A poster presentation

Abstract

A study on the water environment of enclosed coastal sea, Ariake Sea, Japan

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Introduction

Human activities have effected adversely on the water environment of the enclosed seas. Increased population and economic growth have brought additional pollution loads to sea, and consequently the water quality of the enclosed sea has been impaired. Enclosed sea is vulnerable to pollution, because people always gather to live around it and their activities are vigorous there.

This study analyzes the water environment of the Ariake Sea, a Japanese enclosed sea.

Ariake Sea

Overview

Ariake Sea is the largest inland sea in Kyushu Island located at the western end of the Japanese archipelagos. It is stretches up to 17 km east to west, and 100 km north to south and is connected to the East China Sea through Hayasaki Strait on the south (see map below).

We find there one of the most spectacular wildlife in the world. The eastern and northern coast is among the largest wetland in Japan. The marshy land is some 190km^2 wide. The shallow and flat sea floor and large tidal fluctuations have been the primary factors that created such extensive coastal wetlands. Tidal range along the northern coast reaches a maximum of 6m.

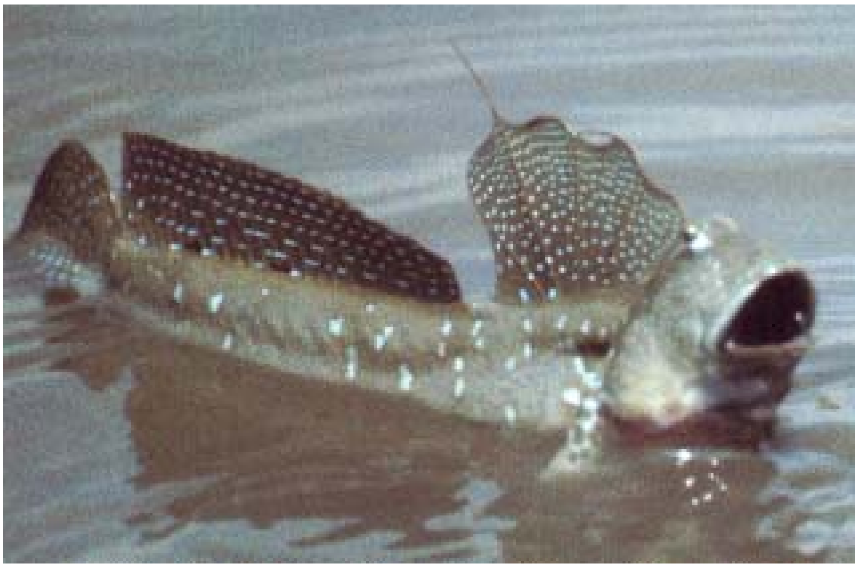

Fig 1 Mudskipper (*Boleophthlamus Boddarertil*)

