Groundwater restoration practices in Europe and China

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Potential effects of deteriorated aquifers

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Water quantity effects from climate change, overexploitation and/or pollution

- Drying out of rivers and lakes and ecosystem effects in GDE (vegetation degradation etc.)
- Soil subsistence with impacts on infrastructure
- Water scarcity and potential adverse effects on agricultural production
- Groundwater flooding

Water quality effects due to pollution

- Human health problems due to consumption of contaminated groundwater used for drinking water supply
- Closing of drinking water wells
- Reduced water availability

Prioritised threats to groundwater

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China:

Overexploitation

Climate change (Drought/increased water scarcity)

Groundwater pollution

- Agricultural diffuse pollution
- Microbial pollution
- Industrial pollution/hazardous waste sites

Saltwater intrusion

Europe:

groundwater pollution

- Agricultural diffuse pollution
- Industrial pollution/contaminated sites
- Microbial pollution from sewer leakages

Climate change (drought/increased water scarcity)

Saltwater intrusion

Groundwater restoration practices in China

Overexploitation – Managed Aquifer Recharge (MAR), Reduction of abstraction by introducing water saving measures (agriculture/-domestic use), Importing surface water/adding new water sources

Diffuse agricultural pollution (Pesticides, nitrate, manure) - Well protection (PRB/funnel and gate, cut off walls), End-of-pipe solutions (on site treatment, drinking water treatment)

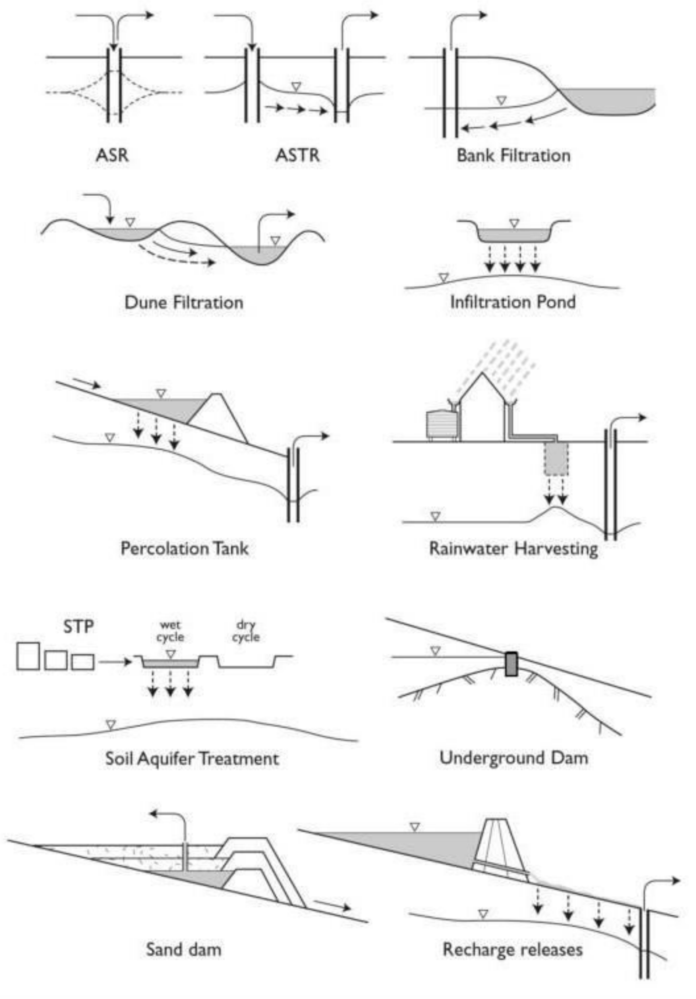
Point source pollution – Ex situ and In situ remediation, containment

