Temperature and conductivity as control parameters for pollution-based real-time control

R.P.S. Schilperoort*, G. Gruber, C.M.L. Flamink*, F.H.L.R. Clemens* and J.H.J.M. van der Graaf***

*Department of Sanitary Engineering, Delft University of Technology, Stevinweg 1, 2628 CN Delft, The Netherlands (E-mail: *r.p.s.schilperoort@citg.tudelft.nl*)

**Institut fuer Siedlungswasserwirtschaft und Landschaftswasserbau, Graz University of Technology, Stremayrgasse 10/I, A-8010 Graz, Austria

Water Science & Technology **Vol 54 No 11–12 pp 257–263** © IWA Publishing 2006

Abstract Most sewer system performance indicators are not easily measurable online at high frequencies in wastewater systems, which hampers real-time control with those parameters. Instead of using a constituent of wastewater, an alternative could be to use characteristics of wastewater that are relatively easily measurable in sewer systems and could serve as indicator parameters for the dilution process of wastewater. This paper focuses on the possibility to use the parameters of temperature and conductivity. It shows a good relation of temperature and conductivity with the dilution of DWF (dry weather flow) during WWF (wet weather flow) a monitoring station in Graz, Austria, as an example. The simultaneous monitoring of both parameters leads to valuable back-up information in case one parameter (temperature) shows no reaction to a storm event. However, for various reasons, anomalies occur in the typical behaviour of both parameters. The frequency and extent of these anomalies will determine the usefulness of the proposed parameters in a system for pollution-based real-time control. Both the normal behaviour and the anomalies will be studied further by means of trend and correlation analyses of data to be obtained from a monitoring network for the parameters of interest that is currently being set up in the Netherlands.

Keywords Conductivity; control parameter; real-time control; temperature

Introduction

Real-time control (RTC) of wastewater systems is receiving more and more attention, not only from researchers, but also from practitioners in the field. The aim of control of the system is optimizing system performance, which is conventionally assessed in terms of CSO volumes, pollutant loads, or effluent concentrations. However, most parameters used as a performance indicator are not easily measurable online at high frequencies in wastewater systems, which hampers RTC with those parameters. An additional bottleneck is that the standards defined in the European WFD (Water Framework Directive) include constituents which, with current techniques, cannot be monitored in wastewater systems at all (Breukel, 2002).

Pollutants in DWF (dry weather flow) are both dissolved and adsorbed to particles, whereas pollutants in WWF (wet weather flow) are predominantly adsorbed to particles (Flamink, 2004). Therefore, the information required for RTC during WWF conditions consists of suspended solids transport and the dilution of DWF. This implies that the parameter turbidity, in combination with some indicator of the dilution of DWF, will be sufficient as a set of control parameters. This paper focuses on possible indicators of the dilution of DWF.

Large flows in the sewer system often coincide with diluted wastewater. However, especially at the onset of a storm event, wastewater with a DWF concentration can have a WWF flow rate. Therefore, flow rate alone is not a sufficient indicator for DWF

doi: 10.2166/wst.2006.744

Downloaded from https://iwaponline.com/wst/article-pdf/54/11-12/257/431196/257.pdf
by guest

dilution. Several constituents of wastewater originate mainly from DWF (e.g. NH_4^+) and can be used therefore as an indicator of DWF dilution. None of these, however, are very easily measurable on a large scale inside the sewer system (Vanrolleghem and Lee, 2003). There are examples of rather successful measuring programs that include, for instance, NH_4^+ and COD (e.g. Gruber *et al.*, 2005), but relative high maintenance demand and cost hinder, as yet, a system-wide application.

Instead of using a constituent of wastewater, an alternative could be to use a characteristic of the wastewater as a control parameter. Temperature and conductivity, for example, are characteristics of wastewater that are relatively easily and robustly measurable in sewer systems and could therefore serve quite well as indicator parameters for the dilution process of wastewater. This paper discusses the relation of temperature and conductivity with the dilution of DWF during WWF and the potential to use these parameters for RTC.

Methods

Temperature and conductivity as control parameters

In order to study the behaviour of the parameters of temperature and conductivity in wastewater, data from the city of Graz (Austria) have been used. A measuring station near a CSO provides information on the amount of water entering the site (Q sewer inflow) and (besides other wastewater constituents) its temperature (T inflow), the NH_4^+-N concentration and its conductivity. Temperature is measured *in situ*, the latter two in a bypass construction. For a complete overview of the measuring station, please refer to Gruber *et al.* (2004).

