Pollutant Load Analysis for the Environmental Management of Enclosed Sea in Japan

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Abstract

Recent data shows that household, industry and other non-point sources contribute 43, 30 and 27 percent of TOD load respectively to representative enclosed sea areas in Japan. Most of the load relates to our dietary life.

The structural cause of eutrophication is that N, P cycle of food has changed to be largely opened by the input of imported food and feed and use of chemical fertilizer. The self-supply rate of food decreased from 48% 1970 to 32% 1990 as for N and from 46% to 29 % as for P in Japan. Dependence of chemical fertilizer was 45 % for N and 59% for P in 1990. From the budget of N, P in farmland, 596 10^3 tones of N equivalent to 44% of input should be denitrified, and 391 10^3 tones of P equivalent to 77% of input should be accumulated in soil. Correspondingly, the contents of available P in farmland soil show clear increase. N contents are not changed remarkably, and the concentration of nitrate in groundwater has been already saturated in many cases.

To solve eutrophication problems, we should reconsider agriculture and our dietary life. The fundamental countermeasure is to reduce the input of N, P from outside, and keep our own farmland and agriculture so as to receive organic wastes soundly.

Introduction

Through internet surveys, the authors overviewed environmental issues in enclosed sea areas in the world. At present UNEP organizes 13 regional sea projects including The Black Sea, The Mediterranean Sea , East Asian Region and North-West Pacific Region and so forth. The Black Sea Project was started in 1992 and has already published good reports. Baltic Sea has also been intensively tackled with by Scandinavian and other countries intensively. Chesapeake Bay Project seems quite preceding already up to NPO or citizen’s involvement and has enough information services. In all these projects, eutrophication remains to be one of the main problems still now.

Table 1 summarized the outlines of enclosed sea areas where EMECS meeting was held so far. Tokyo Bay was also added for reference. Baltic Sea and Black Sea seem to be too large for discussing eutrophication issues in common. Even in Seto Inland Sea, we can observe the different states for each block usually divided into 10.

Table 1 Comparison between Enclosed sea areas visited by EMECS and Tokyo Bay

Sea area	Main rivers and lakes	Main cities in watershed	Recent symptom
Seto Inland Sea	Yodo River, Lake Biwa, Kojima Lake	Osaka, Kyoto, Kobe, Okayama, Hiroshima	Fishery production decreasing since 1985 Oyster in Hiroshima damaged by red tide
Tokyo Bay	Edogawa, Arakawa Tamagawa	Tokyo, Yokohama, Chiba	Occasional bloom of blue tide
Chesapeake Bay	Saskenahan, Potomac	Bortimore, Washington Annapolis	Main part is blue crabs Water quality is stationary inspite of load reduction
Baltic Sea	Dvinian, Oder, Wisla Ladoga Lake	Helsinki, Stokholm, Berlin Kopenhagen, Peterburg	High salt water below 60m Fishery production decreasing
Black Sea	Danube, Dnepr, Don Azov Sea	Munchen, Wien, Budapest, Bucharest, Kiyev, Kharkov	Anoxic water below 180m Mnemiopsis continues to plague the sea

Sea area	Surface area (10^3 km2)	Mean depth (m)	Water inflow (10^6m3/d)	Watershed (10^3km2)	Population (10^4)	Load inflow (t/d)		Fishery production (10^3 t/y)	Water quality (mg/l)	
						N	P		N	P
Seto Inland Sea	22	37	204	42.9	1880	737	42.6	570	0.27	0.027
Tokyo Bay	1.4	39	42	8.3	2140	281	23	38	1.00	0.065
Chesapeake Bay	6.5	8.5	225	166	1300	181	18	>435	0.65	0.030
Baltic Sea	422	55		1688	8000	2548	148	860	0.39	0.043
Black Sea	461	1000<?			16000	1773	138			

Anyhow, it was very impressive that Dr.Brunner in his report of Danube relating Black Sea Project, recommended to reduce eating meat and to monitor the contamination level of sewage sludge. It should be also noted that Danish authority obligates farmers to make fertilization plan and regulates the utilization of manure up to 45-50% for Nitrogen. I reminded that the fundamental cause of eutrophication derived from our dietary life almost over 80% when we started to study around 1972. We must produce food for increasing population, using chemical fertilizer and pesticides. Excess nitrogen and phosphorus have been discharged to water area through farmland directly and also through urban areas indirectly. It seems very difficult to solve eutrophication problem because it is related our living itself.
Considering these backgrounds, and changing scheduled topics a little, this paper discusses the fundamental cause and countermeasures of eutrophication based on the case of Japan.

