Oil Spill Management to Prevent Catastrophic Shutdown of Desalination

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Overview

- 1. Research background
- 2. QEERI research for oil/water separation technologies
- 3. Conclusion & recommendation

1. Research background

Country	2005		
	Desal Production (mcm)	Domestic Demand (mcm)	Desal to Demand ratio (%)
Bahrain	122.7	133	92
Kuwait	589.1	610	96.5
Oman	67.932	170	40
Qatar	250.13	252	99
Saudi Arabia	1,063.28	2,458	43
UAE	812.61	951	85
Total	2,905.75	4,574	63.5

Countries	Causes	Consequences
United Arab Emirates (UAE)	Diesel spilled from a damaged tanker (1997) A spreading oil slick from a sunken barge (1998) An oil slick reached the emirate's beaches from the sunken tanker Zainab. (2001) Oil spill in the Arabian Gulf off the west coast of UAE reached the Al-Fujairah coast (March 2017). Oil spill after attacks on 4 oil tankers in UAE waters (2019) UAE oil spill causes 2km of damage Thick layer of oil affected a major desalination plant at Fujairah (2013)	Shut down a water desalination plant and left Sharjah emirate without water for a day. Forced Emirates of Sharjah and Ajman to close two desalination plants, Al Liyya Water Desalination Plant was temporarily shut down to protect the inlets of the plant. Fujairah oil spills caused by tankers illegally cleaning their holds. Bunker spill from one of the four vessels attacked near Fujairah emirate. It affected a major desalination plant at Qidfa.
Saudi Arabia	Oil spilled during Persian Gulf War (1991) Oil spills brought under control at Yanbu Port. (2022)	Shut down a desalination plant that provides drinking water to millions of people. Authorities shut the desalting plant at Safaniya. Pollution caused by an oil leak in Jeddah.
Kuwait	Oil spilled from an offshore oilfield (2017)	Shut down the desalination plant for two days.
Egypt	Clean-up efforts in Egypt's Red Sea under way following oil spill (Aug 2022)	Jordan's official news agency Petra reported an oil spill at the berth of a container terminal in the port of Aqaba. Preliminary investigations determined that the spill had been caused by a docking ship in the area.
Yemen (2015 – 2022)	***Very near miss*** The FSO Safer tanker had been rusting away off Yemen's coast since 2015. It threatened to release roughly four times the amount of crude oil spilled off Alaska in the Exxon Valdez disaster of 1989.	

Qatar only has a few days' strategic water storage in case of emergencies

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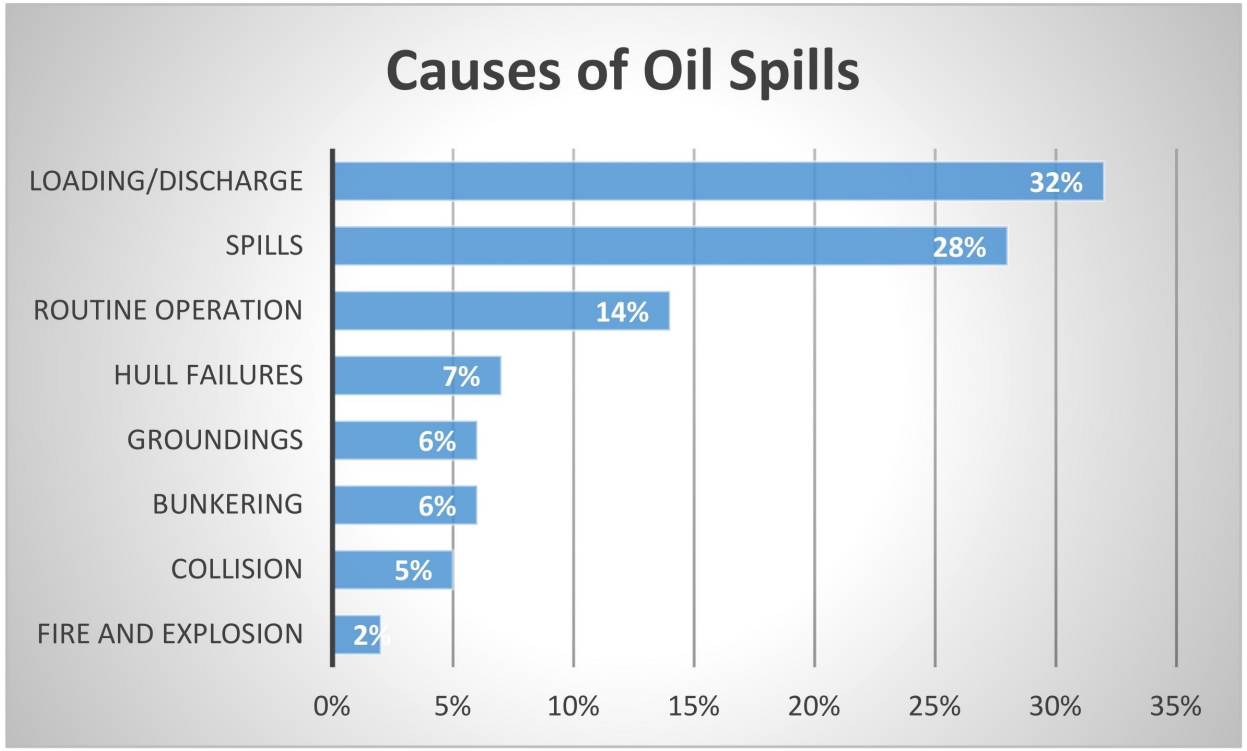


Fig. 1. Different causes of oil spills

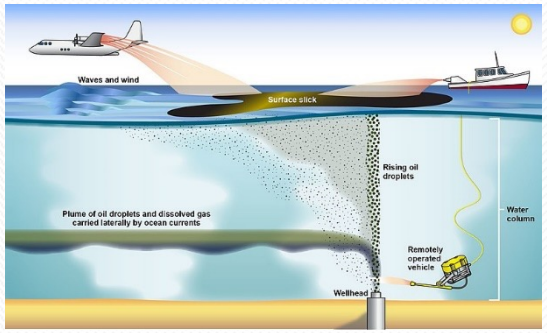
No	Form	Size
1	Free Oil	> 150μm
2	Dispersed Oil	20–150μm
3	Emulsified Oil	< 20μm
4	Dissolved/Soluble Oil	< 5μm
5	Oil-wet solids	–

