DEVELOPMENT OF SOLAR ASSISTED MEMBRANE DISTILLATION SYSTEM USING SOLAR THERMAL COLLECTOR

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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Peningkatan permintaan air bersih dan pencemaran alam sekitar telah membawa kepada peningkatan penggunaan tenaga boleh diperbaharui untuk sistem penyahgaraman air laut. Satu teknologi penyahgaraman air laut yang berkembang pesat ialah penyulingan bermembran berkuasa solar (SPMD), dimana boleh menangani kekurangan air bersih tanpa meningkatkan kos elektrik. Walau bagaimanapun, teknologi terkini tidak mengkaji prestasi terma sistem SPMD tersebut dan hanya menggunakan pengumpul terma suria komersial (STC) sepanjang eksperimen. Objektif kajian ini adalah untuk menilai prestasi sistem SAMD buatan sendiri untuk aplikasi air laut dari segi prestasi pemisahan dan kelestarian tenaga di bawah keadaan cuaca Malaysia. Dalam kerja ini, sistem Pengumpul Terma Suria Plat Rata (FPSC) telah direka untuk mendapatkan prestasi haba yang tinggi dengan mengubah diameter tiub (D = 3/4-inci dan 3/8-inci), jarak paip (S = 18.5 cm dan 27.0 cm) dan kadar aliran jisim masuk (0.01 - 0.05 kg/s). Selepas memilih reka bentuk FPSC yang terbaik, sistem itu kemudiannya dipadankan bersama sistem penyulingan bermembran secara langsung (DCMD) untuk kajian air laut. FPSC tersebut berfungsi sebagai pemanas bagi larutan suapan yang terdiri daripada air laut simulasi dan air laut sebenar bagi penilaian dalaman sebelum diuji di bawah cahaya matahari secara langsung. 2.5% berat natrium klorida (NaCl) telah digunakan sebagai air laut simulasi mewakili air laut standard. Dalam kajian ini, membran-membran yang sudah kotor juga dianalisis untuk kecenderungan penskalaan menggunakan mikroskop elektron pengimbas (SEM) dengan sinar-X penyebaran tenaga (EDX). Bagi bahagian reka bentuk, dapat diperhatikan bahawa pengumpul paip dengan diameter tiub 3/4-inci memperoleh prestasi haba dan kecekapan pengumpul yang lebih baik berbanding dengan diameter tiub 3/8-inci, yang telah mencatatkan kenaikan sebanyak 3.5% dan 9.4%, masing-masing. Sementara itu, jarak paip sebanyak 18.5 cm mendapat prestasi haba dan kecekapan pengumpul 4.3% dan 12.6% lebih tinggi masing- masing berbanding jarak paip 27 cm. Dari segi kadar aliran jisim masuk, kadar aliran jisim optimum ialah 0.03 kg/s dengan keamatan sinaran antara 250 hingga 1050 W/m^2. Reka bentuk terbaik berdasarkan tiga parameter tersebut kemudiannya digunakan dan digandingkan dengan sistem DCMD untuk analisis dalaman dan luaran menggunakan air laut. Untuk penilaian luar, sistem SAMD telah dianalisis di bawah cuaca cerah dan mendung. Fluks resapan maksimum apabila sistem dikendalikan di bawah cahaya matahari langsung ialah 4.35 kg/m^{2}j. Berkenaan dengan penolakan garam, penolakan 99.9% telah dicapai dalam semua eksperimen dan resapan tersebut dibandingkan dengan air minuman standard. Walaupun kualiti resapan akhir adalah setanding dengan air minuman, beberapa kekotoran telah dikesan semasa analisis SEM-EDX. Dapat disimpulkan bahawa sistem SAMD yang dihasilkan boleh menjadi pilihan teknologi hijau dalam penyahgaraman air laut kerana ia hanya memerlukan minimum elektrik daripada grid kuasa.