Basic information

Surface area：1,700 km^2
Volume ：34 km^3
Average depth：20 m
Maximum depth：164.6 m

Location

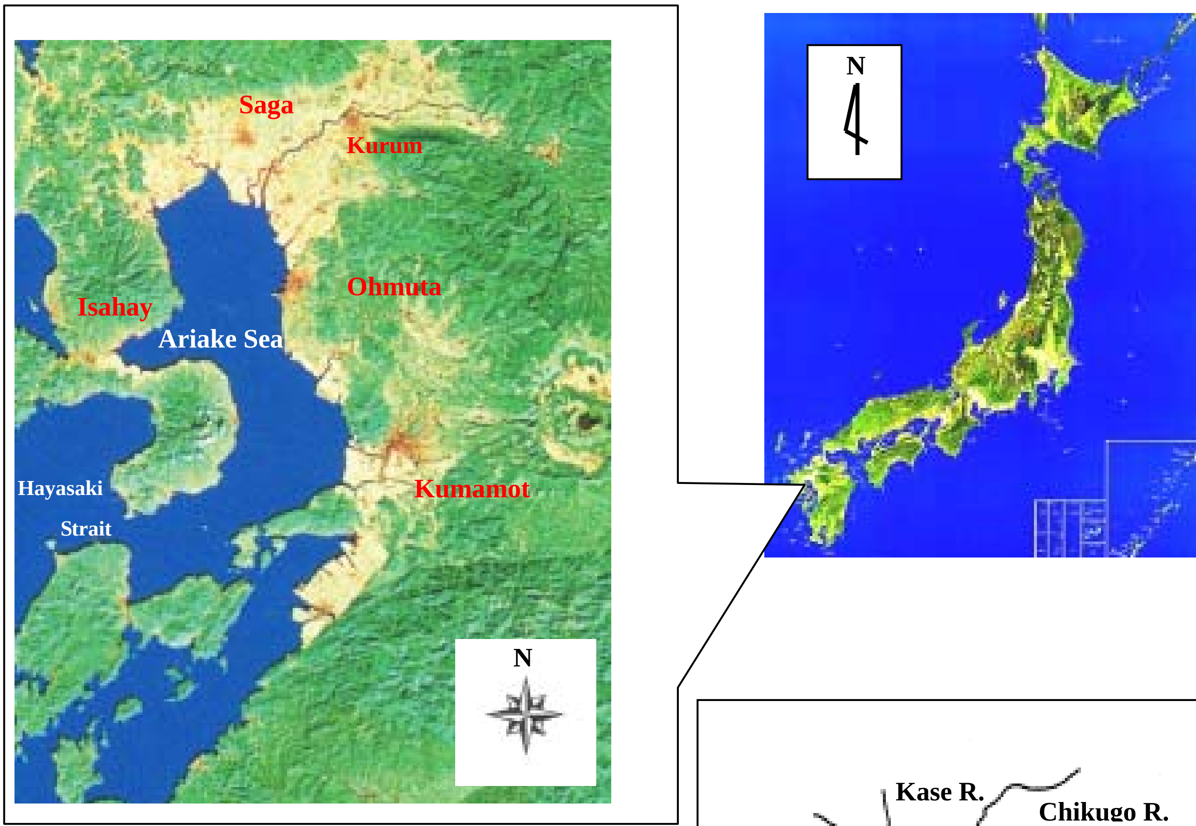

Fig 2 The location of Ariake Sea

Hydrology

Water circulation in the sea is largely influenced by the tidal energy system. Surface currents flow from south to north along the eastern coast.

By this mechanism, silt and contamination substances tend to stagnate in the western coastal zone at the inmost part of the sea.

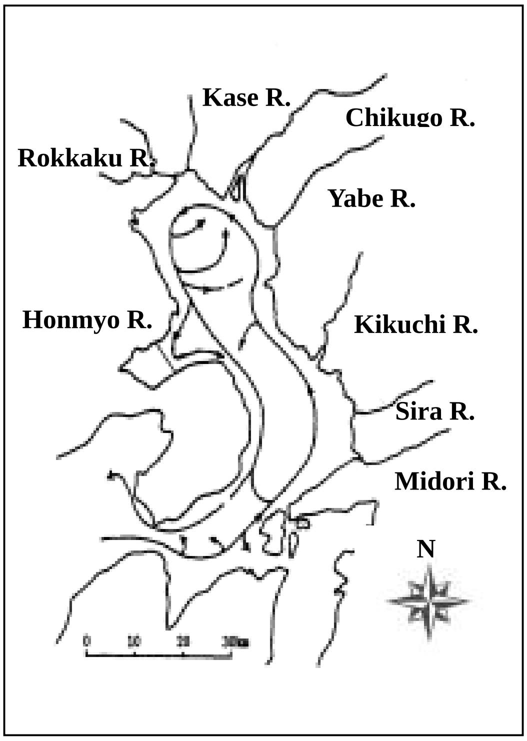

Fig 3 Water circulation in Ariake

Effect of natural hazard

Debris flow hazard

Unzen Fugendake located at the southwest gulf of the sea erupted in November 1990.

The pyroclastic flow occurred from May 1991 and hugo amount of debris ejecta increased disaster.

The total amount of volcanic product eruped is1.7km^3.

A volcanic product can flows with a heavy rainfall and did flow into the west coast zone of Ariake Sea.

The amount of outflows to the sea is 0.76 km^3.

As a result, the density of benthic organism of offshore waters fell down rapidly.

Fig 4 Volcanic of Nagasaki Unzen Fugendake
(The lava and pyroclastic flow which dye night sky red)

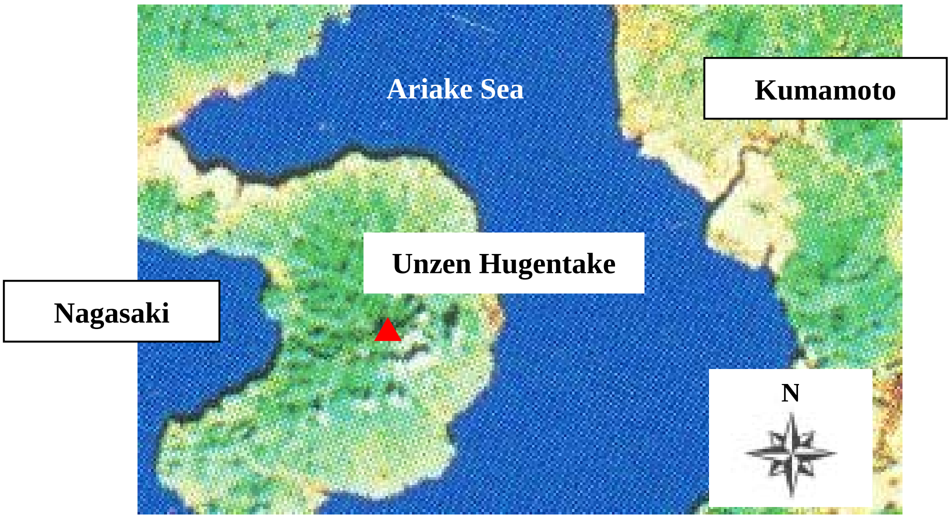

Fig 5 The Location of Unzen Fugendake

By this change, the catchs of wing shell (*Arina Pinnata*) of at the west coast has been decreasing sharply and the people in this area has quitted wing shell fishing according to the aggravation of the fishery environment.

