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UNDER THE THEME: UNIFYING RESEARCH EFFORTS TO DEVELOP DESALINATION TECHNOLOGIES

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Centre of Excellence in Desalination Technology

Effect of Intermittent Operation on Performance of a Solar-Powered Membrane Distillation Pilot Unit

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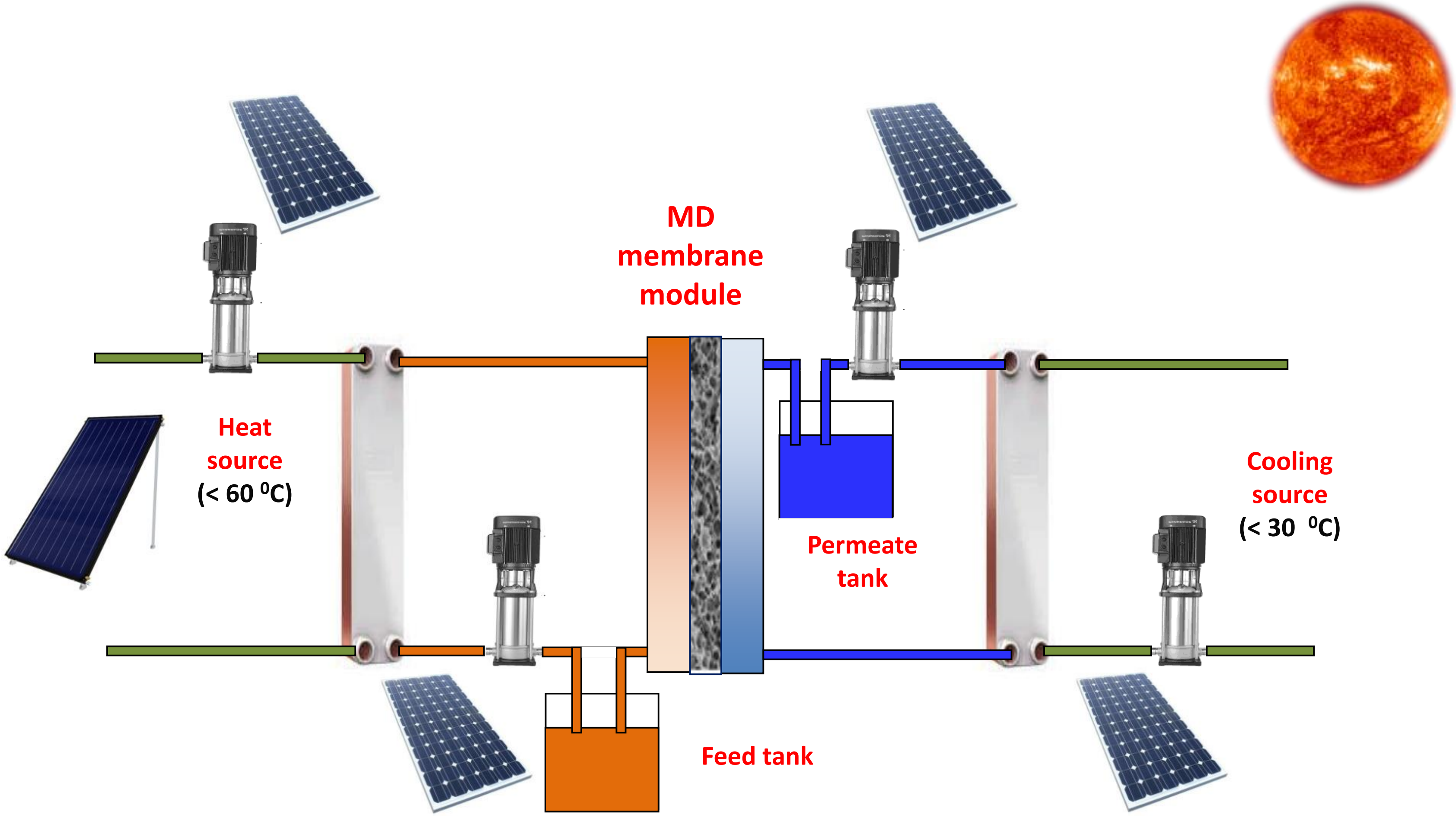
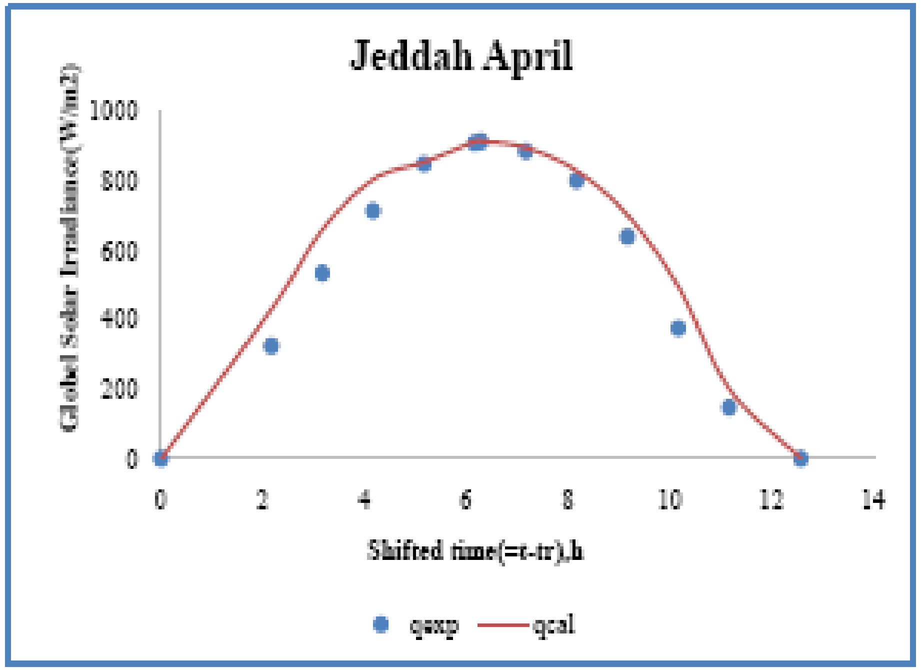
Main features of solar powered membrane distillation (SPMD) system

1) SPMD system requires both thermal and electrical energy for operation



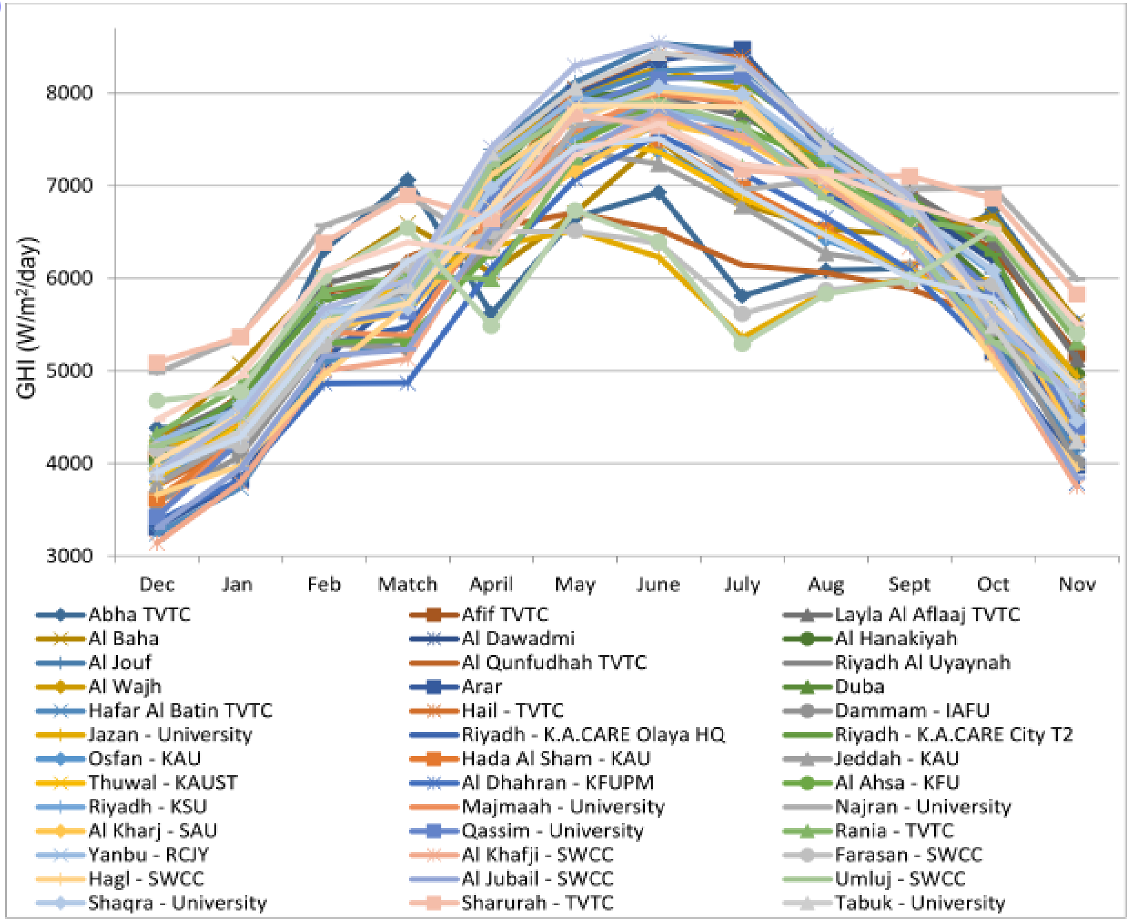
Main features of solar powered membrane distillation (SPMD) system

