

Overview of water purification techniques (for Super-K)

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References:

<https://doi.org/10.1016/j.nima.2020.163549> for water system for EGADS

<https://arxiv.org/abs/2109.00360> for the water system for Super-K Gd

Important notes

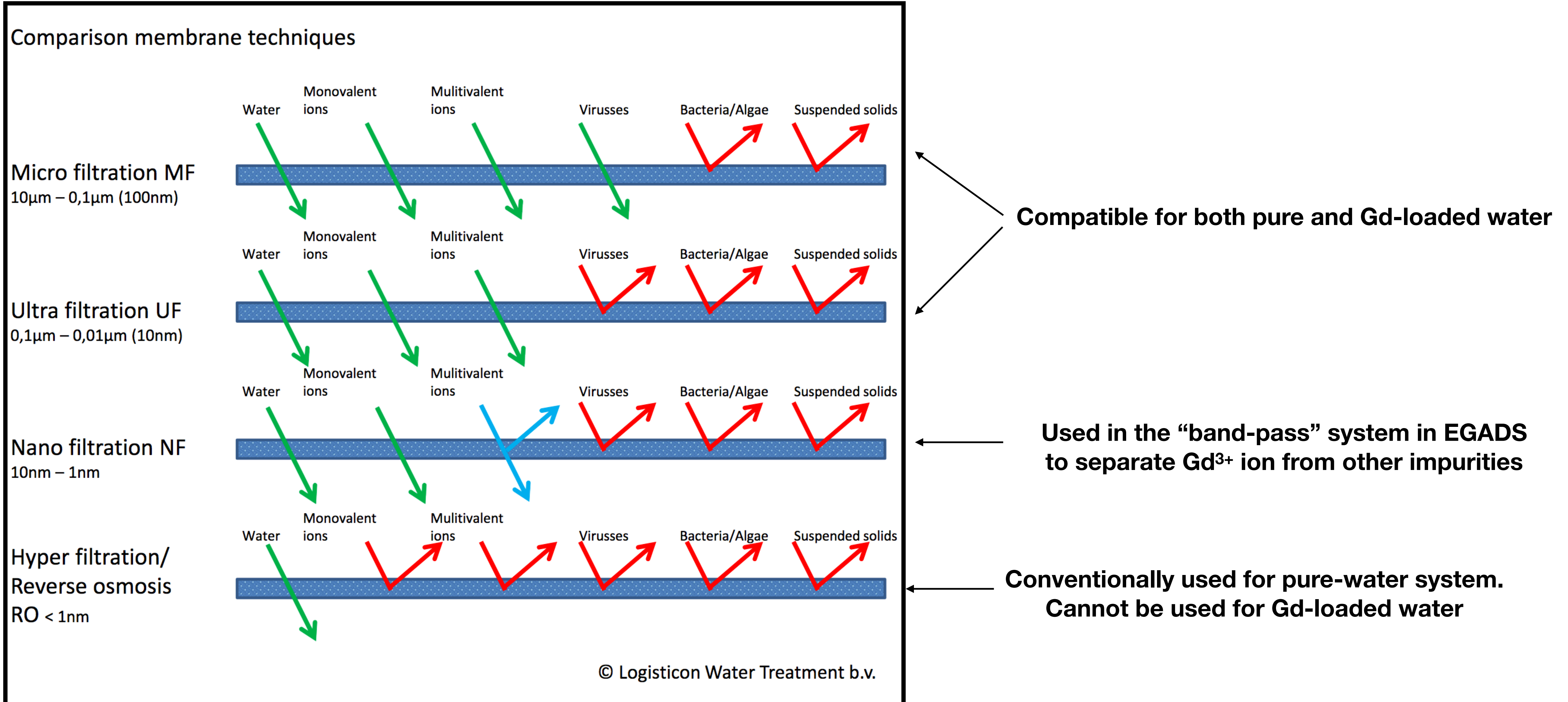
- Our requirement for water quality:
 - High water transparency
 - Less radio impurities
- Requirements in “typical” industries
 - For clean environment (such as semi-conductor production): Small impurities
 - For food industries: less bacteria that is harmful for human body
- Our requirements are very different from what is required outside of our field
- The system for Super-K is a result of many try-and-errors by ourselves
- Still not have a complete theory that explains what is causing light attenuation in water
- Trials-and-errors would be required to find out required components for WCTE and IWCD

