Desalination xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

Low pressure SWRO membrane for desalination in the Mega-ton Water System

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HIGHLIGHTS

- Low pressure SWRO for energy saving was studied in the Mega-ton Water System project.
- TEM analysis revealed a relationship between membrane morphology and performance.
- New SWRO membrane was obtained by the precisely controlled polycondensation technique.
- The developed SWRO membrane showed an excellent performance at 4.5 MPa feed pressure.

ARTICLE INFO

Article history:
Received 17 October 2014
Received in revised form 16 February 2015
Accepted 20 February 2015
Available online xxxx

Keywords:
Seawater desalination
Reverse osmosis
Energy saving
Environmental friendly
Morphology

ABSTRACT

Reverse osmosis (RO) technology has been widely applied to water treatment such as seawater desalination, and lots of large plants with RO are in operation in the world. However, global water problems are still getting more serious, and much larger plants will be required to secure sufficient water resource in the near future. Mega-ton Water System project was carried out with the aim of developing key 21st century water treatment technologies for sustainable management of water environment and for low-carbon path. Low pressure RO membrane for seawater desalination has been studied in the project as a part of the core technologies to realize mega plant which is capable of producing 1,000,000 m^3 of freshwater per day. Fundamental and scientific research for RO membranes based on fine structure analyses by means of transmission electron microscopy with a special technique for sample preparation was conducted, and practical tools for designing new innovative RO membrane were acquired by the structure analyses to quantify the physicochemical and chemical properties of RO membranes. As the result of studying on structural design of RO membrane, low pressure SWRO membrane which enables to reduce energy consumption compared to conventional ones in the past of SWRO was obtained.

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1. Introduction

Although water is taken for granted, it is our most precious finite resource and is confronted with a critical situation today. Human race has been consuming huge amount of water resources and polluting water sources from the Industrial Revolution onward. While world population tripled in the 20th century, global water consumption has risen almost six-fold [1]. Nowadays, a lot of countries and regions are under water stress or water scarcity, especially in Middle East, North Africa, South Asia and China [2,3]. Furthermore, water withdrawals is projected to increase by some 44% by 2050 due to growing demands from manufacturing, thermal power generation, agriculture and domestic use [4]. Regarding water pollution, an estimated 90% of all wastewater in developing countries is discharged untreated directly into rivers, lakes or the oceans [5], and there are more than 700 million people relying on unsafe drinking water sources in the world [6,7]. Therefore, water issue is one of the most serious worldwide problems as well as global warming. Water treatment technologies for securing sufficient and safe water sources are strongly required.

Membrane technology for water treatment is regarded as indispensable in this century for it can provide high-grade and sustainable water supply. Especially, RO membranes have been widely applied in desalination field to not only seawater desalination but also brackish water desalination including industrial and sewage wastewater reclamation, and the market of RO membranes has been rapidly growing. Energy saving and improvement of water quality have always been two major subjects in seawater reverse osmosis (SWRO) desalination. At the point of energy saving, the average energy consumption in SWRO plants has been reduced to one fifth for these 40 years and current energy consumption in total desalination process and RO pass are respectively

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http://dx.doi.org/10.1016/j.desal.2015.02.037
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Please cite this article as: M. Kurihara, et al., Low pressure SWRO membrane for desalination in the Mega-ton Water System, Desalination (2015), http://dx.doi.org/10.1016/j.desal.2015.02.037

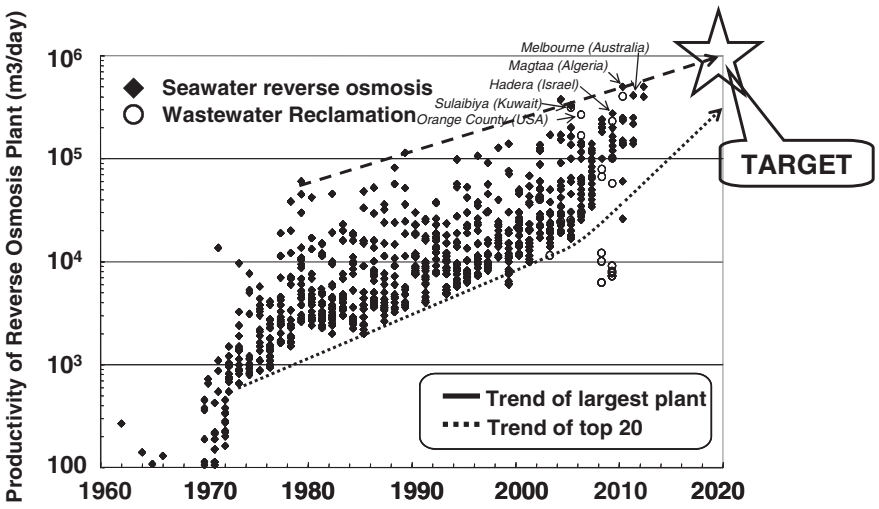

Fig. 1. Change in size of SWRO plant and WW reclamation RO plant.