Transition of human and livestock excreta and chemical fertilizer in Japan

Fig.1 shows the change of human excreta disposal in Japan during 40 years. In 1955, 90% of night-soil was utilized as fertilizer to farmlands. Through the economic growth and urbanization, night-soil lost the value of fertilizer and was substituted by chemical fertilizer. The author remember well the change of the power balance between farmers and non-farmers requesting to dip-up night-soil about 1955-1960.
Now, 50% of Japanese people are serviced by sewage treatment and 25% use private treatment system, i.e. 3/4 of people use flush toilets. Even in small agricultural villages, 100 % use of flush-toilet is targeted. Actually, only 1% of human excreta is utilized to farmland at present and the rest is treated by advanced night-soil treatment systems.

Fig.2 and **Fig.3** show the transition of N, P load derived from human dietary, livestock excreta and chemical fertilizer. Human load includes gray water derived from food and garbage. The load divided by the area of arable land is shown in those figures.
As for Nitrogen, human load has been increasing almost linearly, livestock excreta has been increasing with saturation curve. Unexpectedly the amount of chemical fertilizer was used at the level of 100 kg/ha/year 1955 not much different from the present level. In the early periods, the arable land was used partly two times, therefore chemical fertilizer per planted area increased from 69 in 1955 to 120 in 1996. Recently, 3 kinds of load are in almost same level. Considering that even livestock excreta is not easy to be recycled at present, it is easily understood that Nitrogen is far more in excess in Japan.
As for Phosphorus, similarly human load has been increasing almost linearly, and livestock excreta has been increasing with saturation curve. Chemical fertilizer has increased as saturated from 30 in 1955 to 60 recently. The amount per planted area was 20 kg/ha/year in 1955 and 60 recently. However, the levels of livestock excreta and especially human load are less than that of chemical fertilizer. It means the organic resources of P may be more easily recycled than organic nitrogen.

Fig.1 Transition of the human excreta disposal in Japan

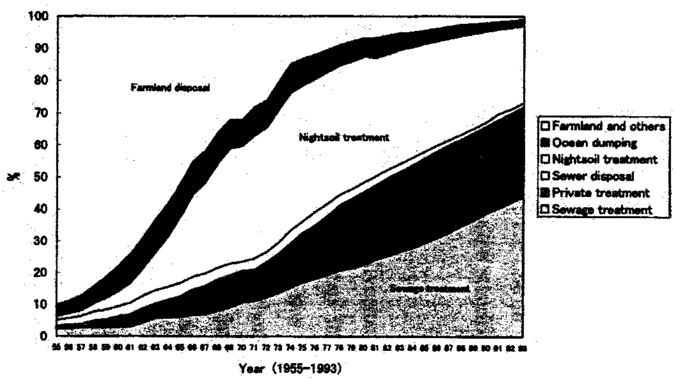


Fig.3 Human load and livestock excreta and chemical fertilizer consumption per hectare of arable land in Japan

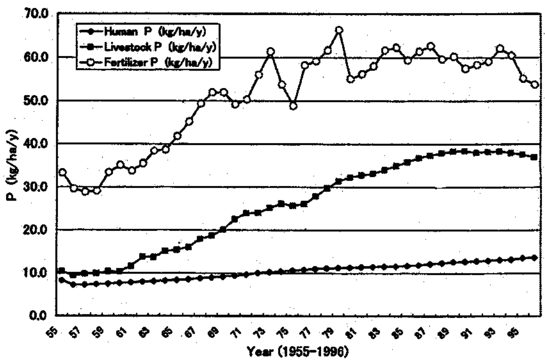


Fig.2 Human load and livestock excreta and chemical fertilizer consumption in Japan per hectare of arable land

