Investigations on Economic Efficiency and Cost Sharing for Watershed Management in Japan

流域管理のための経済効率性と費用負担に関する検討

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INVESTIGATIONS ON ECONOMIC EFFICIENCY AND COST SHARING FOR WATERSHED MANAGEMENT IN JAPAN

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ABSTRACT

This paper describes the efforts to utilize economic instruments such as trading and taxation in water quality management field in Japan. We discuss the issues and introduce them, mainly based on Study Committee held by MLIT. Regulation has been common in environmental policy in Japan. However, economic efficiency in administration take attention and several trials are going on. Especially, trading among wastewater treatment plants seems relatively feasible in terms of steady flow and similar players. The investigated and designed system is rather centralized, considering financing on a watershed basis, covering only wastewater treatment plants. This seems to be a disadvantage of the system, but this has a chance to involve other point and nonpoint sources through this adjustment system. A case study, targeting the watershed of Tokyo Bay, was conducted, which revealed over 30% cost saving is attained. This result is certainly based on an ideal and simple situation, but the system certainly saves the abatement cost and worth while considering positively. Hot spots were not found in the case study. This system should be positively considered because it is not only effective in a monetary way but also promote better management of sewerage works, better information system and public involvement.

KEYWORDS

Economic incentive, Cost sharing, Watershed management, Wastewater management

INTRODUCTION

Command and control has been a popular method in environmental management. However, though the compliance of the regulation prevailed, still there remains many water bodies incompliance of the water quality standards. Recently, economic tools such as tradable permit systems are capturing attention in the field of environment for efficiency. The United States is vigorous in adoption of trading, while some European countries utilize taxation in environment issues. It may be time that Japan initiates economical instruments in a positive fashion.

Under this turning point of social changes, administrative governments should take considerations in economic tools in order to minimize the cost and seek for the better environment. Actually, the

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adoption of the introduction of the economic tools is provided in the law[1]. Recent recommendations by relevant council or committees provide that wastewater management should adopt economic tools in an aggressive manner. However, wastewater management system, which evolves over several decades and the roles are shared by several government systems, is rather complex together with many players and rules, whether the systems are prescribed by laws or not.

In this paper, based on the discussion and the simulations of Study Committee held by MLIT, the possible effectiveness of the proposed system is shown. The traditional system is also commented with the comparison.

CURRENT SITUATION OF WATER QUALITY MANAGEMENT

The basic of water quality management in Japan is to set environmental goals as WQSs[2] of public water areas[3], and to limit effluent standards of direct dischargers. National effluent standards are relatively lax, and prefectural standards are set on a local basis by prefectures, which are effective for most cases. Unlike TMDL (Total Maximum Daily Loads), this does not strictly seek for attainment of WQSs (Water Quality Standards), but is set in consideration of the feasibility of treatment technology. Effluent standards are still prevalent in Japan, and this does not entail permit system.

Watershed management is a key word for holistically addressing water-related issues in general. Particularly, this approach is needed in sewerage administration because local authorities conducting sewage works are apt to focus on their own benefits alone, leaving public welfare beyond their administrative boundaries. The concept is as follows; administrative systems are based on human boundaries, but as natural phenomena occur on a watershed, so the issues should be dealt with. **SWMS (2003)** gives the definition of "the Approach to Watershed Management" as follows and pointed out the need; "bringing together sewerage managers in the basin, tying them up extensively with other bodies including local citizens and businesses, and among those stakeholders, (i) sharing a common concept and purpose, (ii) sharing the risks and the burdens required to reduce them, and (iii) while reducing overall risks and burdens to the minimum, promoting the achievement of common objectives via co-operation." In order to address water-related issues including water pollution, this issue must be identified as a common problem for local governments and citizens/businesses in the basin, and a variety of efforts such as wastewater treatment must be mobilized effectively.

Two current watershed approaches in Japan are (a) Total Pollution Control, and (b) CBPSS (Comprehensive Basin-wide Planning for Sewerage Systems). Total Pollution Control is in the charge of Ministry of the Environment, which is above the scope of this paper. As compared with other water administrations, a sewerage administration strongly suggests the necessity of "the watershed management approach", because sewerage managers are all local authorities. One river basin generally has plural municipalities, and the benefit of sewage works spreads over wider area beyond administrative boundaries. The constituents in TPC are COD[4], TN, and TP. The possible constituents are BOD in rivers, and COD, TN (total nitrogen) and TP (total phosphorus) in lakes and coastal waters.

In light of economics[5], there are not any major economic instruments adopted in the management in

[1] Article 22 of Basic Environmental Law
[2] Environmental Quality Standards, inclusive of WQSs, are provided by Article 16 of Basic Environment Law.
[3] In legal and administrative areas, the term "public water areas" is used in Japan as "navigable waters" in the United States.
[4] In water quality management in Japan, COD_{Mn} is employed instead of COD_{Cr}.
[5] Generally, the environmental standard has three types: technology-based, ambient-based, and benefit-based standards.

Japan. Subsidy to wastewater management sector, industrial firms, and agricultural sectors play not a little part in the management. Also, many indirect measures have been taken such as water quality fees on indirect large dischargers. However, it can be said that they are not major tools to make a direct contribution to ambience water quality. Financing and subsidy is related to cost sharing. Almost no vigorous attempts are seen for watershed management. In response, it was determined that cost allocation should also be studied for sharing the total cost appropriately among stakeholders in the basin including the application of economic instruments[6], and it was proposed that cost-sharing in the whole basin should be considered from the viewpoints of the responsibilities of both dischargers and beneficiaries in order to efficiently achieve the WQSs in basin units[7].

CBPSS typifies the watershed management approaches in Japanese administration. CBPSSs, upper level plans of sewage works plans, were formulated to implement sewage works projects most effectively which are required to attain WQSs in target public water areas. Prefectures formulate CBPSSs of public water areas which suffer water pollution by sanitary sewage from two or more municipalities and whose WQSs need to be attained mainly through sewage works[8]. 126 CBPSSs had been formulated as of the end of August, 2003 (**MLIT (2003)**). The CBPSSs' image and items to be considered and specified are shown in **Figure-1**. In this plan, pollution loads are estimated on a watershed basis, and allowable loads are determined so that WQS of the target public water body can be attained in a target year. Load reductions, future loads minus allowable loads, are allocated not only to POTWs but also to other pollution sources such as urban and agricultural areas, while natural loads such as forests, plains and rain are in principle not taken into account for load reductions. Load reduction is often allocated in such a manner that all point sources have the same load reduction ratio. However, the focusing target is the sewage works section, and there are actually no legal guarantees whatsoever for any point sources other than POTWs even though load reductions are allocated to them in CBPSSs.

