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Challenges in the Behavior, Detection, and Remediation of Micropollutants in Hydrogeological Practice

Michal Zak, 26.3.2025

Agenda Items

- Introduction to Micropollutants
- Introduction to Hydrogeological systems
- Geological systems challenges
- Behavior of Micropollutants in Hydrogeological Systems
- Detection Methods for Micropollutants
- Remediation Strategies for Micropollutants

Definition and Types of Micropollutants

Definition of Micropollutants: Micropollutants are organic or inorganic substances found in environmental samples at very low concentrations, often in the nanogram per liter range.

Types of Micropollutants: Common types of micropollutants include pharmaceuticals, personal care products, pesticides, and industrial chemicals and **THEIR METABOLITES.**



Sources of Micropollutants: Common sources of micropollutants include wastewater treatment plants, agricultural runoff, and industrial discharges.

Impact on Water Systems: These micropollutants can enter both groundwater and surface water systems, posing risks to ecosystems and human health. **Important is understanding of behaviour and transformation and fate of micropollutants in water environment – Toxicity of Metabolites?**

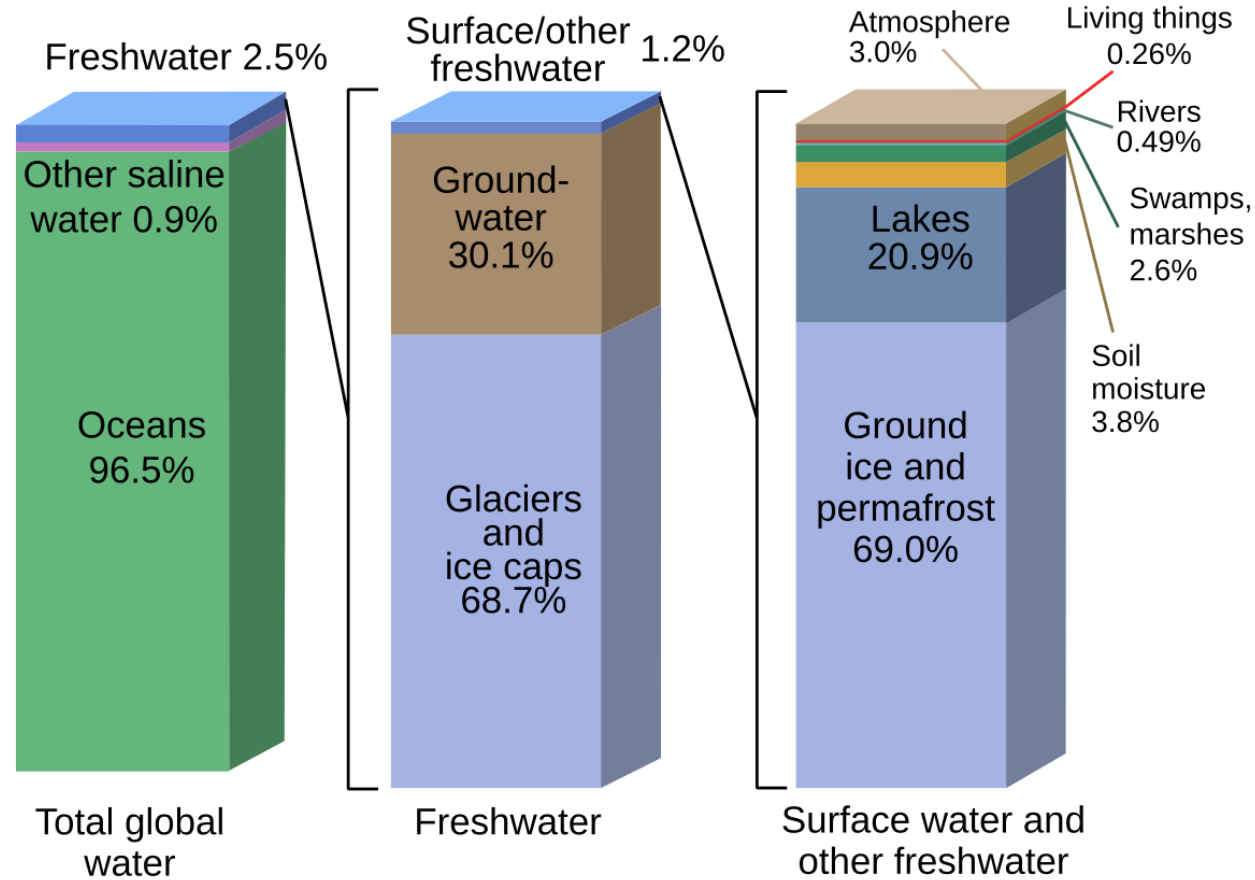
Risks to Aquatic Life: Micropollutants pose significant risks to aquatic life, leading to disruptions in species populations and biodiversity.

