In: Proceedings 11th IWA Conference on Instrumentation, Control and Automation (ICA2013)
September 18-20 2013, Narbonne, France

Establishment of control strategies for chemically enhanced primary treatment based on online turbidity data

Tik S.*, Langlois S., Vanrolleghem P.A.***

* model*EAU*, Université Laval, Département de génie civil et de génie des eaux, 1065 av. de la Médecine, Québec, QC, G1V 0A6, Canada (e-mail : sovanna.tik.1@ulaval.ca)

** Ville de Québec, Division du traitement des eaux, 105 boulevard Henri-Bourassa, C.P. 700, Québec, QC, G1R 4S9, Canada

Abstract: In Quebec City (Canada), the wastewater treatment plants (WWTPs) are highly subject to weather conditions, even more since the construction of combined sewer retention tanks. The primary treatment, which has been diagnosed to be the weak point of the treatment process, has therefore been enhanced by chemical addition. This study's objective is to set up control strategies to optimize chemical dosage in terms of reducing costs and resource use without degrading effluent quality. A basic sedimentation model for chemically enhanced primary clarifiers has been developed, showing that the effect of alum addition can be represented by varying two settling characteristics: the settling velocity and the fraction of non-settleable suspended solids. Using feedback control of alum dosage based on effluent turbidity data, a simulation study predicted savings of about 30% on the chemicals supply compared with the constant dosage, for a similar average performance.

Keywords: chemically enhanced primary treatment; mathematical modelling; real-time process control; turbidity sensors

INTRODUCTION

For years, the Saint-Charles river (Quebec, Canada) has suffered from around fifty combined sewers overflows (CSO) annually. In the effort to regain recreational uses of the river and re-naturalize the riverbanks, fourteen retention tanks (RT), totalizing a capacity of over 150,000 m³, were constructed to reduce the CSO. However, the RT emptying is currently only controlled on the basis of flow rate. At the end of a rain event, the RT are indeed emptied in a way to reach the maximum acceptable flow rate at the inlet of the wastewater treatment plant (WWTP), the aim being to recover the storage volume as fast as possible in case of another rain event.

Two WWTP, named East and West, collect wastewater of the 540,000 inhabitants of Quebec City. They have respectively been designed to treat a mean flow rate of 9,625 m³/h and 6,540 m³/h, their acceptable peaks flow rates being about 15,625 m³/h and 13,125 m³/h. With the current emptying management rules of the RT, the WWTPs have to operate at maximum capacity for extended periods of time after each major rain event. Such conditions can deteriorate the treatment process, especially primary clarification, which induces fouling of the subsequent biofilters treatment stage. To respect legal effluent requirements, the primary treatment has thus been enhanced by chemical addition on an event basis.

A preliminary study based on lab experiments and confirmed by one full-scale test recommended to use 70 mg/L of alum on a dry basis and 0.2 mg/L of polymer (Lajoie and Collin, 2008). However, other experiments have in the meantime shown that in many cases such dosage is often excessive, resulting in operational problems and economical loss. To evaluate the possibilities of optimizing the dosage, experiments have been performed to model the primary clarifier behaviour without and with alum addition. The study's objective was to set up a real-time control system, as a decision-support tool for the operators. Chemical addition control based on online turbidity data is presented here.

DATA ACQUISITION AND ANALYSIS

The legislation standards relevant for this study are based on total suspended solids (TSS) concentration data, which are time consuming and expensive to produce, even more if high frequency time series are needed. Turbidity data recorded by a sensor are thus very interesting. Furthermore, unlike TSS, turbidity data are immediately available, allowing a real-time controller development to be considered.

The possibility to monitor influent and effluent quality of the primary clarifiers has been evaluated, resulting in the permanent installation of a turbidimeter (Hach Solitax®) at the outlet of the primary clarifiers. For the duration of the project, a portable measuring station RSM30 (Primodal, Canada; Rieger *et al.*, 2008) equipped with several sensors, in particular with turbidimeters, has been installed at the inlet of the primary clarifiers. Figure 1 shows typical recorded data of the daily dynamics in turbidity measurements at the inlet and outlet of the primary clarifier and the impact of the rain event occurring on April 17th. Calibration tests showed that the correlation between turbidity and TSS can evolve depending on water characteristics and further investigations may thus be needed in this area. Still, the two measurements dynamics seem alike, which allows us to consider that turbidity measurements provide a suitable assessment of TSS concentration.

From an operational point of view, the long-term in-situ experiments that were conducted revealed that to ensure proper operation, the sensors' maintenance can be limited to one manual cleaning per week. This is an acceptable effort.

