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SeaHERO core technology and its research scope for a seawater reverse osmosis desalination system

Minkyu Park[a], Yun Seok Lee[a], Young Geun Lee[a], Joon Ha Kim[a,b,c*]

[a]*Department of Environmental Science and Engineering, Gwangju Institute of Science and Technology (GIST), Gwangju, 500-712, Korea*
[b]*Center for Seawater Desalination Plant, GIST, Gwangju, 500-712, Korea*
[c]*Sustainable Water Resource Technology Center, GIST, Gwangju, 500-712, Korea*
Tel. +82 (62) 970-3277; Fax +82 (62) 970-2434; email: joonkim@gist.ac.kr

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ABSTRACT

Seawater reverse osmosis (SWRO) desalination is considered one of the most promising technologies for supplying freshwater to the regions suffering from water scarcity. Although a considerable amount of research has been conducted in attempts to improve SWRO desalination technology, reducing the cost of producing freshwater is still required. In Korea, this effort is already been being carried out by the Seawater Engineering & Architecture of High Efficiency Reverse Osmosis (SeaHERO) project. Core Technology 2 (CT2), one of the most important sub-projects out of four CTs under SeaHERO, pursues two main goals: optimization of processes for low energy consumption/high efficiency and localization of core parts/equipments of the SWRO plant. Four unit technologies (UTs) are then incorporated into CT2 and each UT has its own technical target; UT1 focuses on the development of SWRO desalination system integration and optimization technology in terms of energy saving; UT2 and 3 work to develop high performance RO membranes and 16-inch modules with polyamide-type materials and novel (i.e., non-polyamide) materials, respectively; UT4 works to develop a high-pressure/massive-capacity pump and hydrostatic energy recovery device for a high efficiency SWRO plant. Accordingly, the integration of the four UTs of CT2 in the SeaHERO project is expected to contribute to reducing the cost and energy consumption in producing freshwater from seawater using the SWRO process.

Keywords: SeaHERO; Core Technology 2; Process optimization; Membrane; Pump; Energy recovery

1. Introduction

Desalination is a water manufacturing process that has been proposed as a means of converting seawater into freshwater. Since the desalination process utilizes seawater as its source, not only it is capable of stably securing a primary water resource, but the time required to construct a desalination plant is relatively short compared to other water supply processes such as dams. In addition, desalination has become increasingly competitive in terms of total cost since its production cost has gradually decreased due to improved operation and maintenance. In particular, the seawater reverse osmosis (SWRO) process is the most promising desalination technique due to its relatively low production cost, compared to distillation desalination processes [1]. However, in order

* Corresponding author.

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to maximize such advantages, a number of technologies in civil, construction, environmental, mechanical, and chemical engineering should be integrated. In Korea, this integration is in progress in the Seawater Engineering & Architecture of High Efficiency Reverse Osmosis (SeaHERO) project, one of the largest R&D programs in the water industry worldwide. The Korean Ministry of Land, Transport and Maritime Affairs launched this project by supporting a total research fund of over KRW 150 billion (roughly over US $130 million) for a 5-year period that started in 2007 [2].

Technical targets of the SeaHERO project can be summarized as 3L, i.e., large scale, low energy, and low fouling [3]. It is expected that a large-scale plant, a unit train having an 8 MIGD (= 36,000 m^3/d) production rate will be built at the end of the project. In order to maximize energy savings, a reduction in the total energy consumption to below 4 kWh/m^3 is targeted, to be achieved by optimizing the operating and maintenance (O&M) cost of unit operations such as intake, pretreatment, SWRO membrane module, and other processes. Furthermore, to increase the reliability of the SWRO process, this project plans to reduce the effects of membrane fouling/scaling by 50%.

To achieve these 3Ls, four core technologies (CTs) play a crucial role in the project, each focusing on a specific area of study. For instance, the aim of CT1 is to develop future infrastructure technology for the seawater desalination plant. CT2 focuses on localization of the SWRO processes and development of optimized processes to ensure low energy consumption and high SWRO efficiency; CT3 works on the scale-up technologies. Lastly, CT4 concentrates efforts on the development of innovative O&M technology for large-scale SWRO plants. Eventually, the SeaHERO project intends to construct a 10 MIGD (= 45,000 m^3/d) SWRO testbed, which includes the 8 MIGD unit train, through the integration of the four CTs. In this paper, how CT2 contributes to the realization of the SeaHERO project goals is introduced. Note that further details of the SeaHERO project can be found elsewhere [3,4].

2. Core Technology 2

The objective of CT2 is to develop competitive products for the SWRO plant in the world market based on process optimization and the localization of core parts/equipment such as membranes, modules, vessels, high-pressure pumps, and energy recovery devices (ERDs). CT2 also has a unique technical strategy, which consists of optimization, localization, and practical applications. In order to successfully perform the project, a number of academies, institutes, and participating companies have taken part in CT2. Fig. 1 shows the cooperative network of the participants in CT2 and their participation in effectively executing this project.

