Optimization of Installation and Maintenance of Water Quality Sensors in Combined Sewers

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Objective

Obtain good water quality data focusing on total suspended solids (TSS) under the challenging conditions of a combined sewer system by optimizing:

1. Installation and
2. Maintenance (calibration, validation and cleaning)

Motivation

- Lack of high frequency water quality data in sewer systems
- Major reason:
  The sewer is a very harsh environment that does not allow for a simple installation and maintenance of sensors
- Built upon experience with previous installations of online water quality sensors of the model*EAU* research group
- Optimize installation and maintenance scheme for sewers

Material and Methods

Two Automatic Measurement Stations (AMS, RSM30, Primodal Systems, Canada) were installed in the combined sewer system of Bordeaux, France, between April and August 2017.

The AMS were equipped with:

- Spectrometer (TSS 1)
- pH-meter, conductivity-meter and turbidity-meter (TSS 2)

Installation

A flexible and re-usable installation for hardware set-up is key. Fig. 1 shows the installation that consists of two main parts: the sensor rack and its support structure.

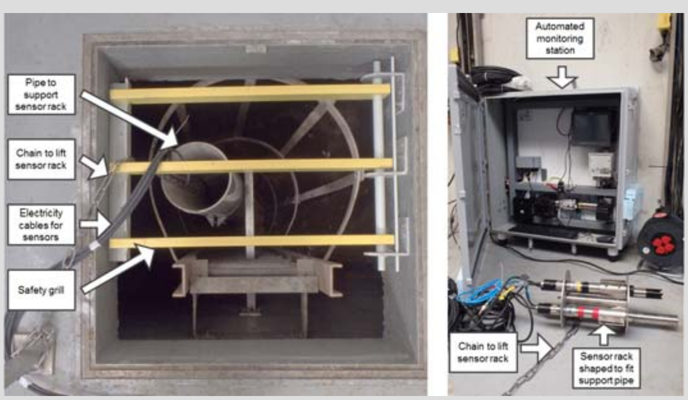

Fig. 1: *Installation of AMS, left-hand side: installed support structure; right-hand side: AMS with sensor rack*

Maintenance

The calibration stability of the turbidity sensor was monitored via the "variation" in the "NTU-TSS" calibration slope. After 30 samples the slope stabilized (Fig. 2).

Fig. 3 shows the increased frequency of manual cleaning towards the end of the measurement period. Adaptation of the self-cleaning mechanism and the sensor's position could not completely counter the observed divergence (e.g. green arrow).

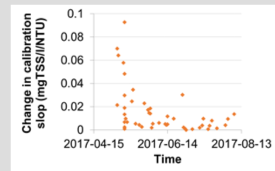

Fig. 2: *Change in the calibration slope (turbidity sensor)*

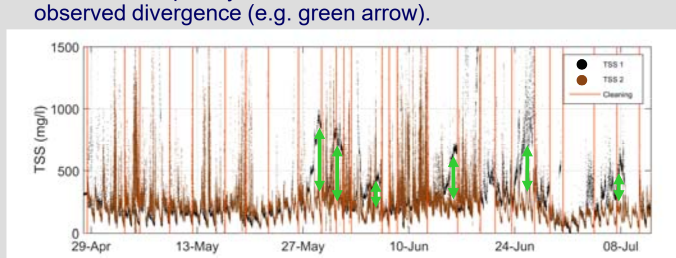

Fig. 3: *Two independent TSS time series (different sensors) with indicated cleaning interventions (vertical lines)*

Well-Adapted Installation and Maintenance

Fig.4 shows one day of two different TSS signals and the corresponding lab values. Very good agreement is observed.