In order to be used as controller inputs, raw data given by the sensors need to be filtered to eliminate non representative data, such as outliers which are identified using statistical methods that are tuned on the basis of recent previous data (Alferes *et al.*, 2012). Moreover, a kernel smoother has been applied to decrease noise. This data treatment is important to help developing a stable controller. With a 5-second measuring interval, the sensor is recording a large amount of data, and a moving average is calculated and stored as 5-minute interval data. With these data simulations of several days of data were performed.

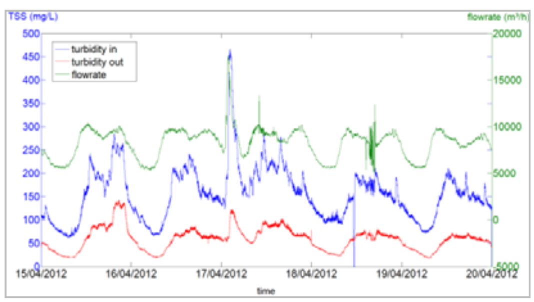

Figure 1 Daily dynamics of flow rate and turbidity at the inlet and at the outlet of the primary clarifier.

MODEL DEVELOPPEMENT AND CALIBRATION

The model used for developing the controller has been set up in WEST® (mikebydhi.com). To determine the hydraulic configuration of the model, several tracer tests using rhodamine WT have been performed. Results showed that the sand traps, at the inlet of which alum is injected, can be modelled by four completely mixed reactors. The primary clarifiers can be fairly well represented by a reactor composed of homogeneous layers. In the present case, eleven layers were needed and the reactor was fed in the sixth layer. Furthermore, a tracer test performed simultaneously on the seven parallel primary clarification units of the East WWTP showed excellent hydraulic distribution over the seven units, allowing them to be modelled together as one lane. Finally, since the turbidimeter at the primary clarifiers outlet is located after a channel, the latter has also been modelled by inserting an additional reactor to ensure that the resulting delay is properly covered. This results in the configuration presented in Figure 2.

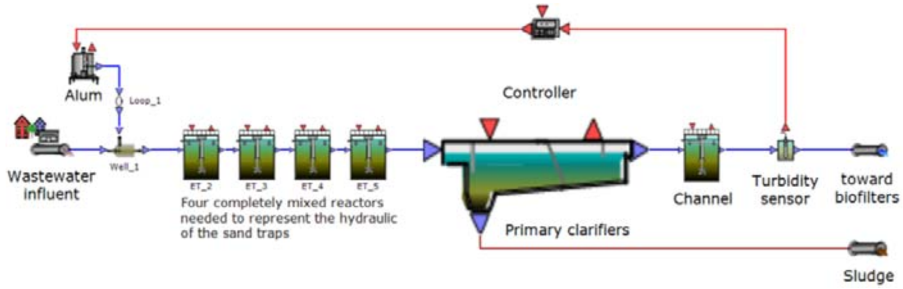

Figure 2 Model configuration of the East WWTP primary clarifier in WEST® (mikebydhi.com).

The proposed sedimentation model was based on the model presented by Gernaey *et al.* (2001). The effect of alum addition on sedimentation was modelled by making the fraction of non-settleable suspended solids depend on the alum concentration (Figure 3a) and by extending the settling velocity model by a dependency on the local alum concentration (Figure 3b).

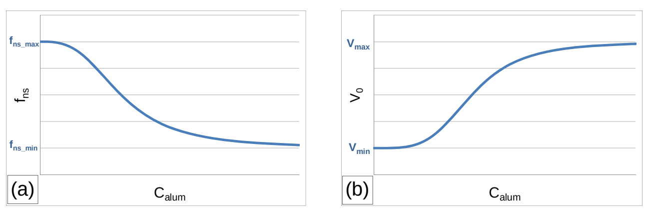

Figure 3 Proposed evolution of (a) the non-settleable fraction of TSS (f_{ns}) and (b) settling velocity, V_0, depending on alum concentration (C_{alum})

The proposed model enhancements allow a fairly good simulation of the primary clarifiers' outlet during an experiment of full-scale alum addition with step concentration changes (Figure 4). The delay between alum addition changes and related outlet TSS concentration variations is clearly visible in the data and simulation results. The peaks observed on the inlet TSS concentration data are probably due to an inaccuracy of the sampling or of the laboratory analysis, since they don't result in an increase of the measured outlet TSS concentration. Hence, the inlet TSS concentration peak values were replaced by the value of a linear interpolation and with this the observed behaviour could be reproduced quite well.

