ABSTRACT

This thesis presents a chemical and mathematical analysis of membranes filtration systems coupled to an anaerobic baffled reactor (ABR). The purpose of this investigation was to gain an understanding of the mechanisms involved in fouling in membranes coupled to an ABR and to use this understanding to develop a guideline for the implementation of a membrane polishing step to ABR sanitation applications. The research objective was derived from previous research at the Pollution Research Group which showed that although the ABR was a robust sanitation technology capable of superior performance over conventional septic tanks, the ABR effluent still requires nutrient and pathogen disinfection polishing to meet local discharge regulations. A similar situation has been reported in some ABR sanitation applications designed by the non-profit organisation BORDA (*Bremen Overseas Research and Development Association*). In these BORDA plants – called DEWATS (*DEcentralised WAstewater Treatment System*) units – the effluent from an ABR is treated by a combination of polishing steps. This includes constructed wetlands, ponds systems and/or anaerobic filters polishing steps. However, these polishing steps can have a large land area footprint and inconsistent pathogen removal has been reported in some plants.

In this thesis, membrane technology was evaluated as an alternate polishing step for ABR sanitation applications as it could be easily incorporated into the design of the ABR (fitted into the last compartment) with little or no change to the overall design. Moreover, membrane technology can be applied at lower land area footprint (than constructed wetlands or ponds) and has proven disinfection capabilities.

One of the challenges in this work was to operate membrane modules without gas scouring and using gravitational water heads to drive the membrane filtration process – in line with decentralised applications (no energy). Moreover, the conditions for membrane filtration were different to aerobic and other anaerobic membrane systems in that the membrane filtration step is at the back end of the ABR where the concentration of suspended solids and biodegradable substances are expected to be low. The novelty of this approach is that the mechanisms governing fouling will be different to other membranes systems (due to differences in membrane tank conditions, and the design and operation of modules).

This thesis presents and analyses the operating data from membrane filtration units treating the effluent from a laboratory-scale ABR system (200 L capacity). The laboratory ABR was fed with a complex synthetic wastewater comprised of ventilated improved pit latrine sludge, representative of black wastewater (faeces and urine), and was operated at different conditions

(phases). Specific membrane challenge experiments were performed during each of these phases of laboratory ABR operation and the results used to gain insight into the fouling mechanisms of membranes coupled to this system. The methods used to characterise the fouling in this thesis were stipulated by project partners from a larger international project – EUROMBRA - into which this work fits.

The principal findings of this research were:

- The laboratory ABR used in this thesis was not well-designed to the feed wastewater. The feed wastewater, made from diluted VIP sludge, had a low biodegradability content. Consequently, the large non-biodegradable portion built up in the reactor which sometimes required desludging or clogged overflow pipes to the ABR train. The main mechanism of treatment in this ABR plant occurred through solids retention and accumulation.
- A standardised test cell technique was used to determine the fouling propensities of the soluble fraction of different sludge sources. The results showed that the samples from starved pilot ABR had the lowest fouling propensity whilst the sample from a conventional anaerobic digester had the highest propensity. Gel-like fouling layers developed from compartment 3 (and to lesser extent from compartments 2 and 4) of the starved ABR which contained biogranules. Although these solutions had low fouling propensities, the layer was highly compressible. The tests also showed that the effluent from a laboratory ABR had similar fouling propensities to other samples (both aerobic and anaerobic) tested. The results could not be statistically validated due to non-linearity of data indicating that improvements to the technique are required.
- Different fouling mechanisms were observed between hollow-fibre and flat-sheet modules treating the same laboratory ABR effluent. This difference was hypothesised to be the result of membrane surface-bulk fluid interactions with an irremovable gel layer formation in the flat-sheet modules and removable 'cake-like' fouling in the hollow-fibre modules. The differences observed were thought to be the result of differences in membrane pore shape and surface topography.
- The fluxes of the modules tested were low (less than 1 $L.m^{-2}.h^{-1}$) under gravitational pressures suggesting that membrane polishing is better suited to small-scale ABR applications.

It was concluded that membrane performance, particularly the type of foulant responsible for fouling, differed according to the module type used. Hence, a situation where one module type can be used for all ABR sanitation applications does not exist. Modules should be rather chosen for performance over time (higher quality product with reduced production versus a lesser quality product with higher production) and/or intended purpose of discharge (into a water body or less restricted agricultural irrigation). The practical experience gained from this study was used to design a membrane sump for a full-scale experimental DEWATS plant.