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Pre-treatment Methods for Seawater Desalination and Industrial Wastewater Treatment : A Brief Review

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ABSTRACT

Feed water that need to be pre-treated before using methods such as, microfiltration, Ultrafiltration, nanofiltration and reverse osmosis is characterized by containing turbidity, bacterial content and total dissolved solid which causes fouling and scaling in membrane performance. Thus, it is necessary to develop a method which is cost effective. Pre-treatment has been shown as a good method to enhance the performance and reducing the cost of replacement for membrane of the RO/NF as it helps to remove turbidity, bacteria and TDS (Total dissolve solid), COD and Colour. In this paper, a brief review on the pretreatment in different industry will be clarified such as pretreatment of seawater, and wastewater treatment. Basically, methods of pretreatment can be categorized as coagulation, flocculation, sedimentation, microfiltration, ultrafiltration, ozonation and etc. Therefore, this review can provide a better alternative in solving the membrane fouling and scaling problem.

Keywords: Pre-treatment, Sea Water, Industrial Wastewater, Fouling

I. INTRODUCTION

With the growth of population, water consumption and water demand for domestic and industrial needs is constantly increasing. Fresh water is now extensively consumed around the world and people tend to reuse the fresh water from wastewater in order to protect the environment. Many methods have been applied by the researcher to produce the fresh water from wastewater such as desalination of seawater which consists of pretreatment and RO methods. Pre-treatment is the treatment of wastewater by commercial and industrial facilities to remove some pollutants before being fed to another system. The system can be as simple as chemical addition or as complex as the integration of multiple unit processes for a complete water treatment system. Normally, pre-treatment of wastewater is used to control and limit the level of certain pollutants in the wastewater. The objectives of pre-treatment are i) To enhance the quality of feed water to a system, ii) To increase the performance of membrane (reduce membrane fouling), iii) avoid interference with the operation of wastewater treatment plant, iv) Improve the opportunities for reusing and recycling of wastewater, v) Prevent the introduction of pollutants that could cause health and safety problems to the public or the environment.

Pre-treatment of feed water before reverse osmosis (RO) is a key step to increase the performance of RO membrane. Pre-treatment applies different technologies to improve the water quality by employing conventional pre-treatment technologies or membrane pretreatment technologies. Conventional pre-treatment consists of coagulation, flocculation and simple filter while membrane pre-treatment uses microfiltration or ultrafiltration which is slightly expensive than conventional pre-treatment but with a higher efficiency [1].

Nowadays, there are many types of RO being used in wastewater reclamation. However, RO/NF membranes need to be replaced frequently and it will increase the costs/expenses of a plant. Factors that affecting the productivity loss in a membrane are included scaling, particle deposition, biofouling and organic fouling [2].

The deposition of particles on the membrane or pores causes a reduction of productivity [3]. In order to solve this problem, a pretreatment method should be introduced before feed water enters RO where it helps to decrease the membrane fouling and enhance the performance of a membrane. However, it is still lacking of information that related to the pre-treatment. This review has covered the different type of pre-treatment method in industry for the wastewater treatment.

II. METHODS AND MATERIAL

2. Methods of Pretreatment

2.1. Coagulation

Coagulation is a process in which chemicals are added to water, causing a reduction of the forces tending to keep particles apart. Particles in source water are in a stable condition. The purpose of coagulation is to destabilize particles and enable them to become attached to other particles so that they may be removed in subsequent processes [4]. Along with flocculation they were designed to provide palatable water by removing different types of contaminants[5]:

Coagulation process was explained by Shammas (2005) by three different coagulation process and sequential stages [6]:

- **i.** Formation of coagulant
- **ii.** Particle destabilization
- **iii.** Inter-particle collisions

Normally, the first two steps occure in rapid-mixing tank. The inter-particle collisions is induced by slow mixing and it occures in the flocculation basin [7]. CFS process (coagulation, flocculation and sedimentation) is shown in Figure 1.

