Selective Membranes for the Removal of Sodium from Irrigation Water in Greenhouses

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Motivation

Dutch crops are mainly grown on substrates, detached from soil, which allows for recirculation of the irrigation water. High concentrations of Na^+ in water affect the permeability of soil and causes infiltration problems. And most importantly, it is toxic for the crops. Reuse of irrigation water is therefore often limited by the accumulation of Na^+. Nowadays, this irrigation water, containing valuable nutrients, has often to be discharged to the environment as a brine stream. Therefore, reuse of water and nutrients would be enhanced if Na^+ could be selectively removed from irrigation water. However, up to now there is still no cost-effective industrial technology that can selectively remove Na^+.[1] This project aims to develop a membrane-based material that can separate Na^+ from the irrigation water meanwhile preserving other nutrients present, notably K^+. Selectivity will be imposed by using a crown ether with a high Na^+ over K^+ affinity (Fig. 1).

Technological challenge

Regarding real-life applications, the main challenges include:

- The Water Framework Directive (WFD) aims for zero brine emission[2].To comply with this regulation, all drain water should be treated prior to discharge to the environment or fully recycled.
- Regarding their chemical and physical properties (e.g., atomic diameter and valence), Na^+ and K^+ are two very similar ionic species. By implication, the material to be used needs to have the required Na^+ over K^+ selectivity.
- In contrast to an absorbent, a membrane that exclusively permeates Na+ requires no regeneration. Given the high affinity of the crown ether for Na^+, in order to generate a Na^+ flux over the membrane, equally important is the ability of the crown ether to again release Na^+. The system to be developed should demonstrate a delicate balance between these two requirements of high affinity (interaction) and release.

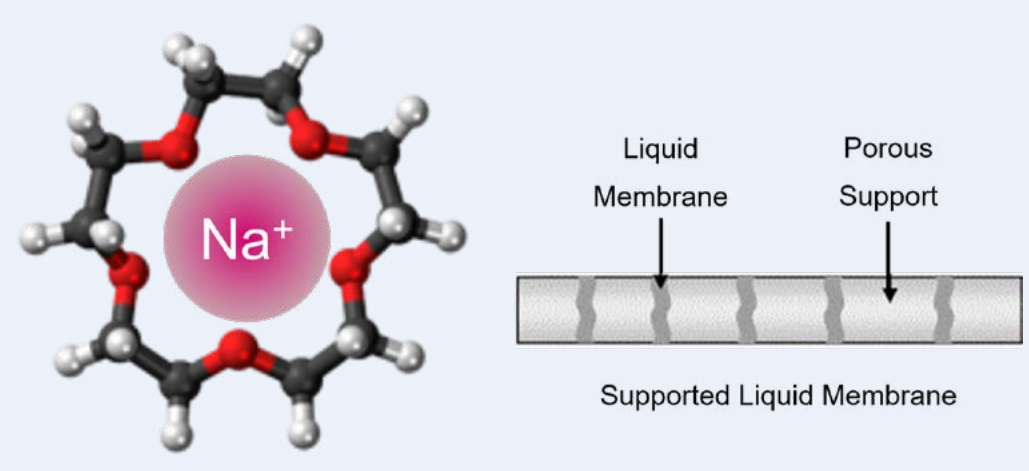

Fig 1. Structure of the Na^+ selective crown ether and Supported Liquid Membrane (SLM)

