DYNAMIC MODELLING OF WASTEWATER TREATMENT PROCESSES

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1. INTRODUCTION

This note describes the development and some applications of STOAT – a PC-based software package containing integrated dynamic models of the processes used in wastewater treatment. Dynamic modelling of wastewater treatment processes can be used to establish better design and operational procedures and can result in significant cost benefits.

2. STOAT DEVELOPMENTS

STOAT (the acronym stands for Sewage Treatment Operation and Analysis over Time) began development in 1989 as a series of research projects. The overall aim was to investigate the feasibility of dynamic modelling of an entire wastewater treatment plant using simulation of individual unit processes. Steady state models of ‘whole’ works, which existed prior to this time, were widely used but suffered from several disadvantages.

- The time-varying nature of the influent to wastewater treatment plants made it necessary to perform extensive calibrations in order to achieve a reasonable match between actual and predicted effluent quality. Such calibration often involved arbitrary adjustment of various ‘treatability’ coefficients which were difficult to measure experimentally.
- The output of a steady state model can only be interpreted as a measure of average performance. It is virtually impossible to derive any accurate information about the extent of performance variations.

Dynamic models of individual processes (principally activated sludge) also existed before 1989. For example, WRc developed a dynamic model of the activated sludge process (ASMODEL) over a period of several years. This model was eventually released to the UK Water Industry and became widely used. The release of ASMODEL was an interesting example of the parallel development of software and computer hardware.

ASMODEL was improved and incorporated into STOAT at an early stage. The microbial kinetics were expressed in terms of BOD since this parameter is used as a measure of treatment plant performance in the UK and much of continental Europe.

Other process models were developed as a collaborative effort between WRc, Imperial College, most of the English Water Utilities, Dwr Cymru, DoE (NI) and all of the Scottish Regional Councils. The Water Industry provided data for model building and testing. All the process models within STOAT were validated against operational UK wastewater treatment plant.

STOAT solves each process model individually within a master program that co-ordinates the transfer of information between the different processes. This approach presented technical difficulties in modelling but required less computer memory than the alternative of treating the entire treatment plant as a set of interlinked differential equations and solving them simultaneously.

The initial research projects were completed in 1992. The second stage involved the provision of a user interface within Microsoft Windows™. During the third stage the range of process models was extended to include activated sludge process variants such as oxidation ditches, and biological nitrogen and phosphorus removal systems. Models of mesophilic anaerobic digestion and thermophilic aerobic digestion were also included.

STOAT was developed over the same timescale as the UK Urban Pollution Management (UPM) methodology and is the treatment plant modelling component of that methodology. As such, STOAT can read and write data files in MOSQITO format, which allows it to work in conjunction with sewerage models such as MOSQITO and its successor Hydroworks-QM from Wallingford Software, and with receiving water models such as MIKE-11 from DHI.

3. EXAMPLES OF THE USE OF STOAT IN THE WATER INDUSTRY

The first version of STOAT was released in November 1994. By August 1995 it was being used by 13 organisations, including Water Utilities, Consultancies and Universities in the UK and abroad. WRc has also used STOAT on behalf of clients on a number of projects. The following examples of modelling projects illustrate some typical applications of STOAT within the Water Industry.

Process Optimisation – Parma, Italy

The City of Parma in Northern Italy has two wastewater treatment plants that serve a total population equivalent of 200,000 people. Both plants also treat large quantities of imported wastes which are brought in by tanker. The imported wastes include landfill leachates, industrial effluents and septic tanks wastes from the surrounding area. The company responsible for operating the works was faced with the problem of maximising the throughput of imported wastes without adversely affecting effluent quality. Both of the treatment plants discharged to a tributary of the River Po and effluent quality requirements are stringent. Nitrogen and phosphorus removal is achieved at both sites.

A STOAT model of one plant (Parma Ovest) was developed on an “entire works” basis and also in a simplified format where only one process stream was modelled. The models were used to investigate the consequences of various strategies for additional treatment of imported wastes that contain very high concentrations of ammonia and BOD. The results of the simulation of works performance could be summarised as follows:

- The design of the anoxic zones used for denitrification in the activated sludge process was inadequate and breakthrough of excessive nitrate concentrations was predicted under certain conditions.
- The capacity of the activated sludge aeration system was too low to treat the extra load imposed on the system by additional imported wastes.
- Increased amounts of imported wastes could be successfully treated if design modifications were carried out to overcome the problems described above and if the wastes were added according to a strategy which balanced the load on the entire plant. This meant that the rate of addition of imported waste was greatest during the period when diurnal variations in the sewered load were at a minimum.

The plant modifications and changes in operational strategy predicted by STOAT simulation were implemented and as a result the amount of imported wastes that could be treated was increased by a factor of three. A second stage of the project is also nearing completion. This has involved modification of STOAT data files so that on-line data can be used to generate simulation results. The on-line data provides information on wastewater characteristics such as organic load and flowrate, and plant operating conditions such as MLSS concentration and recycle rates. Simulations are performed on a frequent, periodic basis to refine the overall treatment strategy further. The procedure described is being repeated for the second Parma treatment plant.

Process Design – Effect of Storm Events

Risk assessment is an important aspect in the design of wastewater treatment plant. It is necessary to strike a balance between the cost of the plant and the probability that it will meet the effluent quality consent imposed. Design procedures are complicated by the need to ensure that effluent quality is maintained during rainfall events that result in temporary increases in hydraulic and organic load. Dynamic wastewater treatment models such as STOAT can be used to develop plant designs that are optimised in terms of capital cost against risk of performance failure. Simulations can be performed using a variety of diurnal influent profiles that correspond to particular load conditions. These diurnal variations can be related to actual geographical locations by the use of appropriate stochastic rainfall events or they may be entirely theoretical. In all cases it is important to establish a final design that is related to input conditions which are likely to occur in practice.

4. FURTHER DEVELOPMENTS

Version 2 of STOAT was released in December 1995. Additional process model have been added for sludge treatment and activated sludge sequencing batch reactors. The option of using the IAWQ COD based treatment models in appropriate processes has also been included. A simplified sewerage model (SIMPOL) has been incorporated into STOAT and this model is designed to work with more complex models such as HydroWorks QM. SIMPOL is not detailed enough to replace HydroWorks QM but it has a computational speed which permits rapid investigation of a range of sewerage systems. The ‘optimal’ SIMPOL results need to be verified with a full HydroWorks QM simulation.

AMENDMENTS

Ver	Description	Date
1.	First Published	February 1998
2.	Editorial amendments	March 2009