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## LIFE RUBIES – Contrôle en temps réel basé sur la qualité des systèmes d’assainissement pour préserver les milieux récepteurs

### LIFE RUBIES - Real-time pollution-based control of urban drainage and sanitation systems for protection of receiving waters

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#### RÉSUMÉ

Le projet LIFE RUBIES (10/2021 à 9/2025) vise à réduire la pollution des réseaux et station d’épuration des eaux usées rejetées en temps de pluie. L’objectif est de développer puis déployer des outils de contrôle prédictif en temps réel basé sur le critère de réduction non seulement des volumes rejetés mais aussi des charges polluantes en s’inspirant les travaux de Ly et al. (2019) et Congcong et al. (2021). L’ensemble de la solution comprend la prévision des précipitations à long et court terme, l’installation de capteurs de qualité dans les réseaux unitaires, le déploiement d’une plateforme de tableaux de bord experts et le développement d’algorithmes mathématiques pour traiter les données et identifier la meilleure solution de gestion du réseau. La solution sera mise en œuvre sur deux pilotes situés à Madrid (Espagne) et à la Métropole Européenne de Lille (MEL, France). LIFE RUBIES est cofinancé par le programme européen LIFE ([https://cinea.ec.europa.eu/life\\_fr](https://cinea.ec.europa.eu/life_fr)).

#### ABSTRACT

LIFE RUBIES (10/2021 to 9/2025) aims at reducing surface water pollution from sewerage systems and wastewater treatment plants (WWTP) discharges during rainy weather. The objective is to develop and deploy Model Predictive Control (MPC) tools for optimizing the sewage system through real-time predictive control based on the criterion to reduce not only the volumes discharged but also the pollutant loads using the work from Ly et al. (2019) and Congcong et al. (2021). The whole solution includes long- and short-term rainfall forecast, the installation of quality sensors in the sewerages, the deployment of an expert dashboard platform and the development of mathematical algorithms to process the data and identify the best network management solution. The solution will be implemented on two pilots located in Madrid (Spain) and Metropole Européenne de Lille (MEL, France). LIFE RUBIES is co-funded by the European LIFE program ([https://cinea.ec.europa.eu/life\\_fr](https://cinea.ec.europa.eu/life_fr)).

#### MOTS CLÉS

Combined sewer overflow mitigation, global quality-based control, receiving body ecological status, wastewater quality monitoring

#### 1 INTRODUCTION

Real-time control (RTC) of wastewater systems is a growing topic as the necessity to protect water resources is enhanced by the climate change (Pleau et al., 2005; Lund et al. 2018, Congcong et al., 2021). RTC of wastewater systems is an alternative to concrete-based solution (so-called grey solutions) to mitigate Combined Sewer Overflows (CSO) and reduce the impact of cities on the aquatic environment. During the past decades, a lot of effort was dedicated to wastewater treatment plant (WWTP) improvement, but still work needs to be done on the network side, even more, on the integrated system, *i.e.* network and WWTP (Saagi et al., 2016; Ledergerber et al. 2019, Mendes et al., 2021).

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consisted in designing the control principles and deploying the quality sensors aiming at both monitoring pollution fluxes and optimizing the wastewater system. The second year consists in deploying a hydraulic based RTC. Finally, the third year is dedicated to the implementation of the quality-based control. Overall, during these deployment steps, the impact of the solutions on the aquatic environment quality is going to be monitored.

## 2 MATERIAL AND METHODS

### 2.1 The pilot sites

#### 2.1.1 The MEL pilot site

The solution is being implemented on the main urban catchment, at its downstream part, *i.e.* along the receiving body, the Deûle River. During the past years, MEL has invested a lot to build storage capacity in order to comply with regulation. These new infrastructures led to important CSO reductions (*i.e.* 50 % of yearly discharge volumes). However, CSO volumes remain higher than the regulation threshold. For instance, in 2018, 8,5 % of the total wastewater volume has been spilled through CSOs that correspond to 4.6 Mm<sup>3</sup>, 837 Tons Total Mass and 181 mg/L TSS, whereas 5 % is considered as the maximum according to the French regulation. This is due to either a need for more storage infrastructures or better management thanks to integrated RTC.

Three strategic infrastructures are controlled on the network: 1/ Bassin Guy Lefort, 2/ Bassin des Bâteliers, 3/ the confluence of the networks of both banks. A fourth control strategy will optimize the activation of the Marquette WWTP's rainwater treatment plant. To do so, five hydraulic and quality monitoring stations have been installed.