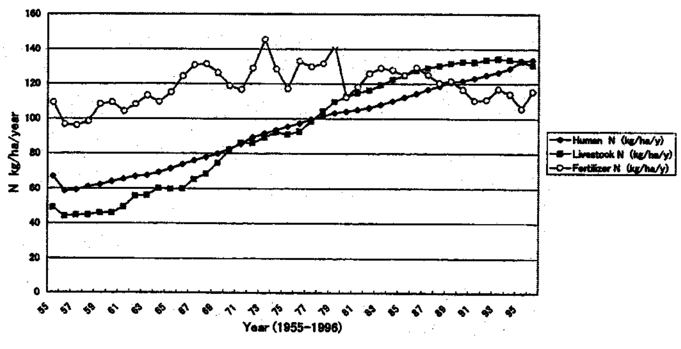


Fig.4 Transition of food suply and intake in Japan

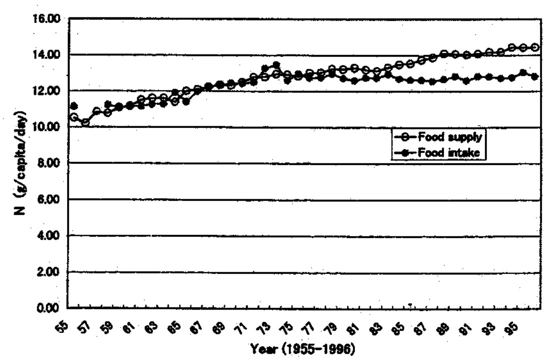


Fig.4 shows the transition of food supply and food intake in Japan since 1955 to 1996. These two sets of value are obtained by totally different way. The values of food supply are obtained from statistics of food by the Ministry of Agriculture, Forestry and Fisheries. The latter values of food intake are obtained by the sampling survey of nutrition for 15000 persons by the Ministry of Health and Welfare.

The differences between them have become larger since about 1975. The difference a little less than 2 g/capita/day has been seen recently. This amount is rather large if we think it is uneaten to garbage or wastewater. As the amount of food uneaten per capita might be not so much increasing, so it is likely that at least such tendency has become larger during this period.

Change of Nitrogen and Phosphorus cycles in Japan

In order to understand the structural characters of eutrophication issues, the author prepared N, P cycles in Japan in 1970 and 1990 as shown in **Fig.5** and **Fig.6**. Various statistics and data of the contents of nutrients are combined to get these figures. Although it passed almost 10 years since 1990, the situations are not much different as assumed in Fig.1 to Fig.4.

The self-supply rate of food and feed in 1990 was 32 %, decreasing from 48 % in 1970 as for N. As for P, the rate in 1990 was 29 %, decreasing from 46 % in 1970. Attention should be paid at the standpoint of food security too other than environmental issues.

The input of N and P to livestock breeding increased 1.6 times as much from 686 to 1080 10^3 tones, and 1.7 times from 142 to 242 10^3 tones per year respectively during 2 decades. Consequently, raw material supply from livestock breeding to food and feed industry increased more than 2 times and the consumption of processed food including meat increased 1.4 times for N and 1.5 times for P respectively. This change of our dietary life inclined to meat made N, P cycle more open and worse.

The consumption of chemical fertilizer into farmland rather decreased by 11% for N and increased only 6% for P corresponding to the decrease of self-supply rate of food. However, the percentage of chemical fertilizer out of total input to farmland was 45 % for N and 59% for P in 1990, still very high although decreased from 1970.

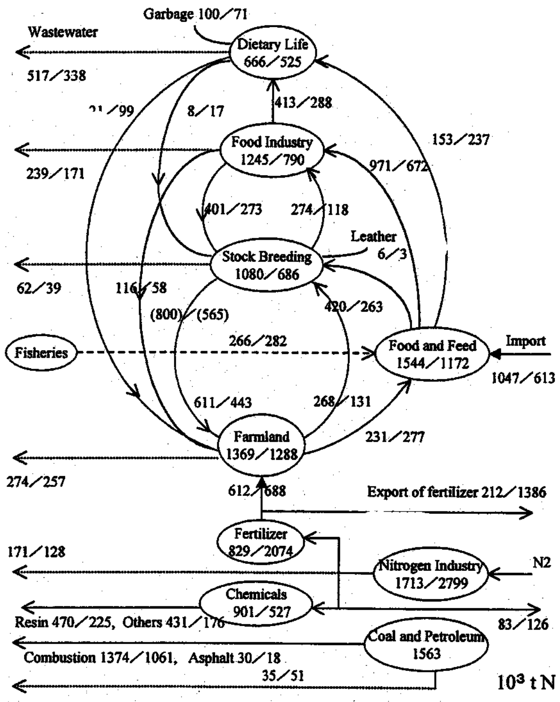


Fig.5 Nitrogen Cycle relating to Food in Japan (1990／1970)

