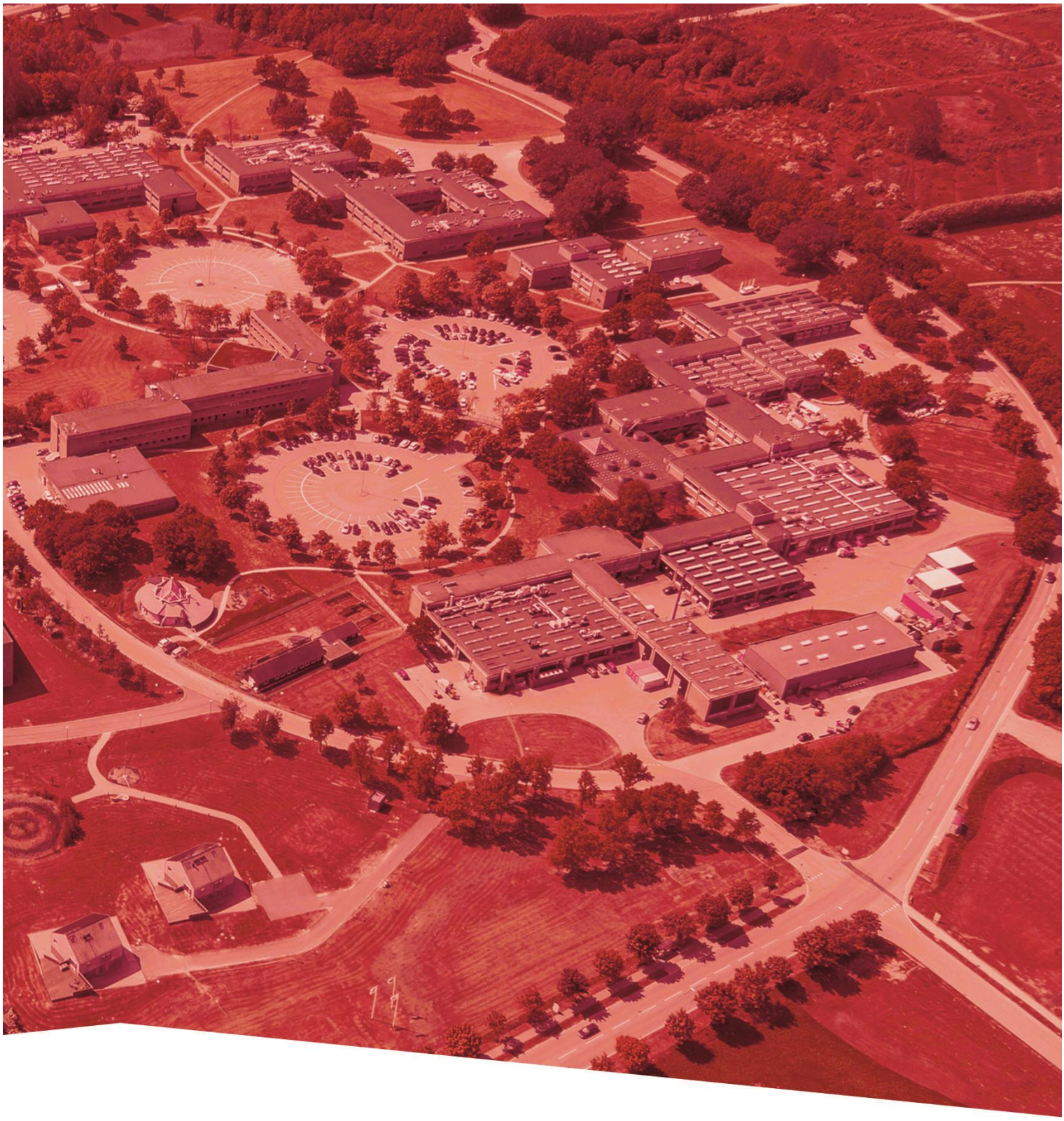

Log reduction values for modules with ceramic membranes

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December 2023
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1. Assignment description

Cembrane has developed ceramic flat sheet membranes placed in modules intended for treatment of drinking water. Cembrane wished to determine the log reduction values for six modules manufactured using similar preparation approach. In this regard, the Danish Technological Institute performed membrane filtration of a test suspension with *E. coli*. Based on samples taken from the test chamber and permeate stream, the log reduction values were calculated for each module at selected sampling times.

2. Experimental setup

Six modules were investigated for their bacteria retention properties using a test suspension of *E. coli* DSM 5698. The modules were tested in setups with a permeate flux of approximately 425 LMH.