Over the 2017-2019 period, the chemical status of Deûle river is considered as bad due to the following upstream compounds: PAH, TBT and fluoranthene. Downstream, nonyphenol and PFOS are added. The good chemical status was not achieved in 2015 and a derogation will be requested for 2027. Regarding the ecological status, the water body is heavily modified and good potential will be requested for 2027. Over the period 2017-2019, the overall ecological status is poor. The physicochemical status is downgraded by O<sub>2</sub>, PO<sub>4</sub><sup>3-</sup>, TP, NH<sub>4</sub><sup>+</sup> and NO<sub>2</sub><sup>-</sup>.

#### 2.1.2 The Madrid pilot site

In Madrid pilot, the receiving water body is the Manzanares river. This is not a very mighty river and the WWTPs of Madrid spill more than 18 Hm<sup>3</sup>/month over a river where they would otherwise circulate less than 4Hm<sup>3</sup>/month. Therefore, the WWTPs is the main water source of the Manzanares river. The Madrid pilot is just a part (around a 20%) of the Manzanares system. For the whole Manzanares system it is estimated that 22,5 Hm<sup>3</sup>/year of CSOs (mix of stormwater and wastewater) are spilled per year (values for 2018). For the Madrid pilot it represents 4.5 Hm<sup>3</sup>/year, and 1,318 Ton/year of suspended solids.

Nutrient concentrations in Manzanares river, especially ammonia, still have much higher values than those compatible with good water conditions, as it can be seen in the public records of CEMAS and SAICA quality stations. In the Rivas Vaciamadrid station, observations above 20mg/L of ammonium are common. These values exceed even the least stringent objectives set at 10 mg/L in RD1/2016 of Hydrological Planning. They are well above the reference limits for a mass of water of its ecotype set at 0.6 mg/L in the RD817/2015. In this context, the effect of the spills impacts tens of kilometers downstream, affecting the Jarama and the main axis of the Tagus River.

### 2.2 The MPC solution description

#### 2.2.1 AQUADVANCED® URBAN DRAINAGE

LIFE RUBIES integrates LIFE EFFIDRAIN methods (2015-2019, LIFE14 ENV/ES/000860) in an existing advanced supervision platform AQUADVANCED® (AQDV) developed specifically for wastewater systems RTC. AQDV has already been deployed in different water utilities (Saint Etienne, Marseille). For instance, on MEL pilot, three actuators will be controlled, including two large retention tanks. The software is dedicated to real-time data management, system monitoring and remote control in connection with a SCADA. It can manage many real-time measurement equipments (flow, water level, volume, discharges, sensors, etc.) and automation systems. The AQDV solution can also manage hydraulics simulator runs using real-time weather forecast to anticipate the system behavior.

**2.2.2 Quality monitoring strategy**

The CSO pilots and the storage units will be equipped with hydraulics sensors and quality sensors making possible to calculate pollutants fluxes for classical parameters (TSS, COD, Nitrogen...) following Patris et al. (2020) calibration protocol. Turbidity and conductivity sensors are being installed (Figure 1) at these locations. The data will be used for pollution fluxes emission calculation and model quality calibration.



Figure 1. Quality sensors installed at Batelier’s location (MEL).

**2.2.3 Quality-based Model Predictive Control**

Two MPC strategies were developed during the previous project LIFE EFFIDRAIN and both will be applied. The first one is a semi-global strategy, the second is a global strategy:

- **Mass-Volume based controller (MV):** a controller for small and medium sewers was developed. The algorithm uses an improved hydraulic model including solid transport equations (based on SWMM, USEPA) that provides spatial and temporal evolution of total suspended solids concentration (TSS) and soluble pollutants. Algorithms for wastewater quality sensors treatment and assimilation were developed to feed and correct the model. The model runs in real-time to predict where and when the most polluted volume is expected within a rain event to prioritize the storage of this volume. It is a multiple local system approach.
- **Model Predictive Controller (MPC):** a controller for large UDN. The algorithms use a model where hydraulic equations were linearized that also includes quality. This model is linked to an optimizer program that searches for best solution within many simulations. Many simulations can be generated as the linearized model can be run within a very short time. This algorithm runs in real-time to constantly find out the system configuration that will lead to lower pollution emitted to the environment (CSO + WWTP). It is a global system approach.

**2.2.4 Natural body monitoring for solution impact assessment**

Water quality in rivers is particularly difficult to assess given its dynamism in time and space. Assessing the evolution of contaminant concentrations during rainy events requires, for instance, the use of high-frequency measurement tools that can detect very rapid changes, or the use of passive integrative sensors that can give representative values of average concentrations over the duration of exposure.

