Eutrophication in Hiroshima Bay

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Several researches for eutrophication in the northern Hiroshima Bay were carried out to investigate nutrient budgets in aquatic circulation processes, i.e. primary production, settling flux of particulate organic matter (POM) and the benthic remineralization.
It became apparent from these investigations that primary production contributed to the organic pollution in the northern bay than land based organic loadings by a factor of 10, that approx. 70-80% of the POM originating in phytoplankton were easily remineralized into inorganic nutrients during the settling process in water, and that approx. 60% of nitrogen and 70% of phosphorus in POM settled on the sediments might be returned to the water column by the release from benthic sediment.

Introduction

The Seto Inland Sea bounded by Honshuu, Shikoku and Kyuushuu supports many kinds of fishery resources because of the richness in natural beaches at ebb tide and submerged aquatic vegetations since long time ago. The unrivaled natural beauty is celebrated by many people and the area is " the land of pleasant living " through sightseeings and recreations. However, the water pollution has gradually been promoted by industrialization and urbanization of the coastal area resulted from remarkable economic development since around 1965. At the same time, red tides have begun to be often seen in the Seto Inland Sea. In 1972, large scale red tides in Harima-Nada gave serious damages to the fishery, which became an object to public concern.
Hiroshima Bay, an elliptical bay, located in the western Seto Inland Sea is about 30 km wide from east to west and 50 km long from north to south (Fig.1). The sea water in the bay is stagnant because the mouth of the bay is enclosed by many islands. The eutrophication in the northern area is most marked as much as Ohsaka Bay in the Seto Inland Sea by reason of the nutrient loadings resulted from the coastal urban area in addition to the geographical characteristics of the bay.
Aquatic eutrophication makes the water polluted due to the growth of phytoplankton,without direct

Table 1. General description of the investigations in Hirshima Bay.

Reserch	Location	Frequency	Contents
Water quality	St.1-4	Monthly	Transparency,Temperature,PH,Cl, DO,TOC,Chlorophyll-a,Nutrients
Sediment quality	St.1 St.5-7	Seasonal	Sediment: Redox potential,TOC,TN,PO_4-P Interstitial water: Nutrient
Primary production	St.1-4	Seasonal	Measurements at four depths in photic layer by light and dark bottle method
Settling flux	St.1-4	Monthly	Estimation from the catches by sediment traps hung at two or three layers during one month
Decomposition in sediment, and nutrient release	St.1 St.5-7	Seasonaly	Measurement of the concentration changes of DO and nutrients with time in water enclosed by an in situ chamber settled on sediments

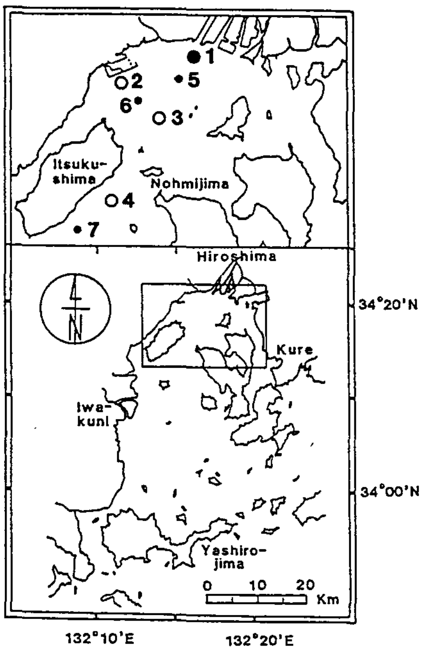

Fig.1. Sampling stations in Hiroshima Bay.

Marine Pollution Bulletin, Vol. 23, pp. 95-99, 1991.
Printed in Great Britain
0025-326X/91 $3.00+0.00

organic loadings from land. The nutrients are repeatedly used for the algal growth by the recycles in the water. For this reason, it is so difficult to improve the water quality which had once been polluted due to aquatic eutrophication, that counterplans to control the pollution should be discussed as first as possible.
Then, several investigations for aquatic eutrophication system in Hiroshima Bay were carried out for the purpose of the effective improvement of the organic pollution.