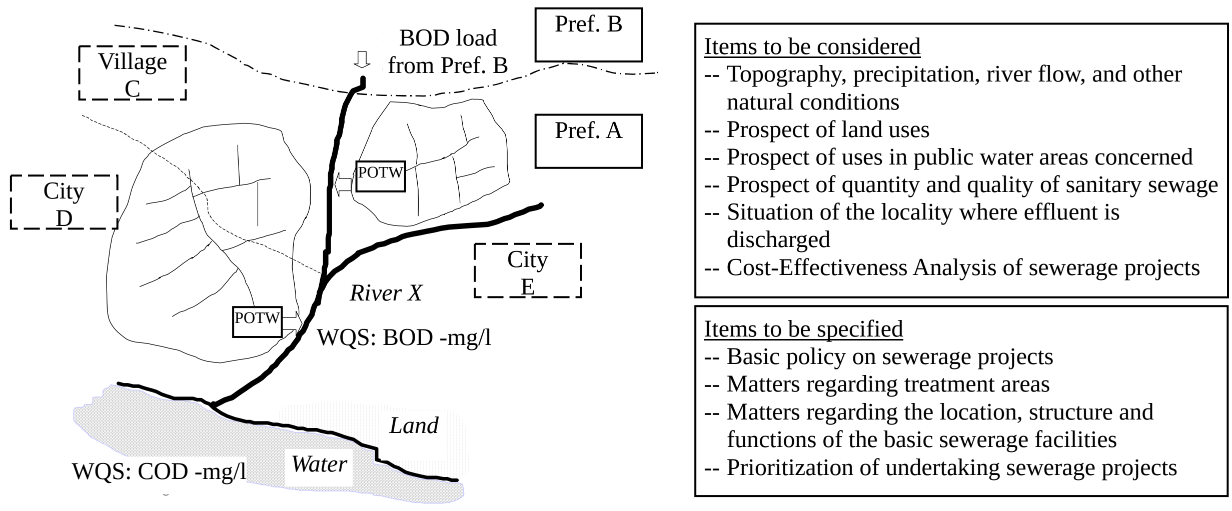


Figure 1. CBPSSs' Image and Items to Be Considered and Specified

In case a target watershed covers two or more prefectures, a conference is to be held for the co-ordination on the allocation of load reduction to prefectures concerned. A relevant prefectural government is supposed to have this conference with MLIT as well as the other relating prefectural governments. On the basis of reached consensus, draft CBPSS is submitted to MLIT, which then gives the approval to the prefecture's request after discussing the proposed plan with the Ministry of

[6] Action Plan for Tokyo Bay Renaissance
[7] the Council of Decentralization Reform (2002)
[8] The requirement of CBPSSs is provided by Article 2-2 of Sewerage Law and Article 2 of Enforcement Ordinance of Sewerage Law.

the Environment. That is, agreement must be reached between the relevant prefectures regarding the load reduction before formulation of CBPSS in each prefecture. The agreement is basically made on "allowable loads" which enable the public water bodies to achieve WQS. Regional bureau of MLIT plays an important role in co-ordination among prefectures, taking fairness and efficiency into account, on the basis of the simulation of pollution load and water quality. After allocation of load reductions regarding sewerage to prefectures concerned, each prefectural government allocates its own portion to POTWs. These allocations are often made so that all POTWs can have the same effluent quality. However, some prefectural governments allocate more load reductions to large-scale POTWs than to small-scale ones. Allowable load of each Prefecture is allocated in proportion to future loads on the assumption that sewered areas are 100% and that every POTW has secondary treatment. It is that a sort of equity is put emphasis on and efficiency is not considered. **Table-1** shows various loads set in CBPSS of Tokyo Bay[9], which covers four Prefectures: Saitama, Chiba, Tokyo, and Kanagawa. Allowable loads are set to achieve WQSs of Tokyo Bay. **Figure-2** shows the countermeasures and allocation of load reductions. **Table-2** shows the result of the allocation among Prefectures.

Table 1. Loads Set in CBPSS of Tokyo Bay

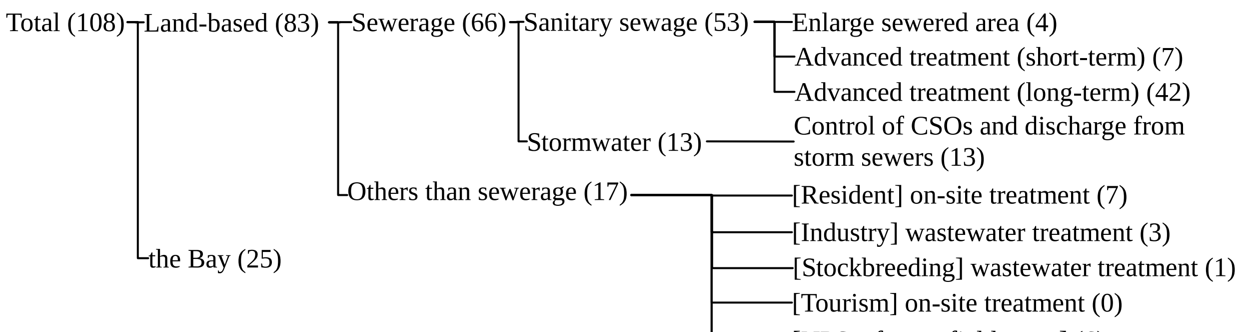
	COD	TN	TP
Future Load	326	405	26.0
Allowable Load	218	220	10.5
Load Reduction	108	185	15.5
Load Reduction by Sewerage	66	174	14.1

Note. Unit is t/day.

Table 2. Allocation of Allowable Loads to Prefectures in CBPSS of Tokyo Bay

	COD	TN	TP
Saitama Pref.	41	38	1.7
Chiba Pref.	68	54	3.3
Tokyo Pref.	56	73	3.5
Kanagawa Pref.	27	30	1.3
Other areas	26	25	0.7
Total	218	220	10.5

Note. Unit is t/day. "Other areas" are three northern prefectures above the four Prefectures, from which pollution loads also come into Tokyo Bay via Tone River.



Note. Unit is t/day.

Figure 2. Allocation of COD Load Reductions in CBPSS of Tokyo Bay

CBPSS is a watershed management, ambience-based approach incorporating load allocation, but no economic instruments, also lack in consideration of cost-sharing. This lack of financing issues is an impediment to a reliable implementation of the plan. Financial institutions should be considered to adequately implement the plan for a more effective watershed management. Under the current system, cost for advanced treatment of each POTW is paid by each local government. Thus, cost-sharing and financing, together with load allocation, should be discussed to seek for a more effective watershed management. According to **Fujiki (2003a)**, regarding financial resources, in

[9] In 1997, the committee of CBPSS of Tokyo Bay reached the consensus of load settings and allocations among the four prefectures concerned: Saitama, Chiba, Tokyo and Kanagawa Prefectures.

