



## POLICY BRIEF

# 1



MAR2PROTECT

## Paving the way for Managed Aquifer Recharge in Europe

*Recommendations for EU-level policy makers*

### Key message

- Managed Aquifer Recharge (MAR) schemes are common in EU Member States as a way of addressing challenges related to water scarcity and water quality. However, there is no unified European policy framework regulating MAR, leading to difficulties with MAR implementation.
- Current MAR schemes operate at the intersection of diverse European directives and regulations addressing the water source (re)used in MAR, and those regulating the water quality for the different [indirect] uses.
- Concrete steps by EU policy makers are required to leverage the potential of MAR for sustainable groundwater management by seizing opportunities for improving policy coherence, and their implementation and evaluation.

### Executive summary

The worsening impacts of global and climate change currently affecting groundwater quality and quantity worldwide have urged discussion about sustainable groundwater management in the water resources community over the last decades (Levintal et al., 2023; Stoksad, 2020). One sustainable groundwater management strategy to protect and enhance groundwater quantity and quality is to design and implement Managed Aquifer Recharge (MAR). The implementation of MAR can be divided into three interrelated policy domains:

1. The **water to be used for recharging** (i.e., [reclaimed] **water source**) is the subject of quality regulations. Here, a particular emphasis is placed on *treated wastewater*, which is the subject of regulations on its treatment, including lists of pollutants (comprising those of emerging concern) and their minimum parametric values.

2. Once the aquifer has been recharged, there are issues related to **aquifer [water] storage and recovery [extraction] of stored water can emerge.**
3. The potential **[indirect] reuse of reclaimed water**, which also influences the quality requirements of the water to be artificially recharged to the groundwater bodies, is the subject of yet another different set of legislation and regulations.

Based on an analysis of major EU policies governing MAR interventions and groundwater protection (Vallejo et al., 2024), **this policy brief presents four concrete recommendations for EU policy makers.** By improving coherence across the diverse policy landscape governing MAR, as well as the implementation and evaluation of related policies, EU policy makers can help leverage the potential of MAR for sustainable groundwater management in the EU.

## Introduction

Population growth, rapid urbanization, and consequent increasing demand for water resources, together with the worsening of climate change risks and water-related crises worldwide, have resulted in a global trend of groundwater resources depletion (Alam et al., 2021; Dahlke et al., 2018). Global insufficiency in water resources requires alternatives to increase water supply (Page et al., 2020). One sustainable groundwater management strategy to protect and enhance groundwater quantity and quality is to design and implement MAR. MAR is an approach that contributes to increasing groundwater supply by artificially recharging aquifers for subsequent recovery or environmental benefit (Dillon et al., 2009). Although MAR has been implemented in Europe since the 1970s, and it is increasingly relevant to increase groundwater availability and prevent groundwater pollution (i.e., salination), **there is no explicit regulatory framework for MAR in the EU.**

