WATER POLLUTION AND ITS CONTROL IN COASTAL WATERS OF JAPAN: PRESENT SITUATION, OBJECTIVES AND STRATEGY

by

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ABSTRACT

The present status of water pollution: concentrations of hazardous chemicals in coastal waters have decreased significantly, mainly due to effluent regulations. In sediments, on the other hand, various kinds of pollutants such as organochlorine, organotin and polyaromatic hydrocarbons are found in relatively high concentrations. These results suggest that a large amount of pollutants discharged in the past persist in sediments; consequently, we need to improve knowledge of the mechanisms that transfer these chemicals from sediments to marine organisms. Concentrations of COD, N and P in seawater have decreased since the Pollution Emission Regulation was adopted; however, toxic phytoplankton blooms, an appearance of low oxygen water mass and production of hydrogen sulfide, especially in bottom waters, were occasionally observed in stagnant waters, such as in Tokyo Bay. Eutrophication is still a serious problem, and has undesirable effects on fisheries production.

Water quality standards (WQSs) for hazardous chemicals were originally created in 1971, and the WQSs of 15 hazardous chemicals such as trichloroethylene were revised in 1993. The WQSs for non-toxic materials such as COD, N and P etc were set differently, considering how coastal waters are actually used. WQSs for N and P were also revised in 1993. Primary productivity and fisheries production in coastal waters are influenced by nutrient concentrations. Therefore, WQSs for N and P should be based on possible changes in fisheries production caused by changes in N and P concentrations. The procedure to establish WQSs for N and P is discussed.

Concentrations of N and P in waste waters are regulated at 120 mg/l (daily average: 60 mg/l) and 16 mg/l (daily average: 8 mg/l), respectively. As it is well known that nutrients are released from sediments, removal of the polluted sediments is an important strategy in mitigating eutrophication.The remediation of polluted sediments using organisms such as polychaeta is now being actively studied. The feasibility of this type of remediation needs to be evaluated.

1. PRESENT STATUS OF MARINE POLLUTION

1.1 Pollution caused by hazardous chemicals

Many kinds of chemicals are used in various industrial and agricultural activities as well as in everyday life. Some of these chemicals can cause marine pollution. Hazardous chemicals found in seawater and sediments of Japanese coastal areas from 1977 to 1992 are summarized in Table 1.

Twelve different hazardous chemicals were found with a detection frequency above 25% in seawater samples, including tributyl phospohate, xylene, toluene, and tributyltin (TBT) and triphenyltin (TPT). These chemicals have been widely used as

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flame retardant plasticizers, solvents, and antifouling agents in ship paint. Among them, TBT and TPT were widely found across the coastal waters (Fig. 1), often at concentrations of 10 ng/l or more, exceeding the provisional WQS.

In sediments, 41 different hazardous chemicals were found with a detection frequency above 25%; more chemicals were found than in seawater. Among these hazardous chemicals, hexachlorobenzene, chlordane, TBT, TPT, and crude oil components such as benzo(a)pyrene, were frequently detected at high concentrations. As hydrophobic chemicals are apt to absorb suspended materials and be deposited in the sediments, large quantities of hazardous chemicals discharged in the past could have accumulated and still remain in sediments today.

Concentrations of hazardous chemicals in seawater have rapidly decreased recently, coinciding with the establishment of WQS and effluent control. The percentage of samples where concentration exceeds WQS values is 0.1% or less now. In terms of vertical distributions of hazardous chemicals in a sediment column (Matsumoto, 1983), higher concentrations of PCBs, Zn, Cu, Pb, Cr or Hg are found in the sediment layers of 1970's, but the concentrations have gradually decreased since then (Fig. 2). These results indicate that their imput into the coastal waters decreased in recent years as a result of an enforcement of effluent control.

In his mercury studies in Minamata Bay, Irie (1994) revealed that mercury concentration was higher in fish that lived permanently in Minamata Bay than in fish that migrated into Minamata Bay from other areas. Mercury concentration was also higher in fish- eating benthic animals, such as polychaetes and large crustaceans. Concentrations increased as the trophic level became higher, suggesting that mercury originating in sediment is one of the source of pollution and is bioaccumulated in fish through the food chain, including the benthic animals. Therefore, it is necessary to establish new methodology for determining allowable concentrations of hazardous chemicals in sediments, and research in that field needs to be promoted in future.

1.2 Pollution caused by nutrients and organic materials (eutrophication)

When seawater concentrations of nutrients and organic materials increase due to land-based activity, the water becomes less transparent and primary production increases. The phytoplankton which are not tranferred to the higher trophic level of food chain, and the suspended materials composed of dead phytoplankton, are deposited on the sediments. Dissolved oxygen (DO) in bottom seawater are consumed during the decomposition of organic materials on the surface of the sediments, and anaerobic water mass (lowDO and high HS) is formed in the bottom layer. A decline of DO concentration and/or an increase of HS can damage aquatic organisms considerably. The most serious impact of eutrophication on the marine environment is manifested in stagnant waters.

The distributions of several environmental parameters, such as the particle size in sediments, the organic materials and HS concentrations in sediments, and DO concentrations in bottom seawater in the Seto Inalnd Sea, are shown in Fig. 3. Polluted coastal areas where percentage of clay particle below 63 was 90 % or more, organic

materials were very high (COD: >20 mg/g, IL: >10 %, N: >2 mg/g, P: >0.6 mg/g) and the bottom water was anaerobic (DO saturation: <60 %, HS in sediments: >0.2 mg/g) included Osaka Bay, Harima Nada, Hiuchi Nada, Hiroshima Bay and Beppu Bay in the Seto Inland Sea. Today, the eutrophication situation is very serious in these sea areas, representing one of the most important marine pollution problems.

Joh (1986) carried out a detailed study on changes in load of pollutants (BOD, TN and TP), nutrient concentration in seawater and the production of fish and shellfish in Osaka Bay. BOD loading increased continuously from the start of the survey in 1955 (205 t/day), reaching 2.8 times that value by 1973 (578 t/day). However, since 1974, BOD loads in both industrial and domestic wastewaters have decreased due to effective removal of pollutant by the water treatment system, and accordingly BOD loading in 1982 was only 2.1 times that in 1955. The change in P loads showed a similar tendency: the P load peaked in 1974 (18.1 t/day), which was 4.3 times the load in 1955 (4.2 t/day); thereafter, the P load decreased to 12.5 t/day in 1982, approximately 3 times that in 1955. The N load in 1982 (177.8 t/day) was 4 times that in 1952 (44.6 t/day). Unlike BOD and P loads, which began to decrease after reaching a peak during 1972- 1974, the N load remained at the same level as before or even increased slightly after 1975. As a result, the N/P ratio in seawater is gradually increasing. The effect of this increase on marine ecosystems needs to be studied. The annual variation of nutrient concentrations in Osaka Bay reflected a change in nutrient load, confirming that these concentrations in seawater were low when the nutrient load from land was small.