Materials and Methods

The investigations for eutrophication,mainly in the northern bay since 1978, are divided roughly into two groups; one is the environmental measurement in water and sediment, and the other is one of the material balances in the recycling of nutrients in aquatic system. Moreover, the latter is composed of the followings; 1)primary production, 2) decomposition and sinking characteristics of particulate organic matter (POM), 3) benthic remineralization in sediments and nutrient release.
The sites and the outlines of the investigations are shown in Fig. 1 and Table 1, respectively.

Results and Discussion

Water quality - The change in transparency over past 30 years demonstrates that the bay is gradually getting worse (Ohuchi,1985). In spite of the area-wide total pollutant load control of chemical oxygen demand (COD) for industrial discharge into the Seto Inland Sea,introduced in 1978, the water quality has not tended to improve at all, which suggests that the organic pollution in the bay may be controlled by the primary production of phytoplankton more than land based organic loadings.
The seasonal changes in transparency and chlorophyll (chl-a) are shown in Fig.2. The transparency shows systematic seasonal variations,a decrease from spring to summer and an increase from autumn to

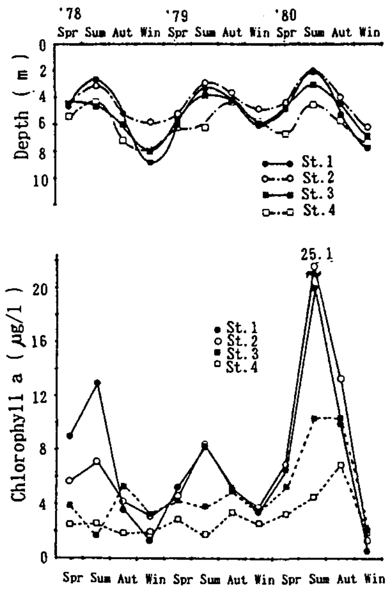

Fig.2. Seasonal changes in transparency and chlorophill a.

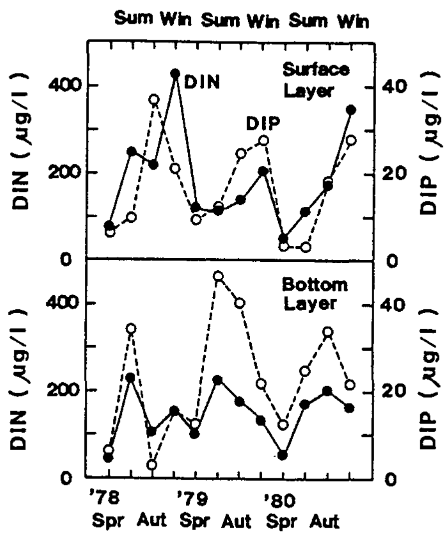

Fig.3. Seasonal changes in dissolved inoganic nitrogen and phosphorus at surface and bottom layers (St.1)

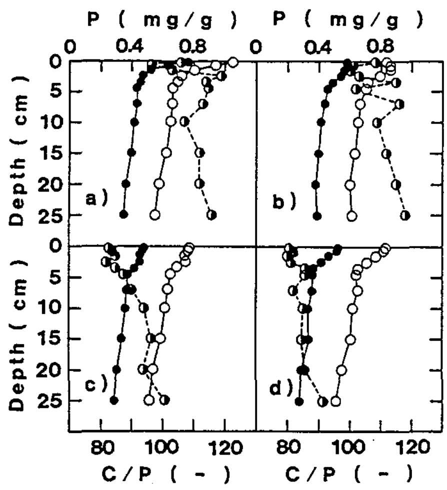

Fig.4. Vertical distributions of phosphorus and C/P ratio in sediments.
a) St-1,b) St-5, c) St-6, d) St-7
○ : TP, ● : PO4-P, ◑ : C/P ratio

winter. In summer, transparency in the coastal area often decreases to 1.5 m, when the concentrations of particulate organic carbon (POC) and chl-a increase. These results represent that the water pollution in summer is resulted from the multiplication of phytoplanktons. The vertical distritions in salinity and water temperature showed stratification to be weakly constructed at surface in April and strengthened in August. However, in September, the temperature drop made it broken gradually from the surface and the turnover was observed through the whole water in November.
Though both nitrogen and phosphorus were similar seasonal changes in water, the seasonal behaviors in nutrient at surface and bottom layers were different (Fig.3). The increases in the nutrient concentrations from summer to autumn at the bottom layer may be due to the release from sediments.

