9. MUNICIPAL WASTEWATER POLLUTANT DISCHARGE REDUCTION: POSSIBILITIES OF "SOFT INTERVENTIONS" IN HOUSEHOLDS IN JAPAN AND IN THAILAND

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Wastewater pollutant discharge reduction efforts have been persued especially in economiclaly developed countries including Japan. Economically leading countries in developing countries including Thailand have large values of the Millenium Development Goals (MDGs) indicator of sanitation. Therefore, we should think about water pollutant discharge reduction function of municipal wastewater treatment in these countries beyond the MDGs sanitation purposes. Yamato-gawa River Social Experiment Program (YR-SEP) for Reducing Domestic Wastewater Pollutant Discharge has been conducted in the Yamato-gawa River drinage area, Japan, since 2005. In the YR-SEP, "soft interventions" in households to reduce pollutant discharge have been disseminated to ordinary citizens through media, schools, and environment NGOs to reduce municipal wastewater pollutant discharge from households and to evaluate water quality improvement in the Yamato-gawa River and its branches. Possible BOD improvement at Oriono-bashi Bridge, a monitoring point near the river mouth, was estimated as 20% based on pollutant load analysis result and estimation of possible pollutant discharge reduction in the households using environmental accounting housekeeping (EAH) books of domestic wastewater. Municipal wastewater generation by water usages and possible pollutant discharge was also estimated in Thailand. The comparison between Japan and Thailand leads to discussion on presentation of a framework for economic analysis of "hard interventions" and "soft interventions" to reduce wastewater pollutant discharge and to improve ambient water quality.

Key Words : *domestic wastewater treatment, on-site treatment, pollutant discharge per capita (PDC), "soft intervention" to reduce pollutant discharge, Yamato-gawa River Social Experiment Program (YR-SEP) for Reducing Domestic Wastewater Pollutant Discharge*

1. INTRODUCTION

Wastewter pollutant discharge reducation is one of major purposes of wastewater treatment especially in developed countries. On the contrary, most important functions of wastewater treatment in developing countries are to prevent infectious deseases and to improve lifestyles.

Yamato-gawa River flows from Nara Prefecture and flows into Osaka Bay (**Figure 1**). The length of Yamato-gawa River is 68 km, and the area of river basin is 1,070 km^2, and population in the river basin is over 2 million. Yamato-gawa River Office, Ministry of Land, Infrastructure and Transportation (MLIT), Japan, has conducted Yamato-gawa River Social Experiment Program (YR-SEP) for Reducing Domestic Wastewater Pollutant Discharge since 2005 (Tsuzuki et al., to be presented). In the YR-SEP, "soft interventions" in the households to