principle discharger is responsible for treating wastewater, that is, the users of sewage works must pay the cost. After allocation of allowable loads in the formulating process of CBPSS, each POTW is subject to command and control. Though national subsidy is still large financial source for a local government, there are practically no considerations on watershed-based financing. The national government and local public bodies pay a certain proportion of the necessary expenses, taking into account the objectives of sewage works projects, the national policy that people should receive equal sewerage services, the fact that the construction of sewerage system requires a large investment which is a major burden on the local public body concerned, and the fact that the sewerage system has external economic impacts on other industrial and social fields. As for advanced treatment, the expenses might be paid by the private firms or residents who are responsible for the treatment at the ultimate stage based on PPP (Polluter Pays Principle) under the strengthened water quality regulation[10]. In principle, if there is pollution right, beneficiaries should pay for that. If there is a PPP, then polluters have to pay. In light of beneficiaries, the study was conducted using CVM (Contingent Valuation Method) in the watershed of Tokyo Bay. **Takaso and Katagiri (2002)** shows that the willingness to pay does not decline relatively with the distance to Tokyo Bay (**Figure-3**). This indicates the cost for the protection of Tokyo Bay should be allocated among all entities in the watershed. Furthermore, **Matsui and Harada (2003)** shows that cost should be shared among all in PI (Public Involvement) questionnaire (**Figure-4**). This result reinforces the indication.

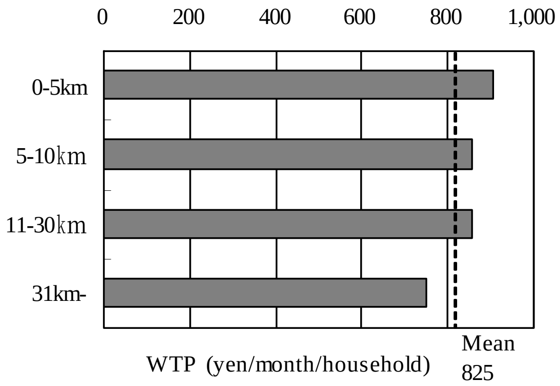


Figure 3. WTP for Tokyo Bay Water Quality Categorized by Distance to Tokyo Bay

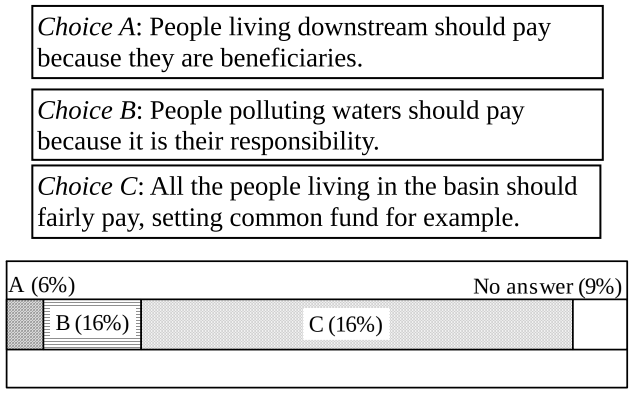


Figure 4. People's Opinions on "Who Should Pay for Clean Ambient Water?"

EXAMINATIONS ON LOAD ADJUSTMENT SYSTEM

In fiscal 2002 and 2003, MLIT set up Study Committee on Water Quality Trading between Sewage Treatment Plants (hereafter referred to as Committee), in order to investigate economic instruments and cost sharing methods of water quality control on a watershed basis. Committee is composed of academics and experts on this issue, and national and local government officials in sewerage planning or managing sections, to reflect each point of views[11]. Considering the Japanese current administrative system, Committee investigated the above and designed one system that may be incorporated into CBPSS. Especially three elements were considered in the investigation and design: efficiency, equity, and incentives. It also covered a case study of the watershed of Tokyo Bay to quantify the system's effectiveness and to identify hot spots[12], which is described in the

[10] On the other hand, the cost of draining stormwater is paid by the local governments similar to the cost of flood control, in other words, is paid from taxes.
[11] The authors were involved in Committee, though not committee members.
[12] Emissions trading, or load adjustment in this case, could cause locally deteriorated sections even when dischargers are brought under control. Such sections are called hot spots.

following chapter.

The designed system, called the load adjustment system, is to seek for economic efficiency, equitable cost sharing, and economic incentives, by adjusting pollution loads among POTWs on a watershed basis. In this system, an allowable load of each POTW in a watershed is determined so that the cost for achieving WQS of a target public water area can be minimised. The difference between the allowable load and the base line of pollution loads is reflected in receiving or paying money, which is called adjustment. Incidentally, allowable loads have to meet a minimum requirement such as secondary treatment, ensuring technology standards. This is designed to make sure the total cost of water quality control is shared among local governments, which are responsible for POTWs, in a watershed, considering equities. Initial allocation is critical in cost sharing and equity. Economic incentives are preserved in institution establishment. For adjustment, a foundation will be established to administer money from and to local governments or national government, the national government can provide a financial assistance to adjust demand and supply or other reasons. This can be incorporated into CBPSSs in a planning stage. Furthermore, environmental benefits are expected as discrete options are available instead of continuous. Also, this sound and rational financing is expected to promote stable implementation of the plans (CBPSSs). In the early phase of the discussion by Committee, water quality trading was positively considered as an economic instrument. However, Committee shifted its emphasis from a decentralised system to a centralised one. It is in part because transaction costs are too high as general, and Japan has not experienced emissions trading in environmental management. The experiences in European countries were consulted, where effluent tax/charge and subsidy are utilized in water quality management on a watershed basis[13].

In order to materialise the above system, the two types are designed in Committee (**Figure 5**). In Type I, each local government is given its base line, which could be an initial allocation in water quality trading. This is made in consideration into equity for example the same average cost as well as to achieve WQSs on a watershed. Each POTW pays a share or receives a dividend proportionally to the excess over or reduction under its base line. To balance the cash flow, a lack in Foundation comes from the finance of national government. In Type II, local governments pay share proportionally to pollutant loads, and local governments who reduce loads by advanced treatment receive money from the Foundation proportionally to load reduction by advanced treatment. The rate of dividend or share is determined to balance the cash flow. If dividend is partially given to local governments, say some portion of collected share, there is no need of national government. However, national government can provide assistance to promote or so. One advantage of Type II is there is no need to establish a base line. The simplified mathematical model is shown in **Appendix**.

[13] France is a typical example.