Joh (1986) also estimated the percentage of production in the lower trophic levels utilized by fisheries production, and concluded that 10 % and 30 % of the phyto- and zooplankton production, respectively, are consumed by fisheries production. On the contrary, 72 % of benthic production are consumed by fisheries. In other words, these results showed that higher primary production does not support higher production in the higher trophic levels. Furthermore, the phytoplankton not consumed by zooplankton are deposited on the sediments, deteriorating the bottom environment. This shift in marine production mechanisms affects the fisheries structure in two ways: by an increase in production of surface swimming fish such as sardines; and a decrease in production of bottom-dwelling organisms such as shrimps and crabs.

2. SYSTEMS FOR PREVENTION OF MARINE POLLUTION IN JAPAN

In Japan, environmental protection legislation has been formulated in line with the concepts outlined in the Basic Law for Environmental Preservation. In order to prevent marine pollution, several pollution control measures such as the regulation of pollutant concentration in waste water, areawide total COD load control, the regulation of the reclamation of the foreshore, and the regulation of ocean dumping of various waste etc. are carried out according to regulations defined by several laws, such as the Water Pollution Control Law, etc.

In addition to regulating pollutant concentrations in wastewater, influxes of hazardous chemicals to the marine environment are prevented by inhibiting their production, import, sales and utilization, based on prior examination of their safety.

Surveys are also carried out at regular intervals to monitor marine pollution levels and to evaluate the effect of measures on marine environment. The Japanese system for preventing marine pollution is outlined in Fig. 4.

3. THE OBJECTIVE OF MARINE ENVIRONMENTAL MANAGEMENT

3.1 Water quality standards (WQS)

In order to investigate various measures to prevent marine pollution, it is first necessary to determine water quality standards. WQSs are classified into two categories: one related to protecting human health (health related WQS), and the other to protecting the living environment (living environment related WQS). The health-related WQS's for 23 hazardous chemicals were established, and WQS values were applied to all aquatic environments, including freshwater and seawater environments. WQSs of these hazardous chemicals were based on the effects on human health. However, a new methodology to determine effects of hazardous chemicals on aquatic organisms is needed to establish new WQS for preserving the aquatic ecosystem.

The WQSs related to the living environment are set up separately for each water body; rivers, lakes and ocean. As shown in Table 2, WQS for pH, COD DO, No. of *E. coli*, n- hexane extracts (oil), total nitrogen (TN), and total phosphorus (TP), were set for different categories based on the utilization of water bodies for preservation of the natural environment, marine resort, fishery grounds, industrial use of seawater, and conservation of environment for sustaining aquatic life . WQSs for TN and TP were revised in 1993.

3.2 Methodology determining the WQSs for TN and TP

Nutrients such as TN and TP are important substances in primary production and consequently affect fisheries production. Therefore, the appropriate concentrations of nutrients to sustain better fisheries production should be considered. The basic idea to establish WQSs of TN and TP for each water body with different utilization purposes is listed in Table 3.

The unpolluted marine environment should be maintained in order to protect endangered marine organisms and to use water bodies as marine resorts. In water bodies for these purposes, transparency was selected as an indicator of marine environment, and WQSs were based on the transparency of 10 m. From surveys in oceans around Japan, it was observed that transparency decreased with greater concentrations of TN or TP. The relationships between transparency and TN or TP were set out as follows, $TN = - 0.076Trp + 0.868$, $TP = - 0.0073Trp + 0.0801$. Using these equations, WQS for TN and TP was calculated based on the transparency of 10 m.

On bathing beaches, WQS for TN and TP were also determined by a transparency of 6 m.

In seawater bodies used for environmental conservation, WQSs were conditioned by DO concentration in bottom waters. According to the studies on effects of DO concentration on benthic organisms, a DO concentration of 2 ml/l or more must be maintained in bottom layers during the summer to sustain benthic organisms. WQS for TN and TP were based on the relationship between DO and TN or TP concentration (TN= - 0.0182 DO + 1.75, TP= - 0.0014 DO + 0.144).

For industrial use of seawater, WQSs for TN and TP were determined by the maximum allowable concentration of suspended materials, and calculated from the relationships between concentrations of suspended materials and TN or TP concentrations.

WQSs for TN and TP regarding fisheries were determined by an appraisal of several factors, including the relationships between sizes of fish/shellfish catch and water quality, and the relationships between yearly changes of various fish/shellfish catch and yearly changes in water quality. TN and TP concentrations in several fishing grounds are shown in Fig. 5. Japanese flounder, red sea bream, shrimps, squid and octopus, and hard shell clams are caught in relatively clean waters (TN: 0.3 mg/l, TP: 0.03 mg/l). In contrast, sea bass and short- necked clams are caught in relatively contaminated areas (TN: 0.6 mg/l, TP: 0.06 mg/l). Mullet and flatfish were caught in both clean and polluted areas.

Relationships between water quality and fishing grounds in Osaka Bay and Kii Channel were also examined by Satomi (1989), and results are presented in Table 4. Fishing grounds for sardines, mullet, sea bass, anchovy, mackerel and horse mackerel are formed in areas with a TN concentration of 0.5 - 1.0 mg/l and TP concentration of 0.05 - 0.1 mg/l; fishing grounds for other kinds of fish such as flatfish etc are formed in relatively clean waters with TN and TP concentrations of less than 0.5 mg/l and 0.05 mg/l, respectively. The good fishing grounds of shrimps, Japanese flounder, etc are found in areas where TN and TP concentrations are below 0.3 mg/l and 0.03 mg/l, respectively. These results suggest that the TN concentration of 0.3, 0.5 and 1.0 mg/l and TP concentration of 0.03, 0.05 and 0.1 mg/l are critical values for fisheries.

