第 IV 部門 Introduction of a Comprehensive Municipal Water Supply Model Incorporating Wastewater Reuse

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Summary

Increased environmental awareness has recently scrutinized the control of man's actions in his surroundings.To alleviate the concerned environmental problems while satisfying water demand for a municipal water supply system, a theoretical water supply and treatment model that incorporates waste water reuse is developed as a water use alternative. Using this model, preferences are analyzed in order to develop an economic pricing policy between an area of a community which desires to reuse a portion of its waste water and one which does not.

1.0 Background

When considering a water system alternative, the pricing policy of the serviced water is the main factor which determines the consumer's willingness to accept the implementation of the project.Thus, for the new alternative to be realized, the user must be induced to pay the fee increase (if any) for operation of the new water system. Up until now, the authors have considered the selection of a municipal water supply system incorporating waste water reuse between the relevant agents involved in the selection, namely the water user (*U*), the environmental management agency (*E*), the water supply agency (*W*), and the sewer management agency (*S*), (Watanabe and Okada, 1995)[1].In this research, we focus our attention towards the water user *U* only. We divide *U* into two types of water users in the municipality: a community which would like to incorporate direct water reuse (*R*) (say a very "environmentally-minded" group within the community) and a community which does not (*N*). As a first step, the examination of the situation as if it were a total conflict is undertaken, so for example, the community which does not wish to participate, opposes the new system's implementation. From a different viewpoint, it would be possible to imagine a community where both parties exist but not as strict, allowing a cooperative situation.

2.0 Model Outline

As mentioned above, we focus our attention towards the two water users, *R* and *N* only.We assumed that the agents *W*, *S* and *E* each provide their assigned service and charge the entire cost they undergo to *R* and *N*. Then *R* and *N* plays a pricing game over this cost in order to set a pricing policy between them by determing their appropriate strategies. We have modeled the following three municipal water systems: the current system with no waste water reuse, a system which implements an on site waste water reuse facility and a system which implements an off site waste water reuse facility, where the treatment of water at the reuse facilities are for low level quality only (see Figure 1 for schematic and above referenced papers for detail). A feature we added to this model was a price adjustment variable X to off site reuse in order to determine the share of reuse so that the selection of this system becomes acceptable to *R* and *N*. The inclusion of X is necessary as currently, it is not yet determined how division of cost is to be administered between the agents for such situations.

The cost components in the model are similar to those utilized in the above reference with a few minor adjustments. Generally they are: C_W-costs for water supply and conveyance, C_S-costs for normal water treatment and conveyance and C_R-cost for reuse incurred when such a system is implemented (note that construction cost and maintenance cost are included in the price charged). These functions are comprised of the following parameters. To measure the control of the flow, the percentage volume of water directed to *R*, μ ,and from this volume, the percentage volume *R* wishes to use for low level use, λ ,were introduced. Notice that for Type II and III, the reuse option is to provide water for low quality use only. Values used for water demand, Q, pre- and added (q and w) water quality load for both high and low level use (subscripts H and L), *N*'s outflow water quality, q_N, and outflow water quality standard, $q_1$are summarized in Table 1 and are discussed in the reference. Note that q_1 is made more severe as an attempt to increase cost C_S, thereby making reuse option more attractive.

3.0 Player Strategies

Strategies for *R* include staying with an existing waste water treatment system, without reuse (Type I), on site reuse (Type II) and off site reuse (Type III). In reaction to the selection of one of these

Table 1- Parameters used in this model

Q (m^3/day)	q_H (mg/l)	w_H (mg/l)	q_L (mg/l)	w_L (mg/l)	q_N(mg/l)	q_1 (mg/l)	μ , λ
100,000	0	150	10	350	200	20, 10	0.1-1.0

