- Other : Positive application of environmental purification ability for water quality

However, these countermeasures for T-N and T-P are only guidance and there is not yet emission regulation system like COD load.

4) Conservation of natural coast beach.

National and local government must designate the areas such as natural sand beach, tidal flat and reef used in swimming, gathering shellfish and fishing as natural conservation districts and protect them. 91 areas are designated as the conservation districts in the S.I.S. until 1995.

5) Restriction against reclamation of shallow coastal area

The reclamation of public water is under obligation to be researched and admitted in Srto Inland Sea Environmental Conservation Council before the implementation.

6) Promotion of environmental protection project as followings

① Waste, municipal sewerage and river-basin sewerage treatment facility

② Disposal facility for waste oil from ship

③ Research and monitoring system for red tide outbreaks

④ Relief for fishermen affected fishery damage by red tide

5. Changes in pollutant effluent load

COD load from the basin was reduced to one half by "LCPMCE" and reduced farther according to the reduction goal in every 5 years by "LCSMCE" to cope with water pollution and fishery damage by red tide. Though load reduction was mainly carried out by industrial effluent restriction and municipal sewerage expansion at first and second stages in "LCSMCE", overall countermeasures for domestic load were promoted such as community plant, raw sewage treatment facility in agricultural area and combined sewage system, etc. from the third stage. On the other hand, nutrient load countermeasure was also carried out by guidance plan of local government under these two laws. The Changes in COD and nutrient loads are shown during these periods in Fig 12-7 [6].

The COD load increased between 1961 and 1968, then decreased rapidly, especially between 1972 and 1979. The increase means load expansion according to industrial development and the decrease is due to load restriction by "LCPMCE". After 1979, it decreased gradually from 1,000 to 800 ton/day during 15 years, reflecting the mass emission restriction by "LCSMCE". Though industrial load was three times larger than domestic one in 1972, it is under domestic load at present by strict restriction of industrial load. To compare their reduction rates, they are respectively 75% in industrial load and 20% in domestic one during past 20 years.

On the other hand, the reduction in T-N and T-P loads are smaller than COD. T-P load reduced by 28% reflecting the reducing guidance but T-N is only 10% during these 10 years. To compare the changes in T-P load sources, domestic load which had occupied about 50% of all loads in 1979 decreased, and the rates of domestic, industrial and the other load became almost even in 1989. The conversion to phosphorus-free detergent contributed to the domestic T-P load reduction.