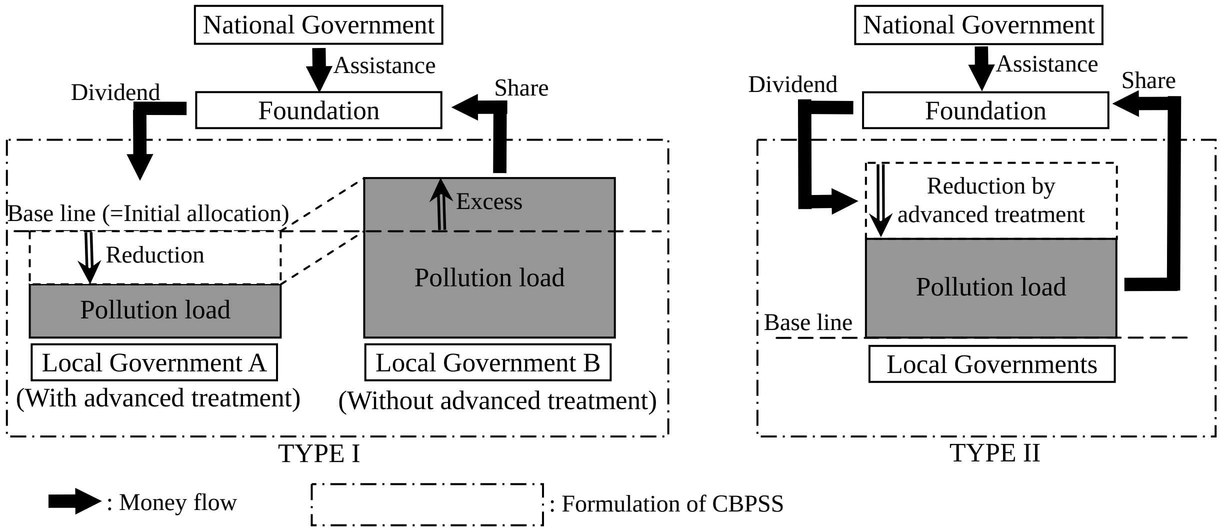


Figure 5. Structures of Two Types of Load Adjustment System

In light of equity, the base line setting is critical to cost sharing. In either type, the total cost is the same, but cost distributions are different. Basically, the adjustment is just to seek for a cost minimization. In most cases under the current administrative system, uniform reduction ratio is imposed to each POTW, which is thought to be equitable in a sense. However, if net average cost defined by **Equations 1 and 2**, instead of reduction ratio, is employed as an index for equity, a system with less dispersion of the index is more preferable. **Appendix** shows that net average costs are less dispersed in Type II than in Type I.

$$\text{Net cost} = \text{Cost for advanced treatment} + \text{share} - \text{dividend} \quad (1)$$

$$\text{Net average cost} = \frac{\text{Net cost}}{\text{Effluent volume}} \quad (2)$$

Though this system limits its target dischargers to POTWs in order to ensure viability (**Figure 6**), it can have a possibility to cover other pollution sources for better water quality management. Exclusion of the other pollution sources from the system reduces the economic efficiency. It comes from the current situation both in difficulty in quantification of NPS loads and in the complex administrations in governmental organizations, legal issues and other conventional things. Considering these difficulties, feasibility could lie only in each section. Thus, the system was proposed in a feasible fashion, by limiting the players to POTWs. However, this challenging system could make a breakthrough for unification of comprehensive water management without administrative boundaries. One way is to lower a base line of local government[14], which undertake some pollution abatement projects in co-ordination with other entities such as agricultural sectors. The load reduction of the other projects can be set as equivalent to the gap of base line. This is to create economic incentives for a better water quality. Type II is more suitable than Type I when NPS is covered by the system (**Appendix**).

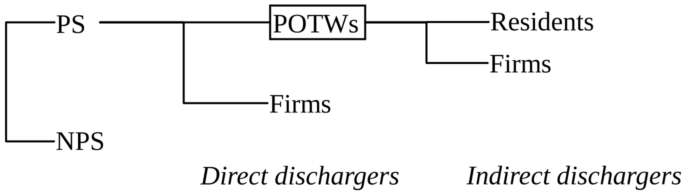


Figure 6. Target Sources of Load Adjustment System

[14] The concept of CDM and JI in Kyoto Mechanism is consulted.

Local issues may affect this load adjustment system as each local government considers not only the target public water area but also the local benefit. Load reductions contribute to local ambient water quality as well as large-scale public water areas. Some local governments may promote advanced treatment for reclamation of wastewater, and this level of treatment is more stringent than the load adjustment system expects. As a result, the marginal cost for each POTW is not equal, and efficiency is lost to some extent. It is shown that local governments with a local benefit from its load reduction promote more advanced treatment in Type II than in Type I (**Appendix**). At the same time, economic efficiency is lost more in Type II than in Type I.

Other than cost saving and possible load reduction, this load adjustment system could have some advantages. The first could be to provide impetus to better management system of POTWs. The load adjustment system takes more attention than the conventional administrative system since it is directly related to cost sharing and the related information is critical. Thus, better management system is required for POTWs' managers. Secondly, the system could promote public involvement and better decision making because it may affect wastewater fees. Lastly, it could create research need for loads quantification such as NPS studies and simulation models. These advantages may be considered in a favourable way for the introduction.

CASE STUDY OF LOAD ADJUSTMENT SYSTEM

In order to estimate the effectiveness of the load adjustment system and to check whether hot spots occur, a case study was conducted through Committee. The watershed of Tokyo Bay was targeted. The adopted system is the same as Committee investigated, but types are not specified because types do not largely affect the result. In a practical calculation, Type I is selected. The base lines are the same as the current CBPSS designates. Local conditions are neglected, and each local government makes a decision to get the efficiency by the target water quality. Adjustable loads are difference between allocated loads and the loads of secondary treatment or the current effluent level, so the minimum requirement is secondary treatment. Target dischargers are seventy-five POTWs in the watershed. The map and the profile of Tokyo Bay are shown in **Figure 7**. Flow chart of this simulation is demonstrated in **Figure 8**. Seawater simulation was conducted to identify hot spots.

