

Upgrading water management in the industry by sustainable monitoring, treatment, and supportive governance mechanisms

Abstract

In a rapidly growing world, water security is increasingly at risk and may soon approach a point of no return. To overturn this dramatic trend, the path to a sustainable future demands urgent action to revolutionise wastewater treatment, cut pollution, and fully align with circular economy principles. In this project, we want to apply the paradigms of sustainability and circularity to upgrade industrial water management through a collaborative synergy among experts from research institutions and companies across Europe with transversal interdisciplinary and complementary competencies. The interlinked efforts provided by our Consortium will deliver holistic, sustainable solutions for water management in industrial sectors, e.g., chemical, pharmaceutical, and agricultural ones. The MAINSTREAM project is built on the idea that technological advances, governance strategies, and social awareness are entangled forces that must be harmonised to swiftly and effectively achieve circularity principles in water management.

Scientific/technological advances

- Surveillance of pollutants in industrial wastewater is fundamental to enable water reuse in a circular model. We will develop innovative and sustainable monitoring procedures for direct in-line tracing of critical pollutants in target wastewater based on high-performance sensor technology to overperform
- Current methods, combining newly green-synthesised molecules with customised sensors at low costs and low-energy consumption, relying on techniques that avoid toxic reagents and reduce liquid waste.
- Computational studies and modelling will provide scientific insights to develop advanced sensor technology. By assessing and deciphering the leading atomic interactions that govern the sensing molecule adhesion on the sensors, as well as their affinity towards the target pollutants, we will rationally control and optimise the sensor detection efficiency. Full ab-initio simulations will be adopted in the framework of molecular dynamics, delivering an in-depth understanding for the sensor design scale-up.
- The need for sustainable and affordable treatments for wastewater is decisive to unblock water reuse in industrial sectors. Innovative advanced oxidation processes will be explored, first in pilot plants and then validated in industrially relevant environments, by engaging industrial players and through real case studies. A full-around assessment of the process will be carried out to enhance sustainability. The goal will be to achieve zero liquid discharge and a full recovery of the water source, promoting circular management of water in industries across Europe and beyond.
- Integrated software and Machine Learning for automatic data management will ensure accurate data collection and real-time analysis of our innovative monitoring systems and treatment processes, achieving proactive decision-making, data-driven improvements, and prediction power.

Political-social aspects and dissemination

- Water-intensive industries are deeply influenced by political and economic frameworks. In MAINSTREAM, we will analyse “Systems of Governance” for water circularity, examining how multi-level, co-governance structures influence the adoption of water reuse and wastewater treatment technologies across industries, with a focus on legal, regulatory, and market-driven mechanisms. We will develop policy and corporate recommendations through case studies, global best practices, and intersectoral exchange of knowledge.
- Public engagement can significantly contribute to the circular revolution. Besides open science practices within the scientific community, new pathways will be explored to reach out to citizens, end-users, and stakeholders. Dissemination actions will be carried out through websites, social media, workshops, and public-open informative initiatives to raise awareness of water circularity in different contexts of society.

KEYWORDS

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► Project partners

- UPPSALA UNIVERSITY - SWEDEN
- POLYTECHNIC UNIVERSITY OF MADRID - SPAIN
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- DOKUZ EYLUL UNIVERSITY - TURKEY
- EARGE ENGINEERING DESIGN INDUSTRY E-ARGE. E TIC. LTD - TURKEY

► Funding organisations

MUR (ITALY) / FORMAS (SWEDEN) / AEI (SPAIN) / BMFTR (GERMANY) / TUBITAK (TURKEY)

► Duration

3 years

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industrial wastewater treatment and reuse, zero-liquid discharge, In-line sensors data-driven monitoring, computational modelling, systems of Governance for water circularity, life cycle analysis, social awareness