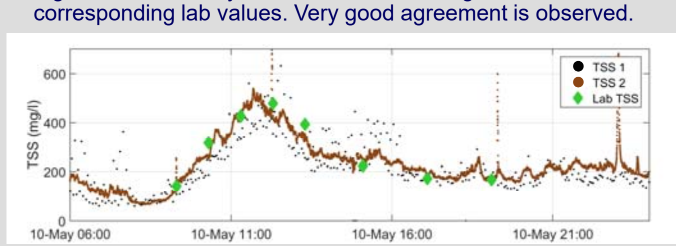

Fig. 4: *Two TSS measurements (TSS 1, TSS2) in comparison with laboratory results (Lab TSS) under good maintenance conditions*

TAKE HOME MESSAGE

- Capturing dynamic behaviour of particulates is possible
- But a considerable investment is required:
  - Initial set-up and continuous adaptation of site
  - Tight and intensive maintenance schedule:
    validation, calibration and cleaning of sensors

Acknowledgement

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Summary

For many reasons, high frequency water quality data are needed for combined sewer systems but rarely do we see such data available. One main reason is the challenge of installing and maintaining the sensors in such harsh measurement conditions. This paper attempts to optimize the installation and maintenance of such sensors in a real combined sewer system and points out different pitfalls and possible solutions when sensors are installed under these hard conditions.

Keywords

Urban drainage, measurement campaign, online data, sensor set-up strategy

Introduction

There are many reasons why high frequency water quality data need to be available to capture the highly dynamic behaviour of a combined sewer system. Nevertheless, these data are rarely at hand, especially if compared, for example, to the availability of water quality data in water resource recovery facilities (WRRF). One reason for this is the very harsh sewer environment that does not allow for a simple installation and maintenance of sensors.

One particular reason to acquire such data is the need to characterize the highly dynamic behaviour of (particulate) organic matter throughout the sewer system and its eventual release to the receiving water. For the given case study, which is located in Bordeaux, France, this is precisely the main concern. Therefore, a measurement campaign was designed to capture the fate of particulate matter within the sewer system and characterize the dynamic variation of their concentrations, for instance, caused by rain events. Sensors were thus installed at two different locations between April and August 2017 to obtain the desired data. One Automatic Measurement Station (AMS) was installed at a major pumping chamber upstream and the second AMS measures the same branch right before the WRRF.

Previous installations of online water quality sensors were made by this research group for instance in the province of Quebec, Canada; Eindhoven, The Netherlands and Copenhagen, Denmark (see for example: Alferes *et al.*, 2013; Alferes *et al.*, 2014; Plana, 2015). This study thus builds upon this experience and presents an optimized installation and maintenance scheme for online water quality sensors in combined sewer systems that is able to deal with the harsh environmental conditions.

Methods

The two measurement points are equipped with one AMS each (RSM30, Primodal Systems, Canada), which were designed according the vision of Rieger and Vanrolleghem (2008). It features flexibility, both with respect to the compact set-up that allows a relatively simple installation at different places and with respect to the modular set-up that allows including different sensors from different brands. For this study, an identical set-up was chosen for both AMS: pH, conductivity and turbidity of the brand WTW and a spectrometer by s::can measuring total chemical oxygen demand (CODtot), soluble COD (CODs) and total suspended solids (TSS). The maintenance protocols for this study built on previous work of Plana (2015), that elaborated protocols and maintenance schedules for the WRRF of Grandes-Piles, Canada. The schedule for the inlet of the WRRF served as starting point for the schedule in Bordeaux, France.

Results and Discussion

The installation of the sensors has been developed in collaboration with LyRE (LyRE, 2016) and aims at flexibility, which is in accordance with the vision for the AMS. The created hardware set-up allows reusing the same installation at different points. As shown for the installation at the inlet of the WRRF in Fig. 1 it consists of two parts: the sensor rack and its support structure. The sensors are mounted on a cylindrical, re-usable sensor rack attached to a chain. To keep the sensors stable and protected, the sensor rack is placed in a pipe support structure and the chain allows to lift them for inspection and maintenance. This is necessary as for both measurement sites the sensors are installed far below ground (five respectively twelve meters).

