8th International Conference on Urban Storm Drainage, 1996

Water Quality Modelling for the Ljubljana Master Plan

Ole Mark* Cecilia Appelgren** Martin Kosir ***
* Danish Hydraulic Institute, Agern Allé 5, 2970 Hørsholm, Denmark.
** Urban Hydroinformatics Centre, Gjörwellsgatan 22, S-100 26 Stockholm, Sweden.
*** Vodovod-Kanalizacija, Ambrozev Trg 7, 61000 Ljubljana, Slovenia

Keywords
Combined sewer overflow, integrated modelling, master plan, mathematical models, MIKE 11, MOUSE TRAP, pollution impact, river, sewer.

Abstract

At present, the development of a Master Plan for the sewer system in Ljubljana, Slovenia, has been initiated. One of the objectives of the Master Plan is to improve the water quality in the Ljubljanica River which flows through the city of Ljubljana. The pollution in the Ljubljanica mainly originates from industries upstream of the city and from numerous combined sewer overflows within the city. Water quality models have been setup for both the river and for the sewer system in order to assess the impact from the combined sewer overflows on the water quality in the river. The present paper describes the methodology and the results achieved so far within the project.

Introduction

The city of Ljubljana - the capital of Slovenia - as an urbanised catchment area of approx. 4,000 ha with approx. 600 ha contributing from impervious surfaces. The length of the sewer system is approx. 700 km and the system has a daily load of approx. 240,000 person equivalents including industrial wastewater. At present, the treatment of the sewage is mechanical treatment at a wastewater treatment plant located downstream of the city.

Today the sewer system does not perform satisfactory. During heavy rain the sewers discharge to the Ljubljanica river and the overflow may couse a sevir decrease in the oxygen concentration in the river. Further, sediment deposits decrease the hydraulic capacity of the sewers (Mark et al. 1995) and problems exist with infiltration of ground water and inflow from the river to the sewer system. In order to improve the performance of the sewer system, the development of a master plan has been initiated. The master plan aims at solving the mentioned problems and at the same time harmonise an upgrade of the wastewater treatment plant with the sewer system.

Methodology for Evaluation the Effect of the Combined Sewer Overflows on the Water Quality in the River System

The methodology for evaluation the effect from the combined sewer overflow (CSO) on the water quality of the Ljubljanica river is based on integrated modelling of both the sewer system and the rivers. Ie the sewer system and the rivers are simulated in conjunction and the results from the sewer modelling is used directly in the river model.

The project is carried out as a relative study of the pollution loadings on the Ljubljanica with pollutographs calculated by use of an advection-dispersion model (MOUSE AD) for the sewer system. Only conservative pollutants are studied in this part of the project. The study of impact on the river from the sewer system includes the following items:

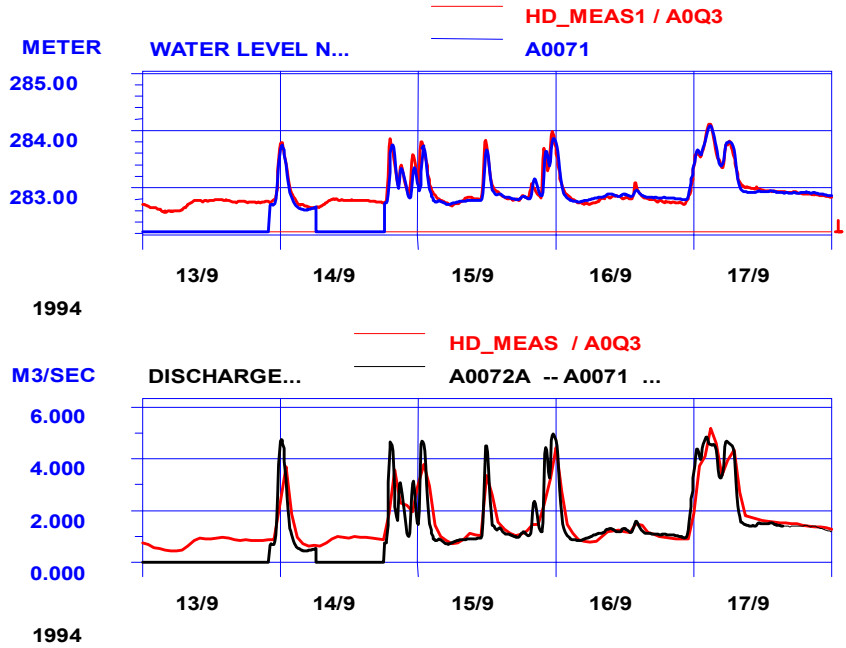
- A hydrodynamic model of the sewer system is setup, calibrated and verified for the existing conditions in the sewer system.
- An advection-dispersion model of the sewer system is setup and verfied against measured concentrations at the three most active overflow weirs.
- A hydrodynamic and an advection-dispersion model is setup and calibrated for the recieving waters, ie the river system.
- Long term simulations, covering 2-3 years, are carried out in order to identify the most important combined sewer overflows with respect to water and mass of pollutants discharged to the river.
- Single rain events are simulated with the advection-dispersion model for the sewer system, in order to evaluate the impact from the CSOs on the concentrations in the river.
- Strategies for rehabilitating the sewer system are evaluated with respect to the water quality in the Ljubljanica river.

