DEVELOPMENT OF DIALOG SYSTEM MODEL FOR EUTROPHICATION CONTROL BETWEEN DISCHARGING RIVER BASIN AND RECEIVING WATER BODY — CASE STUDY OF LAKE SAGAMI (JAPAN)


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ABSTRACT

A computer program based on expert system software was developed and proposed as a prototype model for water management to control eutrophication problems in receiving water bodies (Suzuki et al., 1988). The system has several expert functions: 1. data input and estimation of pollution load generated and discharged in the river watershed; 2. estimation of pollution load run-off entering rivers; 3. estimation of water quality of receiving water bodies, such as lakes; and 4. assisting man-machine dialog operation.

The program can be used with MS-DOS BASIC and assembler in a 16 bit personal computer. Five spread sheets are utilized in calculation and summation of the pollutant load, using multi-windows. Partial differential equations for an ecological model for simulation of self-purification in shallow rivers and simulation of seasonal variations of water quality in a lake were converted to computer programs and included in the expert system. The simulated results of water quality are shown on the monitor graphically.

In this study, the expert system thus developed was used to estimate the present state of one typical polluted river basin. The river was the Katsura, which flows into Lake Sagami, a lake dammed for water supply. Data which had been actually measured were compared with the simulated water quality data, and good agreement was found.

This type of expert system is expected to be useful for water management of a closed water body.

INTRODUCTION

Throughout Japan, many closed water bodies are suffering from eutrophication, and many communities are faced with social problems due to this. However, to date, control policies based on scientific knowledge have rarely been formulated.

Suzuki et al. (1988) started from the construction of a basin-wide structural model of eutrophication phenomena in a closed water body. Various unit processes or mechanisms, such as discharge of effluents, water pollution level, and natural purification ability, were taken into consideration in the model of the system. The system model itself was constructed as a dialog type between the discharging basin and the receiving water body. A general purpose model was developed, and in this study, the model was verified by applying it to a specific basin as a case study.
EXPERT SYSTEM FOR SUPPORT OF WATER MANAGEMENT OF CLOSED WATER BODIES

Planning for water management is complicated, since it includes estimation of pollutant load generation and pollutant run-off, planning of counter measures, and simulation of future water quality. The intelligent knowledge of a professional expert is necessary. However, such experts are not available in many areas, therefore, the authors have developed an expert system using a popular 16 bit personal computer to help non-experts in planning water management. The expert system includes the logic, procedure, basic model equations, and simulation program necessary for good management. It will deal with COD, phosphorus, and nitrogen pollutant materials (although only phosphorus has been considered to date). It is a general system which can be applied to any closed water body.

FUNCTIONS OF THE EXPERT SYSTEM

Input of Data on River Basins, Administrative Districts, and Pollutant Sources

Initially, it is necessary to input data on the numbers and names of river basins and administrative districts, and to select combinations of basins and districts and the kinds of pollutant sources in these districts. Operators input this information by following the instructions given by the computer. Data on pollutant loads are then input in columns on spread sheets, corresponding to the pollutant sources in all the administrative districts and all the river basins.

Input of Data on Pollutant Load per Unit Activity of Sources, Numbers or Areas of Pollutant Sources, and Rate of Pollutant Load Discharge

Five spread sheets (for pollutant load per unit activity of sources, number or area of pollutant sources, generated pollutant load, discharge rate, and pollutant load discharged) are overlapped on the personal computer monitor and appear instantaneously when the appropriate function keys are pressed. These spread sheets have the same columns as for the data input. An operator can randomly enter any item of data into a column, corresponding to the pollutant load source of an administrative district in a river basin (with multiple windows and a full screen editor). When inputting data, another window appears. The following are input in turn: pollutant load per unit activity of sources; number or area; generated pollutant load; discharge rate; and pollutant load discharged. In the case of pollutant load generated and pollutant load discharged, automatic calculations can be utilized.