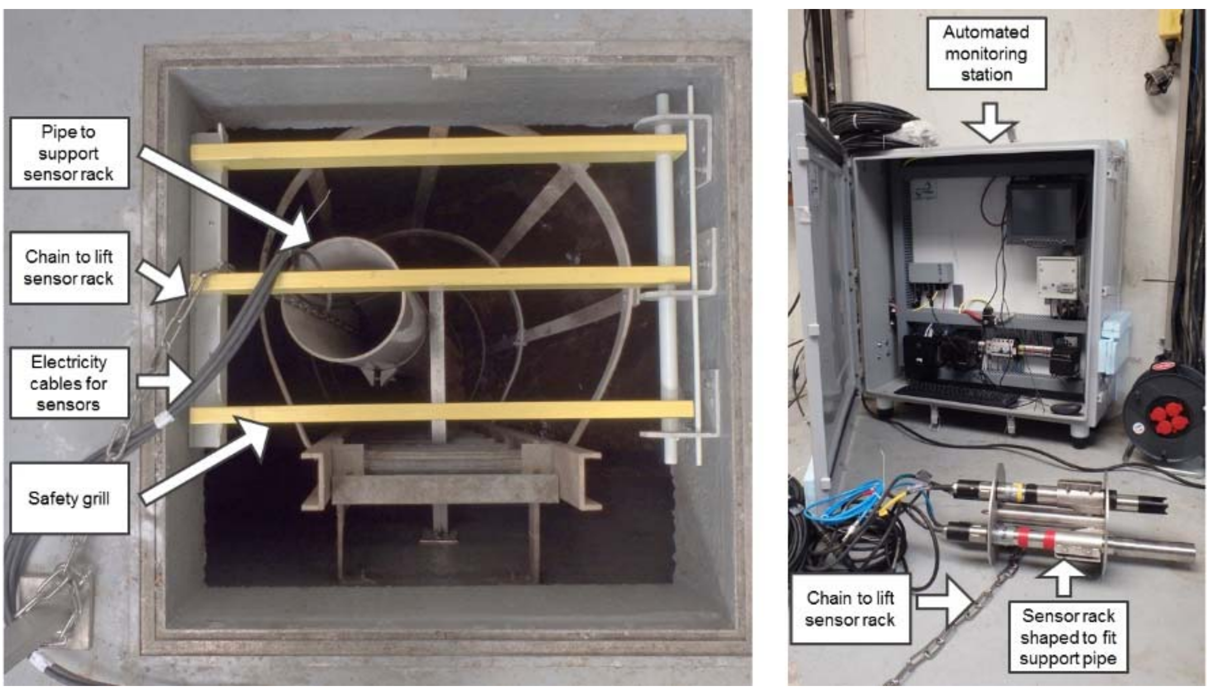

Fig. 1. *Installation of the AMS at the inlet of the WRRF, left-hand side: installed support structure; right-hand side: AMS with sensor rack.*

Building on the work of Plana (2015) two different maintenance protocols were established based on the sensor's imposed cleaning frequency and its need for on-site data quality validation (pH, conductivity, turbidity) or its ability for off-site validation (using lab analysis of grab samples) and calibration (spectrometer). Fig. 2 shows the raw data of the two measurement signals for the total suspended solids (TSS) in between two cleaning events. The two time series clearly show that one sensor suffers from drift, whereas the other does relatively good.

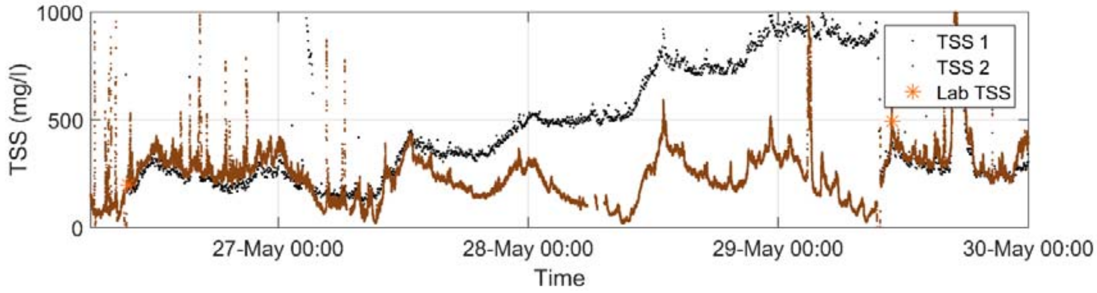

Fig. 2. *Two independent TSS measurements (different sensors) between two cleaning events.*