The desirable TN and TP concentrations for fisheries were considered by examining the change of fish/shellfish catch caused by the changes in water quality in Tokyo Bay, Osaka Bay, and Hiroshima Bay. Four water quality grades were established from the yearly change of the TN and TP concentrations in Tokyo, Osaka and Hiroshima Bays: type I (TN: <0.2 mg/g, TP: <0.02 mg/g); type II (TN: <0.3 mg/g, TP: <0.03 mg/g); type III (TN: <0.6 mg/g, TP: <0.05 mg/g); and type IV (TN: <1.0 mg/g, TP: <0.09 mg/g).

Several examples of the relationships are shown in Fig. 6. Catches of black sea bream dropped when the water quality grade is altered from III to IV or from II to III; however, no change in catch is evident when the grade is altered from I to II. Therefore, the appropriate water quality grade for black sea bream is considered to be type II. Sea bass catches, on the other hand, increased when the water quality grade was altered from II to IV or from II to III. Thus the appropriate water quality grade should be III or IV. The desirable TN and TP concentrations for each fish and shellfish were determined in this way.

Appropriate TN and TP concentrations for porphyra larver were examined using larver growth and seaweed quality as parameters. The desirable minimun value is 0.4 mg/l for TN and 0.04 mg/l for TP, and water quality grade III was appropriate for larver culturing.

3.3 Application of WQS in a seawater body

The types of WQS for TN and TP shown in Table 2 are applied to a waterbody by considering designated uses of the waters. In this way, Tokyo Bay was classified into 3 types of water body (fig. 7). WQS grade is type IV in the coastal area off Tokyo, Yokohama, and Chiba, type III in the central area of the bay, and type II in the mouth of Tokyo Bay. Therefore, designated fisheries uses were classified into 3 types: fishery type 1, II, and III .

4. STRATEGIES

4.1 TN and TP concentration in wastewater (effluent control)

In order to meet the ambient WQS, effluent control is an important marine pollution measure. The following maximun allowable TN and TP concentrations in wastewater were established: 120 mg/l (daily average: 60 mg/l) for TN and 16 mg/l (daily average: 8 mg/l) for TP. As eutrophication was serious in closed and stagnant water bodies, the concept of stagnancy, expressed as a stagnancy index, was introduced in order to prevent eutrophication in these waterbodies. The stagnancy index is calculated from the following equation based on the shape of the semi-closed coastal waterbody.

Stagnancy index = S D / W D

S: surface area
W: width of the entrance
D: maximun depth
D: maximun depth at the entrance

The DO deficient water mass (one of the phenomena caused by eutrophication) has not been observed in the bottom layer when the stagnancy index is below 1. Therefore, an index of 1 is set as a critical value. With an index larger than 1, effluent control should be applied.

4.2 Reinforcement of effluent control

It is important to evaluate current status of water pollution by routine monitoring surveys, and to assess the effect of countermeasures such as effluent control on the marine environment. Furthermore, inflows of TN and TP into coastal water bodies can be reduced by upgrading effluent control through advances in effluent-treatment technologies and the introduction of load control for TN and TP.

4.3 Other countermeasures

It is well known that TN and TP are released from sediments (Yamada and Kayama, 1987). In Osaka Bay, the amount of nutrients freed from sediments may equal inflows from land-based sources. Therefore, an improvement of sediment quality should be a necessary step to prevent coastal water eutrophication. In order to improve the sediment quality, several methods have been applied such as cultivation or aeration of polluted sediments, covering with sand or lime, and dredging. Recently, several methods to mitigate polluted environments using organisms with a specific specific biofunction (bioremediation) have been proposed, and bioremediation is being extensively investigated . Tsutsumi and Montani (1993) reported that the polychaetes, *Capitera capitata*, could didest the organic materials in sediments and effectively reduce organic content in sediments. Bioremediation could represent an effective method to mitigate polluted environments, and should be studied extensively.

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Table 1. Hazardous chemicals detected in seawater and sediments of Japanese coastal waters.

