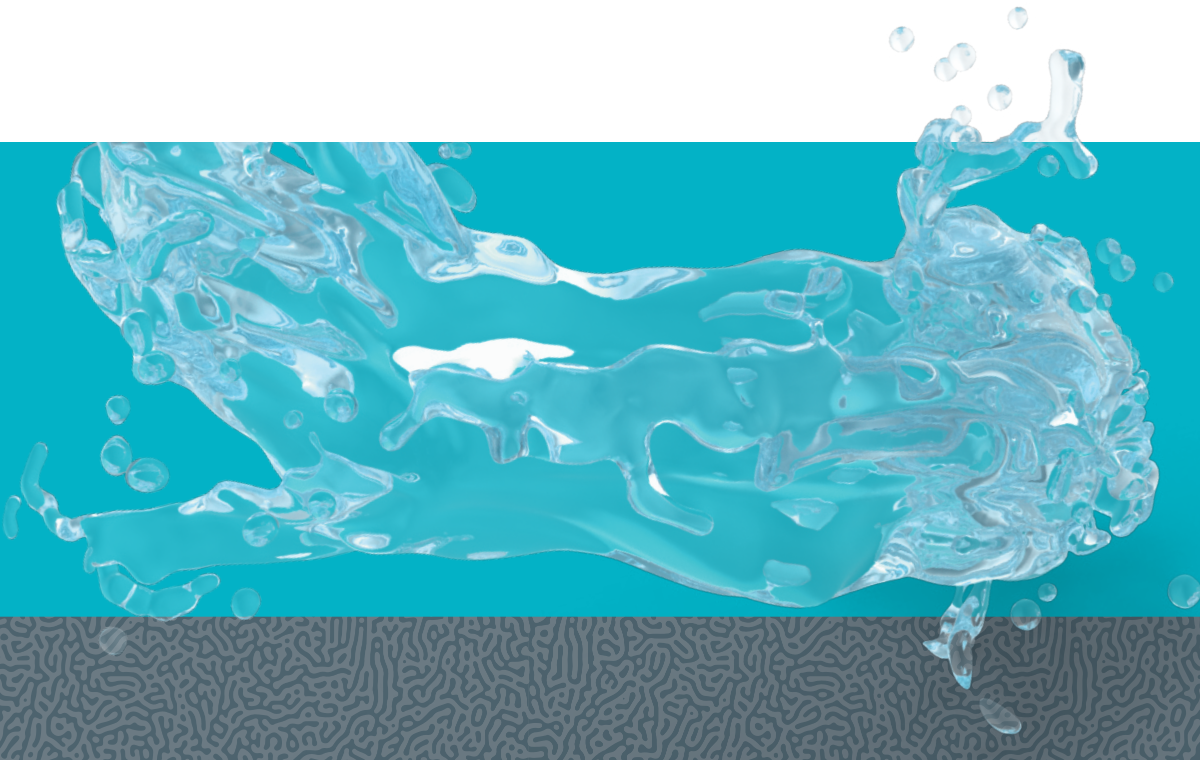
POLICY BRIEF

Can decentralised treatment systems address the challenges of wastewater management in the EU at the local level?



WHY IS THIS POLICY BRIEF IMPORTANT?

- Decentralised wastewater treatment systems (DEWATS) and Nature-based Solutions (NbS) improve the resilience of wastewater treatment systems and support EU water policies.
- DEWATS and NbS can enhance circularity in the water cycle by facilitating local water reuse, reducing energy consumption and improving cost efficiency.
- Decentralised approaches can support the implementation of the revised Urban Waste Water Treatment Directive (UWWTD) by providing wastewater treatment in smaller agglomerations.
- Regulatory gaps and a centralised focus in EU legislation hinder the integration of NbS and DEWATS, limiting their potential in wastewater management and water reuse despite their alignment with circular economy principles.
- Hybrid approaches, combining grey infrastructure and NbS, can enhance wastewater treatment, while offering further social and environmental benefits.

WHO SHOULD READ THIS?