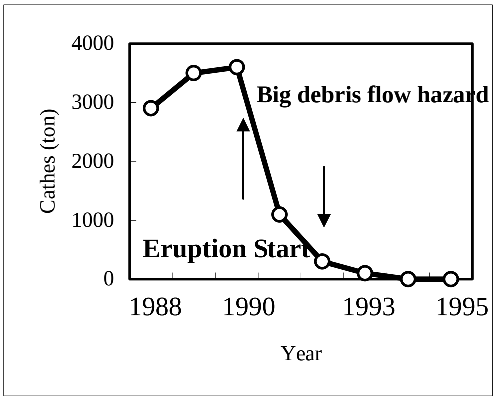

Fig 6 Change of wing shell catches in Nagasaki pref.

Wind damage (trees fallen down at typhoon attack)

In September 1991, the typhoon No. 19 with 942hPa of minimum atmospheric pressure and 61m/sec of maximum-instantaneous-wind-velocity hit northern part of Kyushu Island.

Trees in many forests fell down by the wind damage of the typhoon. Damage concentrated on the mountainous land Chikugo River and the Yabe River basin, and area more than 200km^2 was damaged with 15 million trees fallen down. Outflow of nutrient salts in a soil ingredient and the soil itself took place from collapsed slopes in the ruined forest. In the experiment conducted in the cedar forest of Kitakyushu district, the NO_3-N density in outflow water from the collapsed slope rose rapidly. The reported highest density was as high as 1.3mg/L, this high density continued 2.5years.