Saltwater intrusion – MAR, cut off walls

MAR against overexploitation

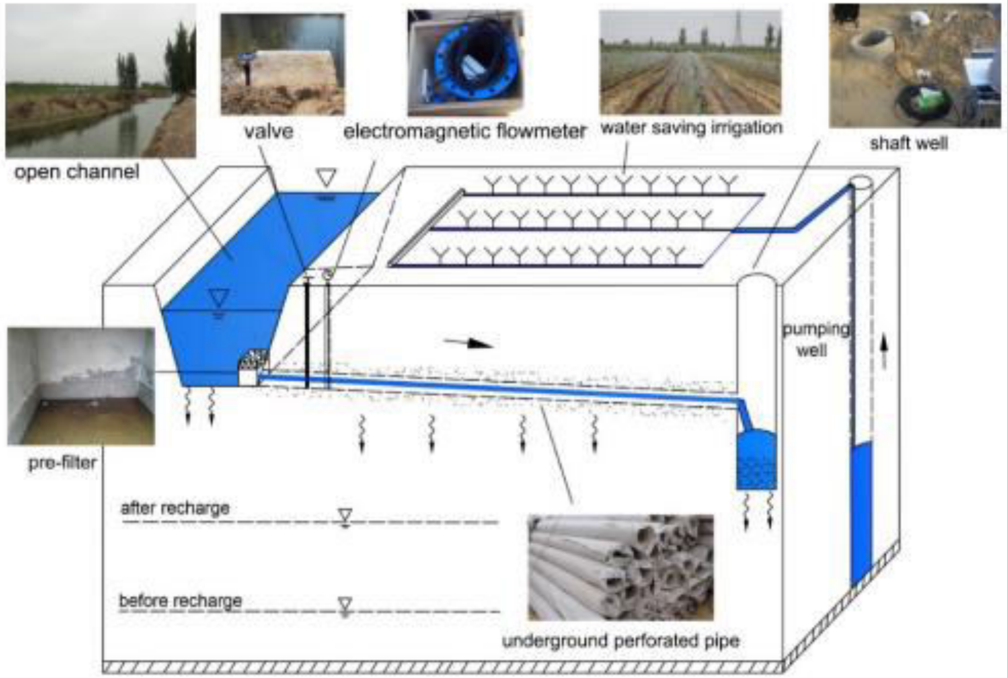
Water sources used in China for MAR:

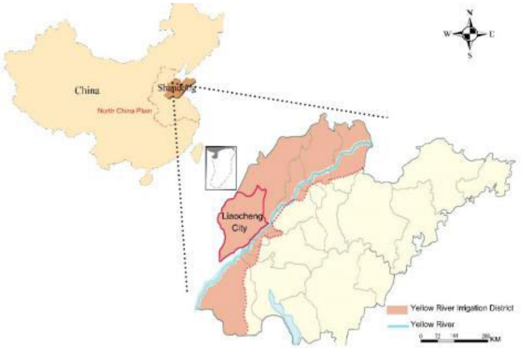
- Lake and river water
- Run off and stormwater
- Irrigation water
- Reclaimed wastewater
- Tap water



MAR project using **river water** in the Yellow River Irrigation District, Shandong

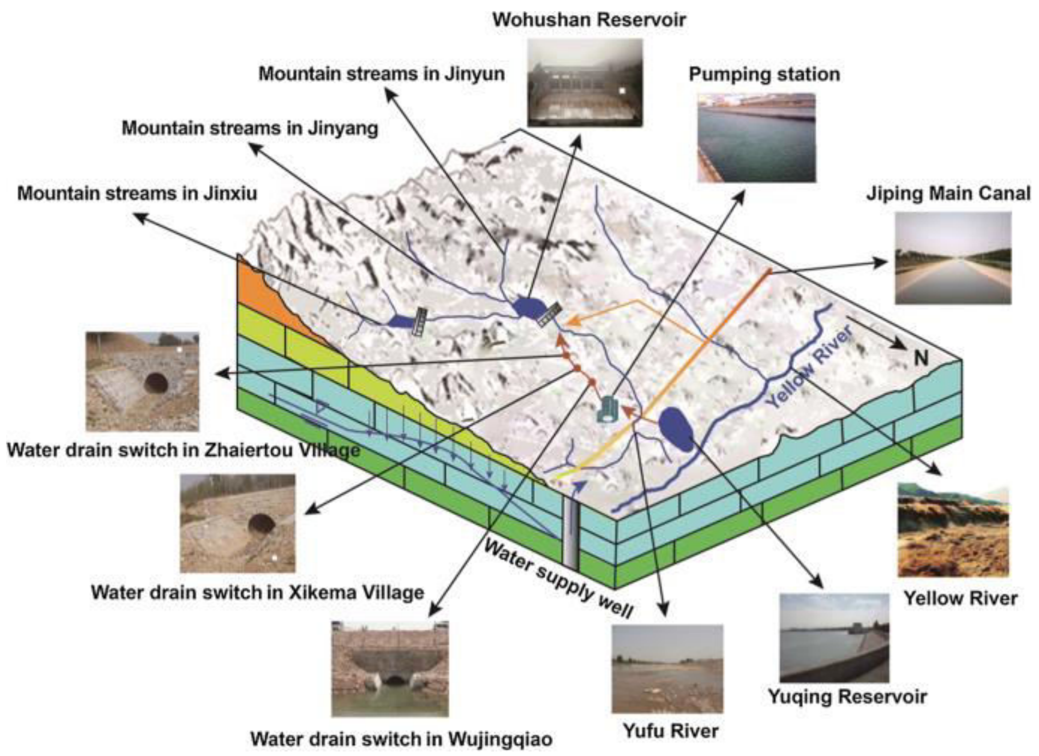
Well – canal combination MAR for irrigation





Liu, S. et al. (2020) Specific Types and Adaptability Evaluation of Managed Aquifer Recharge for Irrigation in the North China Plain. Water 2020, 12, 562; doi:10.3390/w12020562.