Sediment quality - Shiozawa et al(1979) reported that the northern Hiroshima Bay was one of the area where the most organic rich sediments had been settled. The sediments were homogeneous and mostly silt over 20 mg/g in TOC. They were over 25 mg/g in the northern coastal area. The vertical distributions in organic concentrations showed a tendency to decrease exponentially with depth. Inorganic phosphorus has been highly accumulated at surface layer, which may be related to the adsorption to oxyhydroxides at surface oxic sediments (Fig.4). It is considered that the inorganic phosphorus at the surface is repeating the adsorption and desorption with the changes of oxic-anoxic conditions in sediments. Nutrient concentrations in interstitial waters were higher than overlying waters by a factor of 10 in nitrogen and 50 in phosphorus. Their principal components were inorganic, NH_4-N and PO_4-P, respectively. Dissolved organic components scarcely existed in summer, but a little in winter.

Primary production - Seasonal changes in primary productivity were measured during the period from May 1979 to January 1984 at four stations (Date and Hoshino, 1984). The mean values in each station are shown in Table 2. Gross productivities were almost constant except the decrease in winter. However, net productivity was low in summer because of the high respiration rate. Therefore, seasonal characteristics in net productivities were high in spring and autumn, but low in summer and winter. Annual means of net productivities in each station ranged from 1.2 to 1.8

Table 2. Seasonal changes in primary productivitiy in Hiroshima Bay.

Location		Spr.	Sum.	Aut.	Win.	Mean
	PG	4.3	2.9	3.0	2.1	3.1
St.1	R	1.7	2.1	0.5	0.9	1.3
	PN	2.6	0.8	2.5	1.2	1.8
	PG	3.5	3.3	2.4	2.0	2.9
St.2	R	0.9	2.6	0.9	1.0	1.4
	PN	2.6	0.7	1.5	1.0	1.5
	PG	3.9	3.3	2.6	2.2	3.0
St.3	R	0.7	2.3	1.0	0.8	1.2
	PN	3.2	1.0	1.6	1.4	1.8
	PG	1.3	2.5	3.0	1.1	2.0
St.4	R	0.6	1.3	0.8	0.3	0.8
	PN	0.7	1.2	2.2	0.8	1.2

PG: Gross productivity
R : Respiration
PN: Net productivity

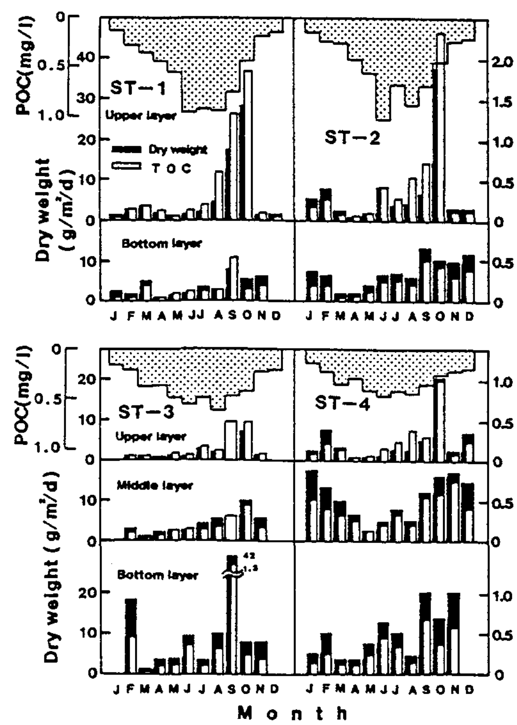

Fig.5. Relation of settling fluxes of particulate matter by sediment traps with POC concentrations in surface layer of sea water.