

# WATER FRACTIONATION STUDIES USING CERAMIC MEMBRANE DIAFILTRATION

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## Abstract

Membrane operators around the world face fouling by organic matter in the feed water as the biggest challenge in achieving operation efficiency. To understand membrane fouling by organic matter in a better way, we need to explore into the matrix that binds water-borne organics together and their physico-chemical properties. The interaction of these so called natural organic matter with the surface and pores of polymeric membranes becomes more important in the study. Splitting the water matrix into different size fractions using ceramic membrane filtration is the technique used in this study. So the paper discusses a few important experimental trials used to study the technique in detail.

**Keywords:** Water/NOM fractionation, Diafiltration, Fouling minimization, NOM, model solutions, membrane capillaries, hybrid coagulation-UF/MF process

## I. INTRODUCTION

Studies on NOM fouling of UF/MF membrane processes, operated both in in-out and out-in modes, are based on earlier studies on water fractionation technique and experiments in a project on fouling minimisation studies using single membrane capillaries.

## II. OBJECTIVES

Objectives of this study are to find solutions to minimise the problem of NOM fouling. The focus is on studying the fouling characteristics of organic/inorganic substances present in surface waters. This can be done by characterising the more fouling-causing components in water, and then to find ways by which such components can either be removed or modified to minimise fouling. Characterising the more fouling-causing components can be done by two different ways – (1) by using single or mixture of model solutions, representing physical/chemical characters of real NOM/Humics in surface waters, (2) by starting with sample surface waters and gradually extracting the different components in steps to find out the more fouling-causing component(s).

## III. MATERIALS AND METHODS

Ceramic membranes normally have an asymmetrical structure composed of at least two, mostly three, different porosity levels. Indeed, before applying the active, microporous top layer, a mesoporous intermediate layer is often applied in order to reduce the surface roughness. The macroporous support ensures the mechanical resistance of the nanofilter.

The ceramic membranes are often formed into an asymmetric, multi-channel element. These elements are grouped together in housings, and these membrane modules can withstand high temperatures extreme acidity or alkalinity and high operating pressures, making them suitable for many applications where polymeric and other inorganic membranes cannot be used. Several membrane pore sizes are available to suit specific filtration needs covering the microfiltration, the ultrafiltration, and nanofiltration ranges (from 5 mm down to 1000 Daltons).

Ceramic membranes today run the gamut from A to Z in terms of materials (from alpha alumina to zircon). The most common membranes are made of Al, Si, Ti or Zr oxides, with Ti and Si being more stable than Al or Si oxides. In some less frequent cases, Sn or Hf are used as base elements. Each oxide has a different surface charge in solution. Other membranes can be composed of mixed oxides of two of the previous elements, or are established by some additional compounds present in minor concentration.

Ceramic membranes are operated in the cross flow filtration mode. This mode has the benefit of maintaining a high filtration rate for membrane filters compared with the direct flow filtration mode of conventional filters. Cross flow filtration is a continuous process in which the feed stream flows parallel (tangential) to the membrane filtration surface and generates two outgoing streams.

A small fraction of feed, called permeate or filtrate, separates out as purified liquid passing through the membrane. The remaining fraction of feed, called retentate or concentrate, contains particles rejected by the membrane.

The separation is driven by the pressure difference across the membrane, or the trans-membrane pressure. The parallel flow of the feed stream, combined with the boundary layer turbulence created by the cross flow velocity, continually sweeps away particles and other material that would otherwise build up on the membrane surface.

#### Element shapes

Ceramic membranes are available from several manufacturers in different shapes, mainly round and hexagonal, and with various channel diameters. A multi-channel construction provides a higher membrane packing density than a tubular element of the same length. The ceramic membrane elements have sealing gaskets attached at each end and are then assembled within housings, available in 316L SS, polyvinylidene and other alloys. A typical industrial installation will have several of these modules arranged in series and/or parallel configuration.

