Toward proactive management of stormwater control measures using low-cost technology

Vers une démarche de gestion proactive des techniques alternatives basée sur la technologie low-cost

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RÉSUMÉ

La maintenance des techniques alternatives (TA) de gestion des eaux pluviales constitue probablement le plus grand frein à leur adoption et leur performance. Garantir une performance sur le long terme correspondant aux objectifs initiaux nécessite un suivi adapté, au bon endroit et au bon moment, afin d'intervenir avant que les dysfonctionnements ne se produisent. Cela a toujours été coûteux financièrement et en main d'œuvre. Mais l'émergence des capteurs low-cost ouvre des perspectives entièrement nouvelles, où des capteurs en grand nombre mesurent tout un ensemble de paramètres et de performances des TA, et génèrent des alertes pour tous les personnels contribuant à leur maintenance. De tels capteurs pourraient piloter des changements de configuration des TA pour optimiser leurs performances à partir (i) de leurs conditions de fonctionnement et (ii) de leur état de maintenance. Réaliser cette ambition nécessitera de tirer les enseignements d'autres champs d'application de ces technologies low-cost afin d'atteindre les objectifs spécifiques à la gestion des eaux pluviales. Des réseaux de capteurs low-cost pourraient ainsi permettre une gestion proactive des TA.

ABSTRACT

Maintenance of stormwater control measures (SCMs) is perhaps the biggest threat to their adoption and performance. Assuring long-term performance which matches the design intent requires suitable monitoring, at the right place and right time, to intervene before malfunctions occur. Doing so has traditionally been very expensive and labour-intensive. The advent of low-cost sensors, however, opens up the potential for entirely new approaches, where numerous sensors measure various aspects of SCM state and performance, generating alerts to those involved in their maintenance. Such sensors could control changes to system configuration to optimise performance relative to (i) operating conditions and (ii) maintenance state of the system. Delivering on this potential will require learning from other related applications of such technology, delivering solutions that match the specifics of stormwater management. Low-cost sensor networks could finally deliver effective pro-active management of SCMs.

KEYWORDS

Asset management, low-cost, monitoring, stormwater control measure

1 HOW INTERNET OF THINGS CAN HELP ASSET MANAGEMENT

1.1 Stormwater Control Measure inspection needs

As with any asset, stormwater control measures (SCMs) need to be managed over their life. Asset management involves managing assets to minimize their ownership and operating cost, while delivering the required level of service (Schulting and Alegre, 2007). It involves life cycle investment strategies and work planning (Mohseni, 2003). To manage an asset, operation and maintenance (O&M) activities are implemented during its lifespan (until replacement). O&M rely on good knowledge of the condition and performance of each asset, using two possible approaches:

• The proactive approach requires action before the failure of any asset, based on the prediction on its deterioration over time, or based on frequent or continuous monitoring. The action will depend on the type of failure, and its estimated consequence, relative to the desired level of service.

• The run-to-failure approach considers that the action will be triggered because of the consequence of a failure which will be observed and reported. A corrective action will be needed to minimize the consequences and repair the failure. The response-time is in this case of high importance.

The run-to-failure approach is obviously not recommended but is most common due, partly, to resource limitation that does not permit inspection on a regular basis the asset or predict its future condition or performance. When considering stormwater control measures, the level of knowledge does not permit today to accurately predict the evolution of hydraulic parameters such as permeability (Gonzalez-Merchan, 2012). Limited resources don’t allow for frequent or continuous monitoring of each stormwater control measure and utilities often choose to monitor the most important (in size or regarding the consequence of a failure). Or at least, “traditional” monitoring of all assets is not possible given the number and spatial distribution of stormwater control measures. This problem seems to be shared universally across the globe (Cossais *et al.*, 2017).

1.2 Inspect at the right moment

The operating conditions of SCMs can be classified as follows (CERTU, 2003): 0-dry weather, 1-low rainfall, 2-average rainfall, 3-heavy rainfall and 4-exceptional rainfall. Each level corresponds to a different service regarding water quality, runoff retention, and flooding risk. The inspections should thus be aligned to the performance and service expected for each condition: e.g. is the vegetation in good condition after a long period of dry weather? Does the system prevent uncontrolled overflows during low rainfall events? However, such inspections are costly, particularly across a large number of SCMs. For example, inspections during or after a rare heavy rain will require a large human resource within a very short period. Missing the period of interest will greatly diminish the value of inspection, but conversely, performing inspection during the storm may pose an unacceptable risk to personnel. Ideally, inspections would target systems not performing well, but often this will not be possible, leading to inefficiencies.

1.3 Adapt the monitoring to the costs and requirements

A promising lead is to consider recent advances in monitoring systems: falling costs, miniaturisation, easy-to-access, modularity and open-source programming. Low-cost sensors and acquisition systems are emerging in many fields, such as in agriculture (Fisher, 2007) and air quality (Morawska *et al.*, 2018). Few existing water monitoring applications include water quality (Rao *et al.,* 2013), sewer overflow monitoring (Montserrat *et al.,* 2013) or pipe inspection (Romanova *et al.,* 2012). Low-cost technologies have revolutionised air quality monitoring, offering massive increases in spatial and temporal data resolution (Morawska *et al.*, 2018). Such promising technology can enable proactive management of assets by providing monitoring data in real time, for a large number of assets, and with a higher resolution. The main question is thus: could we achieve the same revolution in stormwater management and benefits from low-cost technology? What are the challenges ahead of us to achieve this?