Contamination of Drinking Water: These pollutants can contaminate drinking water supplies, posing health risks to humans and animals alike.

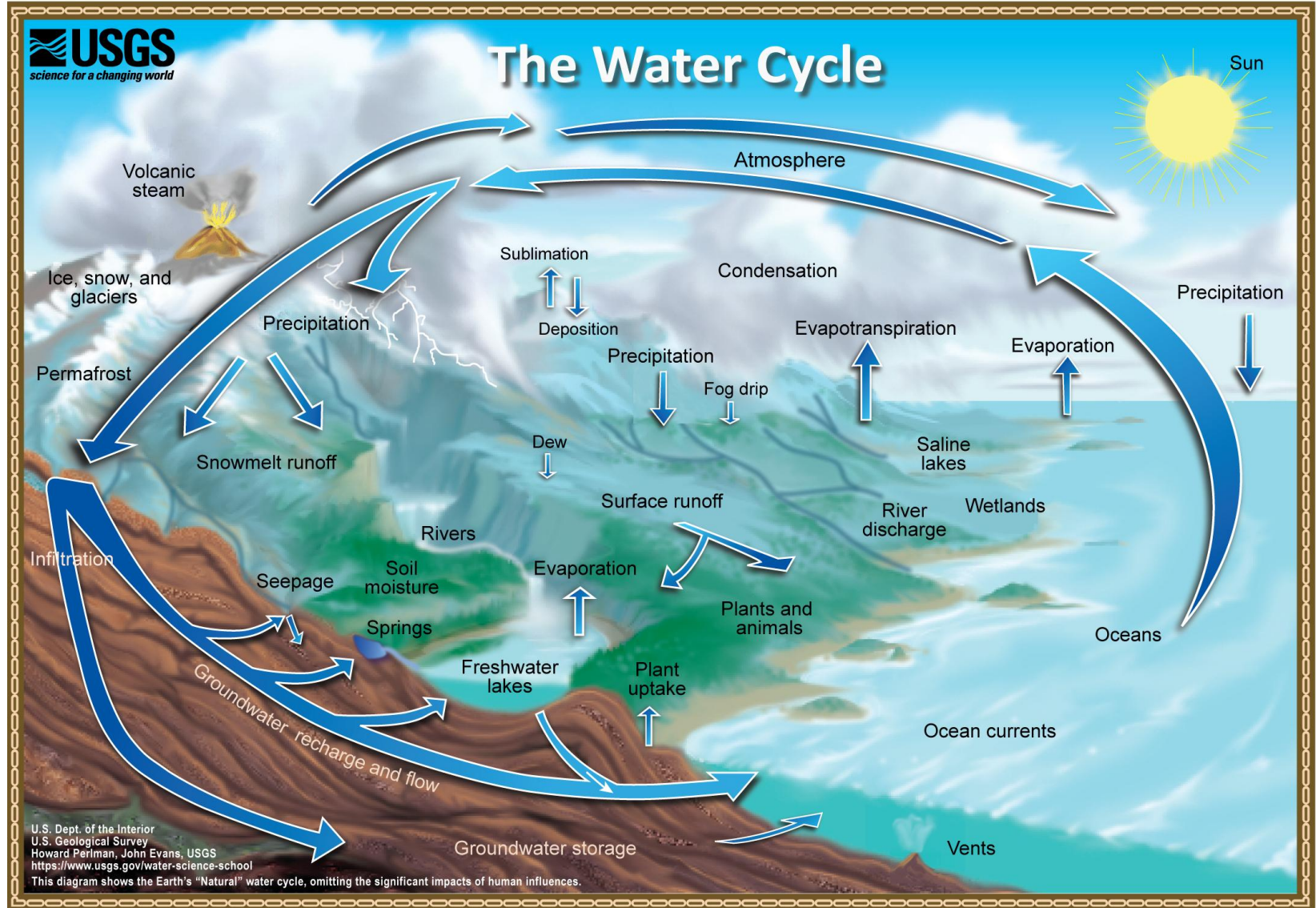
Ecosystem Disruption

Micropollutants can disrupt ecosystems, affecting food chains and overall ecological balance.