### IV. RESULTS AND DISCUSSION

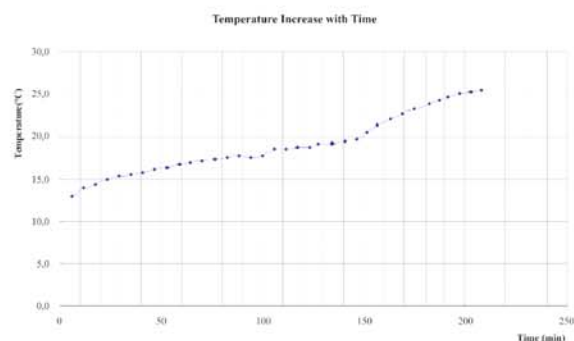
#### A. Dia-Filtration using 0.4 $\mu$ m CMM to Produce P From Rotgen water

To have a comparable result with the former experiments, the parameters are kept to be the same, as shown in Table 1 below.

**Table 1. Operating parameters of 0.4  $\mu$ m CMM**

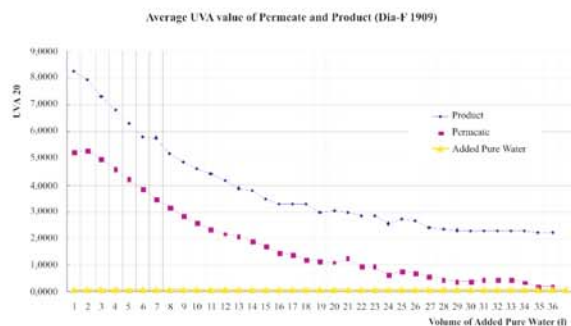
Operating Parameters:	
Flow rate of retentate:	1000 l/h
Flow rate of permeate:	~ 10 l/h
Pressure in the feed side:	1.0bar
Pressure in the retentate side:	0.85 bar
Pump output:	7
Feed Water:	Rötgen Water (P+C+D)
(10 l)	pH: 6.72
	UVA <sub>254</sub> ( $\lambda=254$ ): 9,090
Product:	(P)
(10 l)	UVA <sub>254</sub> ( $\lambda=254$ ): 2,210
Added pure water:	Deionised & carbon free
(35 l)	pH: 6.72
	UVA <sub>20</sub> ( $\lambda=254$ ): 0,067
	Interval 1 l

To keep the concentration of P to be the same level as in the feed water, 20 ml additional pure water is added besides 1 l each time to offset the volume of sample which is taken out from the feed tank. And to prevent changes in the water construction, water temperature is kept below 30 °C during experiment process. The temperature increase can be seen in Fig. 1.



**Fig. 1. Temperature Increase with Time for 0.4  $\mu$ m CMM Dia-filtration**

As shown in Fig.2, UVA<sub>254</sub> ( $\lambda=254$ ) is measured by taking samples of both permeate and product. The UVA<sub>254</sub> value is the Y-axis, and the volume of pure water added to the feed tank is the X-axis. The permeate, product and added pure water in the tank are represented in pink and dark blue and yellow curves respectively. According to our expectation, UVA<sub>254</sub> value of permeate and product decreases with volume of added pure water, the decline is steep in the beginning then becomes more and more slowly, and to a certain degree it will come to be constant, which means that there is pure (P) in the feed tank, all (C) and (D) are drained out of our system. Our experimental data shows the same tendency as expectation. After 36 litres of pure water added into the feed tank and 36 litres of permeate filtrated, the UVA<sub>254</sub> value decreases rather slowly and our experiment comes to the end because there is almost only (P) which remains in the feed tank.



**Fig. 2. Changes in UVA 20 Values with Time for 0.4  $\mu$ m CMM Dia-filtration**

**B. Dia-Filtration using 5kD CMM to produce(P+C) from Rötgen Water(P+C+D)**

A stirrer with rotation rate of 25 r/min is added into the system to get better flow conditions in the feed tank, e.g. to avoid vortex and get homogenous feed water.

To keep the concentration of P the same level as in the feed water, 20 ml additional pure water is added besides 1 litre each time to offset the volume of sample which is taken from the feed tank. And to prevent changes in the water construction, water temperature is kept below 30 °C during experiment process, seen in diagram.