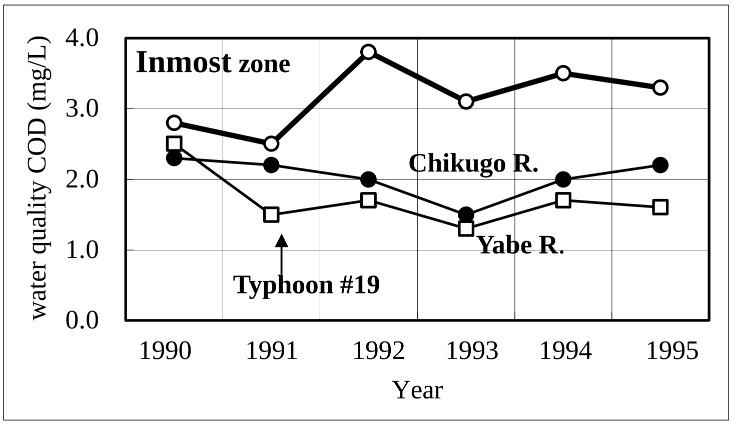

Fig 7 Change of water quality after typhoon disaster

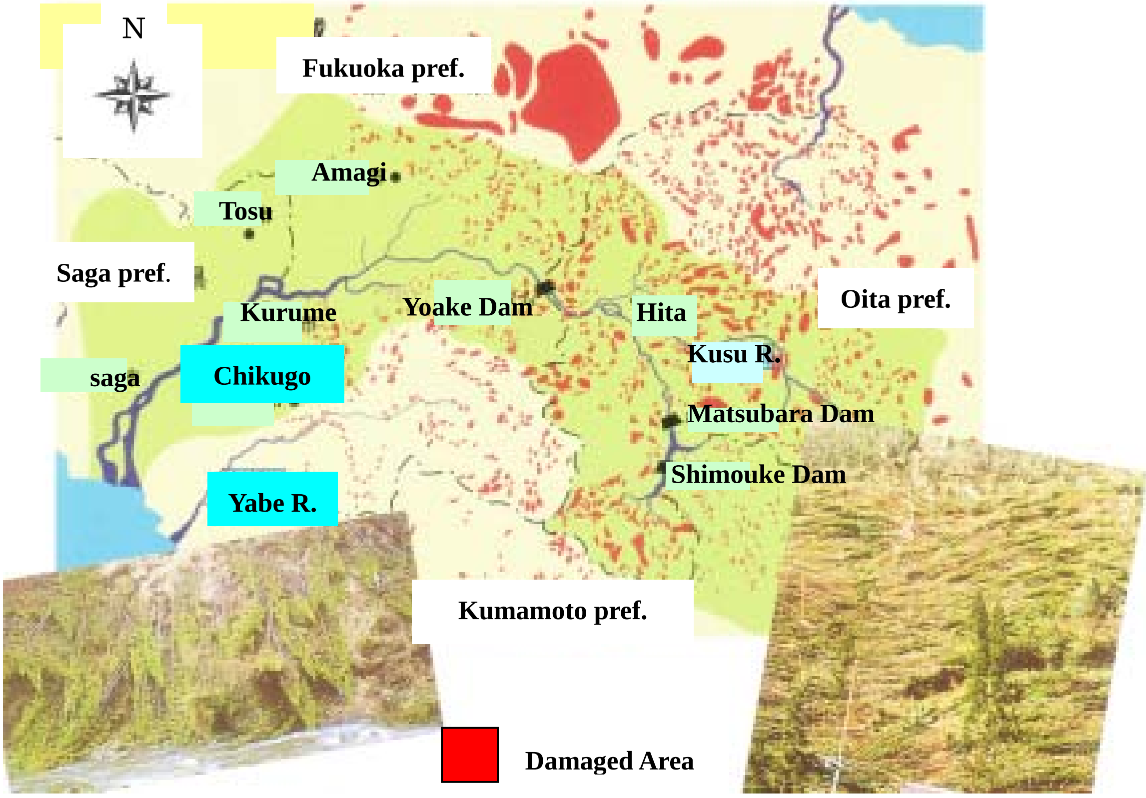

Fig 8 Wind damage (trees fallen down at Typhoon No.19 attack)

Influence by Change of society

Urbanization

With the rapid growth of Japanese economy, centralization of population into the urban area became remarkable and city boundaries have expanded.

This also increased the pollutant load on water environment in those areas.

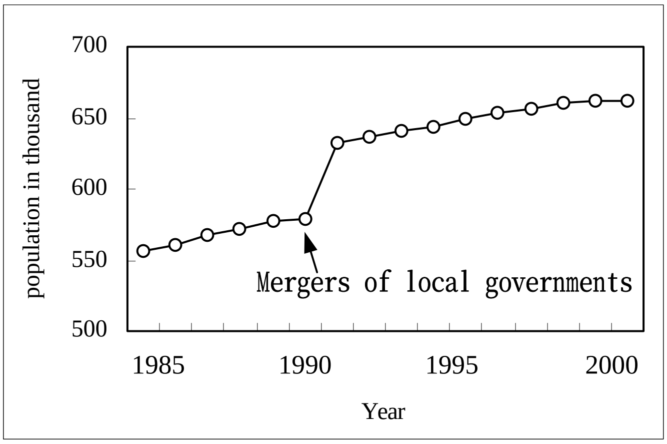

Fig 9 Change in population of Kumamoto City

Depopulation

On the other hand, the outflow of people from rural area continued and the population there decreased rapidly.

The farmlands not cultivated anymore increased remarkably, and the farmlands growing different crops became popular. Moreover, the age of forestry labors have been getting older. Desolation of forests accompanied accelerated outflow of pollutant loads.

The stockbreeding has declined and grazing lands not browsed anymore have increased. All of expanded the effluence of contaminants.

Degradation of water environmental in Ariake Sea (inmost zone)

Trends in the pollutant loads of Chemical Oxygen Demand (COD) are shown in the figure below. The Japanese national water quality standard assigns the area to Grade A, and requires COD values equal to or less than 2 mg/L.

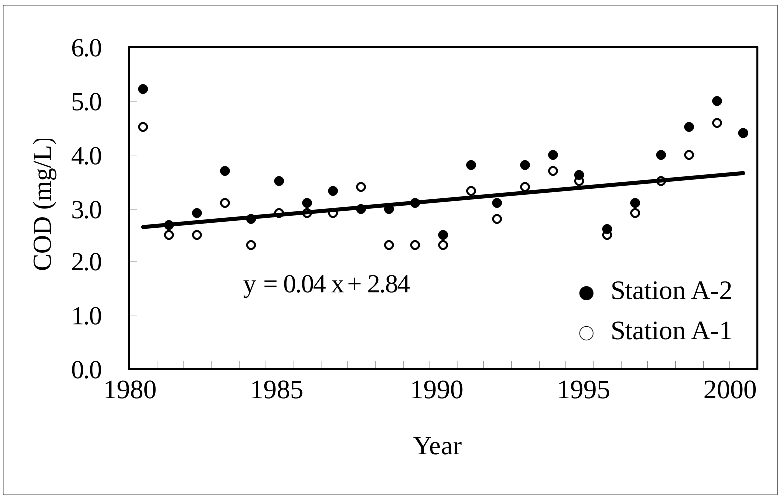

Fig 10 Change in COD concentration in Ariake Sea (inmost zone)

