

## **The Applicability of Salt Cleaning for Control of Membrane Algal Fouling**

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**Abstract.** In this study, the possibility of salt cleaning was evaluated when algae are entered in the drinking water treatment systems with the membrane. As results of respirometer experiment, the activity of algae was the least in case that NaCl was dissolved in algae raw water. The results suggested that NaCl can decrease SMP or EPS produced by the metabolic process of microorganisms. The concentrations of NaCl applied were 20000, 40000, 60000, 80000 and 100000 mg/L respectively, and the cleaning was carried out for 30 min after 6 cycles. The cycle consists of filtration for 28 min, backwashing for 1 min and flushing for 1 min. the cleaning efficiencies were evaluated by flux recovery. After the different concentrations of NaCl cleaning, the cleaning efficiency increased as the concentrations of NaCl increase but the increasing rate of cleaning efficiency was hardly confirmed when the concentration of NaCl increased from 80000 mg/L to 100000 mg/L. Also, the effects on high pH were evaluated when the salt cleaning applied. By 40000 mg/L of NaCl, the cleaning efficiency increased but there is no increase of cleaning efficiency over that concentration. The results obtained from this study indicated that the salt cleaning can be applied and reduce amount of the harmful chemical agent for the membrane cleaning contaminated by algae

**Keywords:** Algae, membrane, respirometer, salt cleaning

### **1. Introduction**

The membrane process can perform perfect solid-liquid separation that is applied various field and also in the water industry [1], [2]. The process has several advantages such as easy operation, stable treatment quality, and relatively little installation space use. Nevertheless, the fatal weakness of the membrane is the decreases in performance due to the fouling on the surface of the membrane [3]-[5]. Especially, a frequent algal bloom that is caused by current climate changes or the other environmental conditions affects irreversible membrane fouling and causes severe problems for drinking water treatment by their metabolites products such as Extracellular Polymeric Substances (EPSs) [6]. EPSs produce and combination between algae and the divalent cation, increase the irreversible fouling on the membrane [7], [8].

To minimize this performance decreases by the membrane fouling, numerous studies have applied pretreatment or optimized membrane operation conditions. Pre-ozonation and prechlorination are generally applied to remove algae [9]-[12]. However, these methods can give stimulus resulting in cell membrane damage and the products by damage cause decrease in membrane performance [13]. The one of the best methods to remove fouling and recover the operation efficiency is chemical cleaning called Clean in place (CIP). The mechanisms of the chemical cleaning are found that the foulants are decomposed by a high concentration of the chemical and transferred by hydrodynamic flows [14]. These principles intend a more effective chemical can weaken the adsorptive power of the foulants and increase the cleaning efficiency [15], [16]. General chemical cleaning is classified to acid and alkali chemical cleaning. The acid cleaning removes

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inorganic membrane foulants and the alkali cleaning chemical like sodium hypochlorite oxidizes organic foulants. These chemical cleanings have a secondary issue of the chemical waste.

In this study, salt cleaning is researched to overcome the disadvantages of the sodium hypochlorite alkali cleaning for the organic fouling control and furthermore, the salt cleaning's possibility for the practical application is checked.

## 2. Materials and Methods

### 2.1. Artificial raw water and membrane

In this study, the membrane requires to foul with algae in the short time. The raw water contains only algae to define the influences of algae. The concentration of algae is set at the algae alarm level in Korea, 25 mg/m<sup>3</sup> of chlorophyll-a. As figure 1, the correlation between chlorophyll-a and turbidity is figured out to prepare the artificial raw water with 10±0.5 NTU of turbidity.

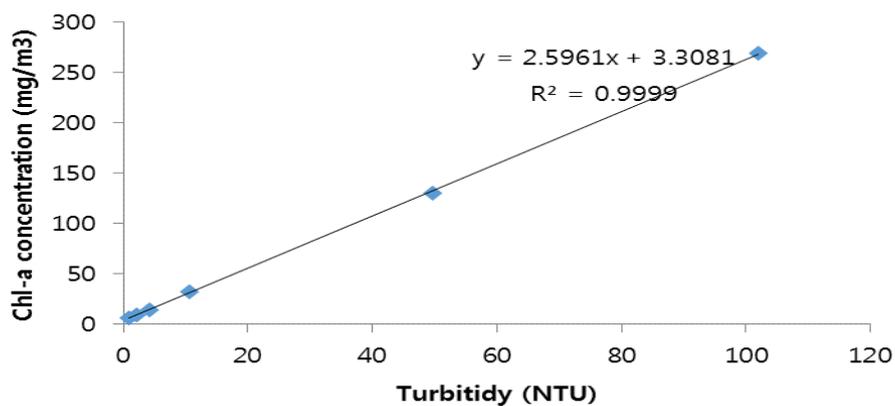


Fig. 1: Correlation between Chl-a and turbidity.