2.1. Process optimization: UT1

Although desalination technology has been tremendously improved and the cost of raw materials has also been relatively competitive in comparison with the past, the production cost of water has not followed this trend due to high energy costs and consumption. This finding implies that the optimization of these processes and O&M are important factors in reducing the production costs. To optimize these processes, the scope of UT1 covers a range from microscopic view studies such as physicochemical phenomena occurring in the membranes and modules to macroscopic view studies that include full-scale plant operation. These infinitesimal-scale studies on phenomena such as concentration polarization, membrane fouling, and the impact of spacers on membranes are then used to predict large-scale plant performance and make the simulations of plant operation more precise.

Eventually, a dynamic process simulator needs to be developed to simulate the overall processes of the entire SWRO plant. To this end, a commercially available version of this simulator consists of three modules: a membrane performance simulator (MPS), a process performance simulator (PPS), and an operation performance simulator (OPS). For MPS development, generalized models that reflect the characteristics of various membranes are being developed prior to selecting commercial membranes as input variables in the final version of the simulator. In order for PPS to simulate various combinations of this process, a study of the integrated process model, involving reverse osmosis (RO), RO network, fouling, and a cost/energy estimation model, is currently underway. Finally, OPS will provide a convenient interface for operators to control the process and to assist the decision-making during this cost-effective O&M.

2.2. 16-inch high-efficiency membrane/module system: UT2

The aim of UT2 is to develop a 16-inch high-efficiency membrane/module system, characterized by pressure resistance and anti-fouling/scaling, as a high functional SWRO membrane that is mainly synthesized using a polyamide-type (PA) material. In general, manufacturing SWRO membranes entails sequential procedures such as casting, coating, and producing a spiral wound module, as standardized in the market. Woongjin Chemical Inc., in charge of UT2, has already stabilized the PA 8-inch SWRO membrane/module system. In the case of the 16-inch membrane/module, several leading companies (i.e., DOW Filmtec and Toray) in the desalination field are releasing the high capacity 16-inch PA membrane/module as a standard; Woongjin Chemical Inc. also succeeded to develop 16-inch membrane/module and is collaborating with professional engineering companies overseas to test the developed membranes/modules.

The focus of UT2 is to develop membranes having more than a 92% boron rejection rate under conditions of 5 ppm boron feed, 800 psig, and pH 8. To satisfy

