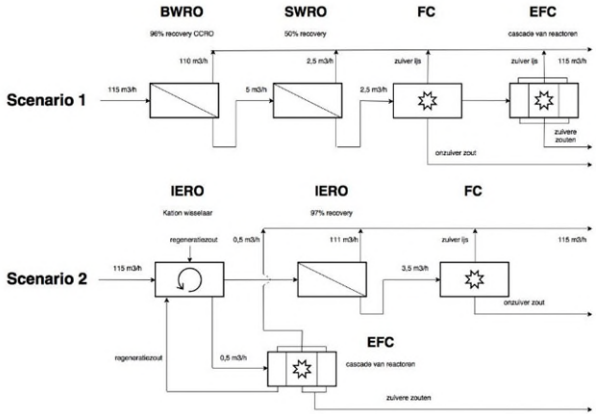
BTO *Executive Summary*

Application of reverse osmosis in combination with freeze crystallisation can provide Vitens with the desired zero liquid discharge drinking water production and high-quality residuals



Total concepts envisaged for the production of water of high quality from brackish groundwater in which solid-phase residual streams are generated

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Based on the National Raw Materials Agreement, Vitens wishes to treat its raw materials – in this case, (brackish) groundwater – more economically and intelligently. Further research and development of the application of (eutectic) freeze crystallisation treating the reject stream produced by reverse osmosis [closed circuit reverse osmosis (CCRO) or ion exchange reverse osmosis (IERO)], can provide Vitens with the desired zero liquid discharge drinking water production, with a portion of the generated residuals being of high quality. This is the outcome of research based on literature and on expert findings, which involved the study of thirteen techniques. Total concepts were developed on this basis. Three other techniques [multi-stage flash (MSF), multi-effect distillation (MED) and supercritical water desalination (SCWD)] actually have the capacity of removing four critical substances (ammonium, chloride, iron and methane) in a single step, but they generate liquid and/or gaseous residual streams, rendering them unsuitable for drinking water production with zero liquid discharge.

Interest: produce drinking water with only high-quality residuals

Based on the National Raw Materials Agreement, Vitens also wishes to treat its raw materials – in this case, (brackish) groundwater – more economically and intelligently. Drinking water production (for the most part) from fresh groundwater for 5.6 million Vitens customers generates a residual stream containing minerals and salts which are currently not (re)used. Vitens is therefore looking for (drinking) water production techniques that generate only high-quality residuals, so that the these can be usefully applied. Accordingly, Vitens requested a screening of water treatment techniques for possibilities for zero liquid discharge treatment of brackish groundwater producing water of drinking water quality. Vitens would like to be able to apply this (combination of) technique(s) location-independently, especially considering location-specific discharge requirements.

Approach: literature study and expert assessments

Based on a screening of the SCOPUS database and inputs from KWR experts, a list was compiled of thirteen techniques that can be applied for the desalination of brackish groundwater. These desalination techniques are briefly described, as are their applications in the treatment of brackish groundwater referenced in the literature.

The techniques were then assessed for their capability of removing four critical components from the brackish water: ammonium, chloride, iron and methane. These substances were selected based on the water-quality data provided by Vitens for brackish groundwater from the 1965_01 recovery well at the Ceintuurbaan pumping station. In addition, for each desalination technique, an assessment was made of the quality of the residual stream and of its phase (solid, liquid, gas).

Result: reverse osmosis combined with eutectic freeze crystallisation offers best prospects

According to the study, three desalination techniques [multi-stage flash (MSF), multi-effect distillation (MED) and supercritical water desalination (SCWD)] have the capability of removing ammonium, chloride, iron and methane from brackish groundwater in a single step. MSF and MED generate liquid and/or gaseous residual streams, and are therefore not suited to the zero liquid discharge production of (drinking) water from brackish groundwater in a single step. Only SCWD is suited to this purpose. However, the quality of the solid residual product generated by SCWD is considered to be so low that landfill would possibly be its highest-value application.

Moreover, the SCWD technique does not seem to be sufficiently developed for pilot or full-scale application.

The only desalination technique that generates a residual stream in the solid phase, and of a quality high enough to enable its reuse in the chemical sector, is eutectic freeze crystallisation (EFC). EFC technology is currently evolving from a low capacity (~< 1m^3) batch process, to a continuous process of higher capacity (~> 1m^3/hour). When an integrated (and therefore energy-efficient) cascade of EFC reactors can be produced, the practical application possibilities will improve. Since EFC is ideally fed with an as concentrated as possible feed stream, (pre)treatment of the brackish groundwater with another desalination technique is an obvious option.

Pre-treatment

Reverse Osmosis (RO) is a proven desalination technique which is applied, among others, to brackish groundwater in full-scale production plants by drinking water utilities. Six alternative RO techniques were therefore explored and compared with a traditional RO design. A software-based calculation of a traditional RO design indicated that 92.5% recovery can be achieved using pH correction and antiscalant. Theoretical calculations/models show that the Desalitech closed circuit reverse osmosis (CCRO) can achieve a higher recovery than the traditional RO design. The ion exchange reverse osmosis (IERO) concept, in which a cation exchanger is placed before a (traditional) RO installation, is also capable of achieving a higher recovery than the traditional RO design. This research provided the basis for the development of total concepts for the production of qualitatively high-grade water from brackish groundwater, which generate solid-phase residuals.

Implementation: research the combination of freeze crystallisation with CCRO and IERO

It is recommended that the alternative RO concepts (CCRO and IERO) in combination with (eutectic) freeze crystallisation be researched, aiming at zero liquid discharge treatment of brackish groundwater. These total concepts should be investigated in more depth in a follow-up study, in order to assess their practical feasibility and prospect for successful implementation.

Report

This tailored research for Vitens is described in the report *Behandeling van brak grondwater* (BTO-2018.064).

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