The lab-scale of pencil type of microfiltration membrane is used for the test. The material of the membrane is PVDF (polyvinylidenedifluoride) is the material of the membrane which is a product of A company. The pore size and the surface area of the membrane are 0.12 μm and 0.0057 m<sup>2</sup> each.

### 2.2. Composition of apparatus

The test system is comprised to perform direct permeation and CEB (chemical enhanced backwashing) without flocculation, coagulation and sedimentation processes. The experimental equipment includes a raw water tank, two volumetric pumps for permeation and backwashing driving, and lab scale of membrane modules. Also measuring instruments are added such as an electronic balance, pressure meters, and a recorder to check permeated flow and TMP changes (Fig.2).

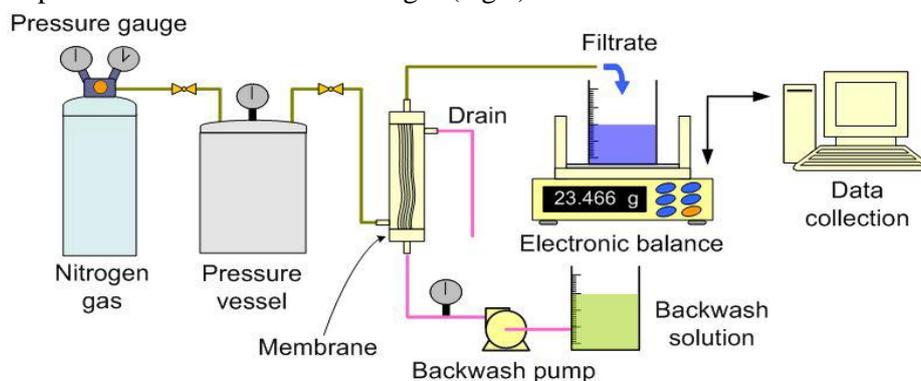


Fig. 2: Apparatus for salt cleaning.

## 3. Results and Discussion

### 3.1. Results of respirometer and production of EPS with different salts

Respirometer is a microorganisms' activity indirect measuring device that estimate partial pressure of the oxygen consumed by microorganisms in zero carbon dioxide condition. To select salt for cleaning chemical, when the different salts are injected into the raw water, the decreases of partial pressure of oxygen are monitored for 1,400 minutes. Unlike the other salts, in case of NaCl, the decrease of the oxygen partial pressure is rarely observed. It is thought that NaCl deteriorate activity of the microorganisms (Fig.3).

