Modular concept for sustainable desalination using capacitive deionization on the example of Vietnam (WaKap)

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Background and problem

Many countries in Southeast Asia such as Vietnam have imminent water problems as its water supply is increasingly threatened by the rising water demand due to a rapid population growth, the increasing water-intensive industrial processes and amongst others, also by climate change: Vietnam has been identified by the International Panel on Climate Change (IPCC) as one of the countries that is most affected by climate change. This includes in particular the rising sea levels and an increase in extreme weather conditions (tidal waves), what leads to an increased salinization of groundwater and surface water. By 2050, the sea level shall rise even more, which will further worsen the salinization of coastal groundwater particularly during the dry season. Furthermore, the groundwater in Vietnam shows high arsenic concentrations, a highly poisonous substance which is naturally washed out of sedimentary rocks. Arsenic has a strong negative influence on the health of the population and the social-economic development of the country itself.

The conditions in Vietnam can be considered being representative for many countries, particularly in Southeast Asia. For this reason, Vietnam has been selected as a demonstration region for innovative water desalination.

The solution: Sustainable techniques

To remove arsenic from the groundwater, an In-situ pretreatment is being considered. Therefore the groundwater is enriched with oxygen and reinjected to the well. Arsenic is bound to ferric oxides in the subsurface and fresh water can be extracted. The main advantages are the high energy efficiency and the chemical- and waste free process.

Capacitive Deionization (CDI) is a novel technology for the desalination of brackish water with a low energy consumption. The combination of the CDI and the Reverse Osmosis (RO) technology shall clearly increase the energy efficiency and the recovery rate for both, groundwater and seawater treatment. For this, an adequate combination process will be tested developed.

A very important objective is the autonomous and renewable energy of the processes. Photovoltaic- and wind energy, realize a self-sufficient and decentralized operation, off the grid. At different pilot sites, adaptable modules shall provide the needed energy.

The project: A modular concept for Vietnam

The objective of the project is to develop a modular and cost efficient concept for sustainable water desalination and arsenic removal. The project is coordinated by the University of Applied Sciences Karlsruhe and is supported by the industrial partners Karl Spiegl GmbH & Co. KG and Winkelnkemper GmbH as well as Fraunhofer ISI. The latter carries out a sustainability assessment, taking into account environmental, economic and social aspects to determine the limits of applicability and assessment of potential effects. Furthermore, based on the results of the project, a marketable prototype for communities and private users in Southeast Asia shall be developed.

Important results obtained to date

After analyzing water samples from different possible sites, the first pilot plant for the treatment of arsenic affected groundwater in Vietnam has been set up in the An Giang province. The In-situ technology has been operated successfully for four months. Hereby arsenic and iron could be removed below the thresholds given by the WHO drinking water guidelines within the first 2 weeks of operation. Furthermore, the first parameters for the energy concept as well as for the sustainability assessment have been identified.

For investigating the energy consumption of the Membrane CDI (MCDI), experiments on a lab scale with saline model water ($c_{TDS} < 2.0$ g/L) have been carried out. The removal of the salt ions has been also tested after spiking the water with As, NH_4^+ and Mn^{2+} (relevant ions with a high concentration present in the Vietnamese groundwater).

To understand the mass transport in the MCDI module, computer based FEM models have been developed. Furthermore, they shall help to design future combined desalination process with RO. A 2D model can resolute the developing electrical double layer close to the porous electrodes and calculate a salt removal rate.