Suan Sunandha Science and Technology Journal

Evaluating a Small-scale Membrane Technology for Removing Salinity in Village Water Supply at Dan Kuntot, Nakhon Ratchasima

Saranbhak Chuersuwan[1*], Hathairath Techapanyarak[1], Nirat Phutadmark[2]

[1]Science Major, English Program, Samsen Wittayalai School, Rama VI Road, Phayathai, Bangkok 10400, Thailand
[2]Research, Development, and Hydrology, Department of Water Resources, 180/3, Rama VI Road, Phayathai, Bangkok 10400, Thailand
***Corresponding author e-mail: saranbhak@gmail.com**

Received: *23 March 2024* / **Revised:** *25 May 2024* / **Accepted:** *25 December 2024*

Abstract
This study evaluates the use of a solar-powered membrane separation device to remove salinity from a village water supply in Dan Kuntot District. Water quality from surface water, freshwater, and tap water were tested for pH, temperature, turbidity, salinity, conductivity, and total dissolved solids (TDS). The results showed that surface water had high levels of salinity (1.6-2.1 ppt), conductivity (3495-3982 µS/cm), and TDS (2097-2351 mg/L). The surface water had a pH in the range of 5.7 to 6.2, temperatures of 27.6 to 29.3 Celsius, and turbidity of 6.8 to 10.1 NTU. The freshwater from the village water supply had a comparable pH (5.5-6.9). Turbidity levels were low (0.25-0.27 NTU). Conductivity and TDS levels were a bit lower to 3342-3415 µS/cm and 2005-2049 mg/L, respectively. Salinity levels remained high, 1.6 ppt. The village water treatment process cannot remove salt molecules. The tap water had an undetected salinity level after the freshwater passed through the membrane device. Conductivity and TDS were much lower, ranging from 14 to 19 µS/cm and 9 to 12 mg/L, respectively. The solar-powered small membrane separation could remove salinity as high as 2.1 ppt down to undetected level. The device could separate salt molecules using membrane technology, significantly reducing salinity levels in the tap water. Conductivity and TDS levels were also considerably lower in the tap water, with more than a 99 percent reduction. However, the produced water had low pH levels. Adding alkalinity would bring the pH close to neutral.

Keywords: Water quality, Salinity removal, Membrane separation, Nakhon Ratchasima, Water treatment

1. Introduction

Nakhon Ratchasima, located in northeastern Thailand, has a semi-arid climate (Thai Meteorological Department, 2023) with less precipitation compared to the other regions in the country. The annual average rainfall was about 1,112 millimeters and had 116 rainy days. This area is known for low productivity due to soil and climate conditions (Department of Mineral Resources, 2015). About 31 percent of soil in the province is classified as saline soil (Department of Land Development, 2023). A large area of saline soil is in Dan Kuntot District (Paosaku, 2016; Phoemphon & Terakulsatit, 2023). Widespread saline soil causes significant challenges for accessing clean and safe water in the area. These salinized lands involve various factors, including natural geological formations, weathering processes, and human activities such as salt mining, irrigation practices (Doula & Sarris, 2016). The presence of excess salts in the soil disrupts its physical and chemical properties, hindering water infiltration, reducing nutrient availability, and impacting agricultural yields, and people livelihood.

Water scarcity is a big problem in the area. Villages rely mostly on surface water for consumption and agriculture. However, surface water quality is affected by saline soil. Most villages use a traditional water treatment plant with sand filtration to remove turbidity and provide freshwater. During dry season, the freshwater had high salinity because the water treatment plant cannot remove salt molecules in the surface water. As a result, freshwater is not suitable for consumption.

In 2022, the Department of Water Resources installed a small-scale membrane separation device to demonstrate the technology for further improving water quality (Department of Water Resources, 2022). The membrane separation device operates by selectively allowing the passage of water molecules while blocking dissolved solids, including salts (Goh, Wong, & Ismail, 2022). To evaluate the capability of the membrane separation device in removing salinity, this research monitored water quality in terms of salinity reduction and relevant parameters. Three types of water samples were compared and tested for salinity levels before and after treatment. The findings can be used to improve the water quality and assure the villagers of a clean water supply.

