나노여과에 의한 휘발성 유기물질의 제거 특성

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Rejection characteristics of volatile organic compounds by nanofiltration

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1. Introduction

Nanofiltration and/or reverse osmosis membrane process is one of the promising technologies for advanced treatment of industrial, wastewater, and drinking water (Oh, 2000; Monthon, 2001). The possible target solutes of theses process are heavy metals, endocrine disruptors and so on (Oh, 1998). Most of these compounds are highly toxic and low concentrations in environment. It is very difficult to evaluate rejection of these compounds with high accuracy by NF and RO because of their low concentration and high toxicity.

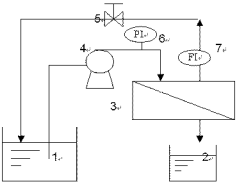
In this study, rejection characteristics of volatile organic compounds (VOC) by nanofiltration were investigated. The rejections were experimentally obtained by using nanofiltration membranes to explain mechanism of the separation. Rejection values are considered as a function of size related characteristics (calculated width).

2. Material and method

2.1 Nanofiltration

Rejection characteristics of VOCs were examined by using five types of nanofiltration membranes. Nanofiltration experiments were conducted by using a cross flow nanofiltration unit. A membrane module was a flat sheet type with an effective surface area of 60 cm^2. Properties of nanofiltration

membranes such as skin layer and nominal salt rejection are listed in Table 1. The physical properties of target solutes used are shown in Table 2. The mixed standard solution was prepared by dissolving these organic compounds in acetone. The feed solution of 50μg/L concentration applied to each membrane test experiment had 5% leachate of constituted volume. The leachate was taken from a municipal landfill site for solid waste disposal and filtered to be suspended solid free. The reason for the leachate addition was to reduce adsorption of the garget solutes. As a check on the effect of solution environment other feed solutions without leachate, with 1 % and 10 % leachate of constituted volume were also prepared. Generally samples were taken after 3 hours from the introduction of the feed solution to enable steady state conditions of permeate membrane surface were thus eliminated. For each membrane, the rejection of a compound i, R_i (%), was calculated using the expression of . Where $C_{p,\ i}$ and $C_{r,\ i}$ are the concentration for the permeate and the retentive. Rejection values were measured at low membrane pressures of 0.1 to 0.3MPa. The pH of the feed solution was neutral.



1: Feed solution, 2: Permeate solution, 3: Test cell (C10T),
4: Pump, 5: Pressure regulating valve, 6: Pressure gauge,
7: Flow meter

Figure 1. Schematic diagram of cross flow nanofiltration experimental set-up

Table 1 Properties of nanofiltration membranes

NF Membranes	Company	Skin Layer	Nominal Salts Rej.
ES10C	Nitto Denko	Polyamide	99.5%↓
LF10		Polyvinylalcohol /polyamide	99.5%↓
HTR729HF		Polyvinylalcohol /polyamide	92%↓
UTC60	Toray	Aromatic polyamide	55%↓
UTC70		Aromatic polyamide	99%↓

2.2 Chemical analysis

Gas chromatography/Mass spectrometer (GC/MS, Shimadzu Corporation GC-17A, QP5000A) was used for the analysis of the organic molecules. Before the injection into the port of GC/MS used with the selected ion monitoring (SIM) quantification, the volatile organic compounds were extracted by using the solid phase micro extraction (SPME, Spec Co. ltd.) methods. In the case of plasticizers, the extraction by dichloromethane was

carried out. Salt rejections were measured by ion-chromatograph.

Table 2 Physical properties of target solutes

VOC	Abbrev.	M.W.	Chemical Formula
1,1-Dichloroethylene	DCEY	97	$C_2H_2Cl_2$
Chloroform	Chlo	119	$CHCl_3$
1,1,1-trichloroethane	1TCE	133	$C_2H_3Cl_3$
Carbon tetrachloride	CTC	154	CCl_4
Benzene	Benz	78	C_6H_6
1,2-dichloroethane	DCEY	99	$C_2H_4Cl_2$
p-Xylene	pX	106	C_8H_{10}
Trichloroethylene	3CEY	131	C_2HCl_3
1,2-Dichloropropane	DCP	113	$C_3H_6Cl_2$
Bromodichloromethane	BDM	164	$CHBrCl_2$
cis-1,3-Dichloropropene	CDCBY	97	$C_3H_4Cl_2$
Toluene	Tol	92	C_7H_8
trans-1,3-Dichloropropene	TDCB	97	$C_3H_4Cl_2$
1,1,2-Trichloroethane	2TCE	133	$C_2H_3Cl_3$
Tetrachloroethylene	4CEY	166	C_2Cl_4
Dibromochloromethane	DBCM	208	$CHBr_2Cl$
m-Xylene	mX	106	C_8H_{10}
o-Xylene	oX	106	C_8H_{10}
Bromoform	Brom	253	$CHBr_3$
1,4-Dichlorobenzene	DCB	147	$C_6H_4Cl_2$

3. Results and Discussion

Rejection characteristics of various organic compounds such as plasticizers and VOC by low-pressure nanofiltration were investigated. Organic compounds exist as neutral solutes, which have no electrical charge. Therefore, the charge effect on the rejection of organic compounds by nanofiltration could be negligible, while the size factor of organic compounds could play a role on the transport mechanism through nanofiltration.

3.1 Molecular structure simulation

Molecular structures of VOC were investigated. Figure 2 shows the computation of the other two size parameters from molecular structure using the computer program CS ChemOffice by an energetic optimization in an iterative procedure.

3.2 Molecular structure and rejection characteristics

Rejection characteristics of VOC were compared with their structural parameters. Table 2 shows calculated molecular structure parameters such as molecular length, radius and width and the rejection of VOCs by nanofiltration membranes.

The molecular width of VOCs was under 0.3nm approximately. Each target materials have a different molecular width. Some particular solutes always showed significantly higher rejection than other of the same size range of VOCs. For example, the molecules of DCB, 4CEY, Benz and 3CEY exhibited higher rejection than other molecules within similar molecular size. Their structure was semi-flat shape with branched functional groups. Rejection of DCP and 2TCE was lower than that of other similar size of VOCs. This phenomenon could be explained by the combined effect of configuration of

structure. The structural formula of DCP and 2TCE was flat-shape, but other VOC was either semi-flat or with slightly branched-functional groups. Flat shaped compounds were observed to be more permeable than other target solutes having branched functional groups and within the same molecular size range.

4. Conclusion

Rejection characteristics of volatile organic compounds by low-pressure nanofiltration were investigated. The molecular structure of volatile organic compounds was simulated. The molecular width of VOC was under 0.3nm approximately. The molecular widths plot gave the best correlation of VOC with rejection of them. Moreover, flat and semi-flat shaped compounds were observed to be more permeable than other target solutes having branched functional groups and within the same molecular size range.

5. Reference

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