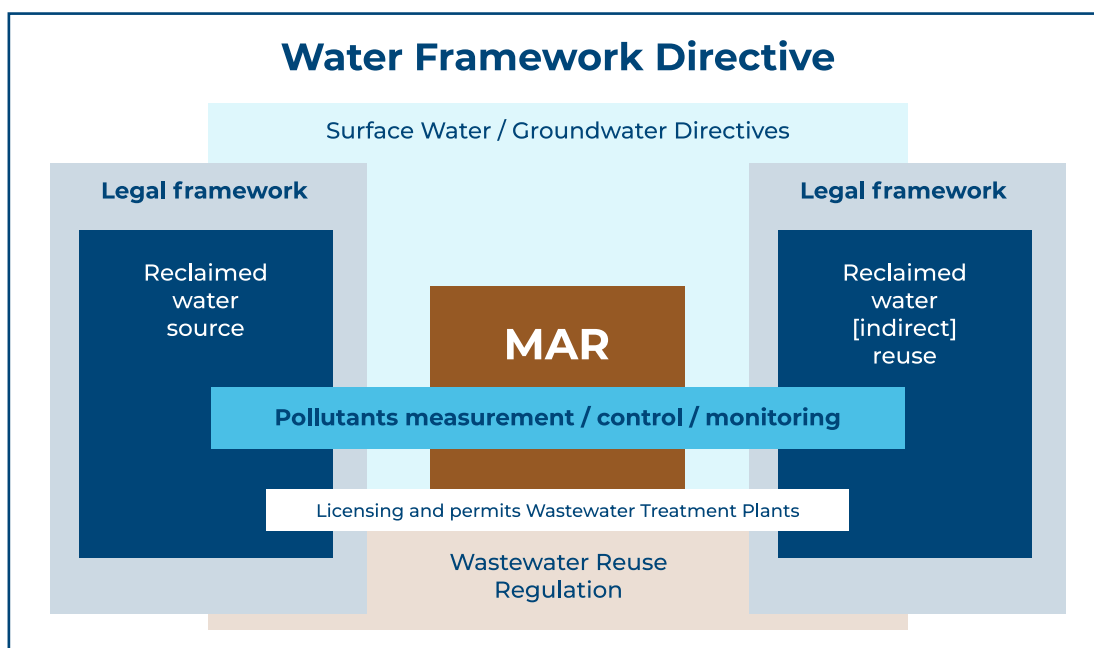
Nevertheless, MAR is currently operating at the intersection of a range of (overlapping) *policy* domains, namely

- (1) groundwater management,
- (2) use of reclaimed water sources,
- (3) reuse of recovered water, and
- (4) reuse of treated wastewater,

all of which require monitoring and controlling of pollutants.

To understand how these policy domains influence the implementation of MAR, we approach them through those regulatory directives or legislations related to both, the source of water (e.g., wastewater) and the [indirect] reuse (e.g., drinking water, irrigation) of reclaimed water. MAR cuts across both of these two domains. Moreover, the regulations concerning pollutants (including their measurements and monitoring) are transversally related to policies governing reclaimed water sources and reuse.

## Conceptual framing of EU legislation regulating MAR



## Relevance

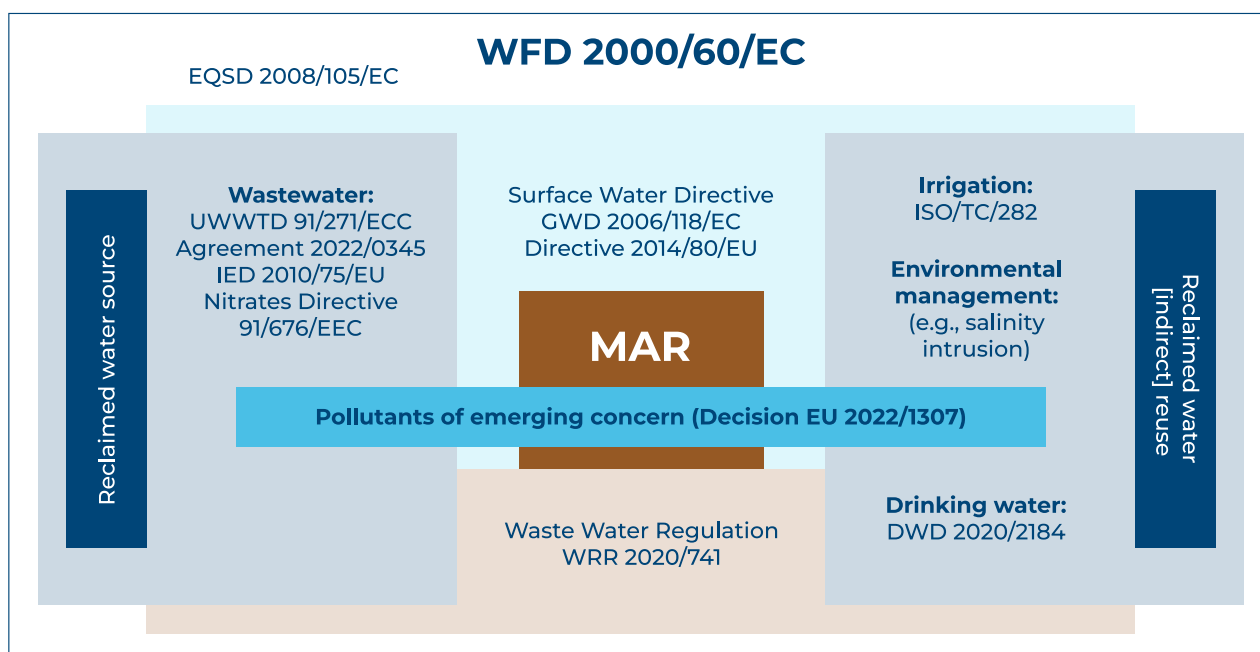
Due to climate change and industrial overexploitation, European groundwater has been seriously affected by global and climate change impacts. The insufficiency in water resources for irrigation and agriculture and the intense extraction of surface and groundwater resources require alternatives to increase water supply (Page et al., 2020). MAR is an approach to address decreasing