2. Materials and Methods

2.1 Study area

Ban Nong Kratiam Tai (Lat 15.260786, Lon 101.832172) is in Nong Bua Lakorn Sub-District, Dan Kuntot District, Nakhon Ratchasima (Figure 1). The village is mainly an agricultural community, with a total of 163 households (Nong Bua Takiat Municipality, 2023). The main crops are rice, cassava, and sugar cane. This area has natural salt deposits on the soil, which is considered an area of low soil quality. An earthen reservoir was used to store surface water for the village water treatment plant. The reservoir receives water from Lam Chaing Kai downstream of Dan Kuntot District.

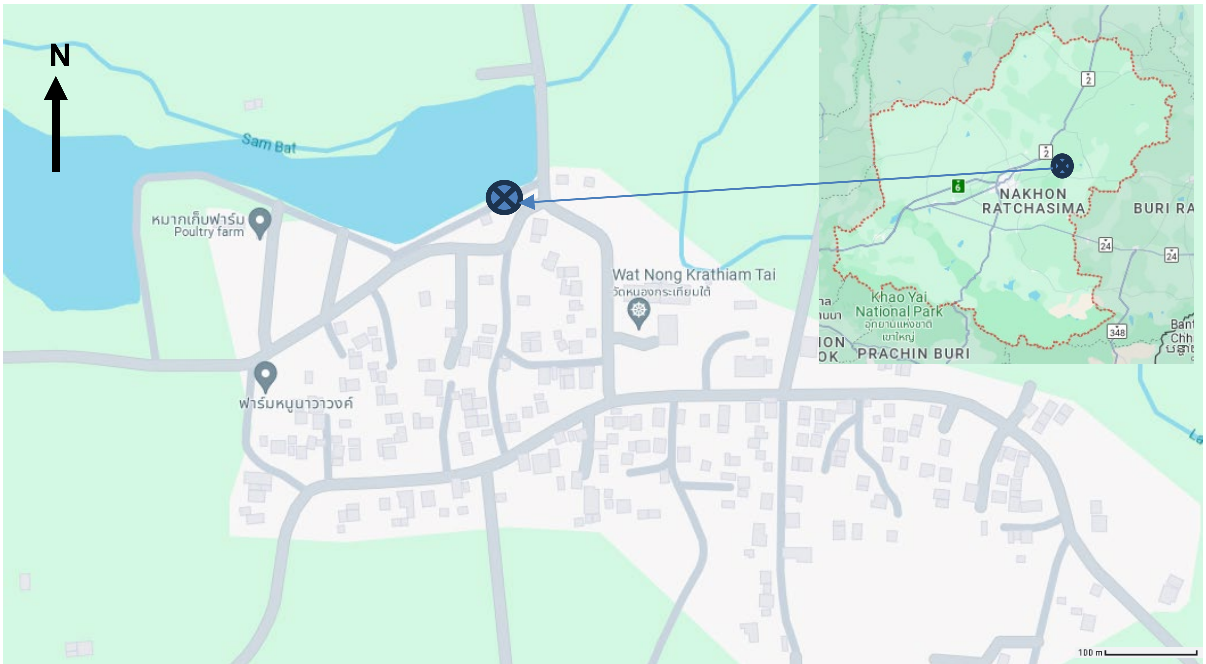

Figure 1. Study area at Ban Nong Kratiam Tai, Dan Kuntot District, Nakhon Ratchasima.

2.2 A small and solar-powered membrane device for salinity removal

The Department of Water Resources installed a small and solar-powered membrane device based on a research project in Nakhon Ratchasima in 2022 (Department of Water Resources, 2022). The device is designed to treat freshwater from the village water treatment plant, with up to 2.5 ppt salinity, through a membrane separation. It consists of a pre-treatment unit to remove residue chlorine and hardness in the water using absorption and ion exchange techniques. Then, the water is filtered through two coarse filters to remove the remaining residues from the pre-treatment unit. A vertical pump is used to push the water through two membrane filter units. The membranes can capture salt molecules while allowing water molecules to pass. Clean-produced water is sent to a storage tank ready to distribute water to the village (Figure 2).