Table. 1. Various forms of oil existing in water

Offshore oil spill response measures

Oil spill responses

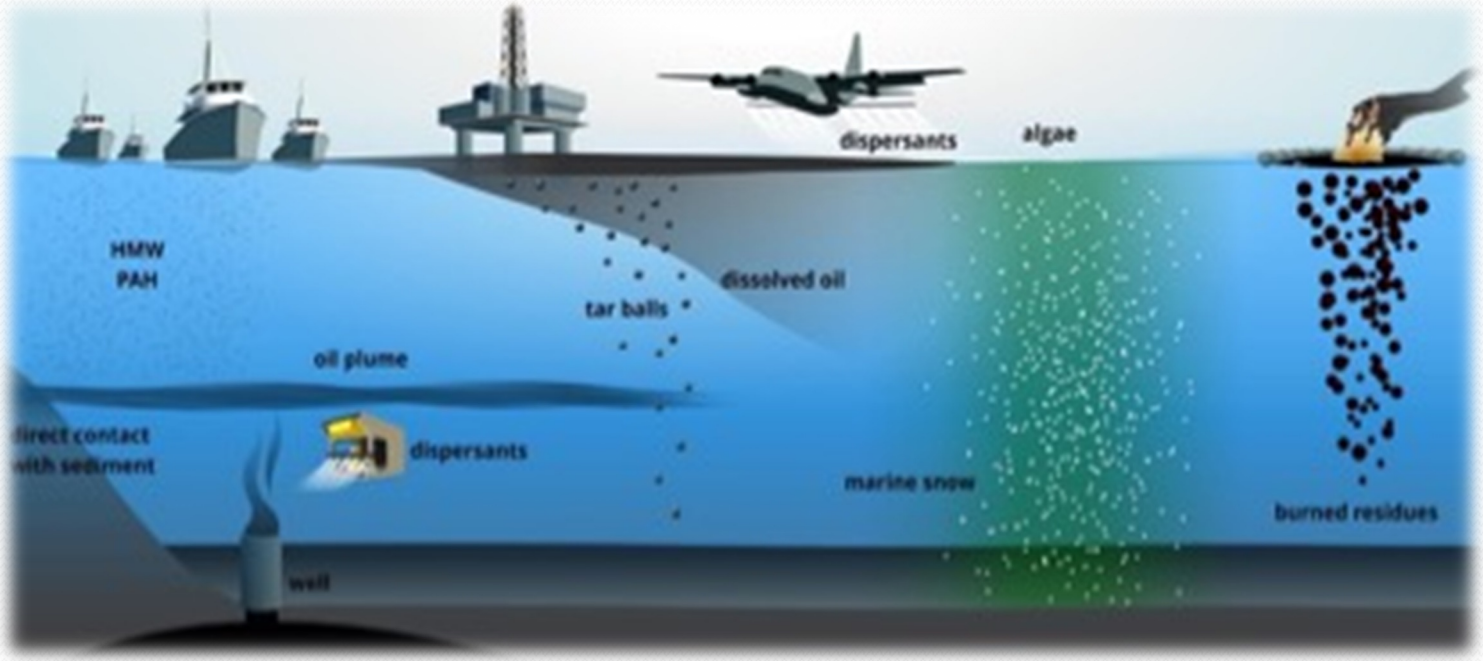
- Booming + skimming



- Chemical dispersant

https://en.wikipedia.org/wiki/Boom_%28containment%29

The fates and transport routes of spilled oil



Oil drops are dispersing into the water column and reaching the seabed, where sea water is taken as feed water for desalination plants.