MAR with **multi-source water**, Jinan, Shandong



Zhang, Z., Wang, W. (2021) Managing aquifer recharge with multi-source water to realize sustainable management of groundwater resources in Jinan, China. Envir.Sci.Pollut.Res., 28, 10872–10888

MAR using **reclaimed water** to prevent groundwater level decline in the Chaobai River

Zheng, F. et al. (2014) Effects of Reclaimed Water Use for Scenic Water on Groundwater Environment in a Multilayered Aquifer System beneath the Chaobai River, Beijing, China: Case Study. J. Hydrol. Eng., (20)

MAR installations in China and worldwide

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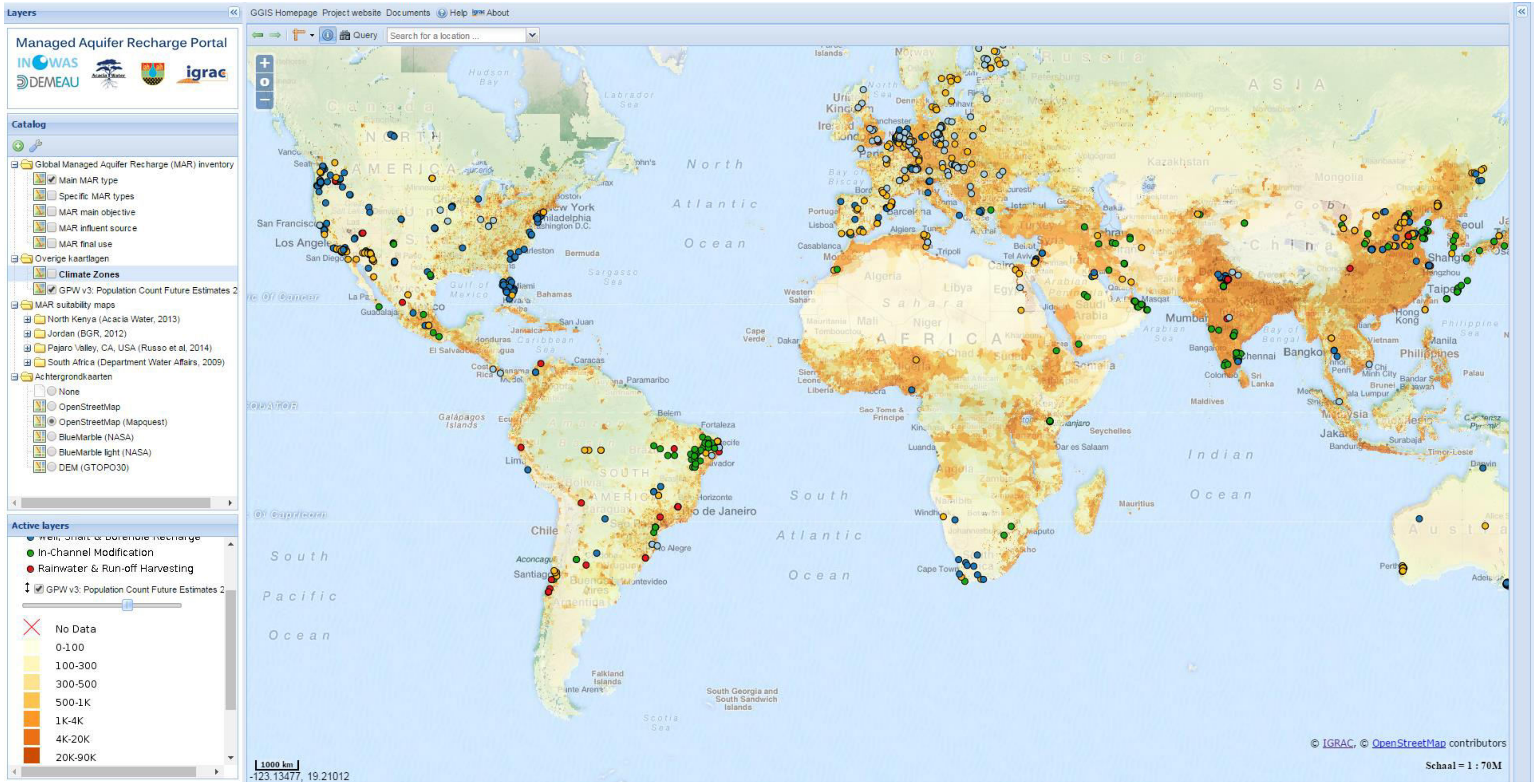