Operation of SPMD system is unsteady (depends on variation of solar irradiance throughout the daytime and the year)



Experimental and calculated data for Jeddah April

Source: M.K. El-Adawi et. al., International Refereed Journal of Engineering and Science (IRJES) 2015, *4 (6): 85-93*



Average daily total Global Horizontal Irradiance (GHI) of 44 stations over the one-year study period

Source: Awan et.al. , Sustainability 2018, 10, 1129

Main features of solar powered membrane distillation (SPMD) system

Operation of SPMD system is intermittent (daytime only)

Questions of the study

- *What is the best operation protocol for intermittent operation of SPMD system?*

- *What are the effects of the intermittent operation on the performance of SPMD system?*

Evaluation of different intermittent operation protocols on bench scale DCMD System

Defining intermittent operation protocols

- **Three experiments denoted A, B, and C were carried out on a bench-scale DCMD testing unit.**
- **Each experiment represents a pre-defined operation protocol**

Day-1
Feed: Distilled water

8 days

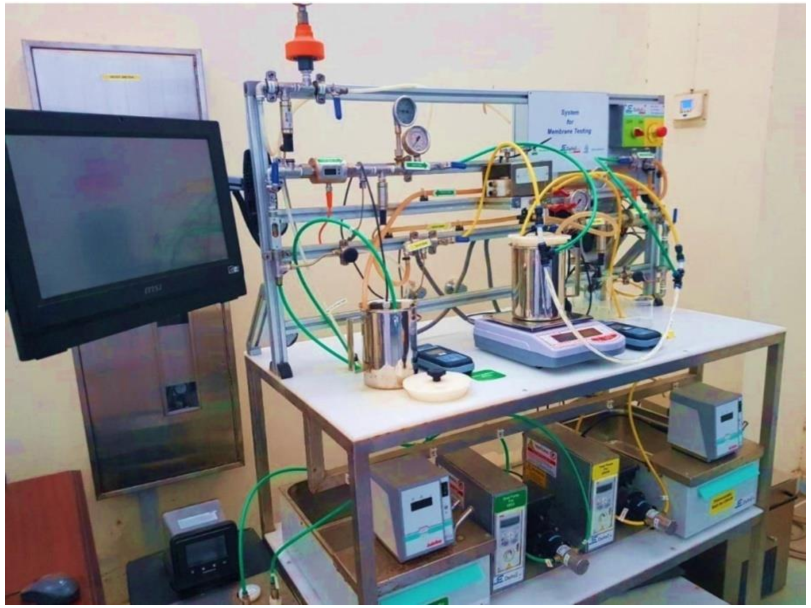
Days-2 to 8
Feed: SWRO brine, TDS 55 g/l

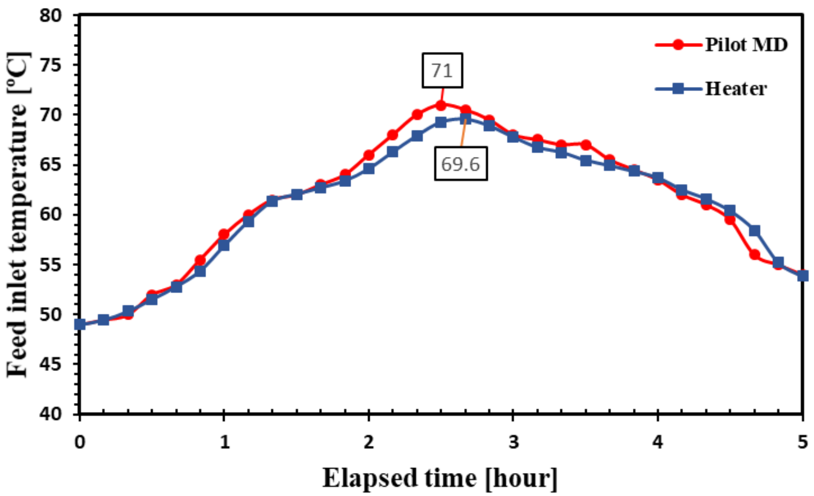
A
(Wash and drain protocol):
The feed channel of the module is washed with a distilled water at the shutdown event , drained, and left to dry overnight

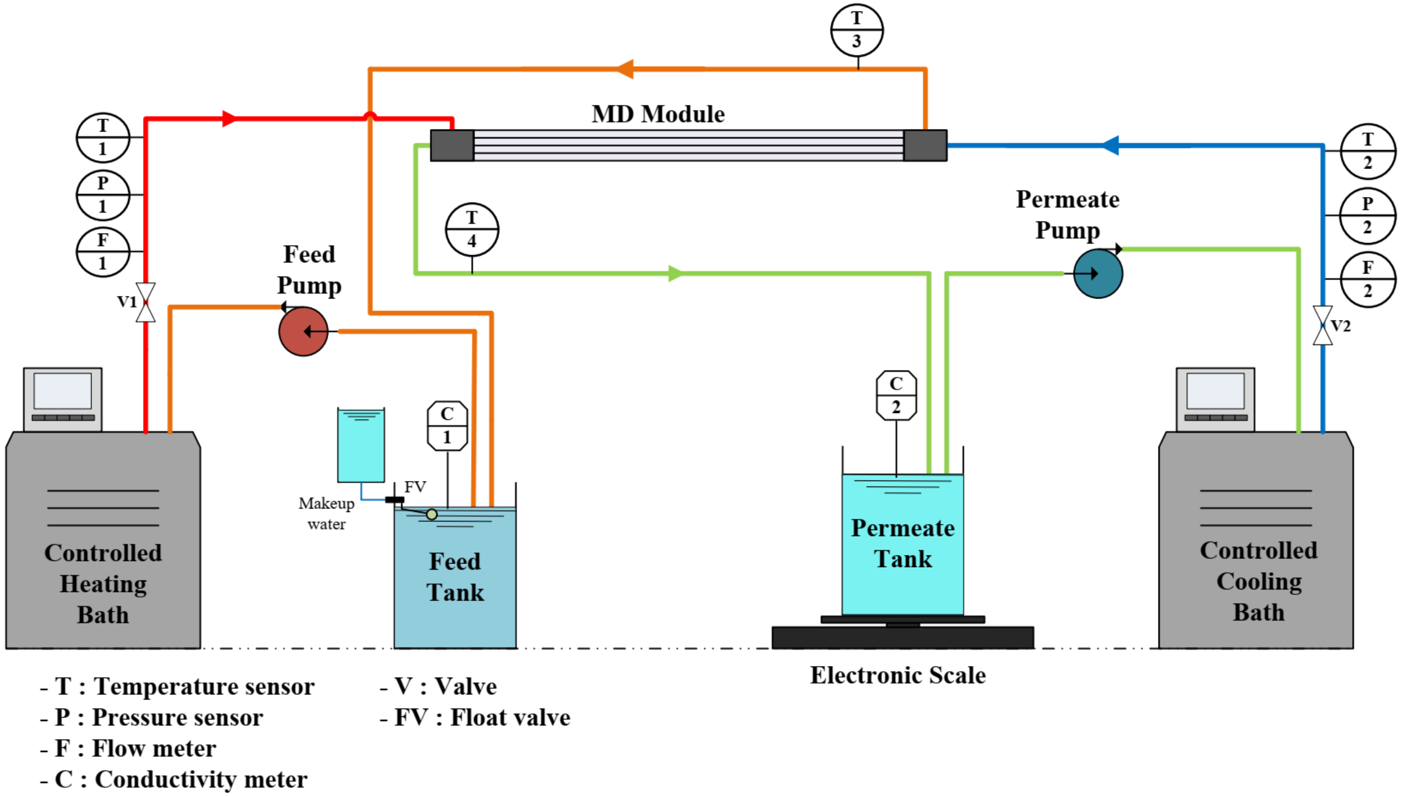
B
(Drain protocol):
The module is only drained from liquids at the shutdown event and left to dry overnight

