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Managing Water in the West

Use of Ceramic Membranes for Produced Water Treatment

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Bureau of Reclamation

Outline

- Why use ceramic membranes for produced water treatment
- Benefits and limitations of ceramic membranes
- Comparison of ceramic and polymeric membranes
- Ceramic membrane manufacturers and products
- Use of ceramic membranes for produced water

Treatment of Produced Water

Degree of treatment depends on raw water quality and desired end use

Domestic Home Use

Surface Discharge

Livestock & Crop Irrigation

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Pretreatment Technologies

- Current approaches:
  - Dissolved air flotation
  - Media filtration
  - Polymeric membranes
- Novel approaches:
  - Ceramic microfiltration and ultrafiltration
  - Membrane distillation

CeraMem®

(Hydroflow™)

Hydroflow™

Degremont

Treatment Design Criteria

- Geographical issues
  - Minimal Maintenance
  - Easy to operate
  - Robust and reliable
- Changing water quantity and quality
  - Flexible
  - Modular
- Cost
  - Minimal pretreatment
  - Low chemical and energy demand

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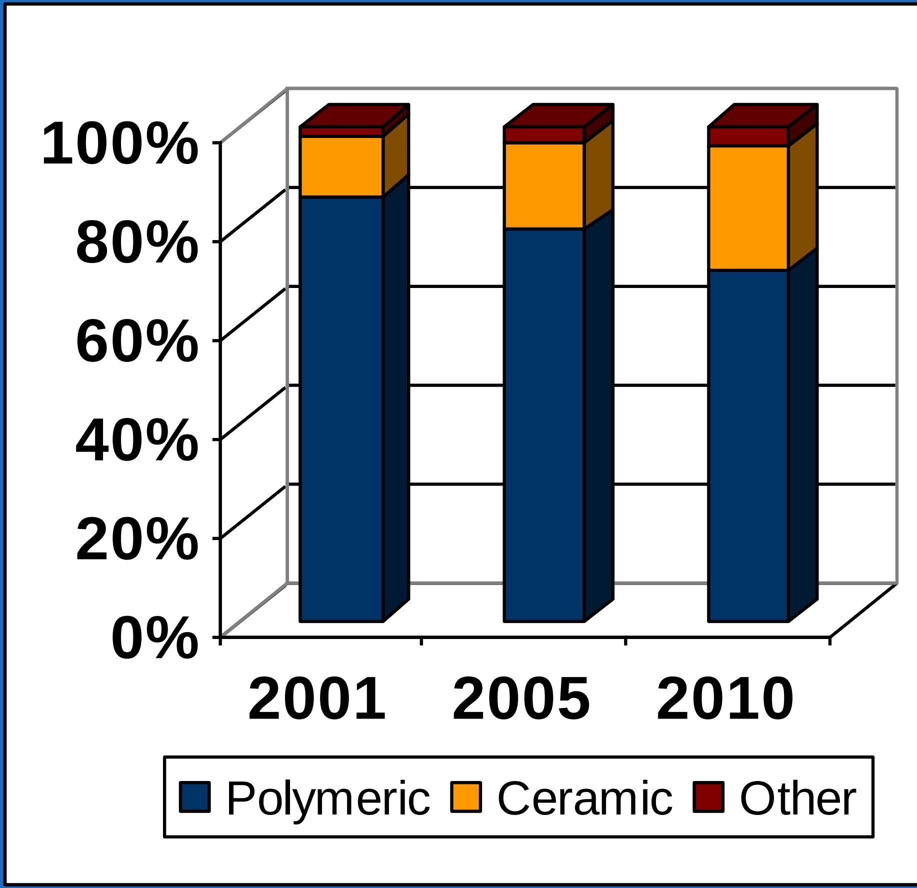
Benefits and Limitations of Ceramic Membranes

- Benefits
  - High mechanical strength
  - High chemical compatibility
  - High flux (up to 300 gfd)
  - Long operational life
  - Thermal stability
  - Potentially lower life-cycle cost
- Potential limitations
  - High capital cost

Membrane Filtration Market

The ceramic membrane market share is expected to grow in future years!