Chemicals	Seawater				Sediments			
	No. of sample		Detection frequency (%)	Concentration (μg/l)	No. of sample		Detection frequency (%)	Concentration (μg/l)
	Detected	Total			Detected	Total		
Diisopropylnaphtalene					6	117	5.1	0.0019 ~ 0.1
1-phenyl-(3,4-xylyl)ethan					12	117	10.3	0.013 ~ 0.16
o-terphnyl					10	117	8.5	0.0012 ~ 0.1
m-terphnyl					12	117	10.3	0.0021 ~ 0.19
p-terphnyl					7	117	6.0	0.0034 ~ 0.15
Dibutylhydroxytoluene					17	117	14.5	0.008 ~ 0.41
Tributylphosphate	39	117	33.3	0.006 ~ 0.58	48	117	41.0	0.0019 ~ 0.24
Nitrobenzene	22	115	19.1	0.13 ~ 3.8	19	117	16.2	0.009 ~ 1.5
Polychloronaphtalene					15	75	20.0	0.02 ~ 1.0
Hexachlorobenzene	6	77	7.8	0.0016~ 0.0022	63	76	82.9	0.00011~0.48
Polychloroterphenyl					37	75	49.3	0.001 ~4.7
1,2,3-trichlorobenzene	2	111	1.8	0.05 ~ 0.07	19	111	17.1	0.0004 ~0.053
1,2,4-trichlorobenzene	8	111	7.2	0.01 ~ 0.13	33	111	29.7	0.0005 ~0.03
1,3,5-trichlorobenzene	1	111	0.9	0.02	18	111	16.2	0.0006 ~0.0247
Pentachlorobenzene					30	111	27.0	0.0001 ~0.0112
α-Naphtylamine					3	111	2.7	0.005 ~0.0055
Diisopropylnaphtalene					3	120	2.5	0.049 ~0.064
1-phenyl-1-(2,4-dimethylphenyl)ethan					3	120	2.5	0.022 ~0.027
1-phenyl-1-(3,4-dimethylphenyl)ethan					3	120	2.5	0.019 ~0.027
Chlorinated paraffin					31	120	25.8	0.5 ~8.5
Organic silicone compounds					68	120	56.7	1.0 ~70.0
n-phenyl-2-naphthylamine					27	126	21.4	0.005 ~ 0.074
Heptachlor					14	87	16.1	0.0002~ 0.0037
γ-chlorodene					27	126	21.4	0.0002~ 0.0040
Oxychlordane					3	126	2.4	0.0002~ 0.0003
Heptachlor epoxide					3	126	2.4	0.0002~ 0.0006
trans-chlordane					90	126	73.2	0.0002~ 0.075
cis-chlordane					76	126	60.3	0.0002~ 0.051
trans-nonachlor					68	126	54.0	0.0002~ 0.055
cis-nonachlor					43	126	34.1	0.0002~ 0.022
Hexachlorophene					45	126	35.7	0.006 ~ 0.500
Hexabromobenzene					3	126	2.4	0.0031~ 0.0043
Alkyldimethylbenzylammonium chloride					30	126	23.8	0.1 ~ 5.2
Cyclohexylamine					3	126	2.4	0.0032~ 0.041
1,2-dimethylnaphtalene					5	138	3.6	0.0038~ 0.16
1,3-dimethylnaphtalene					24	142	16.9	0.03 ~ 0.61
1,4-,1,5-,2,3-dimethylnaphtalene					13	147	8.8	0.03 ~ 0.29
2,6-dimethylnaphtalene					18	141	12.8	0.032 ~ 0.31
2-isopropylnaphtalene					1	141	0.7	0.032
2-naphtylamine					6	147	4.1	0.0023~ 0.0051
Benzoic acid	31	111	27.9	0.24 ~ 2.1	112	146	76.7	0.02 ~ 2.0
p-t-butyl benzoic acid	2	105	1.9	0.2 ~ 0.3	2	138	1.4	0.02 ~ 0.021
o-xylene	12	137	8.8	0.04 ~ 1.2	24	111	21.6	0.0005~ 0.007
m-xylene	15	126	11.9	0.04 ~ 1.2	33	118	28.0	0.0005~ 0.015
p-xylene	4	122	3.3	0.06 ~ 0.48	12	105	11.4	0.0005~ 0.0038
Ethylbenzene	7	133	5.3	0.03 ~ 1.1	28	120	23.3	0.0005~ 0.028
Styrene	7	121	5.8	0.03 ~ 0.5	13	125	10.4	0.0005~ 0.0075
Toluene	29	91	31.9	0.03 ~ 2.7	46	87	52.8	0.0005~ 0.044
Benzene	19	112	17.0	0.03 ~ 2.1	37	98	37.8	0.0005~ 0.03
Isopropylbenzene	8	135	5.9	0.09 ~ 0.44	6	111	5.4	0.00058~0.011
2-methylpyridine	5	96	5.2	0.32 ~ 2.7	67	94	71.2	0.0012~ 0.108
3 and 4 methylpyridine	3	93	3.2	0.2 ~ 0.81	64	94	68.1	0.0018~ 0.142
Melamine	89	150	59.3	0.1 ~ 7.6	36	117	30.8	0.01 ~ 0.32
Triphenyltin	73	119	61.3	0.005 ~ 0.088	99	129	76.7	0.001 ~ 1.1
1,1-dichloroehtane	36	129	27.9	0.005 ~ 0.08	4	117	3.4	0.00014~0.00048
1,2-dichloroehtane	66	141	46.8	0.02 ~ 3.4	5	126	4.0	0.00062~0.0028
Tetrabromobisphenol A					20	130	15.4	0.002 ~0.108
Hexabromodiphnyl ether					4	141	2.8	0.0045 ~0.018
Octabromodiphnyl ether					3	135	2.2	0.015 ~0.022
Decabromodiphnyl ether					39	129	30.2	0.004 ~6
Anthraquinone					21	53	29.6	0.018 ~3.7
CVP					6	57	10.5	0.006 ~0.02

Table 1. Continued.

Chemicals	Seawater				Sediments			
	No. of sample		Detection	Concentration	No. of sample		Detection	Concentration
	Detected	Total	frequency (%)	(μg/l)	Detected	Total	frequency (%)	(μg/l)
Chloropyrifos					11	69	15.9	0.007 ~ 0.08
Pyrene	8	69	11.6	nd ~ 0.065	68	71	95.8	nd ~ 3.9
Benzo (a) anthracene					112	145	77.2	nd ~ 2.1
Benzo (a) pyrene					122	134	91.0	nd ~ 3.7
Benzo (e) pyrene					72	74	97.3	nd ~ 1.8
Benzo (b, j, k) fluoranthene					118	159	74.2	nd ~ 5.5
Benzo (g, h, I) perylene	1	72	1.4	nd ~ 0.05	72	72	100.0	nd ~ 1.31
Benzo (a, h) anthracene	1	75	1.3	nd ~ 0.1	55	60	91.7	nd ~ 0.34
Monophenyltin	14	67	20.9	nd ~ 47.3	28	55	50.9	nd ~ 1.1
Diphenyltin	5	72	6.9	nd ~ 27.0	31	53	58.5	nd ~ 0.5
Aniline	33	104	31.7	tr ~ 0.33	81	116	69.8	tr ~ 0.24
o-anisidine	2	48	4.2	0.02 ~ 0.027	3	41	7.3	tr ~ 0.0073
m-anisidine	5	48	10.4	0.02 ~ 0.058				
o-chloroaniline	7	78	9.0	tr ~ 0.56	25	64	39.1	tr ~ 0.028
m-chloroaniline	3	45	6.7	tr ~ 0.06	24	43	55.8	tr ~ 0.043
p-chloroaniline					15	42	35.7	tr ~ 0.05
n-methylaniline	3	69	4.3	0.038 ~ 0.093	4	66	6.1	tr ~ 0.014
n,n-dimethylaniline					3	63	4.8	tr ~ 0.027
2,4-dinitroaniline					1	75	1.3	0.56 ~ 0.56
Diphenylamine	3	81	3.7	0.4 ~ 1.2	12	63	19.0	tr ~ 0.2
Chlorpyrifos					9	24	37.5	tr ~ 0.038
n-nitrosodiphenyl amine	2	81	2.5	0.5 ~ 0.09				
Acrylamide	11	153	7.2	tr ~ 0.1	20	150	13.3	tr ~ 0.003
Nitrobenzene	1	153	0.7	tr ~ 0.17	2	162	1.2	tr ~ 0.07
o-nitroanisol					1	51	2.0	tr ~ 0.027
n,n-demethylformamide	18	48	37.5	tr ~ 6.6	9	48	18.8	tr ~ 0.11
Pyridine	6	36	16.7	0.13 ~ 0.2	18	39	46.2	0.0068 ~ 0.11
Quinoline					2	39	5.1	tr ~ 0.006
Triethylamine	3	27	11.1	tr ~ 0.56	15	33	45.5	tr ~ 0.064
p-nitrotoluene	1	57	1.8	tr ~ 0.21				
Dimethylsulfoxide	17	45	37.8	tr ~ 9.2	17	42	40.5	tr ~ 0.098
o-toluenesulfonamide	6	84	7.1	tr ~ 0.67	6	84	7.1	tr ~ 0.045
p-toluenesulfonamide	9	162	5.6	tr ~ 0.84	26	162	16.1	tr ~ 0.854
Molinate	1	42	2.4	tr ~ 0.077	1	42	2.4	0.0037 ~ 0.0037
Simetryn	6	78	7.7	tr ~ 0.27	2	78	2.6	tr ~ 0.023
Isoprothiolane	26	78	33.3	tr ~ 0.27	8	78	10.3	tr ~ 0.034
Benthiocarb					3	165	1.8	tr ~ 0.05
Acetonitrile	15	147	10.2	tr ~ 7.4	25	155	16.1	tr ~ 1.9
Acrylonitrile					8	151	5.3	tr ~ 0.016
Bentazone	1	75	1.3	6.7 ~ 6.7				
Tributyltin	52	99	52.2	nd ~ 0.084	88	102	86.3	nd ~ 0.42
Triphenyltin	10	90	11.1	nd ~ 0.044	57	95	60.4	nd ~ 0.09

