Knowledge-based Water Quality Management Model for the Urban Area

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1. Introduction

With the development of urbanization, the water quality management becomes more and more important in order to protect the natural environment from the human activities. In this study we propose a model for managing the water quantity and quality in the urban area. First, we classify the basin into 4 land-use types. Then, a simulation model for calculating the discharge and the pollutant loading of BOD is developed for 3 rivers and 31 points. Finally, a knowledge base and a real-time operation system are proposed by using the fuzzy inference theory. See Figure 1.

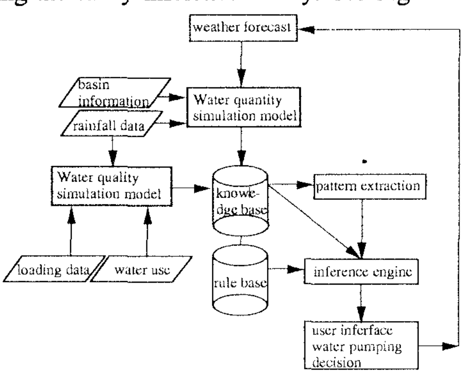

Fig. 1 Flow chart of the research project

2. Landuse and hyetograph pattern

2.1 Landuse type and loading factor

As the basic input data of the model, landuse and precipitation data are firstly shaped. Figure 2 is the map of study area, which is the main part of Gifu city in Japan. We classify the land into 4

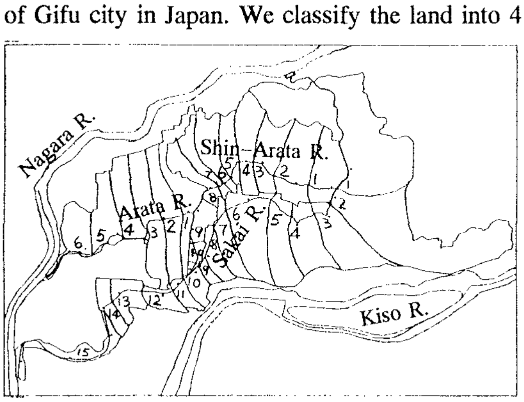

Fig. 2 The study area

kinds of landuse types and each sub-area belongs to one of landuse types and loading factors, which are listed in Table 1[1].

	Terms	BOD	Unit
Industrial	Food	181	g/m.Yen/year
	Fibre	426	"
	Paper	897	"
	Inorganic chemistry	53	"
	Organic chemistry	1,150	"
	Petroleum & lime	22	"
	Leather	443	"
Agricultural	Paddy	10.8	g/d/ha
	Plowed field	10.0	"
	Forest	2.5	"
Domestic	Treated	25.0	g/d/capita
	Non-treated	5.9	"
Commercial		27.2	"

Tab. 1 Loading factors

2.2 Hyetograph pattern and valid precipitation

According to the weather condition, 5 patterns of hyetograph are abstracted, which are the peak-front, peak-behind, peak-center, mild, and double-peak. According to the geographical situation such as the infiltration conditions and low-lying areas, the valid precipitation are calculated.

3. Simulation model

3.1 Water quantity simulation

According to the condition of the study area, the Storage Function method and Muskingum method[2] are applied. Assumed that there are valid precipitations $R_{(t)}$, the inflow can be got through the following equations;

$$\begin{cases} I_{(1)}=A_1R_{(1)} \\ I_{(2)}=A_1R_{(2)}+A_2R_{(1)} \\ \quad\cdots\cdots \\ I_{(t)}=A_1R_{(t)}+A_2R_{(t-1)}+\cdots+A_pR_{(t+1-p)} \end{cases} \tag{1}$$

where, $I_{(t)}$ is inflow (m^3/s), A_i is the sub-area (km^2), p is the number of sub-areas. Considering the basin storage affection and discharge stagnant, Muskingum method is used as follows;

$$Q_{(t)}=C_1I_{(t)}+C_2I_{(t-1)}+C_3Q_{(t-1)} \tag{2}$$

where, $Q_{(t)}$ is the outflow.