Water saving irrigation methods to counteract overexploitation

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Measure	Remaining Potential in Guantao (Mio. m³/yr)	Cost/Subsidy (CNY/m³)
Traditional water saving* (small fields and low pressured pipe irrigation)	0.4	1.6
Highly efficient water saving* (drip irrigation in green houses)	0.7	2.5
Highly efficient water saving* (sprinklers)	0.8	2.5
Mulching*	0.2	1.0
Conservation tillage* (maize)	< 1	<0.5
Conservation tillage* (wheat)	0.6	1.3
Rain fed cropping**	0.9	4.5
Water saving cultivars***	4	1.9
Fallowing of winter wheat**	10	3.0
Yellow River and reservoir water (No increase, improvement of efficiency in use of existing imports only)	< 15	0.4
SNWT Central Route (Replace remaining deep aquifer pumping for drinking water supply)	4	2.5
SNWT Eastern Route	(Extension to Hebei under construction)	< 1

* These measures contribute to water saving by reducing unproductive evaporation. If the irrigation water is taken from the deep aquifer, all reduction in pumping contributes to real water saving.

** These measures save groundwater by not pumping at all.

*** These measures save groundwater by increasing WUE of crops.

Other measures to counteract overexploitation

- Permit policy for well drilling
- Well-Spacing policy
- Quota management
- Water resources fee and tax
- Irrigation water price Policy
- Water Rights System and Water markets
- Replacing groundwater by (imported) surface water

Table 2.3 Effect of imported surface water on groundwater over-pumping control in 2014–2016

Project	Year of implementation	Imported surface water (Mio. m^3)	Number of wells closed in urban/rural areas	Groundwater replaced in rural areas (Mio. m^3)	Affected population/farmland in rural area
SNWT	2014–2016	511	4964	197	4.34 Mio. Capita
Yellow River diversion	2014–2016	784	6898	360	3.28 Mio. Mu
Wei River diversion	2014–2016	157	1649	71	0.7 Mio. Mu

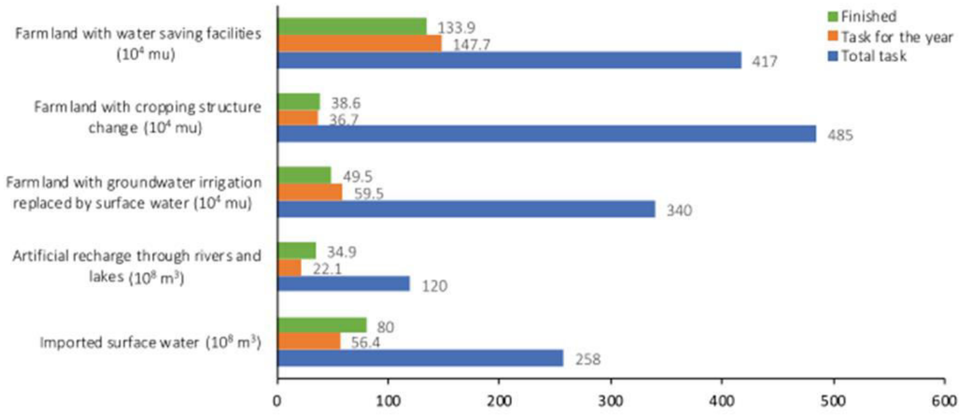

Fig. 2.4 Main measures listed in Action Plan 2019 for BTH area: Implementation progress of year 2019, in comparison to task figures for 2019 as well as the whole implementation period until 2022. Data source: (MWR GIWP and Hai River Comission 2020)

