System for the Acquisition and Analysis of Physico-Chemical Parameters of Surface Waters of Ferrol and A Coruña

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Abstract: The increasing pressure of urban and industrial activities on aquatic ecosystems, plus stricter water quality standards, highlights the need for continuous monitoring. This study aims to present the planned implementation of a data acquisition framework based on the Eureka Manta+35 multiparameter probe, designed to monitor surface waters in the municipalities of Ferrol and A Coruña. Real-time measurements of pH, temperature, conductivity, turbidity, dissolved oxygen, ammonium and nitrate will be sent to the cloud via IoT. Data processing is expected to include outlier filtering, drift correction, and cross-validation with laboratory analyses. Analytical techniques such as Fourier spectral analysis, regression, and correlation will be applied to identify spatiotemporal patterns and anthropogenic impact gradients. The anticipated outcomes will enable the quantification of pollution sources, support the assessment of ecological risks, and underpin adaptive management strategies in line with European water directives.

1 Introduction

Surface water bodies in urban and peri-urban environments are complex ecosystems where hydrological, biogeochemical, and ecological processes converge under significant anthropogenic pressures. Several studies have shown that urban and industrial discharges, combined with high population density, critically alter the ecological quality of aquatic systems (Fisher et al., 2018; Friends of the Bay, 2023). In this context, the Galician municipalities of Ferrol and A Coruña represent an ideal setting for analysing the interaction between natural processes and human disturbances, as they combine rivers, reservoirs, and coastal transition zones exposed to varying degrees of urban and industrial pressure.

Conventional sampling programmes, based on weekly or monthly spot checks, are insufficient to capture the spatial and temporal variability of these systems. Short-lived events such as stormwater discharges, nutrient pulses, or rapid oxygen fluctuations often go undetected, leading to biased assessments of water quality. Insufficient sampling can also cause aliasing, where high-frequency processes are misinterpreted as low-frequency signals. This is particularly critical for microbial-driven processes, which operate on hourly to daily scales. The limitations of grab sampling have been well documented, showing that near-continuous monitoring provides a more accurate representation of pollutant dynamics (Cassidy and Jordan, 2011).

Automatic high-frequency monitoring has emerged as a robust alternative to overcome these shortcomings. Recent work has demonstrated its capacity to reveal diel cycles, phytoplankton blooms, hypoxia episodes, and storm-driven variability (Halliday et al., 2015; Marce et al., 2016). In urban streams, high-frequency data have also clarified the links between nitrate dynamics and other water-quality variables, supporting both ecological research and management strategies (Kermorvant et al., 2023). Multiparametric probes such as the Eureka Manta+35 allow the continuous collection of key variables at minute or hourly resolution, enabling the identification of background trends as well as episodic events of ecological significance.

The validity of these instruments has been confirmed by independent evaluations. For example, the United States Geological Survey (USGS) assessed the Eureka Manta probe in field conditions and confirmed its suitability for scientific applications (Tillman, 2017). At the same time, international experiences in urban and peri-urban contexts (Fisher et al., 2018; Friends of the Bay, 2023) have demonstrated their practical value for understanding water quality dynamics.

This paper describes the monitoring protocol to be implemented in surface water bodies in Ferrol and A Coruña using the Eureka Manta+35 probe. The objective is to establish a robust, continuous, and sustainable observation system that provides high-resolution data to support both ecological research and urban water management. This initiative aligns with the European Water Framework Directive (Parliament and the Council of the European Union, 2000), which requires Member States to ensure the good ecological and chemical status of surface waters through reliable and continuous monitoring.

The structure of this paper is organised as follows: Section 2 details the materials and methodology employed in the study, Section 3 summarises the expected results, and Section 4 provides conclusions together with future perspectives.

2 Materials and methodology

The workflow followed in this study, from field data collection to cloud processing and scientific analysis, is summarised in Figure 1. This diagram provides an overview of the methodological approach applied before describing the study area, experimental design, instrumentation, calibration, and data analysis procedures.