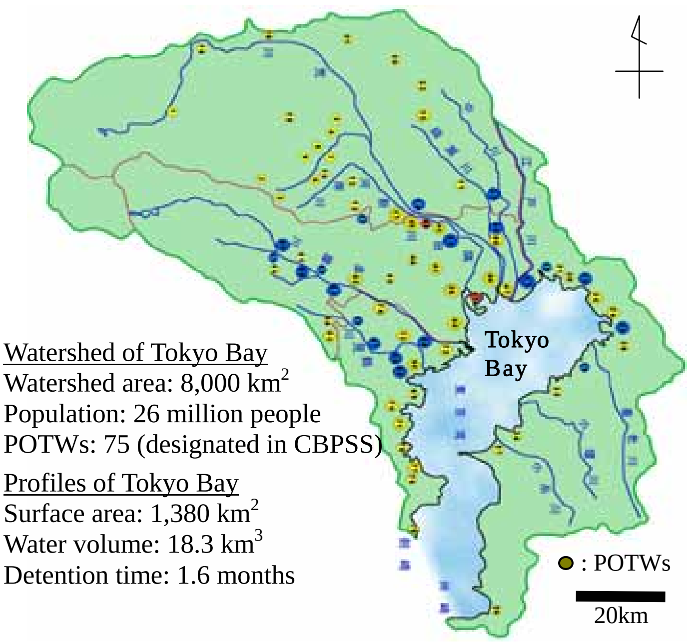


Figure 7. Map and Profile of Tokyo Bay and Its Watershed

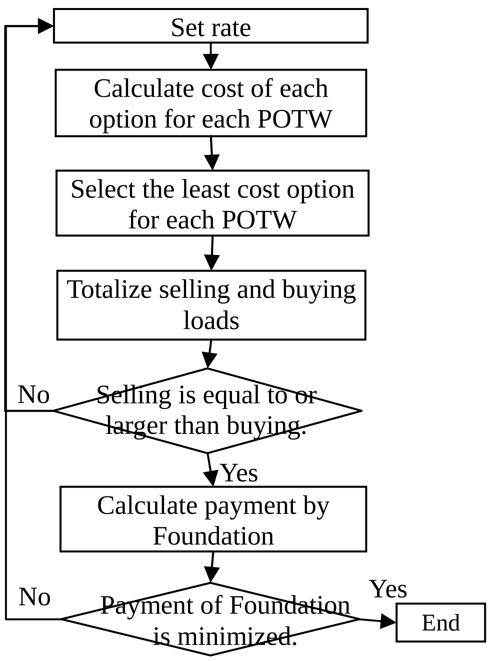


Figure 8. Flow chart of Simulation

Other assumptions are as follows; (i) Constituents to be adjusted: COD, TN, and TP, independently, (ii) five options are set as in **Table 3**. (iii) Cost is assessed on an annualized basis, which consists of annualized construction cost plus maintenance cost. Annualized construction cost is calculated by **Equation 3**, (iv) completion of secondary treatment is assumed for all the POTWs, (v) the base line for adjustment is assumed to be the same as the allocation of allowable load targets to prefectures regarding CBPSS of Tokyo Bay, and (vi) Target year: 2012. Data were collected from the report of CBPSSs, supplemented by questionnaires to local governments concerned.

Table 3. Options for Advanced Treatment

Options	Treatment processes	Effluent (mg/l)		
		COD	TN	TP
Level 1	Activated sludge process	20	22	2.5
Level 2-1	Anaerobic-anoxic-oxic process + Sand filtration	9.6	9	0.4
	Step-feed biological nitrogen removal process + Coagulant	10	7.5	0.5
	Entrapping immobilization nitrification-denitrification process + Coagulant	10	10	0.5
	Advanced oxidation ditch process + Coagulant	10	10	0.5
Level 2-2	Activated sludge process + Coagulant	12	22	0.5
	Oxidation ditch process + Coagulant	12	22	0.5
Level 3-1	Bardenpho process + Sand filtration	8	3	0.2
	Bardenpho process	8.2	4.5	0.4
Level 3-2	Bardenpho process + Sand filtration + Activated carbon	4.4	2.6	0.2

$$\text{Annualized construction cost} = \text{Construction cost} \times \frac{i(1+i)^n}{(1+i)^n - 1} \tag{3}$$

where Discount rate: $i = 2.1\%$[15], and Useful life: $n = \begin{cases} 15\text{years (apparatus)} \\ 50\text{years (facilities)} \end{cases}$[16]

The results of the simulation are shown in **Table 4**, **5**, and **6**. The load adjustment system is estimated to save 31% of the advanced treatment costs in total (**Table 5**), and also to reduce 19% of COD, 2% of TN, and 2% of TP in total (**Table 6**). The equilibrium rates of water quality constituents are 0, 959, and 5,335 yen/kg (**Table 4**). Zero of COD's rate indicates the adjustment of only TN and TP enables enough COD's reduction. When costs of POTWs are added up in each prefecture, only Saitama Prefecture incurred increased cost with the system. This meant the other prefectures did not have to undertake as much advanced treatment in each prefecture as without the system. Saitama Prefecture paid 4,837 million yen/year to the foundation, and the others received some amount from the foundation. The difference 1,519 million yen/year comes from the national government. In the end, all the four prefectures enjoyed plus cost saving with the system.

Table 4. Equilibrium Rates in Simulation

COD	TN	TP
0	959	5,335

Note. Unit is yen/kg.

[15] 2.1% was selected as an interest rate of a national government loan in July 2002.
[16] Useful life of sewerage facilities is specified in Memorandum No. 77 dated June 19, 2003 of Sewerage Works Division, Sewerage and Wastewater Management Department, City and Regional Development Bureau, MLIT "Regarding Reconstruction of Sewerage Facilities."

Table 5. Result of Costs in Case Study

	Cost without system	Cost with system	Share - Dividend	Net cost	Cost saving ratio	
					Real	Net
Saitama Pref.	14,114	15,618	-4,837	10,781	-11%	24%
Chiba Pref.	13,063	7,680	315	7,995	41%	39%
Tokyo Pref.	28,538	15,921	1,531	17,452	44%	39%
Kanagawa Pref.	10,200	6,573	1,473	8,046	36%	21%
Total	65,916	45,792	-1,519	44,273	31%	33%

Note. Unit in cost is million yen/year.

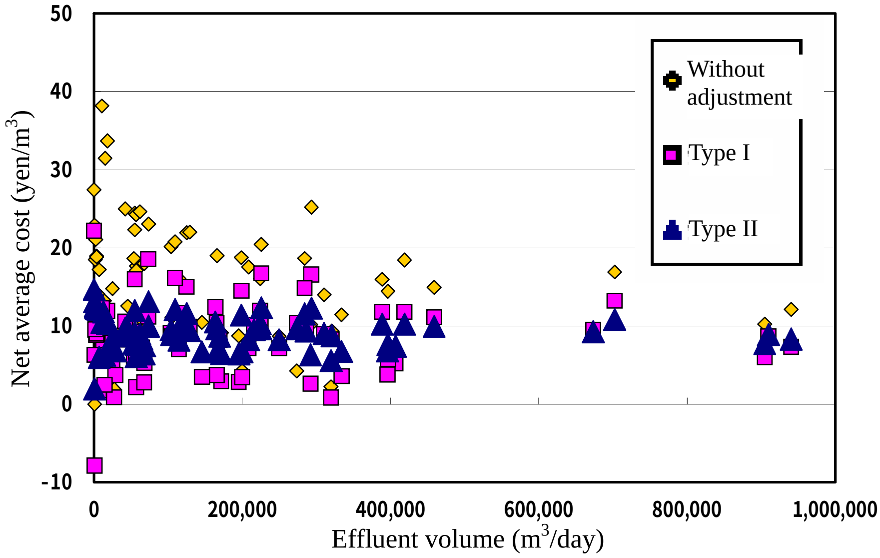
Table 6. Result of Loads in Case Study

		Loads without system			Loads with system			Load reduction ratio		
		COD	TN	TP	COD	TN	TP	COD	TN	TP
Prefecture	Saitama Pref.	41,858	37,733	2,236	32,748	26,656	1,743	22%	29%	22%
	Chiba Pref.	26,043	21,642	1,101	19,294	24,024	835	26%	-11%	24%
	Tokyo Pref.	71,990	63,312	3,165	61,771	65,541	3,550	14%	-4%	-12%
	Kanagawa Pref.	29,670	24,727	1,238	22,896	27,857	1,432	23%	-13%	-16%
Subwatershed	Ara River	18,675	19,381	1,247	17,562	19,564	1,372	6%	-1%	-10%
	Naka River	27,277	23,070	1,225	19,999	16,956	914	27%	27%	25%
	Shingashi River	59,151	49,249	2,464	47,383	44,404	2,193	20%	10%	11%
	Tama River	16,748	16,014	799	16,116	19,473	1,030	4%	-22%	-29%
	Tsurumi River	28,385	23,656	1,184	21,401	25,210	1,375	25%	-7%	-16%
	Chiba coastal	19,325	16,044	821	14,248	18,471	676	26%	-15%	18%
Total		169,561	147,41	7,741	136,709	144,078	7,560	19%	2%	2%

Note. Unit in load is kg/day.