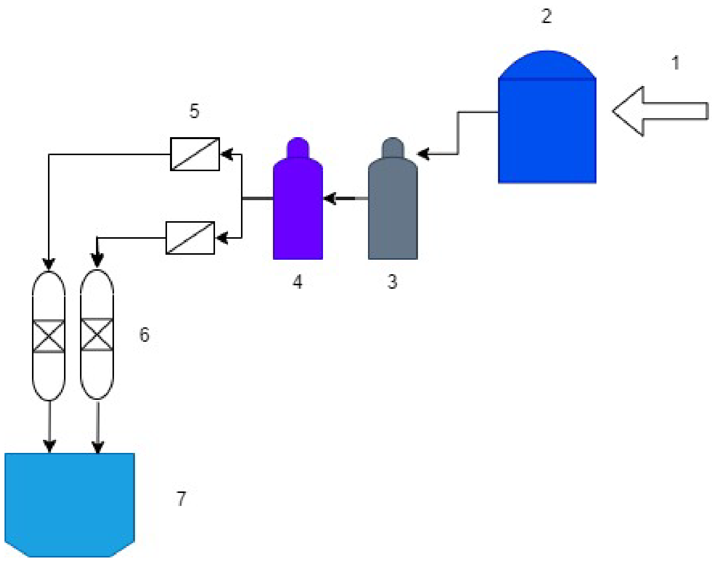

Figure 2. Diagram of a small-scale membrane separation device: 1 freshwater input, 2 storage tanks, 3 ion exchange resin, 4 activated carbon, 5 coarse filters, 6 membranes, and 7 tap water tank.

2.3 Water quality measurement

The Department of Water Resources used portable devices to measure three sources of water: surface water, fresh water, and tap water. Five water quality parameters were measured to evaluate salinity removal by the small and solar-powered membrane device (SSMD). Conductivity, total dissolved solids (TDS), pH and water temperature were measured using YSI ProDSS (YSI Inc., Ohio, USA). Salinity was determined by a YSI Pro30 (YSI Inc., Ohio, USA). Turbidity was determined by a Hach 2001Q (Hach Inc., CO, USA). Since the integrity of the membrane is also affected by water temperature, the temperature was measured as an auxiliary parameter. All instruments were calibrated before use according to manufacturer protocols, ensuring the proper use for field measurements. All standard solutions were used to calibrate the measuring devices and they are NIST-traceable solutions, e.g., YSI conductivity calibration (10,000µS/cm), pH (YSI buffer solution at pH 4, 7, and 10), turbidity (YSI 6080 turbidity standard). All water quality measurements were done on-site. Replicate measurements were performed five times during site visits between 2022 and 2023. The collected data were recorded in a spreadsheet program for analysis.

3. Results and Discussion

3.1 Surface water quality

The Department of Water Resources monitored the surface water in the reservoir using portable devices for measuring pH, water temperature, conductivity, TDS, and salinity. The pH levels ranged from 5.7 to 6.2, within the acidic level (Figure 3 left), but the range was within the Surface Water Quality Standards (pH = 5 to 9), according to the Pollution Control Department (PCD). The water temperature was between 27.6 and 29.3 Celsius. Water salinity was between 1.6 and 2.1 ppt. Salinity at these levels was high for surface water. At 0.5 to 1.0 ppt of salinity, the usefulness of water become restricted for agriculture and community (ANZECC, 1992), Turbidity was the only parameter that was not measured directly in the reservoir because the turbidity meter requires a small amount of water sample placed inside a curette. The water samples were taken from the reservoir, and less than 20 mL of water sample was needed. The turbidity levels of surface water were 6.8 to 10.1 NTU. High levels of conductivity were 3495 to 3982 µS/cm (Figure 3 right). A similar trend was observed for TDS, ranging from 2097 to 2351 mg/L.