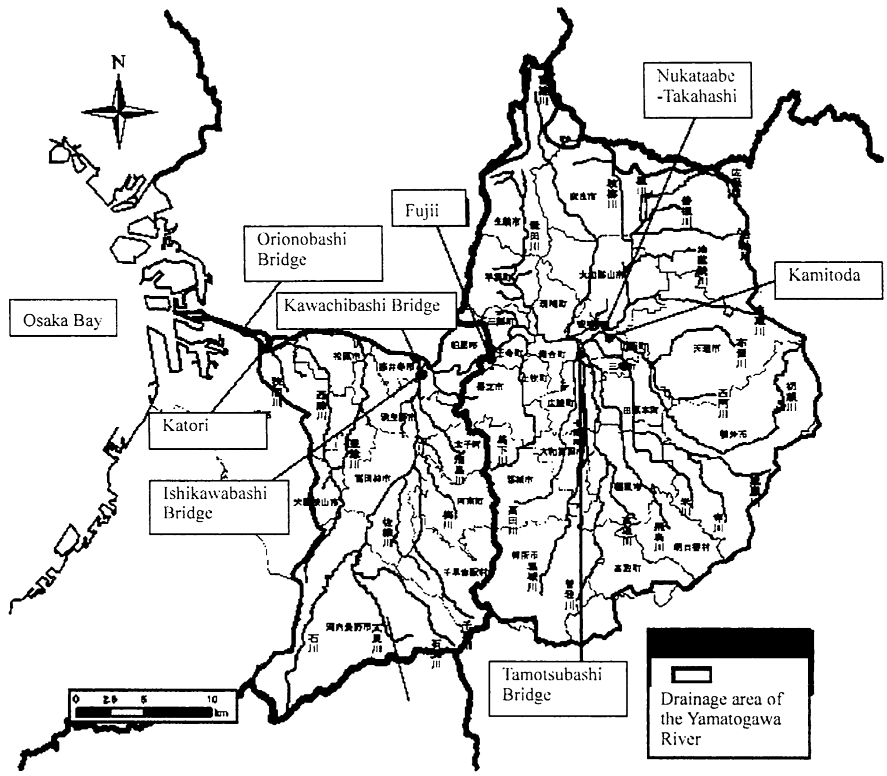

Figure 1 Yamato-gawa River drainage area (Original source: Yamato-gawa River Office, Ministry of Land, Infrastructure and Transportation, MLIT, Japan)

reduce pollutant discharge have been disseminated to ordinary citizens through media such as televisions, radios and newspapers, schools, environment NGOs and so on to reduce municipal wastewater discharge from households and to evaluate water quality improvement in the Yamato-gawa River and its branches. Three interventions emphasized in the YR-SEP were (1) not to waste food and drink without preparing too much, (2) not to drain rice washing water and other liquid residue, and (3) to wipe out dishes with residue before washing. Yoneda et al. (2006) estimated BOD improvement at Oriono-bashi Bridge, a monitoring point near the river mouth will be 40% as the maximum BOD improvement with "soft intervensions" in the households.

In Thailand, on-site treatment systems especially for black water, wastewater from toilet, are installed in most houses even in wastewater treatment plants (WWTPs) service area (Tsuzuki and Thammarat, 2008). Mathurasa (2005) analyzed water quantity and quality of effluent from latrine, one cessapool, two cessapools, and package tank, in a peri-urban area of Bangkok, Thailand.

Original concept of environmental accounting housekeeping (EAH) books of domestic wastewater was derived from EAH books of carbon dioxide (CO_2) which were prepared against climate change by national and local governments, environment NGOs, and companies including utilities (Tsuzuki, 2006). CO_2 release amounts from daily life and savings with EAH books of CO_2 can be estimated. Estimation of savings are sometimes more attractive than CO_2 release amount reduction for ordinary citizens. Therefore, economics aspects of water pollutant discharge reducation should be considered.

In this paper, we have estimated possible pollutant discharge reduction with "soft intervensions" in households based on the pollutant load analysis by Yoneda et al. (2006) and environmental accounting housekeeping (EAH) books of domestic wastewater (Tszuuki, 2006), estimated water quality improvement in the Yamato-gawa River, and estimated pollutant discharge by water usages and possible pollutant discharge amount in households in Thailand. Based on the results and pollutant discharge reduction function of wastewater treatment systems (Tsuzuki and Thammarat, 2008), we have discussed micro and macro economics aspect of pollutant discharge reduction from municipal wastewater by "hard interventions" and "soft interventions".

2. METHOD

2.1 Pollutant load analysis and water quality estimation of YR-SEP

Pollutant load analysis was conducted based on Yoneda et al. (2006). Pollutan sources included in the analysis were municipal wastewater include WWTPs effluent and onsite treatment effluents, industrial effluent flowing into WWTPs as influent, non-point sources including paddy fields, vegetable fields, forest and urban areas. Typical onsite treatment methods applied in this area are the same as those in other areas in Japan, combined *joukasou*, simple *joukasou*, and night soil treatment system.

Possible pollutant discharge reduction in the households was estimated with environmental accounting housekeeping (EAH) books of domestic wastewater (Tsuzuki, 2006). In the estimation, pollutant generation per capita (PGC) and pollutant discharge per capita (PDC) were derived from Yoneda et al. (2006). Original sources of the values are Kunimatsu and Muraoka (1989). The estimation was based on two combination sets of "soft interventions" in households (**Table 1**).

Water quality estimation was conducted using flow rate on March 8, 2005, the day when the first YR-SEP was conducted. Water quality largely depended on the flow rate of the Yamato-gawa River (Yoneda et al., 2006).