Table 6 shows some subwatersheds were expected to have 22% increase of TN loads and 29% increase of TP loads at maximum. However, seawater simulation demonstrated that no significant adverse changes in seawater quality were found to occur. Some adjustment confinement such as prefectures or sub-watershed boundaries did not have to be established.

The dispersion of net average costs in two types is shown in **Figure 9**. Apparently from **Figure 9**, net average costs are less dispersed in Type II than in Type I, and the case without the system has the most dispersed distribution. The standard deviation of each type is 7.2, 4.7, 2.3 yen/m^3.



Net cost = Cost for advanced treatment + share - dividend

Net average cost = Net cost / Effluent volume

Figure 9. Dispersion of Net Average Cost in Two Types

CONCLUSIONS

The current administrative system should be improved in terms of efficiency, incentives, and equity on a watershed basis.

“Load adjustment system” is examined and designed to reflect the above three elements in Committee.

Case study, targeting Tokyo Bay, showed that the maximum cost saving was over 30%, and that some load reductions were also estimated with no hot spots.

The load adjustment system should be favourable considered also due to other advantages such as better management of POTWs.

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ACRONYMS

BOD: Biochemical Oxygen Demand
CBPSS: Comprehensive Basin-wide Plan(ning) of Sewerage Systems
COD: Chemical Oxygen Demand
CVM: Contingent Valuation Method
MLIT: Ministry of Land, Infrastructure and Transport, Government of Japan
NPS: Nonpoint Source
POTW: Publicly Owned Treatment Work
PI: Public Involvement
PPP: Polluter Pays Principle
TMDL: Total Maximum Daily Load
TN: Total Nitrogen
TP: Total Phosphorus
TPC: Total Pollution Control
WTP: Willingness To Pay
WQS: Water Quality Standard

APPENDIX: The Simplified Mathematical Model of Load Adjustment System

It is assumed that a target watershed has n POTWs, that m constituents loads of water quality are adjusted, and that loads from POTWs are continuous though available options generally make them discrete. Definitions of terms are as follows.

q_i: Effluent volume of POTW i,
$x_{i,k}$: Constituent k load which POTW i discharges,
x_i: Comprehensive load index of POTW i,
$L_{i,k}$: Initial allocation of constituent k load to POTW i in Type I,
L_i: Initial allocation of comprehensive load index to POTW i in Type I,
X_k: Allowable constituent k load in a watershed,
s_i: Cost which advanced treatment of POTW i locally yields (a function of x_i),
c_i: Cost of advanced treatment by POTW i,
y_i: Net cost which POTW i incurs,
C: Cost of advanced treatment plant by all the POTWs in a watershed,
Y: Net cost which all the POTWs in a watershed incur,

α_k : Rate of share/dividend regarding constituent *k* in Type I (unit: yen/kg),
α : Rate of share/dividend regarding comprehensive load index in Type I (unit: yen/kg),
β_k : Rate of share regarding constituent *k* in Type II (unit: yen/kg), and
g: Ratio of all the dividends to all the cost for advanced treatment in Type II (from 0 to 1).

In case of Type I

$$y_i = c_i + \sum_{k=1}^{m} \alpha_k (x_{i,k} - L_{i,k}) .$$

When a net cost of each POTW is minimized,

$$\frac{\partial y_i}{\partial x_{i,k}} = \frac{\partial c_i}{\partial x_{i,k}} + \alpha_k = 0 .$$

Thus,

$$\frac{\partial c_i}{\partial x_{i,k}} = -\alpha_k ,$$

which means that marginal costs regarding each constituent which incurs all the POTWs are equal.

$$Y = \sum_{i=1}^{n} y_i = \sum_{i=1}^{n} \left(c_i + \sum_{k=1}^{m} \alpha_k (x_{i,k} - L_{i,k}) \right) = \sum_{i=1}^{n} c_i + \sum_{k=1}^{m} \alpha_k \sum_{i=1}^{n} (x_{i,k} - L_{i,k}) = \sum_{i=1}^{n} c_i \quad \text{since} \quad \sum_{i=1}^{n} x_{i,k} = \sum_{i=1}^{n} L_{i,k} .$$

However, as options for each POTW are discrete,

$$\sum_{i=1}^{n} x_{i,k} < \sum_{i=1}^{n} L_{i,k} \quad \text{instead of} \quad \sum_{i=1}^{n} x_{i,k} = \sum_{i=1}^{n} L_{i,k} .$$

As a result,

$$Y < \sum_{i=1}^{n} c_i .$$

The following is paid by a foundation;

$$\sum_{i=1}^{n} c_i - Y = \sum_{k=1}^{m} \alpha_k \left[\sum_{i=1}^{n} L_{i,k} - \sum_{i=1}^{n} x_{i,k} \right] .$$

In case of Type II

$$y_i = c_i + \sum_{k=1}^{m} \beta_k x_{i,k} - g c_i = (1-g) c_i + \sum_{k=1}^{m} \beta_k x_{i,k}$$

When a net cost of each POTW is minimized,

$$\frac{\partial y_i}{\partial x_{i,k}} = (1-g) \frac{\partial c_i}{\partial x_{i,k}} + \beta_k = 0 .$$

Thus,

$$\frac{\partial c_i}{\partial x_{i,k}} = -\frac{\beta_k}{1-g} .$$

which means that marginal costs regarding each constituent which incurs all the POTWs are equal.

$$Y = \sum_{i=1}^{n} y_i = \sum_{i=1}^{n} \left((1-g) c_i + \sum_{k=1}^{m} \beta_k x_{i,k} \right) = (1-g) \sum_{i=1}^{n} c_i + \sum_{i=1}^{n} \sum_{k=1}^{m} \beta_k x_{i,k} = \sum_{i=1}^{n} c_i \quad \text{since} \; g \sum_{i=1}^{n} c_i = \sum_{i=1}^{n} \sum_{k=1}^{m} \beta_k x_{i,k} .$$

$$\alpha_k = \frac{\beta_k}{1-g} \qquad g \sum_{i=1}^{n} c_i = \sum_{i=1}^{n} \sum_{k=1}^{m} \beta_k x_{i,k}$$

When the solution in Type I is known, β_k and *g* in Type II are determined as below.