Figure 1 shows the variation of the parameters Q, T and NH_4^+-N during a 5-day period in April 2005. The first day (17 April) was a dry weather day with a typical variation in sewer flow over the day. The temperature of the water shows the same kind of variation: over a range of approximately 1.5 °C, relatively low temperatures during the night and relatively high temperatures during the day. Ammonium nitrogen concentrations vary

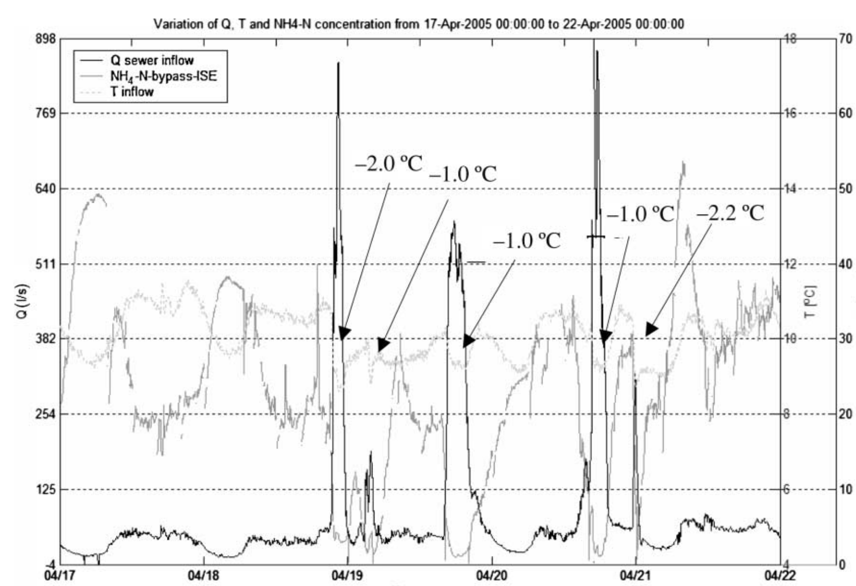

Figure 1 The variation of Q, T and NH_4^+-N for 18 April – 22 April 2005 in a monitoring station in Graz, Austria

Downloaded from https://iwaponline.com/wst/article-pdf/54/11-12/257/431196/257.pdf
by guest

between 20 and 30 mg/L. The values for NH_4^+-N during nighttime are invalid due to a failure of the bypass pump and should therefore be disregarded.

During the second day (18 April), a storm event occur red around 21:00 hours. Figure 2 shows in more detail the variation over the day of the parameters Q, T and NH_4^+-N. The storm event caused the sewer flow to increase from around 60 L/s to more than 850 L/s. At the same time, the concentration NH_4^+-N decreased due to dilution of wastewater from 20 mg/L to less than 5 mg/L. Prior to the storm event, the temperature of the wastewater shows the same variation as the previous day, with a difference between night and day temperatures of around 1.5 °C and a gradual transition in between. At the onset of the storm event, a sudden and sharp temperature decrease of about 2 °C can be seen. Apparently, the mixture of dry weather flow with colder storm water run-off causes the temperature of sewer water to decrease. The same dilution process that causes the ammonium nitrogen concentration to decrease is also responsible for the decrease in wastewater temperature. Therefore, for this specific example, temperature can be considered an indicator parameter for the dilution process after the onset of a storm.

The question arises as to whether this consideration holds for all storm events. To this purpose, more storm events have been studied. In Figure 1, considering the second (19 April 03:00 h), third (19 April 16:00 h), fourth (20 April 15:00 h) and fifth (20 April 23:00 h) storm events, the same phenomenon can be observed: a sudden and sharp temperature decrease that breaks the series of gradual temperature changes over a day. Comparison of the last two storm events indicates that the magnitude of the temperature change does not relate directly to the magnitude of the storm event: the large storm event of 20 April 15:00 h caused a temperature change of nearly 1 °C, the much smaller event later that day a change of more than 2 °C.

The observations in Figure 3 show that, depending on the predominant wastewater and air temperature conditions, a storm event also can cause a temperature *increase* in wastewater. The figure shows the variation of sewer flow and wastewater temperature for 4 and 5 June 2005 at the same monitoring station in Graz, Austria.