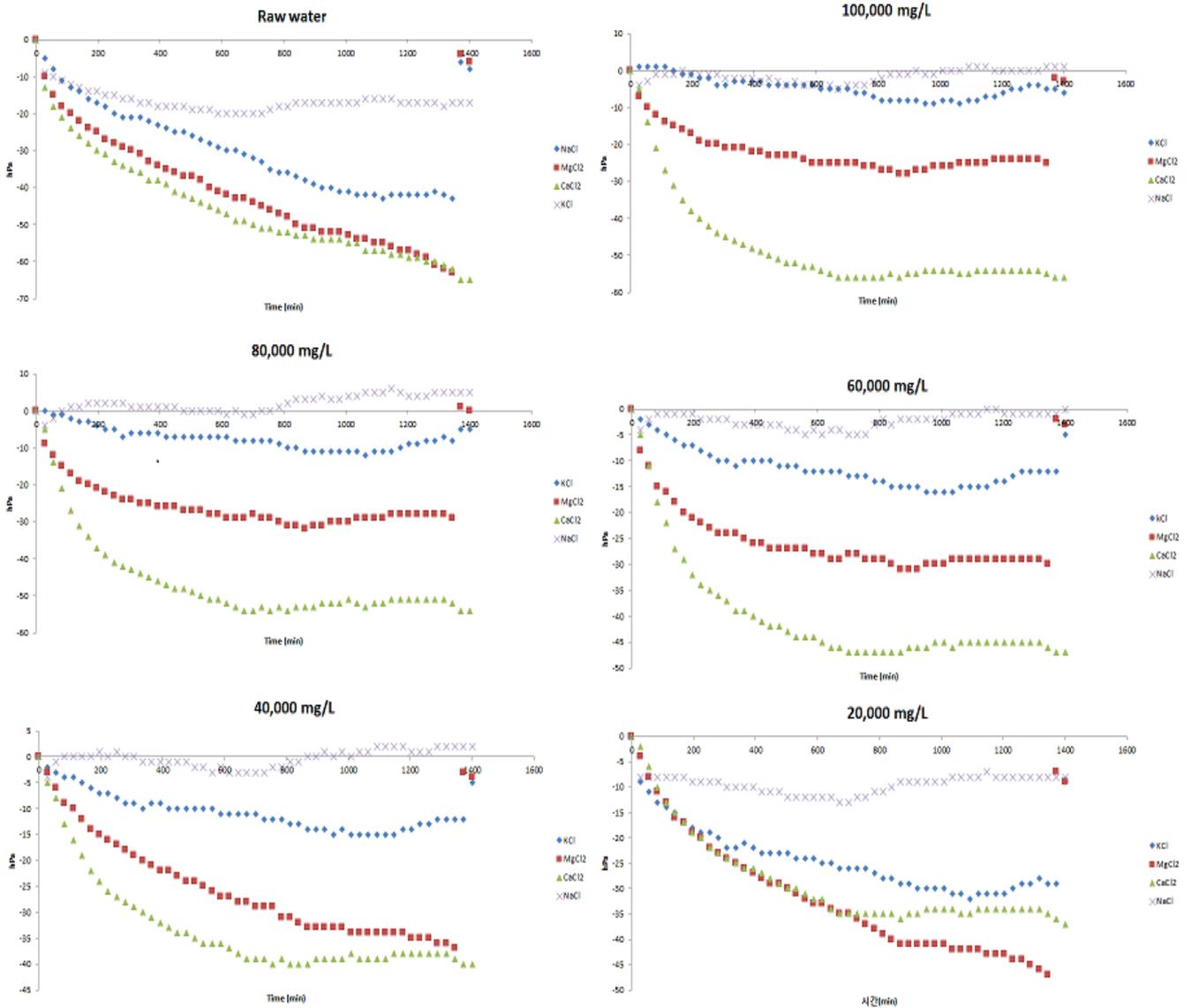


Fig. 3: Results of respirometer for optimal concentration with different salts

Extracellular Polymeric Substances (EPS) are common membrane organic foulants and produced by metabolism of the microorganisms and cell lysis [17], [18]. When an oxidizer like NaOCl is contacted microorganisms, the great plenty of EPS are emitted by cell lysis and this phenomenon effects on the membrane fouling. In the salt cleaning, the microorganism can be controlled by osmotic cell death. From the EPS changes at figure 4, when NaCl is injected initially, the EPS is produced immediately, but after 2 hours, the NaCl result shows declining trend of the EPS amount. Therefore, from the results of the tests, 80,000 ml/L of NaCl is appropriate for salt cleaning since minimization of EPS production and control the microorganisms' metabolism.