$$\beta_k = \alpha_k \frac{C}{C + \sum_{k=1}^{m} \alpha_k X_k} \qquad g = \frac{\sum_{k=1}^{m} \alpha_k X_k}{C + \sum_{k=1}^{m} \alpha_k X_k}$$

Impact of local conditions

In case local conditions are considered, a net cost of POTW *i* is expressed as follows;

$$y_i = c_i + \sum_{k=1}^{m} \alpha_k (x_{i,k} - L_{i,k}) + s_i \quad \text{(Type I)} \qquad y_i = (1-g)c_i + \sum_{k=1}^{m} \beta_k x_{i,k} + s_i \quad \text{(Type II)}.$$

When a net cost of each POTW is minimized,

$$\frac{\partial c_i}{\partial x_{i,k}} = -\alpha_k - \frac{\partial s_i}{\partial x_{i,k}} \quad \text{(Type I)} \qquad \frac{\partial c_i}{\partial x_{i,k}} = -\frac{\beta_k}{1-g} - \frac{1}{1-g}\frac{\partial s_i}{\partial x_{i,k}} \quad \text{(Type II)}.$$

In either case, marginal costs are not equal, and economic efficiency is lost in terms of the target water quality management. The differential is lower than without the local conditions, and advanced treatment is promoted.

$$\frac{\partial c_i}{\partial x_{i,k}} inTypeII - \frac{\partial c_i}{\partial x_{i,k}} inTypeI = -\frac{g}{1-g}\frac{\partial s_i}{\partial x_{i,k}} < 0$$

By comparison, Type II is more affected by local issues, and this means advanced treatment is more promoted in Type II than in Type I, and at the same time the efficiency is lost more in Type II than in Type I.

Dispersion of net average cost

$$y_i inTypeII = (1-g)c_i + \sum_{k=1}^{m} \beta_k x_{i,k} = (1-g)c_i + \sum_{k=1}^{m} (1-g)\alpha_k x_{i,k} = (1-g)\left(c_i + \sum_{k=1}^{m} \alpha_k x_{i,k} \right)$$

$$\frac{y_i}{q_i} inTypeI = \frac{1}{q_i}\left[c_i + \sum_{k=1}^{m} \alpha_k (x_{i,k} - L_{i,k}) \right] = \frac{1}{q_i}\left(c_i + \sum_{k=1}^{m} \alpha_k x_{i,k} \right) - \sum_{k=1}^{m} \alpha_k r_k$$

$$\frac{y_i}{q_i} inTypeII = \frac{1-g}{q_i}\left(c_i + \sum_{k=1}^{m} \alpha_k x_{i,k} \right)$$

Thus, if $\Delta(\bullet)$ means deviation, then

$$\Delta\left(\frac{y_i}{q_i} \text{ in Type II} \right) = (1-g)\Delta\left(\frac{y_i}{q_i} \text{ in Type I} \right) \quad \text{for all } i.$$

Thus, the following expression holds, where $SD(\bullet)$ means standard deviation.

$$SD\left(\frac{y_i}{q_i} \text{ in Type II} \right) = (1-g)SD\left(\frac{y_i}{q_i} \text{ in Type I} \right).$$

Investigations on Economic Efficiency and Cost Sharing for Watershed Management in Japan

Toshiaki Yoshida, and Osamu Fujiki

Ministry of Land, Infrastructure and Transport, Government of Japan

Outline

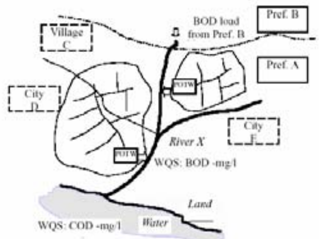
- *Review water quality management in Japan*
  - Efficiency/ Cost sharing/Watershed management
  - CBPSS: Comprehensive Basin-wide Planning of Sewerage Systems
- *Investigations on "Load Adjustment System"*
  - Design the system
  - Consideration on Efficiency, etc.
- *Case study of the system*
  - Quantify the effectiveness
  - Identify hot spots
  - Equity considerations
- *Conclusion*

Review water quality management in Japan

- Water Quality Standards
- Effluent Standards:
  Mix of Ambient-based and technology-based standards.
  Almost no elements of benefit-based standards.
- Watershed management
  CBPSS: Comprehensive Basin-wide Planning of Sewerage System
  TPC: Total Pollution Control
- No major economic instruments are adopted in environment management in general. Subsidy still plays a large role in water quality management.
- Efficiency, and incentives should be vigorously considered.

CBPSS

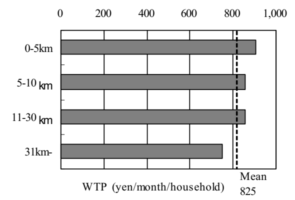
- Formulated to implement sewage works projects most effectively which are required to attain WQSs in target public water areas.
- Allocate load reductions to POTWs, taking into account the other pollution sources.



- Load reduction is often allocated in such a manner that all point sources have the same load reduction ratios.

Problems/Issues of the current management

- No economic instruments or incentives.
- Insufficient implementation of CBPSS, in part due to financing issues.
- No vigorous control of NPS.
- Cost sharing in a watershed, e.g. equal net cost for a large-scale public water bodies.



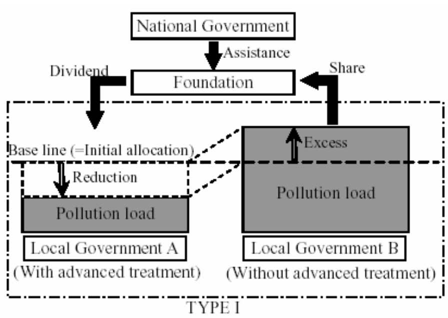
Investigations on "Load Adjustment System"

- In fiscal 2002 and 2003, MLIT set up "Study Committee on Water Quality Trading between Sewage Treatment Plants"
- To investigate economic instruments and cost sharing methods of water quality control on a watershed basis.
- Designed "load adjustment system," with materialised two types.
- Efficiency, equity, and incentives are considered.
- Committee members: academics, national and local government officials.

