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AN INTEGRATED METHODOLOGY FOR THE IMPACT ASSESSMENT OF THE DESIGN AND OPERATION OF THE SEWER - WASTE WATER TREATMENT PLANT SYSTEM ON THE RECEIVING WATER QUALITY

ABSTRACT

The poster deals with an integrated methodology for the assessment of the impacts of alternative sewer and waste water treatment plant (WWTP) management scenario's on the quality of the receiving waters. The input time series for the flows and concentrations at the combined sewer overflow (CSO) structures and at the treatment plant intake are obtained through a continuous sewer simulation model. The WWTP model is based on a structured dynamic model describing COD 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. The impacts of the emissions at the CSO structures and from the WWTP is simulated with the help of a river quality model. The methodology is illustrated on the combined sewer network of Brussels. Scenario's without and with CSO control measures in the sewer are considered. At the treatment plant, the simulation study evaluates the effect of potential control strategies such as ratio control of the RAS, step feed and retention of first flush in a storm tank.

INTRODUCTION

On a yearly basis, the emission of pollutants from combined sewer systems into the receiving water represents only a fraction of the total pollutant amount that will be processed by the waste water treatment plant. Nevertheless, the impact of CSO on the receiving waters cannot be neglected, mainly with respect to peak concentrations and to the accumulation of toxic substances. More over, this impact will increase with the improvement of the treatment efficiency. In order to reduce the impact of the CSO, additional storage and real time control may be considered in the sewer system. In combination to - or as a consequence of - the latter actions, the loading of the WWTP may be increased. This, on its term, results in a larger variability of the effluent characteristics of the WWTP.

With regard to water quality regulations, two alternative approaches can be distinguished : the Uniform Emission Standard (UES) and the Environmental Quality Objective/ Environmental Quality Standard (EQO/EQS). Under the EQO/EQS approach, the objectives with regard to the use(s) of the water are defined first and case specific standards are derived to achieve compliance with the objectives. The UES approach focusses on emission standards, irrespective of local circumstances but considering technology based criteria. Most actual regulations concerning CSO can be classified under the UES approach. They prescribe a limitation of the overflow frequency (3-10/year) and/or on a certain dilution ratio (e.g. 1:5) that must be obtained before CSO is allowed. The actual, case specific, environmental impacts of the overflows on the receiving waters are hereby not properly considered.

The aim of good drainage design - in pollution terms - is to balance the effects of continuous and intermittent discharges against the assimilation capacity of the receiving water, in order to optimize the quality of the receiving water at minimal cost. If this definition is accepted, the analysis of the problem in compliance to the EQO/EQS approach imposes itself. Hereto, the effects of pollution abatement scenario's are to be considered through a statistical analysis of immission characteristics of the receiving water. Also a holistic view becomes imperative : all flow and pollutant sources should be considered on a basin scale and all flow situations and the dynamics of the system have to be considered.

METHODOLOGY AND MODELS USED

General

In order to perform a statistical analysis of the immission characteristics of the receiving water, long time series of those characteristics must be generated for each of the scenario's considered. The use of hydrologic, hydraulic and quality simulation models becomes hereby imperative. Conceptual models that incorporate the fundamental quantity and quality determining processes are available for the river system, the treatment plant and for the sewers. However, due to their complexity - and consequently large computation times - their application is limited to the simulation of specific events. If continuous simulations are aimed at for the generation of long time series, models with a simpler conceptual background and whereby also the system is represented in a simplified way have to be used.

The sewer model

The KOSIM model (ITWH) was used for the sewer simulations. In this model, the sewer system is represented by a number of reservoirs connected in series or parallel. A conceptual rainfall-runoff model transforms the rainfall series into a flow series for the subbasin. Pollutant inputs are generated from the dry weather flow cycle and concentrations and - during rainfall - through the principle of constant concentration associated to the storm flow. Sedimentation and resuspension are modeled for each subbasin, based on critical discharges for settlement and sediment removal. Within the system, flows and pollutants are conveyed downstream by accounting for a constant travel time. Weirs and different types of storage basins may be considered. The hydraulic calculations for these structures are based on the continuity equation, on maximal flow capacities and on stage-discharge relations. In the storage basins, the settlement of pollutants and sediments is described by classical sedimentation theory. No interactions between pollutants and/or the sediment are considered.

The wastewater treatment model

A traditional carbon removal wastewater treatment system has been used. It consists of primary clarification, 3 completely mixed aeration tanks in series and a final clarifier. As the biotransformation model was the IAWQ-1 model with elimination of nitrification and denitrification processes, 5 state variables were considered for all compartments in the plant : heterotrophic biomass, inert particulate material, slowly hydrolyzable particulate substrate, soluble substrate and oxygen.

Together with the information on wastewater temperature, an overall heat balance was used to model the dynamics of the mixed liquid temperature. The dependence of mass transfer and biodegradation on temperature was also modelled. For the primary clarification a model was developed on the basis of the 5-layer model of Lessard & Beck. A first order hydrolysis reaction of the slowly biodegradable particulate fraction is included and the settling velocity depends on sewage features, i.e. storm sewage has better settling properties than normal sewage. Secondary clarification was modelled according to Takacs, using a 10-layer one-dimensional model.