During the measurement campaign, several important factors were identified that influenced the performance of the sensors. One is the self-cleaning mechanism of the sensors that is essential to their successful operation and needs to be adapted to the situation. In comparison to installations at WRRFs the self-cleaning frequency had to be increased. Another factor to consider is the position of the sensors in the water. Whereas the supporting pipe structure and sensor rack imposed a vertical position of all sensors, the position in the flow could be adapted: it is crucial that the arriving flow and with it the contamination does not get stuck in the measurement paths of the sensors.

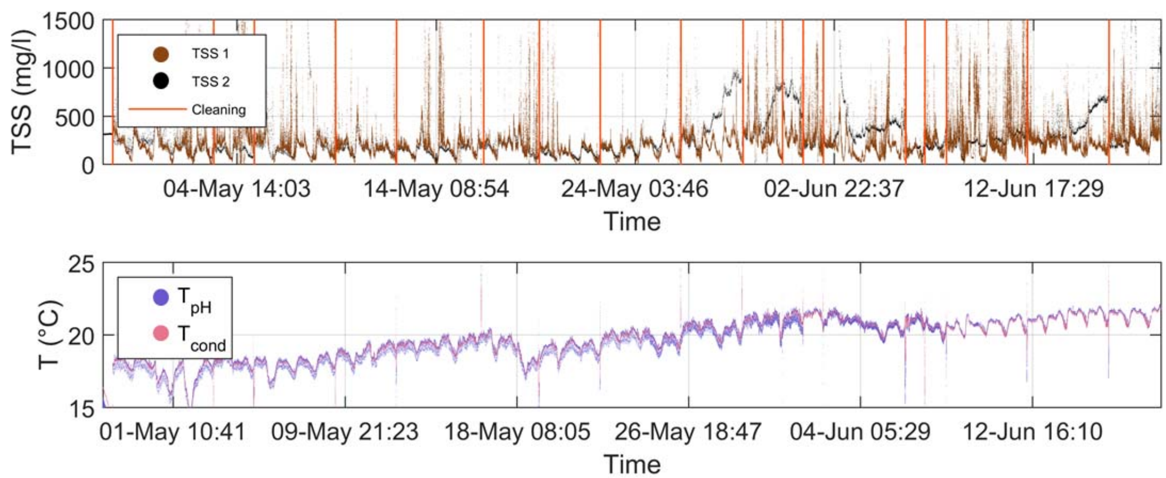

Fig. 3. *Two independent TSS time series (different sensors) between April and June (top) with indicated cleaning events (vertical lines) and corresponding temperature measurements (bottom).*

These changes were made in order to counter the observed need to increase the manual cleaning frequency that is time-consuming. Indeed, manual cleaning had to be performed two to three times a week. Compared to installations at WRRFs, this is not astonishing as the sensors were directly placed in the sewer that causes more fouling. An interesting observation is however that it seems that the cleaning frequency that was sufficient in the beginning of the campaign was no longer by the end of it.