In brief, overnight cultures of *E. coli* DSM 5698 were mixed with pretreated tap water to achieve a final concentration of approximately $2 \cdot 10^6$ CFU/mL. Two IBC tanks containing 1 m^3 test suspension were prepared for each membrane filtration. The test suspensions were homogenized using a forced mixer for 2 minutes, before filling the test chamber containing one module with approximately 600 L test suspension. Test suspension was continuously added to the test chamber during membrane filtration to ensure constant volume in the test chamber.

Residual air was removed from the system by running the membrane filtration for 2 minutes before sampling. The modules were sampled after 0 min., 15 min., and 30 min. of membrane filtration. Permeate samples were taken from an outlet located at the permeate line, and grab samples from the test chamber constituted the feed samples. Sampling occurred simultaneously and the samples were evaluated in singlicates by serial dilution and plating on TC Compact Dry plates. The plates were incubated overnight at 37°C before evaluating the CFU counts. Only CFU counts between 14-330 were used for calculations. In case the obtained plate counts for undiluted samples were below 14 CFU, a lower limit at 14 were used for calculating the number of *E. coli* present in the permeate stream and thus the log reduction value. The lower limit (14) is based on the fact that the variability increases the smaller the CFU counts are, meaning the subsequent calculations may lead to wrong results. Hence, a modules true log reduction value is equal or higher than the log reduction value determined using the lower limit (14 CFU counts). For module 3, a malfunction in the flow sensor resulted in a disruption in the filtration for 10 minutes, before continuing the experiment. Samples were still collected after 0 min., 15 min., and 30 min. of filtration.

All modules underwent cleaning and backwashing. Modules were backwashed with an initial cleaning solution to remove potential biofilm due to water exposure of these modules from previous filtrations. Cleaning involved a chloride solution followed by excessive cleansing and backflushing using pretreated tap water. This ensured that no chlorine was left to effect testing.

3. Results

Membrane filtration was performed on six modules to determine their log reduction values. The tests were performed with a permeate flux at approximately 425 LMH.

The number of *E. coli* detected in the feed and permeate samples at different sampling times is presented in table 1, including the obtained log_{10} reductions. For module 1, module 2, and module 4 the number of CFU counts per plate were below the detection limit (<14 CFU/mL) for all measurements. Furthermore, the number of CFU counts per plate were below the detection limit at the final measurement for module 3, module 5, and module 6. Consequently, 14 CFU/mL were used to calculate the number of detected ECOR4 in the permeate stream and the log reduction value.

Table 1: Log_{10} transformed CFU/mL for feed and permeate samples evaluated at two or three sampling times.

Module	Sampling time	Feed log_{10} (CFU/mL)	Permeate log_{10} (CFU/mL)	Log_{10}(CFU/mL) reductions
Module 1	0	6.30	≤1.10	≥5.20
	15	6.15	≤1.10	≥5.05
	30	6.03	≤1.10	≥4.93
Module 2	0	5.95	≤1.10	≥4.85
	15	6.05	≤1.10	≥4.95
	30	6.04	≤1.10	≥4.94
Module 3	0	6.38	1.36	5.02
	15	6.23	1.15	5.09
	30	6.15	≤1.10	≥5.04
Module 4	0	6.20	≤1.10	≥5.10
	15	6.15	≤1.10	≥5.04
	30	6.18	≤1.10	≥5.07
Module 5	0	6.48	1.34	5.14
	15	6.31	1.20	5.11
	30	6.16	≤1.10	≥5.06
Module 6	0	6.43	1.57	4.86
	15	6.39	1.20	5.19
	30	6.17	≤1.10	≥5.06

*The number of CFU/plate were lower than the detection limit, meaning 14 CFU/mL were used for subsequent calculations. Hence, log reductions values are equal or greater than the reported log reductions.

As shown in table 1, the bacteria concentration in the test chamber fluctuated slightly during the experiment due to the use of two suspensions. The number of bacteria in the feed stream had a standard

deviation between 0.03 to 0.16 log_{10}(CFU/mL) for individual modules, and an average standard deviation at 0.11 log_{10}(CFU/mL) across all modules. These variations are attributed the use of two test suspensions per experiment. The number of bacteria measured in the permeate stream had a slightly broader range for the standard deviation with values between 0.00-0.24 log_{10}(CFU/mL) for each module. This corresponded to an average standard deviation at 0.08 log_{10}(CFU/mL) across all modules.