Table 1 Combinations of "soft interventions" for two cases in this study

Combination of pollutant discharge reducation "soft interventions" in households	
Case 1	Bath: Decrease shampoo and soap; Kitchen: Decrease detergent, Do not drain rice washing water, Use net for kitchen, Treatment during and after cooking; and Washing clothes: Decrease detergent
Case 2	Bath: Decrease shampoo and soap; Kitchen: No use of detergent, Do not drain rice washing water, Use paper filter for kitchen, Treatment during and after cooking; and Washing clothes: Decrease detergent

Table 2 Water usage amounts by purposes in Thailand (Source: Modified from Mathurasa, 2005)

Water usage		Provincial		Chiang Mai		Bangkok
		Urban	Rural	Dry season	Rainy season	
Toilet		14	10	20	16	27
Bathroom	Shower		22			
	Bowl	30				68
	Average			27	38	
Laundry	Machine	25				45
	Hand		21			
	Average			27	26	
Kitchen	No screen		21			
	With Screen	17				4
	Average			30	24	
Total		86	74	104	104	144

Table 3 Typical water quality of wastewater by usage purpose in Metropolitan Bangkok Area, Thailand (Source: Sinsupan, 2004)

Parameter		pH	COD_{Cr}	BOD	TKN-N	PO_4-P	SS	FOG[a]
Unit		-	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}
Toilet		7.7	1,500	700	300	24	560	540
Bathroom	Bowl	7.1	230	120	8	6	45	400
	Shower	7.0	400	260	38	1	80	480
Laundry	Hand	7.2	200	70	14	10	60	500
	Machine	7.7	460	150	12	24	55	520
Kitchen	With screen	7.2	960	540	18	13	210	500
	No screen	6.3	2,900	1,800	120	90	1,200	2,700

a: Fat, oil and grease. Original source: Pansawas (1987).

2.2 Pollutant discharge estimation in Thailand

Water usage amounts by water usage purposes in Thailand was modified from Mathurasa (2005) (**Table 2**). Typical water quality of wastewater by water usage purposes in Bangkok Metolopolitan Area (BMA), Thailand, (Sinsupan, 2004) was applied for wastewater characteristics by usage (**Table 3**). The essimation was conducted for urban and rural Provincial Area, dry and rainy seasons in Chiang Mai, and Bangkok. In these estimations, shower and bowl for bath, machine and hand washing for washing clothes and with screen and no screen for kitchen were hypothesized for the five estimation cases as shown in **Table 2**. Average values were used for some cases.

2.3 Framework for micro and macro economics analysis

When we think about pollutant discharge reduction by "soft interventions" in households, we should notice that they would influence economics of households, companies in the specific fields and governments. Thus, we propose a framework for micro and macro ecnonomics analysis of "hard interventions" and "soft in terventions" in this study. When we apply some "soft interventions" in households, wastes change their outlet from liquid to solid. Therefore, solid wastes are also considered in the framework.

3. RESULTS

3.1 Pollutant discharge reduction by "soft interventions" in YR-SEP, Japan

Pollutant discharge reduction by "soft interventions" was estimated based on EAH books of domestic wastewater (**Table 4**). In the estimation, pollutant generation per capita (PGC) and pollutant discharge per capita (PDC) were derived from Yoneda et al. (2006). Original sources of the values are Kunimatsu and Muraoka (1989). The estimation was based on two combination sets of "soft interventions" in households (**Table 1**). Pollutant reduction was estimated as 15.2 g-COD_{Mn} person^{-1} day^{-1} or 38% of pollutant discharge per capita (PDC) for COD_{Mn}, 2.4 g-TN person^{-1} day^{-1} or 26% of PDC of total nitrogen (PDC-TN) and 0.2 g-TP person^{-1} day^{-1} or 21% of total phosphorus (PDC-TP) for households with simple *joukasou* in Case 1. For Case 2, pollutant discharge reducation was estimated as 20.8 g-COD_{Mn} person^{-1} day^{-1} or 52% of PDC-COD_{Mn}, 3.6 g-TN person^{-1} day^{-1} or 39% of PDC-TN and 0.3 g-TP person^{-1} day^{-1} or 32% of PDC-TP for households with simple *joukasou*. For households with combined *joukasou* and night soil treatment,

Table 4 Pollutant discharge reduction estimation of "soft interventions" in households in Japan