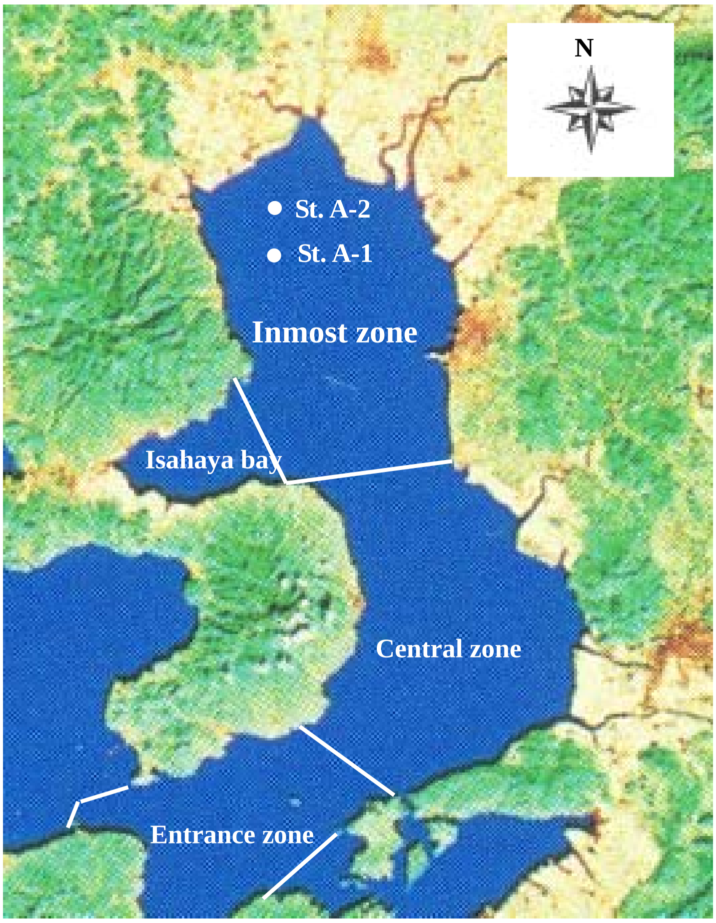

Fig 11 Zone in Ariake Sea

The total fish catch is declining because of urbanization and coastal development which brought about loss of tidal flats and seaweed beds. The overall effect is the degradation of the area's water environment. And the number of red tides has gradually increased since the 1980s, which coincides with the period of rapid economic growth in Japan.

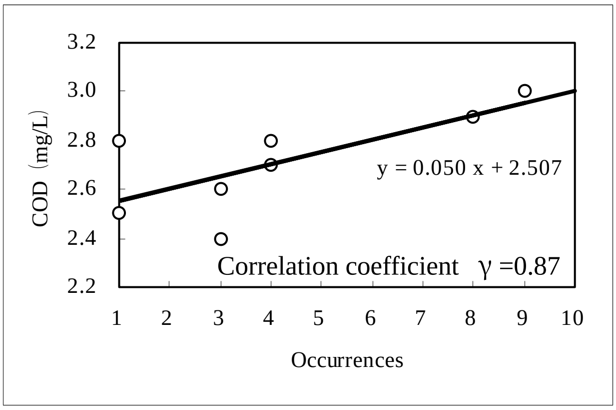

Fig12 Correlation of COD and the red tide occurrences

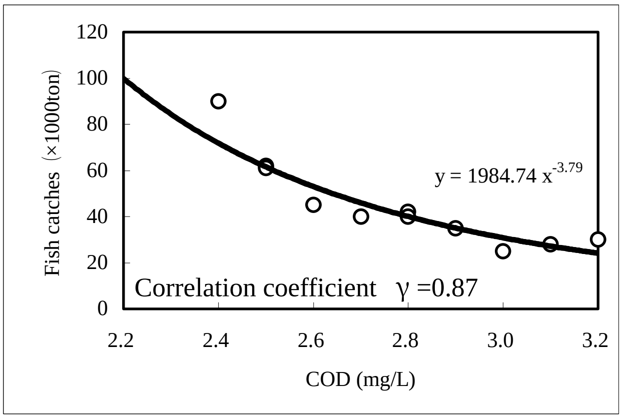

Fig13 Correlation of COD and fish catches

Pollutant loads in the Sea

Ariake Sea collects water precipitation in area approximately 8,500 km^2 covering about 20 per cent of Kyusyu Island. Eight Japanese national first-grade rivers flow into the Sea, with a total annual freshwater supply of 8.5 billion m^3. It provides drinking water and irrigation of farmland.

Pollutants from industrial effluent and domestic sewage are discharged into the Sea through these rivers. According to the survey by the Ministry of Land, Infrastructure and Transportation of Japan, the regional sewerage treatment system was 40 per cent in the year of fiscal 2000.

