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# AUTOMATED HYDRAULIC SYSTEM FOR ON-LINE MONITORING OF TREATED WASTEWATER QUALITY

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***Abstract:*** *Wastewater monitoring is the process of examining sewage to gain insight into conditions within a community. It supports public health, environmental stewardship, and the management of water infrastructure. Monitoring includes gathering samples from sewer systems - such as the influent to treatment plants or points within the sewer network - and analyzing them for: chemical markers like pharmaceuticals and pesticides; Industrial contaminants; nutrient levels, including nitrogen and phosphorus. The article presents an automated wastewater quality monitoring installation. A system of electrically controlled valves directs water from the discharge of a hospital treatment system to a sensor module that analyzes a series of parameters based on an algorithm.*

***Keywords:*** *Wastewater sampling, on-line monitoring, sensors module*

## 1. Introduction

In order not to exceed the limits imposed by national and European legislation for waters discharged from factories, hospitals, or municipal wastewater treatment plants, periodic monitoring of the efficiency of treatment processes is required.
Monitoring the quality of treated wastewater at the outlet of a city's wastewater treatment system represents an essential step in environmental protection and the maintenance of public health, given the large volume of wastewater generated by the population, industry, and commercial activities.
Monitoring the quality of treated wastewater at the outlet of a hospital treatment system is an essential process for protecting the environment and public health, considering that wastewater from healthcare facilities may contain pathogenic microorganisms, pharmaceutical residues, chemical substances, heavy metals, and other specific contaminants. This monitoring aims to verify the efficiency of treatment processes and ensure compliance with current regulatory standards through the analysis of physico-chemical parameters such as pH, temperature, conductivity, turbidity, nitrogen, and phosphorus, as well as microbiological parameters such as *E. coli* and enterococci. For contaminants specific to the hospital environment, pharmaceutical residues, disinfectants, heavy metals, or other elements are monitored.
Sampling is carried out using automatic or composite methods in order to realistically reflect daily variations, and the equipment used includes online sensors, automatic analyzers, and sampling stations. The results are reported periodically (daily, monthly), and their analysis allows for the rapid identification of potential malfunctions in the treatment installation and the protection of natural receiving waters or the sewer network. Thus, systematic monitoring ensures strict control of discharged water quality and contributes to reducing environmental impact.
A number of authors have conducted reviews or studies on wastewater monitoring. For example, Moretti, A. et al., in paper [1], review classical laboratory methods versus innovative real-time solutions, providing a practical comparison of automatic analyzers, the limitations of laboratory methods, and the potential of online sensors for traditional parameters and emerging indicators.
Li, X. et al., in paper [2], provide a detailed analysis of emerging contaminants (pharmaceuticals, personal care products, endocrine disruptors), their sources, modern analytical methods, and existing gaps in monitoring practices.

Chen, H. et al., in [3], present recent advances in optical sensors, remote sensing, and multi-scale data integration (satellites, drones, and shoreline sensors), and discuss the applicability of these technologies for monitoring the quality of urban effluents.
Kreuter, M. W. et al., in [4], discuss the expansion of wastewater monitoring in the context of public health surveillance (wastewater-based epidemiology), the lessons learned during the COVID-19 pandemic, and the implications for continuous monitoring of pathogens and antimicrobial resistance (AMR).
Antonini, G. et al., in [5], present a concrete example of innovation: an image-analysis-based sensor combined with machine learning for the real-time detection of secondary effluent characteristics.
In the technical report [6], the prevalence of emerging contaminants in wastewater streams, their occurrence frequency, and recommendations for practical monitoring at the regional level are identified.
Santhosini, R. et al., in [7], analyze IoT-based implementations for continuous monitoring (low-cost sensors, communication systems, and data management), highlighting the advantages for detecting rapid variability as well as limitations related to accuracy and calibration.
Karim, M. S. et al., in [8], review electrochemical, optical, and bioreceptor-based sensors for wastewater assessment, discussing their robustness in complex environments and the need for calibration under real-world conditions.

## 2. Automatic monitoring system

The general block diagram of the monitoring system is shown in Fig. 1. It includes a series of functional modules comprising solenoid valves, manual valves, solution reservoirs, pumps for water circulation, and a clean water pump used for water jet washing of the measurement chambers that contain the sensors. The diagram also includes a Command and Control Module (CCM), consisting of a programmable controller and a computer.