Ingredients of water purification

- Filtration
 - Primary method to remove impurities
 - Different strategy need to be taken for Gd-loaded water
- Ion exchange resin
 - Special resin developed for Gd-loaded water
- UV sanitization
 - Kill and remove bacteria
- Degassing
 - Remove Rn
 - Remove O₂ to slow bacteria growth
- Water flow / temperature control
 - Efficient water replacement
 - Reducing Rn backgrounds (allow Rn to decay before reaching the FV)

Filteration

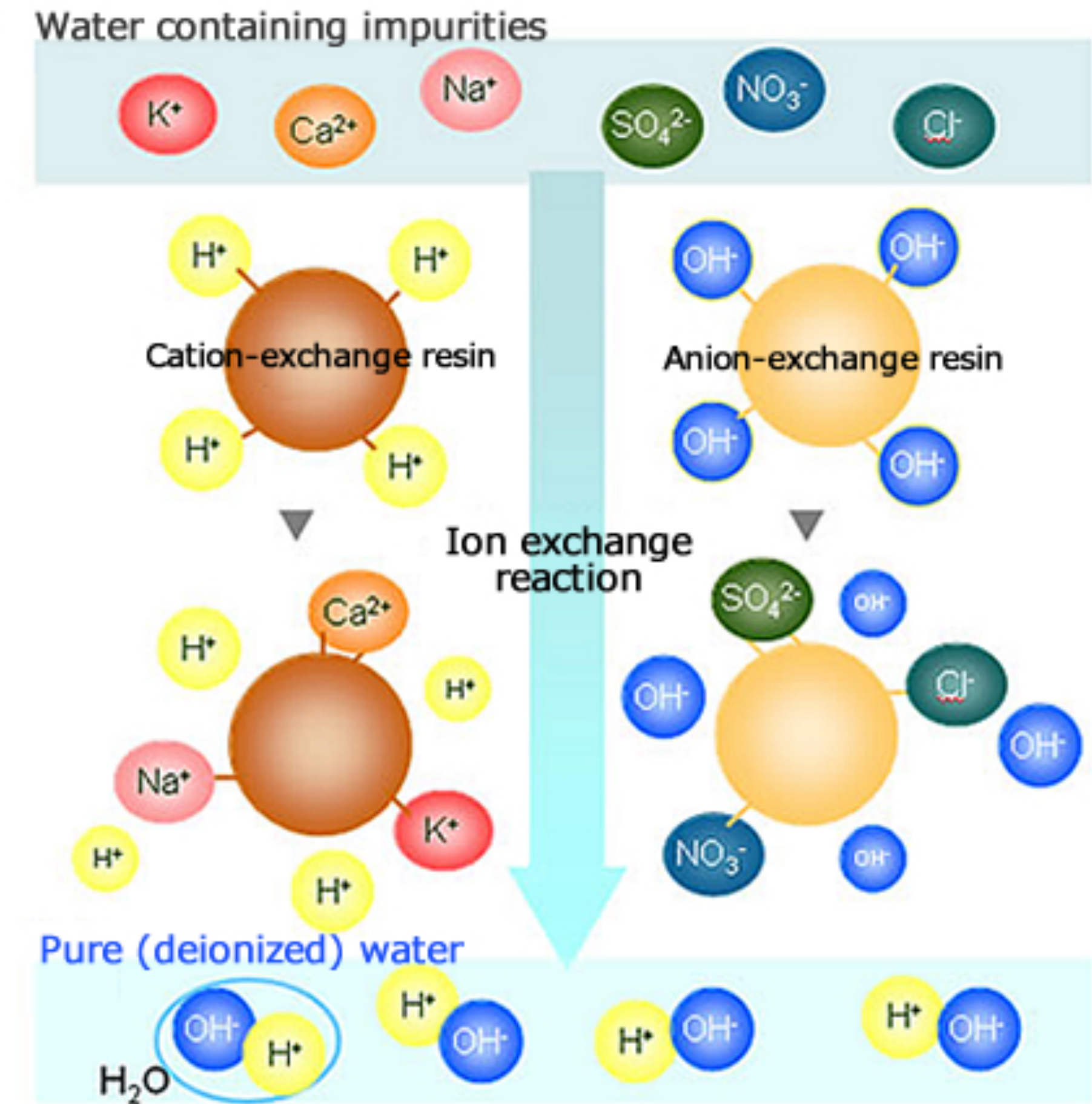
<https://www.logisticon.com/en/technologies/membrane-filtration/>



