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iMERMAID

POLICY BRIEF

Wastewater Management in the Mediterranean sea : Towards Resilient, Smart and Circular Water Systems

Wastewater Management in the Mediterranean sea : Towards Resilient, Smart and Circular Water Systems

iMERMAID is an EU-funded project focused on protecting the Mediterranean Sea basin, its sensitive ecosystems and the ecosystem services it provides, which play a crucial role in a variety of different socioeconomic activities. It aims to address the growing threats of chemical contamination and pollution caused by human activities, with a particular focus on contaminants of emerging concerns. iMERMAID intends to integrate innovative strategies for prevention, monitoring, and remediation, particularly around the Mediterranean Sea. This project builds upon the research and innovation activities of 11 projects. Bringing together a consortium of 26 partners from Europe and beyond, the project encourages collaborations to develop advanced sensor and remediation technologies, strengthen regulations to reduce contamination, enhance economic opportunities, and thereby improve the quality of life for EU residents.

iMERMAID aims to bridge technological development with regulatory advancement. This is particularly timely as the revised Urban Wastewater Treatment Directive (UWWTD) introduces new obligations for pollutant monitoring, Extended Producer Responsibility, and treated wastewater reuse. These reforms resonate with iMERMAID's five demonstration sites, which showcase modular treatment systems, real-time sensor networks, and smart reuse models tailored to Mediterranean challenges.

In parallel, the European Water Resilience Strategy (WRS) sets out a broader vision to modernise water infrastructure, combat persistent contaminants like PFAS and pharmaceuticals, and improve cross-sectoral water governance. To unlock the full potential of these innovations, regulatory alignment and integration across the water and marine acquis will be essential.

In this context, the upcoming revision of the Marine Framework Strategy Directive (MSFD) in 2027 provides an opportunity to strengthen synergies with the UWWTD, and the broader Zero Pollution objectives. iMERMAID offers testbeds for operationalising these objectives and accelerating the deployment of water-smart solutions across the Mediterranean region and beyond.

Recommendations

- Encourage the integration of electrochemical, in situ sensors into national and regional wastewater monitoring plans to fulfil new obligations under the UWWTD and MSFD.
- Promote Modular Remediation Units Adapted to Local Contaminants
- Promote Smart Reuse Schemes through Digital Monitoring and Standards
- Consider iMERMAID's digital architecture as a reference model for data integrity and real-time compliance monitoring in UWWTD and the MSFD
- Strengthen Source-to-Sea Coherence via MSFD Revision
- Create a Reference Framework for National Reuse and Monitoring Standards

Deploying innovation to implement the new Urban Wastewater Treatment Directive

Together, the following recommendations aim to operationalise the source-to-sea continuum, mainstream emerging pollutant monitoring, and unlock the potential of digital, modular, and reuse-ready solutions to implement the UWWTD.

1.1.1 Encourage the integration of electrochemical, in situ sensors into wastewater monitoring plans

Encourage the adoption of electrochemical, in situ sensors for real-time detection of PFAS, pharmaceuticals, and metals. iMERMAID deployed validated sensors in User Case (US) 2 (Tunisia), UC 3 (Italy), and UC 5 (Greece), enabling continuous monitoring of CoECs such as diclofenac, ibuprofen, BPA, Bentazone, and PFOA. These technologies are directly applicable to UWWTD Art. 10(1) and MSFD Art. 8(1)(b)[1].

Weeefiner's system and Heavy Metal Box installed in SMAT plant in Brandizzo (more info here).

1.1.2 Promote Modular Remediation Units Adapted to Local Contaminants

Support implementation of portable, decentralized treatment technologies through EPR and targeted Article 8(4) measures. iMERMAID provides cost-efficient and modular remediation systems that could be implemented by the utilities or industrial actors[2] like:

- Microfluidic photocatalytic systems (UC 2, UC 5) for organic micropollutants.
- Pulse Discharge Plasma (UC 1) for pesticides and BPA.
- 4D Scavenger (UC 3) for heavy metals like Zn, Cu, and Al

Based on the "polluter pays" principle, these units match the new requirements for targeted treatment and align with Extended Producer Responsibility (UWWTD Art. 9). EU Member States should:

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[1] iMERMAID. *Development and Deployment of Electrochemical Sensor Box for CoECs and Oil Monitoring*. Deliverable D2.1, Horizon Europe iMERMAID Project, 2024 ; iMERMAID. *Heavy Metal Monitoring Sensor Box: Design, Calibration, and Field Testing*. Deliverable D2.2, Horizon Europe iMERMAID Project, 2024 ; iMERMAID. *Policy Integration Strategy and Roadmap for Innovation Uptake*. Deliverable D6.2, Horizon Europe iMERMAID Project, 2024.