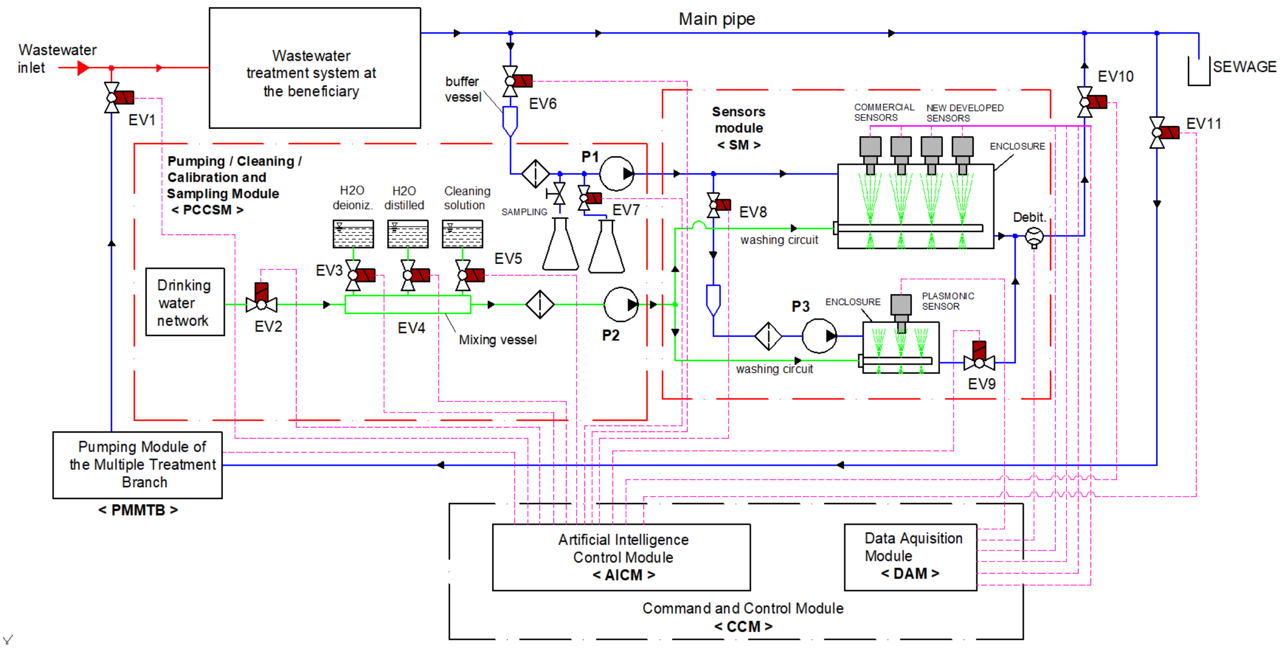


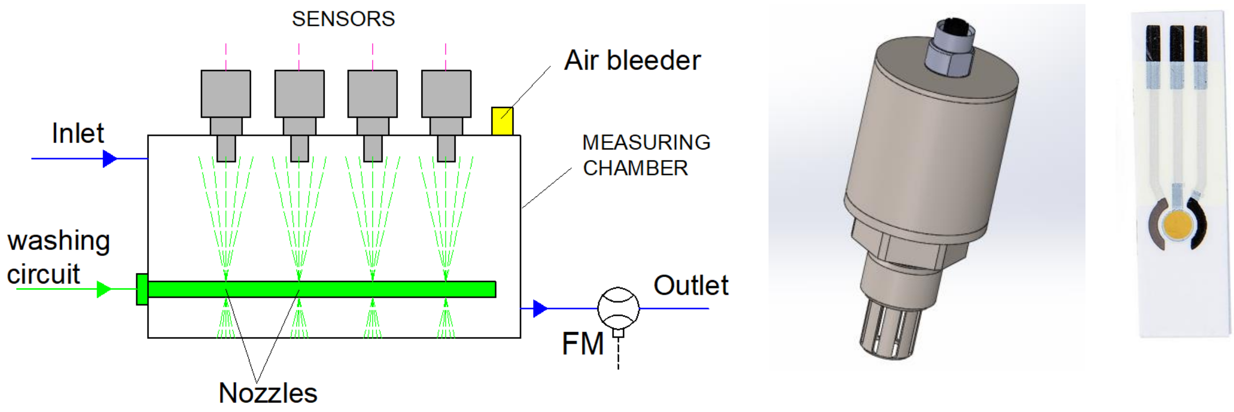

**Fig. 1.** General block diagram

### 2.1 Pumping cleaning calibration and sampling module (PCCSM)

The module receives treated wastewater from the output of treatment system at the beneficiary through a T-fitting. Pump P1 draws liquid from a preloaded buffer vessel through valve EV6 and sends it to the Sensors Module (SM). The module also receives clean water through solenoid valve EV2 for the preparation of the washing solution, which is pumped by P2 to the pipes with nozzles that spray the sensors in the measuring chambers after each sample measurement. Through solenoid valves EV2 to EV5, a recipe for the washing solution can be loaded into a mixing vessel.

### 2.2 Sensors module (SM)

The module contains two measuring chambers: one with electrochemical sensors and one with a measurement system using a plasmonic sensor that can identify a specific compound that needs to be specially detected. Through solenoid valve EV8, the buffer vessel can be supplied, from which pump P3 can feed the plasmonic sensor chamber. The plasmonic sensor chamber also has an integrated pipe with pressurized washing nozzles for cleaning after each processed water sample.
Figure 2a shows the schematic of the measuring chamber with electrochemical sensors. The chamber has an inlet port, an outlet port, a pipe with washing nozzles, full and empty level switches, and an automatic air bleeder. The sensors are mounted in housings according to the 3D drawing (Fig. 2b). The electrochemical sensor plate (Fig. 2c) is mounted with the electric terminals facing the electronic amplifier and is sealed with resin. The worn-out sensors can be replaced, as the housing can be dismantled.




a) b) c)

**Fig. 2.** Measurement chamber with sensors:
a) Measurement chamber schematic;
b) – housing for the electrochemical sensor and electronic amplifier;
c) – electrochemical sensor model.