ABSTRACT

The increase in freshwater demand and environmental pollution is leading to an increase in the use of renewable energy for the seawater desalination system. One fast-growing seawater desalination technology is solar assisted membrane distillation (SAMD), which can address the shortage of fresh water without increasing the cost of electricity. However, the present technology did not study the thermal performance of the SAMD system and simply used the commercial solar thermal collector (STC) during the experiments. The objective of this study is to evaluate the performance of in-house made SAMD system for seawater application in terms of the separation performance and energy sustainability under the Malaysian weather condition. In this work, Flat Plate Solar Thermal Collector (FPSC) system was designed to obtain the high thermal performance by varying the tube diameter (D = 3/4-inch and 3/8-inch), pipe spacing (S =18.5 cm and 27.0 cm) and inlet mass flow rates (0.01 - 0.05 kg/s). After choosing the best FPSC design, the system was then integrated into the direct contact membrane distillation system (DCMD) for sea water testing. The FPSC functions as a preheating of the simulated and actual seawater feed solution for indoor assessment before testing under direct sunlight. 2.5 wt.% of sodium chloride (NaCl) was used as the simulated seawater represents the standard seawater. In this work, fouled membranes were also analyzed for the scaling tendency using scanning electron microscopy (SEM) with energy dispersive X-Ray (EDX). For the design part, it can be observed that the pipe collector with tube diameter of 3/4-inch obtained better thermal performance and collector efficiency as compared to the 3/8-inch tube diameter, which recorded of 3.5% and 9.4% increment, respectively. Meanwhile, 18.5 cm pipe spacing was 4.3% and 12.6% higher in thermal performance and collector efficiency, respectively, compared to 27 cm pipe spacing. In term of inlet mass flow rate, the optimum mass flow rate is 0.03 kg/s with a radiation intensity ranging from 250 to 1050 W/m2. The best design based on the three parameters was then used and coupled with the DCMD system for indoor and outdoor analysis using seawater. For the outdoor evaluation, the SAMD system was analyzed under sunny and cloudy weather. The maximum permeate flux when the system was operated under direct sunlight is 4.35 kg/m^2h. With respect to the salt rejection, 99.9% rejection was achieved in all experiments and the permeate was compared to standard drinking water. Although the final permeate quality is comparable to that of drinking water, some impurities were detected during the SEM-EDX analysis. It can be concluded that the manufactured SAMD system can be a green technology option in seawater desalination because it requires only a minimum electricity from the power grid.

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LIST OF SYMBOLS

C	Celsius
CO_2	Carbon dioxide
NaCl	Sodium Chloride
LPM	Litre Per Minute

LIST OF ABBREVIATIONS

AD	Adsorption Desalination
AGMD	Air Gap Membrane Distillation
AR	Anti-Reflective
CPC	Compound Parabolic Concentrator
DC	Direct Current
DCMD	Direct Contact Membrane Distillation
ED	Electro Dialysis
EDX	Energy Dispersive X-ray
EST	Evacuated Solar Tubes
ETHPSC	Evacuated Tube Heat Pipe Solar Collector
ETSC	Evacuated Tube Solar Collector
FD	Freeze Desalination
FPHPSC	Flat Plate Heat Pipe Solar Collector
FPSC	Flat Plate Solar Collector
GOR	Gain Output Ratio
HDH	Humidifier and Dehumidifier
HPSC	Heat Pipe Solar Collector
ITC	Instituto Technologico de Canarias
LCD	Liquid Crystal Display
MD	Membrane Distillation
MED	Multi-Effect Distillation
MSF	Multistage Flash
MVC	Mechanical Vapour Compression
PCM	Phase Change Material
PE	Polyethelene
PGMD	Permeate Gap Membrane Distillation
PHP	Pulsating Heat Pipe
PP	Polypropylene
PTC	Parabolic Trough Collector
PTPE	Polytetrafluoroethylene
PTSC	Parabolic Trough Solar Collector

PV	Photovoltaic
PVDF	Polyvinylidene Fluoride
PV/T-PCM	Photovoltaic and Thermal with Phase Change Material
RE	Renewable Energy
RO	Reverse Osmosis
SAMD	Solar Assisted Membrane Distillation
SEM	Scanning Electron Microscopy
SPMD	Solar Powered Membrane Distillation
STC	Solar Thermal Collector
TRR	Thermal Recovery Ratio
TSD	Total Dissolved Salts
TVC	Thermal Vapour Compression
VC	Vapour Compression
VMD	Vacuum Membrane Distillation
WRC	World Radiation Centre

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