4 kWh/m^3 and 2–3 kWh/m^3 [8–10]. However, innovative advancement of RO membrane technology for further energy saving is continuously required in order to satisfy the growing water demand.

2. Mega-ton Water System project

2.1. Target of Mega-ton Water System

As stated above, RO technology is widely used all over the world to secure sustainable water source and to solve the water issues. It is interesting to note that the size of water treatment plants with RO technology shows a trend. Fig. 1 shows the productivity of top 20 RO plants constructed in each year. According to the advancement of technologies, plant scale has been getting larger for several decades, and huge water treatment plants capable of producing more than 100,000 m^3 of freshwater per day (equivalent to the daily supply for around 400,000 people) have been built after the 2000s. However, water problems continue to worsen and even larger plants with producing capacity of 1,000,000 m^3/day will be required in the foreseeable future.

This has led to urgent needs of developing innovative water treatment systems which address the problems caused by the construction of mega plants (1,000,000 m^3/day plant), such as massive energy consumption and environmental destruction. Compared to small plants, it is possible to design an optimum layout through effective accumulation of components in the mega plants. This layout can decrease total foot print of the plants, increase energy efficiency and decrease environmental impact. Therefore, technological developments for mega plants were required. "Mega-ton Water System" project, which was a cutting-edge research and development project in Japan, was carried out to develop 21st century key technologies on water treatment for sustainable management of water environment and for low-carbon path [11–14]. The project aimed at developing innovative water treatment technologies and proposing "Mega-ton Water System" which is necessary for realizing mega plants. Mega-ton Water System consists of various innovative technologies, bacteria friendly RO system, low-pressure multi-stage RO system, low pressure SWRO membrane, highly efficient energy recovery device, high pressure resin pipes, etc. This study focused in the ultimate improvement of current SWRO membrane performance as one of the core technologies used in the Mega-ton Water System. The goal of the RO membrane study was the development of the world's top class low pressure SWRO membrane. Although conventional SWRO needs a high operation pressure around 56–70 kgf/cm^2, we aimed to reduce operation pressure by 10 kgf/cm^2 for energy saving in seawater desalination.

2.2. FIRST program

The fund for this study was provided from the Japanese Prime Minister's Cabinet by an advanced research assistance program which was called FIRST (Funding Program for World-Leading Innovative R&D on Science and Technology) [9,15]. The FIRST Program was an advanced funding program that covers research in various fields and provides multi-stage support from basic research aimed at generating new knowledge to R&D on themes having short-term application. The goal of the program was to advance the kind of cutting-edge research and to develop world-leading technologies within an R&D period of approximately 5 years for contributing to society and people's welfare through the application of its results in the near future. The Council for Science

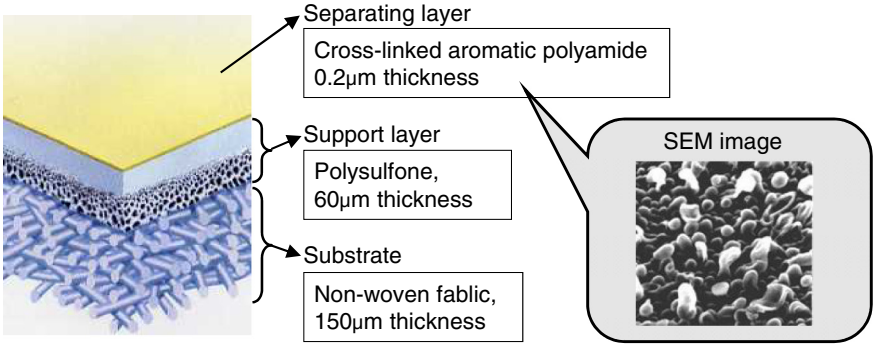

Fig. 2. Structure of polyamide composite RO membrane.

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