AN IMMISSION BASED EVALUATION OF THE EFFICIENCY OF THE SEWER-WWTP-RIVER SYSTEM UNDER TRANSIENT CONDITIONS

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KEYWORDS

Modelling, integrated approach, sewer system, CSO (combined sewer overflow), WWTP (waste water treatment plant), river system, continuous simulation, immission

INTRODUCTION

In most European countries the regulations with regard to CSOs are based on a limitation of the overflow frequency and/or based on a dilution ratio following the UES (Uniform Emission Standard) approach. In that approach, the case specific environmental impacts of the overflows on the receiving waters are not accounted for.
This paper deals with an integrated methodology for considering the effects of the transient flow and load characteristics in the sewer-WWTP-river system. Continuous simulations are carried out to this purpose. They guarantee that discharge and climatological changes are taken into consideration. A holistic approach is necessary to include the risk that a combination of factors leads to a critical situation which can hardly be assessed when focussing on a part of the system only. The effects of pollution abatement scenarios are studied through a statistical analysis of immission characteristics of the receiving waters, resulting in CDF (concentration-duration-frequency) curves. These curves make it possible to gain insight on the duration and the frequency of occurrence of events with a non- allowable concentration of for instance dissolved oxygen. This methodology allows for an analysis of water quality problems in agreement with the Environmental Quality Objective/Environmental Quality Standard (EQO/EQS) approach (Tyson et al., 1993).
Part of the Brussels urban drainage system was chosen to illustrate the described methodology.
The emphasis in this paper is put on the results obtained with the river impact model. The authors would like to refer to Bauwens et al. (1995a) for an explanation on the interactions between the sewer system and the WWTP and on the behaviour of the latter under transient conditions.

METHODOLOGY, MODELS USED AND RESULTS

General

Scenarios without and with CSO control in the sewer are considered: options CSO and BAS. In the CSO option, an overflow structure at the end of each collector discharges excess flow to the river, while in the BAS option on-line storage basins are placed at the same outlets to limit the overflow frequency to 7 per year. The collectors are connected to a WWTP by a trunk sewer with a capacity of 5 DWA (dry weather flow).
At the WWTP, the simulation study evaluates the effect of potential control strategies such as by-pass (S1), retention of first flush in a storm tank (S2), step feed (S3) and ratio control of the RAS (return active sludge; S4).
The impact of the effluents on the river system in either scenario is studied. Time series of flows and concentrations from both sewer system and WWTP are used as input to a continuous river model in order to consider the problems from an immission point of view. Only the results of the simulations for 1986 will be discussed here.
More details on the overall approach and on every part of the system can be found in Fronteau et al. (1995).

The sewer system

The input time series for the flows and concentrations at the CSO structures and at the WWTP intake are obtained through the continuous simulation model KOSIM (Harms et al., 1987). 10 minute rainfall data have been used as input for the model. The sewer network is schematized based on previous detailed hydraulic simulations. In the storage basins, the settling of pollutants and sediments is described by classical sedimentation theory. No interactions between pollutants and/or the sediment are considered. Although the model is capable to take erosion and deposition processes into account in the subbasins, no use of it has been made due to the lack of data.

The waste water treatment plant

The WWTP model is based on a structured dynamic model describing COD (chemical oxygen demand) removal and final settling. Special emphasis is put on the sludge inventory of the plant since this is considered to be the main problem area under storm conditions. As biotransformation model, the IAWQ model n°1 with elimination of nitrification and denitrification processes is used (Henze et al., 1987). Together with the information on waste water temperature, an overall heat balance involving different heat loss and generation terms (Van der Graaf, 1976) is used to model the dynamics of the mixed liquor temperature. The dependence of mass transfer and biodegradation on temperature has been modelled in the traditional way. For the primary clarification a model has been developed on the basis of the 5-layer model of Lessard and Beck (1988). A first order hydrolysis reaction of the slowly biodegradable particulate fraction is included and the settling velocity depends on sewage features. Scouring is taken from Alarie et al. (1980). Secondary clarification is modelled according to Takács et al. (1991) using a 10-layer one-dimensional model.