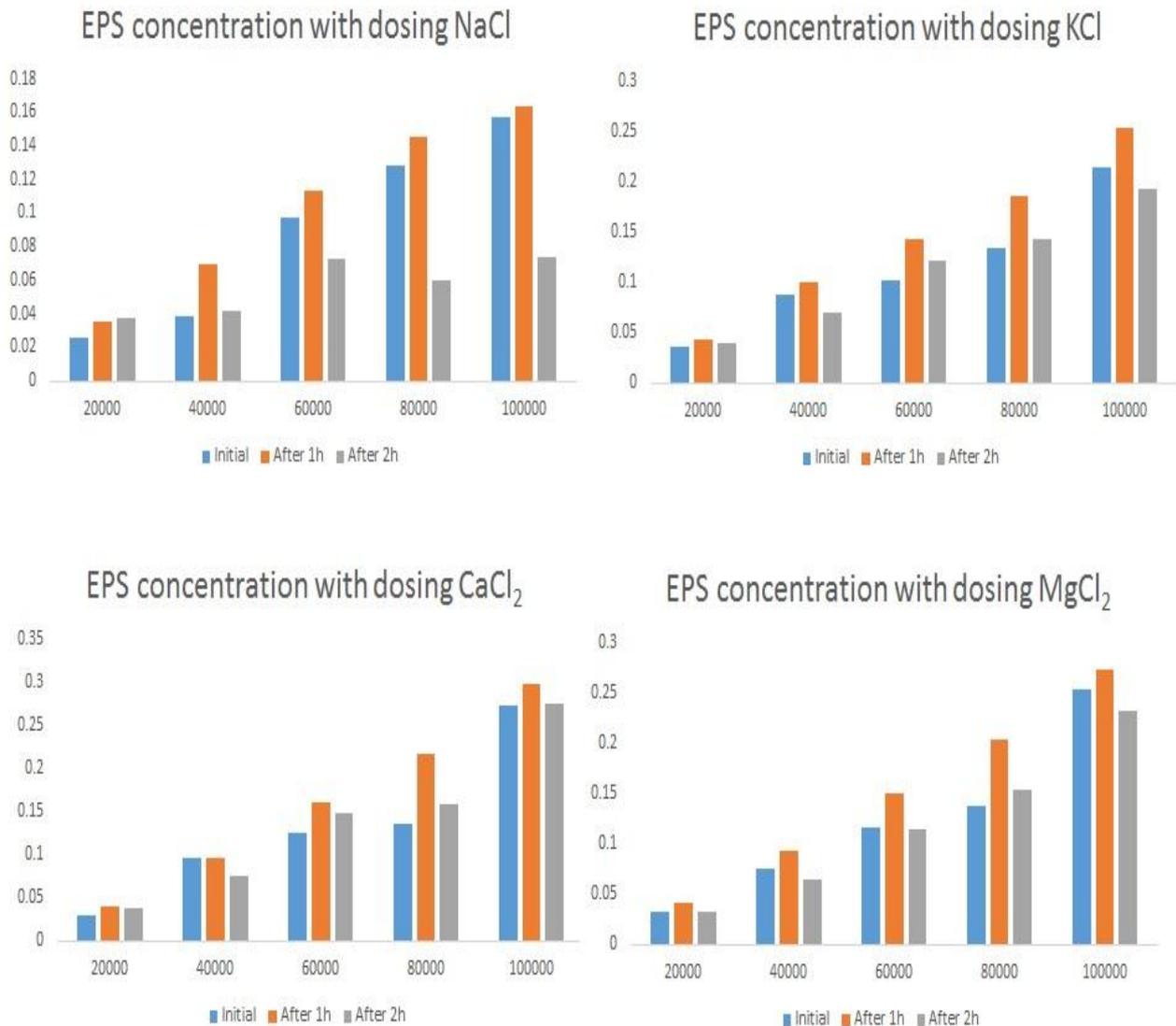


Fig. 4: EPS concentration with dosing various salts

### 3.2. The efficiency of salt cleaning

The lab-scale of membrane continuously permeates the artificial raw water for 3 hours at 0.5 bar of pressure. For 30 minute of CEB with the change of the NaCl concentrations, the performance of salt cleaning is estimated. As shown as figure 5, when the NaCl concentration increases, the quantity of permeated water escalates and the amount of water directly relates the efficiency of salt cleaning. However, over 80,000 mg/L of NaCl salt cleaning, the upward performance trend is diminished.

Principles of salt cleaning explain the efficiency of high concentration of the salt that the weakening foulants bonds and the hydrodynamic flows. The foulants bonds are not loosened over the critical concentration of the salt [18].

### 3.3. Selection of salt cleaning time

TOC concentration of the backwashing effluent with different cleaning time is measured to evaluate the removal efficiency of the algal fouling on the membrane surface. The cleaning time conditions are 10, 20, 30, 45, 60, 90 and 120 minute of salt cleaning. The TOC test results can draw an optimized salt cleaning time. As the result of TOC test of backwashing effluent, after 45 minutes of salt cleaning, TOC sharply decreases. This is thought that after 45 minutes of salt cleaning, the removal of organic matter rarely increases. Consequently, 45 minutes is selected an optimal salt cleaning time.