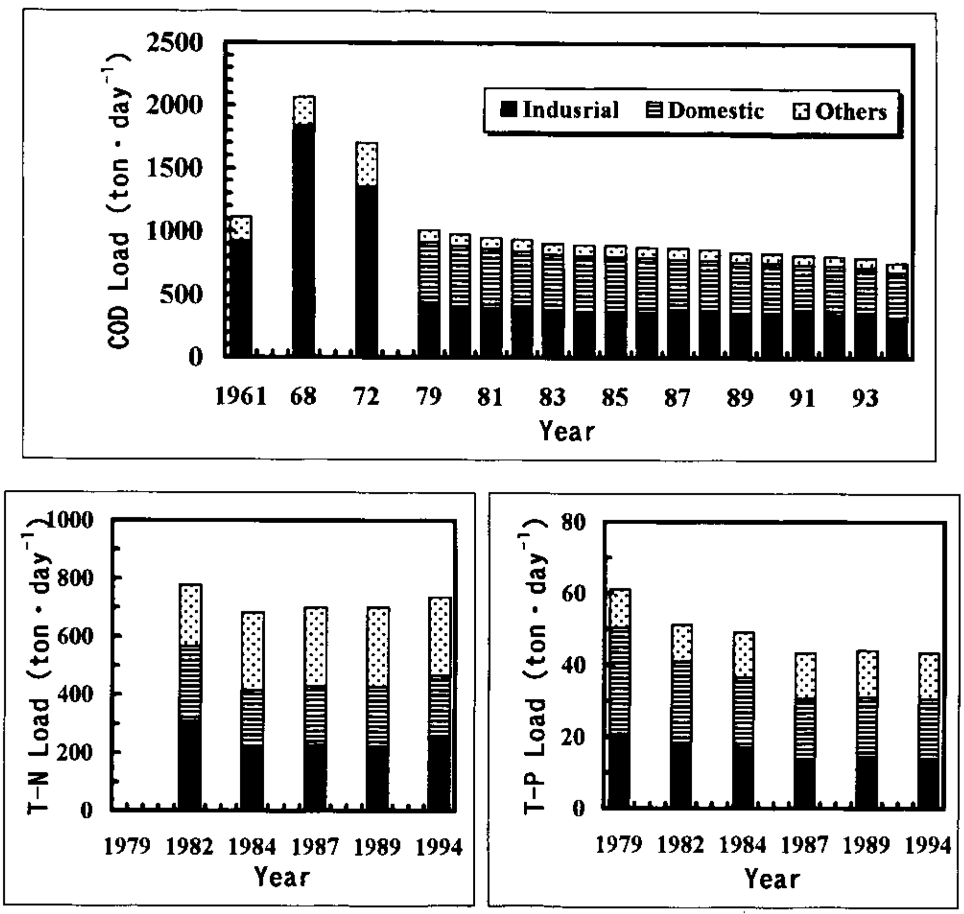


Fig.12-7 Shifts in COD,T-N and T-P loads from effluent

6. Water environment in the S.I.S.

6.1 Changes of water quality

Though various countermeasures have been taken against water pollution in the S.I.S., achievement rate in the environmental standard for COD, etc. has remained at the same level, about 80% for 20 years in spite of the severe reduction of COD load due to "LCPMCE" and "LCSMCE". In each category, the achievement rate is lowest, only 43% in category A, cleanest area, in 1994. Annual mean values for COD, T-N, T-P and Chl.a at surface water of all monitoring stations in comprehensive research in the

S.I.S. are shown in Fig. 12-8. An improving trend is rarely found in each item, except for abnormal peak of Chl.a in 1985 ~ 86. Annual mean values are 6 ~7m in transparency, 1.5 ~ 2.0 mg/L in COD, 3 ~4 μg/l in Chl.a, 0.25 ~ 0.3 mg/l in T-N and 0.025 mg/l in T-P, although they show a little variations in seasons.

Horizontal distribution of COD in the same research is shown in Fig. 12-9. These data represent mean values during 5 years. Osaka Bay and northern Hiroshima Bay show the highest concentration. The Chl.a concentration shows a similar distribution to COD. We can easily infer that organic pollution in the S.I.S. is associated with algal growth from a good relationship between them. T-N and T-P concentration in each bay and water are shown in Fig.12-10.

Though there was no improving tendency in water quality on the whole, COD concentration got recover in Osaka Bay but increase a little in Hiroshima Bay, Bisan-Seto and Bingo-Nada [6].

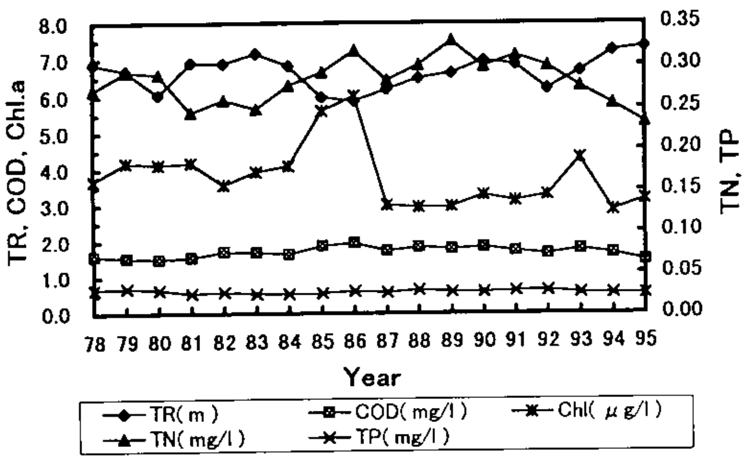


Fig.12-8 Yearly change in mean water quality in the S.I.S.

