Towards an integrated management of the Ile-de-France sanitation system

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KEYWORDS

Modelling, combined sewer, WWTP, river, artificial intelligence

ABSTRACT

Between 1970 and today, the sanitation system in the Paris area has undergone a real industrial transformation. This change consisted, on the one hand, in improving the quality of the treatment of the wastewater treatment plants, and, on the other hand, in changing the practices of flow management in the sewer networks. This evolution in sanitation has led to a spectacular reduction in the flow of pollutants discharged into the Seine, allowing the restoration of its physio-chemical quality and the improvement of its microbiological quality.

Pursuing this improvement process requires the development and deployment of intelligent operating support tools. In the management of hydraulic flows, tomorrow it will be a question of moving towards an integrated management of the system made up of the sewerage network, the treatment plant and the river. The principle of this integrated system is to adapt the quality of the outfall of the sanitation system to the state of the river and thus to ensure that regulatory objectives are achieved with a limited and controlled environmental impact. Thus, in the future, wastewater treatment plants will be required to be able to adapt their performance according to the constraints imposed by the sanitation network (flow, loads applied in pollution) and the treatment objectives defined according to the state of River. To meet these challenges, for several years now, the SIAAP (Greater Paris Sanitation Authority) Innovation Department and its partners have developed a network of measurements enabling real-time data to be acquired within the network of sewerage, treatment plants and the river. The processing of these data and their use will help to develop mathematical modeling tools that will ultimately make it possible to assess in real time the impact of the operating choices of treatment plants on the river. This impact is evaluated with regard to the quality of the river, the forecast of pollution flows brought to the factories and the capacity of the factories to process these flows.

1 INTRODUCTION

Between 1970 and today, the sanitation system of the Paris conurbation has undergone substantial industrial transformation. This change consisted of improving the treatment quality of the wastewater treatment plants (WWTP) of the Paris conurbation, growing from only treatment of carbon pollution to a complete treatment of carbon, nitrogen and phosphorus. The construction of treatment facilities has been followed by the evolution of the wastewater dispatching practices in the sewer networks. The implementation of a real-time management of influent flowing through the networks, based on metrological and mathematical tools (MAGES, Model for the management of the wastewater of the Paris conurbation), allowed a significant reduction of the volume of non-treated water sent into the river from combined sewer overflows (CSO) during rain events (Rocher and Azimi 2017). Such changes have led to a strong reduction of pollutants discharged into the Seine; reduction which allowed the improvement of the microbiological quality of the river and helped to restore its good ecological and chemical status (Rocher and Azimi 2016; Rocher and Azimi 2017). The return of an important fish diversity in the river shows the restoration of the quality of the Seine; 32 different species of fish are recorded today in the Seine around the city of Paris compared with 3 in 1970 (Azimi and Rocher 2016).

To continue the improvement of the quality of the river, the development of smart tools is required to support operators. From the management of water flows today, one has to move towards an integrated management of the whole system made by the sewer, the WWTP and the (Figure 1). This integrated system consists to adapt the quality of the wastewater to the river conditions for satisfying the regulatory objectives (good ecological and chemical status in surface water body).

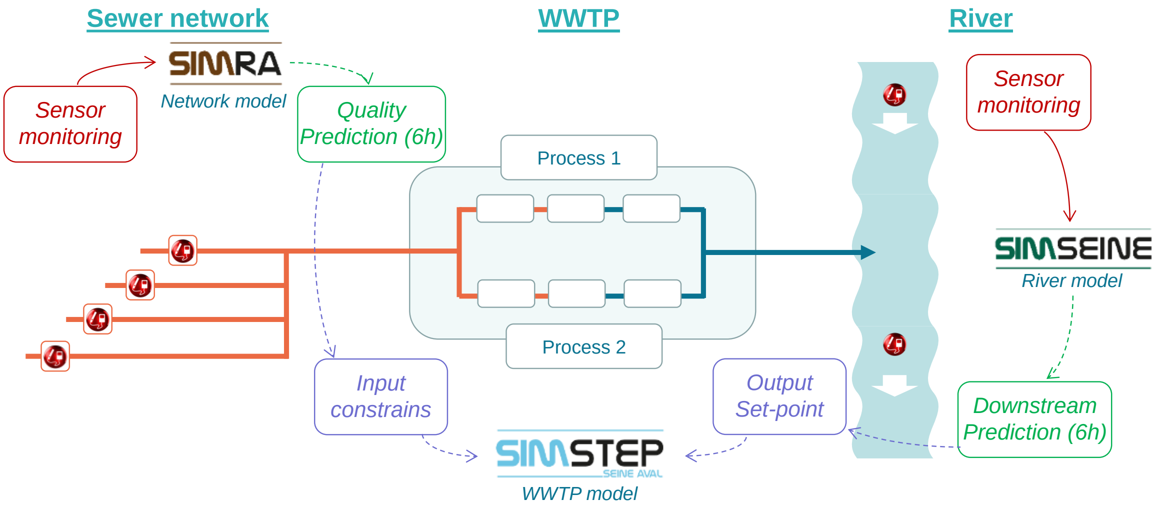

Figure 1. Diagram of an integrated management of the system made by the sewer network, the WWTP and the river. (Red color represents the monitoring, green color represents quality predictions and purple represents the constrains and output set-point)