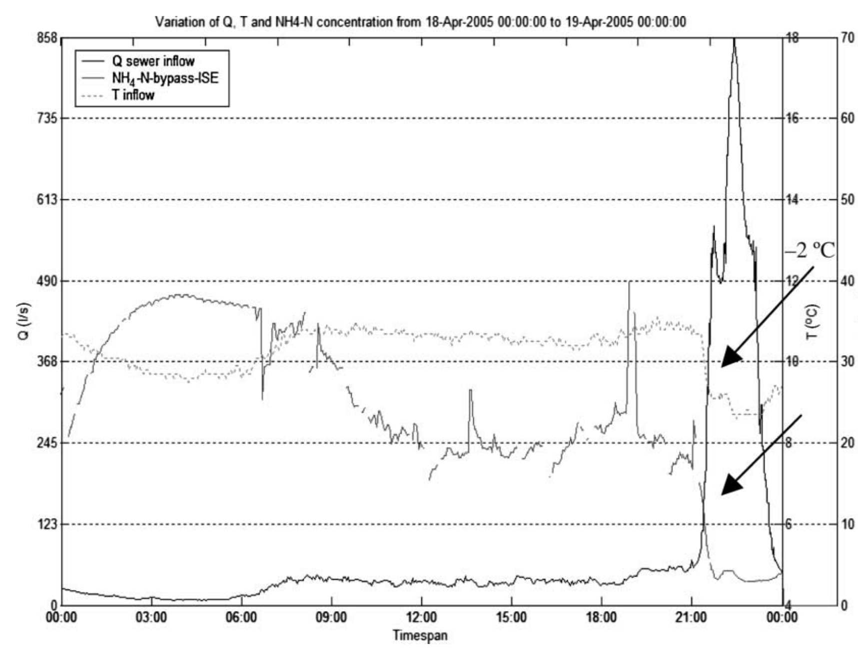

Figure 2 Detail of Figure 1: the variation of Q, T and NH_4^+-N on 18 April 2005

Downloaded from https://iwaponline.com/wst/article-pdf/54/11-12/257/431196/257.pdf
by guest

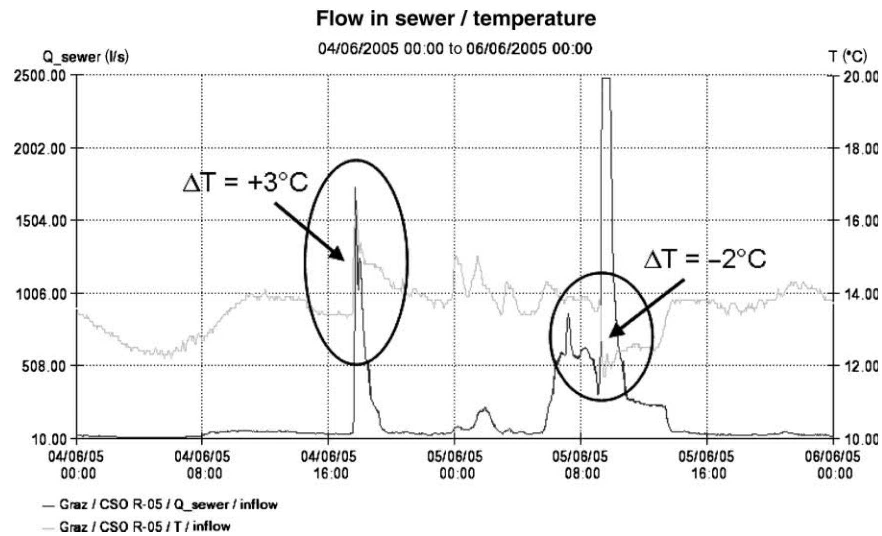

Figure 3 The variation of Q and T on 4 and 5 June 2005 at a monitoring station in Graz, Austria

During the two days, two storm events occurred: the first in the late afternoon of 4 June, the second the following morning. The first storm event caused a temperature change of plus 3 °C, whereas the second storm event is associated with a temperature change of minus 2 °C. This apparent contradictory behaviour can be understood when studying the weather conditions in the area before and during the storm events. 4 June 2005 was a warm day in Graz with a maximum temperature of approximately 29 °C. Before entering the sewer system, the runoff of the afternoon storm event was significantly warmed up by street and roof surfaces that had been exposed to these temperature conditions during most of the day. Therefore, the temperature of the wastewater *increased* when it became diluted with storm water runoff. The following night, however, the atmospheric temperature dropped to 13 °C. The runoff of the storm event in the morning of 5 June did not warm up as on the previous day, simply because all surfaces had lost their warmth during the relatively cold night. Consequently, it caused a *decrease* in wastewater temperature in the process of dilution.