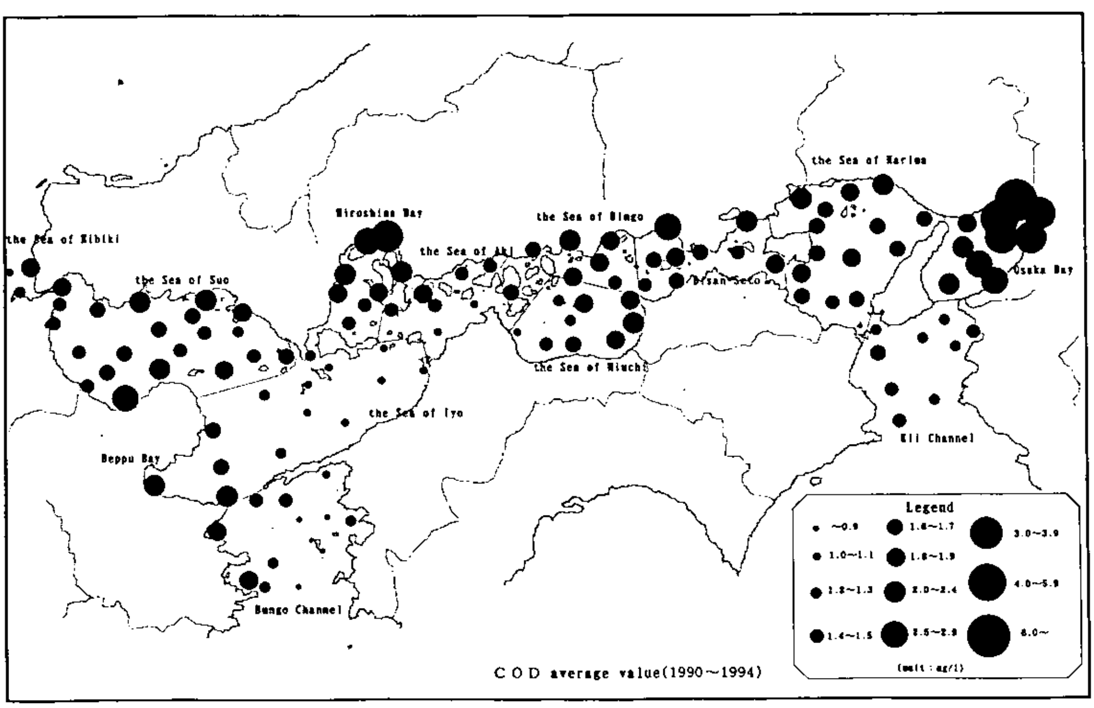


Fig.12-9 Horizontal distribution in mean COD concentration during 1990~94

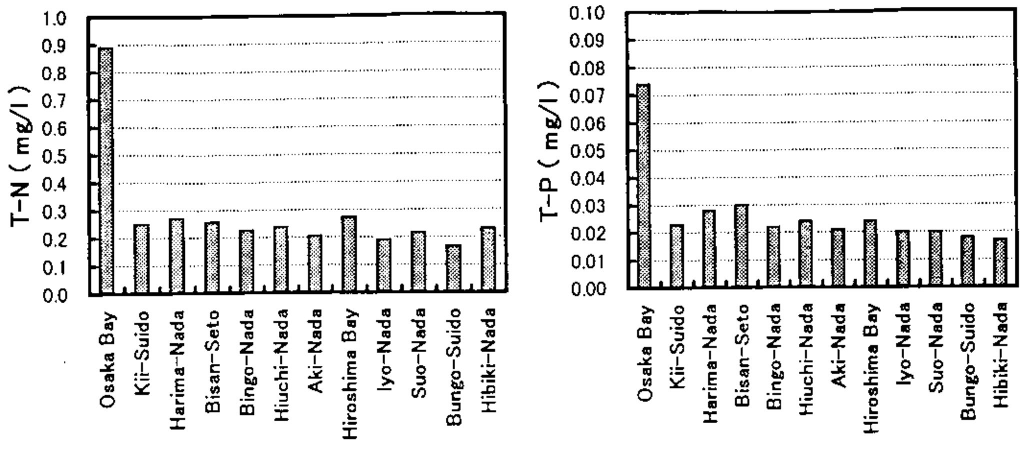


Fig.12-10 Nutrient concentration level in each water area

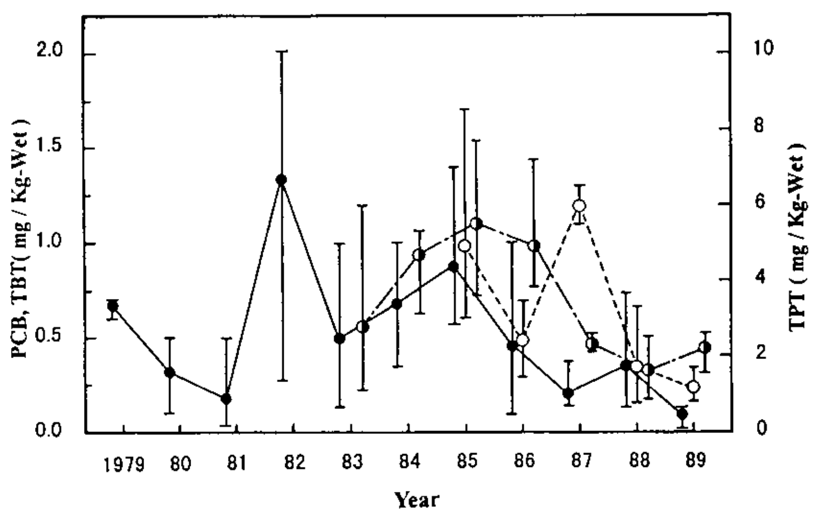


Fig.12-11 Changes in concentrations of chemical substances contaminated in fishes
●:PCB, ○:TBT, ◑:TPT, Bar means maximum and minimum

Besides organic pollution, there has been pollution by various toxic substances. For example, early in 1970, fishes and oysters highly contaminated by mercury and cadmium were found in Tokuyama Bay and the central coast area in Hiroshima prefecture, respectively. However, water pollution by these heavy metals have been improved due to effluent restriction by "WPCL", and water quality in the whole area has now been kept under environmental standards for human health. But it is pointed out that there is other pollution by non-regulated organic substances such as organic tin used in ship bottom coat in the coastal area at present[16].

Though there is a environmental standard in PCBs whose pollution is observed inter-nationally, the concentrations at all datum points in the coastal sea are ND (less than 0.5 μ g/l). However, Kankyo-Cho is monitoring various toxic substances in environmental water, sediments and fishes including non-regulated substances from 1978, because chemical substances tend to be concentrated into fishery resources. Some examples of yearly changes in