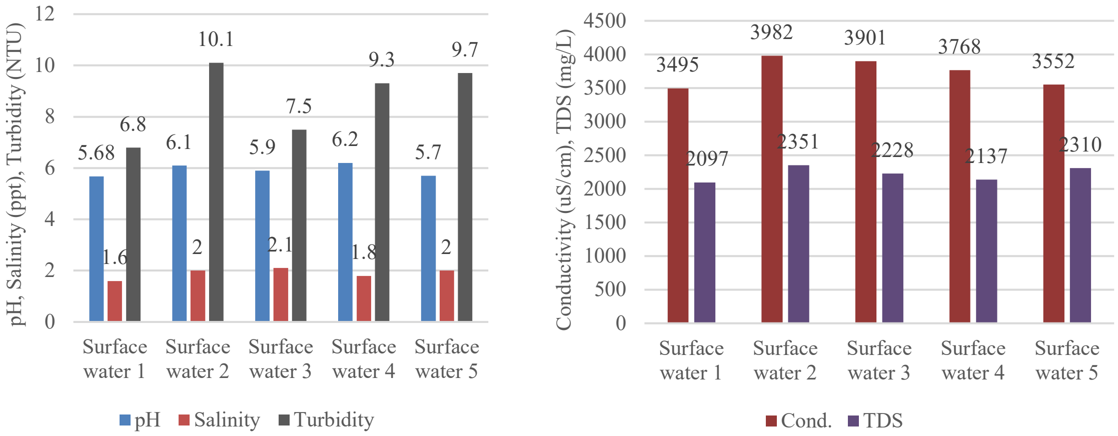

Figure 3. pH, salinity, turbidity, conductivity, and TDS in the surface water.

3.2 Freshwater quality

Freshwater sample was collected from the water treatment plant. Turbidity was low, 0.25 – 0.27 NTU, because the suspended solids were removed during the treatment processes, unlike the surface water. Thus, turbidity was not the concern factor in freshwater. Freshwater had a pH between 5.5 and 6.9 (Figure 4 left), comparable to surface water. Salinity was relatively consistent at 1.6 ppt, slightly at the lower end of the levels found in surface water. Temperatures ranged from 27.8 to 28.9 Celsius. Conductivity levels ranged from 3342 to 3415 µS/cm; TDS ranged between 2005 and 2049 mg/L (Figure 4 right). Both conductivity and TDS levels were lower than the surface water, but these parameters suggested that soluble ions remained in the water after the removal of turbidity from the sand filtration.

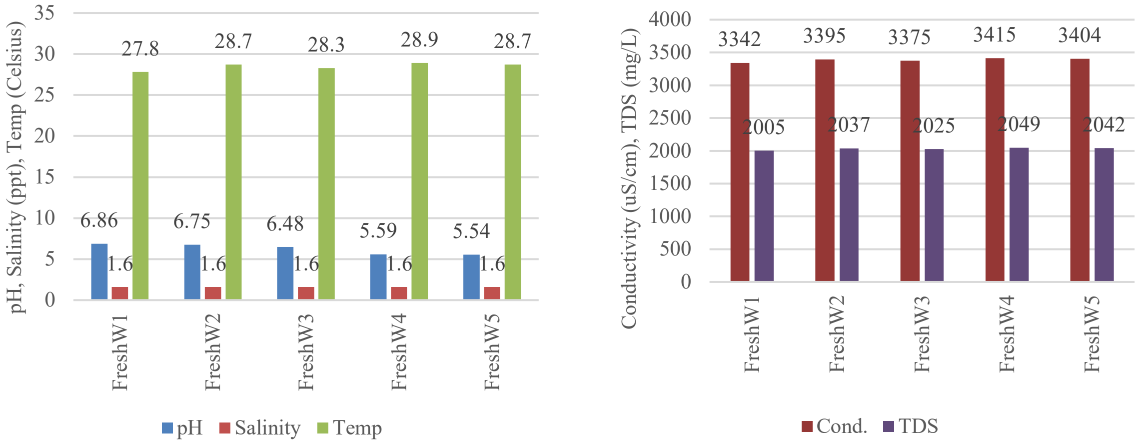

Figure 4. pH, salinity, turbidity, conductivity, and TDS in the freshwater.