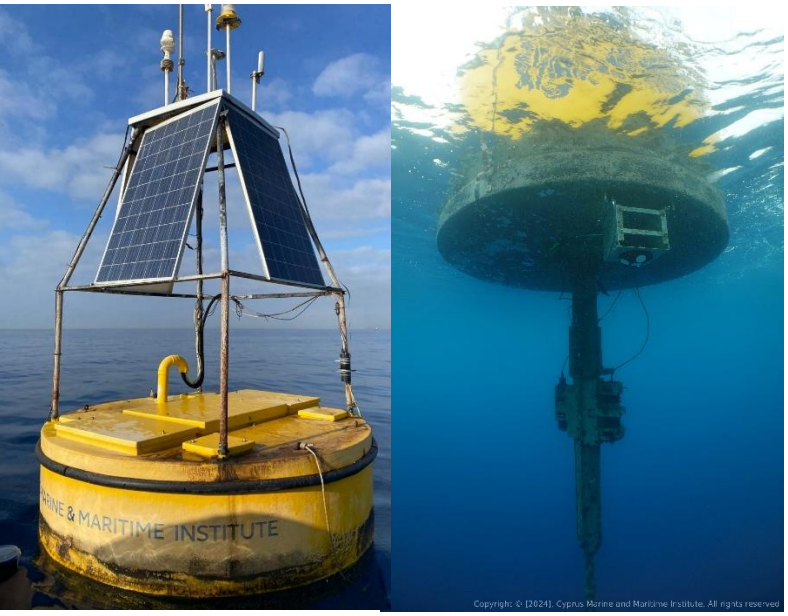
[2] iMERMAID. *Bioaccumulation and Biomagnification of Contaminants of Emerging Concern in Marine Food Webs*. Deliverable D2.3, Horizon Europe iMERMAID Project, 2024 ; iMERMAID. *System Dynamics Modelling and Scalability Assessment of Water Innovation Solutions*. Deliverable D5.2, Horizon Europe iMERMAID Project, 2024.

- Encourage industrial actors as well as relevant authorities to pilot and upscale modular treatment units adaptable to local contaminants and flow rates, particularly in industrial and rural facilities.
- Leverage co-benefits with the MSFD and its objective to monitor contaminants and pollution effects (art. 11 & annex III).

1.1.3 Promote Smart Reuse Schemes through Digital Monitoring and Standards

Currently, only 2.4% of wastewater is reused in the EU. The WRS encourages the expansion of treated wastewater reuse in agriculture, cities, and industry. iMERMAID tested RO with recycled membranes in UC 2 and validated safe reuse scenarios via monitoring in UC 5. These are actionable within UWWTD Art. 12 and WRS Water-Efficiency First Principle guidelines (Section 2.2)[3].

1.1.4 Consider iMERMAID's digital architecture as a reference model for data integrity and real-time compliance monitoring in UWWTD and the MSFD



With the revised UWWTD and Water Resilience Strategy requiring better performance reporting and public transparency, iMERMAID's blockchain-secured monitoring platform, cloud data integration, and visualization dashboard offer a template for interoperable EU-wide systems[4].

By adopting iMERMAID's digital architecture as a reference model for data integrity and real-time compliance monitoring in the UWWTD guidance document (Art. 25) as well as its promotion in the Water Sector Digitalisation Action Plan (section 3.1). This adoption should also be paired with the revision of the article 11 of the MSFD.

CMMI (Cyprus Marine and Maritime Institute) buoy tested in Amathus, Limassol (more info here).

1.1.5 Strengthen Source-to-Sea Coherence via MSFD Revision

The revision of the MSFD, announced for 2027, presents an opportunity to reinforce legal and monitoring coherence across the UWWTD, WFD, and MSFD for pollutants of emerging concern. UC 4 (Cyprus) piloted

[3] iMERMAID. *System Dynamics Modelling and Scalability Assessment of Water Innovation Solutions*, 2024 ; iMERMAID. *Policy Integration Strategy and Roadmap for Innovation Uptake*, 2024.
[4] iMERMAID. *Regulatory and Policy Gap Analysis: Alignment of iMERMAID Solutions with the EU Legislative Framework*. Deliverable D6.1, Horizon Europe iMERMAID Project, 2024 ; iMERMAID. *System Dynamics Modelling and Scalability Assessment of Water Innovation Solutions*, 2024 ; iMERMAID. *Policy Integration Strategy and Roadmap for Innovation Uptake*, 2024.

a buoy-based sensor for oil, and heavy metals, and linked satellite data for marine water quality[5]. It both supports the objectives set in the MSFD, the UWWTD and the WFD.

Moreover, iMERMAID shows the need for joined-up policies to handle CoECs, reuse, and digital monitoring from inland to coastal waters. iMERMAID monitoring (UC 2, UC 3, UC 4) reveals their widespread presence in water, sediment, and seafood. Current MSFD descriptors (D8, D9, D10) under-represent these substances[6].