From few decades, coagulation has been successfully used to enhance the water quality both in conventional pretreatment and low pressure membrane pretretament of Seawater Reverse Osmosis. In some cases, coagulation has some additional advantages in reducing the fouling of MF/UF and enhancing performance of a plant. Nevertheless, many issues has to be considered before pretreatment can be used effectively in the water treatment membrane field, such as the proper selection of coagulant type, the optimal dosage, the overall cost and benefits of chemical pre-treatment to MF and UF systems.The common coagulants are alunimium silicates, aluminuim hydroxides, aluminium phosphates [8], ferric chloride, ferrous sulfate, lime, potassium polymer ferrate (VI), aluminum sulfate and PACI (Polyaluminium Chloride Technology). However, Kim et al. and (Kabsch-Korbutowicz M. , 2006) stated that Alum is the best coagulant to be used because of the highest solid removal efficency and it can bring considerable membrane fouling reduction [9, 10].

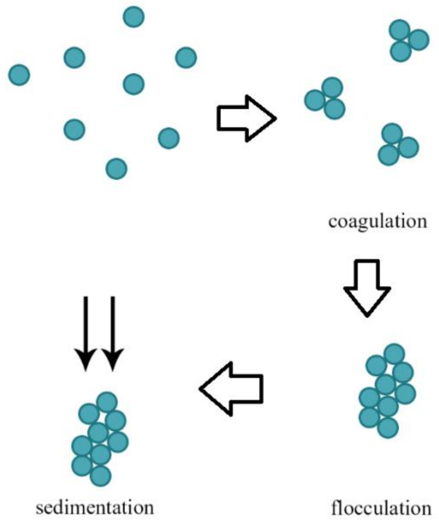

Figure 1 : Coagulation, Flocculation and Sedimentation Source

The interaction of aluminium residulas with ambient silica in RO membrane will form aluminium silicates which causes collidal forming in the system. However, PACl (Polyaluminium Chloride) can be used instead of using alum, which minimises colloidal fouling because it may decrease the alunimium-antiscalant interactions [11].

2.2. Activated Carbon

Adsorption is an effective physico-chemical treatment processes used remove heavy metals from aqueous solutions. The advantage of using adsortion is the low cost and the avalibility of different types of adsorbent specially if it is natural, needs little processing and is an industrial byproduct material [13]. One of the most common adsorbent is activated carbon, which is a form of carbon that has been treated to produce very large surface area available for adsorption or chemical reaction. Activated carbon is used in drinking water and wastewater treatment, since it can effectively remove particles and organics from water. [14].

There are two popular forms of activated carbon, powdered and granual activated carbon, PAC and GAC. PAC is used to remove organic or inorganic impurites in high level from water or wastewater due to its high surface area and high degree of microporosity. Usually PAC is the most common absorbent coupled with ultrafiltration to enhance the overall treatment process, even though reduction of the UF fouling is still controversial [15]. It was concluded by some researchers that the removal effeciency of organic matter was enhanced, and at the same time, good control of membrane fouling was acheived [16]. On the other hand, others claimed that fouling control was not improved when PAC-UF, but high removal of organic matter was acheived [17]. It can be stated that the different types of PAC with different properties and doses is responsible for this contrevirsol view [15].

Matilainen et. al. [18] reported that the granular activated carbon is most effective in removing the high molar mass (HMM) matter and intermediate molar mass (IMM) matter. However, it is really hard to remove low molar mass (LMM) matter. Thus, LLM organic fraction will increase due to the bacteria living in the filter and release of metabolites from filter bed.