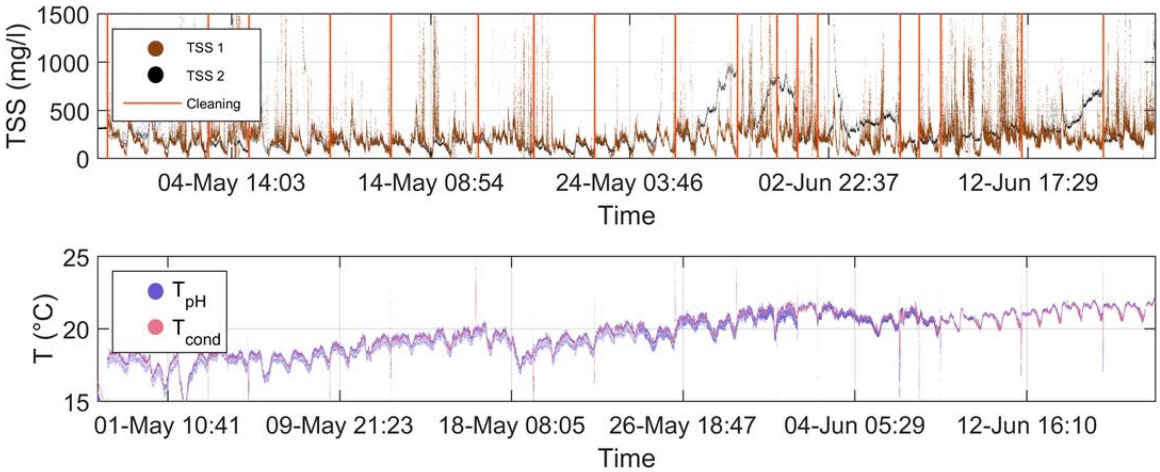

Fig. **3** shows the raw data of the TSS over a longer time series with the manual cleaning indicated as orange lines. Simply evaluating the measurement noise shows that the data quality was better at the beginning than by the end. And this despite the fact that the cleaning frequency was lower in the beginning. The increase in noise was confirmed by the increase in fouling that was observed on the sensors. With time the sensors were dirtier when they were taken out for maintenance. Not only was more trash stuck on them, film formation was also clearly more prevalent. Whether this film was a biological in nature or the result of some precipitation is unknown, but its appearance might be related to the increase in wastewater temperature (from about 18˚C to almost 22˚C) and the very few rain events.

The previous figures showed that the maintenance of the sensors needs to be adjusted to their needs and the given circumstances. However, if installation and maintenance are well adapted and done properly, the highly dynamic behaviour of particulates can be captured under the very challenging conditions of a sewer system. To demonstrate the obtained data quality Fig. 4 shows the TSS for the two different sensors over a day and the corresponding lab values collected in an intensive sampling campaign. The values of the laboratory and the sensors are in very good accordance.

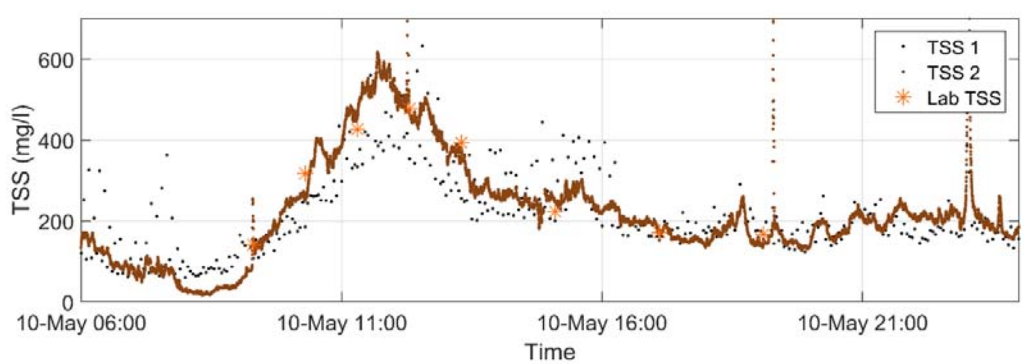

Fig. 4*. Two TSS measurements in comparison with laboratory results for a well-maintained day.*

Conclusions

Capturing the highly dynamic behaviour of particulates is possible, but a considerable investment is required. The investment does not only include the initial set-up of the sensors, but also includes the investments for accommodating the measurement site and more so to properly maintain the data quality as a tight and intensive maintenance schedule needs to be met.

Acknowledgement

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