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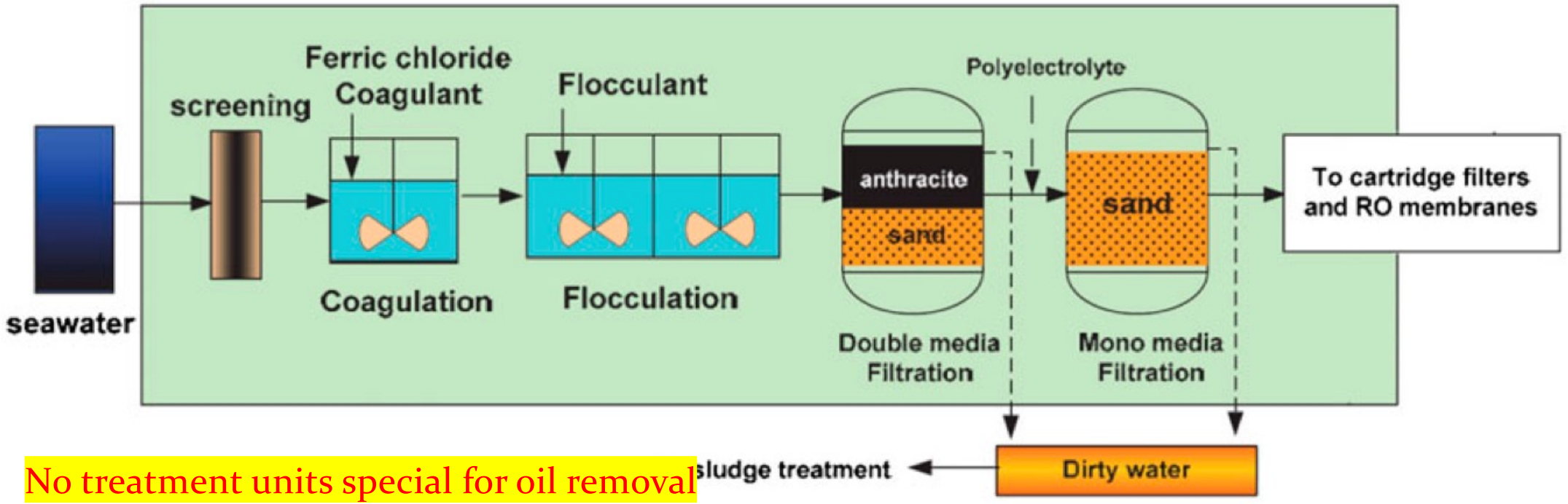
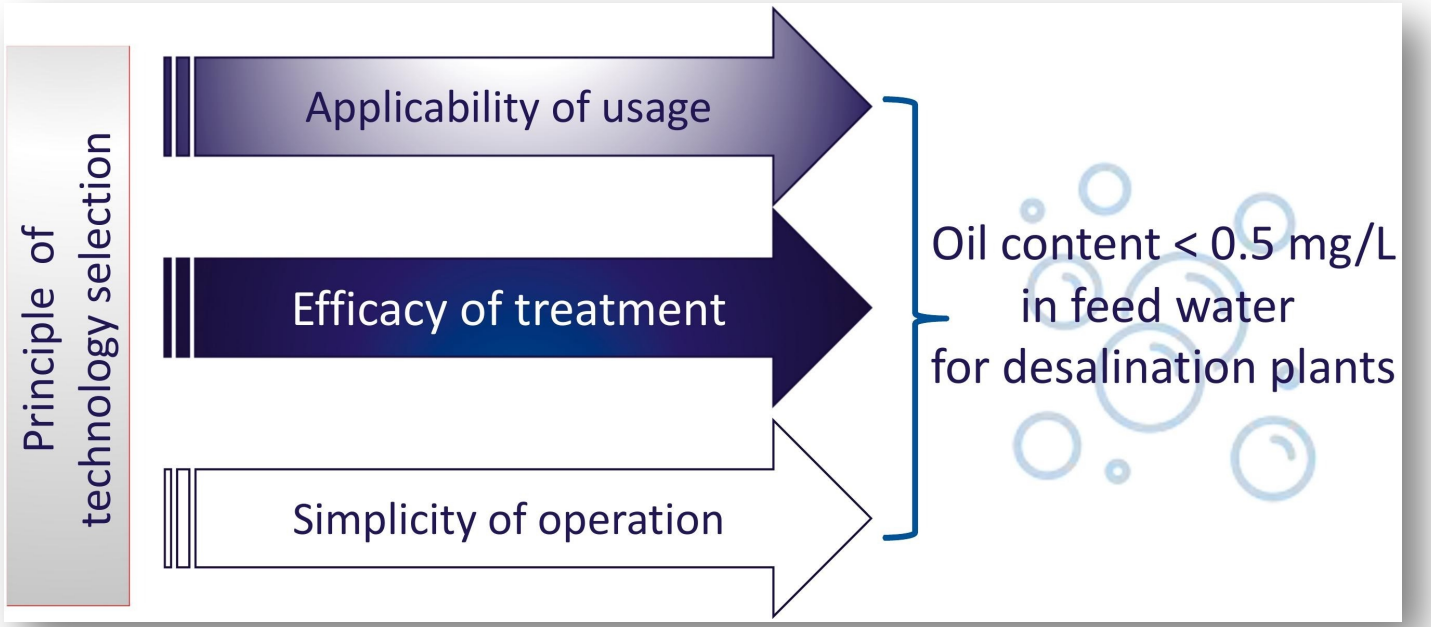
Onshore *pre-treatment process for feed water in Qatar's desalination plant*

10.1080/19443994.2014.989921



No treatment units special for oil removal

It is essential to develop effective & comprehensive oil spill response measures, including all the aspects of offshore cleanup, seawater intake and onshore pretreatment,
to prevent desalination plant shutdown.



The team comprehensively analyzes various oil-removing technologies from the aspects of (1) offshore oil spill cleanup, (2) seawater intake, and (3) onshore pretreatment. A robust strategy with the integration of all aspects is recommended to protect the seawater quality and desalination facilities, with the objective to prevent desalination plant shutdown during oil spill incidents.

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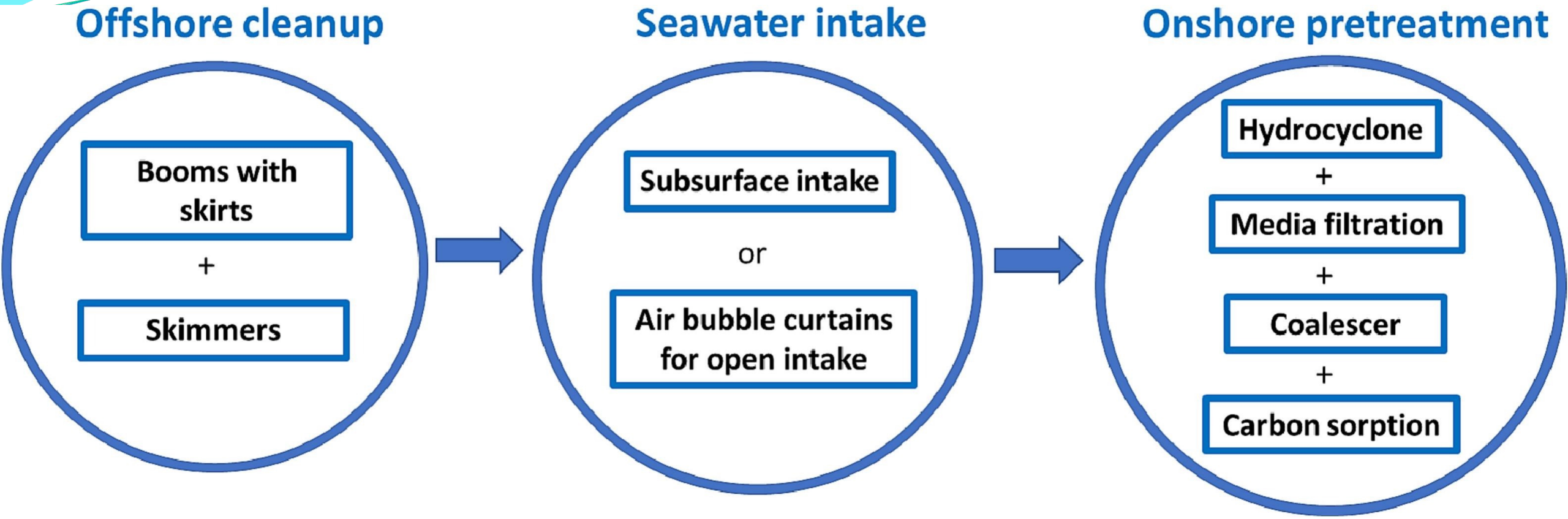

Fig. 24. Summary of the recommended technologies to build a comprehensive and robust process to prevent desalination plant shutdown during oil spill incidents.