The examples in Figures 1 and 3 show that the observed temperature changes due to dilution of wastewater are within a broad range of both positive and negative values. The reason for this is obviously that the temperature of storm water runoff that enters the sewer system lies within an even broader range due to the multitude of factors that influence the runoff temperature. The temperature of the rain before it reaches the ground, the amount of energy available in the various surface types (influenced by the season, hours of sunshine, cloudiness, etc.), and the time available for energy transfer all influence the 'average' temperature of storm water runoff. It would be rather difficult to take into account all these influences if one would want to calculate the temperature of the storm water runoff. A more practical way would be to *measure* the temperature of the actual runoff (in, for instance, a gully pot) at various representative locations throughout a catchment area and average the values proportional to the relative contribution of those locations. Knowledge of the temperature of storm water runoff determines the range of temperatures between which the registrations will vary: from the temperature of dry weather flow just before the onset of the storm event to the temperature of storm water runoff when sewer flow consists for nearly 100% of storm water. Hence, with both temperatures, the current dilution rate can be derived.

Downloaded from https://iwaponline.com/wst/article-pdf/54/11-12/257/431196/257.pdf
by guest

A small difference in temperature between storm water runoff and dry weather flow means no or little temperature change during the dilution of wastewater. An example of this can be seen in Figure 4, where the variation of the parameters Q and T are shown for 18 May 2005. The large storm event at 12:00 a.m. caused hardly any response from the wastewater temperature registration ($\Delta T < 1\,^{\circ}\mathrm{C}$). It is likely that this can be contributed to near identical temperatures of dry weather flow and storm water runoff. In these cases, it is impossible to use only the parameter temperature as an indicator parameter for the dilution process after the onset of a storm; additional information is required.

Possible additional information can be obtained by simultaneously monitoring, for example, the conductivity of the wastewater. Figure 5 shows the variation of the parameters Q and conductivity during (a part of) the same 5-day period in April 2005, as

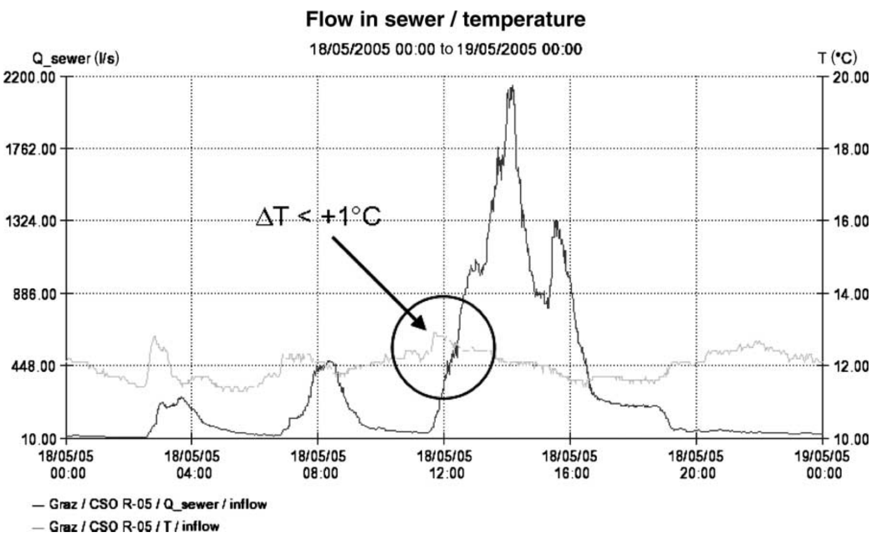

Figure 4 The variation of Q and T on 18 May 2005 at a monitoring station in Graz, Austria