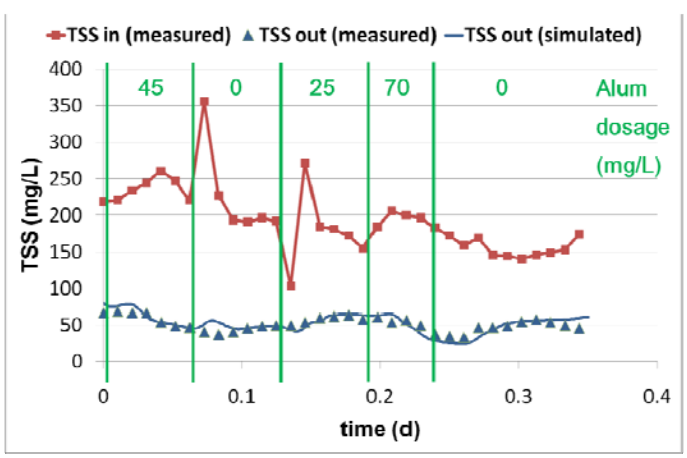

Figure 4 Experimental and simulated TSS results of a full-scale experiment on August 25th, 2011. The flow rate was approximately constant at 9,300 m^3/h.

CONTROL STRATEGIES

First, a feedback control on the primary clarifiers' outlet turbidity data was considered (Figure 2). A basic PI algorithm was implemented. To evaluate the possible gain of installing a controller, a simulation study was conducted using recorded inlet turbidity data. Three scenarios were simulated:

1) open loop situation, no alum is added;
2) a constant dosage which ensures that the TSS concentration at the outlet of the primary clarifiers is below a given value most of the time;
3) a controlled system which aims at respecting the same TSS concentration.

The results show that scenario 2 presents over-performance, which means that too much chemicals are used. Scenario 3 presents similar performance in terms of the respect of the effluent TSS limits. Yet, the effluent TSS presents higher peaks due to the controller response delay (Figure 5). However, this lack of reactivity can possibly be reduced by making some changes to the control algorithm, such as the inclusion of a feed-forward component.

The current algorithm already predicts incentive savings of about 30% on chemicals supply between scenario 2 and 3. Trials on wet weather conditions data are ongoing.

Once the controller is further optimized by additional simulation studies, implementation in the real system is planned and full-scale experiments will be performed to further validate the model and refine the tuning of the controller.

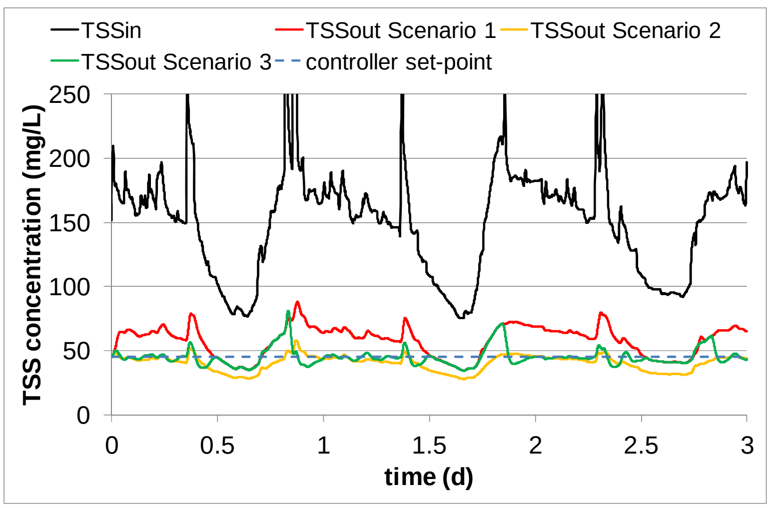

Figure 5 Combined TSS results of the 3 simulated scenarios.

ACKNOWLEDGEMENT

This study was conducted with funding provided by the Ville de Québec. Peter Vanrolleghem holds the Canada Research Chair on Water Quality Modelling.

REFERENCES

Alferes J., Poirier P. & Vanrolleghem P.A. 2012. Efficient data quality evaluation in automated water quality measurement stations. In: *Proceedings International Congress on Environmental Modelling and Software (iEMSs2012)*. Leipzig, Germany, July 1-5 2012.

Gernaey K., Vanrolleghem P.A. & Lessard P. 2001. Modeling of a reactive primary clarifier. *Water Sci. Technol.* **43**(7), 73-81.

Lajoie A. & Collin L. 2008. Ajout d’alun et/ou de polymères à la décantation primaire de la station Est. Technical report, Quebec City, Canada. pp. 54. (in French)

Rieger L. & Vanrolleghem P.A. 2008. mon*EAU*: A platform for water quality monitoring networks. *Water Sci. Technol.* **57**(7), 1079-1086.