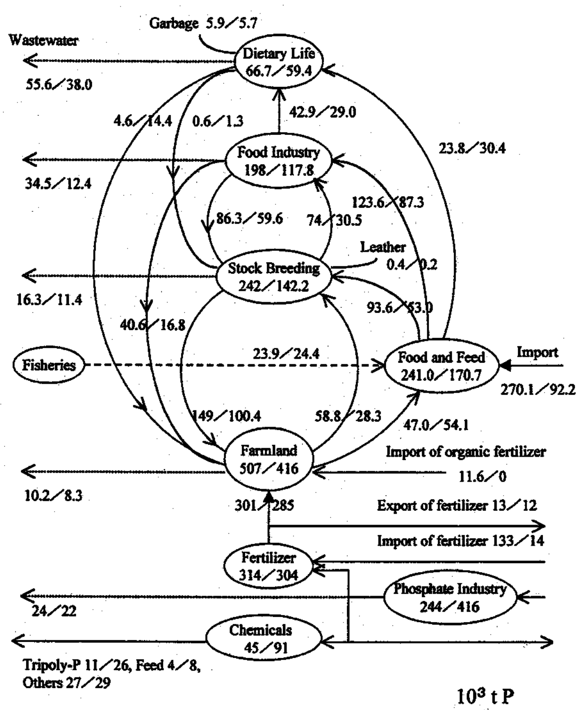


Fig.6 Phosphorus Cycle relating to Food in Japan (1990／1970)

From the budget of Nitrogen, 596 10^3 tones should be denitrified, assuming the contents in soil steady and the loss to water environment to be 20 % of total input. The amount corresponds to 44% of total input to farmland.

On the other hand, as for Phosphorus, 391 10^3 tones should be accumulated in the soil, assuming the loss to water environment to be 2 % of total input. The amount corresponds to 77 % of total input to farmland.

In Fig.5 and Fig.6, dotted lines with leftward arrows show the load of wastewater after subtracting the recycled portion. The values for livestock breeding sector especially for N are left obscure. If we use the values of livestock excreta obtained from budget other than the reported values of excreta itself, the load to wastewater will become larger, otherwise more than 100 thousands tones of loss by denitrification should be considered also from this sector. Anyhow, it is clear that as recycled portion decreases and wastewater portion from households, food industries and livestock breeding increase.

Although industry sectors are not studied intensively, it may be useful to compare the potentials between food and feed sectors and industry sectors.

As for Nitrogen, industrial fixation of N_2 and N contained in coal and petroleum are the main other sources. Input as the form of other natural organic products like timber and raw silk consumed in Japan was not much as 82 10^3 t N in 1990.

The scale of nitrogen industry decreased remarkably from 1970 to 1990. This is caused by the decrease of export of chemical fertilizer. Production of industrial chemicals rather increased. Large part of them is finally disposed of by incineration and it is considered that the effect on N load to water environment might be small, at most 10-20% of total load into eutrophic sea areas. Among industries, fertilizer, cokes production, nylon, acrylonitrile, melamine, urea resin, cupra-rayon, fermentation chemicals, leather processing and so forth might be large N dischargers. As for P, phosphate production from imported phosphorus ore decreased and other phosphate chemicals like tripolyphosphate also decreased. Input in the form of other natural organic products consumed in Japan was not much as 7.2 10^3t P in 1990.

Change of N, P contents of soil and nitrate contamination of ground water

As above mentioned, from the mass-balance of large amount of N and P are assumed to be denitrified and accumulated in farmland soil respectively.
Fig.7 and **Fig.8** show the change of N and P contents in farmland soil in Japan, reported as the average of nearly 20 thousands of samples by the Ministry of Agriculture. Although the remarkable change of N contents can not be seen, continuous increase of available P contents are seen (Fujiwara1996). We should pay attention hereafter more about the potential of P-accumulated soil.