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Desalination

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Oil spill management to prevent desalination plant shutdown from the perspectives of offshore cleanup, seawater intake and onshore pretreatment

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2.

QEERI research for oil/water separation technologies

2.1

New environment-friendly processes for oil/water separation

Problem identification

Air flotation process adopted by Qatar Energy to treat produced water

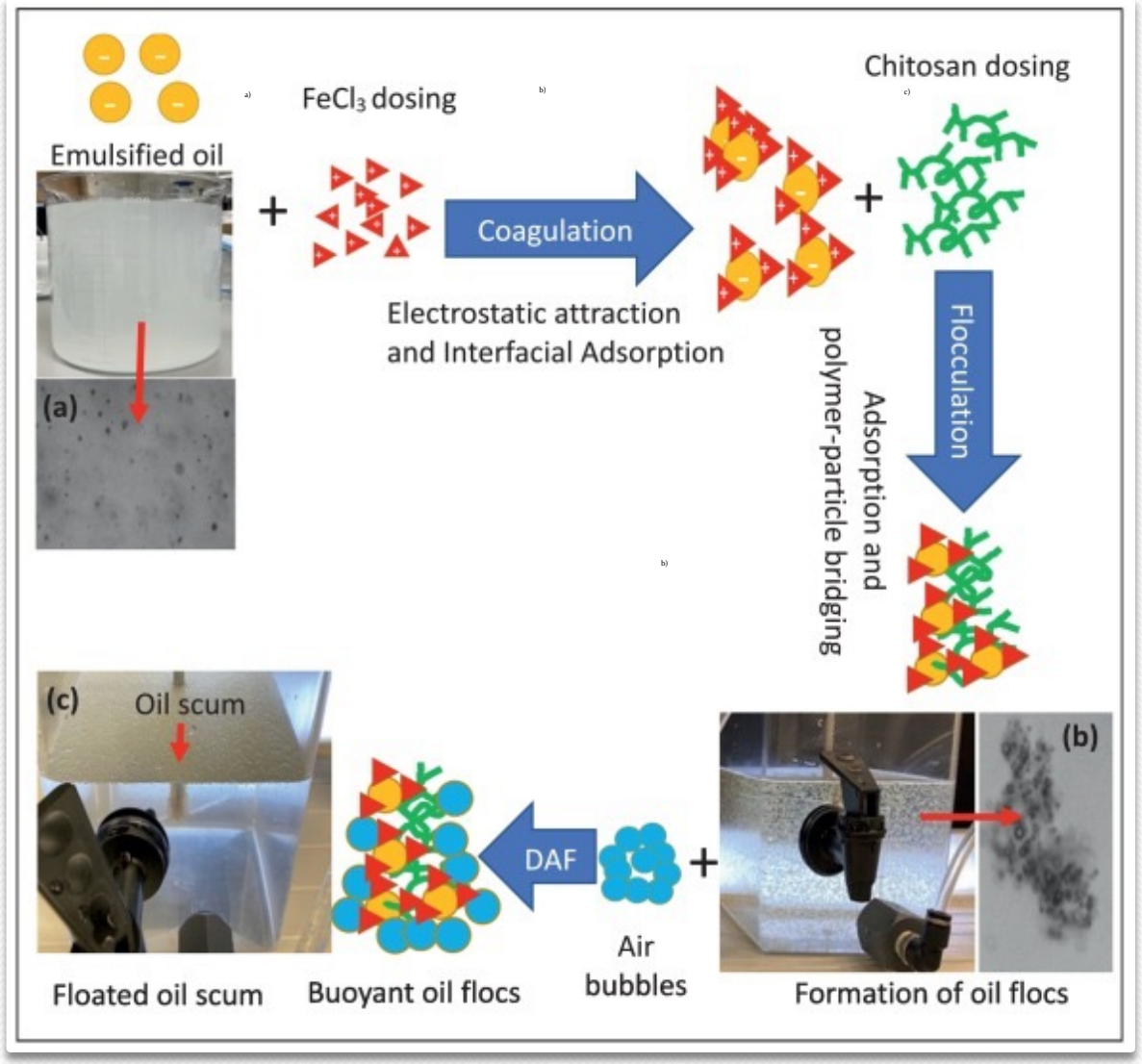
Coagulation/flocculation/air

Figure 1. Halul island, operated by Qatar Petroleum, serves as the crude oil export terminal for Qatar marine crude oil produced from offshore oilfields.