Table 2. WQSs related to living environment.

Type of sea area	Purpose of usage	WQS						
		pH	COD (mg/l)	DO (mg/l)	E. coli (MPN/100 ml)	n-hexane extract (mg/l)	TN (mg/l)	TP (mg/l)
A	Preservation of natural envionrment beach for swimming fishery 1	7.8 -8..3	<2	>7.5	<1,000	nd		
B	Fishery 2 industrial water	7.8 -8..3	<3	>5	-	-		
C	Environmental conservation							
I	Preservation of natural environment						<0.2	<0.02
II	Beach for swimming fishery I						<0.03	<0.03
III	Fishery 11						<0.6	<0.05
IV	Fishery III, industrial water and environmental conservation						<1	<0.09

Table 3. WQSs for TN and TP for each utilization objective of water area and basis for determination.

Sea Area	Purpose of Usage	Ways of utilization	Basis for determination
I	Preservation of natural environment	Sightseeing and recreation activity such as scuba diving. Protection of endangered marine organisms.	Transparency above 10 m (determined from the relationships between transparency and TN or TP).
II	Beach for swimming Fishery type I	Sea bathing is possible. Fish and shellfish which ar feeble to water pollution can be caught (shrimp, crab, black sea bream, flounder, etc).	Transparency above 6 m (Relationships between fish/shellfish catch and water quality (see text).
III	Fishery type II	Production of following, fish will be supported. (sardines, sea bass and flatfish) Not a suitable environment for shrimps, crabs and flounder.	Relationships between fish/shellfish catch and water quality (see text).
IV	Fishery type III Industrial water Environmental conservation.	Fish and shellfish tolerating to water pollution will be caught. (sea bass, sardines).	Relationships between fish/shellfish catch and water quality (see text). DO concentration of bottom water should be maintained at 2ml.l or more in summer in order to sustain benthic organisms.

Table 4. Relationships between quality of fishing ground and the concentrations of COD, TN and TP in Osaka Bay and Kii Chanell.

Fish/shellfish	Concentration												
	COD (mg/l)				TN (mg/l)				TP (mg/l)				
	<2	2-3	3-4	4<	<0.3	0.3-0.5	0.5-1.0	1.0<	<0.03	0.03-0.05	0.05-0.1	0.1-0.2	1.0<
Sardines		4	5	5			6	8			8	5	1
Mullet	1	2	6	4		1	7	5		1	4	6	2
Sea bass		5	4	5			8	6			7	4	3
Anchovy		4	1	3			2	5			6	2	
Mackerel		6	4	2			8	4			8	2	2
Horse mackerel		4	1	3			5	3			5	1	2
Black sea bream	8	4	1	1	5	4	3	2	5	4	2	1	1
Juvenile sardines	8	5			3	6	4		1	8	4		
Sea eel	9	5			4	7	3		6	7	1		
Cutlass fish	72				6	2	1		6	3			
Flatfish	10	6			3	11	2		7	8	1		
Frog flounder	6	4			3	6	1		5	5			
Sand lance	10				9	1			10				
Spanish mackerel	7				6	1			7				
Yellow tail	9				9				9				
Red sea bream	6				6				5				
Japanese flounder	1				1				1				
Common octopus	14	1			11	4			13	2			
Cuttlefish	3				1	2			1	2			
Kuruma shrimp	8				6	2			5	3			
Shrimps	10				7	6	1		10	4			
Blue crab	8				5	4	1		2	5			
Mantis shrimp	6				4	3			2	5			
Sea cucumber	6				6				6				

Numerals indicate number of good fishing ground.