The river system

The dissolved oxygen (DO) concentration is considered to be the most relevant immission characteristic for the assessment of the impacts on the receiving water. The DO time series is obtained through water quality simulations of a part of the river Zenne using SALMON-Q (HR Wallingford, 1994). The river has been divided into a number of elements in each of which the necessary equations are solved (Fig.1).

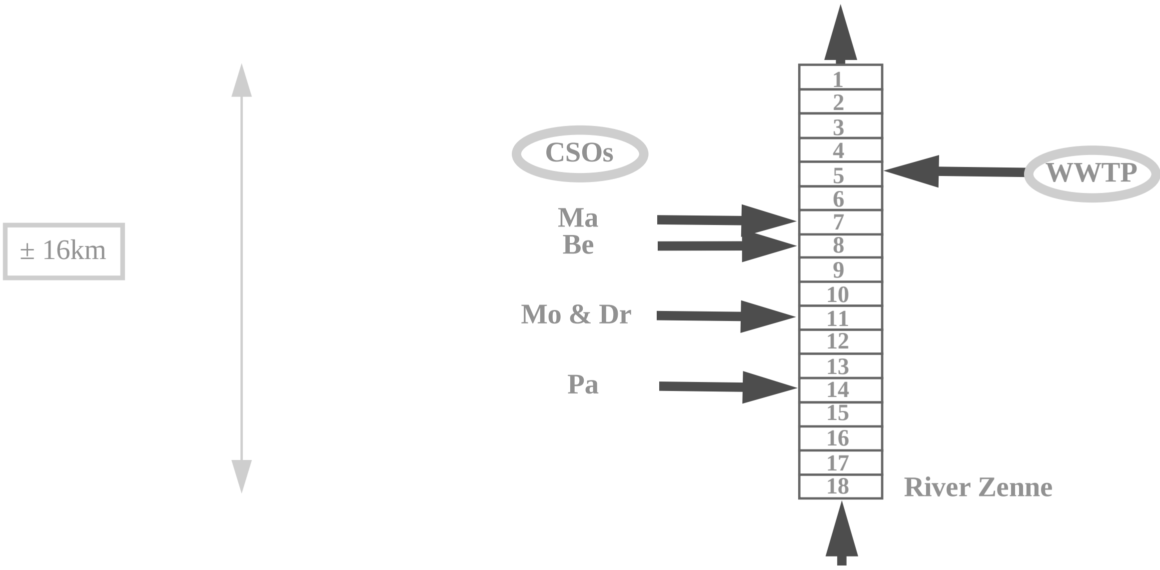

Fig.1: Schematic representation of the river model

Time series of discharge, temperature, suspended solids, particulate and dissolved BOD (biochemical oxygen demand) and DO from the CSO and WWTP effluents (output of the models described above), have been used (time step: 10 minutes). Also upstream discharge series and downstream level series are necessary for the simulations. Initial conditions, parameters and supplementary boundary conditions have been obtained from literature and by previous performed modelling studies on the river Zenne. A simple oxygen balance in the water column has been considered, i.e. reaeration and BOD degradation have been taken into account. Temperature influences have been included. No sediment transport has been modelled because of insufficient data.

Results

By comparing both CSO and BAS option with regard to river flows for WWTP scenario S2, it is noticed that peak discharges reach lower values and are less frequent under the BAS option. On the other hand, storage basins seem to have a limited effect on the most important storm events which still give rise to overflow. The two most important peak discharges over the year 1986 are more or less identical for both options. Upstream from the WWTP, the global beneficial effect of the storage basins on the DO concentrations is very clear (Fig.2). Also in this case however, the most harmful situations do not seem to differ much according to both options: they are caused by storms which are not being controlled under the BAS option.