Figure 2. Gas flotation equipment used for oil/water separation in Qatar. https://www.alderley.com/press-releases/alderley-delivers-another-complete-produced-water-package-qatar/

Proposed solution

Figure 3. The issue with current air flotation process: the brown color of treated effluent, which is stained by the industrial coagulants (ferric chloride), and non-biodegradable sludge



Journal of Water Process Engineering, Volume 47, June 2022, 102836, https://doi.org/10.1016/j.jwpe.2022.102836

hybrid coagulant/flocculant system with ferric chloride as coagulant and chitosan as bio-degradable flocculant

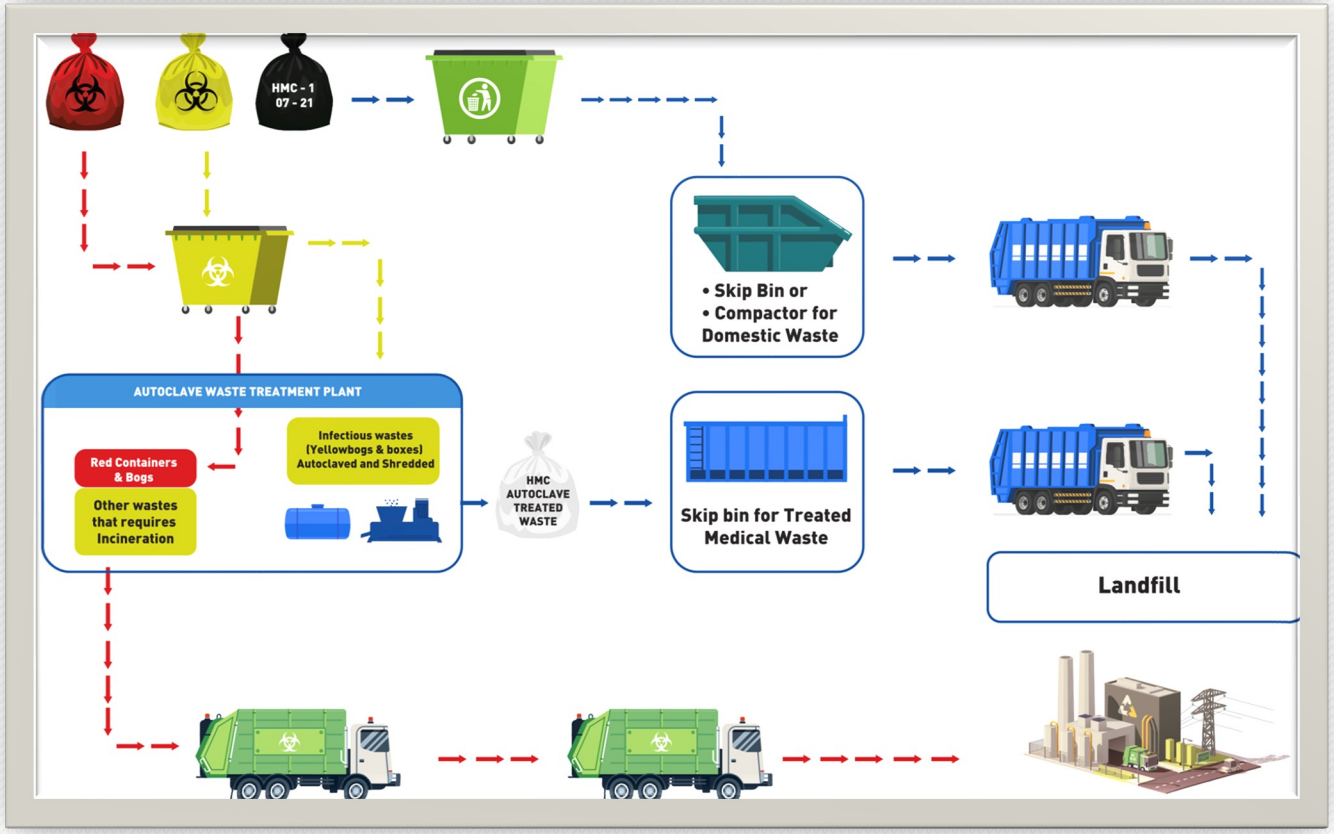
2.2

Turning medical waste materials to valuable product

- Circular economy

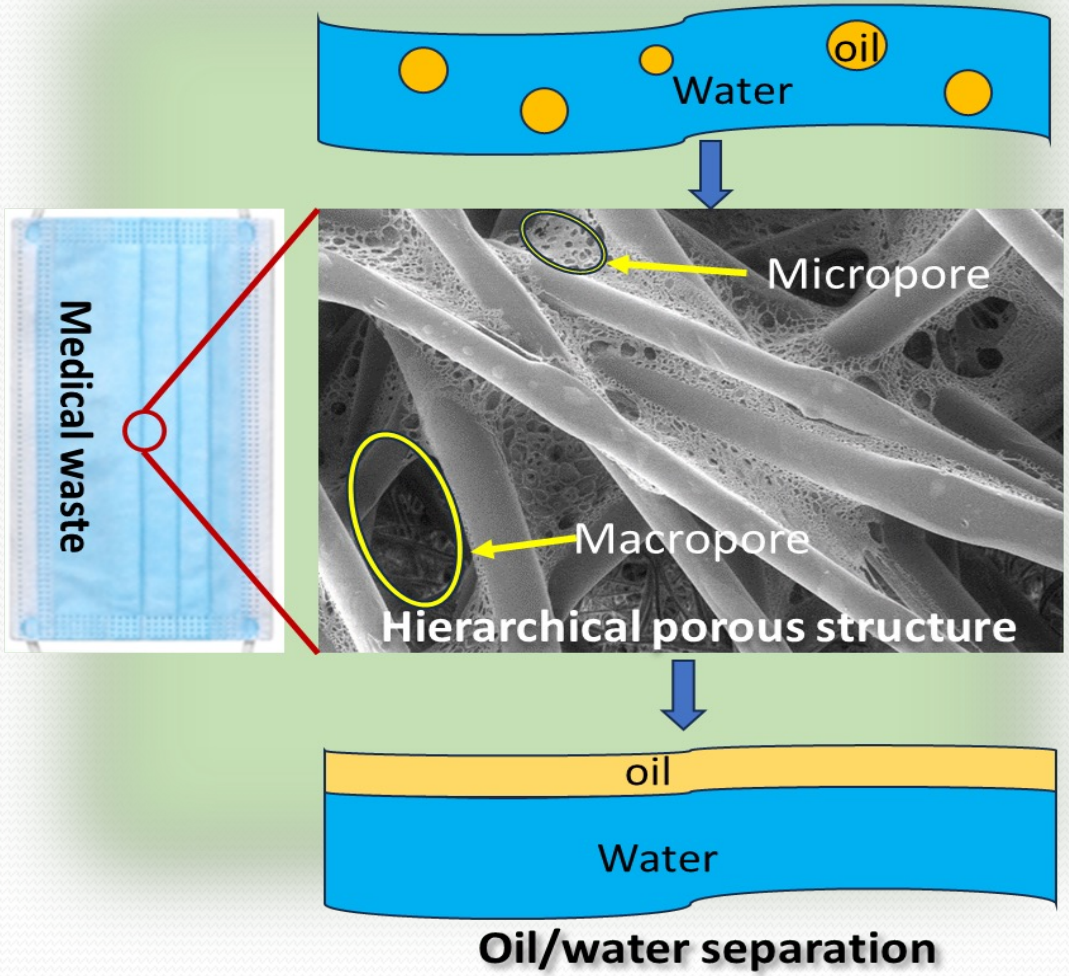
Large amount of medical waste without beneficial reuse