2.3. Membrane technology

Membrane technology is mainly consists of microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). However, for the pretreatment purposes, MF, UF and NF membrane technologies are usually used in water treatment. MF and UF are normally used instead of using rapid sand filtration in conventional water treatment, where the removal of microbial contaminants and some particulate can be effectively achieved by MF and UF . The main differences between MF and UF are shown in table 1 [19]

Table 1. Comparison between UF and MF on the basis of various parameter [22]

Parameter	MF	UF
Membrane	Porous, isotropic	Porous, asymmetric
Pore size	50 nm–10μm	5–20 nm
Transfer mechanism	Sieving mechanism (the solutes migrate by convection)	Sieving and preferential adsorption
Type of solution treated	Solution with solid particles	Solution with collides and/or macromolecules
Permeability range	10–100 m3/(m2.bar.d)	1 m3/(m2.bar.d)
Pressure applied	1 bar	1–5 bar
pH (depending on membrane type	—	1-10

2.4. Ozonation

Ozonation is well known technology for wastewater treatment because of the effective ability O_3 to oxidize many organic contaminants in aqueous solution [20].

Ozonation has become an attractive technique for water treatment since it has some advantages such as: (1) the produced sludge does not increase; (2) It takes only one step to remove color and organic matter; (3) Can be installed easily on a site; (4) It is less harmful than other oxidative processes; (5) The end products of ozone are generally nontoxic [20-22]. However, ozonation for water and wastewater treatment requires huge amount of energy [23].

3.0 Type of Pretreatment

There are many types of pretreatment coagulation, flocculation, sedimentation, adsorption, disinfection and membrane filtration such as microfiltration, ultrafiltration and nanofiltration. However, pretreatment used in a system is dependent on the quality of feed water. Many possibility can be applied in pretreatment in order to produce the desire water quality before enter a NF/RO. For example, if the water quality is very poor that contains high turbidity, bacterial content and total dissolved solid, the system may require coagulation, flocculation and sedimentation to remove turbidity, disinfection to reduce bacterial content and combine with MF/UF to remove total dissolved solid. Thus, it aids to prevent the fouling in the NF/RO and enhance the performance of the membrane as the quality of water that being feed to NF/RO is acceptable. In most of the cases, researchers tend to optimal the conditions by applying pretreatment methods that help to prevent fouling in RO/MF as the replacement of membrane in RO/NF is expensive and high energy requirement.

3.1. Pre-treatment Method for Seawater

There are many pretreatment methods for desalination of seawater such as conventional pretreatment by using coagulation, flocculation, sedimentation and filter [1, 12, 24- 28], membrane technology by employing high rate dissolved air flotation, MF & UF ([1, 24, 25, 29-31], beach well system [24], dead-end backwahable hollow fiber ultrafiltration [32], [33], ozonation followed by microfiltration [34], nanofiltration [35] and ozonation with biological activated carbon [14]. Due to the increasing world population, it is essential to produce the potable water in good quality by using desalination of seawater [28].

3.1.1. Conventional Pretreatment of Seawater

Conventional pretreatment has been applied in many pretreatment of seawater from many decades due to its simple handling methods. It is a traditional pretreatment for RO/NF that consists of several processes such as coagulation [36], flocculation, sedimentation, filtration and disinfection. It is frequently used for pretreatment for RO to lower the silt density index (SDI) and helps to remove turbidity and suspended solids [25]. Since the separation process is gravity driven with coarse filtration, conventional pretreatment requires a bigger footprint to install the facilities in a plant. Besides, the operation needs labour to operate the system, a huge amount of chemical is required and difficult to control under variable condition. Seawater contains high degree of turbidity, bacterial contents and TDS. Thus, coagulation, flocculation and sedimentation are combined to remove the high turbidity and suspended solids of seawater while disinfection is used to prevent the biofouling with the addition of chlorine [1, 25, 27, 29, 37].