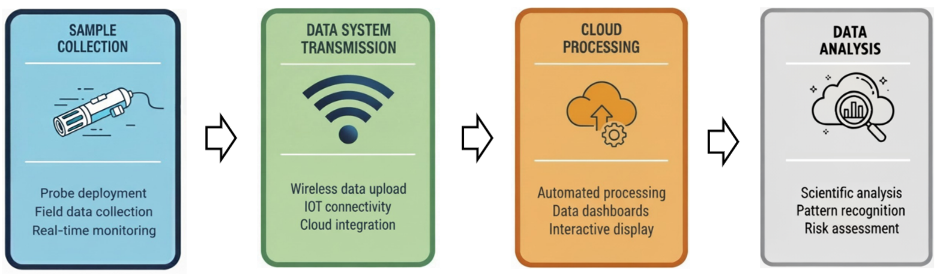

Figure 1: Workflow for Environmental Data Acquisition and Analysis (*Source: own elaboration*)

2.1 Study area and experimental design

The study area comprises several surface water bodies located in the municipalities of Ferrol and A Coruña (Galicia, north-western Spain). These environments include small and medium-flow river sections, streams that drain urban and peri-urban areas, and reservoirs used for multiple purposes such as water supply, recreation, and flow regulation. The region is particularly suitable for this type of study due to its high degree of anthropogenic pressure, which combines urban discharges, industrial activities, and intensive exploitation of water resources. This combination generates a unique comparative framework for analysing both natural dynamics and human-induced variability. The monitoring protocol has been designed in accordance with

Spanish legislation (Royal Decree 817/2015, 2015) and the European Water Framework Directive (Parliament and the Council of the European Union, 2000), which establish the criteria for assessing the ecological and chemical status of surface waters. To validate the approach, the first sampling tests will be conducted in selected areas within the University of A Coruña (UDC) facilities, chosen for their representativeness and ease of access. These preliminary campaigns will make it possible to check the feasibility of the monitoring protocol and guarantee the correct functioning of the equipment under real field conditions. Figure 2 shows the location of the initial sampling area.

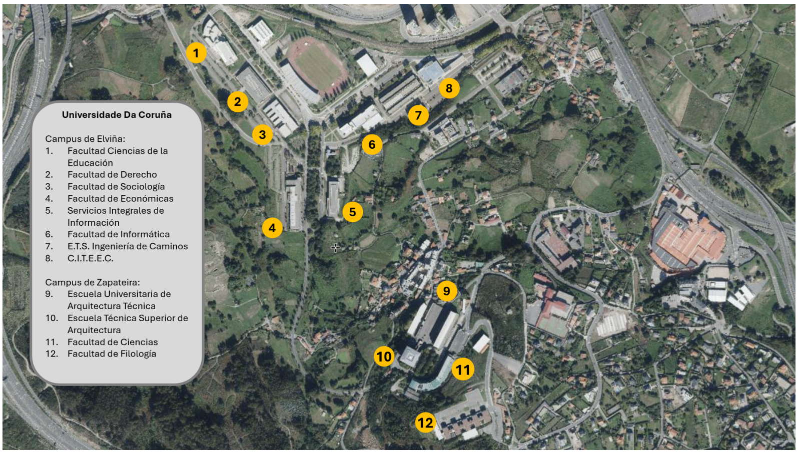

Figure 2: Location of the initial sampling area within the University of A Coruña (UDC) facilities (*Source: own elaboration*)

The experimental design relies on the deployment of a single multiparametric probe that will be systematically rotated across different sampling points in Ferrol and A Coruña. This strategy allows coverage of a wide gradient of anthropogenic pressure and ensures comparability among sites. Sampling points will be selected according to three main categories:

- Areas directly influenced by urban or industrial discharges
- Intermediate sections subject to mixed influence from anthropogenic pressures and natural forces
- External or natural sectors with low human pressure

The sequential monitoring of these areas will provide spatiotemporal data series suitable for distinguishing background variability from anthropogenic impacts and for identifying gradients of ecological alteration across the region. The successful implementation of this design requires advanced instrumentation and rigorous calibration protocols, which are described in the next section.