3.2 Water quality simulation

To calculate the loading, the classical Streeter-Phelps formula is applied as follows;

$$\frac{dL}{dt}=-kL \tag{3}$$

where, L is the loading (g/s), k is the purification coefficient. Considering the deoxygenation and reaeration in the river, following changed form is used;

$$L=L_0 e^{-(k_1+k_3-k_2)t} \tag{4}$$

where, L_0 is the initial loading, k_1 is the deoxygenation coefficient, k_2 is the reaeration coefficient, k_3 is BOD removal coefficient for the deposition and adsorption. According to the Streeter–Phelps' formula, the current loading at the reference point L_p can be calculated. We set the total loading in the area as L_s, and the loading runoff ratio K can be shown as;

$$K=\frac{L_p}{L_s} \tag{5}$$

Setting the criterion in the reference point as L_c, the reduction of loading ΔL is as follows;

$$\Delta L=L_s-L_c \tag{6}$$

The loading motion equation and continuity equation[2] are as follows;

$$L=KS^mQ^n \tag{7}$$

$$S=S_0-\int_0^t Ldt \tag{8}$$

where, K is the loading runoff coefficient, m is accumulated loading motion coefficient, n is the loading motion coefficient, Q is discharge, L is loading, S is the accumulated loading, S_0 is the initial accumulated loading.

3.3 Results

Figure 2 shows a part of the running results. The upper one is the precipitation patterns, the middle is the hydrograph corresponding to pattern A, while the lower one is BOD sequence in the Sakai river.

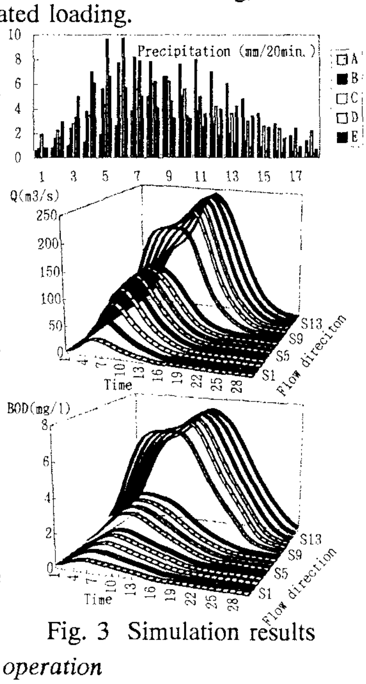

Fig. 3 Simulation results

4. Knowledge base & fuzzy inference

4.1 Real–time operation

Based on the data of precipitation, pumping water, water use, hydrograph and pollutant loading, a knowledge base is built to support the real time operation in the Nagara Pumping Station which is located at the most upstream point of the study basin. The pumping water is to maintain the water quality criteria in the study area with necessary channel discharge for the self–purification of river. The decision–making, or operation rule is defined in IF–THEN form as follows;

IF Q=Q AND L=L THEN P=P

In this way, the pumping water drawing rule base is extracted. The pumping discharge is decided according to the water quantity and quality in the basin with the method of fuzzy inference. First, the similarity $f(i)$ between the calculated sequence $c(t)$ and the one in knowledge–base $b(i,t)$ is defined by;

$$D(t)=\min_T\{\max_T [|c(t)-b(i,t)|]\} \tag{9}$$

$$f(i)=-\frac{1}{a}D(i)+1 \tag{10}$$

where, a is the gradient of fuzzy membership function $f(i)$. If we define $f(i)$ as discharge similarity, $g(j)$ as water quality one, pumping discharge P can be obtained through;

$$\omega(i,j)=\frac{f(i)+g(j)}{2} \tag{11}$$

$$P=\frac{\sum_{i=1}^{I}\sum_{j=1}^{J}\omega(i,j)\kappa(i,j)}{\sum_{i=1}^{I}\sum_{j=1}^{J}\omega(i,j)} \tag{12}$$

where, $\omega(i,j)$ is fidelity, $\kappa(i,j)$ is the pumping discharge in the knowledge base.

4.2 Conclusions

To deduce the pollutant loading in the river, pumping water from the Nagara river is effective in non–rain days. On the other hand, to improve the aquatic environment in the area, the comprehensive strategies are necessary. With the development of the regional economics and the increasing of the population, new sewerage system, long and short–term real–time operation system must be established to achieve the aim that BOD in the three rivers are less than 5 mg/l in the year of 2000 or later.

5. Reference

(1) Handbook of hydraulic formulas, Japan Society of Civil Engineering, 1985

(2) Nonpoint–source loading model analysis, Yasuhiko Wada, Gihodo Publishing Co. Tokyo, July 25, 1990