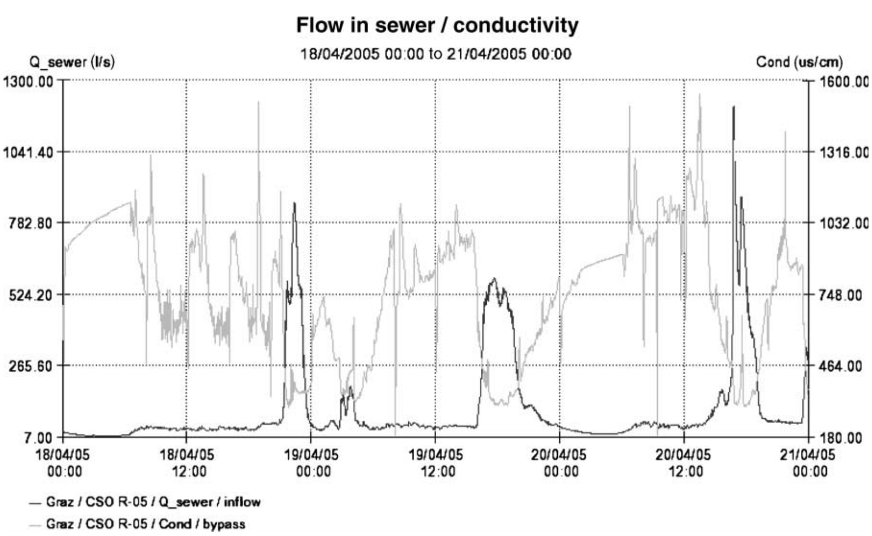

Figure 5 The variation of Q and conductivity from 18 April – 21 April 2005 at a monitoring station in Graz, Austria

Downloaded from https://iwaponline.com/wst/article-pdf/54/11-12/257/431196/257.pdf
by guest

used in Figure 1. Compared to the behaviour of the parameter temperature, the variation of conductivity during dry weather flow is more capricious. Nevertheless, at the onset of a storm event, the dilution process can be well distinguished with sudden and sharp drops to relatively small values for conductivity compared to the registrations during dry weather flow. Again, the dilution process that causes the ammonium nitrogen concentration to decrease is also responsible for a reduction in conductivity. Therefore, in addition to the parameter temperature, conductivity can be considered an indicator parameter for the dilution process after the onset of a storm. A simultaneous monitoring of both parameters leads to valuable additional information in case the temperature registration shows no reaction to a storm event.

Reversely, Figure 6 gives an example of a strong temperature variation during which the flow registration indicates normal DWF conditions. The question arises as to whether

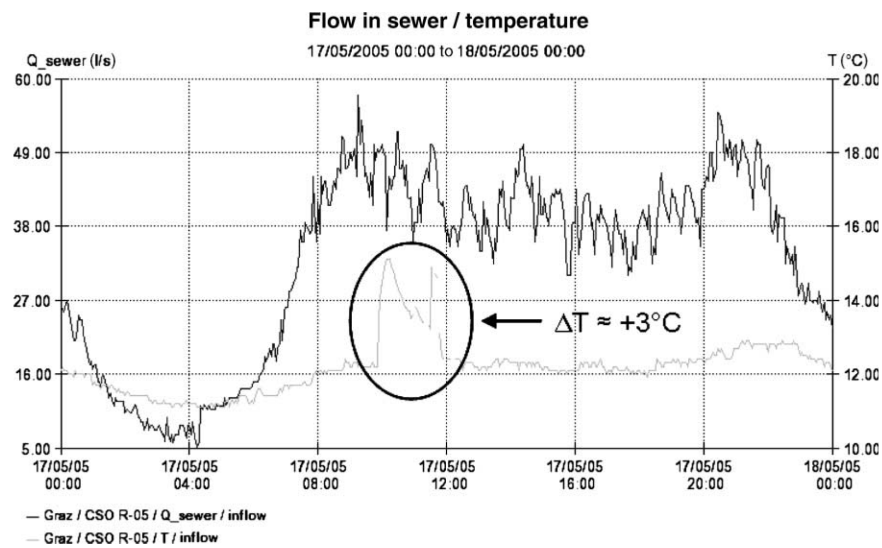

Figure 6 The variation of Q and T on 17 May 2005 at a monitoring station in Graz, Austria

