POTENTIAL OF ELECTRODEIONIZATION FOR INTEGRATED MEMBRANE SYSTEMS IN WATER SEGMENT

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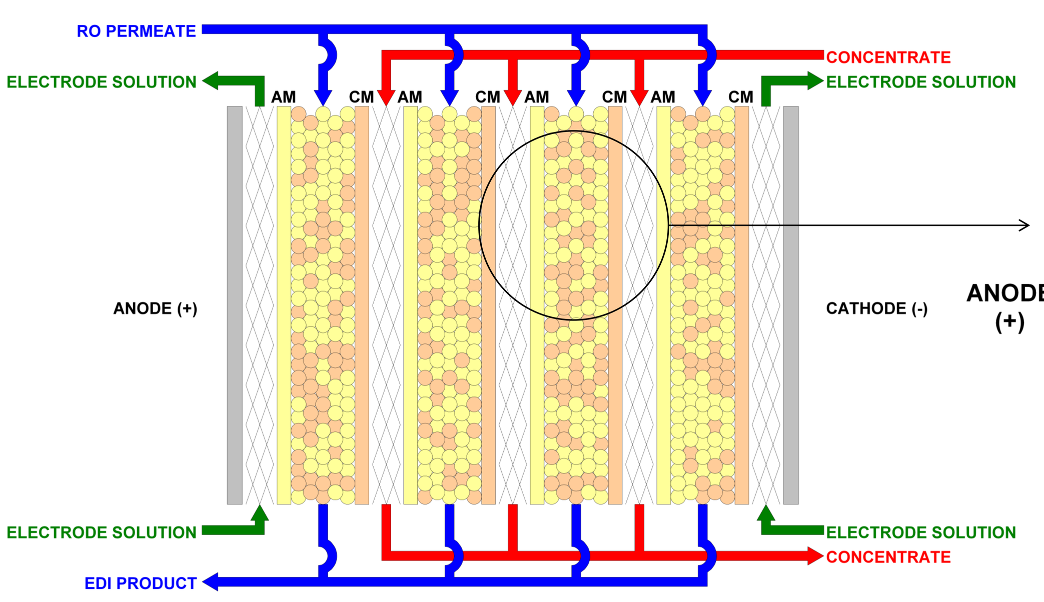
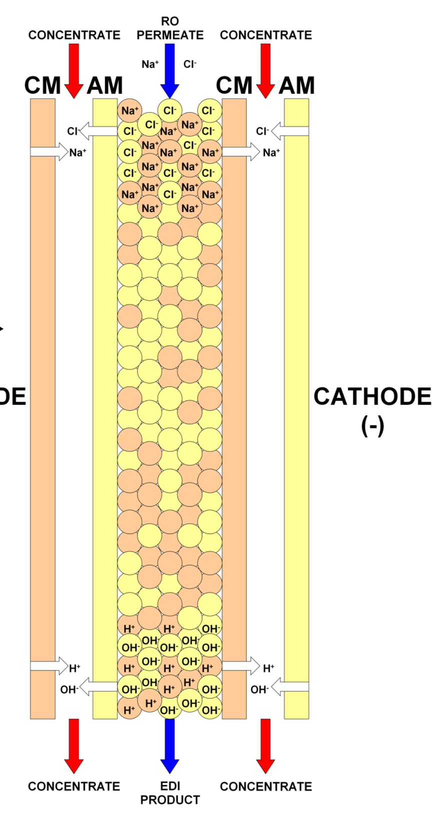
Abstract:

Electrodeionization (EDI) has been accepted as an advantageous alternative to conventional mixed-bed ion-exchange technologies in the production of high purity water worldwide. The greatest potential of the process is to further treat reverse osmosis (RO) permeate to produce 5 to 18 MΩ.cm resistivity water. The process typically removes more than 99 % of strong electrolytes and carbon dioxide from water and is also capable of removing high portions of silica, boron etc. from water in these applications. EDI can be also effective in the treatment of waters with a higher TDS of up to ~1000 mg/L. In these cases, the salt removal is always lower than that obtained in the treatment of RO permeate grade or better quality water and lower than that obtained with RO in most cases but always higher than that obtained with electrodialysis (ED) operating in a continuous single-pass mode. For example, EDI-X module available from MEGA a.s. removes more than 70 % of salt from a feed solution containing 500 mg/l of ammonium nitrate at a nominal product flow rate in a single hydraulic stage. Further, EDI can operate at a high water recovery of 90 to 95 % as opposed to 75 % of RO and 85 % of ED for water treatment applications and is lower in investment costs than both RO and ED. In addition, RO can have low rejection for some ions such as nitrates while EDI removes all strong electrolytes. Thus, EDI can be used as a final demineralization step in combination with RO and ED to reduce product TDS and investment costs and to increase the overall water recovery. The only limitation to the EDI process is that it requires good pre-treatment to avoid scale formation and fouling. We have proposed a hybrid technology for treatment of ammonium nitrate based waste waters with a TDS of 2,000 to 8,000 mg/L. The technology combines continuous single-pass ED, ED operated in a feed-and-bleed mode and EDI. Using this technology, it is possible economically to produce demineralized water containing a few mg/L of ammonium nitrate on the one hand and simultaneously a brine containing 100 to 200 g/L of ammonium nitrate on the other hand.

Principle of electrodeionization

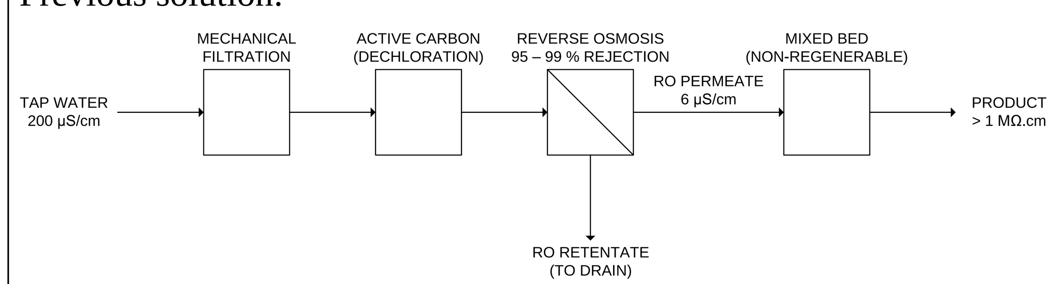




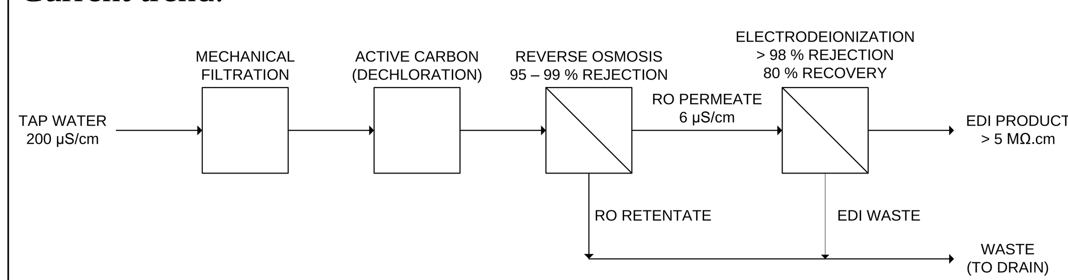
CM = Cation-exchange membrane
AM = Anion-exchange membrane

High-purity water production: Laboratory application

Previous solution:



Current trend:

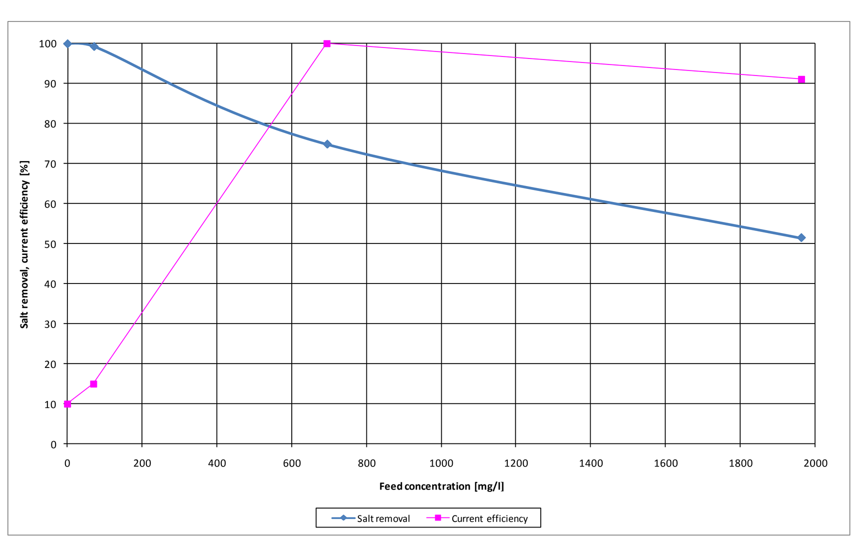


Fully automated IWA 60 EDI system available from WATEK s.r.o. in combination with EDI-Z2-AF module available from MemBrain s.r.o.

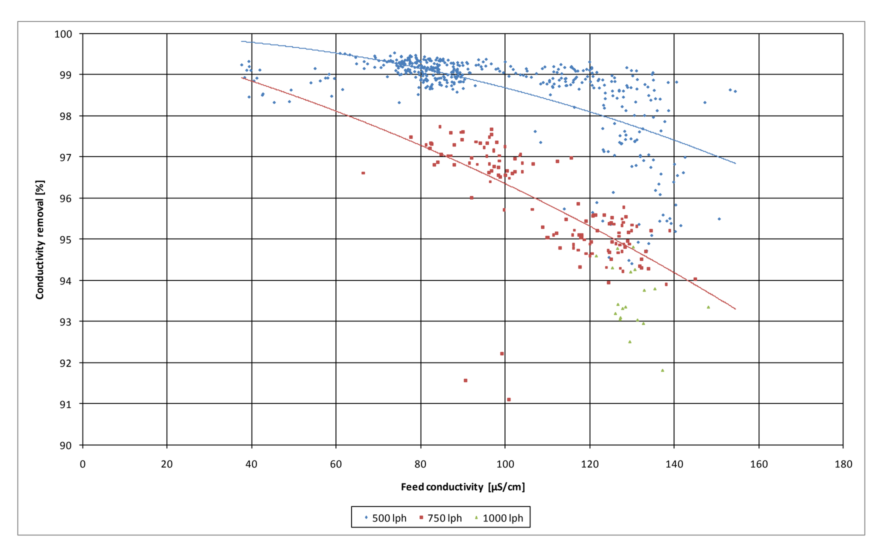
EDI benefits:
- continuous operation,
- no regeneration chemicals needed,
- no cartridge replacement needed,
- small footprint,
- modular,
- high water recovery,
- high salt rejection,
- better product quality,
- low power consumption (< 0.3 kWh/m^3).

Industrial modules – Performance in continuous single-pass mode

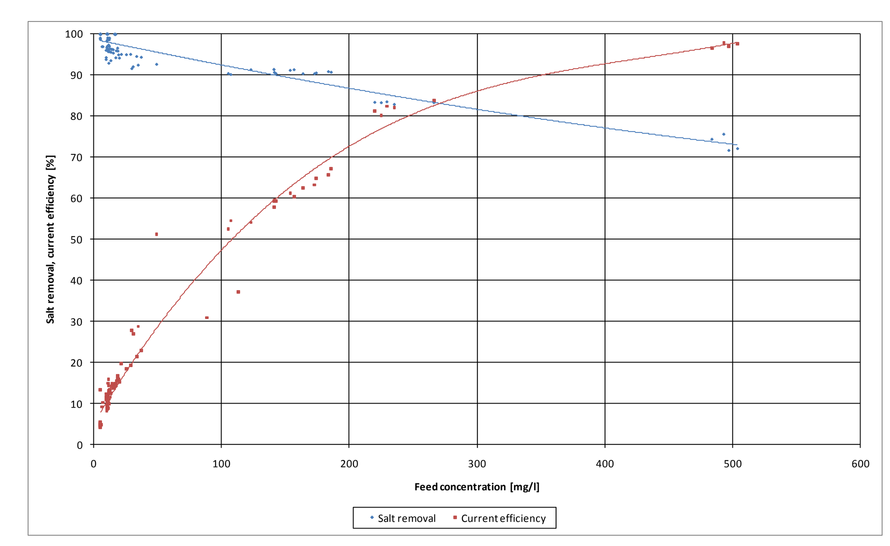
EDI-Y module available from MemBrain s.r.o.