2.2 Instrumentation, calibration and quality control

The main instrumentation of this study is the Eureka Manta+35 multiparameter probe (Eureka Water Probes, 2022), specifically designed for the continuous monitoring of physico-chemical parameters in aquatic environments. This probe accommodates up to 11 different sensors, making it highly versatile for diverse water quality applications. In the present configuration, it incorporates standard sensors for temperature, pH, conductivity, turbidity, and dissolved oxygen, as well as ion-selective electrodes (ISEs) for nitrate (NO_3^-) and ammonium (NH_4^+). These latter parameters are fundamental for diagnosing eutrophication processes and assessing anthropogenic pressures from urban and industrial discharges. The probe will be installed in structures adapted to the hydrodynamic conditions of each site to ensure reliable operation, even during episodes of high flow or heavy rainfall. The recording frequency will be set at constant intervals of 15 minutes, generating high-resolution time series capable of reflecting both background trends and specific fluctuations. Data transmission will be carried out through a 10 m submersible cable with an integrated adapter powering the probe and connecting it to a Libelium Smart Water eXtreme datalogger (Plug & Sense! platform). This system, powered by an autonomous solar panel, enables real-time transmission of the recorded variables to the cloud via WiFi. The full monitoring setup, integrating the probe, datalogger and power system, is illustrated in Figure 3.

1. Eureka Manta+35 multiparameter probe
2. Connection underwater cable
3. Libelium Smart Water eXtreme datalogger
4. Solar panel

Figure 3: Monitoring equipment used in the study: Eureka Manta+35 multiparametric probe, Libelium Smart Water eXtreme datalogger with solar panel, and connection cable (*Source: own elaboration*)

The reliability of measurements will be ensured by a strict calibration and quality control protocol, following manufacturer recommendations and prior laboratory tests. Each sensor will be periodically calibrated with specific standard solutions:

- pH sensor: calibrated using pH 7 and pH 10 buffer solutions
- Conductivity sensor: calibrated with known conductivity standard solutions (e.g., 1413 μS/cm)
- Turbidity sensor: calibrated using calibrated turbidity suspensions (e.g., 0 NTU, 10 NTU, 100 NTU standards)
- Dissolved oxygen sensor: calibrated using stirred deionised (DI) water fully saturated with oxygen
- Nitrate (NO_3^-) and ammonium (NH_4^+) sensors: calibrated with standard solutions of known concentration at two points (low and high concentration)

Calibration will be performed with Manta 2 Control Software, which provides guided steps to adjust and verify parameters in the laboratory prior to deployment. The software also monitors the Sensor Response Factor (SRF) to assess sensor condition and calibration quality. Additional quality control will include visual inspection of sensor integrity, cleaning and removal of deposits using the probe's anti-fouling features, and verification of data transmission and storage systems. Furthermore, field measurements will be periodically cross-checked against specific laboratory analyses of collected water samples. These procedures will ensure stable, accurate, and reproducible datasets throughout the monitoring campaigns.

2.3 Data processing and analysis

The data collected will undergo a workflow including cleaning, validation, and statistical analysis to ensure quality and extract meaningful information. Outliers caused by sensor malfunctions or transient disturbances will be removed, instrumental drift will be corrected through reference series and periodic calibrations, and cross-checking with laboratory analyses will be used to verify accuracy.

Statistical analysis will combine complementary approaches. Correlation analysis will be applied to evaluate pairwise relationships: Pearson coefficients for linear associations and Spearman's rank correlation for monotonic but non-linear trends. Regression models will be used to quantify and predict the influence of environmental drivers. Simple and multiple linear regression will evaluate how parameters such as temperature, turbidity, and nutrients affect dissolved oxygen, while polynomial regression will be applied where non-linear responses are expected. Logistic regression will be used for categorical thresholds, such as the probability of hypoxia events (DO < 4 mg/L). For longer time series, time-series regression methods (e.g., ARIMAX) or generalised additive models (GAMs) will be considered to account for autocorrelation and smooth non-linear effects.

Finally, spectral and multivariate techniques such as Fourier transforms and principal component analysis (PCA) will be employed to detect diel and seasonal cycles, reduce dimensionality, and identify dominant environmental patterns. These combined approaches will facilitate the characterisation of spatiotemporal variability and the detection of both anthropogenic and natural drivers of water quality.