Ion exchange resin

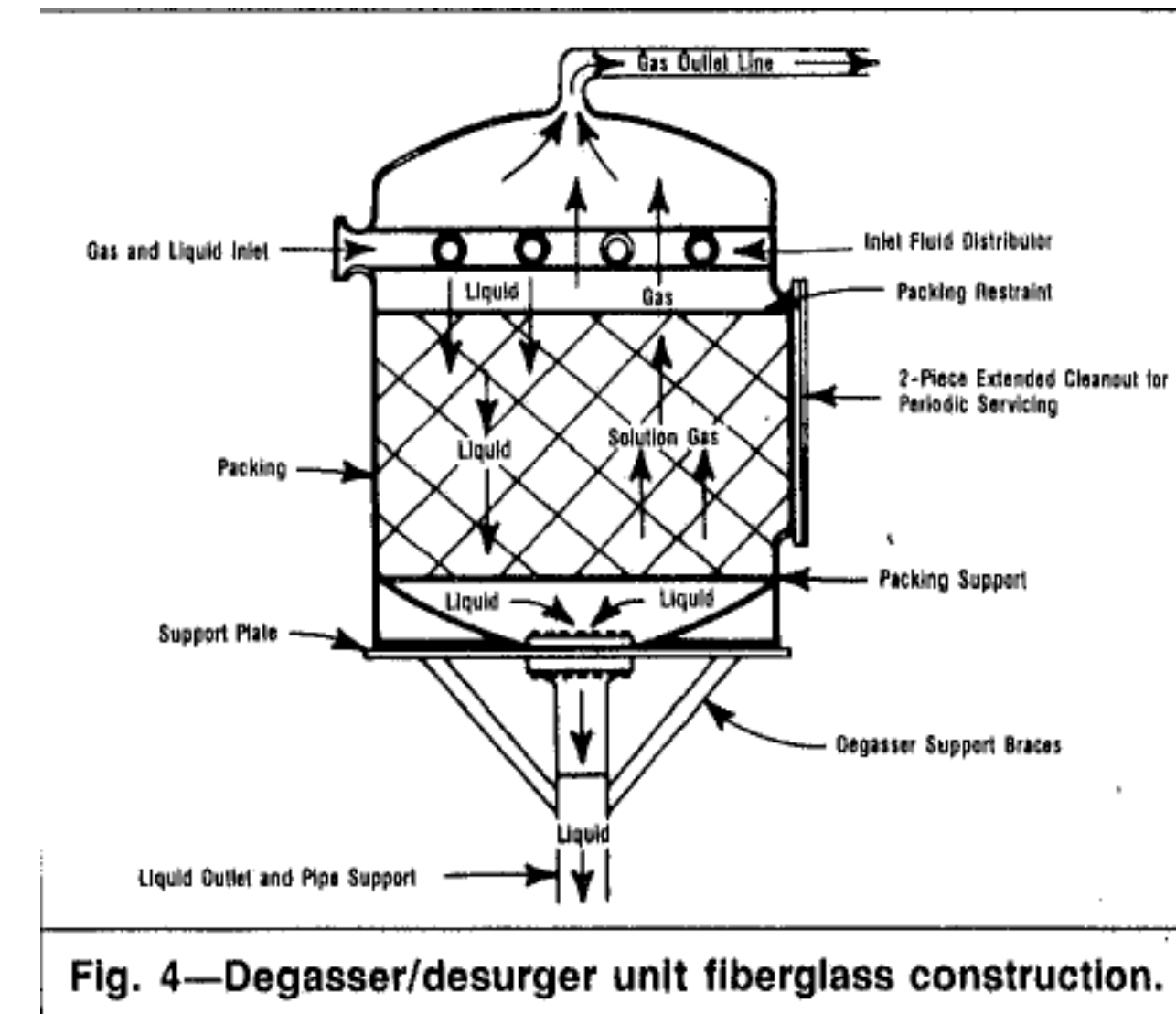


- Typically replaces ion impurities to H^+ or OH^-
- Commonly used for pure-water production
- Developed a special resin for SK-Gd (collaboration w/ ORGANO)
 - AMBERJET1020(Gd): Replaces positively charged ions (cations) impurities with Gd^{3+}
 - AMBERJET4400(SO4): Replaces negatively charged ions (anions) with SO_4^{2-}

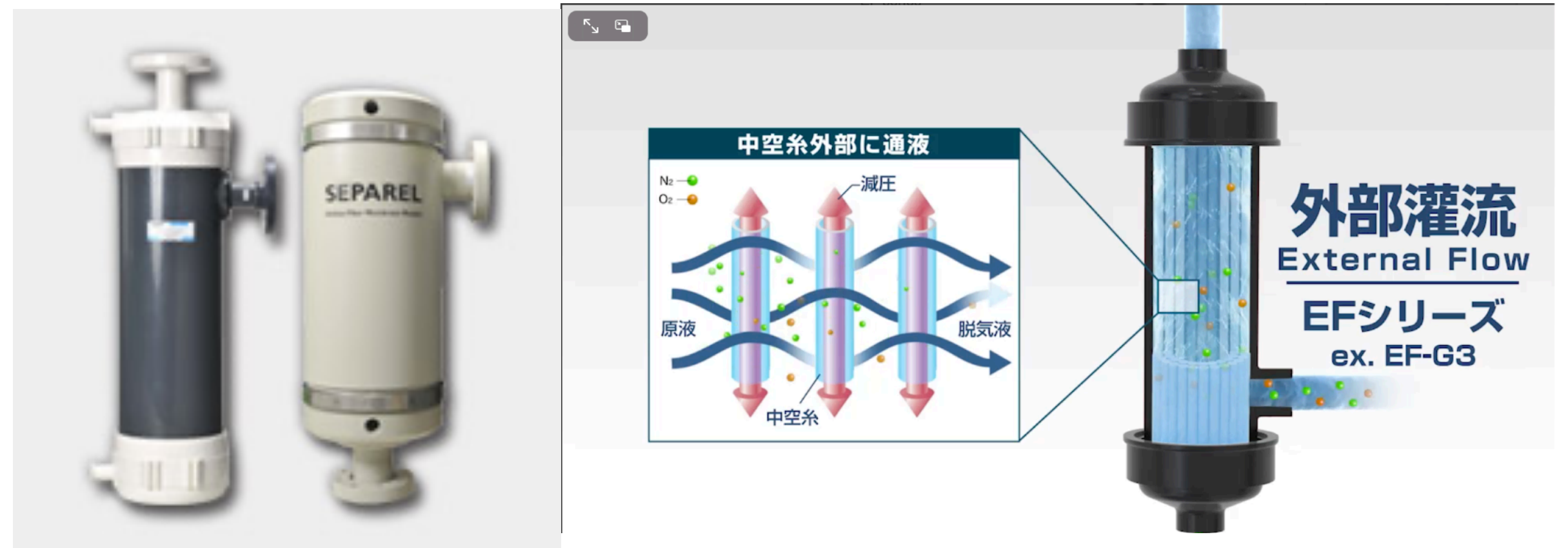


Degasifier

- Essential item to remove Rn in water
- Might not be needed for WCTE and IWCD
- Two techniques used for SK/SK-Gd:
 - Vacuum degasifier: Use >10m tall column to separate water and gas
 - Membrane degasifier (MD): use special membrane to separate gas and water
- Both require a vacuum pumping system



<https://www.separel.com/products/water.html>



UV sanitization

- UV sanitization
 - Kill bacteria and catch them in micro filter in later stage
 - Wavelength: ~250 nm
- UV oxidation
 - Decompose organic compounds into gas or ions
 - Catch them in ion exchange resin in later stage
 - Wavelength: ~180 nm