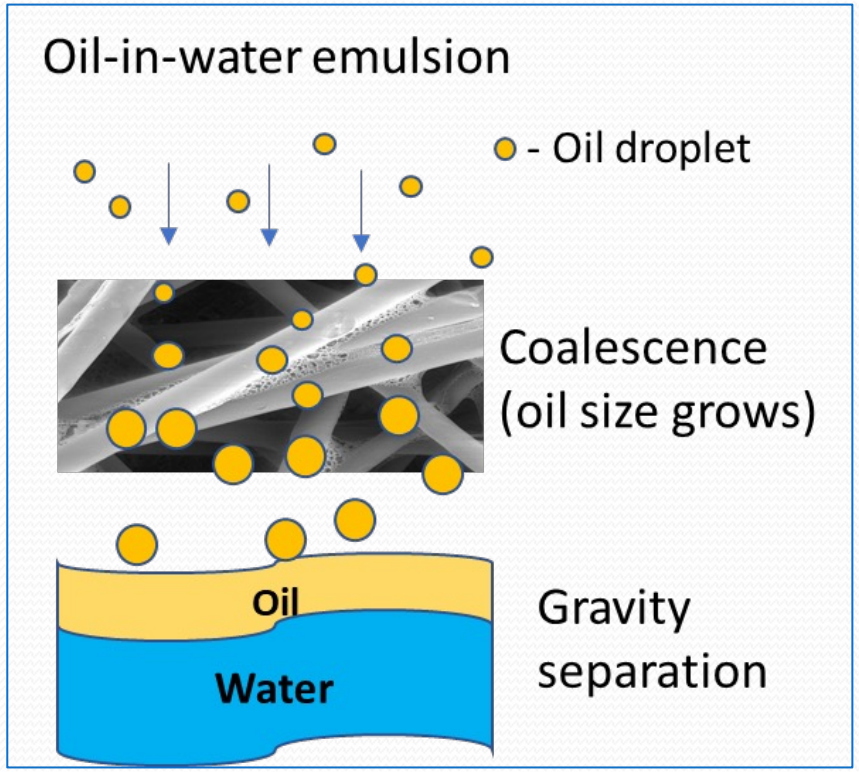
3.4 billion face masks or face shields are discarded every day.