Fig.7 Nitrogen concentration in farmland soil in Japan after the Ministry of Agriculture Forestry and Fisheries 1992

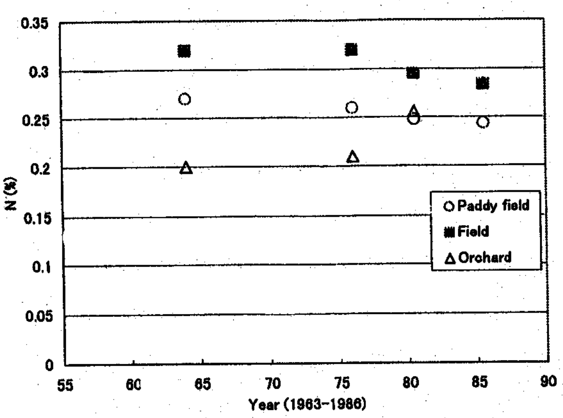
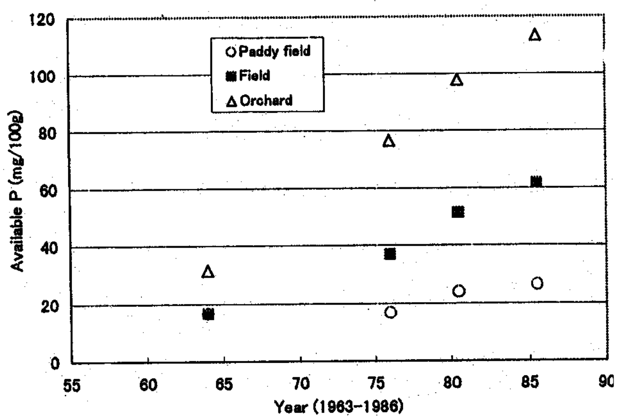


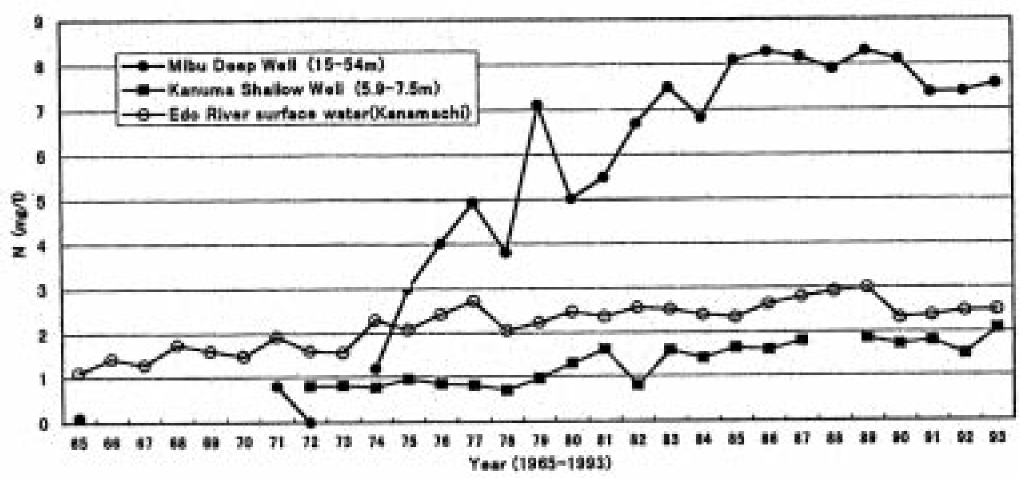
Fig.8 Available phosphorus concentration in farmland soil in Japan after the Ministry of Agriculture Forestry and Fisheries 1992



Another important problem is the nitrate contamination of groundwater. **Fig.9** shows an example of such data collected from public waterworks in Kantoh plain where Tokyo is also located. Nitrate N concentration looks at steady-state level both in deep well and shallow well. This tendency can be seen in many cases in Japan, although the period of saturation differs from each other. Japan Environmental Agency (JEA) added nitrate nitrogen of 10 mg / l in groundwater to the environmental criteria as a health-relating-item in 1999.