The river quality model

The SALMON-Q model (Wallingford Software) is a dynamic model for river quality analysis. It considers the advection dispersion equations for dissolved substances and suspended solids in one-dimensional channel networks. For this study, the DO balance was modeled, accounting for the decay of BOD, reaeration and algae respiration (photosynthesis was not considered as the river is covered).

THE SYSTEM

The sewer system

Part of the Brussels urban drainage system was chosen as a model to illustrate the problem. The system consists of five collectors on the river Zenne. The total drainage area is about 5400 ha and contains ca. 300 000 inhabitant equivalents. The five collectors are connected to a WWTP by a trunk sewer with a capacity of 5 times the dry weather flow. At the outlet of each collector, an overflow structure discharges the excess flow to the river (option CSO). In a second scenario, on-line storage basins are placed at the outlet of each collector, to limit the overflow frequency to 7 per year (option BAS).

Measured data were used for the pollution load under dry weather flow conditions, while literature data were used for washoff concentrations during storms. With regard to the sedimentation problem, it was assumed that no sedimentation takes place in the pipe network. In the storage reservoirs, the sedimentation efficiency depends on the degree of filling of the basin.

The wastewater treatment plant

Four operating scenarios were evaluated with respect to the impact on the effluent quality, i.e. the combination of clarifier effluent and treatment plant bypass, especially under transient flow conditions :

- S1. Base Case : a maximum of 5 DWF is passed through the primary clarifiers (2 hours retention time), of which 2.5 DWF is sent to the aeration tanks, the remainder being bypassed to the river. In the aeration tanks (9 hours RT), dissolved oxygen (DO) control is based on a 3 intensity level system allowing to increase the aeration capacity if DO decreases below 2 mg/l. Similarly, reduction of the aeration intensity occurs when DO increases above 4 mg/l. For the secondary clarification (6 hours RT), a constant sludge recycle flow rate defined by a recycle ratio of 25 % of mean DWF. The sludge age was approximately 9 days.
- S2. Storm Tank : a storm tank with a volume of 6 hours DWF is installed after the primary clarifiers; whenever the outflow of the primary clarifiers exceeds 2.5 DWF, the excess is diverted into the storm tank. When the tank is full, the excess is bypassed to the river.
- S3. Step Feed : distribution of the influent over the 3 aeration tanks instead of input into the first one.
- S4. Ratio control of the recycle flow rate : the recycle flow rate is no longer constant but is set to 25% of the influent flow rate.

The river

Between the inlet and the outlet from Brussels, the river was partitioned in segments of about 800m for the calculations with the quality model. Emissions (BOD, DO, SS, temperature and flows) from the CSO and from the WWTP were considered on a 10 minute time base. At the downstream boundary, measured flows, daily temperatures and concentrations were imposed for BOD (5mg/l), DO (7mg/l) and SS (10mg/l).

MAJOR RESULTS

The results presented are based on the simulations for the complete year of 1986 on a 10 minute time base.

A major reduction of the CSO emissions is obtained through the installation of the storage basins in the sewer network, especially with regard to the suspended solids. Although this leads to a decrease in the efficiency of the WWTP and to an increase in the emissions from the treatment plant by about 50%, the net effect of the basins is still beneficial. However, the basins have only a marginal effect on the - from the point of volumes - most important overflow events.

The global emissions for the different WWTP scenario's show only minor differences. The best overall scenario is the one with the storage tank (S2) which gets round the limitation of the capacity of the WWTP. The more complex management schemes for the WWTP do not prove to be globally superior to the S2 scenario. However, some trends in the concentration and mass flux distributions indicate that these schemes might be useful in the framework of a dynamic - influent driven - management of the WWTP under transient conditions. This could especially be the case if the settling characteristics of the sludge are less good than those assumed for this study.

The immission simulations clearly show the abrupt deterioration of the water quality during CSO events. These events are usually short-lived, but successions of - not necessarily extreme - CSO events during period of low river flows and high temperatures may cause critical situations (DO < 3 mg/l) that may last for several weeks. Downstream of the WWTP, the difference between the scenario's without and with CSO control measures becomes less marked. Critical situations still occur, even with the CSO control, but they are less frequent and of shorter duration.

CONCLUSIONS

The study has proven that tools are available nowadays that allow for an integrated approach of the sewer - WWTP - river system. The methodology based on the statistical analysis of long time series of immission characteristics is the best - if not the only - way to evaluate the risks associated to the system : some of the most critical situations encountered would most probably not have been assessed in an event based approach, as they resulted from combinations of events and conditions.

By this, however, the authors do not pretend that the use of the models is straightforward. Several problems remain to be solved with regard to the modelling, including the conceptual representation of phenomena (e.g. 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 imission characteristics (which are the relevant variables and what are the relevant stochastic characteristics of the series ?) towards the environmental impacts.

ACKNOWLEDGEMENT

The authors wish to thank the Administration for Natural Resources and Environment of the Brussels Region, under which authority part of this study was conducted.

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