2.4 Methodological references

The methodological design follows the validation recommendations proposed by the USGS in the evaluation of the Eureka multiparametric probe (Tillman, 2017), which guarantees the reliability of measurements in field conditions. In addition, it is based on protocols used in international high-frequency monitoring experiments in urban and lake systems, such as those described by Fisher et al. (2018) and Friends of the Bay (2023). The adoption of these methodological references ensures the comparability and international relevance of the results generated.

3 Expected results

The project is expected to generate continuous, high-resolution time series for key physicochemical parameters like temperature, pH, conductivity, dissolved oxygen, turbidity, ammonium (NH_4^+), and nitrate (NO_3^-). This detailed data will allow for characterizing both baseline trends and specific fluctuations, overcoming the limitations of conventional, discrete sampling.

By applying a combination of statistical and multivariate approaches - including correlation and regression models, spectral analysis (e.g. Fourier transforms), and dimensionality-reduction techniques such as principal component analysis - the study aims to identify diel, seasonal, and annual cycles and relate them to external drivers such as temperature, precipitation, and anthropogenic loading. This integrated analysis is intended to underpin predictive models for surface water responses to disturbances.

The methodology is expected to enable the quantification of anthropogenic impacts arising from urban discharges, industrial activities, and recreational uses in Ferrol and A Coruña. In particular, it should allow the assessment of eutrophication processes linked to nutrient enrichment and their effects on dissolved oxygen and turbidity, thereby defining an impact gradient.

Reliability will be ensured through cross-validation with laboratory analyses, confirming data consistency, correcting potential sensor deviations, and establishing error margins. This process will provide robust datasets for long-term monitoring.

The results are also expected to establish an initial comparative framework for other urban and peri-urban water bodies in Galicia. This database will support the identification of similarities and differences in patterns of anthropogenic pressure and ecological response, while contributing to standardised indicators of ecological quality.

Finally, the findings should provide practical value for municipal and regional authorities by informing water quality management, strengthening discharge control, and ensuring compliance with European directives such as the Urban Waste Water Treatment Directive (UWWTD, 1991). They will also demonstrate the potential of multiparametric instrumentation integrated with IoT, fostering technology transfer and participatory science initiatives, and contributing to European monitoring requirements.

4 Conclusions and future prospects

The use of high-frequency multiparametric instrumentation, like Eureka Manta+35, represents a decisive step towards consolidating robust, continuous, and sustainable surface water monitoring systems. The generation of detailed time series will overcome limitations of conventional sampling, substantially increasing early detection capacity for pollution episodes, sudden water quality changes, and ecological risk situations in urban environments subject to high anthropogenic pressure.

In the short and medium term, integrating field records with hydrological and biogeochemical models will enable simulation of scenarios under increasing human pressure and climate change conditions. This includes projecting phenomena such as urban discharges associated with intense storms, hypoxia episodes in urban reservoirs, or algal blooms in nutrient-affected watercourses. International experiences have shown that this approach links management measures (such as sanitation improvements or nutrient input reductions) to measurable ecosystem responses, facilitating evaluation of environmental policies and technical interventions.

In the long term, this initiative could seed a Galician network for environmental monitoring of surface waters, interconnecting different urban and peri-urban water bodies under a common framework for data collection, analysis, and interpretation. Such a network would enhance Galicia's scientific and technical capacity while aligning its monitoring programmes with European directives on water quality, water security, and climate change adaptation. By aligning with European and national frameworks-including the Parliament and the Council of the European Union (2000), the UWWTD (1991), and Royal Decree 817/2015 (2015) - this initiative strengthens Galicia's capacity to meet regulatory obligations while advancing innovative approaches to water quality management.

In short, this project is not limited to describing the current dynamics of surface waters in Ferrol and A Coruña but aims to lay the foundations for an adaptive management system capable of anticipating risks, guiding restoration measures and protecting strategic ecosystems against the environmental challenges of the 21st century. As demonstrated by established programmes in North America and Europe, the key lies in maintaining long, comparable and open-access series that constitute a scientific, technical and social heritage of enormous value for the future sustainability of aquatic systems. This article is thus presented as a statement of intent, the purpose of which is to lay the foundations for a continuous observation network that can be transferred to other urban and peri-urban environments in Galicia.

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