C
(On/Off protocol):
The unit is turned off at the operation end while keeping the feed and permeate inside the module overnight

Material and methods







Material and methods

Operating parameters

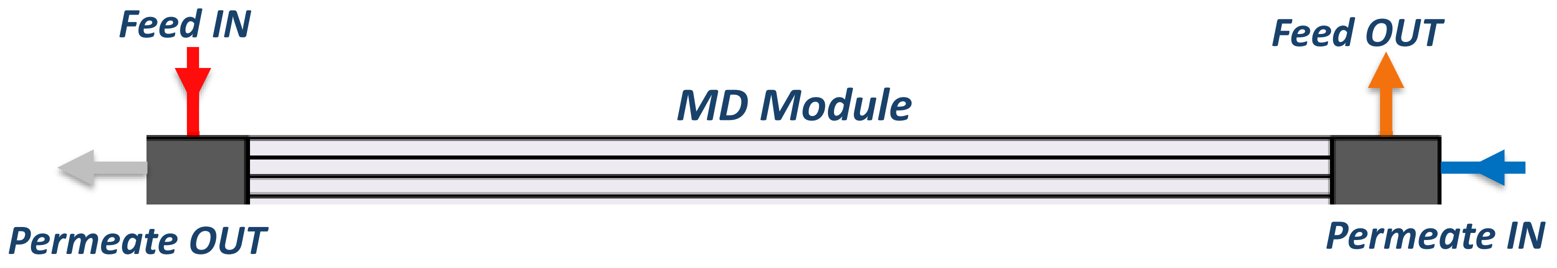
Flow rates:

Q_f = 2.9 l/min

Q_p = 1 l/min

Permeate inlet temperature

T_p = 20 °C



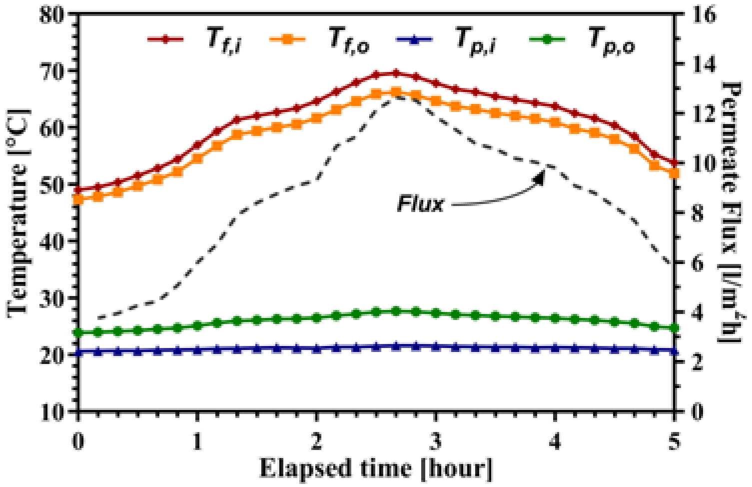
Feed inlet temperature

T_f = variable

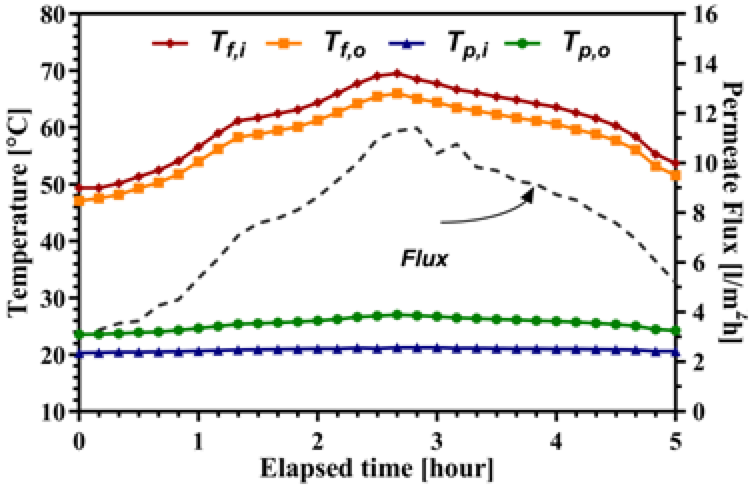
DCMD- hollow fiber module	Properties
Membrane material	PVDF
Number of hollow fibers	15
Nominal inner diameter of the fiber (mm)	0.75
Nominal outer diameter of the fiber (mm)	1.2
Mean pore size (µm)	0.1
Module diameter (mm)	12
Effective module length (m)	0.33
Effective module's membrane area (m^2)	0.018652

Hourly variation of permeate flux under intermittent operation

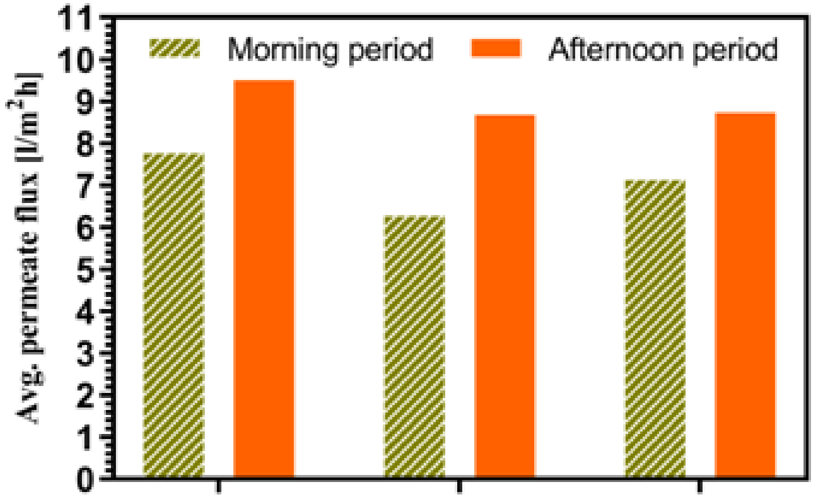
Inlet feed temperature and permeate flux profiles of the MD module for protocols A, B, and C during day 2