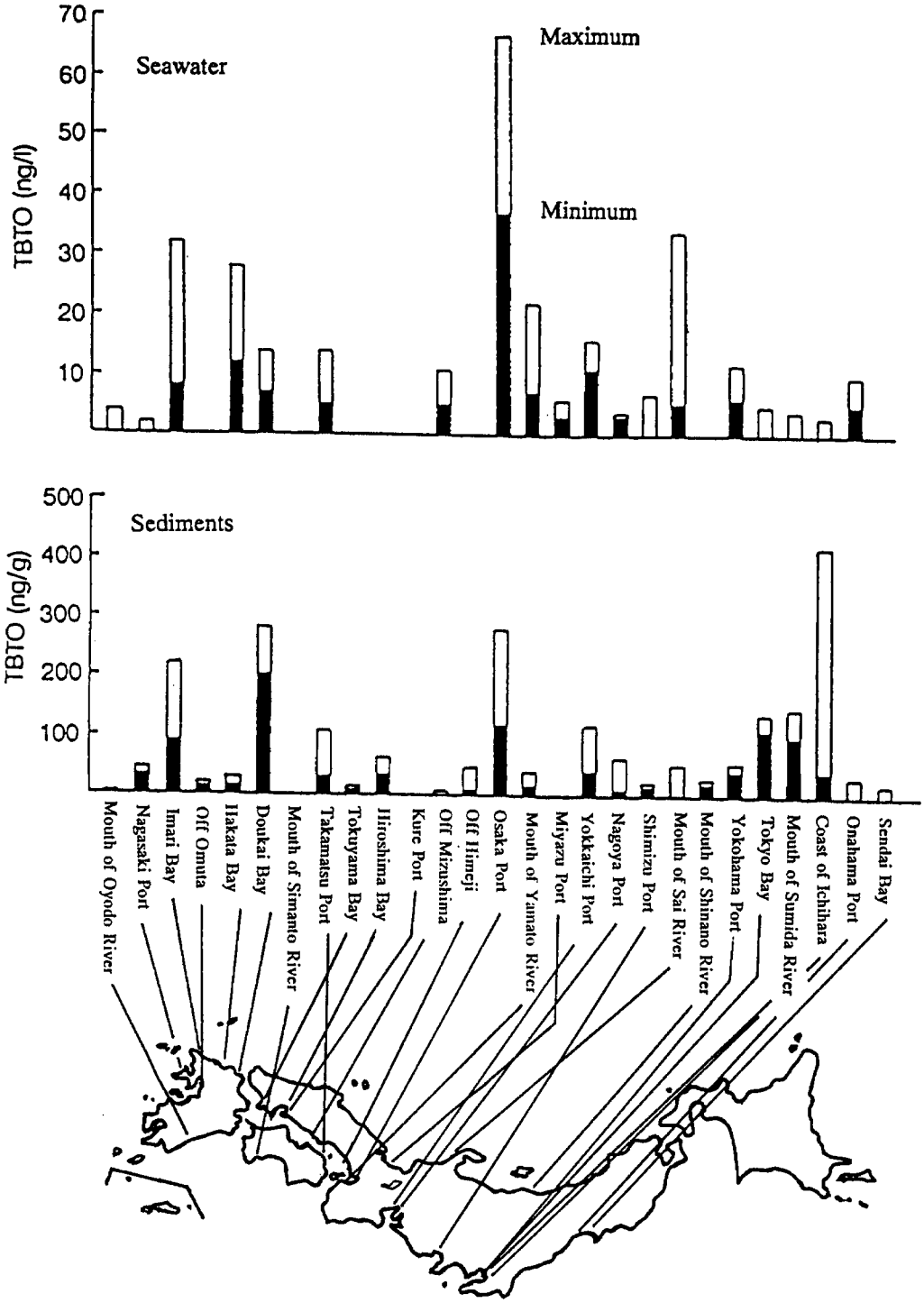

Fig. 1. Distribution of TBTO in Japanese coastal waters.

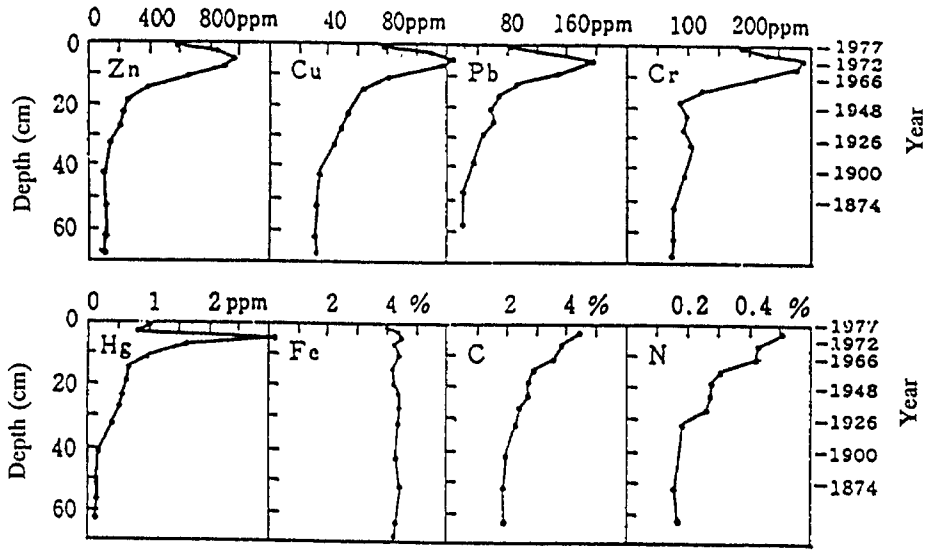

Fig. 2. Vertical distributions of heavy metals in the sediment column in Tokyo Bay.