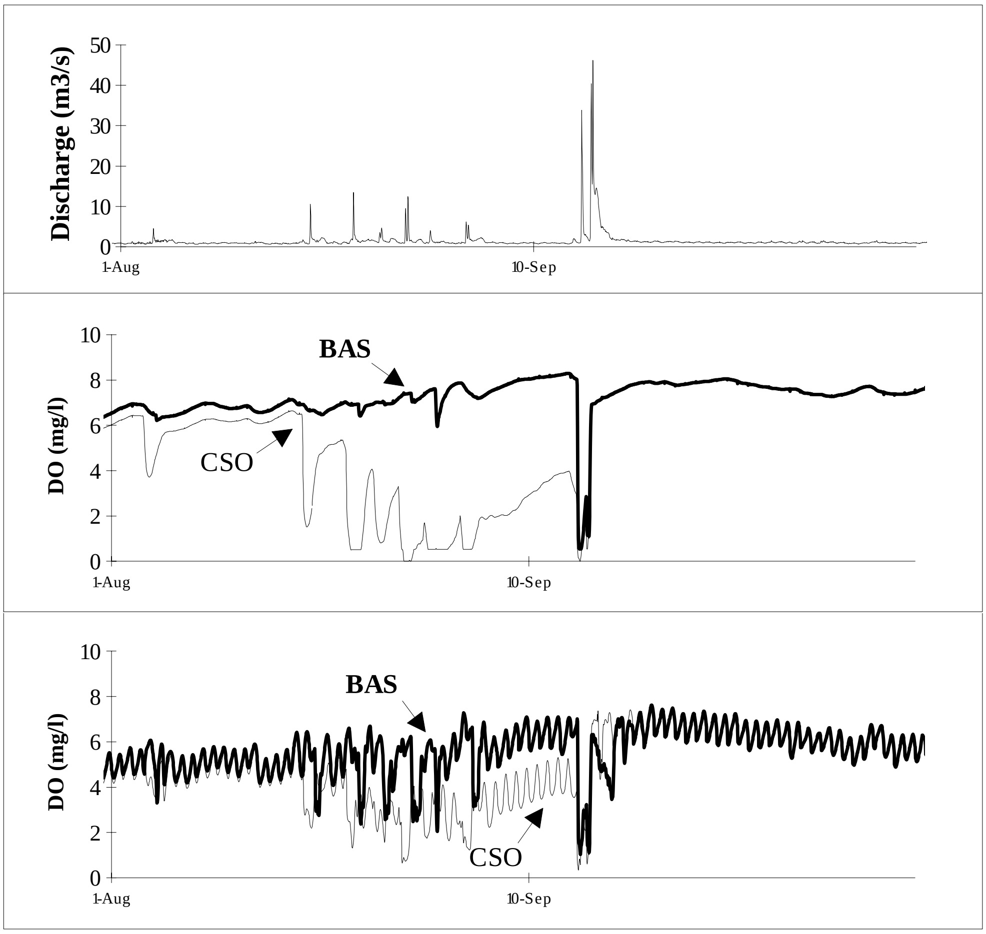

Fig.2: Time series for DO concentrations upstream and downstream from the WWTP for CSO and BAS option

An interesting exception is a period in Augustus 1986. Successive, not extreme overflow events during this period (CSO option) lead to a critical situation for more or less 2 weeks. The river is not capable to restore the DO balance due to the low base flow of the river and the high temperature during that period of time. For a short, but important storm event happening half of September, and for similar successions of overflows during other seasons, it is however noticed that the low level of DO concentration very suddenly climbs to reach higher values again. The events of August and September illustrate very clearly that a combination of factors, influencing the water quality of the river, needs to be accounted for when analysing the effect of overflows.