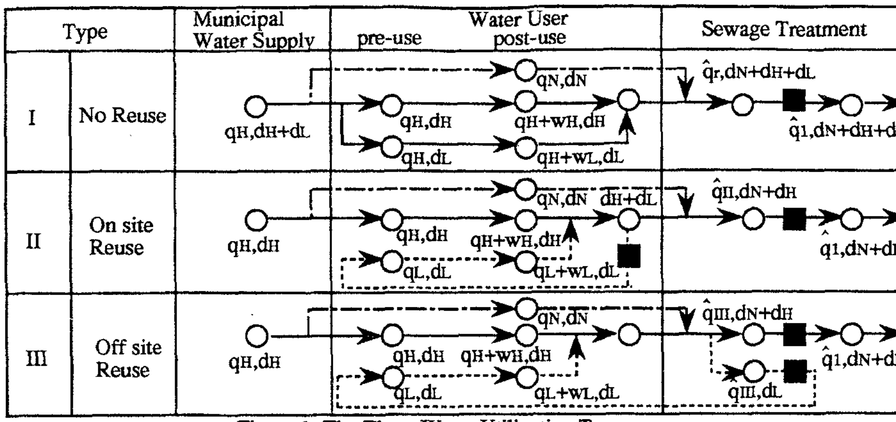

Figure 1: The Three Water Utilization Types

→ flow of water ---→ flow of water for reuse —→ flow of water for N

■ water treatment plant ○ water quality check point

Table 2- Cost Matrix for *N* and *R* (given in 100,000,000 Japan Yen/year, C'=Type I, C''=Type II, C '''=Type III)

		R Type I	*R* Type II	*R* Type III
N	FIX	$[(C_W'+C_S')\mu,\ (C_W'+C_S')(1-\mu)]$	$[(C_W''+C_S''+C_R'')\mu-(C_W'+C_S')(1-\mu),\ (C_W'+C_S')(1-\mu)]$	$[(C_W''+C_S'''+C_R''')\mu-(C_W'+C_S')(1-\mu),\ (C_W'+C_S')(1-\mu)]$
N	AC	$[(C_W'+C_S')\mu,\ (C_W'+C_S')(1-\mu)]$	$[(C_W''+C_S'')\mu(1-\lambda)/(1-\mu\lambda)+C_R'',\ (C_W''+C_S'')(1-\mu)/(1-\mu\lambda)]$	$[C_W''\mu(1-\lambda)/(1-\mu\lambda)+C_S'''\mu+(C_R'''-X)\mu+X,\ C_W''(1-\mu)/(1-\mu\lambda)+C_S'''(1-\mu)+(C_R'''-X)(1-\mu)]$
N	AC-III	$[(C_W'+C_S')\mu,\ (C_W'+C_S')(1-\mu)]$	$[(C_W''+C_S'')\mu(1-\lambda)/(1-\mu\lambda)+C_R'',\ (C_W''+C_S'')(1-\mu)/(1-\mu\lambda)]$	$[C_W''\mu(1-\lambda)/(1-\mu\lambda)+C_S'''\mu+(C_R'''-0X)\mu+0X,\ C_W''(1-\mu)/(1-\mu\lambda)+C_S'''(1-\mu)+(C_R'''-0X)(1-\mu)]$

systems, the strategies available to *N* are to fix his share of the total cost to the *status quo* (FIX). On the other hand, he allows change to his costs in accordance to his appropriate demand, with the introduction of the pricing adjustment, X, for the other strategies. On one extreme, *N* allows change to his cost as according to his water demand (AC) while on the other extreme, *N* again allows a change to his cost but for Type III, have *R* pay for the entire reuse cost (AC-III) (justified by the fact that *R* is taking the initiative to reuse its waste water and may be willing to pay for any additional costs as necessary).

In common game theory language, this game is a finite, non-cooperative, non-constant sum game. This game can be represented by a 3x3 bimatrix, such as that in Table 2. The first and second terms in each cell represent the cost incurred by *N* and by *R* respectively and are calculated through combinations of C_W, C_S and C_R with μ and λ being parameterized.

4.0 Stability Analysis

The method of stability analysis used was taken from a procedure from Conflict Analysis by determining the preference vector for each agent, then a stablilized state between them. A stable state was classified as either rationally stable, where there are no unilateral improvements to be made from the current state, or sanctioned stable, where the other player has a counter move to a unilateral improvement and that countermovement would result in a worse situation. It was determined that stability occurs when Type II reuse is introduced and *N* decides to fix his price.

5.0 Conclusions and Topics for Further Study.

In conclusion, stability for the introduction of a Type II reuse system for *R* and *N* can be introduced, however only under very strict conditions. Thus, additions to the model so that selection of Type II and III, when *N* is pursuaded to allow change to his cost is necessary. It is also conceivable that cooperation could exist when implementing a reuse system, where use of agreements between agents are made and thus, is also subject to further investigation.

[1]Watanabe,H. and Okada,N.,(1994),"Game theoretic analysis of integrated environmental management with combined reuse of waste water", Effective Environmental Management for Sustainable Development, Kluer Academic Publishers,Dordrecht, The Netherlands, 43-56