EDI-Y module performance for NaCl solution at the minimum product flow rate (500 lph)



EDI-Y module performance for Na_2SO_4 solution at a varying product flow rate

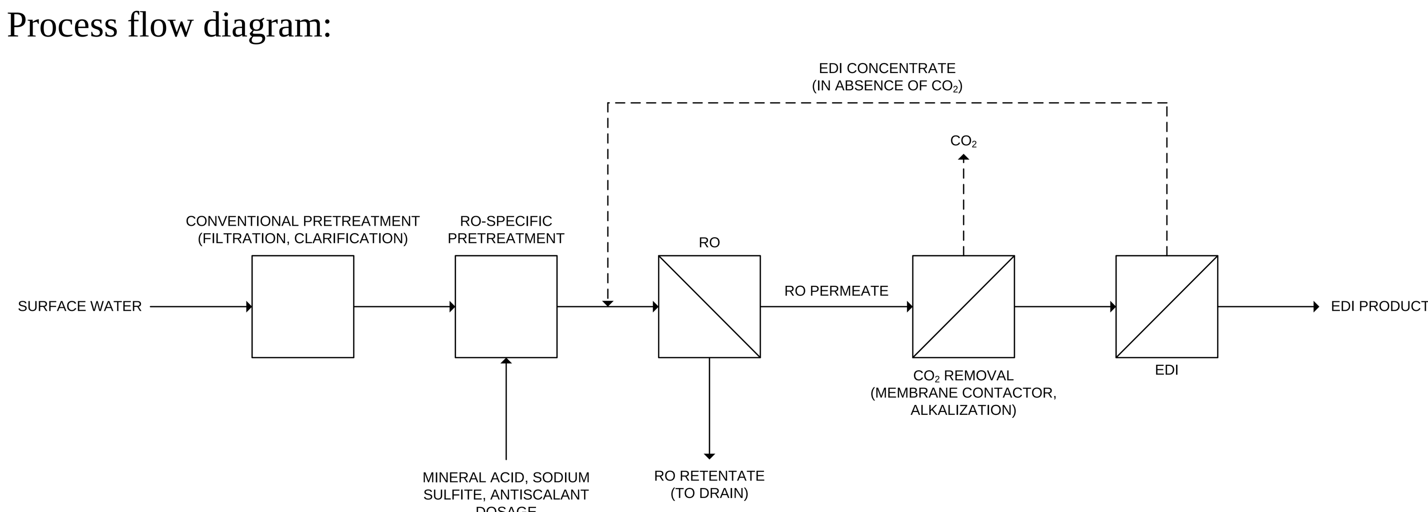


EDI-X module performance for NH_4NO_3 solution at the nominal product flow rate (4 m^3/h)

EDI-X module available from MemBrain s.r.o.

High-purity water production: Application in power generation industry

Process flow diagram:



- With EDI we reach the required limits of feed water quality in power industry given by guidelines for boilers
  - ➔ κ < 0,1 µS/cm
  - ➔ c (SiO_2) < 20 µg/kg
  - ➔ c (Fe) < 10 µg/kg

  etc.
- When we reach the required limits we protect the turbine and avoid the corrosion and scaling in steamlines and hot water lines

The goal:

- EDI is ideal solution for final purification of makeup water for boilers, especially for high presure boilers and steam generators in power plants and thermal power stations
- EDI can replace the mixed-beds columns and so reduce consumption of chemicals for regeneration ➔ this makes it more economical and more ecological in comparison with ion-exchange technologies
- EDI in combination with RO can replace the whole process of ion-exchange technologies in power or thermal station, beginning with demineralization columns and finishing with mixed-bed stations
- EDI also in combination with RO does not require regular operation and so provides savings of operating cost
- EDI can help to stop the blowdown and radically reduces the continual blowdown volumes.
- EDI in comparison with ion exchange technologies makes additional space savings, the modules are small and compact and we also avoid the space for regeneration utilities

2 m^3/h EDI pilot system at a thermal power station

Applicability:

- When it is necessary to fill the PowerTech Guidelines for feed water, boiler water and steam quality for power plants (VGB-R 450 Le) and reach the required limits for feed water
- EDI in combination with ED is possible for low salinity waters and waters with low SDI and provides ¨higher recovery than RO/EDI
- Because of low water recovery of RO (typically 75 %) and high costs of water clarification, RO/EDI is considered to be used where clarification is not applied

Performance issues:

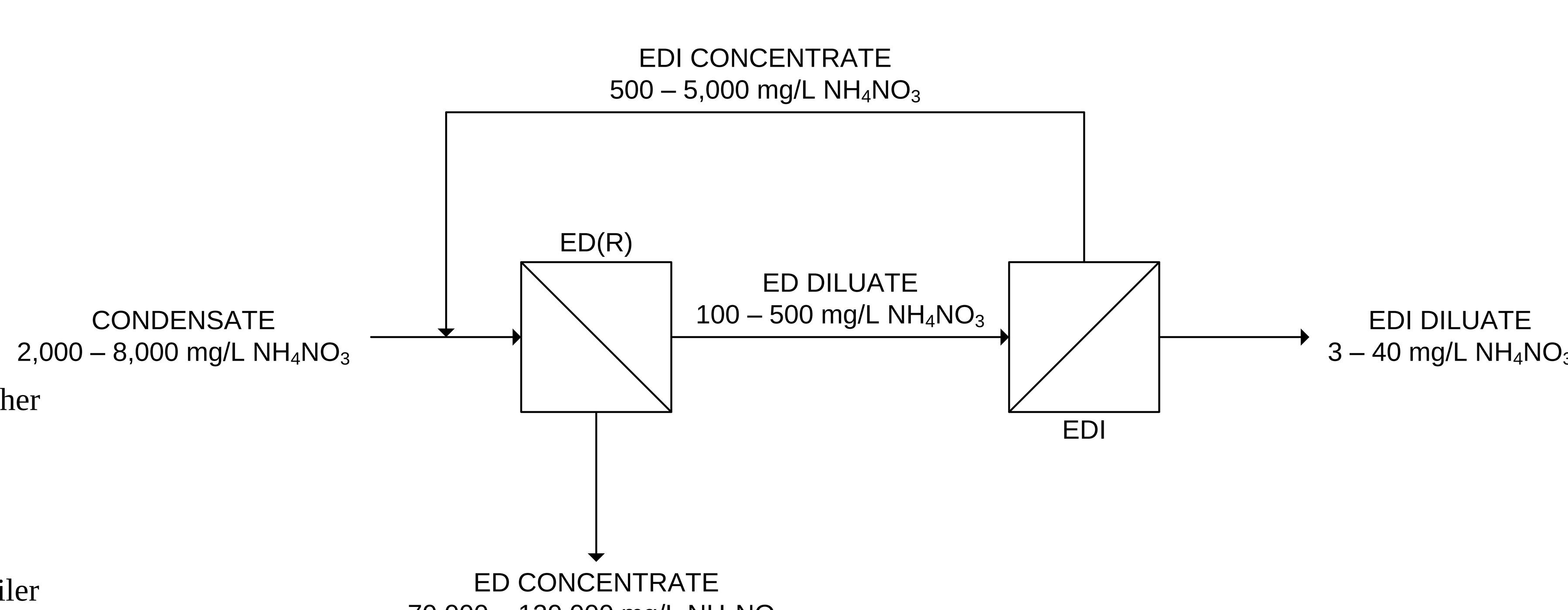
- EDI typically removes 98 – 99.8 % carbon dioxide and sillica dioxide
- EDI concentrate can be used as feed water for RO
- Any traces of carbon dioxide limit the resistance of the product water. For example, 5 and 10 MΩ.cm water will contain 0.02 – 0.03 mg/L and 0.004 – 0.005 mg/L free carbon dioxide, respectively.
- Carbon dioxide must be removed to a very low level prior to EDI to obtain high-resistivity product water.
- The good pretreatment must be guaranteed because of complicated cleaning of ion exchange resin in the chambers of EDI
  - ➔ RO is ideal pretreatment
  - ➔ low SDI must be kept
  - ➔ when the RO is not prior to EDI, the microfiltration or ultrafiltration is sufficient