Measures against agricultural pollution - PRB

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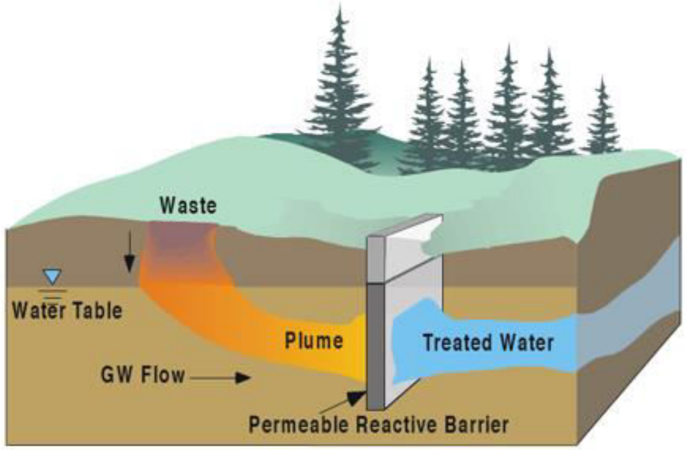
A permeable reactive barrier (PRB) is a trench or well comprised of a reactive media that removes contaminants from groundwater. PRBs are situated perpendicular to groundwater flows in order to maximize contaminant interception. There are two primary configurations for PRBs: trenches and injection wells.

A PRB is not a barrier to the water but only to the contaminant.



In-situ PRB treatment technology for nitrate pollution in Qingzhou

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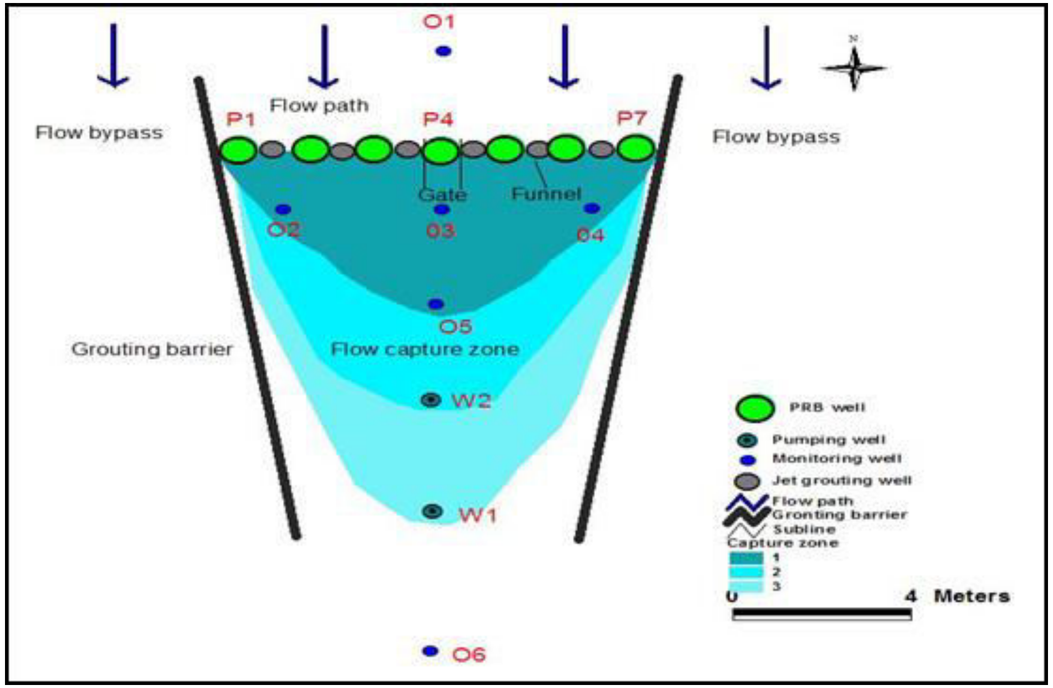
The in-situ treatment technology of nitrate pollution was demonstrated in Qingzhou area based on the research results of Laizhou project “Research on PRB Remediation Technology of Nitrate Pollution in Shallow Groundwater” applying so-called funnel-and gate



Technologies for remediation of point sources

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Table 2 Key techniques for groundwater remediation

Remediation technique	Technique principle	Characteristics
Ex situ		
Pump and treatment	Groundwater is extracted and sent to the sewage treatment system for decontamination	Suitable for the treatment of soluble pollutants
Excavation method	The method of soil excavation can be used to treat and remediate the polluted groundwater	Only suitable for a small range of groundwater pollution
In situ		
Bioremediation	Utilize microorganisms to transform contaminants into less harmful daughter-products	Long processing time, need the integrated application
Air sparging	Inject air into the aquifer, and the pollutants in the groundwater move into the vadose zone with the air. Combine with the soil vapor extraction method to treat the pollutants in the groundwater	Suitable for soil with good permeability and homogeneous quality
Electrokinetic remediation	The charged ions of the metal undergo directional migration under the influence of the electric field force, and the pollutants eventually gather together for centralized treatment	Suitable for organic and heavy metal pollution
Chemical oxidation	Carried out by oxidizing reaction between oxidizing agent and pollutant in groundwater	Easy to affect the geological and ecological environment
Permeable reactive barrier	A trench is excavated downstream of the hydraulic gradient of the groundwater to form a reaction wall. When the sewage flows through the reaction wall, the pollutants in the groundwater are adsorbed, oxidized, and biodegraded	Low cost and large application scope