Table 1 Pollutant loads in Ariake Sea (ton/year)

Year	Residential Wastewater	Tourist Wastewater	Industrial Wastewater	Barn Wastewater	Natural Wastewater	Other	Total	Water quality in the sea
1990	12,266	98	7,788	6,685	2,031	-207	28,661	2.8(mg/L)
1991	18,244	146	11,820	9,820	3,087	-298	42,819	2.5
1992	6,030	49	3,986	3,204	1,042	-96	14,215	3.8
1993	39,857	326	27,875	20,899	7,038	-624	95,371	3.1
1994	3,962	33	2,718	2,044	713	-72	9,398	3.5
1995	5,876	49	4,123	2,996	1,083	-99	14,028	3.5
1996	5,752	49	4,090	2,920	1,086	-103	13,794	3.6
1997	16,883	145	12,710	8,530	3,266	-298	41,236	2.6
1998	11,007	96	8,048	5,534	2,183	-201	26,667	3.1
1999	10,759	96	7,982	5,381	2,189	-200	26,207	4.0
2000	5,256	48	3,968	2,614	1,098	-104	12,880	4.5

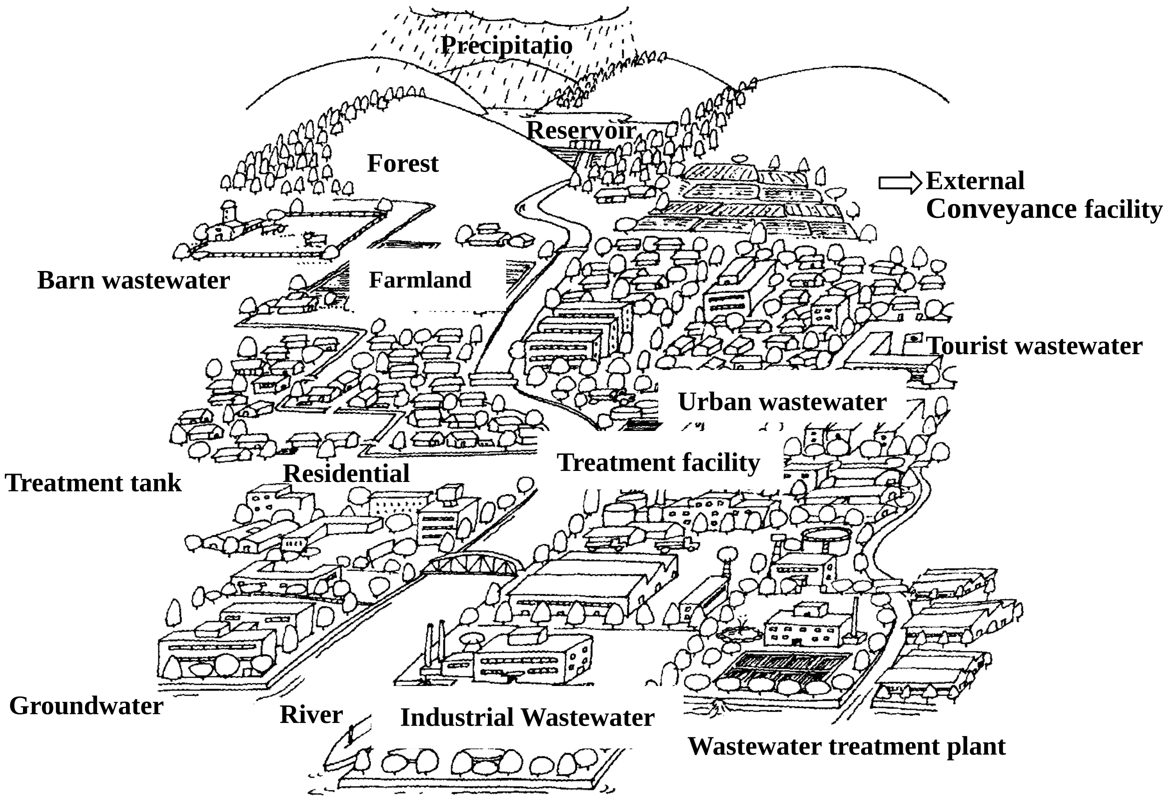

Fig 14 Pollution source

Table 2 Classification of Pollution source

Source	Condition	Point	Wastewater		Ratio
Pollution source	Steady	Point source	Residential	Human waste	Population
				Waste water	
			Tourist wastewater	Human waste	Tourists
				Waste water	
			Industrial wastewater		Industrial value
			Barn wastewater	Cows	Animals
				Pigs	
				Horses	
	Unsteady	Non point source	Urban wastewater	Housing site	Area
			Farmland wastewater	Paddy field	
				Upland field	
			Precipitation	Dust, Yellow sand	
			Forest		
			Others	Wasteland	
			Farmland wastewater	No cultivate farmland	
				Farmlands growing different crops	
			Eruption	Volcanic product	
			Barn wastewater	No manage land	
			Forest	Trees fallen by storm	
		Outside or Storage	Reservoir		Scale
			External conveyance facility		

Analysis of water environment in Ariake Sea

Multiple liner regression analysis

The correlation between the water quality (COD) of the Ariake Sea and run-off pollution loads are analyzed by the multiple linear regression analysis method. The result is as follows.