1.4 Low-cost technology

Although the literature is increasing very rapidly on this subject, there is still no clear definition of the concept. According to Morawska *et al.* (2018), “the term ‘low cost’ is relative, depending on the users and the specific purposes, and has been used loosely in the literature”. There seems to be a common understanding that low-cost technology refers to a significantly lower price compared to a traditional technology for the same use. The cost reduction results from the low price of the sensors, and possibly other parts of the monitoring system (interface, communication, storage, etc.). Cost reduction can also result from finding the right parameters to monitor that will give maximum information on the performance.

2 EXPECTED CHALLENGES

2.1 A question of trust?

The greatest concern of the low-cost sensor approach is the reliability of the sensors or the whole monitoring system (Kumar *et al.*, 2015). Table 1 summarises the different parameters recommended for testing the performance of a proposed monitoring system. Such parameters are not specific to low-cost sensors but are often investigated when dealing with the latter. When buying 'traditional technology', sensors are often pre-calibrated by the manufacturer and their parameters are documented, but is generally lacking for low-cost technology. This will involve more investigation but could be an opportunity to encourage and promote high quality and best practices in metrology. It is also "important that the sensors/monitors are tested under both laboratory and field conditions" (Morawska *et al.*, 2018), which should become part of best practices and quality assurance in metrology.

Table 1: Reliability considerations for low-cost sensors

Parameters	Description
Longevity or stability	Time of operation before replacement (Kumar *et al.*, 2015)
Accuracy	Agreement between the measurement and true value (JCGM, 2012)
Repeatability	Measurement precision under a set of repeatability conditions of measurement (JCGM, 2012)
Reproducibility	Agreement between measurements of the same measure and carried out under varying conditions of measurement (JCGM, 2012)
Resolution	Smallest change in a quantity being measured that causes a perceptible change in the corresponding indication (JCGM, 2012)
Response time	Duration between a step change in condition and the first observable corresponding change in measurement response (JCGM, 2012)
Sensitivity to the environment	Effect of environmental factors (temperature, relative humidity) on sensor output (Rai *et al.*, 2017)

2.2 DIY?

Low-cost technology often requires parts from different providers, and then requires customised programming. Modularity and the open-source nature of such tools are major advantages that come with a cost in terms of time (to build and program) and skill requirements. Moreover, the choice is becoming vast for common sensors such as temperature or distance (water level). There is a need for guidance to end-users in choosing suitable sensors for their requirements (Rai *et al.*, 2017).

2.3 Big or small data?

Because of their cost and modularity, low-cost monitoring often consists of spatially distributed sensors enabling monitoring of many locations, more physical or environmental parameters, at a higher resolution (Kumar *et al.*, 2015; Morawska *et al.*, 2018). However, this also increases the calibration and data-processing requirements. This may involve new practices: big data analysis tools and new calibration approaches such as calibrating a set of sensors instead of each sensor one at a time. New practices also encompass the choice of sensors with binary sensors (e.g. level switches) which do not need calibration and are easy to test.

2.4 The right use

A key challenge is to optimise the use of new technologies, not simply replacing the functionality of existing systems. Mapping of a system, monitoring and analysing system data in real-time, processing the data on-site, etc. offer a new range of possibilities for asset management; possibilities, inspired by SCADA (supervisory control and data acquisition). Such possibilities can be divided into three categories: to inform, to act and to understand. The first range of possibility (to inform) has been called *e-maintenance* (Muller *et al.*, 2008). Low-cost technology can be used to monitor, store data and send measurements or summaries to a central system. For example, water-level can be monitored regularly along with rainfall, and instead of sending all this data, the system will send the permeability computed after each rain event. Muller *et al.* (2008) also defined the very interesting concept of *collaborative maintenance* with the idea that the data is sent to multiple actors such as drainage, garden or street sweeping services, encouraging strong coordination between these departments. The second possibilities concern the actions that the system can take. Real-time capability could not only send alerts, but could be used for real-time control (e.g. adapting an outlet valve to a level of water), or real-time maintenance (e.g. change diversion rates in case of storage failure). Such real-time capability could replace a resource consuming human intervention and allow a more rapid response. The third possibilities (to understand) is related to research and concern the improvement of knowledge and modelling of these systems. Expanding the number of sites monitored, the resolution and the diversity of parameters measures can lead to effective predictive models. It is worth noticing that the required performance of the monitoring system will not be identical for all possibilities (as for the costs), and will depend on the objectives: alerts may be based on imprecise data because they will verified by human actions, real-time management requires a more robust system and research needs have often the most demanding requirements in term of performance.

Today these possibilities may appear like dreams, but the technology is available, and we must now build first the concepts if we want the dreams to become a reality.

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