Wang et al. Environ Sci Eur (2021) 33:5

Physical barrier against saltwater intrusion

Groundwater restoration practices in EU

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Point source/industrial pollution measures

- In situ/on site remediation, immobilization, containment, contaminant source removal
- Regulation & policy (Environmental Quality Standards, polluter pays principle, source mapping, etc.)

Agricultural diffuse pollution

- Regulation i.e. pesticide bans
- Protective measures (protection zones, afforestation, Stakeholder management)
- Drinking water treatment

Climate change/water scarcity

- MAR
- Use of alternative water sources/Water saving

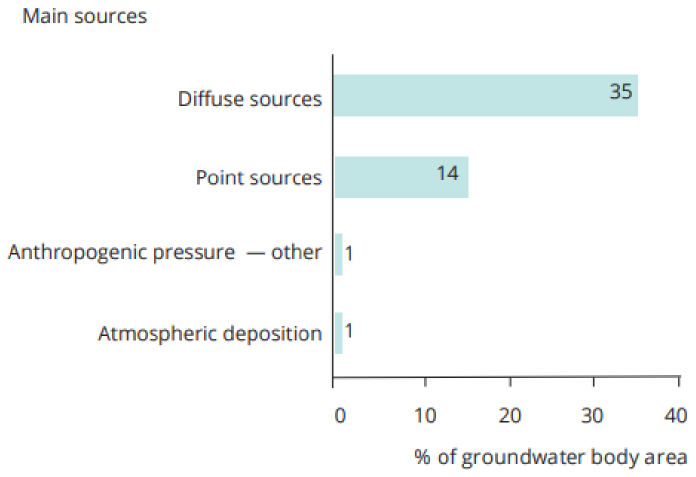
Saltwater intrusion

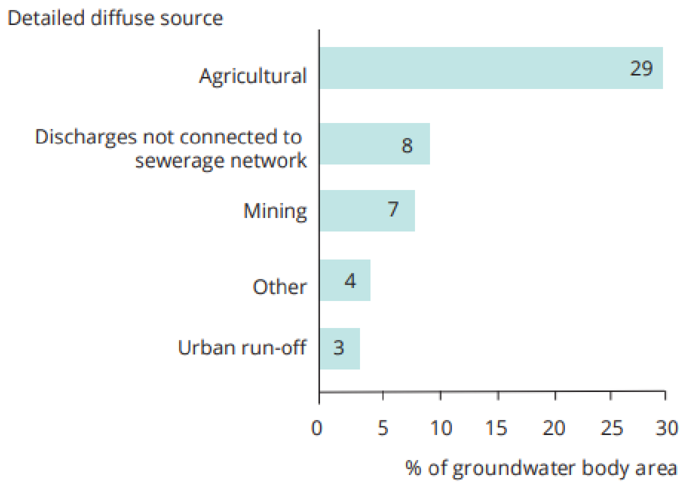
- MAR

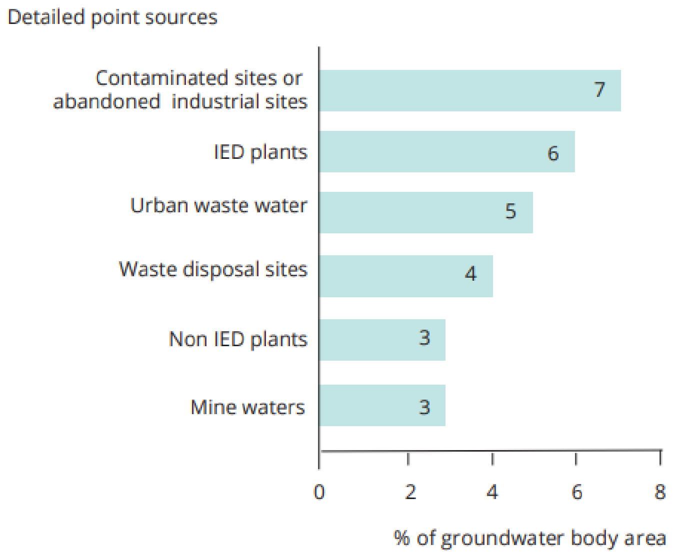
Groundwater chemical and quantitative status in EU