The two main issues concerning the river are real time quality monitoring and the ability to give an estimation of its quality for the subsequent 6 hours. Based on this forecast, adapted target values can be set for the WWTP outfall. Therefore, a densification of sensors has to be done in the river for monitoring the quality of surface waters. Moreover, based on the existing tools, a mathematical model has to be designed for the prediction of the river water quality, named SIMSEINE (Even et al. 1998; Even et al. 2004; Flipo et al. 2004; Even et al. 2007; Flipo et al. 2007).

Considering the sewer network, the existing model of prediction of the water flows into the sewer system (MAGES) has to be completed with data concerning the quality of the wastewater passing through the networks. In this way, the pollution concentrations received by the WWTP would be predicted for the subsequent 6 hours with a SIMRA model. This implies a densification of the instrumentation in sewer network for its monitoring (integration of turbidity and conductivity sensors) and an evolution of the MAGES model to be able to estimate the transport of matter, and not only the transport of water volumes.

Finally, the operation of WWTP should evolve considerably, because it holds a central place within the integrated system. Thus, the WWTP should be able to adapt its performances to the constraints imposed by the sewer network (flows, applied pollution loads) and the target values set for the river. To reach this goal, a prediction model, named SIMSTEP has to be designed, validated and calibrated.

At the end of the story, the three models (SIMRA, SIMSTEP, SIMSEINE) will have to “talk” together to help operators to make the right decision at the right moment.

These research activities are carried out in two research programs, Mocopee and MeSeine Innovation. Created in 2014, the Mocopée research programme is built around four areas of research devoted (1) to the design of innovative metrological tools (continuous measurement and methods for characterizing matrices), (2) to the modelling and control of wastewater and sludge treatment processes, (3) to the integrity of wastewater transport and treatment systems, and (4) to innovative concepts (upstream research and recovery). On the other hand, the MeSeine Innovation research programme created in 2020, helps to advance knowledge on the quality of the Ile-de-France rivers and develop tools for assessing and anticipating any environmental stress.

2 THE RIVER QUALITY MONITORING AND MODELLING

2.1 Monitoring of the Seine

Since 1990, the SIAAP has implemented a monitoring network in the river Seine all along the Paris area to assess the influence of urban activities on the water quality (Figure 2). This monitoring network, named MeSeine integrates assessment of the quality of surface water using different approaches such as physio-chemistry, bacteriology, micro-contamination and biotope (O_2, carbon, nitrogen, phosphorus, bacterial indicators, regulated micro-pollutants, emerging micro-pollutants, fish species, macro-invertebrate, micro-algae). The network covers the river Seine from Choisy-le-Roi to Méricourt, more than 30 30 km away from the last SIAAP WWTP.

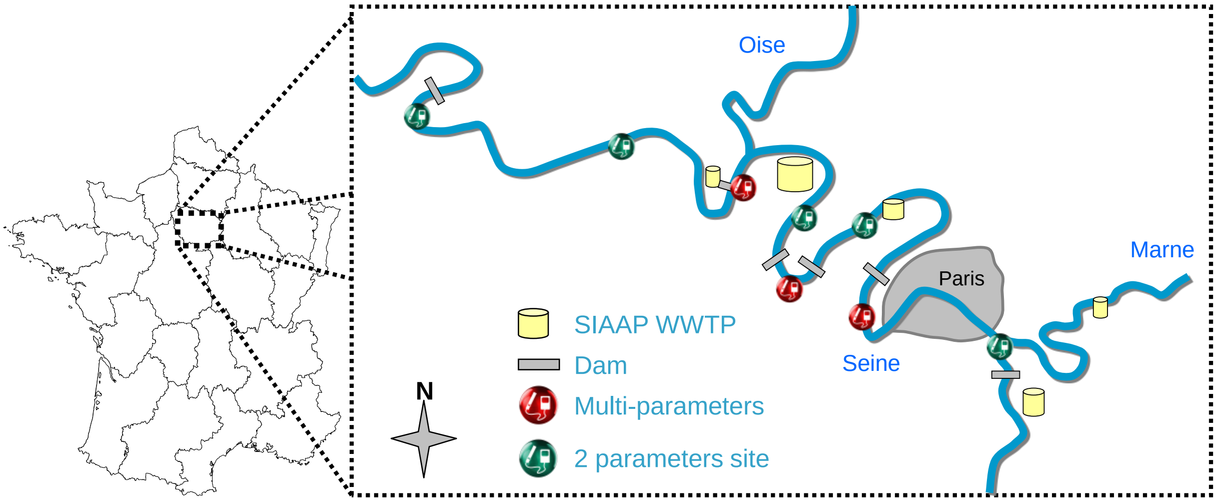

Figure 2. The monitoring stations on the river Seine along the SIAAP area (MeSeine monitoring network)