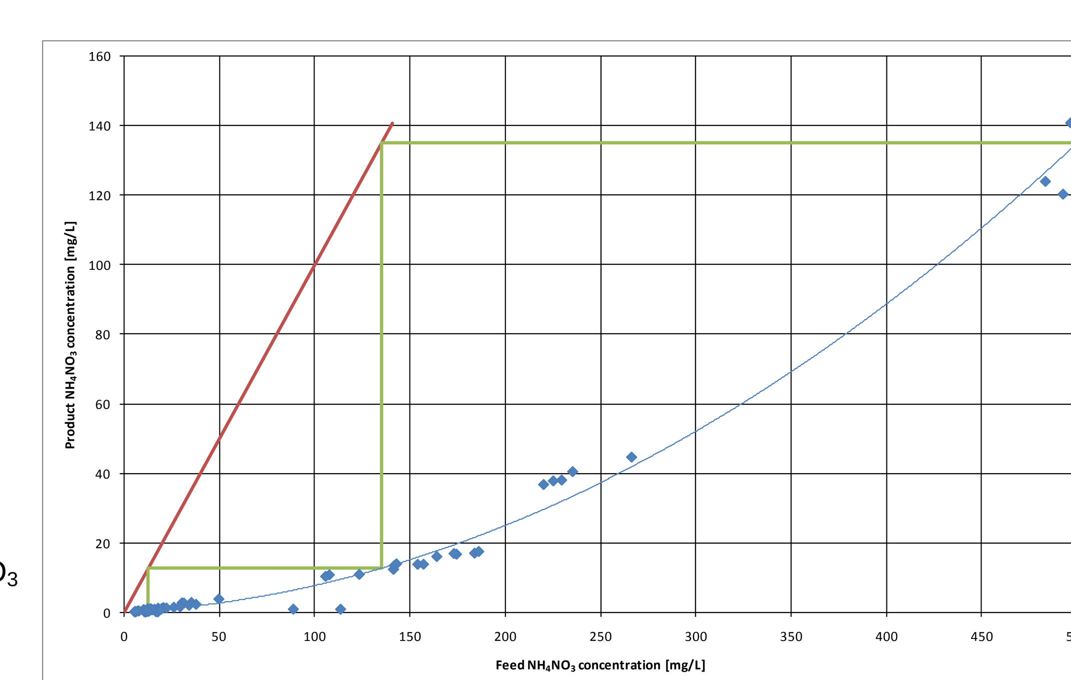
Application in the treatment of ammonium nitrate containing steam condensate

The problem:
- NH_4NO_3 manufacturing generates contaminated steam condensate that must be treated before disposal/reuse.
- Conventional techniques such as evaporation/distillation, ion-exchange, reverse osmosis are cost intensive or limited.

Our goal:
- Use of ED/EDI to make a closed-cycle technology with low operating costs.
- ED operates at a higher water recovery (85 – 90 %) and produces concentrate with a higher salt content than RO that can be reused in manufacturing.
- ED has a low specific power consumption (per m^3 treated liquid) for low TDS feeds.
- EDI produces high-quality water for use as boiler feed water or absorption water in the production of nitric acid.

Process flow diagram:





EDI-X module: 2 and 3 hydraulic and electrical stages required to reduce the initial feed NH_4NO_3 content of 500 mg/L to less than 13 mg/L and 0.5 mg/L, respectively, at the nominal product flow rate (4 m^3/h). Power consumption: ~2 kWh/m^3.