3.1.2. Membrane Technology Pretreatment of Seawater

It is noted that conventional pretreatment may be required to prevent fouling in a membrane for RO, but conventional pretreatment does not completely remove the colloids and suspended particles to a desire water quality that may reduce fouling of membrane. As a result, microfiltration, ultrafiltration and even nanofiltration are introduced as a pretreatment method. Nowadays, MF/UF has gained acceptance as pretreatment method as MF/UF can produce a desire quality of feed water that may reduce the cleaning of a MF/UF. It is because most of the pollutants such as turbidity, bacterial contents and TDS will reduced tremendously after the seawater passes through the membrane filtration. Hence, the RO membrane can be operated in a longer time such as half a year before replacement. MF and UF are attractive pretreatment techniques as they can continuously produce good quality water at low pressure levels. Thus, it means MF/UF will provide a higher reliability and better overall economics of RO seawater desalinating process as labors do not require and they are fully automated with minimum chemical used with extremely compact land to build the MF/UF [3, 27, 30]. Some of the researchers may prefer new approach such as nanofiltration (NF) as pretreatment to RO process. It is because pretreatment NF for seawater in RO processes prevents membrane fouling by removing high degree of turbidity and bacterial content, prevents scaling by reduction of scale forming hardness ions and is expected to lower the required pressure to operate RO plant by removal of TDS of feed seawater [38].

3.1.3. Ozonation of Seawater

Ozonation process can be included in the pretreatment process to break down the organic matters to simpler forms for better biodegradation. Ozonation is introduced for desalination process due to its possibility to prevent membrane fouling when combining with MF/UF. If MF/UF is used as pretreatment method alone, membrane fouling still occurred [38]. Lai et. al. [14] suggested that ozonation technique improve the biodegradability of RO brine.

3.2. Pretreatment Method for Wastewater (Industrial) Treatment

Commonly, many pretreatment methods can be applied for wastewater treatment such as conventional pretreatment by using coagulation, flocculation, sedimentation and filter, membrane technology by using MF, UF and NF, granular activated carbon, biological treatment and ozonation.

3.2.1. Biological Treatment of Wastewater (Industrial)

The COD content of some industrial wastewater is very huge, so it should be treated before dumping it to avoid its dangerous impact on the environment. For example, the concentration of organic matter in tannery wastewater is very high with a significant content of ammonium substances, salts as well as sulphur.

Sabino et. al. [39] suggested that biological treatment can be used as pretreatment followed by a physico-chemical process and membrane filtration. Approximitly 67% removal of COD was achieved by biological pre-treatment , while the removal of refractory organic compounds was obtained completly by the membrane system. Baccell et. al. [40] stated that some of the impurities found in the alkaline industrial wastewater can be degraded due to the microbial actions. However, the number of the microbial cells and their growth determine the kinetics and yields of such degradation.

3.2.2. Conventional Pretreatment of Wastewater (Industrial)

Zahrim et. al. [41] found that the effeciency of coagulation is based on the molecular structure, ionic character, molecular mass and auxiliary chemicals of dye. It is noted that some of the benefits of using polymer as flocculant include reduction of sedimentation tank size, operation in a wider pH range, better removal in the presence of chemical auxiliary. Thus, it is necessary to select the suitable type and optimum dosage of metal coagulant-polymer and the presence of metal coagulant-polymer in feed should be minimized to avoid rapid fouling [39].

According to Golob et.al. [42], applying the cationic flocculant (2.5 mL/L) with aluminium sulphate (20 mg/L) will help to remove 98% of dye concentration, reduction of TOC and COD by 50% & 40% respectively for real textile wastewater. For real textile wastewater, Suksaroj et.al. [43] reports that using ferric chloride (56 mg Fe/L) and cationic polymer (5 mg/L) can remove the turbidity and colour by 64% and 92% respectively which may help to prevent the fouling problem while Georgiou et.al. [44] showed that employing ferrous sulphate (400 mg/L) with lime (800 mg/L) and cationic polymer (8mg/L) will aid to remove 80-90% of colour and removal of COD by 50-55%. Besides, Lin and Chen [45] showed that if using polyaluminium chloride(PAC) and electrochemical treatment, it is possible to remove 97% of colour and 73% of COD for dyeing and finishing mill. In print dyeing wastewater, Capar et.al. [46] suggested that applying the optimum dose of chemical percipitation with alum dose 150mg/L can achieve the removal of colour and turbidity more than 90%. Thus, it is economically feasible if this pretreatment is combined with nanofiltration as it successfully treated the print dyeing wastewaters of carpet manufacturing industry for the purpose of reuse. But, it is noted that in the refinery plant, Schneider et. al. [47] repoted that conventional pretreatment is not suitable as there are occured the severe biofouling problems due to the failure of pretreatment in reducing the cell numbers and organic carbon at higher feed temperature during opration.