these toxic substances contaminated in fish (Perch) in the S.I.S. are shown in Fig. 12-11. In Japan, the production, import and usage of PCBs had been prohibited by the " Law Concerning the Examination of Manufacture, etc. of Chemical Substances (LCEMCS)" in 1973 and the concentration shows decreasing after 1982. Organic tin was also applied to " LCEMCS " in 1990. Organic tin in fish had exceeded acceptable daily intake (ADI) level for food

(1.6 μg/kg/day in TBTO, 0.5 μg/kg/day in TPT) shown by Kosei-Sho in middle 1980 but fishes over the level are rarely found at present, because related industries regulated the production by themselves before several years of 1990 [17,18].

6.2 Sediment pollution

Horizontal distribution of total organic carbon (TOC) in sediments is shown in Fig 12-12 [19]. Narrow areas or areas near the ocean with rapid current and little settlement of particles in the water have the lower silt content and TOC concentration than other areas. Sediment in Osaka Bay, central Hiuchi-Nada, Hiroshima Bay, western Shuo-Nada and Beppu Bay show polluted conditions over 20 mg/g in TOC.

These distributions were surveyed by Kankyo-Cho during 1981 ~ 1985, and same survey (Mud content, IL, COD, TOC T-N,T-P and Macrobenthos) was carried out again 10 years later to research the change in the sediment pollution. The result showed no improving tendency in the sediments statistically. In the second survey, heavy metals are also measured with these items.