3.3 Tap water quality

Tap or produced water was the water from the small-scale membrane separation. pH levels were lower than in freshwater (5.2 to 6.1), which is normal after membrane filtration due to the absorption of carbon dioxide gas and lack of minerals. Salinity was not detected in tap water (Figure 6 left) because salt ions cannot pass the membrane. Conductivity and TDS were drastically reduced to less than 20 µS/cm, and 12 mg/L, respectively (Figure 6 right). The results clearly showed that the small-scale membrane separation was capable of removing dissolved ions associated with salinity, conductivity, and TDS.

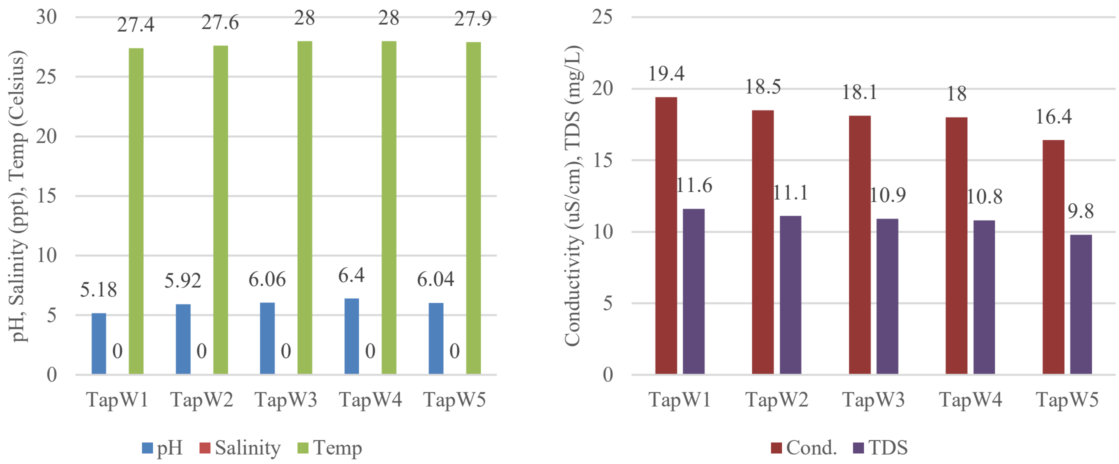

Figure 5. pH, salinity, turbidity, conductivity, and TDS in tap water.

The membrane separation device can remove salinity from freshwater very effectively. No salinity was detected in tap water after the freshwater had passed through the membrane. Similarly, levels of conductivity and TDS in freshwater, on average, were lower from 3386 µS/cm and 2032 mg/L to 18 µS/cm and 11 mg/L, respectively (Table 1). Removal efficiency of conductivity and TDS can achieve 99.5% in this case. The comparisons of each parameter are in Figure 7.

Table 1. Salinity removal of surface water, freshwater, and tap water.

Parameter	Surface water	Freshwater	Tap water	% Removal*
pH	5.9	6.2	5.9	Not related
Conductivity (µS/cm)	3740	3386	18	99.5
TDS (mg/L)	2225	2032	11	99.5
Temperature (Celsius)	29.1	1.6	27.8	Not related
Salinity (ppt)	1.9	28.5	Not detected	100

