Trace Organics Transmission in RO Water Reclamation

Potential collaborative project – SSP and TP Programmes at NTU

1. Background

1.1 TP Project on RO Water Reclamation - Fouling studies,

The TP programme has several projects under the theme ‘Water Production’. One of these projects is ‘RO Desalination and Reclamation – Fouling Studies’. This project has objectives which include, (i) measuring and modeling biofilm development in a crossflow RO system, (ii) assessing the influence of flux per se on biofilm development, developing and testing in-situ monitoring of the biofilm (in collaboration with H-C Flemming),and (iii) assessing the role of the spacer in biofilm development. Through collaboration with the PUB, it is planned to link this study to the Bedock Newater demonstration plant . A PhD student has already started on this project.

The above project will not focus on solute transmission. However it is recognized that the developed biofilms will provide an unstirred ‘boundary layer region,’ and increased concentration polarization, and enhance transmission of trace organics (see 1.2).

1.2 Trace Organics Transmission in RO Water Reclamation

A project addressing the topic ‘Trace Organics Transmission in Reverse Osmosis Water Reclamation’ is a natural extension of the RO Fouling Studies project. This was recognized in the original TP proposal which referred to a potential project on ‘factors affecting the transmission of trace organics in RO water reclamation’.

In the downstream stages of an RO reclamation plant, such as NeWater, nutrients and trace organics will be most concentrated. Biofouling under these conditions could lead to enhanced transmission of undesirable trace organics, including endocrine disruptors and species such as DMA. The transmission will depend on the intrinsic separation properties of the membrane as well as the solute concentration at the membrane surface, C_w .The value of C_w will be determined by the imposed flux, the biofilm thickness and structure and the diffusion coefficient of the solute in the biofilm.

It is proposed to study the target solute retention both theoretically and experimentally. The theoretical study will involve analyzing the transport processes in the fluid boundary layer, the biofilm and the membrane. In particular the diffusion and convection of solutes in the ‘unstirred biofilm layer’ will be modeled. The intrinsic retention properties of the membrane can be independently measured (or in theory estimated by molecular modeling). Experimental data for diffusion of organic solutes will be obtained for model biofilm EPS (such as alginate) in a diffusion cell or similar device. In addition it may be possible to obtain diffusion data for developed biofilms grown in the crossflow cell by in-situ analysis of injected tracer and application of the transport model.

The objectives of this proposed study will be:

- to develop a theoretical model describing trace solute transmission through RO membranes as a function of type and extent of biofouling;
- to measure diffusion of organic solutes through model and developed biofilms;
- to measure transmission of trace organics through RO membranes operated in crossflow with model and developed biofilms and compare performance with model predictions;
- based on the above to determine the significance of biofilms and control strategies (such as cleaning) on operation of RO water reclamation plant.

1.3 SSP Project on Bacterial Alginate and RO

As part of the SSP Clean Waters Programme Stanford University have proposed a project to study how bacterial alginate (a model EPS) interacts with RO membranes to further understanding of the effects of biofilms on RO performance. The project includes,

(i) development of a miniaturized adsorption assay (AA),
(ii) comparison of AA with lab flow cells,
(iii) measure alginate adsorption on RO materials,
(iv) determine effect of alginate adsorption on flux and rejection,
(v) identify adsorption control strategies.

The developed AA protocol will facilitate comparison of a wide range of membrane chemistries and surface treatments and additive effects. Part (iv) proposes to use a modified AA test to obtain semiquantitative data on flux and solute effects. The project includes comparison and verification of the AA data in crossflow cells (part(ii)).

2. Proposal

The SSP project and the proposed TP project have an overlapping set of objectives. In particular both projects aim to study the effect of ‘biofilms’ on the performance of RO membranes. The existing TP project is looking at factors relating to fouling resistance caused by biofilms in a crossflow facility, and the proposed TP project would look at solute transport, having access to the crossflow facility.

It is proposed that aspects of the two projects be combined to allow a PhD student to work initially at Stanford on the development and application of the AA assay (parts (i) to (iii) of the SSP proposal). The work would then be continued at NTU to quantify target solute diffusion in model (alginate) using a modified AA assay or diffusion cell and diffusion in developed biofilms (using the existing crossflow RO facility). Collaboration with the student investigating RO fouling is envisaged as he will be developing protocols for growing biofilms in the facility.

The SSP student will also develop the model referred to in 1.2 to allow data assessment and prediction of performance under various scenarios.

The TP programme will make available the RO crossflow facility.

It is proposed that Professors Anthony Fane and Martin Reinhard be principal supervisors of the PhD student at NTU and Stanford respectively, with Drs Harry Ridgway, Wong FookSin and Karina Gin are cosupervisors.

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