Calculation and Summation Function

There are many different social and economic activities taking place in river basins. Thus, multiple pollutant sources exist and many kinds of effluents are observed. The calculation and summation of the pollutant loads generated and discharged in such river basins is thus complicated. The re-calculation and re-summation for correction and modification of inputs is also very complicated, and is necessary when the various pollution counter measures are considered. However, this process is very quick when the spread sheets of this expert system are used (there is almost no waiting time).

Reference Data Base and Self-learning Function

It is very rare that all the information necessary, such as pollutant loads per unit activity of sources and discharging rates, can be measured and collected on site for estimation of pollutant load generated and pollutant load discharged. Generally, only a few actual measurements are available. Further, it is difficult to collect recently measured data. However, the expert system has a uniform data base on pollutant load per unit activity of each source and discharging rate of each source, the data for which have been collected from references. This data base can be called up in one of the multi-windows during data input.
Estimation of Pollutant Load Run-off

An attempt was made to estimate the pollutant load from run-off entering river reaches between one district and another. The estimation of pollutant load in run-off was based on a simulation model of self-purification, which accounts for purification by the river bed (which is a typical property of a shallow river). The pollutant load entering the water body can be estimated by summing the series of estimations made for these reaches.

Estimation of Water Quality of a Receiving Water Body

The average seasonal or annual changes in present or future water quality of a receiving water body, such as a lake, can be estimated, based on a simple ecological model and Vollenweider model. This is done by inputting information into the computer on the estimated total pollutant load in run-off from the river basin and the specifications of the water body, such as area, depth, retention time of flowing water, and stratification in the lake.

SIMULATION MODEL

A partial differential equation was developed as the self-purification model for a shallow river. The model accounts for transport of phosphorus and its assimilation by algae at steady state along the direction of flow (one dimension). The algal growth rate was assumed to be Monod-type. The partial differential equation was converted to a finite difference equation for computation.

The mass balances of algae and phosphorus were investigated in a complete mixing tank divided into upper and lower layers, as a double layer model of a lake. Algal growth was assumed to take place in the upper layer only, and respiration in both layers. Mixing of phosphorus and algae between the two layers and sedimentation of algae from both layers are assumed. Inflow of phosphorus and outflow of phosphorus and algae were considered.

APPLICATION OF THE EXPERT SYSTEM TO THE UPPER RIVER BASIN OF LAKE SAGAMI

The expert system was used to analyse the present state of eutrophication in the upper river basin of Lake Sagami. Lake Sagami is a dammed lake located to the west of Tokyo. The lake was formed by the construction of a dam on the River Katsura, which rises from Mount Fuji. Water from the lake is utilized in the waterworks of Yokohama, Kawasaki, and Tokyo. With the co-operation of the city and town administrations and the Fire Department, data on the numbers and area of pollution sources for Mount Fuji and 10 city and town districts in the river basin were collected. Data accumulated from various references and entered into the expert system were utilized when the pollutant loads per unit activity of sources were entered. Various parameters, such as depth, width, and flow rate, were measured on site for every river reach. The lengths of the reaches were measured on maps with a scale of 1/50 000. The calculation and summation processes resulted in an estimate of total run-off of phosphorus to the lake of 108 ton/year. Water quality in the lake was simulated, as in Fig. 1, by using total run-off, measured flow rate (3 630 000 m$^3$/day) and lake volume (48.2 x 10$^6$ m$^3$). This figure can be compared with Fig. 2, which shows the actual measurements for recent years. It was found that the results from simulation coincided almost exactly with the actual measurements.

CONCLUSIONS

The expert system, developed by Suzuki et al. (1988), was used to estimate the present water quality status of one typical polluted river basin. The river investigated was the Katsura, which flows into Lake Sagami. The lake was formed by the damming of the river, and the water is utilized by various waterworks. Actually measured data were compared with the results of water quality simulation, and good agreement was found. This type of expert system is expected to be useful for the water management of a closed water body.
Fig. 1. Simulation of water quality in Lake Sagami

Fig. 2. Measured water quality in Lake Sagami

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REFERENCE