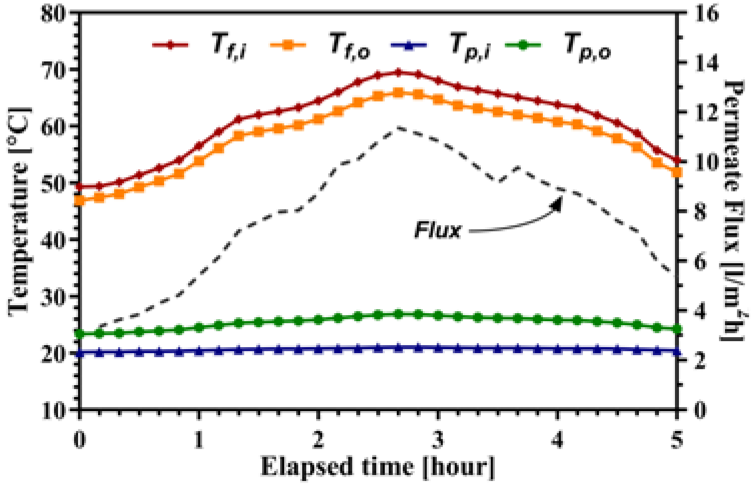
Protocol A



Protocol B



Protocol A Protocol B Protocol C



Protocol C

Hourly variation of permeate TDS under intermittent operation

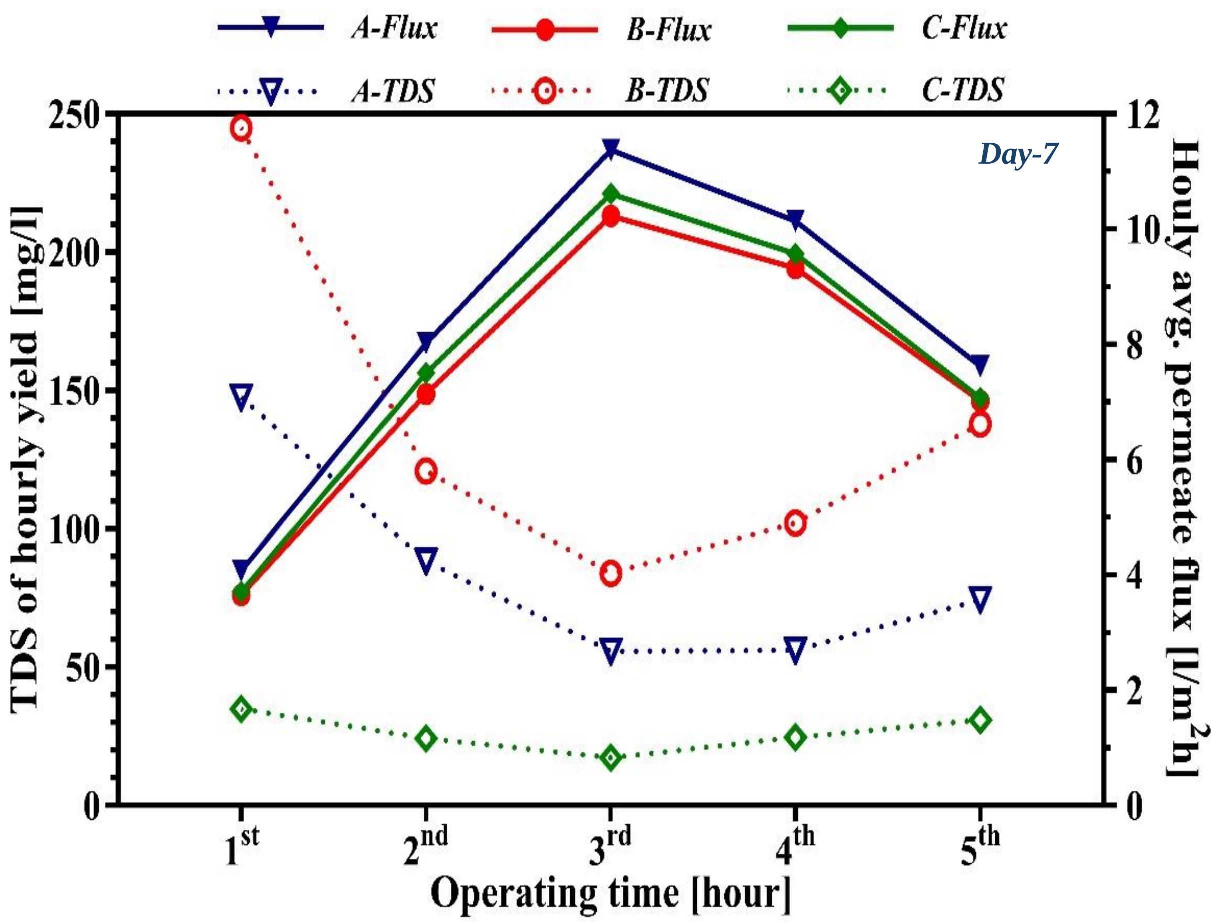
High permeate TDS values during the first hour of operation in experiments A and B (for day 7)

1ST hour
A 147 mg/l
B 245 mg/l

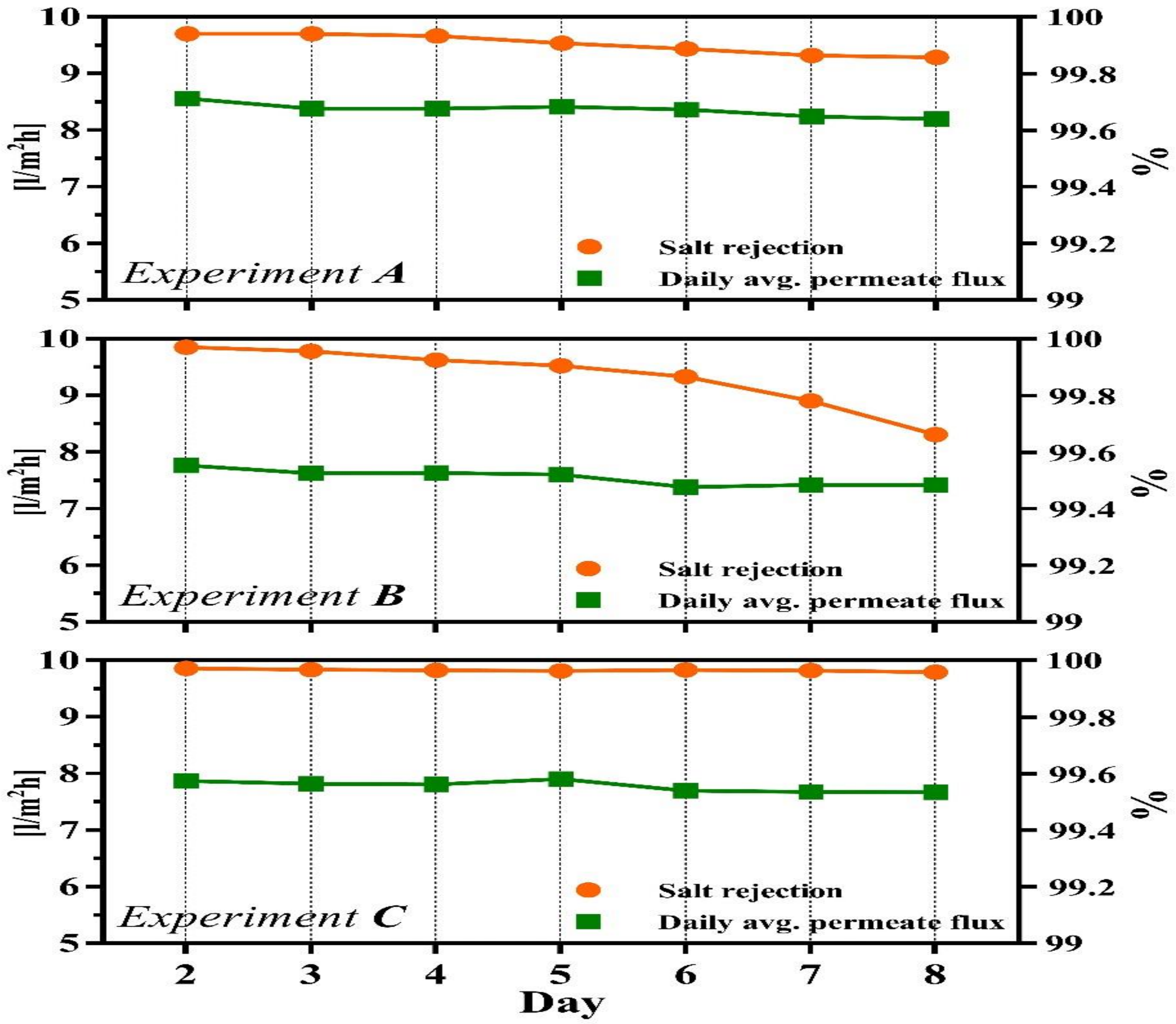
3rd hour
56 mg/l
84 mg/l

Deposition of salt particles on the membrane surface due to dry out at night time