Diagram 1 Multiple liner regression analysis

Regression statistics

Multiple correlation R	0.9748
Multiple determination R^2	0.9502
Correction R^2	0.8754
Standard error	0.2166
Data	11

Table of variance analysis

	Degrees of freedom	Variation	Variance	Variance ratio	Significance F
Regression	6	3.578	0.596	12.708	0.014
Residual	4	0.188	0.047		
Total	10	3.766			

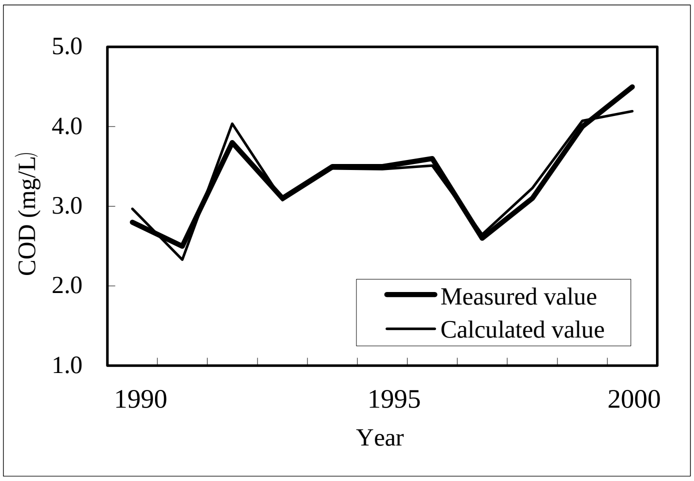

Table 3 Importance coefficient of explanatory variables

	Residential Wastewater	Tourist Wastewater	Industrial Wastewater	Barn Wastewater	Natural Wastewater	Other
Coefficient	5,496	129	-909	-2,747	-1,743	27.7
Rank	①	②	④	⑥	⑤	③

.

Table 4 Pollutant loads of river basin connected to Ariake Sea (ton/year)

year	Chikugo R.	Honmyo R.	Rokkaku R.	Kase R.	Yabe R.	Kikuchi R.	Sira R.	Midori R.	Others R.
1990	14,313	311	1,434	1,466	966	3,929	2,639	1,692	8,517
1991	31,381	2,299	4,828	3,243	3,249	12,986	8,543	5,561	19,085
1992	9,285	758	731	2,454	492	1,933	1,247	822	2,909
1993	30,513	2,751	4,925	3,302	3,308	12,786	8,086	5,406	19,683
1994	2,997	447	497	999	334	1,269	1,179	533	3,000
1995	8,870	1,441	2,260	1,512	1,010	1,888	2,288	1,575	6,091
1996	8,813	1,426	1,517	1,011	1,014	1,887	2,177	2,374	6,037
1997	29,246	3,133	5,090	3,383	3,390	9,427	6,888	5,302	19,942
1998	8,717	3,099	3,844	3,394	1,530	3,768	2,934	2,397	5,928
1999	12,995	1,379	2,322	1,533	1,535	5,647	4,612	4,015	8,811
2000	4,304	909	779	1,025	513	1,880	1,734	1,614	2,910

Diagram 2 Multiple liner regression analysis

Regression statistics

Multiple correlation R	0.9235
Multiple determination R^2	0.8528
Correction R^2	-0.4722
Standard error	0.7445
Data	11

Table of variance analysis

	Degrees of freedom	Variation	Variance	Variance ratio	Significance F
Regression	9	3.211	0.357	0.644	0.756
Residual	1	0.554	0.554		
Total	10	3.3766			

Table 5 Importance coefficients of explanatory variables in river basin

	Chikugo R.	Honmyo R.	Rokkaku R.	Kase R.	Yabe R.	Kikuchi R.	Sira R.	Midori R.	Others R.
Coefficient	0.75	1.18	-1.75	2.04	-6.32	-5.08	7.14	-1.58	3.33
Rank	⑤	④	⑦	③	⑨	⑧	①	⑥	②

Prediction of the water environment Ariake Sea

Table 6 Pollutant loads in Ariake Sea (2000year) (ton/year)

Waste Water	Residential Wastewater	Tourist Wastewater	Industrial Wastewater	Barn Wastewater	Natural Wastewater	Other	Total
Pollutant loads	73,291	456	40,167	26,525	7,318	-696	147,061
Run-out pollutant loads (discharge)	35,037	317	26,.357	17,425	7,318	-696	85,758
Run-off pollutant loads (flow in the sea)	5,256	48	3,968	2,614	1,098	-104	12,880

The prediction of the water environment in Ariake Sea is as follows. In the prediction, however, the sewage treatment rate in fiscal 2010 is assumed as 100%.