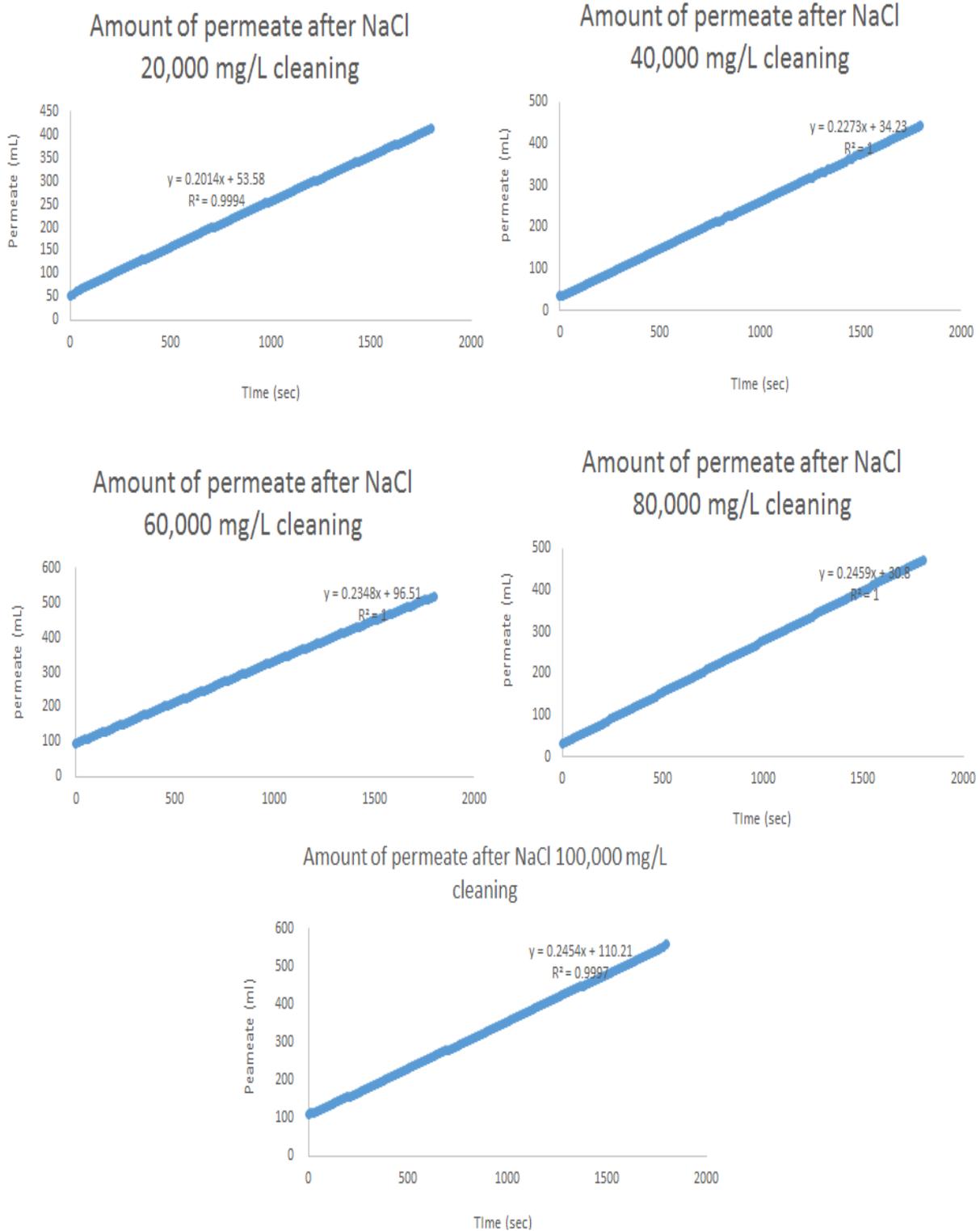


Fig. 5: Amounts of filtration after NaCl cleaning

#### 4. Conclusions

The purpose of this study understands the salt cleaning efficiency when algae foul the membrane. In the experiment of 4 salts using, NaCl shows optimal salt to be applied to salt cleaning through the results of respirometer and EPS product. From the membrane permeate test results, NaCl shows the optimal removal performance at 80,000 mg/L of concentration. The TOC results of backwashing effluent draw the cleaning time of 45 minutes. This study is limited membrane algal fouling only, however it might apply the practical study of the salt cleaning experimental data for control of algal fouling

Table 1: TOC concentration in backwashing water

NaCl(mg/L) \ Time (min)	20,000	40,000	60,000	80,000	100,000
10	2.479	2.529	2.512	2.482	2.587
20	2.32	2.305	2.221	2.355	2.415
30	2.238	2.221	2.221	2.301	2.363
45	2.201	2.181	2.192	2.251	2.021
60	1.799	2.039	2.069	1.969	1.924
90	1.691	1.921	2.033	2.013	2.01
120	1.675	1.915	2.035	2.003	2.012

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