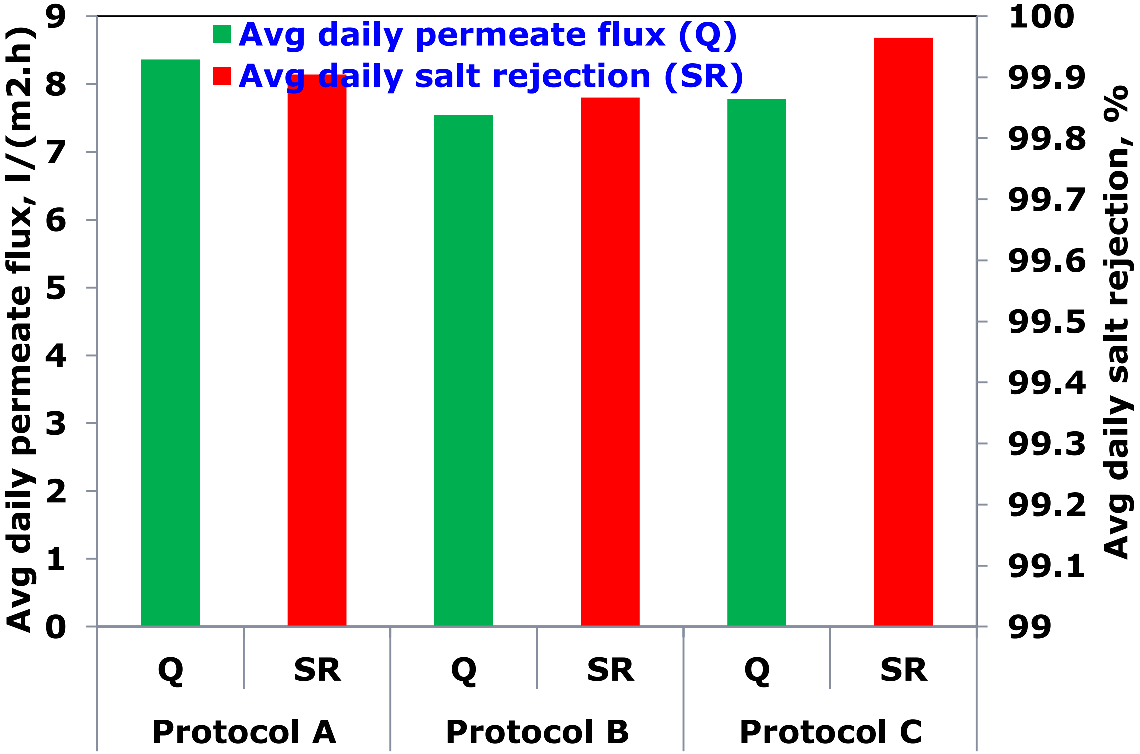
A higher permeate vapor flux at elevated temperature results in greater dilution of any saline flux in liquid form through locally wetted pores



Variation of average daily permeate flux and average daily salt rejection under intermittent operation



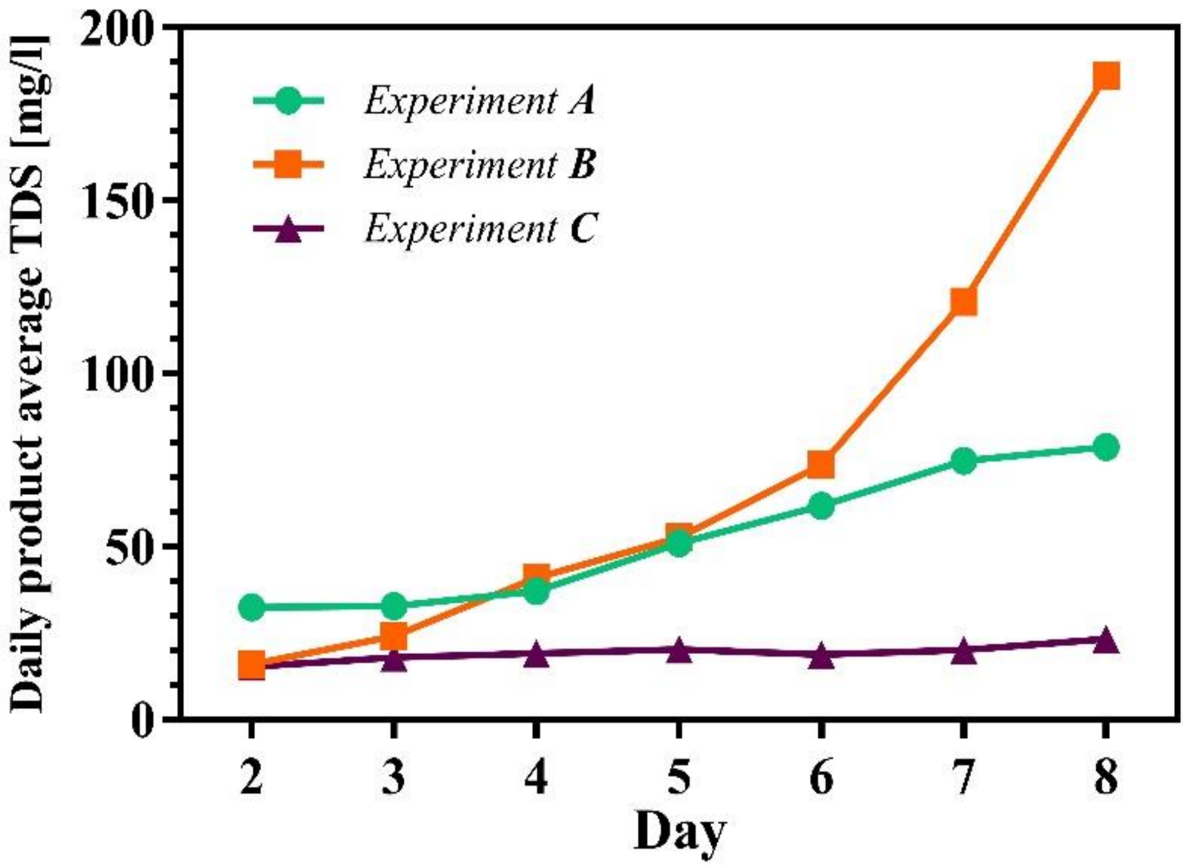
- Insignificant variations in the average daily permeate flux between protocols
- Slight decrease in average daily permeate flux over time
- Gradual degradation in SR factor especially in protocol B



Variation of average daily TDS of permeate water under intermittent operation

Protocol B is less preferable:

Deposition of salt particles on the membrane surface due to dry out at night time



Phase 2: SPMD Pilot study

Performance evaluation of a solar powered DCMD pilot unit under intermittent operation

Material and methods

Thermal sink system

2 water cooling units,
capacity of cold water tank 500 l, compressor H.P : 2.5, cooling capacity : 1000 liters/h.
Heat exchanger: 9 kW