Pollutant load into enclosed sea areas

Fig.9 Inorganic N concentration in ground water in Kantou Plain



JEA has been estimating pollutant load into enclosed sea areas Tokyo Bay, Ise Bay and Seto Inland Sea, by summing directly measured data up for point sources of large scale like sewage treatment plants, industrial wastewater so forth, combining unit-loading-rate method for other non-point sources.

Recent data are shown in **Table 2**. Household wastewater, industrial wastewater and other non-point sources contribute 43, 30 and 27 percent of TOD load respectively to these representative enclosed sea areas in Japan. Here, TOD was calculated by the formula below. Here, COD is COD_{JIS} using permanganate.

$$TOD=3COD+(19.7TN+143TP)/2 \quad \cdots \quad (1)$$

Table 3 shows the comparison between the values of discharged load estimated by the JEA and those we estimated using unit-loading-rate method. Although these data are not up-to-date, it is assumed to be not so changed in recent periods as shown in **Fig. 10** with white and black squares. For household wastewater and industrial wastewater, our values for COD and P are larger than those of JEA. For agriculture and others, our values apt to be larger for COD and smaller for N and P. The contribution of agriculture may be smaller than in case of lakes and reservoirs, because the human activities facing to enclosed sea areas are generally concentrated in Japan.

Method of Unit-loading-rate to estimate input load into enclosed sea areas

For reference, **Table 4** shows the values of unit-loading-rate used in the estimation of discharged load to Tokyo Bay in 1988. The values used by JEA are shown in **Table 5**. The values listed in Table 4 were set through a lot of field surveys and such studies to arrange the data shown in Fig.5 and Fig.6.

The input load into enclosed sea areas is calculated as follows.

Unit-loading-rate of discharge = Unit-loading-rate of generation Discharge rate or ×(1 − Removal fraction of treatment) ···· (2)

Discharged load = Unit-loading-rate × Number of discharging units ···· (3)

Reaching load to concerned water areas = Σ(Discharged load×Reaching fraction)

Reaching fraction = Flow-out-fraction×Flow-down-fraction ··· (4)

$$= \{1-\exp(-k_1X_1)\} \times \{1-\exp(-k_2X_2)\} \quad \cdots\cdot \quad (5)$$

Here, k_1 , k_2 : Decreasing coefficient in flow-out stage or flow-down stage (km^{-1}),

X_1 , X_2 : Flow-distance in flow-out stage ($X_1=A^{0.5}$) or flow-down stage (km).

Table 2 Pollutant load into 3 enclosed sea areas in Japan (Environment Agency 1994)

tones/day
COD: Mn−method

	Tokyo Bay			Ise Bay including Mikawa Bay			Seto Inland Sea			Percentage of TOD (%)	
	COD	TN	TP	COD	TN	TP	COD	TN	TP		
Sewage treatment plant	79.8	127.6	9.09	15.3	17.4	1.35	85.8	106.9	6.39	19.6	
Combined private treatment	8.9	7.9	0.83	10.8	8.7	0.89	14.2	14.0	1.32	2.9	
Privater treatment for flush toilet	14.0	23.0	2.42	12.1	20.7	2.00	23.1	41.3	3.24	7.1	
Night−soil treatment	0.9	2.5	0.14	1.2	2.6	0.13	3.0	8.1	0.38	0.9	
Household gray water	94.1	13.8	1.75	94.5	15.3	2.00	239.5	37.6	5.28	12.0	42.4
Industrial wastewater	28.9	46.6	2.78	56.8	38.8	3.44	208.1	244.7	8.14	23.9	
Industrial wastewater of small scale	9.7	2.0	0.92	14.0	3.8	1.20	47.0	5.9	2.64	3.1	
industrial wastewater not regulated	20.0	2.0	0.48	12.3	4.2	0.94	52.2	7.4	3.15	3.3	30.3
Livestock breeding	6.3	4.5	2.02	12.8	11.8	4.50	32.8	85.5	4.47	9.0	
Acuaculture	0.0	0.3	0.02	0.0	2.6	0.70	0.0	42.0	3.62	3.5	
Farmland and others	23.5	50.9	2.55	16.2	48.0	1.35	40.3	143.7	3.96	14.8	27.3
Total	286.0	281.0	23.0	246.0	174.0	18.5	746.0	737.0	42.6		100.0