groundwater availability by implementing artificial processes. MAR is also an instrument through which treated wastewater could be reused and re-entered to the water cycle, contributing to the clean and sustainable water goal for 2027. Hence it is important to understand the European legal and regulatory setting that shapes the implementation of MAR at the European level.

## Challenges

At the EU level, a range of legal frameworks for water management influence MAR, either regarding the inputs (reclaimed water source - mostly wastewater) or the outputs ([indirect] reuse of the reclaimed water [indirect] reuse) (see Figure).

### Water management legal frameworks in the EU



Transposing policy directives from the European to the national levels of its Member States is a **complex and lengthy task** requiring gradual national policy amendments and the introduction of new pieces of national legislation. This process is made more complex because MAR does not have a legal definition within the EU legislation, given its variety of forms. Although artificial aquifer recharge (as MAR is also known) is recognized as a supplementary method in the Water Framework Directive (WFD 2000/60/EC (updated in 2023)), the Surface Water Directive and the Groundwater Directive (GWD 2006/118/EC (with amendment Directive 2014/80EU)), **there are not guidelines for MAR implementation.**

**The interaction across policies gets even more complex when we consider models of MAR recharging with treated wastewater as reclaimed water source**, which aligns with the EU Circular Economy Action Plan. MAR schemes reusing wastewater fall under the Waste Water Regulation (WRR 2020/741) and the Urban Waste Water Treatment Directive (UWWTD 91/271/EEC (amended by EU 2022/0345)), with more specific urban wastewater reuse regulations. For those MAR schemes reusing industrial wastewater, the regulations established in the IED 2010/75/EU must be considered.

A particular challenge regarding the regulation of MAR is the case-by-case implementation, as not only do aquifers have different characteristics calling for a site-by-site approach, but MAR also differs in the source of reclaimed water and the intended indirect reuse. **EU-level policies and regulations address related issues concerning reclaimed water sources and [indirect] reclaimed water use but not MAR itself.** These EU regulatory frameworks push MAR decision-making and specific regulations to the Member States. However, no clear guidelines or blueprints are provided.

The Action Plan for Circular Economy through the Waste Water Regulation (WWR 2020/741) reinforces reusing treated wastewater as reclaimed water for diverse (non)human activities and uses. The intention is **not** to build a support mechanism to increase water consumption; rather, it intends to introduce reclaimed water for reuse as a substitute. Although this is clear at the EU level through the related regulations, including the Action Plan for Circular Economy, **this objective gets lost when policies are framed at the national level in the EU Member States.**

Regarding the *Pollutants of Emerging Concern*, the watch lists published by the EU are not entirely aligned with those included in national policies. **The list of traditional pollutants and the list of 'pollutants of emerging concern' from the EU are not easily transposed to the national level** due to the restrictive [national] rules already in place, mechanisms to implement measures as national regulations are not yet fully adopted, the lack of monitoring [and technological] mechanisms at the local level and the increase in costs that would be involved in addressing them.