The MeSeine network has 8 high-frequency measurement stations for temperature and dissolved oxygen. These devices make it possible to have, in real time, a very good information about the quality of the water. As part of the integrated management project, 3 stations, strategically located in the Paris area, are being fitted out with additional measures (Figure 2, red dots). In addition to the temperature and the oxygen, these three sites will ultimately allow real-time monitoring of nitrogen and phosphorus. Thus, at all times, it will be possible to have clear and reliable information on the quality of the river along the SIAAP area of influence and to feed a mathematical model to predict the water quality for the subsequent 6 hours.

2.2 The Modelling of the Seine River

The SIAAP is already able to predict the quality of the river Seine using the ProSe mathematical model. The ProSe software can simulate the water quality of a set of rivers constituting a hydrographic network. A river is defined by a set of variables among which we distinguish physical variables, such as water speed, depth, wetted section, which determine the transport of constituents and the development of biological processes in the environment, and biochemical variables, which changes depend on reactions with other constituents and internal (temperature) and external (lighting) factors to the system.

The ProSe software is made up of several sub-models the resolution of which is decoupled in order to allow modular use. A hydraulic model solves the one-dimensional Saint-Venant equations and is coupled with a transport model by advection and dispersion, a transport model of particles and a biochemical model based on the RIVE model (Billen et al. 1994; Garnier et al. 1995), representing the main processes involved in the water column and benthic process modules in the silt or periphyton

Given its modular structure the applications of the ProSe model are numerous. Designed to study the issues concerning the water quality and deoxygenation of an ecosystem, it is also suitable for treating hydraulic questions (effect of movements of thresholds, validation of series of measurements, flow propagation) and transport of conservative constituents (propagation of pollutants, interpretation of tracing campaigns, transfer time, reverse problem of finding a source of pollution).

The work that has been done on the ProSe model until now was to improve its simulation quality regarding nitrogen and phosphorus. The coming issue is now to adapt its functioning to a real time modelling fed by the data coming from the MeSeine monitoring network.

3 THE SEWER NETWORK MONITORING AND MODELLING

As part of the operation of the sanitation network, SIAAP has developed a hydraulic model of its sewer system, the MAGES model. Based on data from speed, flow and water height sensors and fed by a meteorological model, MAGES makes it possible to predict the water flows passing through the sewer network and arriving at the SIAAP's WWTP over periods of 6 to 24 hours.

SIAAP is currently working on the development of a wastewater quality measurement station. The objective is to allow the evaluation of the quality of the effluents (suspended solids, nitrogen) through physical measurements (turbidity, conductivity, UV). Once this measuring station has been validated in terms of its operation and maintenance needs, it can be deployed at different nodes of the sanitation network and thus make it possible to obtain, in real time, reliable information on the quality of the effluents passing through. These data will then be integrated in real time into the MAGES model, or into an adapted model, in order to obtain predictive information on the quality of the water arriving at the plants.

4 THE WWTP MODELLING

The Seine Aval (SAV) wastewater treatement plant, the largest WRRF in France (5 million PE, Paris), is being upgraded in order to tackle todays' wastewater treatment challenges such as urbanization and water resources protection. Under this modernization programme, more intensive nutrient removal processes including membrane bioreactors (MBR) and biofilters have been applied in the plant. In 2022, chemically enhanced primary treatment (CEPT) will also be added to the plant. Without support tools such as mathematical process models, treatment performance evaluations and operation strategy developments will be complicated for the plant with large-scale use of intensive processes. Therefore, in parallel with the upgrade of the Seine Aval WWTP, SIAAP launched a project to develop a whole plant model for the SAV facility. Currently, models for the nitrifying biofilter and post-denitrifying biofilter process as well as the CEPT process have been successfully established. The modelling works for the pre-denitrifying process and the MBR process are still underway.

5 CONCLUSIONS

Deploying this global management system means not only that a dense sensor network has to be available to monitor the evolution of water quality passing through the three compartments (sewer – WWTP - river). It also means that the collection and the processing of data produced by these measurement systems, in real time, have to be considered. For both river and sewer, a data validation chain has to be set between the monitoring network and the models discarding invalid data and keeping only reliable ones. The issue to tackle will be then to make the automatic data processing and model predicting to obtain a result that will feed the models. After what will come the time for all these models (Sewer, WWTP, river) to talk to each other to help operators to make the good decision at the right moment!

To be continued…

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