Combination of pollutant discharge reducation "soft interventions" in households	Simple *joukasou* COD_{Mn}	T-N	T-P	Combined *joukasou* COD_{Mn}	T-N	T-P	Night soil treatment COD_{Mn}	T-N	T-P
	g person^{-1} day^{-1}			g person^{-1} day^{-1}			g person^{-1} day^{-1}		
Case 1	15.2	2.4	0.2	1.9	1.6	0.2	13.0	0.6	0.1
Case 2	20.8	3.6	0.3	2.6	2.3	0.3	17.8	0.8	0.2
PDC[a)] reduction effect of Case 1 (%)	38	26	21	38	26	21	39	27	21
PDC[a)] reduction effect of Case 2 (%)	52	39	32	52	39	32	53	40	32
PGC[b)]	50.0	12.0	1.60	50.0	12.0	1.60	50.0	12.0	1.60
PDC[a)]	40.0	9.2	0.80	5.0	5.9	1.04	33.8	2.0	0.50
Ratio of PDC[a)] to that of simple *joukasou* (%)	-	-	-	13	64	130	84	22	62

a) PDC: pollutant discharge per capita; and b) PGC: pollutant generation per capita.

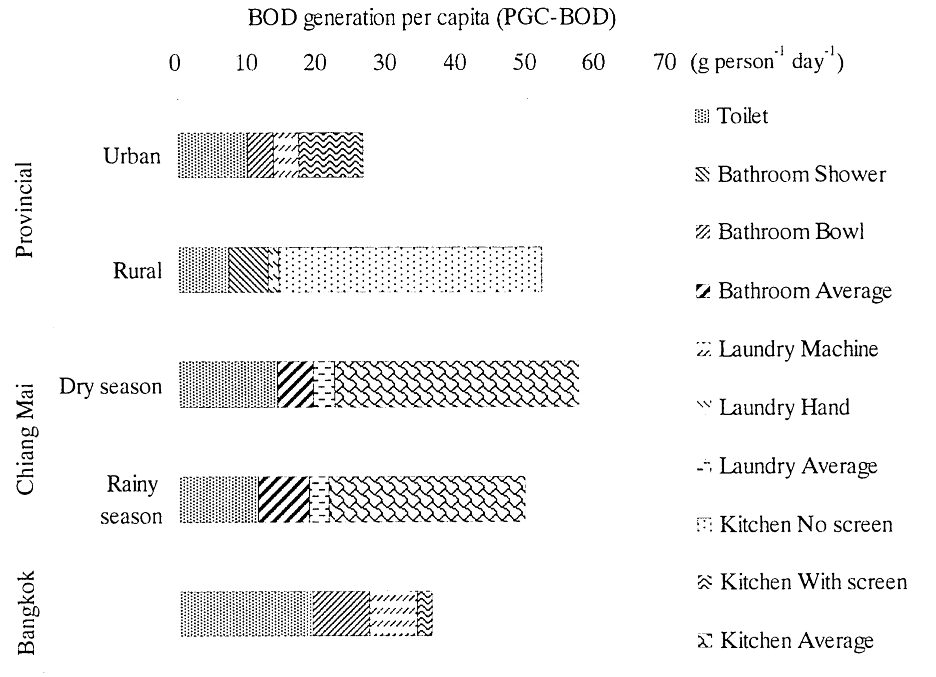

Figure 2 BOD generation per capita (PGC-BOD) in Thailand

absolute values of pollutant discharge reducation were different from those for households with simple *joukasou*, however, the percentages of PDC reducation were almost the same as those with simple *joukasou*.

PDC-COD_{Mn} can be estimated to decrease about 50% with the combinations of "soft interventions" in households. The reduction amount is corresponding to 20% BOD decrease at Oriono-bashi Bridge (**Figure 1**).

3.2 Pollutant discharge estimation in Thailand

BOD generation per capita (PGC-BOD) by water usages in Thailand was estimated based on water usage amounts and typical wastewater quality by water usages (**Figure 2**). PDC-BOD was estimated as 26-56 g-BOD person^{-1} day^{-1} for the five cases. Contributions of kitchen wastewater were estimated comparatively large among the water usages especially for rural in Provincial Area and two season cases in Chaing Mai. On the contrary, kitchen wastewater contributions were relatively small for urban in Provincial Area and Bangkok. This is because with screen was hypothesized for these two smaller cases, and water usage amount of kitchen in Bangkok is smaller than that in other cases.