1.1.6 *Create a Reference Framework for National Reuse and Monitoring Standards*

Drawing from UC 2, UC 5, and D6.2 policy analysis, iMERMAID showcases a data architecture that bridges local reuse, national reporting, and cross-border consistency[7]. There is a need to promote interoperable national platforms, supported by digital tools and flexible standards tailored to regional conditions.

To Go Further

Somrani, A.; Shabani, M.; Mohamed, Z.; Abohelal, K.; Alsharari, S.S.; Hannachi, A.; Ghaffour, N.; Pontié, M. *Dual Repurposing of End-of-Life BWRO Membranes: Ultrafiltration Membranes for Advanced Wastewater Treatment and Cation Exchange Membranes for Fungal Microbial Fuel Cells*. Membranes 2025, 15, 5. https://doi.org/10.3390/membranes15010005

Armaković, S., Vujić, Đ., & Brkić, B. (2024). Computational Multiscale Study of the Interaction Between the PDMS Polymer and Sunscreen-Related Pollutant Molecules. Molecules, 29(20), 4908. https://doi.org/10.3390/molecules29204908

Reynoso, E. C., Sfragano, P., González-Perea, M., Palchetti, I., & Torres, E. (2024). Aptasensors for the Detection of Environmental Contaminants of High Concern in Water Bodies: A Systematic Review. Chemosensors, 12(59), 25. https://doi.org/10.3390/chemosensors12040059

Laschi, S., Sfragano, P., TADINI-BUONINSEGNI, F., GUIGUES, N., & Palchetti, I. (2024). Development of a flow system for decentralized electrochemical analysis of heavy metals using screen-printed electrodes: the importance of sensor stability. https://doi.org/10.1039/D4AN00616J

Permann-Doubkova, M., Armengaud, E., Uroševič, V., Pontie, M., Christoforou, E., Hadjioannou, L., Flourentzou, N., & Barletta, S. (2024). iMERMAID: SMART SYSTEM TO SAFEGUARD THE MEDITERRANEAN SEA. EPoSS Annual Forum 2024 (EPOSS), Cork, Ireland. Zenodo. https://doi.org/10.5281/zenodo.13348171

[5] iMERMAID. *Site-Specific Baseline of Contaminants of Emerging Concern in Water and Sediments*. Deliverable D1.2, Horizon Europe iMERMAID Project, 2024 ; iMERMAID. *Policy Integration Strategy and Roadmap for Innovation Uptake*, 2024.

[6] iMERMAID. *Site-Specific Baseline of Contaminants of Emerging Concern in Water and Sediments*, 2024 ; iMERMAID. *Development and Deployment of Electrochemical Sensor Box for CoECs and Oil Monitoring*, 2024 ; iMERMAID. *Bioaccumulation and Biomagnification of Contaminants of Emerging Concern in Marine Food Webs*. Deliverable D2.3, Horizon Europe iMERMAID Project, 2024 ; iMERMAID, *Benchmarking and Analysis of current aspects, requirements, specifications & conceptual architecture*, Deliverable 4.2, January 2024.

[7] iMERMAID. *System Dynamics Modelling and Scalability Assessment of Water Innovation Solutions, 2024 ; iMERMAID. Regulatory and Policy Gap Analysis: Alignment of iMERMAID Solutions with the EU Legislative Framework,* 2024 ; *iMERMAID. Policy Integration Strategy and Roadmap for Innovation Uptake,* 2024.

The Mediterranean Sea and its surrounding regions support a diverse variety of essential socioeconomic activities. It is one of the highly exploited water ways and the influence of anthropogenic activities on its marine habitats and ecosystems has grown significantly since the industrial revolution. Because of this, the Mediterranean Sea basin is very vulnerable to chemical contamination and build-up. To safeguard the Mediterranean Sea basin from contaminants for emerging concerns (CoEC), iMERMAID will integrate, coordinate, and synergize innovative preventive, monitoring, and remediation solutions. iMERMAID will build an evidence-based multidimensional framework that will guide policymaking and transform societal perceptions to reduce CoEC usage, emissions, and pollution. Furthermore, next generation sensor and remediation solutions will be developed within iMERMAID to monitor and remove prioritized chemicals from its source while reducing upstream pollution. iMERMAID builds an ideal interdisciplinary team by bringing together prominent SMEs, researchers, regulators, and innovation professionals who have been essential in improving the knowledge and awareness of CoEC. Beyond state-of-the-art techniques, iMERMAID will strive to strengthen regulations against CoEC, expand economic possibilities and competitiveness, improve the standard of living for EU residents, while preventing the accumulation of chemical pollution in the Mediterranean Sea basin. iMERMAID will empower the efforts to create a zero pollution, contaminant free waters by enabling the Chemical Strategy's goals to become a practical reality.

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