WASH-WATER EFFLUENT PRODUCT RECOVERY

ADVANCED MEMBRANE FILTRATION TECHNOLOGY

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PCI Membranes

Background

PCI Membranes was contacted by a multinational consumer goods company that specialises in producing a wide range of hygiene and personal care products, to evaluate the feasibility of using a tubular membrane system for the treatment of a laundry detergent wash-water resulting from one of their global manufacturing sites, with a target to concentrate the wash-water to a satisfactory level whilst generating a permeate stream that is good enough for disposal into the local sewer network.

Following the chemical and physical evaluation of the wash-water, PCI Membranes selected the appropriate tubular membrane type and, using one of PCI Membranes'pilot units configured with a 4ft B1 type module with series flow end caps and instrumentation, completed an extensive trial on the wash-water and collected sufficient design data and samples for laboratory analysis.

The Challenge

Depending on the location of the manufacturing facility, the acceptable level of pollutants in the permeate stream vary; with the major concern mostly related to the amount of chemical and biological oxygen demand (COD & BOD) and followed by the concentration of total dissolved or suspended solids, oil & grease, dissolved sulphates and total nitrogen.

Below is a summary of the wash-water sample that has been tested by PCI Membranes and the required permeate stream specification of a specific manufacturing site. In general, the inlet concentration of the wash-water stream to be treated and the expected treated water quality vary in relation to the production site. Hence, to reproduce the variation in the feed stream, PCI has diluted the fresh wash-water sample to 10%, 30% and 50% prior to completing a series of test on each diluted stream.

Table 1: Summary of the tested samples during the trial.

	COD (mg/l)	BOD (mg/l)	Conductivity (mS/cm)
Fresh sample – 100%	407000	86000	18
50% Dilution	223800	42841	9.247
30% Dilution	126440	30241	5.648
10% Dilution	39620	12558.9	2.084

Whilst the fresh sample at 100% concentration would actually correspond to a 90% rejected/unmarketable product material and a 10% wash-water solution, the client objective is to mainly process a wash-water stream with a membrane system and therefore, the fresh sample has been diluted with demineralised water and tested accordingly - this has also helped to reduce the viscosity and the pollutant concentration of the starting material; whilst the viscosity of the 10% product to water dilution is relatively low, there is a rapid increase in viscosity of the other tested samples at 30% & 50% dilution with the concentration; posing no issues to the system performance as the opened channel configuration of the tubular membrane is designed to cope with very high viscous liquids.

Table 2: Acceptable permeate quality concentration for disposal.