<https://arxiv.org/abs/2109.00360>

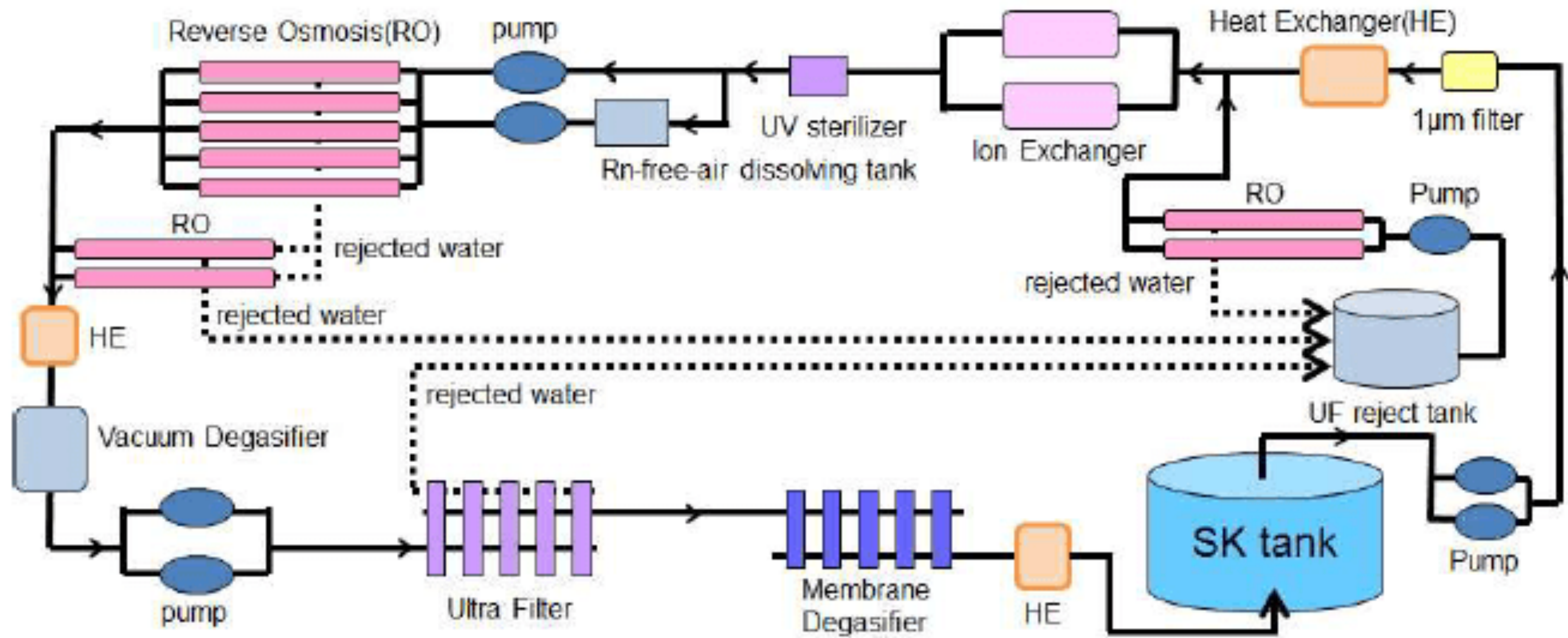
- **UV sterilizer** – Wavelength: 253.7 nm; power: 0.97 W; Chiyoda Kohan Steritron UEX (lamp: CS1001N).

- **TOC lamp (UV oxidation)** – Wavelengths: 253.7 nm and 184.9 nm; power: 4.02 W; Chiyoda Kohan Steritron WOX (lamp: CX1501).