- Policy makers at EU and national level developing and revising legislation related to the **Water Framework Directive**
- Practitioners and policy makers at local and regional level
- Practitioners working in water management, or in other cross-cutting fields (climate adaptation and resilience, land use planning, energy, agriculture)
- European Commission officials with interests in the topics of water management, nature-based solutions, water quality and pollution, nature conservation, water – energy nexus, agriculture, or related topics (e.g. Directorates General ENV, CLIMA, AGRI, ENER)

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Introduction

WASTEWATER MANAGEMENT AT THE LOCAL LEVEL

At a strategic level the European Union has demonstrated commitments towards promoting circular economy practices and reducing pollution in the wastewater management sector. The **EU Green Deal** has set up a target to achieve climate neutrality by 2050, which requires efforts in the energy neutrality of wastewater treatment processes and circularity in treatment processes for the enhancement of water reuse, sludge management, and the valorisation of biomethane from wastewater treatment processes. As well, in the **Zero Pollution Action Plan**, the EC has set up targets aiming at expanding the coverage of wastewater treatment, and extending the implementation of advanced treatments for the removal of nutrients and emerging pollutants.

According to the EC, currently 98% of produced wastewater in the EU is adequately collected and 92% meet the treatment requirements. However, the latest EEA report on **Europe's state of water 2024** describes that good status is not achieved for more than half of surface water bodies and groundwater sources in the EU due to the intense pressure of human activities in rivers, lakes, estuaries, and coastal waters. The pressures on the water environment come from point pollution sources such as wastewater treatment plants, industries, and storm overflows, as well as diffuse pollution sources, like urban and agricultural runoff.

Wastewater management in the European Union currently faces significant challenges at the local level, particularly in rural areas, small communities, and low densely populated regions. According to the EC, wastewater treatment systems in the EU mostly follow centralised approaches consisting of sewage networks and treatment plants including physical, chemical, and biological processes (**European Commission, 2022**). These systems are constructed to address certain contaminant loads and are designed for a specific population, representing high investment costs and having a limited capacity to adapt to changing conditions, such as population growth, urban sprawl, and extreme weather events.

This implies that to achieve the EU Green Deal and Zero Pollution ambitions, further efforts are required for pollution reduction from wastewater effluents, including treating emerging pollutants as well as addressing the challenges related to wastewater produced by smaller agglomerations. It is necessary to change the focus of wastewater treatment systems, aiming for the decentralisation of treatment systems, the integration of Nature-based Solutions (NbS) and the adoption of hybrid treatment technologies.


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WHAT ARE DECENTRALISED WASTEWATER TREATMENT SYSTEMS?

Decentralised wastewater treatment systems (DEWATS) are an alternative approach in which wastewater produced by individual households, clusters of buildings, small communities or industrial facilities is treated locally, close to the source of generation, minimising environmental impacts and favouring resource recovery (Libralato et al, 2012). DEWATS can include a variety of technologies, such as septic tanks, aerobic treatment units, as well as NbS like treatment wetlands.

The significance of exploring decentralised wastewater treatment in the EU context cannot be overstated. As the EU strives to meet its environmental goals, including those outlined in the Water Framework Directive and UWWTD, DEWATS offer several potential advantages, regarding coverage and cost effectiveness, reduction of environmental risks, water reuse, addressing combined sewage overflows and improving the resilience of treatment systems (Bernal et al, 2021). As well, DEWATS and NbS can foster water resilience, mitigating floods and fostering water reuse (Mguni et al., 2022).TThese systems can contribute to the implementation of the EU Strategy on Adaptation to Climate Change and are relevant approaches for the newly launched Water Resilience Strategy.

As the EU continues to address wastewater management challenges, particularly in areas unsuited for centralised systems, the potential of decentralised approaches becomes increasingly relevant. This policy brief will explore how decentralised wastewater treatment systems can effectively address these challenges through the integration of NbS, examining their feasibility, benefits, and potential drawbacks in alignment with the EU's regulatory framework.


Image: INRAE / Stephane Troesch

Regulation and the implementation of DEWATS

HOW CAN NBS AND DEWATS SUPPORT POLICY IMPLEMENTATION?

The consideration of wastewater as a resource and water reuse is at the core of DEWATS (Garrido-Baserba et al, 2024) and there is ample evidence of the efficiency of NbS for wastewater treatment (Cross et al, 2021). Considering the implementation of smaller and local units, wastewater can be treated close to the source, specially aiding the local reuse of treated water for different purposes (e.g. irrigation). This approach would reduce the need of transportation of water through a network for treatment and for its reuse, potentially reducing the use of energy for pumps and thus improving the cost efficiency of reused water. This increase of circularity in urban water cycles supports the implementation of the Circular Economy Action Plan.