Where is Earth's Water?

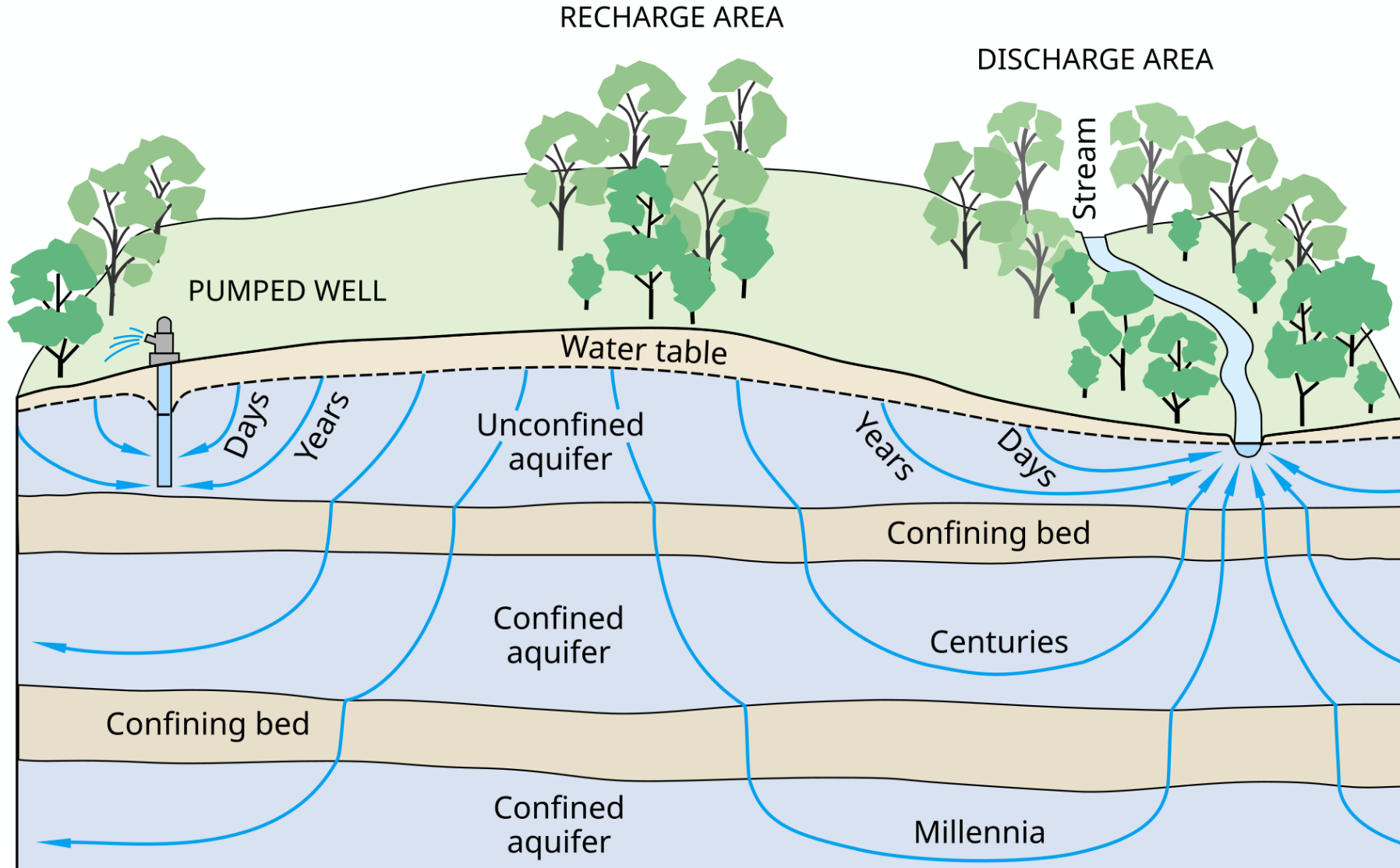


What is the Hydrogeological system?