Table 3 Comparison of the estimated load into Seto Inland Sea and Tokyo Bay

Seto Inland Sea	COD Mn		TN		TP	
	a	b	a	b	a	b
Household sewage	399	406	204	206	14.5	28.9
Industrial wastewater	356	421	223	209	16.6	21.7
Agriculture and Others	82	288	273	56	13.0	7.4
Total	837	1115	700	471	44.1	58
Tokyo Bay	COD Mn		TN		TP	
	a	c	a	c	a	c
Household sewage	243	247	183	207	15.1	22.9
Industrial wastewater	76	159	72	88	5.2	9.2
Agriculture and Others	36	49	65	38	5.7	1.7
Total	355	455	320	333	26.0	33.8

a: Environmental Agency 1989 b: Ukita et al 1987 excluding Hibiki and Bungo
c: Nakanishi & Ukita 1988

Fig. 10 Transitn of CODmn concentration and pollutant load into Seto Inland Sea

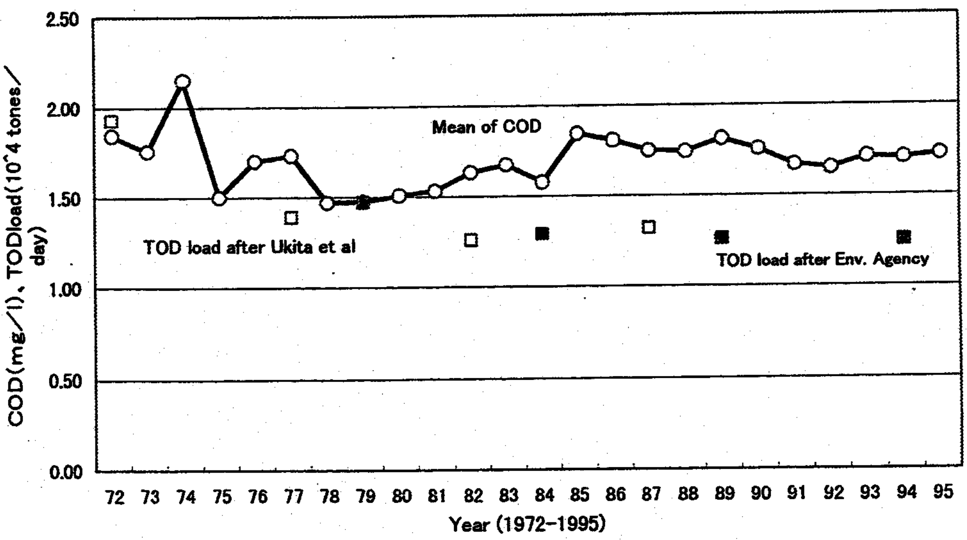


Table 4 Unit-loading-rate of discharge (for Tokyo Bay 1988)