In the next sections more details are given on the calibration and the validation of the models.

Hydraulic Description of the Sewer System

The hydrodynamic model of the Ljubljana sewer system is a full hydrodynamic MOUSE model for sewers. (Lindberg et al 1989). The model has been calibrated and verified against water levels and discharges measured at 17 locations. An example of the calibration results from the hydrodynamic model can be seen in Figure 1.

Figure 1.Example of calibration results for the Ljubljana sewer system (Gustafsson et al. 1995).



Transport of Pollutants in the Sewer System

The transport of pollutants in the sewer system is described by use of an advection-dispersion model (MOUSE AD) based on the full hydrodynamic MOUSE model. The MOUSE AD model is a part of the MOUSE TRAP modelling system (Garsdal et al 1994). MOUSE AD is capable of describing the transport of dissolved conservative pollutants in sewer systems and hence it is capable of describing the temporal variation of the pollutants discharged out of the sewer system during rain events.

The MOUSE AD model has been established based on the hydrodynamic model for the Ljubljana sewer system. For the present project the input data for MOUSE AD consist of the loadings to the sewer system from the industry together with concentrations measured in the wastewater during dry weather flow. Based on measurements the concentration of the selected pollutant, Ammonium, was set to 33.8 mg/l in the wastewater. The rain is assumed to be clean as no data is available for this parameter. The dispersion coefficient has been selected to 2 m^2/s, which is a typical value for sewer systems.

In order to validate the model measurements have been carried out in three combined sewer overflows during three rain events. For each overflow structure Ammonia, Oxygen, COD, suspended solids and electrical conductivity were measured. For the present project only simulations with Ammonia has been carried out; however it could be interesting also to try to simulated BOD/COD. This may however be difficult as sediment deposits exist in the sewers and these may contribute significantly to the COD in the CSOs.

Two rain events of the tree rain event have been simulated so far: one rain event in April and one rain event in May 1995. The results in terms of times series of concentration at some of the overflow weirs can be seen in Figure 2.

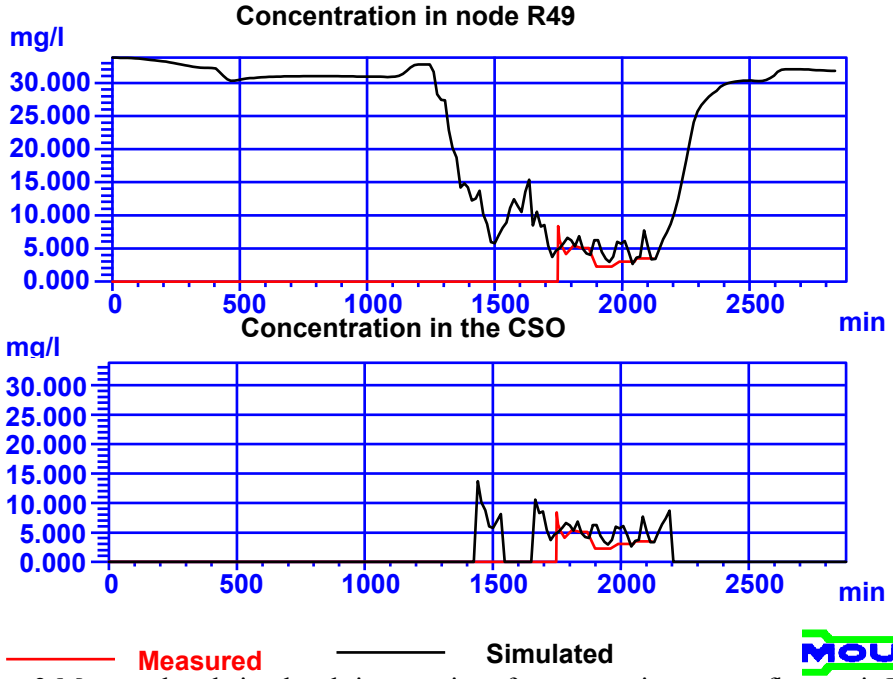


Figure 2 Measured and simulated times series of concentration at overflow weir R49 for the rain event in April 1995. Left: the time series concentration behind the weir in the sewer system. Right: the time series of concentration in the CSO.