- **A total of 74 % of EU groundwater bodies (by area) are in good chemical status**. Through pollution from nitrates and pesticides, agriculture is the main pressure causing failure to achieve good chemical status in groundwater. Nitrates affect over 18 % of the area of groundwater bodies.
- In total, 160 pollutants caused failure to achieve good chemical status.
- There has been only limited improvement in groundwater chemical status between the first and second RBMPs because of sustained pressure from agriculture and long recovery time
- **90 % of the area of groundwater bodies is reported to be in good quantitative status**.
- The main pressures causing failure to achieve good quantitative status are water abstraction for public water supply, agriculture and industry.
- Groundwater quantitative status has improved by about 5 % since the first RBMPs were reported

Main pressures identified in relation to groundwater chemical status

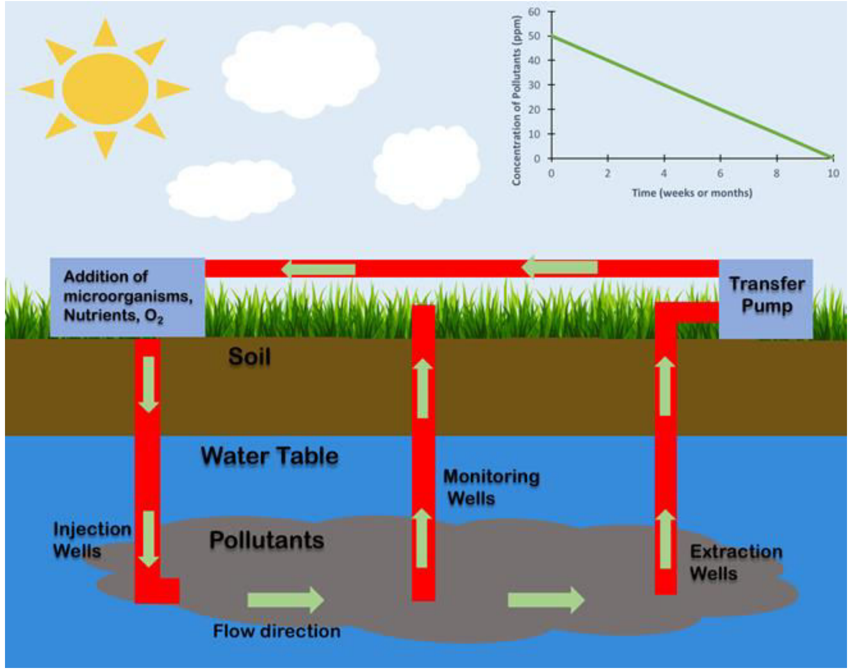






Techniques for groundwater point source remediation

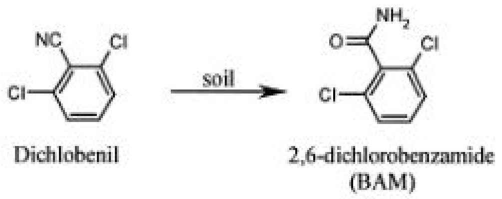
- Pump and treat technologies (*On site* remediation)
- *In situ* remediation (bioremediation, oxidation, ventilation)
- *Ex situ* treatment
- Ex situ advanced drinking water treatment at the water supply water facility (various technologies)
- Abandon location