Downstream from the WWTP, the difference between both options decreases (Fig.2) due to higher BOD values caused by the WWTP under the BAS option. The CDF curves (Fig.3) learn us that critical situations (DO < 5mg/l) occur more often under the CSO option such that the BAS option remains beneficial even downstream from the WWTP.
Few differences have been noticed between the different WWTP control strategies. Slightly better results are achieved under scenario S2, as expected from the interpretation of the WWTP behaviour. For the BAS option, the WWTP inflow increases significantly due to depletion of the reservoirs. Under scenario S2 the amount of waste water that receives no biological treatment is reduced. However, in case of longer rain periods, this solution is less effective.

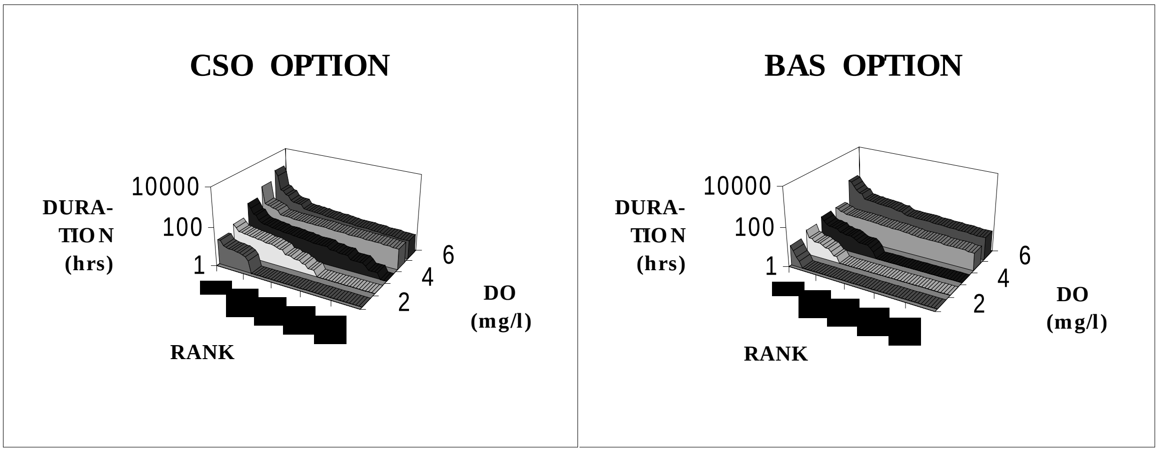

Fig.3: CDF curves for DO concentrations downstream from WWTP under CSO and BAS option

CONCLUSION

Continuous simulations for the integrated sewer-WWTP-river system have been carried out and the efficiency of different sewer and WWTP scenarios has been evaluated from an immission point of view. The following conclusions can be formulated.

The installation of storage basins does not seem to prevent important storm events to give rise to overflow. A major reduction of the CSO emissions is obtained though. Even if the BAS option leads to an increase in the emissions from the WWTP, the net effect of the basins remains beneficial. Although few differences have been noticed between the different WWTP control strategies, the scenario with the storage tank (S2) seems to get round the limitation of the capacity of the WWTP. It has been shown that a combination of factors, influencing the water quality of the river, needs to be accounted for when analysing the effect of overflows.

On a 486 pc (66MHz), the simulation of one year with the models described in this paper requires less than 30 minutes computation time for the sewer system and less than 2 hours for the WWTP. For the river impact simulations however, about 30 hours are necessary for simulation of a period of one year (time step: 10 seconds). Although cumbersome, due to the extremely large amounts of data, the statistical analysis of the results does not represent a fundamental problem. A profound analysis of the results for each subcomponent of the system remains important.

Several problems still are to be solved with regard to the modelling, including the conceptual representation of phenomena (i.e. surface washoff and sediment transport in sewers) and the parameters of the models (especially with regard to the biochemical reactions and the settling properties). With regard to the overall immission based methodology, a major problem is seen to be the translation of the immission characteristics (which are the relevant variables and what are the relevant stochastic characteristics of the series) towards the environmental impacts.

An extension of the described approach towards the ammonia problems is actually being realised.

For a detailed description of the complete study, the authors would like to refer to Bauwens et al. (1995b).

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