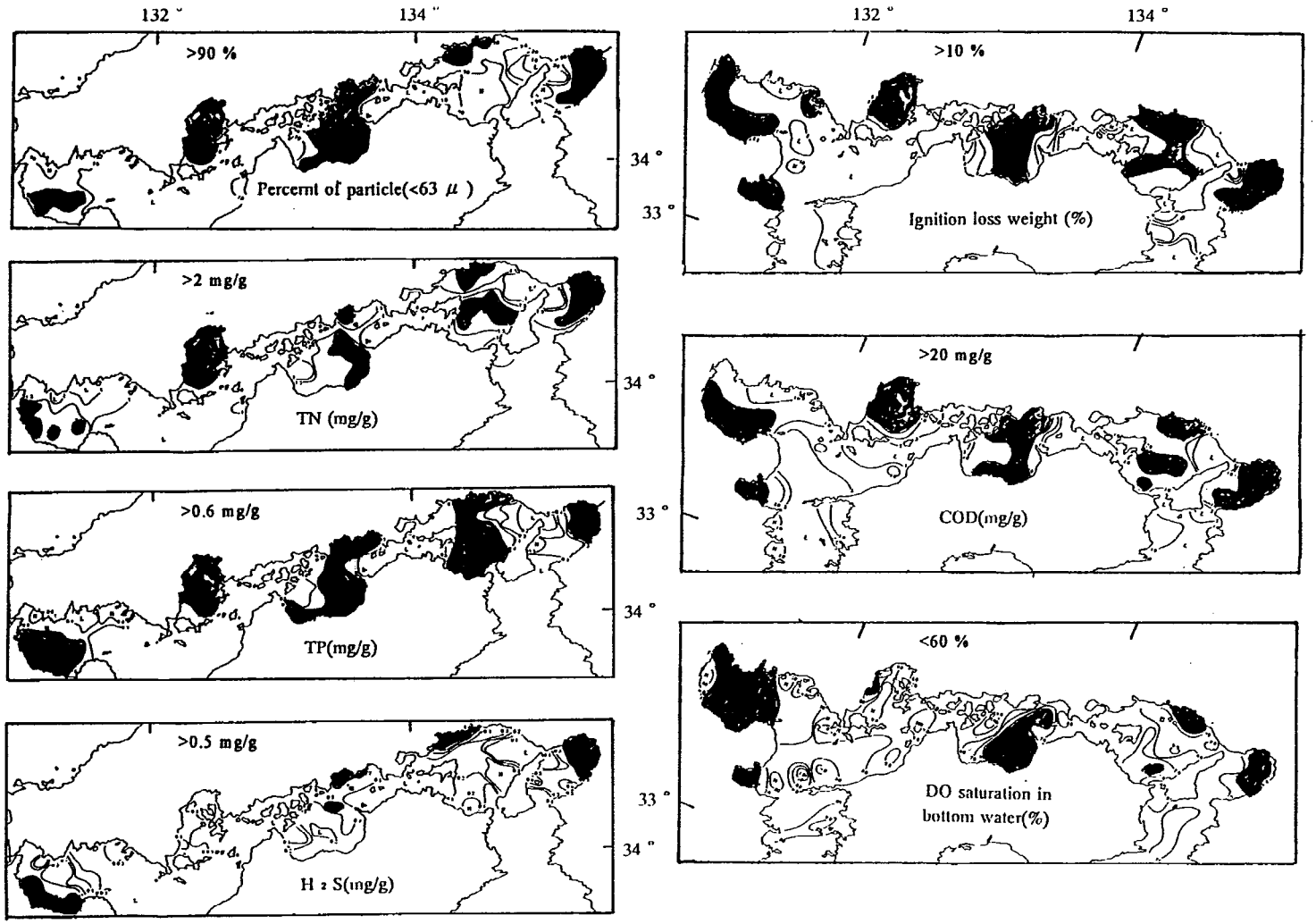

Fig. 3. Distribution of percentage of particle below 63μ, TN, TP, H_2S, ignition loss weight and COD in sediments and DO saturation in bottom water in the Seto Inland Sea.

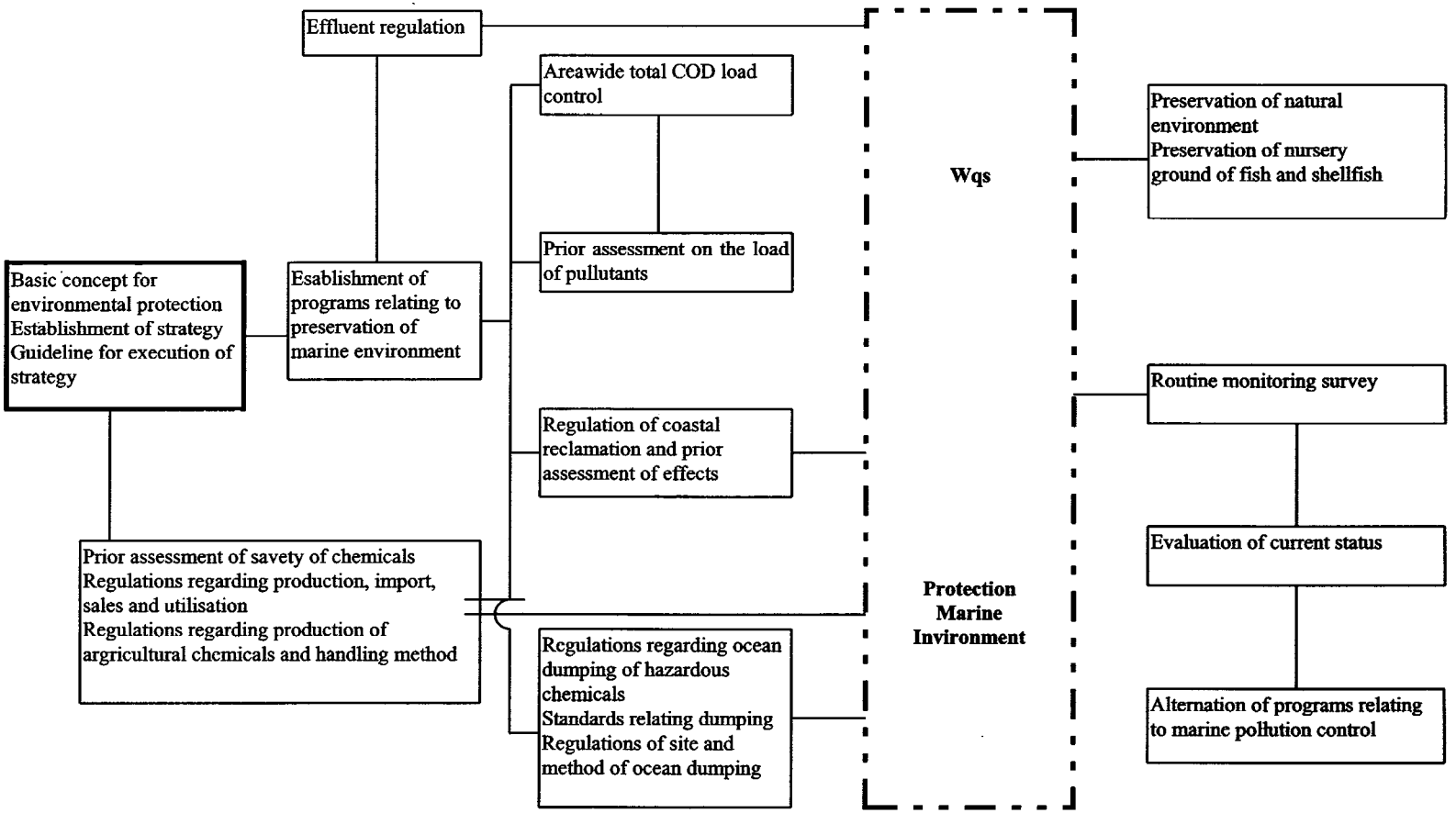

Fig. 4. Marine pollution control scheme in Japan.