https://www.sciencedirect.com/science/article/pii/S2667010021000184

Application - as coalescence media for oil/water separation





2.3

Inorganic nanofiber-based membranes for oil/water separation

Issues for commercial membranes

1. low water flux

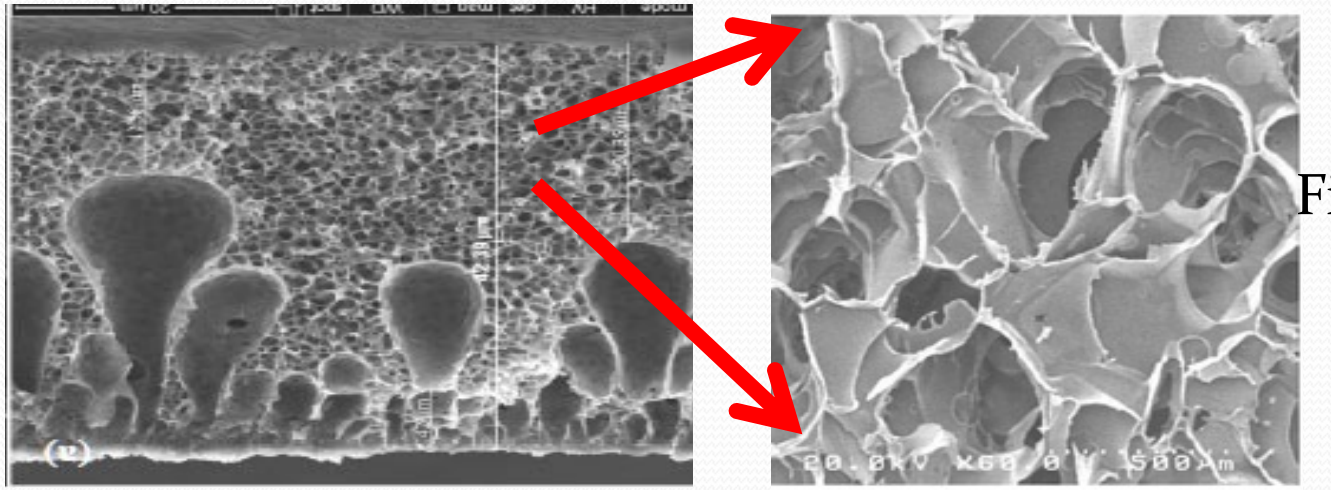


Fig. 1. Segregated pore structures

2. membrane fouling

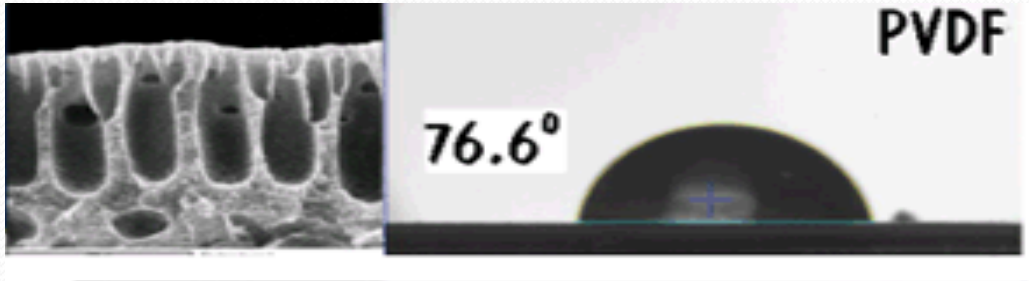


Fig.2. Hydrophobic (oleo-philic) materials

Type 1: Asymmetric membrane with inorganic nanofibers/polymeric microfibers

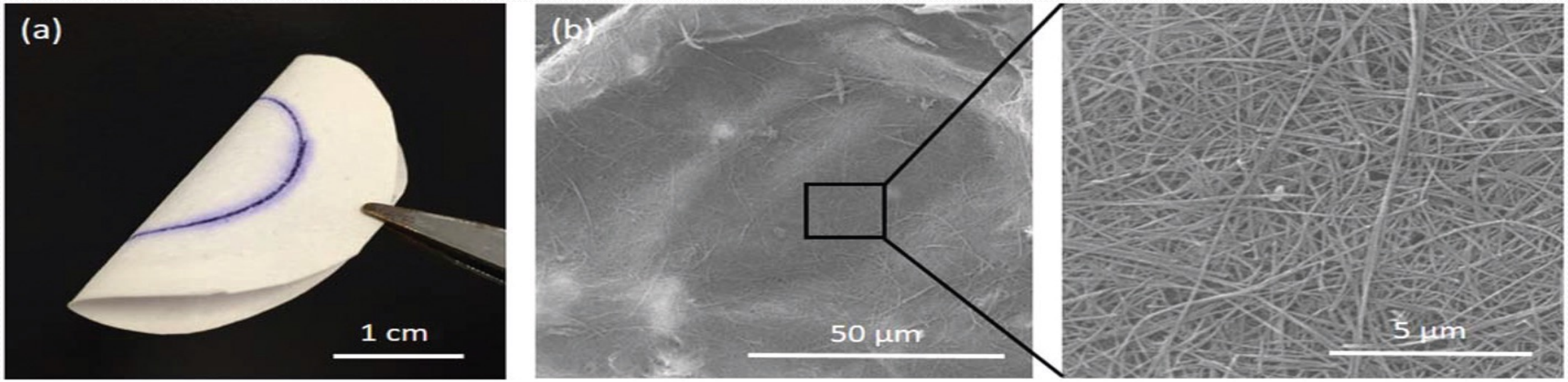


Fig. 3. new membranes with ultra-long (> 30 µm) titanate nanofibers coated on top of commercial cellulose microfiber substrates.

Fig. 8. Schematic of two-layer structure of the new membrane

Nanoscale, 2017,9, 9018-9025, https://doi.org/10.1039/C7NR02364B

Type 2: Symmetric membrane with ZnO nanorods on woven carbon cloth

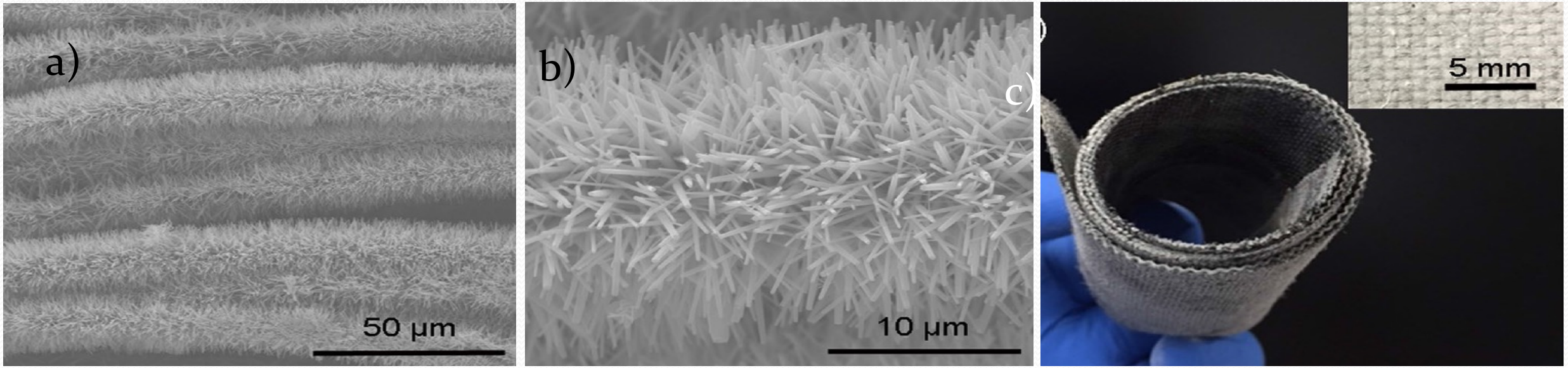


Fig. 4. (**a**). SEM image of the fabricated membrane (ZnO nanorods on carbon cloth). (**b**) enlarged SEM image of a single carbon fiber with grown ZnO-NRs, (c). Photo image of the fabricated membranes, showing its flexibility.