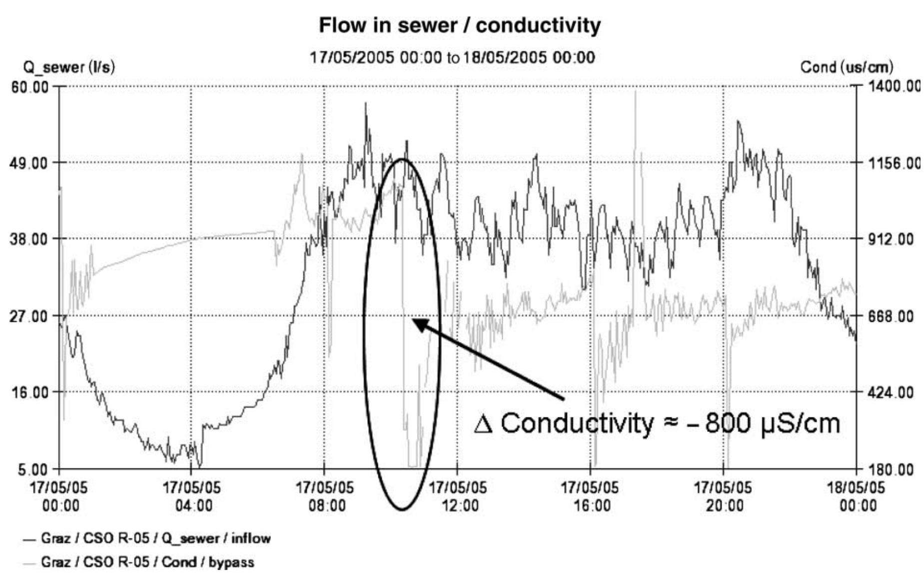

Figure 7 The variation of Q and conductivity on 17 May 2005 at a monitoring station in Graz, Austria

Downloaded from https://iwaponline.com/wst/article-pdf/54/11-12/257/431196/257.pdf
by guest

the temperature sensor has produced invalid registrations. Comparison with the data for conductivity (Figure 7) shows a strong decrease of conductivity at the same moment the temperature change occurs. Hence, the reactions of temperature and conductivity might be explained by a (small) industrial discharge of relatively warm and clean wastewater. This example shows the added value of using both parameters: an anomaly in the expected behaviour of one parameter can be explained using information of the other parameter.

Conclusions

Considering all aforementioned examples, it can be concluded that, for the monitoring station in Graz, Austria, the parameters of temperature and conductivity are promising indicator parameters for the dilution process of wastewater that occurs after the onset of a storm event. The simultaneous monitoring of both parameters leads to valuable back-up information in case one parameter shows an invalid or no reaction to a storm event. However, due to various reasons, anomalies occur in the typical behaviour of both parameters. Normal behaviour, as well as anomalies, can be studied by means of trend and correlation analyses of the measured data. The frequency and extent of anomalies will determine the usefulness of the proposed parameters in a system for pollution-based RTC. To obtain a large amount of useful data, a monitoring network for the parameters of interest is currently being set up in the Netherlands. At multiple locations throughout an extensive sewer network in and around the city of Eindhoven, temperature and conductivity will be monitored for several successive months. Monitoring sites include in-sewer locations, as well as several gully pots. The obtained data will provide information on their behaviour under varying circumstances and the chances and obstacles in using the parameters of temperature and conductivity for pollution-based real time control.

Acknowledgements

The first author gratefully acknowledges funding by the partners of the working group ‘Interactions within wastewater systems II’: Arcadis, DWR, Grontmij, Waterboard Groot Salland, Hollands Noorderkwartier, Royal Haskoning, Tauw, Waterboard De Dommel and Witteveen + Bos.

References

Breukel, R.M.A. (2002). *Monitoring oppervlaktewateren volgens de Europese Kaderrichtlijn Water (in Dutch)*, RIZA report 2003.003, RIZA, Den Haag, the Netherlands.

Flamink, C.M.L. (2004). Afvalwatersysteemoptimalisatie in het licht van de Kaderrichtlijn Water (in Dutch). In *Proceedings of the 4th Symposium ‘Interacties binnen het afvalwatersysteem’*, pp. 19–30, Delft, the Netherlands, 28 October 2004.

Gruber, G., Winkler, S. and Pressl, A. (2004). Quantification of pollution loads from CSOs into surface water bodies by means of online techniques. *Wat. Sci. Technol.*, **50**(11), 73–80.

Gruber, G., Bertrand-Krajewski, J., De Bénédittis, J., Hochedlinger, M. and Lettl, W. (2005). Practical aspects and strategies by using UV/VIS sensors for long-term sewer monitoring. In *Proceedings of the 10th International Conference on Urban Drainage*, Copenhagen, Denmark, 21–26 August 2005, CD-ROM edition.

Vanrolleghem, P.A. and Lee, D.S. (2003). On-line monitoring equipment for wastewater treatment processes: state of the art. *Wat. Sci. Technol.*, **47**(2), 1–34.

Downloaded from https://iwaponline.com/wst/article-pdf/54/11-12/257/431196/257.pdf
by guest