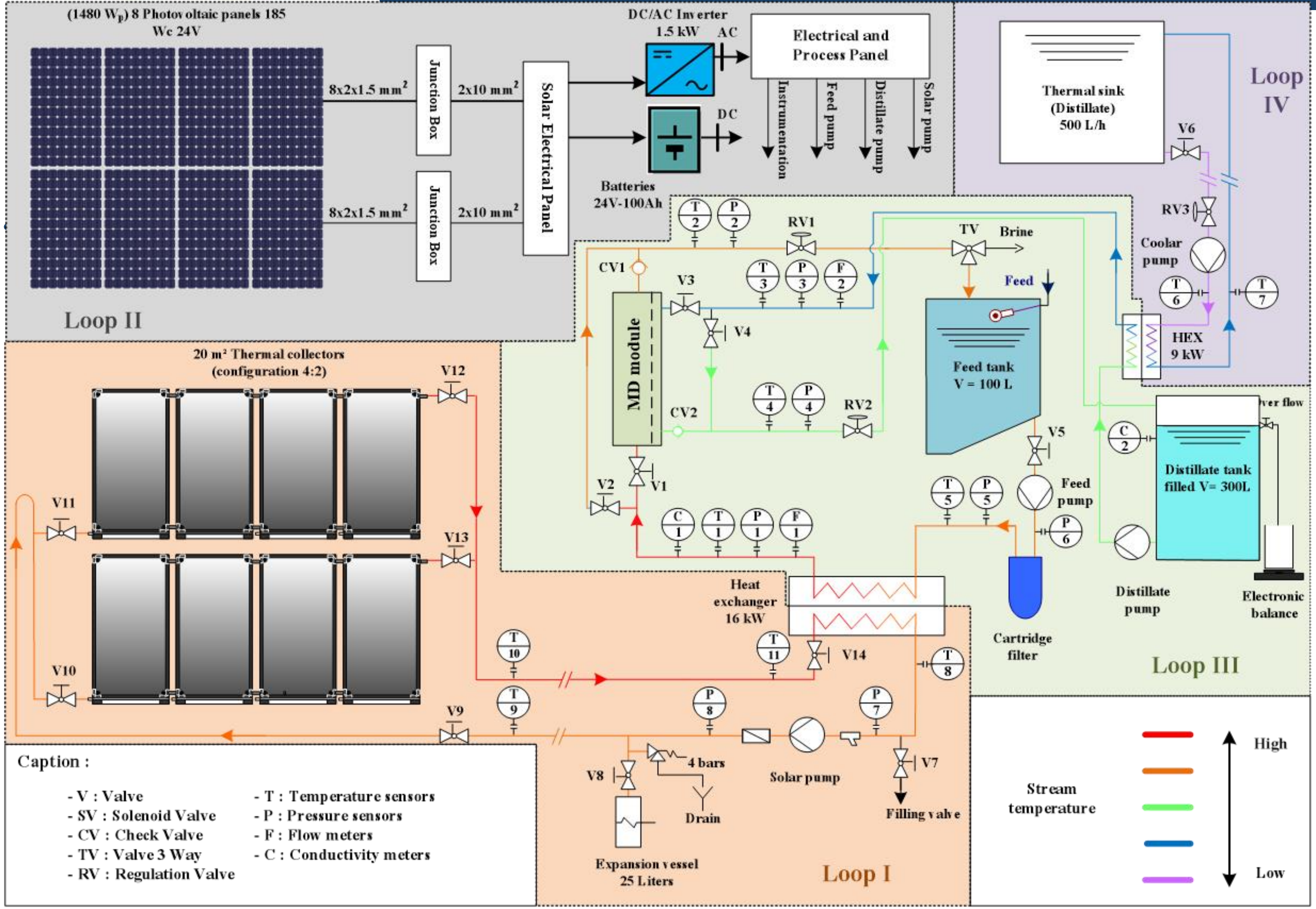
PV system

8 PV panels assembled in parallel- peak capacity 1.480 kW_{peak}
Electric batteries
DC/AC inverter

Solar collector system

8 flat plate collectors arranged in a series: parallel (4:2) configuration- total effective area 20 m^2
Heat exchanger: 16 kW.

Material and methods



Schematic diagram of the SPMD pilot unit

Material and methods

Specifications of the membrane module

Module model	MICRODYN® - MD 063 CP 2N
Membrane material and type	Polypropylene/ Hollow fiber
Module configuration	Shell-and-tube
Number of fibers	200
Fibers inner diameter (mm)	1.8
Pore size (µm)	0.2
Membrane area (m^2)	0.75