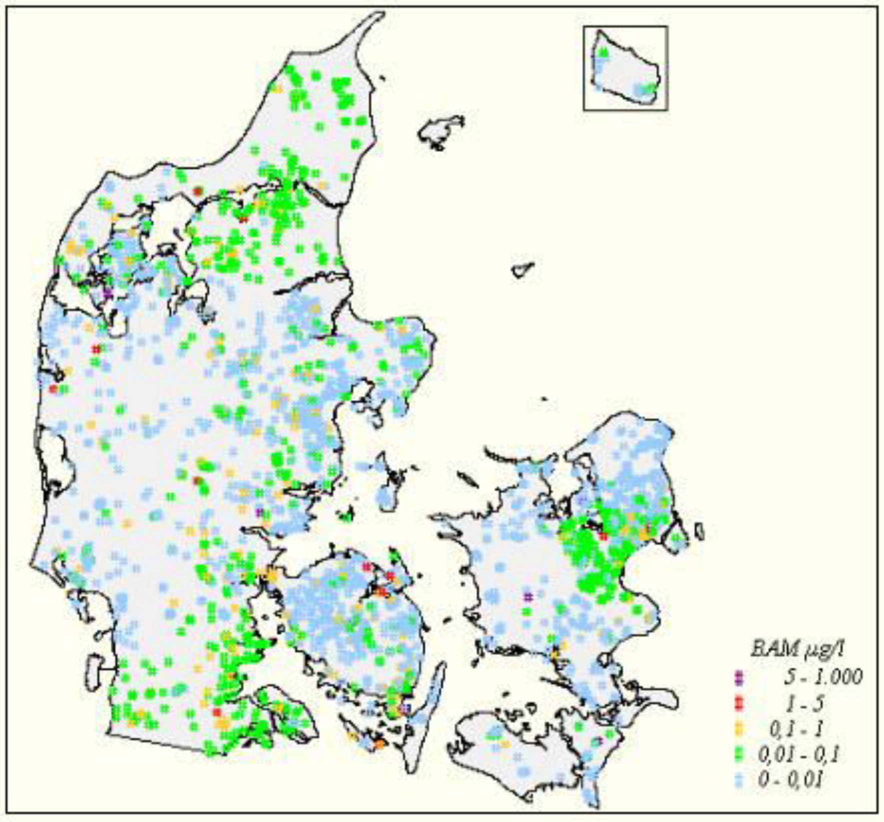


Agricultural pollution – pesticides in focus

Metabolites:

2,6-Dichlorobenzamide (BAM)





N,N-dimethylsulfamid (DMS)

PFAS, Which is found in many pesticides

Restoration of groundwater contaminated by diffuse sources

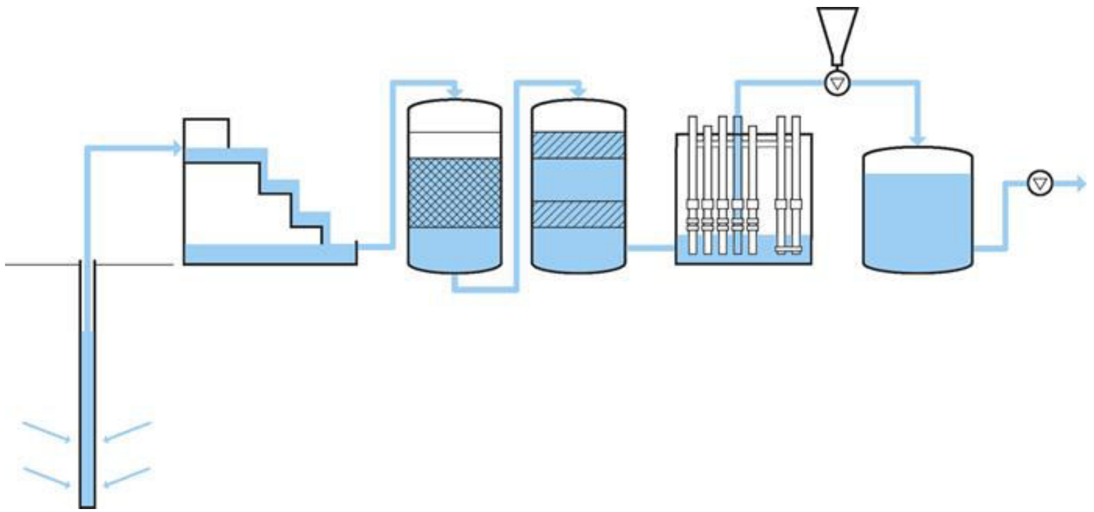
Advanced drinking water treatment at water works (activated carbon filtration, RO, etc.)

Protective measures

- Afforestation
- Extraction well protection

Preventive measures

- Prohibiting sludge application
- Pesticide bans
- Change of agricultural practices
- Stakeholder (farmers, small holders) education
- Media campaigns



Tendencies in groundwater restoration in China and EU

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China

Focus on **groundwater quantity and availability**:

Reduce overexploitation to prevent land subsistence and prevent water scarcity

Focus on **technology** development and practical solutions

Remedial actions for **prevention of exposure**

Focus on water saving **technologies** rather then demand side behavioural changes

Lately more focus on pollution driven water scarcity

EU

Focus on **groundwater quality**:

Reduce human health impacts by decontamination

Dual focus on technical remedial actions and demand side management measures

Remedial actions for **cleaning** the groundwater/removal af contaminants

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Thank you for your attention !

感谢您的参与和关注！

谢 谢 ！