COD: Mn-method

	COD	N	P		COD	N	P
Household human excreta	(g/capita/day)			**Industrial wastewater**	(g/d)/(100Myen/y)		
Sewage treatment	2.65	4.23	0.47	Food processing	0.80	0.69	0.071
Combined private treatment	3.07	4.34	0.61	Textile	2.58	0.26	0.120
Privater treatment for toilet	4.29	6.15	0.70	Cloth	0.23	0.03	0.004
Night-soil treatment	2.21	3.90	0.39	Wood products	1.08	0.07	0.007
Sewer disposal	2.38	3.81	0.47	Furniture	0.15	0.03	0.014
Ocean dumping	0.00	0.00	0.00	Pulp & paper	8.75	0.57	0.074
Farmland and others	0.22	1.30	0.02	Print & publishing	0.28	0.03	0.004
Household gray water	(g/capita/day)			Chemicals	1.99	1.74	0.130
Sewage treatment	2.74	0.94	0.22	Oil & coal	0.25	0.33	0.003
Combined private treatment	3.17	0.96	0.29	Rubber	0.27	0.32	0.031
No treatment	12.69	1.60	0.41	Leather	6.64	3.99	0.077
Office human excreta	(g/capita/day)			Cement & ceramic	0.45	0.04	0.004
Sewage treatment	1.32	3.29	0.29	Steel	0.13	0.31	0.032
Combined private treatment	1.53	3.37	0.39	Nonferrousmetal	0.32	0.32	0.072
Privater treatment for toilet	2.15	4.78	0.44	Metal products	0.19	0.08	0.036
Night-soil treatment	1.10	3.03	0.25	Machinary	0.06	0.04	0.014
Sewer disposal	1.19	2.96	0.29	Electric machine	0.06	0.06	0.022
Ocean dumping	0.00	0.00	0.00	Transport machine	0.06	0.04	0.029
Farmland and others	0.11	1.01	0.01	Minute machine	0.06	0.04	0.014
Office gray water	(g/capita/day)			Others	0.13	0.04	0.007
Sewage treatment	1.37	0.47	0.04	**Chemical fertilizer**	(g/ha planted area/d)		
Combined private treatment	1.59	0.48	0.06	Rice	76.8	56.9	3.84
No treatment	6.34	0.80	0.08	Wheat & Barley	26.6	76.9	2.66
Sludge of private treatment	(g/l)			Beans	26.3	24.7	2.63
Night-soil treatment	0.48	0.45	0.15	Potetos	34.3	73.2	3.43
Sewer disposal	0.38	0.44	0.13	Vegitables	47.4	178.4	4.74
Ocean dumping	0.00	0.00	0.00	Orchad	33.3	137.3	3.33
Farmland disposal	0.04	0.14	0.01	Industrial crops & tea	46.6	211.2	4.66
Others	0.19	0.14	0.01	Feed crop	12.2	43.3	1.22
Livestock breeding	(g/head/day)			Others	31.6	79.9	3.16
Cattle	55.7	52.6	1.45	**Organic fertilizer**	(g/ha arable land area/d)		
Pig	13.0	10.6	0.65	Arable land	16.1	16.1	0.54
Chiken	0.20	0.46	0.188	**Natural load**			
				Forest & wasteland	4.11	0.82	0.05
				Farmland	(kg/km2/d)		
				Urbanized area	5.48	2.74	0.14

Table 5 Unit-loading-rate of discharge for non-point sources by JEA

COD: Mn-method

	COD	N	P		COD	N	P
Household wastewater	(g/capita/day)			**Land**	(g/ha/d)		
Combined private treatment	9.5	7.8	0.74	Forest & wasteland	2.5	18.7	0.5
Privater treatment for toilet	4.4	7.0	0.60	Farmland (Paddy field)	17.5	76.3	1.0
Livestock breeding	(g/head/day)			Farmland (Field)	10.4	77.3	1.0
Cattle	49.5	43	3.4	Farmland (Orchad)	10.0	77.7	1.0
Horse	49.5	26	2.8	Others	10.0	18.9	0.5
Pig	16.7	10.4	6.3				
Chiken		0.30	0.020				

and meteorological conditions, especially amount of rainfall and so forth. In case of Tokyo Bay, the values of 0.04, 0.05 and 0.06 km^{-1} were adopted for COD, N and P respectively. In this case, the over-all reaching fraction for them were 0.73, 0.70 and 0.67 km^{-1} respectively. The evaluation of the load from farmland is not enough because of the shortage of intensive study including surveys under rainy weather. Also, the comprehensive studies on flow-out and flow-down-fraction are not enough to formulate the coefficients of k_1, k_2 as the function of meteorological and geological conditions.

Conclusions

To control eutrophication problems and nitrate contamination of groundwater, we should reconsider agricultural practices and our dietary life. The fundamental countermeasures are to reduce the input of N and P from outside, and keep our own farmland and agriculture so as to be able to receive organic wastes derived from food and feed. We should recognize that the most primary recycling of food had been forgotten for a long period and eutrophication was the natural consequence of it.

Now, we are entering to 21 C, the era of recycling and simbiosis. Recycling of materials we use is necessarily the duty of mankind. In Japan also, people are concerned to produce compost more from garbage and sludge as an option of solid waste recycle, however the demand of such organic fertilizer is not certified. Planted area decreased from 8233 10^3 ha in 1956 to 4783 10^3 ha in 1996 in Japan. Similarly, the number of farmers decreased 1168 10^4 to 321 10^4. The results of questionnaire survey on the demand of night-soil treatment sludge conducted in 1971, show that 46% of farmers had already lost their will to use such recycled fertilizer.

We should recycle food and feed, produce healthy food and then reproduce healthy children. The comment that monitoring the contamination of sewage sludge is important, might have very profound meanings.

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