The first part of figure 2 shows the diurnal variation in the concentration of the wastewater. The second part of the figure shows the dilution by the rain together with the measured concentrations. Figure 2 shows a good agreement between the measured and the simulated concentration of Ammonium in the overflow water at weir R49. Similar results were achieved for the the other overflows structures both for the rain in

April and for the rain in May. Based on these results it was concluded that the model was capable of predicting the concentration of Ammonia in the CSOs. At present (Ultimo 1995) longtrem simulations are carried with historical rain event in order to identify the most important CSOs with respect to pollutant mass discharged out of the sewer system.

Modelling of the Receiving Waters

A MIKE 11 model **Ref./4/** has been established for the Ljubljanica river, which flows through the city of Ljubljana. The river model contains the two main rivers: Ljubljanica (61 cross-section) and Grubrajev (15 cross-sections), the two tributaries: Mali Graben and Gradascica and four hydraulic structures.

The downstream boundary for the river model is a rating curve derived from the mean slope in the last part of the Ljubljanica. The MIKE 11 model has been calibrated against a steady state profile in the river. The steady state profile consisted of a constant flow of 180 m^3/s. The deviation between the steady state profile and the model was maximum in the order of 30 cm. A short summary of the calibration results can be seen in Table 1. The model has been validated against water levels measured at the Moste gauge staion in the Ljubljanica river.

Table 1. Obeserved and simulated water levels on the Ljubljanica river.

Chainage on Ljubljanica (km)	Observed water level (m)	Simulated water level (m)	Difference in water level (cm)
15.841	264.60	264.90	0.30
16.091	264.8	264.88	0.08
21.653	265.5	265.53	0.03
22.056	265.9	266.00	0.10
22.633	271.1	270.8	-0.30
22.801	272.8	273.0	0.20

The water quality model selected for the project is a MIKE 11 advection-dispersion mode, ie no water quality processes are included. For the project measurements of the quality parameters in the river were taken upstream and downstream of the city.

Conclusion

An advection-dispersion model has been setup for the sewer system in Ljubljana as a part of the development of a master plan for the sewer system. The model has been

validated against measured concentration of Ammonium at three overflow structures for two rain events. The sewer model gives a good prediction of the concentrations in the CSOs. Long term simulation are carried out in order to indetify the CSOs which have the most sevir impact on the water quality in the river.

An advection-dispersion model has been setup for the receivinf waters in order to evaluate the effect of the CSO on the water quality in the rivers. The river model has been calibrated against a steady state profile and validated against water levels simulated at one gaouge station.

These two models constitute the basis for intergrated modelling of the impact from the sewer system on the rivers. The modelling of the impact from the sewer system on the water quality in the river will be carried out when flow data from 1995 becomes available.

References

/1/. Garsdal, H., Mark, O., Dørge, J., Jepsen, S-E. (1994). MOUSE TRAP: Modelling of Water Quality Processes and the Interaction of Sediments and Pollutants in Sewers. Specialized International Conference: *"The Sewer as a Physical, Chemical & Biological Reactor"*. Aalborg, Denmark.

/2/. Gustafsson L. G et al. (1995) *Ljubljana Sewerage Master Plan. Summary activity 1-5.* Internal report Danish Hydraulic Institute, Denmark.

/3/. Mark, O., Cerar, U. and Perrusquía, G., (1995). "Prediction of Locations with Sediment Deposits in Sewers." Specialized International Conference: *"The Sewer as a Physical, Chemical & Biological Reactor"*. Dundee, Scotland.

/4/. Danish Hydraulic Institute. **MIKE 11 Short Description.** Danish Hydraulic Institute, Agern Allé, 2970 Hørsholm, Denmark.

/5/. Lindberg, S., Danish Hydraulic Institute, Jørgensen, Willemoës, T., EMOLET: **"MOUSE - Modelling of Urban Storm Sewer Systems."** International Symposium on Comparison of Urban Drainage Models with Real Catchments, Dubrovnik, April, 1986.