DEWATS and NbS can also strengthen the application of the Sewage Sludge Directive. Certain types of treatment wetlands (e.g. French Vertical Flow wetlands and sludge treatment reed beds) can perform dewatering and stabilization of the sludge. These solutions can improve the quality of the sludge as the processes like filtration and biodegradation can reduce the concentration of pollutants, and the degradation of organic matter can enhance the sludge quality, increasing its suitability for agricultural use (Cross et al, 2021; Droto et al, 2017). Thus, DEWATS allow on-site sludge treatment and can promote local use as fertiliser.

The implementation of DEWATS and NbS for the reduction of water pollutants will also have an impact on the quality of surface water bodies and groundwater. Therefore, these solutions can support the targets and objectives of other policies and regulations within the EU Water Framework Directive, including the Drinking Water Directive and Bathing Water Directive.

In November 2024, the revised UWWTD was adopted at EU level, which sets EU-wide rules for collecting, treating, and discharging wastewater. The revised

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Directive aims at addressing remaining pollution sources related to wastewater management, which includes small agglomerations, Individual Appropriate Systems (IAS), and stormwater overflow and urban run-off. In the revision, the scope of the UWWTD was broadened to include the regulation of small agglomerations of 1000 p.e., new obligations were introduced to regulate more decentralised systems (IAS), further reduction of nutrient loads is required (reduction of concentration levels of Nitrogen and Phosphorus), and it addresses the treatment of emergent pollutants through its monitoring and the introduction of quaternary treatment systems for their removal.

DEWATS integrating NbS can play a key role in enhancing the resilience of existing wastewater treatment systems, especially of Combined Sewage Systems, considering the high variability of precipitation regimes and the increase of extreme events caused by climate change. On one hand, NbS like rain gardens, vegetated roofs, treatment wetlands, and detention basins can reduce urban run-off and support wastewater treatment plants by mitigating **stormwater overflows** (Kõiv-Vainik et al., 2022) Additionally, NbS (e.g. treatment wetlands or retention ponds) can also be used as additional treatment systems targeting stormwater overflows before their discharge in surface water bodies, thus reducing the risk of pollution during high precipitation episodes. The integration of DEWATS and NbS can generate more flexible urban wastewater treatment systems, capable of withstanding higher flow variability in comparison to conventional wastewater treatment plants.

Additionally, the requirements of the UWWTD for further **nutrient removal and treatment of emerging pollutants** can benefit from the incorporation of NbS as an additional treatment, which can be integrated in the wastewater treatment plant or as separate units based on land constraints. Treatment wetlands can deliver both efficient removal of nutrients, as well as control of emerging contaminants (Dotro, G. et al, 2017). On the other hand, in the implementation of DEWATS, water can be reused locally for irrigation or agriculture, in which case a higher concentration of nutrients would be desirable as it can replace fertilisers. In the case of emerging pollutants, such as pharmaceuticals and viruses, NbS can deliver very good levels of removal efficiency (Dotro, G. et al, 2017). There is also evidence showing that the coupling of grey and green technologies show promising results in the removal of emerging pollutants, including microplastics and organic micropollutants (Castellar et al, 2024).

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PEREIRA CASE STUDY (NICE)

NbS for wastewater treatment in smaller agglomerations

In the case of **small agglomerations**, centralised wastewater treatment systems are not feasible due to the high infrastructure investment, operation costs and the high wastewater flow and composition variability. The high flexibility of DEWATS in terms of design and low infrastructure costs, allow them to be more easily tailored to local needs. A clear example of how NbS can be used for such purposes is the **NICE pilot in Pereira**, a middle size city with a population close to half a million, located in the main coffee producing region of Colombia. The main economic activities of the city are related to commerce and services. The city is aiming for the construction of an activated sludge WWTP that will serve Pereira and the neighbouring municipality Dos quebradas, with an expected mean waterflow of 1.62 m^3/s. Among the challenges the city is facing, the City's Master Plan for Water Security mentions the integration of water management practices, looking at the reliability of long-term drinking water supply of the population and sanitation and access to wastewater treatment in urban and rural areas.

Pereira has been implementing several pilot-scale NbS aiming to understand the impact of these solutions in relation to water management. In terms of wastewater management, two pilot-scale PTARS integrating constructed wetlands have been developed (La Florida and La Bananera), as well as the Urban Real Lab (URL) in the context of NICE testing the potential of NbS for domestic wastewater treatment at the Pereira Technological University. As well, an additional URL has been installed to test the use of NbS to improve the quality of water of the Otún river.