### 2.3 Command and Control Module (CCM)

The CCM module includes an Artificial Intelligence Control Module (AICM), implemented using a computer running AI algorithms, and a Data Acquisition Module (DAM), implemented with a programmable logic controller (PLC). Control signals for solenoid valves, pumps, and functional sensors (water level and flow) are managed by the programmable controller, which communicates with the artificial intelligence module. The sensors are connected to the analog inputs of the programmable controller, while the solenoid valves are actuated via digital outputs.
The artificial intelligence control module is designed to significantly improve the accuracy, consistency, and reliability of the data acquired by the wastewater monitoring system. It operates as an intelligent advanced processing layer integrated on top of the existing sensor infrastructure.

The module aims to increase the measurement accuracy of physico-chemical parameters by implementing advanced data processing methods, to automatically detect and correct measurement errors, and to reduce the influence of noise, sensor drift, and anomalous values. In addition, it seeks to ensure data continuity in the event of temporary equipment failures, so that the acquired information remains reliable and complete, effectively supporting operational decision-making.
The module also provides decision support by generating intelligent alerts based on the identification of trends and true anomalies within the data streams.

## 3. Automated on-line water sample measurement

Automated algorithm for on-line water sample measurement refers to the use of intelligent computational methods integrated with real-time sensors to continuously monitor water quality parameters. These algorithm automatically collect, process, and analyze data such as pH, turbidity, conductivity, temperature, and contaminant concentrations, enabling rapid detection of anomalies or pollution events. By operating on-line, the system eliminates the need for manual sampling and laboratory analysis, reducing response time and human error. Furthermore, automated algorithms can apply data filtering, calibration, and predictive models to improve measurement accuracy and support decision-making in water treatment plants, environmental monitoring, and smart water management systems [9, 10].
The structure of the algorithm for automated water sample measurement can take the form shown in figure 3.