Natural (geological) systems challenges

- **System inertia – the age of the water in collectors**
- **Groundwater is considered a drinking source primarily without treatment**
- Large scale: Usually complex and complicated, collectors x low permeable layers combinations
- Impossible to analyze or simulate complete system in laboratory
- **„Hard data“ are available only for distinct scattered points of the system**
- Interpolation and extrapolation from points to 3D space needed
- Simplification necessary to understand to the system



Conceptual model in hydrogeology

- **A description of a groundwater flow system, focused on:**
 - Definition of hydraulic functions permeability etc. of the rock bodies (aquifer/aquitard) – again challenge from scattered points.
 - Identification of spatial extent of aquifer(s) and aquitard(s)
 - Delineation of the recharge and drainage zones
 - Flow budget and assessment of available groundwater resources
 - Assessment of natural groundwater chemistry, including its evolution along the flowpath

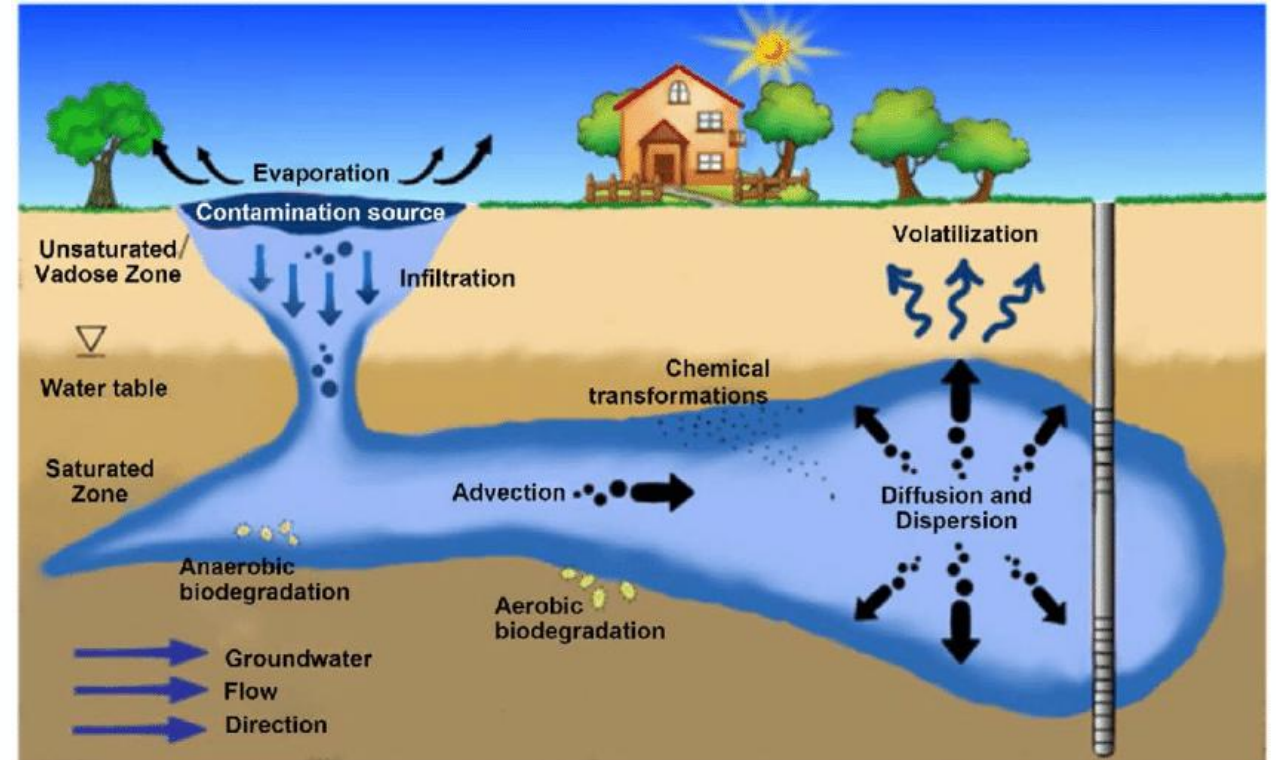
Transport and Fate of Micropollutants

Transport Mechanisms

Micropollutants are transported through soil and water systems primarily via advection and diffusion, influencing their spread in the environment.