3.3 Framework for micro and macro economics

A framework for micro and macro economics analysis was considered for households, companies in the fields of detergent and wastewater treatment and the governments. In the households, paper filter or plastic net, and paper to wipe out dish should be purchased to conduct some interventions (**Table 5**).

Table 5 Micro econmics elements of wastewater and solid wastes discharge in households

	Spendings	Saving	Influence
Wastewater discharge	Filter and net for kitchen sink Paper to wipe out dishes	Reducing detergent usage amount	Bacterial infection
Solid waste discharge	Microbiology granules Insects	Reducing general purchase	Bacterial infection Harzardous materials damage

Table 6 Micro econmics elements of detergents companies in detergent sales decreasing conditions

Fields of companies	Conditions for/against companies development	Possible directions
Detergents	Decrease of sales of detergents	Development of biodegradable detergents Development of phosphate-free detergents Technology transfer of biodegradable and phosphate-free
Wastewater treatment	Public investement for water quality improvement	Development of treatment facilities Development of wastewater treatment planning

On the contrary, purchase of detergent can be saved with some interventions. Bacterial infectious deseases should be cared for in the interventions.

For detergent companies, some "soft interventions" in the households would lead to decrease of detergent sales (**Table 6**). Development of biodegradable detergents or phosphate-free detergents will be necessary. Technological transfer to developing countries should be a change to increase sales in the market. For companies in the field of wastewater treatment, awareness of water environment by the ordinary citizens should enhance understanding their works by people, which should be one of the reasons for public investment in this field. To enhance their sales, development of treatment facilities and treatment planning should be necessary.

Figure 3 shows a macro economics framework for pollutant discharge reducation by "soft interventions" in households. "Soft interventions" and "hard interventions" should be discussed in the macro economics framework.

4. DISCUSSIONS

In this study, BOD decrease at Oriono-bashi Bridge, the Yamato-gawa River, Japan, was estimated as 20%. Contribution of COD_{Mn} load from the Yamato-gawa River to Osaka Bay was estimated as about 15% of total COD_{Mn} inflow (Osaka Bay Environment Database, 2008). Therefore, "soft interventions" can reduce 3% of COD_{Mn} inflow to Osaka Bay by only "soft interventions" in the

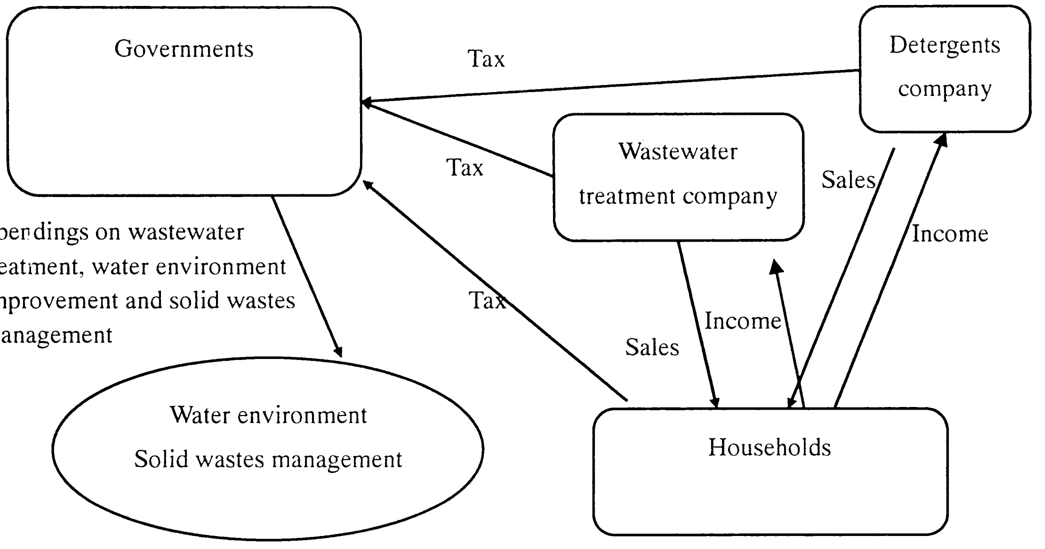

Figure 3 A macro economics framework for wastewater pollutant discharge reduction with "soft intervensions" in households

Yamato-gawa River drainage area assuming BOD decrease and COD_{Mn} decrease are the same level. If all the people in Osaka Bay drainage area conduct "soft interventions", total COD_{Mn} inflow decrease would be as large as 20%.