The La Florida Wastewater Treatment Plant (PTAR) is located in the most populous and socioeconomically dynamic area in the upper Otún River basin. Built in 2002, the plant aims to improve water quality and ensure its suitability for human consumption. Its design harmonizes with the landscape to foster community acceptance. With a treatment capacity of 2.5 L/s, the PTAR incorporates preliminary treatment (screening and grit removal), primary treatment (septic tank and upflow anaerobic filter), and horizontal subsurface flow wetlands spanning 540 m^2. These systems achieve approximately 85% removal of biochemical oxygen demand (BOD) and reduction of coliforms.

On the other hand, La Bananera Wastewater Treatment Plant (PTAR) is located approximately 1.5 km upstream from the Otún River water intake point, where water is collected for treatment at the Pereira Drinking Water Treatment Plant (PTAP). Built in 2007, the PTAR was designed to improve water quality and ensure the resource's potential for human consumption while integrating harmoniously with the landscape to encourage community acceptance. With a treatment capacity of 1.2 L/s, the plant includes preliminary treatment (screening and grit removal), primary treatment (septic tank and upflow anaerobic filter), and horizontal subsurface flow wetlands covering 768 m^2, achieving approximately 90% removal of (BOD) and coliform reduction.

The Pereira Technological University URL features vertical and horizontal constructed wetlands with varying configurations of sand and gravel as support media, planted with **Heliconia sp.** and **Equisetum arvense**. Experimental setups tested the combination of various media heights and hydraulic loads, resulting in removal efficiencies of over 85% BOD5 and 90% in suspended solids in vegetated systems. The system produces high-quality effluent suitable for reuse and significantly reduces pollutants, including pathogens like E. coli and nutrients like nitrogen. This aligns with circular economy principles, showcasing the system's adaptability to hydraulic variability and resilience to urban challenges related to climate change. These findings position constructed wetlands as robust, nature-based solutions (NbS) for sustainable urban water management, supporting the NICE project's goal of integrating NbS into the urban water cycle through environmentally responsible and circular approaches.

Image: Aguas y Aguas de Pereira

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GIRONA CASE STUDY (MULTISOURCE)

Wastewater treatment featuring NbS to enhance circularity

Even though there are regulatory barriers, there is a need to provide evidence on how NbS can enhance the circularity of wastewater treatment. This is done at pilot scale through the **Multisource project** in Girona, located in northeastern Catalonia, Spain. The city sits at the confluence of four rivers (Ter, Onyar, Galligants, and Güell) and experiences a Mediterranean climate. However, Girona is currently facing a severe drought, with over three years of rainfall amounting to only half the annual average. Amid these challenges, Girona is undergoing a transformation to become a more resilient, liveable, and sustainable city.

Among the various initiatives underway, the MULTISOURCE pilot project for greywater treatment employs a hybrid, modular green wall technology to provide innovative solutions for water reclamation and reuse. Specifically, two green walls designed for greywater treatment will soon be operational: one at the headquarters of the Catalan Institute for Water Research (ICRA) and the other at an elementary school in the Sant Narcís neighborhood. The treated water will be reused for irrigating urban gardens in both cases. While the ICRA pilot focuses on process optimisation, the school pilot emphasises education and raising awareness to engage the general public. Additionally, a third green wall, installed at a social housing building in Sant Quirze (a nearby town Girona), has been operational for over 1.5 years. This system treats greywater from three apartments using Greta technology (developed by Alchemia-Nova) and reuses it for toilet flushing within the same apartments. Advanced treatment methods are also being integrated with green wall systems to ensure higher water quality and safer reuse. For example, the green wall effluent in Sant Quirze undergoes ozonation for further purification. Performance evaluations of the Sant Quirze green wall demonstrate high treatment efficiencies, with over 90% removal of conventional physicochemical and microbiological pollutants and 60–99% removal of emerging contaminants, such as organic micropollutants and microplastics. Still, another green wall, installed at a hotel in a tourist resort in the Girona region, has demonstrated successful results in greywater treatment and reuse for nearly a decade.

These technologies have been assessed not only for their technical performance but also for their environmental and social co-benefits. Quantifiable benefits include increased green space, enhanced biodiversity, carbon sequestration, and stakeholder engagement involving local authorities, students, and residents. Economic viability has also been analyzed through detailed cost-benefit assessments, accounting for investment, operational, and maintenance costs.