Interactions with Soil Particles

The fate of micropollutants is influenced by their interactions with soil particles, which can affect their mobility and degradation.

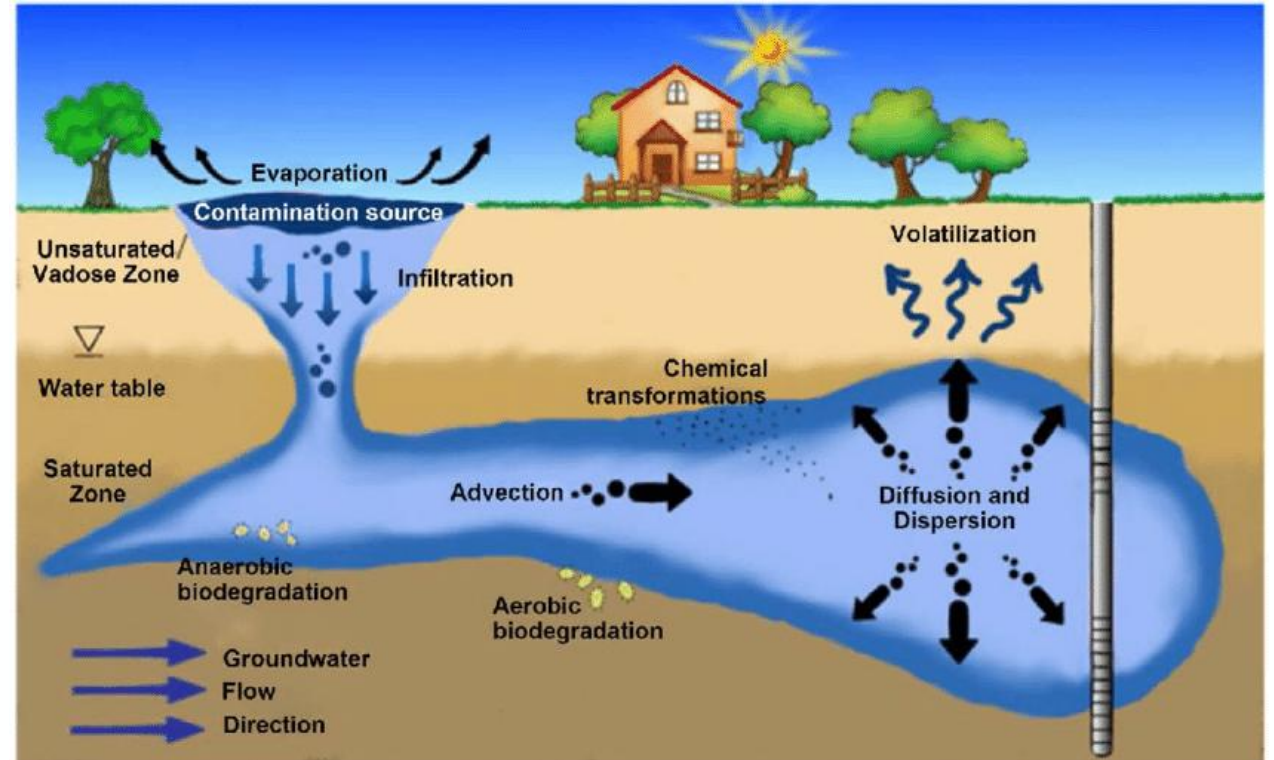


Transport and Fate of Micropollutants

Role of Microbial Communities

Microbial communities play a crucial role in determining the fate of micropollutants through biodegradation and metabolic processes.

Natural Attenuation?



Factors Influencing Micropollutant Behavior

Impact of pH Levels: The pH level of water affects the solubility and mobility of micropollutants, influencing their behavior in aquatic environments.