The WFD 2000/60/EC recognizes the basin as the unit for water management and water planning, and, therefore, *River Basin Management Plans, RBMP* (see WFD Annex II, 1.2) programs and monitoring processes following the environmental objectives stated in the WFD 2000/60/EC directive. These RBMPs have an average six-year planning horizon (i.e., 2017-2021-2027). However, **no requirements on how to regulate groundwater through RBMPs is provided.**

## Recommendations for EU policy makers

### Policy complexity: multi-level, multi-actor

*In order to reduce the complexity and uncertainty in the transposition of directives, the existing regulatory frameworks influencing MAR should be harmonized across the EU and the national levels, taking into account MAR-related issues alongside other water management practices and goals. **Opportunities for harmonizing MAR-related requirements and processes** (availability and quality of source water, recharge techniques, guidelines for 'limiting' and 'preventing' pollutants in source water) **should be seized** when updating/revising relevant policies, such as the River Basin Management Plans in 2027. In order to do so, the participation of MAR experts will be crucial.*

### Diverging lists of pollutants

*In order to harmonize the list of pollutants monitored, European authorities could use MAR projects as a way to monitor and prepare projections (through modelling) of groundwater pollution. For this, **harmonisation in the list of pollutants monitored (and modelled) under MAR is needed.** Since most MAR projects are financed at national or supra-national levels, calls for proposals should include an explicit requirement to address officially listed pollutants, including those on the watch list of pollutants of emerging concern.*

### Increased water consumption due to wastewater reuse

*Emphasize the European objectives regarding the reuse of reclaimed water as a **mechanism for water-saving rather than increased water use.** Evaluate as soon as possible whether the water-saving objective is adequately transposed to the national level in Member States.*

### Challenges with monitoring and reporting

























*In order to advance the harmonisation of methodologies for required monitoring and reporting, **establish custodians** for the methodologies used for monitoring the quantity and quality of reclaimed water sources and reused water, based on FAIR data principles.*

## Way forward

The variety of legislative tools and the diversity of the actors and contexts they address reflect the complex nature of water management legislation in general and that related to MAR in particular. Distinct challenges need to be addressed, as identified in Vallejo et al. (2024), at one or

more governance level (see table). The recommendations provided in this policy brief for European policy makers. A sister policy brief (Policy Brief 2 [10.5281/zenodo.14137664](https://doi.org/10.5281/zenodo.14137664)) details recommendations for national policy makers in EUR Member States.

## Overview of challenges and recommendations at three governance levels in the EU

Challenge	Policy Recommendation (in brief)	Europe	National	Regional / local
 <b>Policy complexity: multi-level, multi-actor</b>	Seize opportunities for harmonizing MAR-related requirements and processes			
 <b>Challenges with River Basin Management Plans</b>	Set up a special Mutual Learning Exercise to include the MAR component in the RBMP at sub-national level within EU member states			
 <b>Local implementation of wastewater treatment obligations</b>	Undertake regular national consultations (including MAR experts) with water service actors			
 <b>Diverging lists of pollutants</b>	Shape calls for proposals for MAR projects to address officially listed pollutants			
 <b>Increased water consumption due to wastewater reuse</b>	(Re)emphasize agreed European objectives regarding the reuse of reclaimed water as a mechanism for water-saving and not as a local tool for increasing water use			
 <b>Challenges with monitoring and reporting</b>	Seize MAR as an opportunity for filling data gaps, reporting obligations, and groundwater protection actions			
 <b>Navigating policy complexity and implementation</b>	Create regional and/or national competence centres or contact points that provide a “one-stop shop” for MAR practitioners			

## Acronyms

**AI:** Artificial Intelligence

**DSS:** Decision Support System

**MAR:** Managed Aquifer Recharge

**RBMP:** River Basin Management Plans

## How to cite

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## Project summary

The MAR2PROTECT project aims to provide an innovative, holistic approach to prevent groundwater contamination from the impacts of global and climate change through developing a set of innovative technologies for Management Aquifer Recharge (MAR) and a new generation of MAR management tools. The core of this

innovative MAR approach is the M-AI-R-DSS tool, an innovative Decision Support System (DSS) that aims to incorporate technological and societal engagement information using an Artificial Intelligence (AI)-based tool that will help monitor and enhance groundwater quantity and quality in real-time.