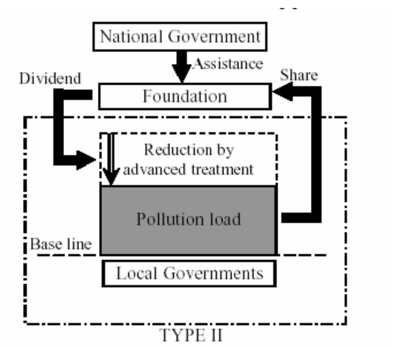
Outline of load adjustment system

- To set base lines of pollution loads, or to allocate, among POTWs so that target WQS can be achieved.
  (In allocation, **equity** can be accommodated.)
- To adjust pollution loads among POTWs for **minimisation** of advanced treatment costs.
- POTWs pay or receive money according to its effluent loads for **cost sharing** in a watershed.
- Foundation is established to administer adjustment, and financial assistance may be provided from national government.
  [Centralised, rather than Decentralised as emissions trading]

Structure of the system (Type I)

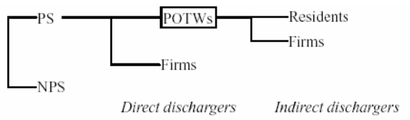


Structure of the system (Type II)



Considerations about the system

- **Efficiency**: Type I and Type II have the same.
- **Equity**: Type II is more preferable than Type I, if net average cost, rather than load reduction ratio is considered.
  Net average cost = Net cost / Effluent volume
  Net cost = Cost for advanced treatment + share - dividend
- **Incentives** can be incorporated in the system.
- Local conditions affect treatment levels of POTWs. Type II is more affected.
- Target dischargers: POTWs limited, but possible to cover other sources by changing a base line of loads.



Other advantages

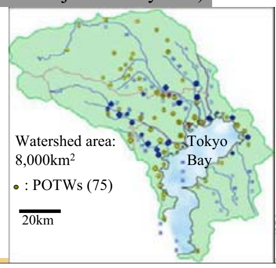
- Other than cost saving/cost sharing, it have advantages such as
  (1) Possible load reduction
  (2) Stable implementation of CBPSS
  (3) Better management and information system of POTWs
  (4) Public involvement promoted
  (5) More research need for load quantification.

Case study of the system

- To quantify effectiveness of the load adjustment, which minimize the total advanced treatment cost for attainment of WQS. → Maximum efficiency possible

Without adjustment (Current CBPSS) vs. *With adjustment* (Load adjustment system)

- To identify hot spots caused by this adjustment.
- Target: Tokyo Bay
- Type I is assumed.
- COD, TN, are TP are treated independently.



Assumptions

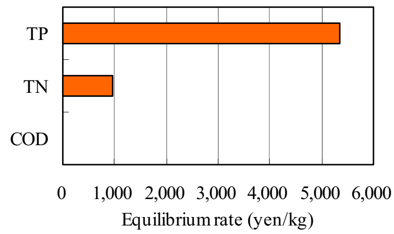
Options	Treatment processes	Effluent (mg/l) COD	TN	TP
Level 1	Activated sludge process	20	22	2.5
Level 2-1	Anaerobic-anoxic-oxic process + Sand filtration	9.6	9	0.4
	Step-feed biological nitrogen removal process + Coagulant	10	7.5	0.5
	Entrapping immobilization nitrification-denitrification process + Coagulant	10	10	0.5
	Advanced oxidation ditch process + Coagulant	10	10	0.5
Level 2-2	Activated sludge process + Coagulant	12	22	0.5
	Oxidation ditch process + Coagulant	12	22	0.5
Level 3-1	Bardenpho process + Sand filtration	8	3	0.2
	Bardenpho process	8.2	4.5	0.4
Level 3-2	Bardenpho process + Sand filtration + Activated carbon	4.4	2.6	0.2

- The options are available for POTWs.
- Target year: 2012
- Cost is assessed on an annualized basis.

$$\text{Construction cost} \times \frac{i(1+i)^n}{(1+i)^n - 1} + \text{O\&M cost}$$

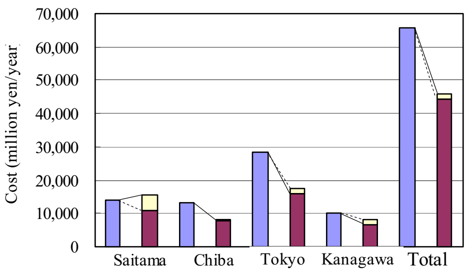
i: Discount rate, n: Useful life

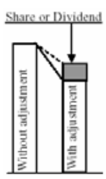
Result of equilibrium rates



- COD does not have an equilibrium rate
- → COD is fully treated if TN and TP is adjusted.

Result of costs

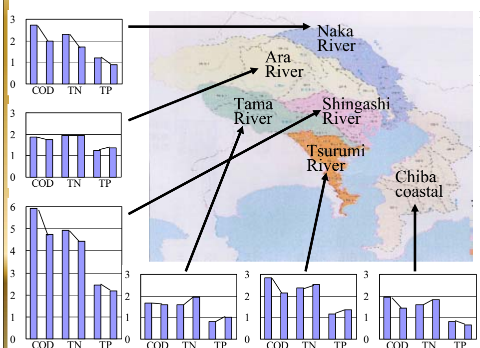


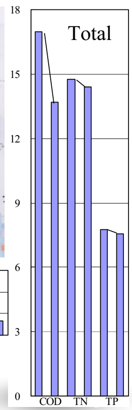


- 31% of cost saving is achieved.
- Saitama Pref. undertake advanced treatment more than initially allocated and receives dividend in total.

Result of loads

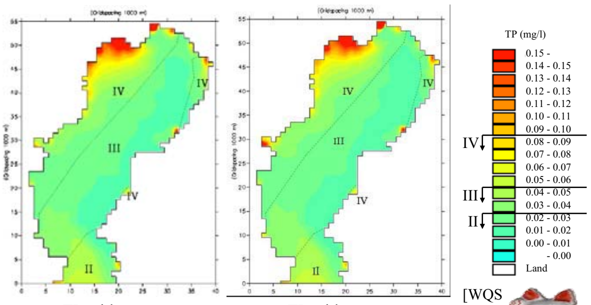
Note. Unit in COD and TN is 10t/day, and unit in TP is t/day.





- Total load reduction; COD: 19%, TN: 2%, and TP: 2%.
- Some subwatersheds have 22% increase of TN load, or 29% TP load at maximum.

Result of Seawater Simulation [Hot spots]



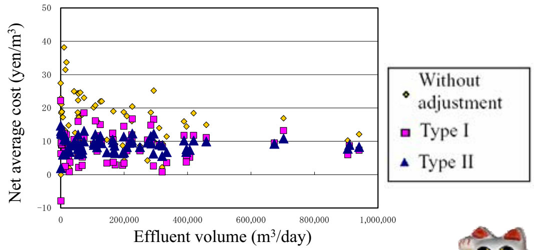
TP without system TP with system

- No significant changes in ambient water quality, no hot spots.

Dispersion of net average cost [Equity]

Definition: Net average cost = Net cost / Effluent volume

Net cost = Cost for advanced treatment + share - dividend



- Dispersed; Type II < Type I < Without adjustment

  [SD (yen/m^3)] [2.3] [4.7] [7.2]

- Type II is preferable in terms of equity.

Conclusion

- The current administrative system should be improved in terms of efficiency, incentives, and equity on a watershed basis.
- “Load adjustment system” is examined and designed to reflect the above three elements in Committee.
- Case study, targeting Tokyo Bay, showed that the maximum cost saving was over 30%, and that some load reductions were also estimated with no hot spots.
- The load adjustment system should be favourable considered also due to other advantages such as better management of POTWs.

Thank you for your attention.