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Stormwater treatment with ultrafiltration: Characterisation of backwash water

Traitement des eaux pluviales par ultrafiltration: Caractérisation des eaux de rétrolavage

Saida Kaykhaii, Inga Herrmann, Annelie Hedström, Kerstin Nordqvist, Maria Viklander

Department of Civil, Environmental and Natural Resources Engineering, Luleå
University of Technology, Campus Luleå, 971 87 Luleå, Sweden (Saida.Kaykhaii@ltu.se)

RÉSUMÉ

Les eaux de rétrolavage font partie intégrale du traitement membranaire ; elle constitue environ 2 à 10 % de la production d'eau claire, ce qui pourrait représenter un volume important à l'échelle industrielle. Les caractéristiques et la contamination des eaux de rétrolavage sont donc des paramètres importants à comprendre pour trouver une méthode de traitement ou d'élimination appropriée. Dans cette étude, les eaux de rétrolavage d'un procédé de traitement par des membranes d'ultrafiltration pour le traitement des eaux pluviales a été caractérisée. Les concentrations de matières en suspension (MES) et de carbone organique total (COT) étaient 2,4 et 24 fois plus élevées dans les eaux de rétrolavage que dans les eaux pluviales entrantes. Les concentrations de métaux particulaires et dissous ($<0,45 \mu\text{m}$) dans les eaux de rétrolavage étaient élevées. Par exemple, les concentrations moyennes de Cu et Cr totaux étaient de 742 ± 215 et $737 \pm 243 \mu\text{g/L}$. Ces concentrations étaient en moyenne un facteur de 29 ± 9 et $41 \pm 15,9$ plus élevées que celles dans l'eau pluviale brute pour Cu et Cr. Des méthodes telles que la coagulation, l'électrocoagulation et l'évaporation pourraient être utilisées pour traiter davantage l'eau de rétrolavage. La fraction résiduelle contiendrait une concentration élevée de métaux, qui seraient un déchet ou pourraient être une ressource pour la récupération des métaux à l'avenir.

ABSTRACT

Backwash water is an integral part of membrane treatment, normally making up between 2 and 10 % of the clean water production which constitutes a large volume on an industrial scale. To identify suitable treatment or disposal methods for backwash water, it is important to understand the characteristics of the backwash water and what contaminants it contains. In this study, the backwash water from an ultrafiltration membrane process for stormwater treatment was analysed. Concentrations of TSS and TOC were 2.4 and 24 times higher in the backwash water than the influent stormwater. The concentration of particulate and dissolved ($<0.45\mu\text{m}$) metals in the backwash water was high, for example, the average concentration of total Cu and Cr was 742 ± 215 and $737 \pm 243 \mu\text{g/L}$. In addition, the average concentration factors for Cu and Cr were 29 ± 9 and 41 ± 15.9 . Methods such as coagulation, electrocoagulation and evaporation could be used to further treat backwash water. The residue fraction would contain high concentrations of metals that need to be disposed or could potentially be a good resource for metal recovery in the future.

Keywords :

PES/PVP, particulate metals, TOC, dissolved metals, backwash water harvesting

1 INTRODUCTION

1.1 Backwash water management

Due to climate change, increasing water scarcity, and population growth, water resources need to be managed more sustainably. Stormwater treatment methods which enable water to be reused have therefore become more important (Daniela et al. 2019). In urban areas, stormwater flows over impervious surfaces, collecting a variety of pollutants that need to be removed, if the water is to be reused or discharged to the environment (Prudencio and Null 2018). If stormwater is to be reused as technical or potable water it needs to achieve high standards, requiring the use of efficient methods such as membrane treatment (EPA 2012; Kus et al. 2012). Ultrafiltration membranes can be used to remove turbidity and TSS from highly turbid stormwater (Ortega Sandoval et al. 2019). In order to extend the life of the membrane it must be backwashed and cleaned regularly to remove particles from the surface..

During the ultrafiltration process, regular membrane backwashing generates backwash water which contains a high concentration of stormwater contaminants (Skolubovich et al. 2017). Determining the appropriate treatment methods for this concentrate depends on the particular characteristics of backwash water. Thus, in this study, the objective was to investigate and characterise the quality of backwash water generated by ultrafiltration of stormwater, and propose possible further treatment and management of backwash water to avoid it being discharged into the mainstream, as occurs in many industries, which leads to faster clogging up of the membrane (Edzwald 2011).