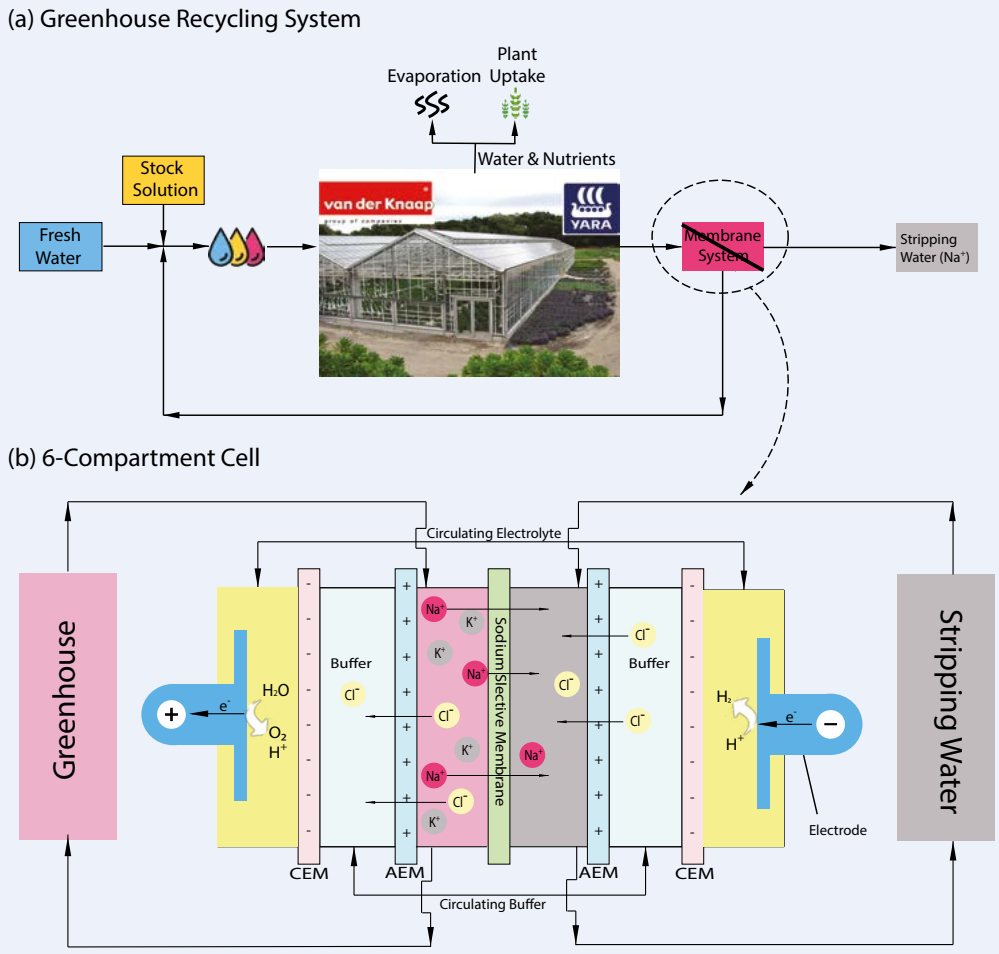

Fig 2. Schematic of the Greenhouse Recycling System

Research goals

In view of the challenges, this project aims developing a membrane-based system for the selective removal of Na^+ suitable to operate under greenhouse conditions. The project comprises the following research goals:

- Investigating and developing a membrane system, e.g. based on the concept of Supported Liquid Membranes (SLMs) as shown in Fig. 1.
- Synthesis of an extractant based on a Na^+ selective crown ether and use as ion carrier in the SLMs.
- Studying the feasibility of electric field-enhanced Na^+ membrane transport using a 6-compartment electrodialysis cell (Fig. 2b).
- Investigating of the membrane system under real-life conditions while exposed to a large scale continuous flow of greenhouse drain water.
- Optimizing the system from both environmental and economic aspects.

[1] D. Parmentier, M. Lavenas, E. Guler, S. J. Metz, M. C. Kroon, 2016, Selective removal of sodium from alkali-metal solutions with tetraoctylammonium monensin, Desalination, 399(2016) 124-127.

[2] Beerling E.A.M., Voogt W., Vermeulen T., Verkerke W., Heinen M., 2011, Complying with society's demands – solving the emission problem caused by irrigation surplus in greenhouses. Acta Hort, 889: 53-57.

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