**Table 2. Operating parameters of 5kD CMM**

Operation Parameters:	
Flow rate of retentate:	1000 l/h
Flow rate of permeate:	~ 6 l/h
Pressure in the feed side:	1.70 bar
Pressure in the retentate side:	1.55bar
Pump output:	9
Feed Water:	Rötgen Water (P+C+D)
(10 l)	pH: 6.44 UVA <sub>254</sub> (?= 254): 8.513
Product:	(P+C)
(10 l)	UVA <sub>254</sub> (?= 254): 5,527
Added pure water:	Deionised & carbon free
(35 l)	pH: 6.45 UVA <sub>254</sub> (?= 254): 0.160 Interval 1 l

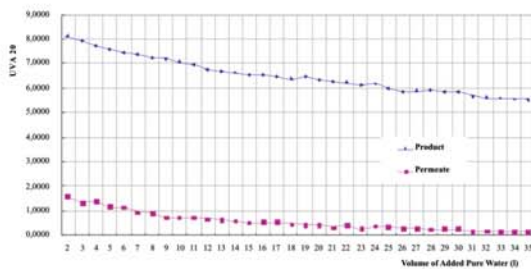


Fig. 3. Temperature Increase with Time for 5kD CMM Dia-filtration

**V. CONCLUSION**

It can be shown as in Fig.3, UVA<sub>254</sub> ( $\lambda= 254$ ) is measured by taking samples of both permeate and product. The UVA<sub>20</sub> is the Y-axis, and the volume of pure

water added to the feed tank is the X-axis. The permeate, product in the tank are represented in pink and dark blue curves respectively. According to our expectation, UVA<sub>254</sub> value of permeate and product decreases with volume of added pure water, the decline is steep in the beginning and becomes more and more slowly, and to a certain degree it will come to be constant, which means that there is pure (P+C) in the feed tank, all (D) are drained out of our system. Our experimental data shows the same tendency as expectation. After 35 litres of pure water added in to the feed tank and 35 litres of permeate filtrated, the UVA<sub>20</sub> (Fig.4) value decreases rather slowly and our experiment comes to the end because there is almost only (P+C) which remains in the feed tank.

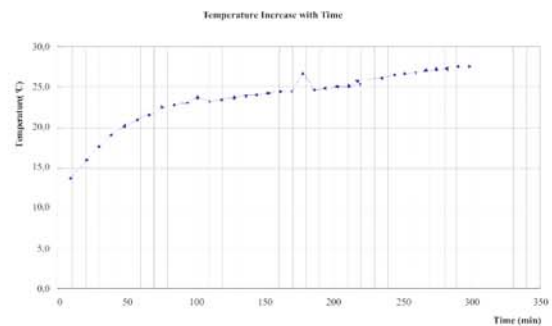


Fig. 4. Changes in UVA 20 Values with Time for 5kD CMM Dia-filtration

**REFERENCES**

- [1] Liu C, 2003, "Membrane fouling – A physicochemical perspective", AWWA Membrane Technology Conference Proceedings.
- [2] Lerch A, Hagemeyer G, Fehn J, Gimbel R, 2002, "The Influence of Coagulation and Flocculation Conditions on the Combination Flocculation/Ultrafiltration for Direct Potable water treatment of river waters", Supplementary Book of Abstracts of the International Congress on Membranes and Membrane Processes, Toulouse, France, 7-12.07.02, S.369 f.
- [3] Habarou H, Makdissy G, Croue J.P, Amy G, 2001, "Towards an understanding of NOM fouling of UF membranes", AWWA Membrane technology conference proceedings.
- [4] Hagemeyer G, Gimbel R, 1999, "Optimization of element design for nanofiltration regarding salt rejection" , in CD ROM of Abstracts and Posters, ICOM, Toronto, The North American Membrane Society, Austin.

- [5] Flemming H C, Szewzyk U, Griebe T, 2000, "Investigative Methods & Applications", Technomic Publishing Co., Lancaster.
- [6] Sundaramoorthy K, Loi-Brügger A, 2006, "Influence of organic-salt interactions on membrane (UF) fouling potential and pre-treatment by coagulation", Desalination, 200, S. 210-212.



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