MICRODYN NADIR

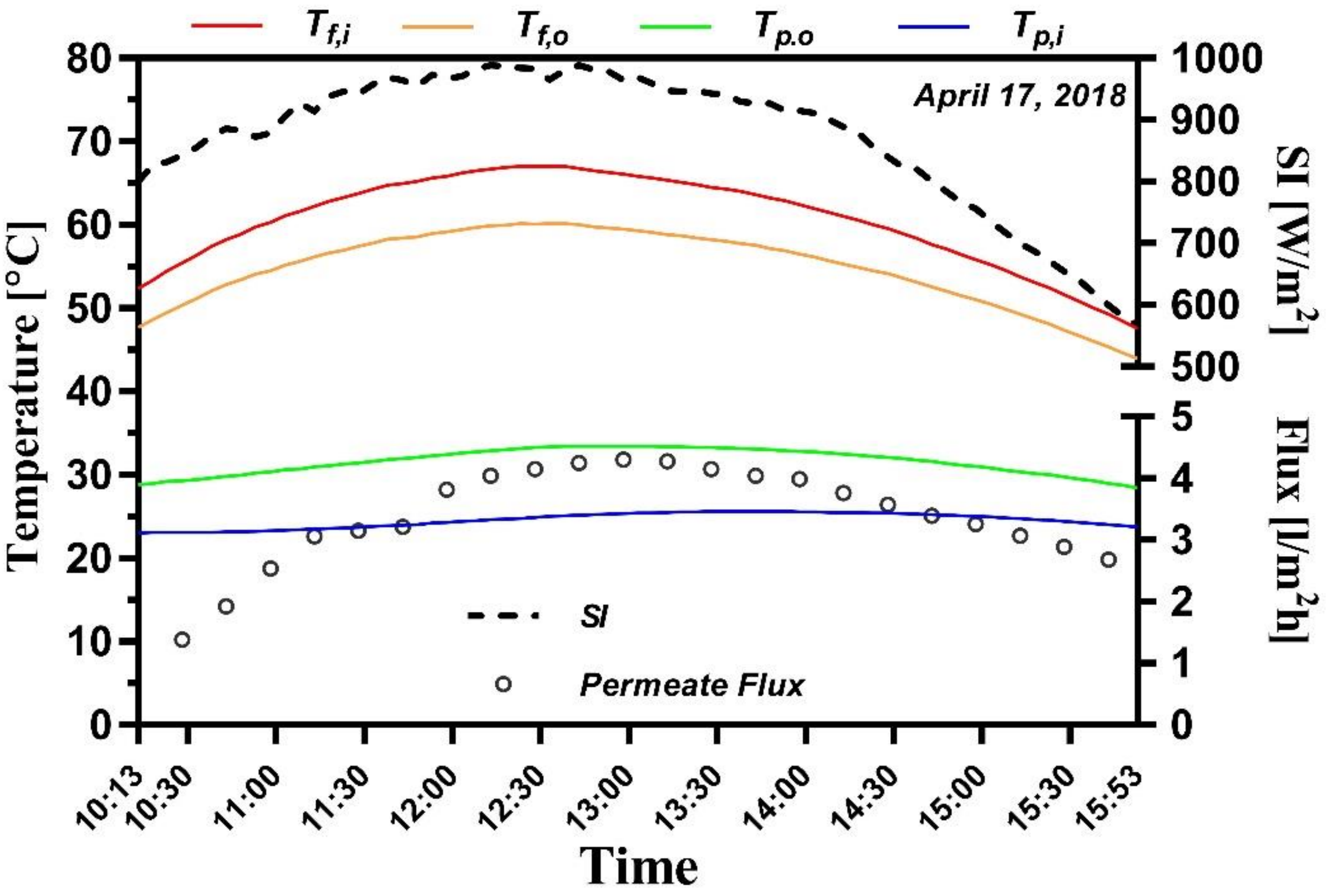
ADVANCED SEPARATION TECHNOLOGIES

Experimental design

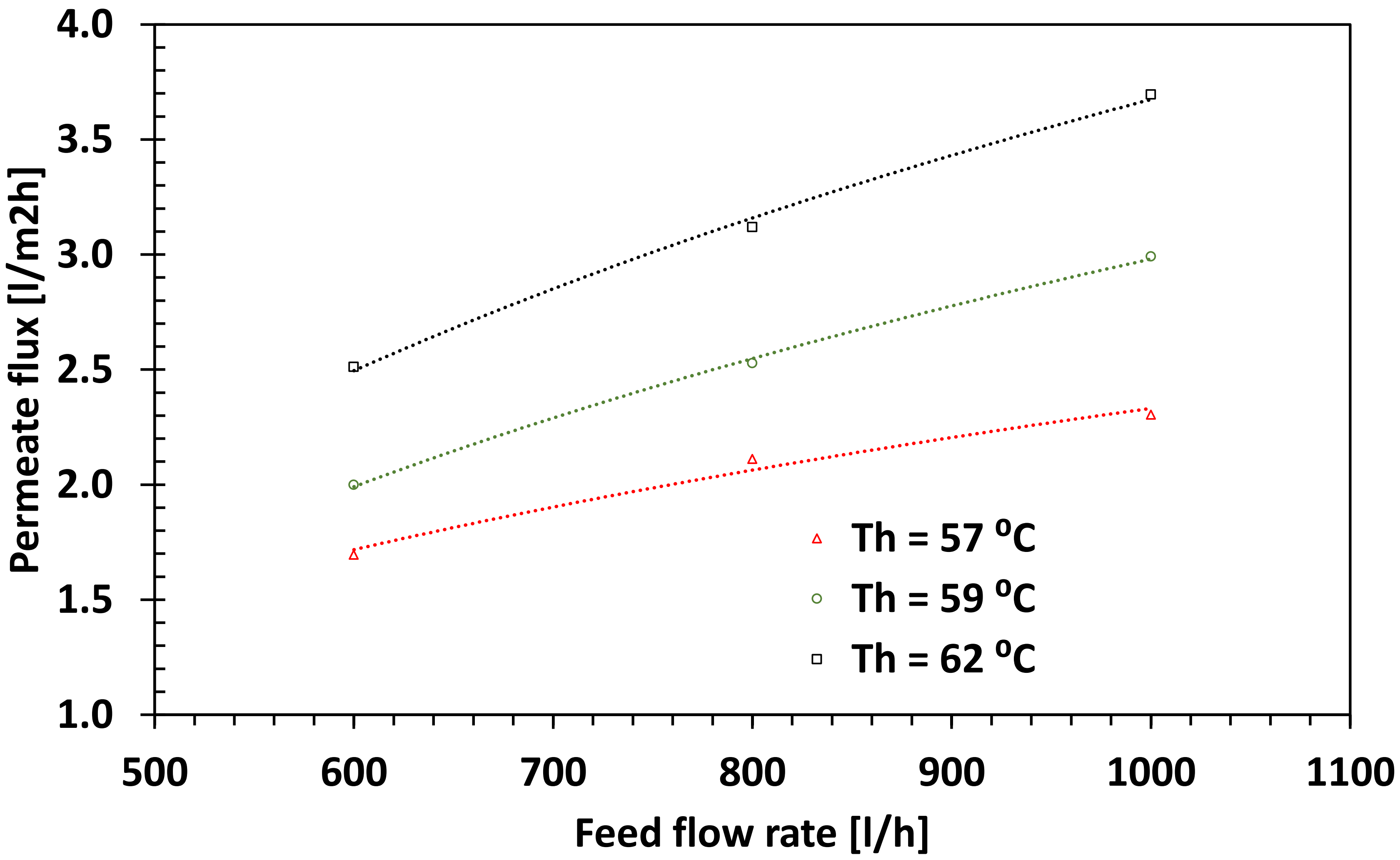
Testing operating parameters

Date of test	Type of feed water	Feed flow rate [l/h]	Permeate flow rate [l/h]	Feed temperature [ºC]	Permeate temperature [ºC]
April 16	Tap water	600	600	Variable with the solar radiation	23±1
April 17	Tap water	800			
April 18	Tap water	1000			
April 19	Seawater	800			
April 22	SWRO brine	800			

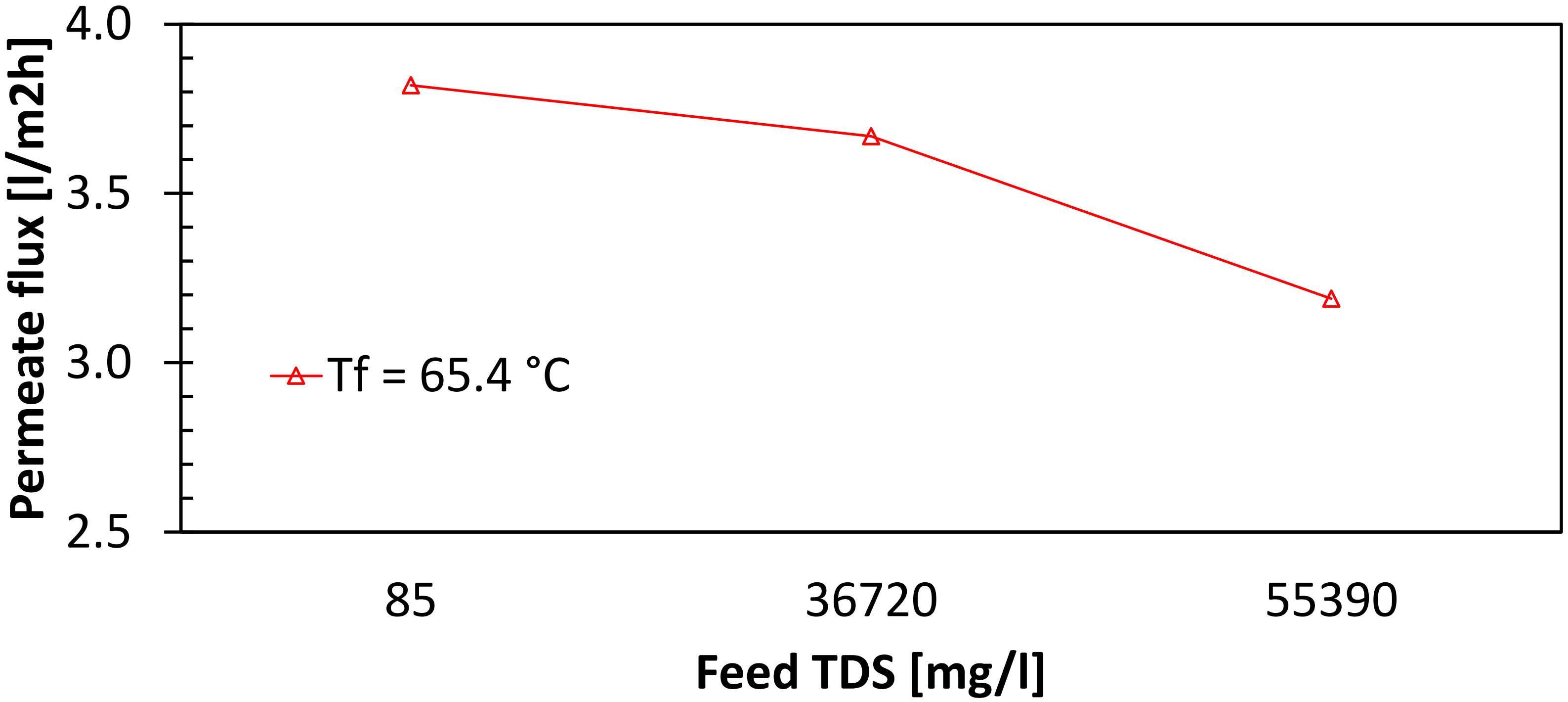
Hourly variation of performance parameters of the SPMD pilot unit