Green wall technologies can be adapted to various building types and scales, including residential, commercial, public, industrial, and touristic facilities, making use of empty vertical spaces. A recently approved (October 2024) municipal regulation in Barcelona mandates greywater treatment and reuse for new buildings and major housing renovations, potentially encouraging the wider adoption of green wall technologies. This innovative NBS, and its comprehensive assessment, demonstrates significant potential to support the transition towards more circular and decentralised water treatment systems.

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It is important to mention that DEWATS are not only relevant for smaller agglomerations, rural or peri-urban areas, but can prove important to densely populated urban areas. DEWATS can be designed to support existing centralised wastewater treatment plants, increasing their capacity and the coverage of the sewage networks, especially in relation to urban sprawl. They can also be used as temporal solutions, considering the smaller investment costs and managing to capture effluents generated in areas before a central wastewater treatment plant is developed. DEWATS and NbS can be integrated within centralised wastewater treatment systems to better address the needs of wastewater management at the local level and reduce pollution sources.

WHAT ARE THE BARRIERS?

Even though the EU Green Deal recognizes the critical role of NbS in achieving key EU policy objectives, particularly in enhancing resilience, these solutions remain largely absent from the current regulatory framework. The recently revised UWWTD acknowledges the role of individual systems and other decentralised solutions in wastewater treatment but fails to explicitly incorporate NbS. While the Directive emphasises circular economy principles, particularly nutrient recovery, energy recovery and water reuse, this focus remains mainly on centralised wastewater treatment approaches.

A complementary piece of legislation, the **EU Regulation 2020/741** on the minimum requirements for water reuse, further promotes circular economy principles in water management by setting quality standards for the safe reuse of treated urban wastewater. However, this regulation makes emphasis on water reuse for agricultural irrigation, covering food crops (processed and unprocessed) and non-food crops such as pastures, fibre, and ornamental plants. The regulation exclusively addresses treated urban wastewater from centralised treatment plants, limiting the scope of reclaimed water sources and applications. While the regulation establishes a framework that can potentially be adapted to incorporate other sources of treated wastewater, it does not explicitly acknowledge decentralised systems or NbS. Furthermore, the regulation does not provide specific requirements for water reuse for other purposes, which can limit the implementation of other potential uses of reclaimed water such as landscape irrigation or industrial uses.

A disconnection exists between the circularity goals in water management and the current regulatory framework. The revised UWWTD acknowledges DEWATS, while local water reuse -an inherent feature of DEWATS- may be limited according to the **EU Regulation 2020/741**. As well, there is an additional regulatory gap given that the UWWTD predominantly applies to urban settings, while the Regulation's focus on agricultural water reuse is most relevant in rural and peri-urban areas. As a result, there is a big limitation on the practical application of reclaimed water.

As highlighted in through the case studies, NbS can significantly contribute to the goals of the revised UWWTD. However, the absence of clear references to NbS in both the Directive and the Regulation risks discouraging practitioners, technicians, and decision-makers from integrating these solutions in their planning. The lack of regulatory clarity around NbS could lead to uncertainty among practitioners, who may fear non-compliance with the Directive when implementing these innovative, nature-based approaches.

Moreover, regulatory frameworks play a key role in shaping public acceptance. Without clear quality standards for reclaimed water from DEWATS and NbS, public trust in these systems will suffer, further discouraging their implementation. In addition to regulation, there is a need for the implementation of effective communication strategies and participative initiatives like citizen science approaches to foster public acceptance of these solutions (**Loghmani-Khouzani et al., 2024**).

These regulatory barriers discourage local decision-makers from launching NbS projects, often waiting for convincing results of demonstration projects before securing funding and committing resources.


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Hybrid approaches and NbS Co-benefits

Existing centralised and conventional wastewater treatment plants can be strategically combined with DEWATS and integrating NbS (Hybrid approaches) to further enhance the coverage of the sewage network, treatment capacity, and removal efficiency of pollutants and nutrients. Existing grey infrastructure, DEWATS and NbS can be considered pieces of a puzzle, which can be combined in different ways and tailored to address the local needs, considering the growing population, the changes in behavioural patterns, and urban sprawl, which can have an impact in the composition and volume of wastewater produced. As well, these hybrid approaches can create more climate resilient and adaptable wastewater management systems, maximising the use of existing infrastructure while addressing future challenges.