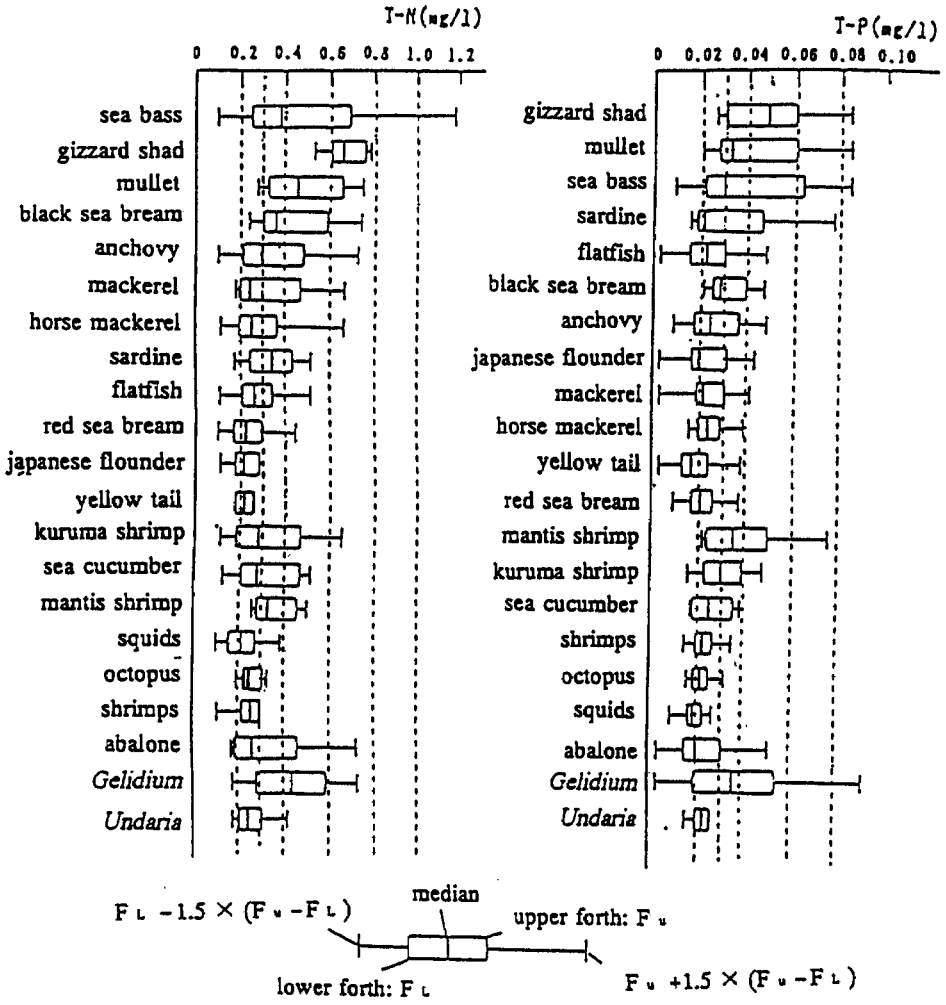

Fig. 5. TN and TP concentrations in seawater in the fishing grounds of various fish, shellfish and seaweed.

Fish species: Black sea bream

Change of water quality	Catch size			Appropriate water quality
	Tokyo Bay	Osaka Bay	Hiroshima Bay	
IV→>IV	Decrease	Decrease	-	
III→IV		Decrease	-	II
II→III	-	Decrease	Decrease	
I→II	-	-	No change	

Fish species: Sea bass

Change of water quality	Catch size			Appropriate water quality
	Tokyo Bay	Osaka Bay	Hiroshima Bay	
IV→ >IV	Decrease		-	
III→IV	Decrease	Increase	-	III ~ IV
II→III	-	Increase		
I→II	-	-	Decrease	

Fig. 6. Changes of fish/shellfish catch size with the change of TN and TP concentrations.

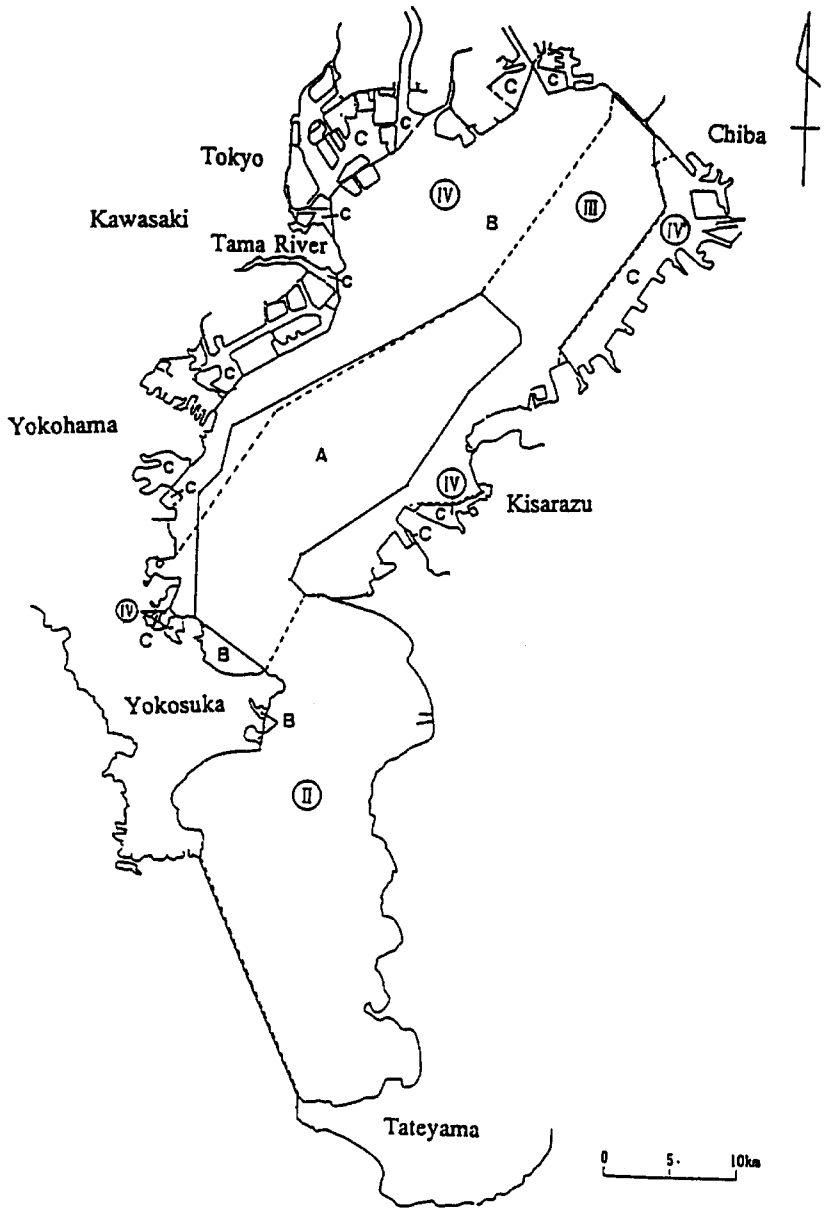

Fig. 7. Designated type in Tokyo Bay - A, B and C for pH, COD, and DO; I, II, III and IV for TN and TP.