In Thailand, contributions of kitchen wastewater were estimated as large in BOD generation per capita (PGC-BOD) especially for no screen kitchen. "Soft interventions" should decrease pollutant discharge from households especially for kitchen wastewater in Thailand. Lifestyles of bath, washing clothes and kitchens are almost uniform in Japan. On the contrary, those in Thailand, one of the economically leading countries in developing counties, are with variety (**Table 2, Figure 3**). Moreover, those in Thailand are changing in accordance with economic development conditions. "Soft interventions" are also introduced in Thailand (Tsuzuki et al., 2009). Therefore, cpnsideration on frameworks for economic analyses is important in regards to water, sanitation and solid wastes management especially in developing countries.

When "soft interventions" are proliferated, detergents sales will decrease and tax from detergents companies will decrease (**Figure 3**). However, governments can save their spendings on "hard interventions" of wastewater treatment. When the savings by decrease of wastewater treatment exceeds tax decrease from detergent companies, government can invest on water quality improvement projects in rivers or lakes including natural purification faciliies.

These kinds of economic analysis should be desirable in developing countries including Thailand where water and sanitation is critical problem with economic and resources deficit.

5. CONCLUSIONS

COD_{Mn} inflow decrease with "soft interventions" in the Yamato-gawa River drainage area was estimated as corresponding to 3% of total COD_{Mn} inflow to Osaka Bay. If "soft interventions" were conducted in all the driangae area of Osaka Bay, COD_{Mn} inflow to Osaka Bay would be 20%.

In Thailand, PGC-BOD was estimated as 26-56 g person^{-1} day^{-1} depending on the areas and seasons. "Soft interventions" should decrease pollutant discharge from households especially for kitchen wastewater in Thailand.

Micro and macro economics analysis framework was proposed in this study. These kinds of analysis should be important especially in developing countries.

ACKNOWLEDGMENT

A part of the study to prepare this presentation was funded by Osaka Bay Wide Sea Area Environment Foundation.

REFERENCES

Mathurasa, L. (2005) Analysis and forecast of domestic water end-uses in Khon Kaen Province, Thailand, MSc Thesis, AIT, Thailand.

Osaka Bay Environment Database (2008) (http://kowan.pa.kkr.mlit.go.jp/kankyo-db/)

Sinsupan, T. (2004). Material flux analysis (MFA) for planning of domestic wastes and wastewater management: case study in Pak Kret Municipality, Nonthaburi, Thailand, MSc Thesis, AIT, Thailand.

Tsuzuki, Y. (2006) An index directly indicates land-based pollutant load contributions of domestic wastewater to the water pollution and its application, Science of the Total Environment, 370, Issue 2-3, pp.425-440.

Tsuzuki, Y. and Koottatep, T. (2008) Toward sustainable wastewater treatment systems in urban and peri-urban area of developing countries: a case study in Bangkok, Thailand, *8th IWA specialized Conference on Small Water and Wastewater Systems and 2nd specialized Conference on Decentralized Water and Wastewater International Network*, February 6~9, 2008, Coimbatore, India, CD-ROM, 8p.

Tsuzuki, Y., Koottatep, T., Wattanachira, S., Sarathai, Y., Wongburana, C. (2009) On-site treatment systems in the wastewater treatment plants (WWTPs) service areas in Thailand: scenario based pollutant loads estimation, Journal of Global Environment Engineering, JSCE, 14, 57-65.

Tsuzuki, Y., Fujii M., Mochihara, Y., Matsuda, K. and Yoneda, M. (to be presented) Natural purification effects in the Yamato-gawa River, Japan, with consideration of domestic wastewater pollutant discharge reduction with the community participation, DIPCON 2009.

Yoneda, M., Morisawa, S. and Tokunaga, R. (2006) Estimation of water quality improvement by community participation in the Yamato-gawa River, Sanitary Engineering Annual Meeting of Kyoto University. (in Japanese)