All along the LIFE RUBIES project, multiparameter probes will be monitoring the rivers such as: Exo (Ysi) probe or Manta (Euraka). They will allow measurements of physicochemical parameters (conductivity, turbidity, dissolved oxygen, pH). Ammonium analyzers (Icon, Metrohm) will be also deployed in prototype mobile stations including smart sampling system controlled by a newly algorithm (Mougin et al., 2022) triggering sampling on quality variation.

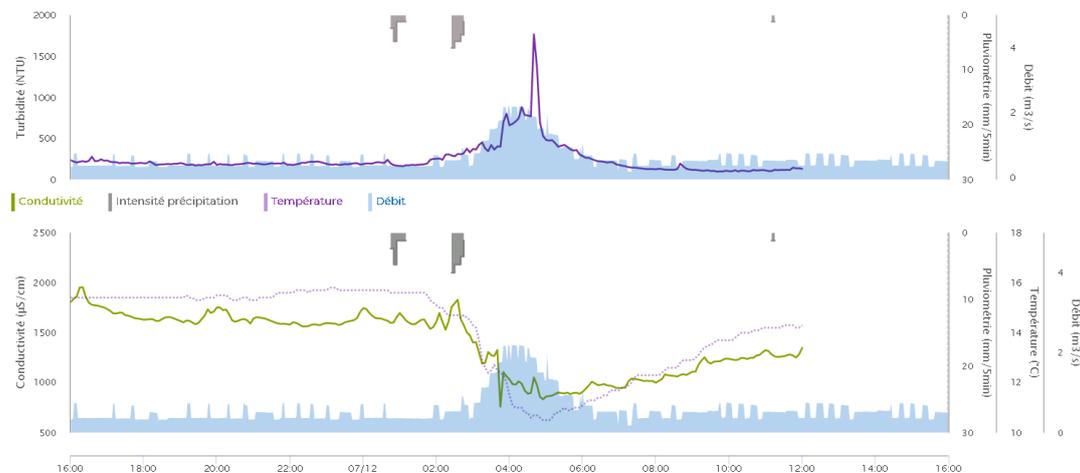


Figure 2. Hydraulics and quality data collected at Bâtelier monitoring station (MEL).

### 3 RESULTS

The Figure 2 reports results obtained during a storm event from one monitoring station on MEL pilot. One can see that the flow increases (0.5 to 2 m<sup>3</sup>/s) resulting from the rain with a sharp turbidity peak (around 200 to 1,500 NTU) and a subsequent instantaneous conductivity drop (around 1,600 to 900 µS/cm). This behavior reflects the solid and soluble pollutants transport in combined sewers that will be used to monitor continuously the classical parameters (TSS, COD, TN, TP) according to Patris et al. (2020).

In addition to the high frequency monitoring station installation, the first manual sampling campaigns on the MEL rivers were performed during dry and wet weather. Results are presented on Table 1 where D1, D2, D3 are respectively sampling points on the Deûle river from upstream to downstream and M1, M2 on the Marque River. The Marque River is an influent to the Deûle where the main WWTP of the urban catchment discharge. The cells colored in Table 1 underline the importance of the difference between concentrations harvested during dry and wet weathers, dark blue being the most different. One can see that NH<sub>4</sub><sup>+</sup> can be higher during wet weather on la Marque while it remains quite similar on the Deûle river. This can be explained by the fact that the treatment plant does not eliminate properly the ammonia during some events. Indeed, the storm treatment line does not include biological treatment but only physico-chemical settling.

Table 1. Concentration results from the manual sampling campaign on the MEL receiving body.

	Weather	D1	D2	D3	M2	M1
NH <sub>4</sub> (mg/l)	dry	0.3	0.8	0.6	3.0	1.1
	rainy	0.4	0.5	0.5	16.4	2.0
V (µg/L)	dry	1.0	1.0	1.1	0.9	1.6
	rainy	1.5	1.4	1.4	1.1	1.0
Mn (µg/L)	dry	3.5	7.0	19.8	57.9	87.0
	rainy	17.2	17.2	41.6	94.7	138.9
Fe (µg/L)	dry	8.9	10.1	25.9	132.0	115.7
	rainy	12.8	8.4	38.5	281.0	222.7
Cu (µg/L)	dry	1.1	1.1	1.0	0.8	0.3
	rainy	0.9	0.8	0.6	1.4	1.2
Zn (µg/L)	dry	16.5	17.2	14.6	18.0	5.8
	rainy	26.4	19.2	15.5	20.0	14.3

### 4 CONCLUSION

To summary, the main goal of LIFE RUBIES is to implement a quality-based model predictive control of wastewater systems in two large European cities in France and Spain. The project is ending the preparatory tasks that are consisting in setting the optimization strategy and deploying the sensors. The first data are being collected and the authors aim at presenting at the conference the details of the control strategy and the analysis of the first results in the sewers and rivers.

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