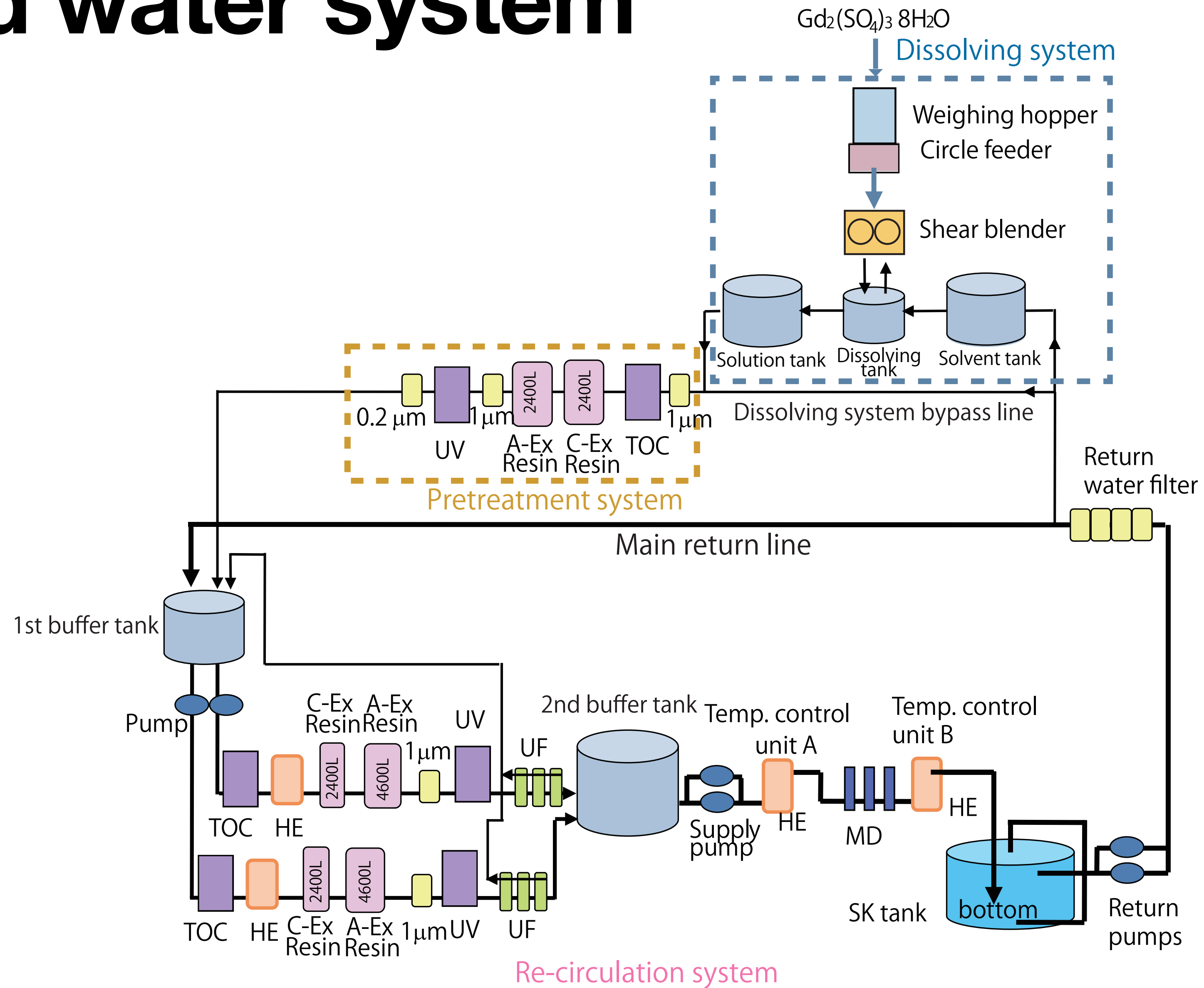


<https://www.waterth.com/uv-sterilizer/ozone-destruction/>

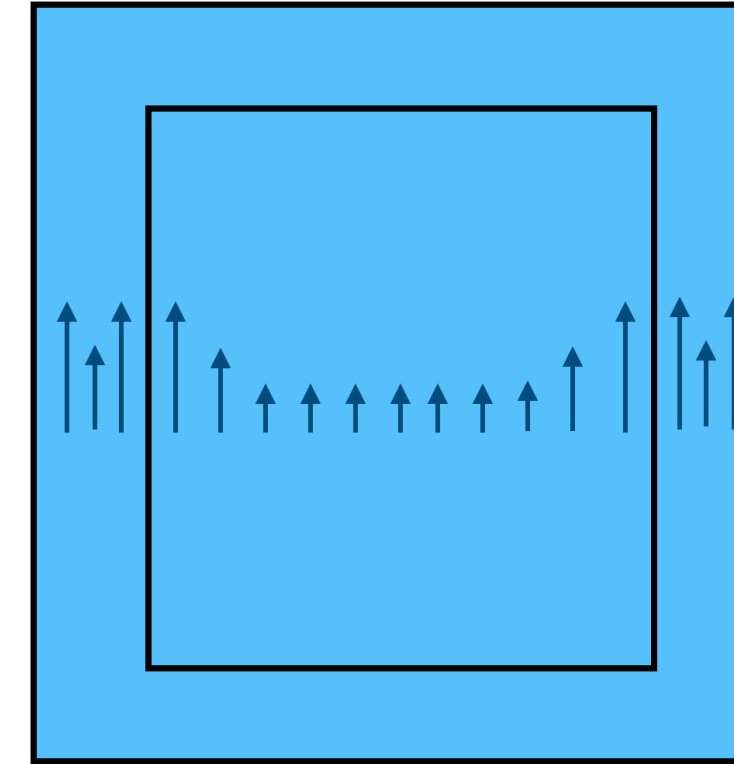
Super-K pure-water system



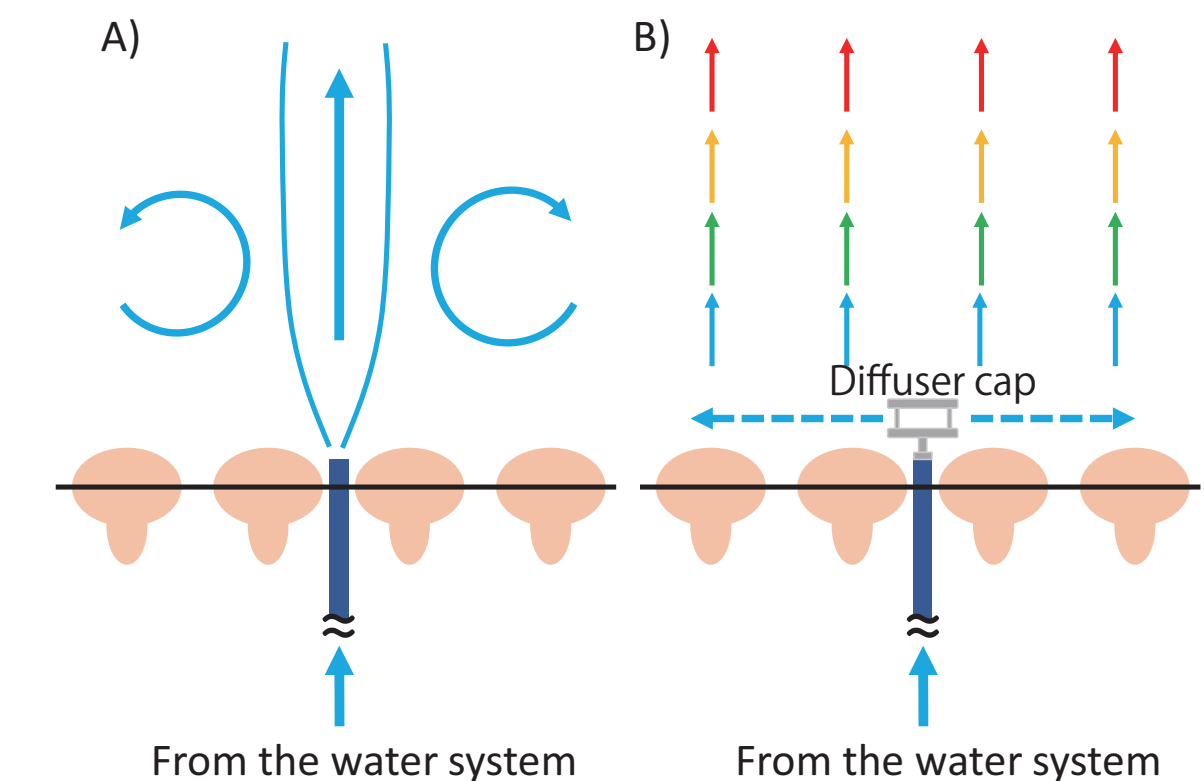
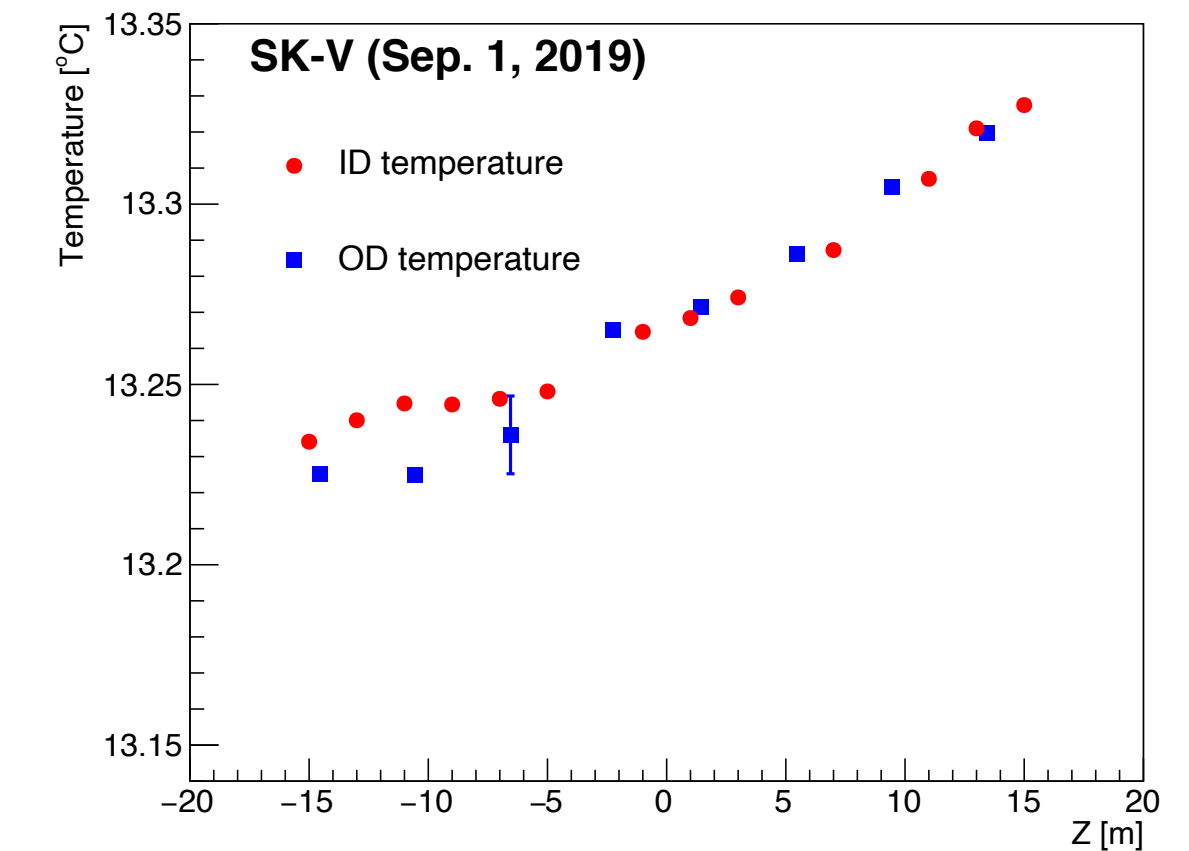
SK-Gd water system



Water flow in the tank



- In Super-K, inject water from the bottom and extract from the top
- Key component to achieve stable vertical flow:
 - Precise temperature control: >0.01 temperature fluctuation will cause significant convection
 - Water injection scheme not to cause significant turbulence in vertical direction



Summary

- Many technologies for pure-water production exists in the market, but how we adopt them for our purpose is not trivial.
 - Our requirements (such as water transparency and RI) are not common in typical industries
- System for SK(-Gd) developed based on many decades of R&D works
- WCTE will be an important platform to find out components that meets requirements for WCTE itself and IWCD