2 METHODS

2.1 Experimental Setup

2.1.1 Stormwater treatment using membrane process

Stormwater was treated using an ultrafiltration PES/PVP membrane module. The stormwater used in these experiments was collected from a manhole that formed part of a stormwater sewer system in a commercial and light industrial area of Luleå, Sweden (65°37'09.8"N 22°03'23.6"E). Prior to the experiment, the collected stormwater was filtered through a 315 µm sieve to separate particles larger than the allowable particle size for the membrane. Two experiments were carried out, involving 30 s and 60 s respectively of backwash for each hour of stormwater treatment. The experiment with the 60 s backwash period lasted for 50 hours without transmembrane pressure (TMP) increase, and the experiment with 30 s of backwash lasted for 14 hours with a TMP increase of 0.3 bar. Before and between experiments, the membrane was chemically cleaned with an alkaline wash (NaOH/NaOH + NaOCl at pH=12) followed by an acid wash with HCl at pH=2.

2.1.2 Backwash water collection

During the two experiments backwash water was collected three times (at the beginning, middle and end of the experiment) to determine whether contaminant concentrations varied with time. As the volume of backwash water was small, backwash water from four consecutive backwash events was thoroughly mixed and analysed for particle size distribution, conductivity, TSS, pH, total and dissolved metals (Table 1), TOC, and chloride. Total and dissolved metal concentrations (<0.45 µm) were analyzed with ICP-SFMS according to ISO 17294-2:2016. TOC, and chloride were analysed according to DIN EN 1484(H3) and CSN EN ISO10304-1. The samples were analysed by an accredited laboratory.

3 RESULTS

The results of this experiment showed that the concentration of particulate metals was significantly higher in the backwash water than in the pre-treated feed (Table 1), indicating that backwashing removed the particulate metals from the feed side and membrane pores. The difference in dissolved concentration of metals between the pre-treated feed and the concentrated backwash water was not significant (according to a t-test). The mean concentration factors of total metals were significantly higher than the mean concentration factor of TSS (Table 1), indicating that the smallest particles were important carriers of metals, and that TSS was not a representative parameter for showing the pollutant concentration effect in backwash water. For example, the concentrations

of Cr and Cu were 41 and 29 times higher in the backwash water than the pre-treated stormwater. Hg was not measurable in the feed but was found in the backwash water at 0.35 µg/L. 93.6 L of treated feed water and 2.5 L of backwash water were produced and sampled for this experiment. The pH of the feed and backwash water were both in the range of 6.8 - 7.5.

Table 1. Mean concentrations and standard deviation (STDEV) of total metals in the feed and backwash water and mean concentration factor.

Parameters	Unit	Pre-treated feed mean ± STDEV		Backwash mean ± STDEV		Mean Concentration Factor mean ± STDEV
TSS	mg/L	205 ± 21		502 ± 168		2.4 ± 0.7
TOC	mg/L	17.5 ± 3.5		414 ± 263		24 ± 11
Cl ⁻	mg/L	4.3 ± 0.01		3.4 ± 0.8		0.8 ± 0.1
Metal		Total	Dissolved	Total	Dissolved	total metal
Al	mg/L	7.1 ± 1.6	0.016 ± 0.02	176 ± 52	0.05 ± 0.009	25 ± 4.4
As	µg/L	1.2 ± 0.23	0.1 ± 0.01	29 ± 9	0.1 ± 0.04	25 ± 6.3
Ca	mg/L	6.8 ± 2.9	2.5 ± 5.5	43 ± 13	0.8 ± 1.6	7 ± 2.8
Cd	µg/L	0.1 ± 0.04	0.01 ± 0.01	2.3 ± 0.7	0.01 ± 0.001	27 ± 5.8
Cr	µg/L	20 ± 6.6	0.1 ± 0.08	737 ± 243	1 ± 0.2	41 ± 15.9
Cu	µg/L	27.5 ± 8.2	3.5 ± 1.3	742 ± 215	3.6 ± 0.6	29 ± 9
Fe	mg/L	18 ± 3.2	0.1 ± 0.1	331 ± 99	0.007 ± 0.01	29 ± 5.9
Hg	µg/L	<0.02	<0.002	0.35 ± 0.1	<0.002	>18 ± 5.8
K	mg/L	5 ± 0.3	0.6 ± 1.2	79.6 ± 23	0.8 ± 0.8	15 ± 3.7
Mg	mg/L	4.9 ± 0.5	0.5 ± 1.1	112 ± 32	0.1 ± 0.3	23 ± 4.4
Ni	µg/L	9.6 ± 2.1	1.1 ± 0.7	275 ± 83	1.1 ± 0.1	29 ± 4.5
P	µg/L	-	17 ± 13	-	18.7 ± 1.8	-
Pb	µg/L	7.7 ± 2.7	0.04 ± 0.07	222 ± 71	0.11 ± 0.01	32 ± 13
V	µg/L	32 ± 7.4	3.9 ± 6.2	905 ± 254	1.3 ± 0.2	29 ± 5.2
Zn	mg/L	0.2 ± 0.05	0.02 ± 0.02	5.6 ± 1.6	0.02 ± 1.8	29 ± 5.47