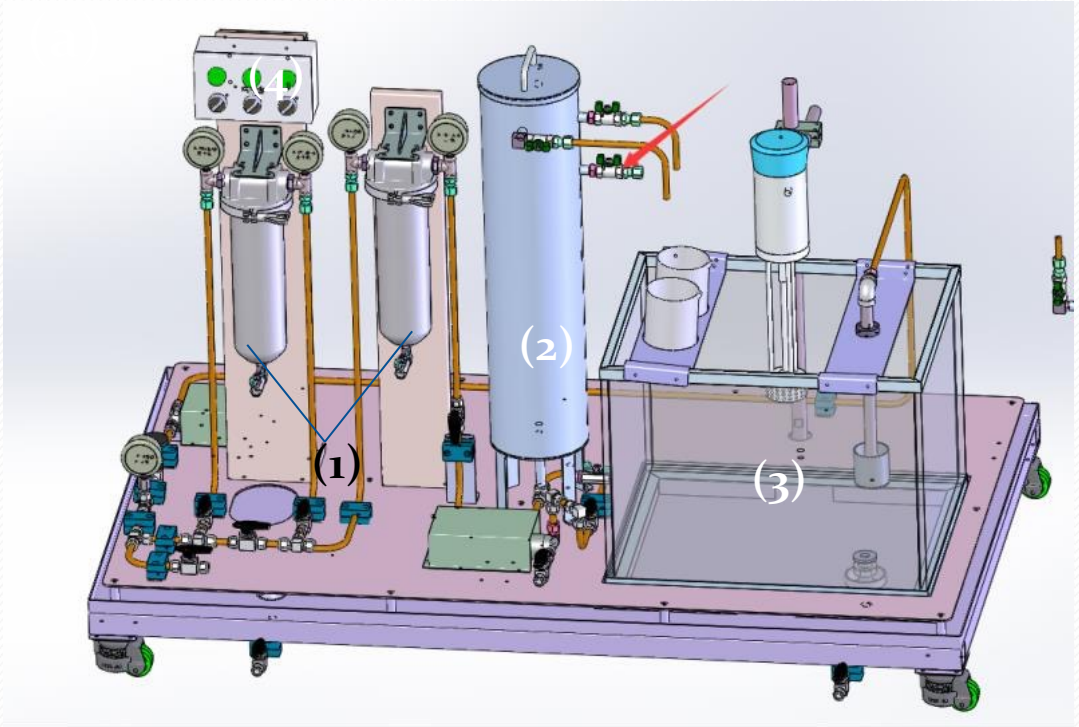
Scientific Reports, volume 7, Article number: 16081, https://doi.org/10.1038/s41598-017-16402-5

	Remarks / Descriptions
29 Peer-Reviewed journal paper publications	**Environ. Sci. & Tech. (IF: 11.4),** **Desalination (9.9),** **Sep. Puri. Tech. (8.6),** **J. Mat, Sci. (11.9),** **Small (15),** **J. Mem. Sci. (9.5), etc.** https://scholar.google.com/citations?hl=en&user=qPGr6UoAAAAJ&view_op=list_works&sortby=pubdate
10 patents filed	(1) United States Provisional 63/033,432 Jun 2, 2020 (2) United States Provisional 63/026,315 May 18, 2020 (3) Oman National OM/P/2019/00392 Sep 30, 2019 (4) Europe National 17903908.6 Oct 29, 2019 (5) China National 201780082956 Sep 30, 2019 CN 110799259A Feb 14, 2020 (6) Qatar National QA/201909/000516 Sep 30, 2019 (7) United States National 16/499,856 Sep 30, 2019 (8) United States Provisional 62619556 Jan 19, 2018 (9) Not Applicable (PCT App) PCT/QA2017/050002 (10) Not Applicable (PCT App) PCT/QA2017/050001 Mar 30, 2017,

2.4.

Prototyping for water treatment technologies

4.1 pilot skid with chemical-free coalescence process for oil/water separation



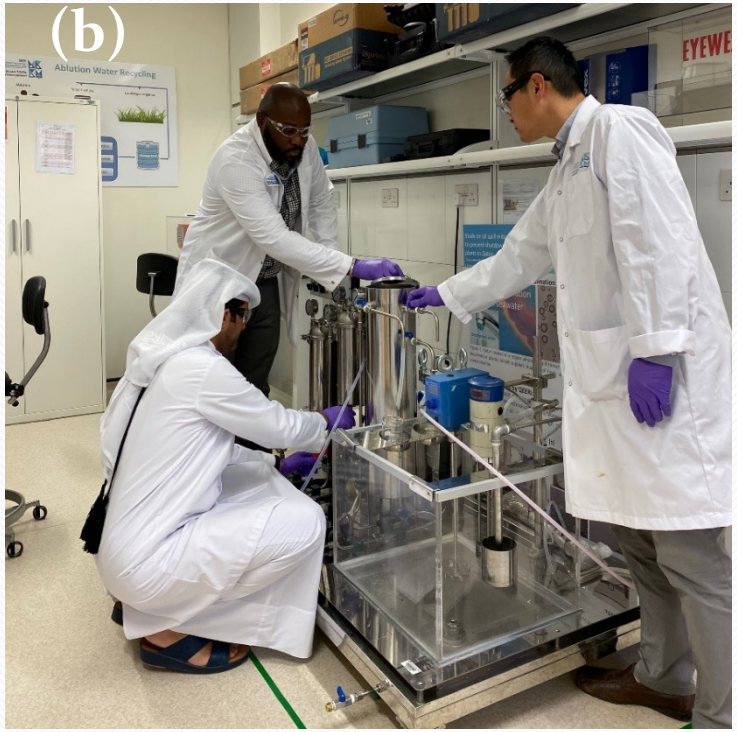


Figure 1. (a) Schematic diagram of pilot skid with coalescence and flotation units for oil/water separation. Wherein, 1. coalescence units, 2. flotation unit, 3. emulsion tank, 4 controller. (b) Modifying and Commissioning of the pilot skid in high bay lab.

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Conclusion and Recommendations

- The operation of desalination plants is very sensitive to the quality of feed water that is influenced by several factors, including the quality of raw seawater, seawater intake procedures, and onshore pretreatment methodologies.

- Existing desalination plants must be re-evaluated and re-designed on the basis of all these factors for oil contaminate removal and to guarantee the quality of feed water in the circumstances of oil spills.

- Since most oil spills happen by accident, and nobody can predict how badly, where, or when they will happen, therefore, the robust oil spill management plan to prevent desalination shutdown must put all the aforementioned factors into consideration.

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