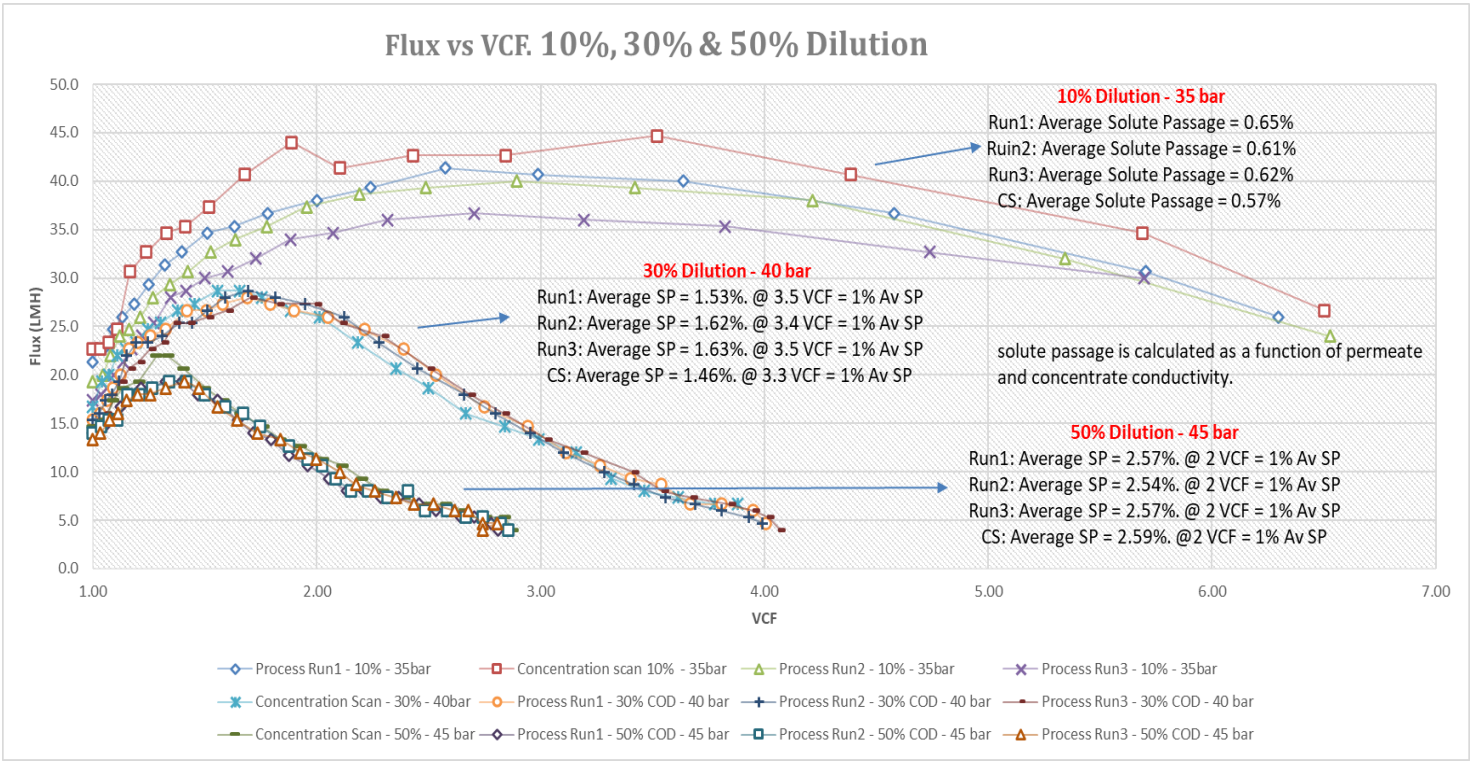
Components	Concentration
COD (mg/l)	< 1100
BOD (mg/l)	600
TDS (mg/l)	2000
Oil & grease (mg/l)	100
Dissolved Sulphates (mg/l)	10
Total Nitrogen (mg/l)	100
Total Phosphate (mg/l)	25
Total suspended solids (mg/l)	800

Test Procedure and Process Output

PCI's reverse osmosis membrane: AFC99, a polyamide thin film composite membrane with 99% sodium chloride retention characteristic was used for the test and all tests conducted in the trials. The membrane suitability with the process fluid was confirmed with the membrane clean water flux recovered post cleaning in place. Cleaning chemical used is either Ultrasil 11, NaOH or Nitric acid and a mechanical clean with a bespoke foam ball – which gave an insight about the membrane fouling characteristic. Samples collected during the trial have been tested for COD, BOD, pH, conductivity, TDS, total nitrogen, total sulphur, dry matter and concentration of organic matter.

For every single dilution range: 10%, 30% and 50%, the following steps were completed: a pressure scan (to quantify flux variation with pressure and determine the optimal operating pressure for the system), temperature scan (analyse flux variation with temperature at fixed pressure and the impact on solute passage to the permeate stream), concentration scan (define flux variation with the volumetric concentration factor) and process run (to outline a detailed variation of the process flux with concentration).

By analysing the pressure scan data completed for all product to water dilution range, an exponential increase in flux per applied pressure was noticed; to minimise any potential fouling/concentration polarisation with increase energy consumption, an optimum operating pressure of 35bar, 40bar and 45bar was used for the 10%, 30% and 50% process run respectively.



Graph 1: Flux vs Volumetric Concentration Factor: 10%, 30% & 50% Dilution.

Graph 1 above shows the flux variation against the volumetric concentration factor for the 10%, 30% & 50% product to water dilution range, with all data collected from both concentration scans and process runs. As expected, the highest flux and volumetric concentration factor have been achieved with the 10% product to water dilution, which also correspond to the lowest solute passage to the permeate stream (circa 65% final product concentration was achieved: 10%*6.5VCF). The 30% product to water dilution was concentrated to a maximum of 4.07 VCF (30%*4 = 120% product concentration), whilst showing a lower flux and a higher solute passage when compared to that of 10% dilution. Similar interpretation applies to the case of 50% dilution test; where a maximum volumetric concentration factor of 2.86 VCF was achieved, equating to a final product concentration of 2.86*50% = 143%.

The temperature scan across all dilution range has been completed with the aim of analysing the process fluid temperature increase with time, whilst quantifying both flux and solute passage variation. As expected, both flux and solute passage increase with the temperature and the impact of this would have to be taken into consideration when designing a full-scale plant if the process fluid temperature differs from ambient temperature. Neither cooling nor heating of the process fluid was required for this test, as the starting temperature of the tested fluid varies between 18 – 20°C to reach a final temperature in some cases of circa 55 – 59°C – the AFC99 membrane itself is able to withstand a maximum operating temperature of 80°C and a 64bar to 80bar maximum operating pressure (B1 module type specific: 80/80 module, 80°C and 80 bar limit).