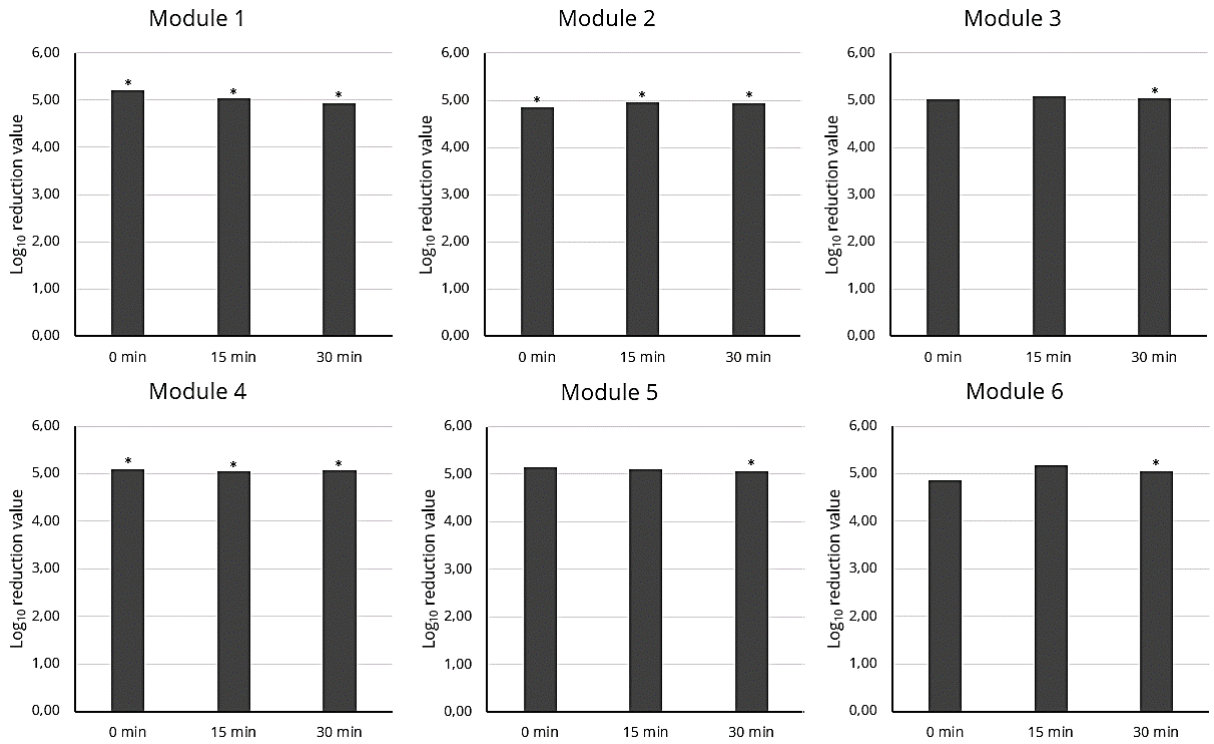

Figure 1: The obtained log_{10} reductions for modules run at 425 LMH. Log_{10}(CFU/mL) reductions for the modules is marked in dark grey columns on the primary y-axis (left). Log reduction values calculated using the lower detection limit (14 CFU/mL) are marked with *. Hence, log reductions values are equal or greater than the reported log reductions.

Figure 1 shows the bacteria retention for six modules after filtration at 425 LMH. The measured bacteria retentions varied between 4.86 and ≥5.20 log_{10}(CFU/mL) for the six modules with the lowest bacteria retention measured for module 6. The log reduction values for each module varied 0.05 to 0.33 log_{10}(CFU/mL) between the highest and lowest measured log reductions, with an average deviation at 0.15 log_{10}(CFU/mL).

The log reductions for each module over time displayed no substantial variation or an overall tendency (either increase or decrease). Hence, a cake layer did not seem to appear during each the test period.

4. Conclusion

Six modules were evaluated for their bacteria retention properties using *E. coli* as a test organism.

The obtained results show:

- Log reduction values between 4.86 to ≥5.20 $\log_{10}$(CFU/mL) were obtained for the six modules.
- The lowest bacteria retention was measured for module 2.
- Standard deviations between 0.03 to 0.16 $\log_{10}$(CFU/mL) was obtained for the feed during each test, and an average standard deviation at 0.11 $\log_{10}$(CFU/mL) across all tests.
- The difference between the highest and lowest log reduction value for individual modules ranged between 0.05-0.33 $\log_{10}$(CFU/mL) with an average at 0.15 $\log_{10}$(CFU/mL).
- No cake layer seemed to appear during the experiments.

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