In addition, these systems provide multidimensional benefits for both citizens and the urban landscape, aligning with the three pillars of the New European Bauhaus (NEB): sustainability, aesthetics, and inclusion. DEWATS integrated with NbS can offer significant social and environmental benefits, including mitigating the urban heat island effect, enhancing urban aesthetics, and fostering citizen engagement (European Commission - DG RTD, 2021). As well, implementation of water treatment NbS contributes to biodiversity and supports ecosystem restoration, aligning with the objectives of the Nature Restoration Law. By incorporating NbS into public spaces, these solutions promote social connections, environmental education, and local employment while encouraging collective action in urban renewal and sustainability. Several projects have already demonstrated how NbS can be effectively integrated into wastewater treatment. A notable example is located in Honfleur (France) where a constructed wetland covering four hectares has been added to the local sewage treatment plant, serving four municipalities while enhancing the landscape (European Commission - DG RTD, 2022).

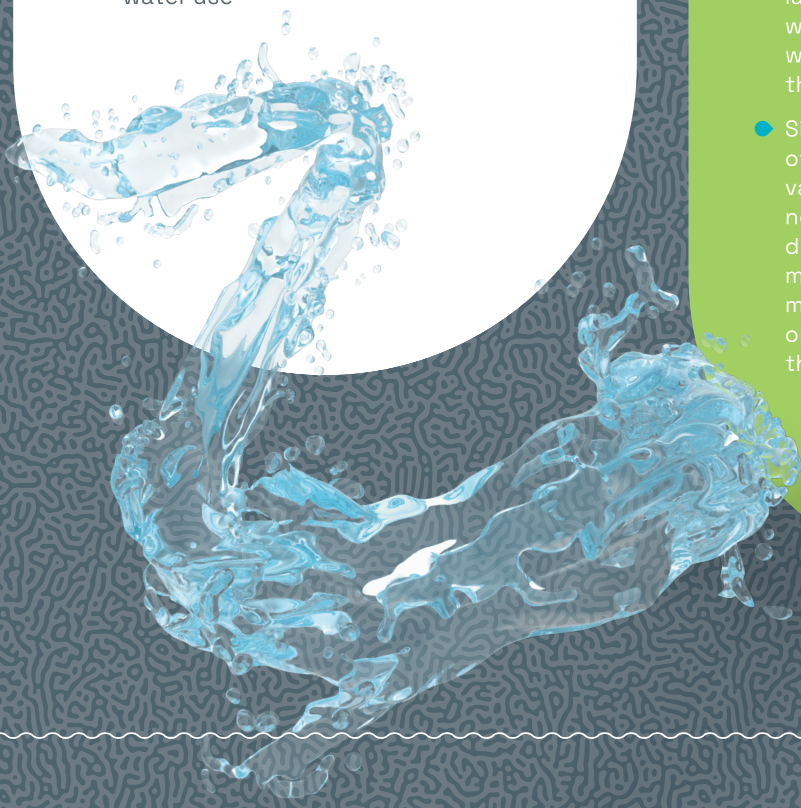

Image: Aqualia

Conclusions

Integrating NbS and DEWATS into wastewater management enhances circularity, resilience, and sustainability by supporting EU water related policies. These solutions improve local water reuse, reduce sludge production, and mitigate stormwater overflows, yet regulatory barriers hinder their widespread adoption. Existing policy, including the revised UWWTD, remain largely focused on centralized treatment, creating uncertainty for decision-makers and limiting the implementation of NbS.

To unlock their full potential, the EU must establish a more inclusive regulatory framework that explicitly integrates NbS and decentralized approaches:

- ensuring alignment across policies
- providing clear quality standards, and
- fostering public trust in reclaimed water use



CALL TO ACTION

- Integration of DEWATS, including NbS, in the planning of wastewater collection and treatment at the local level to support existing Wastewater Treatment Plants
- Introduce harmonised guidance on quality and monitoring standards for reclaimed water from decentralised systems for different purposes (agriculture, landscape irrigation, and industrial reuse), ensuring consistency and fostering public trust across Member States.
- Consistency across the EU level policy landscape regarding the priorities on water and wastewater management, as well as the role of DEWATS and NbS to the achievement of goals.
- Since implementing DEWATS and NbS often requires coordination across various governance levels, there is a need for alignment between EU directives, national guidelines, and local mandates. As well, local authorities might need targeted training, guidelines, or pilot projects to build confidence in these systems.

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