Role of Temperature: Temperature impacts the degradation rates of micropollutants, altering their persistence and mobility in water systems.

Organic Matter Content: Higher organic matter content can enhance the adsorption of micropollutants, thus affecting their mobility and degradation in water.

Traditional Detection Techniques



Solid-Phase Extraction

Solid-phase extraction is a technique used to isolate specific analytes from complex mixtures, enhancing detection accuracy.

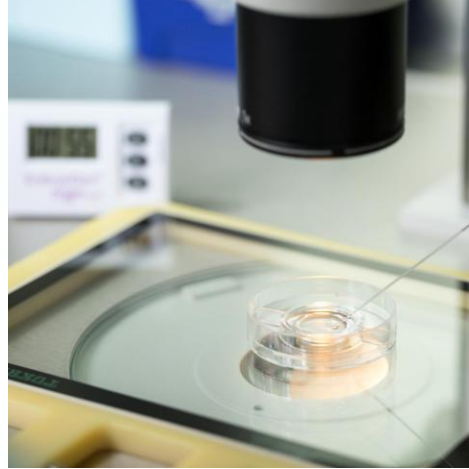
Gas Chromatography

Gas chromatography is a powerful analytical method for separating and analyzing volatile compounds in samples.

Limitations of Traditional Methods

Despite their effectiveness, traditional methods can be time-consuming and may miss certain micropollutants, limiting their utility.

Advanced Analytical Methods



Liquid Chromatography-Mass Spectrometry

LC-MS is a powerful analytical technique that enhances sensitivity and accuracy for detecting micropollutants in various samples
Sensitivity in ng.



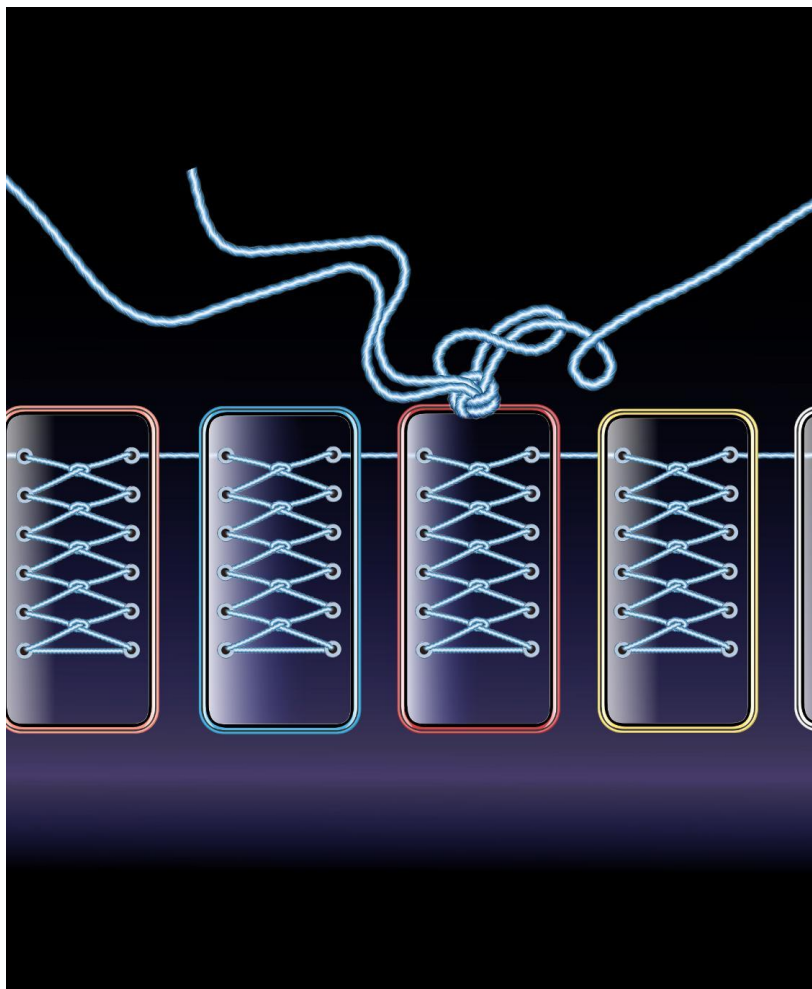
New In-SITU monitoring methods

Electrochemical sensors and biosensors for the analysis of organic pollutants in water at the point of need - our project with CATRIN/MENDELU.