Table7 Pollutant loads in Ariake Sea (ton/year)

Year	Residential Wastewater	Tourist Wastewater	Industrial Wastewater	Barn Wastewater	Natural Wastewater	Other	Total	Water quality in the sea
2010	5,256	48	3,968	2,614	1,098	-104	12,880	4.5(mg/L)
2001	4,840	43	3,618	2,392	999	-95	11,798	3.2
2002	4,424	39	3,283	2,171	900	-86	10,732	3.0
2003	4,009	35	2,948	1,949	801	-76	9,666	2.9
2004	3,593	31	2,613	1,727	703	-67	8,601	2.7
2005	3,177	27	2,278	1,506	604	-57	7,535	2.5
2006	2,762	23	1,943	1,284	505	-48	6,469	2.3
2007	2,346	19	1,608	1,063	406	-39	5,403	2.2
2008	1,931	15	1,273	841	307	-29	4,338	2.0
2009	1,515	11	938	620	209	-20	3,272	1.8
2010	1,099	7	603	398	110	-11	2,206	1.6

*Run-off ratio：0.30 *Sewage treatment rate：100%/2010year

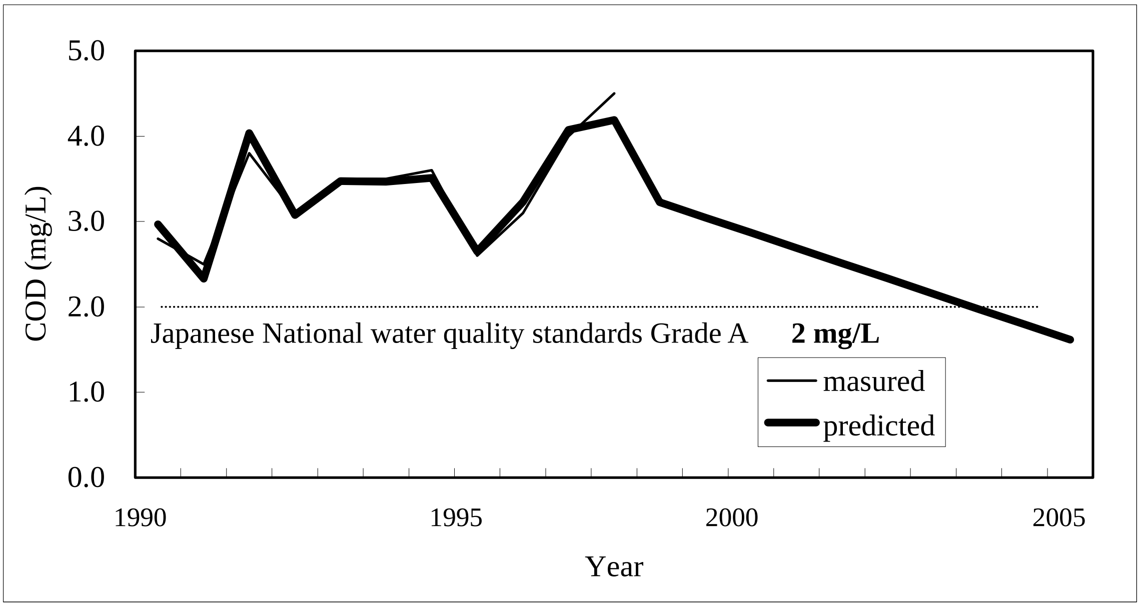

Fig 15 Future prediction on the water environment of Ariake Sea

Conclusion

(1) The water environment of Ariake Sea is supposed to be determined with the pollution loads discharged from the river basins.

(2) Water quality improvement achieved by purification equipments in river basins, (for example, sewage treatment, night soil treatment plant and household treatment tank) has been an effective measures to protect the water environment of Ariake Sea against pollutions.

(3) Some 40% of the sewage of Ariake littoral region is being treated.
Promotion of the sewage facilities is surely the effective way of improving the water environment in question.

(4) The pollution loads from residential wastewater pouring into large-scale river is very influential on the water environment of enclosed coastal sea, Ariake Sea in this study.

(5) Sewage facilities in minor river basins are scarce in this region and, therefore, increasing the number of sewage facilities will greatly be effective.

(6) It is necessary to control the drainage from ruined forest and devastated farmland.

(7) Change of the land use caused by urbanization, the decrease in population, and the wastewater effluence from rotational farmlands growing new crops shall be watched carefully and controlled correctly.