Effect of feed flow rate on permeate flux of the SPMD pilot unit



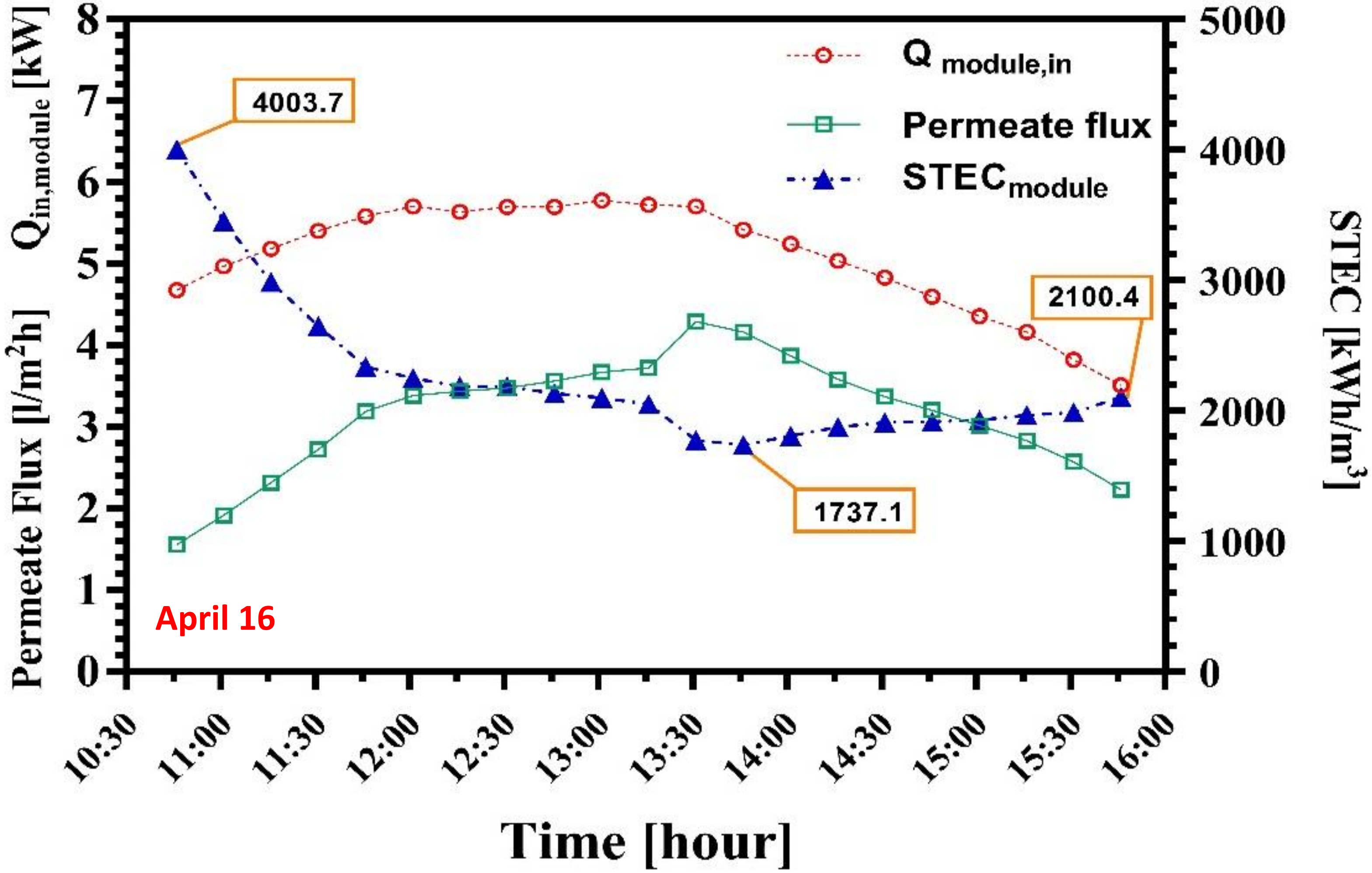
Effect of feed TDS on permeate flux of the SPMD pilot unit



16.5% decrease in the permeate flux when SWRO brine was used instead of tap water. Vapor pressure of water decreases with salt concentration increase.

Specific thermal energy consumption (STEC) of the SPMD pilot unit :

- **STEC values high at the start.**
- **STEC values decreased during the first hour of operation and reached a minimum of 1737.1 kWh/m³**



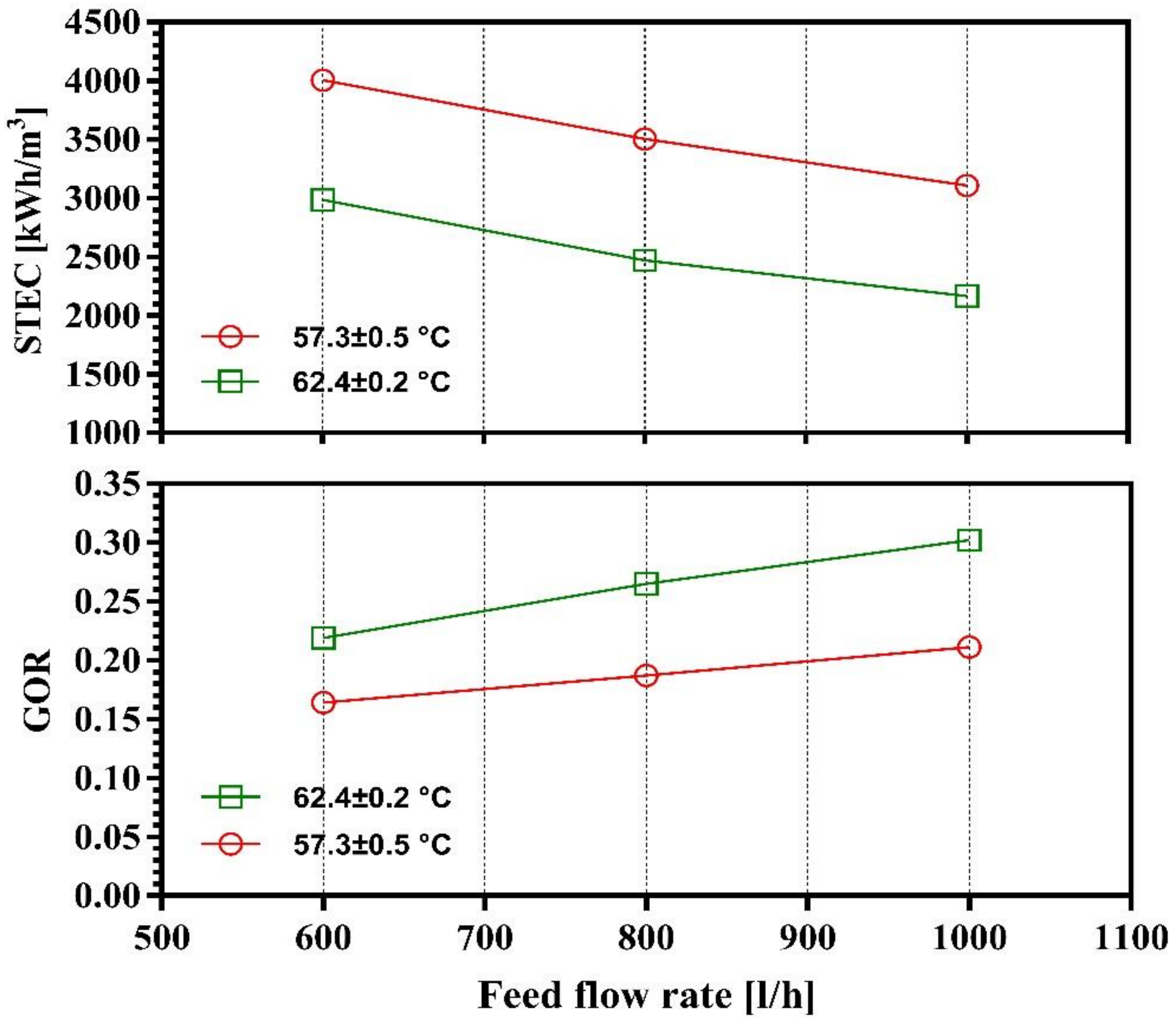
Effect of feed flow rate on STEC & GOR of the SPMD pilot unit :

- Very low GOR values 0.12- 0.37 compared to other thermal desalination processes.
- Low performance and high energy consumption

Limitations

❖ Low permeate flux rates

❖ High conductive heat loss of membrane module



Conclusions

1. The selection criteria for Intermittent operation protocol of SPMD should be based on their effects on the performance parameters and on their suitability for easy operation.
2. The permeate flux was not affected by the type of intermittent operation protocol.
3. The salt rejection is affected by the selected protocol and was low in case of drain without wash Protocol.
4. The on/off Protocol was not only the easiest protocol but was also the best protocol with regard to performance parameters.
5. The performance of hollow fiber DCMD module when operated on SPMD pilot system in terms of productivity and energy consumption was low.

شكرا لكم

Thank You

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