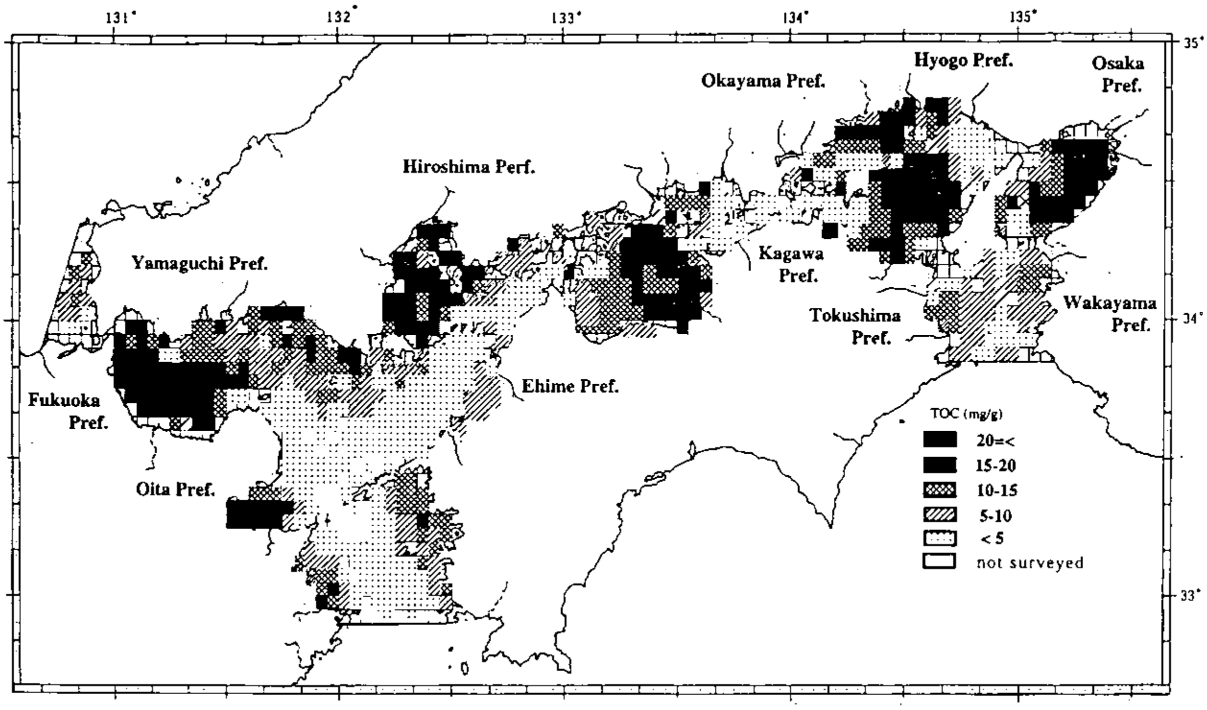


Fig.12-12 Horizontal distribution in TOC in the sediments

7. Prospective subject

The water and sediment qualities don't show improving tendency in spite of various countermeasures such as effluent load reduction, promotion of monitoring and sewerage systems and restriction of reclamation. However, decrease of red tide outbreaks, improvement of water quality in Osaka Bay and maintenance in overall water quality without getting worse will be their own results by the countermeasures.

The main reason of little improvement in the environment is considered water pollution to be controlled by algal growth due to eutrophication besides direct effluent organic load. Hoshika et. al. reported organic matter resulted from primary production occupied 80% of all in Osaka Bay[20]. In Hiroshima Bay , it's also reported that about 90% of organic matter is originated from primary production by phytoplankton [21]. The COD load had reduced by 60% according to effluent restriction. However, reducing rate for nutrient load is low, only 10% in T-N. Coastal eutrophication causes oxygen deficit at bottom water layer to influence ecosystem of inhabitants except for red tide outbreaks. Oxygen deficit under 2mg-O_2/l, threshold level for benthos is confirmed at bottom layer both in Osaka and Hiroshima Bay in summer [22]. Though T-N was also designated as reducing guidance substance with T-P at the forth stage during 1994~99 in "LCSMCE", more effective and drastic countermeasures will be hoped..

Though many countermeasures for organic pollution have been carried out from various points of view until now in the S.I.S., water pollution by toxic substances of new types such as organic tin used in fishery net and ship bottom paint or organophosphorus- and carbamate- pesticides have happened in the coastal water . Moreover, several toxic substances were added to environmental standard for human health, and environmental guideline values for 25 monitoring items were newly introduced since 1993. As environmental pollution by unknown chemical substances is considered to get more serious and significant, monitoring system and countermeasures for these substances should be more focused on.

Finally, public consciousness and policy to conserve the natural beautiful landscapes and to succeed them to descendants for ever will be also important, simultaneously with these countermeasures for environmental water pollution.