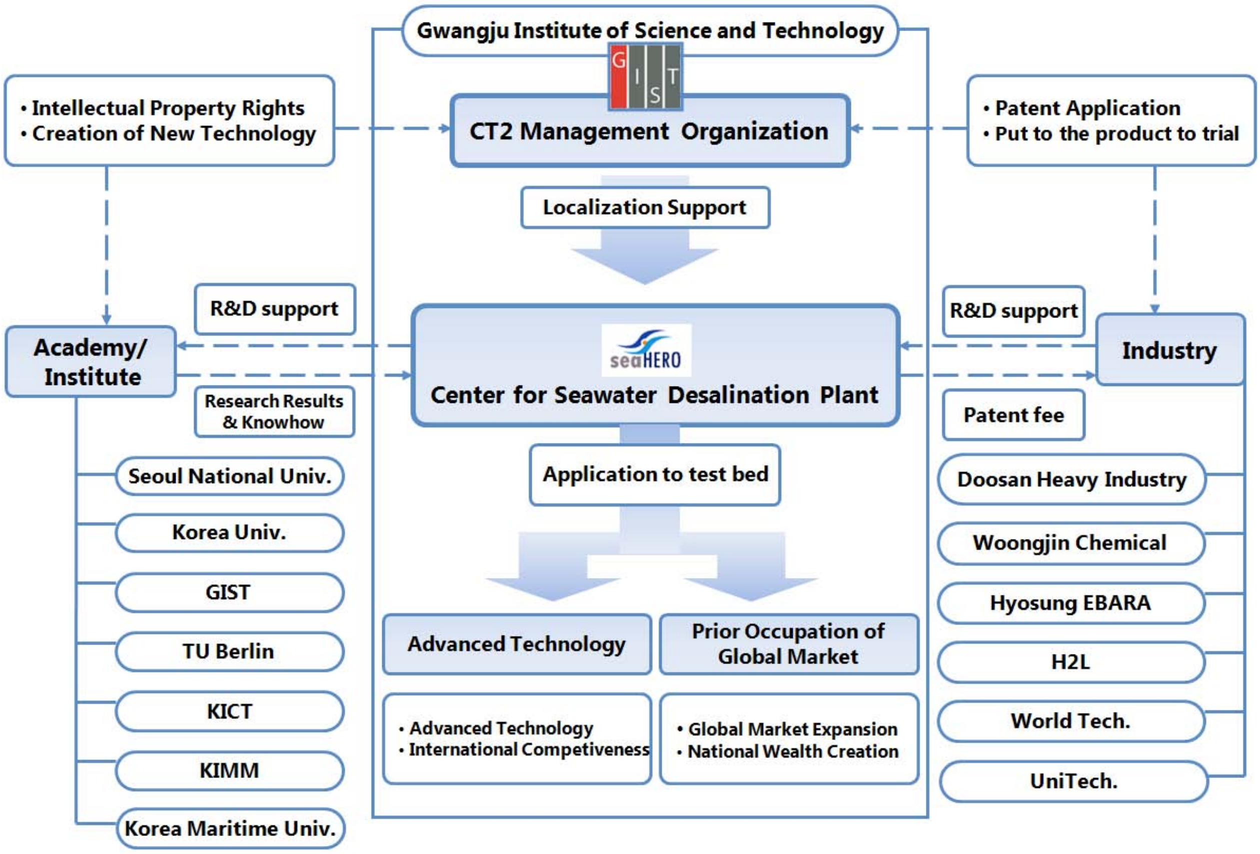

Fig. 1. Cooperation network for SEAHERO Core Technology 2.

the targeted removal rate, surface modification is now being studied, in which a poly(ethylene glycol) (PEG) comb-polymer having both hydrophobicity and hydrophilicity is coated on the membrane surface. In addition, research on ion exchange resin for boron removal is also progressing.

2.3. *Novel material reverse osmosis membrane and spiral wound module: UT3*

Development of new SWRO material membrane and a spiral wound type module with high durability and chemical resistance is the goal of UT3. Currently, aromatic polyamides (AP) are widely used for membrane synthesis since AP membranes have better performance in the separation of non-ionized organic membranes and also have wider pH and operating temperature ranges than cellulose acetate (CA) membranes [5]. The SWRO membrane should satisfy fundamental requirements, including high permeate rate, high salt rejection, and low performance drop during chemical reactions such as hydrolysis and oxidation. Inspite of AP membranes having better performance than CA membranes, they have a limited permeate flux owing to the low surface porosity of the active layer in the membrane; membrane degradation (i.e., decline of permeate flow rate and rejection rate) by fouling is also inevitable. In UT3, efforts to replace existing SWRO membrane materials (i.e., PA) with novel polymers such as sulfonated poly(aryl ether) (sPAE), poly(ether sulfone) (PES), and tetraphenylmethane (TPM) are in progress, in attempts to enhance the durability and chemical resistance and improve the permeate flow rate of membrane. The two main approaches used in UT3 are the cross-linking and layer-by-layer (LbL) self-assembly methods. In the of polymer membrane, the cross-linking method is an efficient way of increasing the long-term durability of the membrane [6]. The LbL method, which uses the electrostatic force of a polyelectrolyte (PE), is a technique used in the preparation of multilayered thin films, which eventually alleviate the long-term durability decline [7].

2.4. *High-pressure pump and energy recovery device: UT4*

Finally, UT4 has two aims, the development and localization of high-pressure/massive-capacity pumps and ERDs. To this end, Hyosung Ebara Co., LTD. is taking part in the project to develop an 8 MIGD high-pressure pump. Since prototyping all possible designs is economically inefficient, more than 100 designs under consideration are being numerically simulated and optimized by response surface methodology (RSM). Furthermore, since SWRO high-pressure pumps are continuously exposed to salty water, corrosion is unavoidable; for a stable SWRO process, a pump with greater than 7-year durability against corrosion is required. Therefore, impellers, axes, and casings should all be made of duplex stainless steel and other non-corroding non-metal materials. However, rotating parts such as rings, sleeves, and bushings, however, cannot be made those materials due to abrasion; accordingly, laser shot peening of duplex stainless steel is applied to increase abrasion resistance, which eventually alleviates damage due to friction between identical metals.

The other aim of UT4 is to develop ERDs such as centrifugal and isobaric devices. Isobaric ERDs provide a maximum operating efficiency of approximately 97%, whereas centrifugal ERDs have a maximum 82% net efficiency [8]. In this project, isobaric ERDs are selected for further development since they have higher potential efficiency than centrifugal ERDs.

3. Conclusions

This paper summarized the detailed tasks of Core Technology (CT) 2 of SeaHERO project. CT2 consists of four unit technologies (UTs) in the pursuit of two main goals: the optimization of processes to achieve low energy consumption/high efficiency and the localization of core parts/equipments in the SWRO plant. It also proposes the integration of a number of desalination technologies to sustainably supply freshwater using the SWRO desalination process at an inexpensive cost. Accordingly, CT2 research will contribute to the success of the SeaHERO project by focusing on the 3L technical targets (i.e., large scale, low energy, and low fouling); consequently reducing the number of people struggling for inadequate access to freshwater, and eventually improving the welfare of humanity.

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