Remediation Strategies for Micropollutants = real economical solution at this moment? = NONE

(it only makes sense to reduce their entry into the environment)

Physical and Chemical Treatment Methods



Adsorption Techniques

Adsorption is a physical method used to capture and remove micropollutants from water using solid materials that attract contaminants.

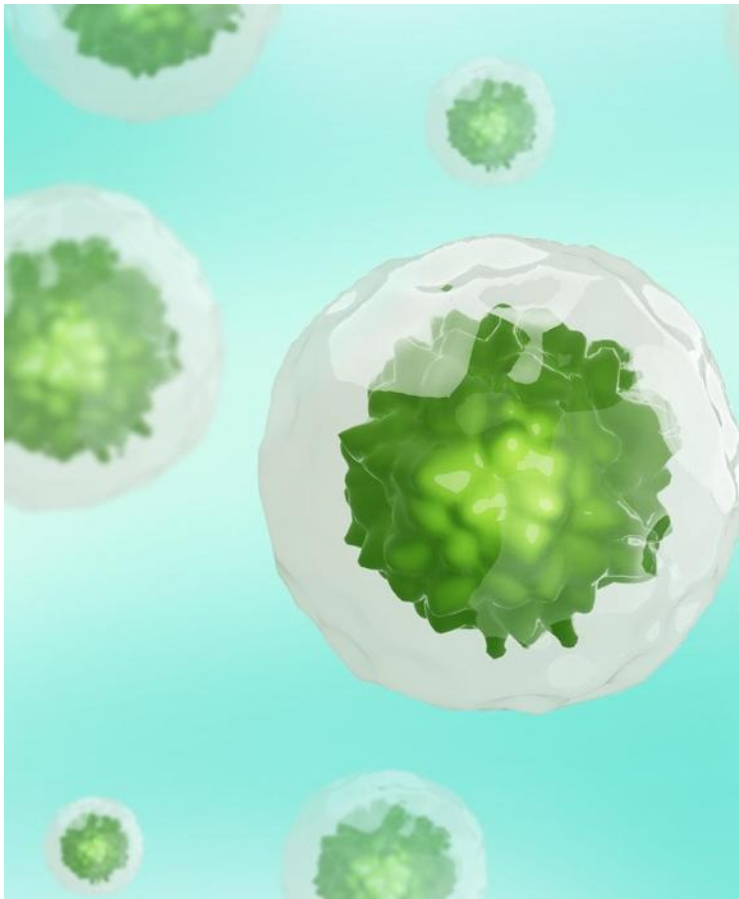
Filtration Systems

Filtration is another physical method that uses filter media to separate micropollutants from water, ensuring cleaner water output.

Oxidation Treatments

Chemical oxidation treatments involve adding oxidizing agents to water, effectively breaking down and removing harmful micropollutants.

Bioremediation Approaches



Use of Microorganisms

Bioremediation relies on microorganisms to naturally degrade micropollutants, making it a viable environmental solution.

Cost-Effectiveness

This remediation method is often more cost-effective compared to traditional methods, providing an economical option for pollution cleanup.

Environmental Benefits

Bioremediation is an environmentally friendly approach that helps restore contaminated sites while preserving ecosystems.

Promising Innovative and Emerging Technologies

Advanced Oxidation Processes

Advanced oxidation processes are innovative methods that utilize powerful oxidants to effectively degrade micropollutants in water and wastewater.

Nanotechnology Applications

Nanotechnology offers unique solutions for environmental cleanup by utilizing nanoparticles to adsorb and break down harmful pollutants at the molecular level.

Conclusion

Challenges of Micropollutants

Micropollutants present significant challenges in hydrogeological practice, impacting water quality and ecosystem health.

Detection Methods

Effective detection of micropollutants is crucial for addressing their impact on water resources and public health.

Remediation Strategies

Implementing effective and **ECONOMICAL!** remediation strategies is essential to mitigate the effects of micropollutants in the environment.

Challenges of the hydrogeological systems

System inertia and system complexity – hard to determine from distinct scattered points, complex redox reactions in the underground.

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