Table 3: Summary of laboratory analysis of samples collected during the trial.

Concentration	Description	Description	COD (mg/l)	Conductivity (µS/cm)	BOD [mg/l]	Dry residue [g/l]	COD Retention (In relation to the concentrate)	Conductivity Retention (In relation to the concentrate)	BOD Retention (In relation to the concentrate)
10% Dilution. Final VCF @ 6.53	FEED	FEED	39620	2084	12558.9				
	PERMEATE	START	440	16.71					
		MIDDLE	246	18.7					
		END*	459	30.15	143	<0,1			
	RETENTATE	START	32760	2126			98.7%	99.2%	
		MIDDLE	57800	3257			99.6%	99.4%	
		END*	218900	11280	77601	122	99.8%	99.7%	99.8%
30% Dilution. Final VCF @ 4.07	FEED	FEED	126440	5648	30241				
	PERMEATE	START	212	43.47					
		MIDDLE	1894	94.35					
		END*	2652	154.4	647	0,49 ±0,14			
	RETENTATE	START	217940	5837			99.9%	99.3%	
		MIDDLE	252780	9494			99.3%	99.0%	
		END*	536300	13160	108000	246	99.5%	98.8%	99.4%
50% Dilution. Final VCF @ 2.86	FEED	FEED	223800	9247	42841				
	PERMEATE	START	553	36.94					
		MIDDLE	8657	424.2					
		END*	5511	307.4	2109	0,81 ±0,24			
	RETENTATE	START	233200	9389			99.8%	99.6%	
		MIDDLE	326200	12380			97.3%	96.6%	
		END*	637600	14310	124800	291	99.1%	97.9%	98.3%
		End* = Overall Permeate/Retentate							

Table 3 above shows the lab analysis summary of some samples collected during the trial. Overall, the reduction of contaminants from the permeate stream in terms of chemical and biological oxygen demand and dry matter was deemed excellent – the total sulphur and concentration of organic matter of the permeate streams of all tested samples are way below the required specification; with 5mg/l and 10 mg/l recorded respectively. Similar interpretation applies to the total nitrogen in the permeate streams with 3.4mg/l, 16.4mg/l and 34mg/l recorded for the 10%, 30% and 50% dilution range respectively. However, defining an acceptable level/concentration of contaminants in the permeate stream depends on the starting wash-water concentration and the extent of the final volumetric concentration factor.

As shown in table 3, if starting with a wash-water sample that has a similar characteristic to that of a 10% product to water dilution or even closer to 20% dilution range, then the tubular reverse osmosis system should deliver the required permeate quality whilst maintaining a satisfactory concentration factor and higher recovery of filtrate water. It was also demonstrated that the pollutants retention characteristic is still within a satisfactory level even when the product is highly concentrated/polluted (30% and 50% product to water dilution range) and, if required, the permeate streams from these could be treated further in order to meet the permeate quality specification.

The same set of AFC99 membrane has been used across the duration of this extensive trial and by using a combination of chemical (Ultrasil 11, NaOH or nitric acid) and/or mechanical cleaning (foam ball) across the process stage, the clean water recovery efficiency of the membrane would stabilise around the 40% range. Considering the nature of the fluid being highly viscous/concentrated and the final concentration factor achieved, the membrane recovery efficiency does not suggest any irrecoverable fouling.

Conclusion

The application of a tubular reverse osmosis membrane AFC99 for the treatment of the laundry detergent wash-water stream has been proven practicable and suitable for achieving the required permeate quality specification. Whilst the concentration of the process fluid tested during this trial varies in relation to product to water dilution, it has also been outlined that the wash-water concentration to be treated could vary from a specific production site to another. Hence, the specific site overall permeate quality requirement can be satisfied by simply implementing a one-stage tubular reverse osmosis system and/or if needed, a 2-stage reverse osmosis system can be used to polish the permeate stream further.

Other advantages that will result from using a tubular reverse osmosis for the treatment of this polluted wastewater stream, is the ability to reuse the filtrate/permeate stream generated from the process to replenish a part of the water usage requirement on site, save on disposal cost (both in relation to the quantity of water to be disposed of and the pollutants content of the stream) and reuse or sale the resulting concentrated product on aftermarkets.

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