3.2.3 Granular Activated Carbon (GAC) Pretreatment of Wastewater (Industrial)

The reuse of treated effluents for industries that required high consumption of water such as dying, paper and petrochemical is very important, since it can minimize the consumption of fresh water and reduce the amount of hazardous pollutants discharged into surface water [47]. Benito-Alcázar et. al. [1] reports that granular activated carbon (GAC) as pretreatment method before to be fed into RO process aids to reduce the turbidity, COD and TOC. However, GAC filtrate is not suitable to be fed into RO process as it may cause fouling to the RO membranes.

3.2.4. Membrane Technology Pretreatment of Wastewater (Industrial)

Kang and Choo [48] reports that MF/UF was used to treat the glass industry wastewater for reuse in the manufacturing process. It showed that MF/UF is a feasible equipment for treating glass industry wastewater as nearly all the particle like fine clay and glass particle will be removed by using membrane having pore size of less than 0.45 µm.

3.2.5. Ozonation Pretreatment of Wastewater (Industrial)

Ozonation is a powerful oxidizing process in which organic compounds reacts either directly or via radicals form. Bes-Pia et.al. [49] uses the ozonation as a pretreatment stage to NF with biologically treated textile wastewater. COD removal of 43% have been achieved if biologically treated textile wastewater is treated by the low ozone doses at 60 min using 3 ozone generators of 4 g O_3/h.

3.3. Pretreatment Method for Municipal/Ground Wastewater

Commonly, many pretreatment methods can be applied for municipal wastewater such as conventional pretreatment by using coagulation, flocculation, sedimentation and filter, membrane technology by using MF, UF and NF, granular activated carbon, biological treatment and ozonation.

3.3.1. Conventional Pretreatment of Municipal/Ground Wastewater

The most common method that is used for pretreatment is conventional method. Lopez-Ramirez et.al. [12] suggested that under the optimum conditions (pH-10.5,

$FeCl_3$=25 mg/L, anionic flocculent=0.5 mg/L, sodium hypochlorite=8 mg/L) can give an average conductivity of 66 µS/cm and low COD(4 mg O_2/L) which may prevent the fouling and biofouling of a RO membranes used while Dialynas et.al. [50] found that employing coagulation with alum and $FeCl_3$ removed dissolved organic carbon (DOC) up to 42% and 52% respectively.

3.3.2. Membrane Technology Pretreatment of Municipal/Ground Wastewater

Kruithof et.al. [51] reported that by applying nanofiltration in surface water treatment can reduce the indicator organisms E.Coli and spores of sulphite reducing Clostridia to under detection limit. Abdel-Jawad et.al. [52] found that using the following pretreatment facilities such as coagulation (Fe III dosage), flocculation tank, sedimentation tank, static mixture, two dual media sand and anthracite filters and combined with RO (to remove all the bacteria and viruses) can produce the fresh water for non-potable uses at reasonable cost.

III. CONCLUSION

At present, the pretreatment is in most cases the preferred technique for sea and wastewater treatment before going to UF and Nanofiltration because of its lower investment cost. Various type of Pre-treatment has been studied. Conventional pre-treatment consists of coagulation, flocculation and simple filter while membrane pre-treatment uses microfiltration or ultrafiltration which is slightly expensive than conventional pre-treatment which enhance the performance of membrane by removing turbidity, bacteria and TDS (Total dissolve solid), COD and Colour. Fresh water treatment practices from sea and wastewater should encourage for complete assessment of environmental impact.

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