Noted: *calculated from the differences between freshwater and tap water

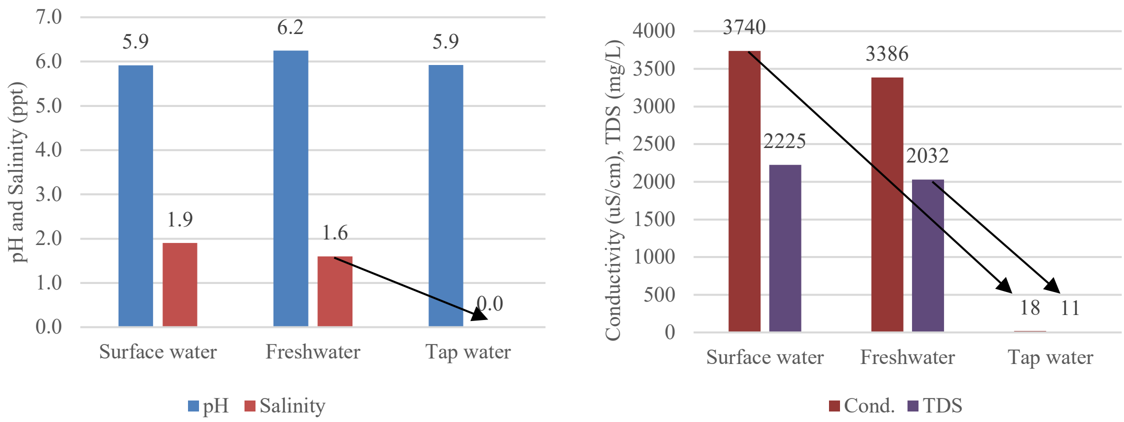

Figure 6. Comparison of pH, salinity, conductivity, and TDS of surface water, freshwater, and tap water.

4. Conclusions

The membrane separation device had high efficiency for salinity removal of freshwater at Ban Nong Kratiam Tai, Dan Kuntot District. The device can remove 1.6 ppt of salinity to not detected level, meaning that salt molecules could not pass the membrane. Water quality in the village with high salinity could be improved and the village's residents could be of benefit from the technology. The removal efficiency of conductivity and TDS was as high as 99.5 percent. Thus, membrane separation technology is an alternative treatment for salinity and dissolved ions removal in the area subjected to saline soil, as demonstrated in Dan Kuntot District. In contrast, the conventional water treatment plant with sand filtration had no effect on salinity removal. The pH of tap water was a concern if the water was used directly by the villagers because it was in the range of acidic. Usually, the pH should not be lower than 6.5 in most recommended use. Alkalinity should be used to neutralize the acidic water if needed. With membrane technology, the water quality in the areas affected by saline soil can be improved significantly.

Acknowledgements

This research was the follow up on a previous research project of the Department of Water Resources, Ministry of Natural Resources and Environment. The authors are thankful for all the support.

Conflict of Interest

The authors declared that there are no conflicts of interest.

References

ANZECC. (1992). *Australian water quality guidelines for fresh and marine waters*. Canberra: Australian and New Zealand Environment and Conservation Council.

Department of Land Development. (2023). *Map of salty and acidic soil*. Office of Regional Land Development 3. Retrieved from http://r03.ldd.go.th/P64/Soil_S_nma.html

Department of Mineral Resources. (2015). *Saline soil area development in the Northeast: Geological approaches*. Bangkok: Division of Mineral Resources Conservation and Management.

Department of Water Resources. (2022). *Final report on a prototype small-scale desalination*. Bangkok.

Doula, M. K., & Sarris, A. (2016). Soil Environment. In S. G. Poulopoulos & V. J. Inglezakis (Eds.), *Environment and development: Basic principles, human activities, and environmental implications* (pp. 213-286). Amsterdam, Netherlands: Elsevier.

Goh, P. S., Wong, K. C., & Ismail, A. F. (2022). Membrane technology: A versatile tool for saline wastewater treatment and resource recovery. *Desalination*, *521*, 115377. doi:10.1016/j.desal. 2021.115377

Nong Bua Takiat Municipality. (2023). *General information*. Retrieved from https://www.nongbuatakiat.go.th/data.php?content_id=6

Paosaku, J. (2016). *Salinity management in Nakhon Ratchasima*. Bangkok: Department of Land Development.

Phoemphon, W., & Terakulsatit, B. (2023). Assessment of groundwater potential zones and mapping using GIS/RS techniques and analytic hierarchy process: A case study on saline soil area, Nakhon Ratchasima, Thailand. *AIMS Geosciences*, *9*(1), 49-67. doi:10.3934/geosci.2023004

Thai Meteorological Department. (2023). *Climate of Nakhon Ratchasima*. Bangkok: Climate Center. (in Thai)