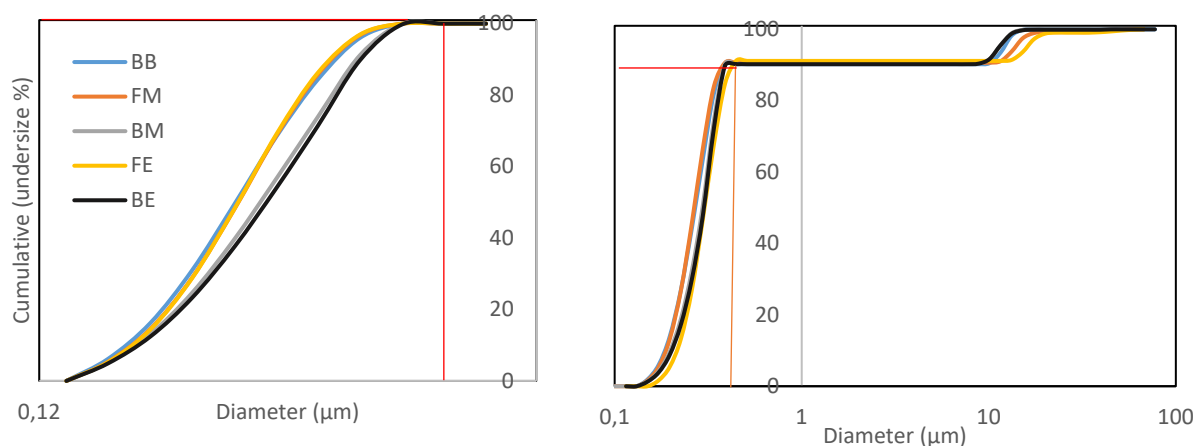


Figure 1. Cumulative particle size distribution of pre-treated feed and backwash water according to a) number and b) surface area. BB=backwash at the beginning of the experiment, FM=feed sample in the middle of the experiment, BM=backwash sample in the middle of the experiment, FE= feed sample at the end of the experiment, BE= backwash sample at the end of the experiment. Red line indicates the grain size of 0.45 µm.

The particle size distribution curves (Figure 1) show that the particles in the backwash water were very small,

mostly <0.45 µm, which is often categorized as dissolved phase material. This study shows that pollutants can be efficiently concentrated into a much smaller volume through membrane treatment. Potential treatment methods for backwash water include a combination of flocculation and aeration, which has previously been shown to reduce conductivity, total dissolved solids (TDS) (Jibhakate et al. 2017). The use of clay ceramics (Shafiquzzaman et al. 2021), coagulation followed by rapid filtration (Yari et al. 2015) or electrocoagulation, evaporation may be able to concentrate the pollutants even further.

4 CONCLUSION

In this study, the concentrated backwash water from an UF membrane used for stormwater treatment was analysed and compared to pre-treated feed water. As, Cd, Cr, Cu, Hg, Ni, Pb were significantly concentrated in backwash water. According to this study, TSS and TOC concentrations in the backwash water were rather high. Comparing the concentration factors for various metals, the TSS concentration factor was significantly lower than the factors for other pollutants, indicating that TSS was not a good indicator of pollution concentration in backwash water. The backwash water contained significant amounts of small particulate bound metals, smaller than 0.45 µm. The average concentration of total Cu and Cr was 742 ± 215 and 737 ± 243 µg/L. In addition, the average concentration factors for Cu and Cr were 29 ± 9 and 41 ± 15.9 . The concentration of dissolved metals, however, did not significantly differ between the concentrate and the feed. The application of different treatment methods for backwash water treatment is of interest for future work.

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