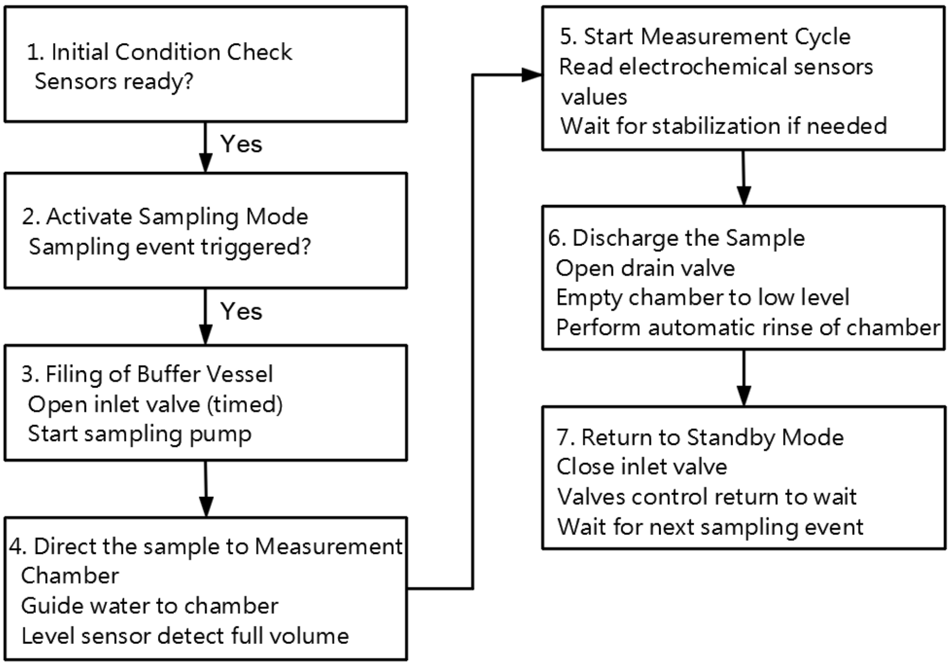



**Fig. 3.** Structure of the algorithm for automated water sample measurement

**The data management system** represents an essential component of the data acquisition system, with the role of archiving the collected information for subsequent analysis and compliance with reporting requirements. Data can be stored locally on the acquisition controller or on dedicated servers or network-attached storage (NAS) systems, in various formats such as CSV, TXT, binary files, or SQL databases. Through specialized software connectors, the system integrates with the existing IT infrastructure, enabling the organization, filtering, searching, and visualization of historical data. This approach facilitates continuous monitoring, performance analysis, and pattern identification, contributing to the development of a robust and efficient solution.

### Synchronization and Sampling

When multiple sensors are used, it is important to ensure their proper synchronization so that the acquired data are coherent. This can be achieved by configuring the sampling rate such that all channels acquire data at the same frequency.
The sampling rate represents how often data are read from the sensors. It must be adjusted according to the nature of the signal and the specific application. For example, for slow-varying

signals (such as temperature), the sampling rate can be lower, whereas for fast signals (such as vibrations or acoustic waves), a much higher sampling rate is required.

**Error Handling and Data Security**

Within a data acquisition system, it is essential to implement mechanisms capable of identifying and managing potential errors occurring during data reading or transmission.
Communication errors may arise due to interruptions in the connection between sensors, the acquisition board, and IT systems. To prevent data loss, the software should include data integrity verification functions and generate alerts when anomalies or gaps in the data stream are detected.
Measurement errors may result from sensor hardware failures, unfavorable environmental conditions, or sensor aging. For this reason, it is necessary to implement plausibility validation methods for the measured values, such as comparison with reference values or automatic identification of values exceeding allowable limits.
Data security measures must be adopted, such as data encryption, to prevent unauthorized access and accidental or intentional data modification.

## 4. Conclusions

Online systems provide frequent or continuous data that enable early detection of anomalies and pollution events, supporting fast and effective decision-making.
Continuously monitored parameters (pH, turbidity, conductivity etc.) allow automatic or informed adjustments in treatment processes, reducing energy use, chemicals, and operating costs.
Sensors may experience clogging or signal drift; sensitivity to organic matter or particles can reduce accuracy without regular maintenance and cleaning.
System benefits are maintained only through consistent calibration, cleaning, inspection and component replacement.
Alarm thresholds and notification workflows (SMS, email) ensure quick reactions from operators and response teams.

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