Advances in materials, configuration, and operational experience will make ceramic membranes more widely used.



Data from Pall Corporation

Membrane Transport Properties

	Pure Water Permeance ($L/m^2/hr/Pa$)	Membrane Resistance (1/m)
Ceramic UF	1.3 ± 0.1	$2.2 \times 10^5 \pm 0.2 \times 10^5$
Polymeric UF	0.87 ± 0.08	$2.3 \times 10^6 \pm 0.2 \times 10^6$

- Ceramic membranes have significantly higher permeance and lower membrane resistance than polymeric membranes
- Ceramic membranes have a lower membrane resistance, therefore require a lower pressure to produced the same volume of water

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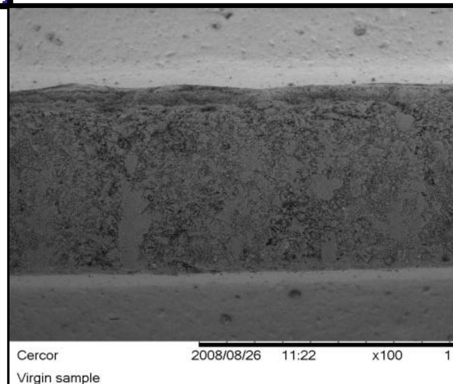
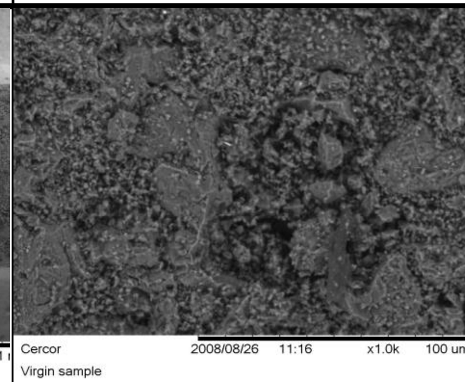
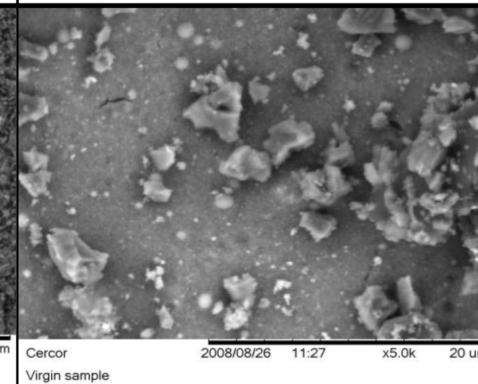
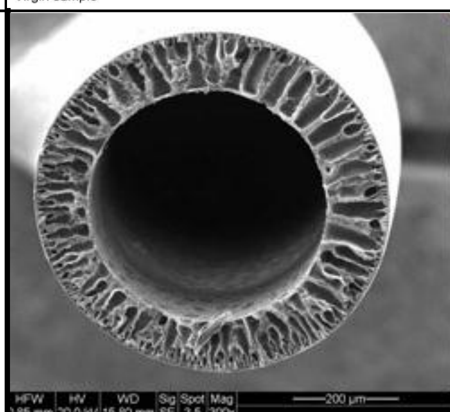
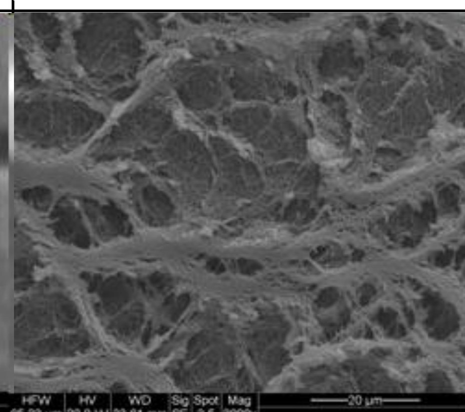
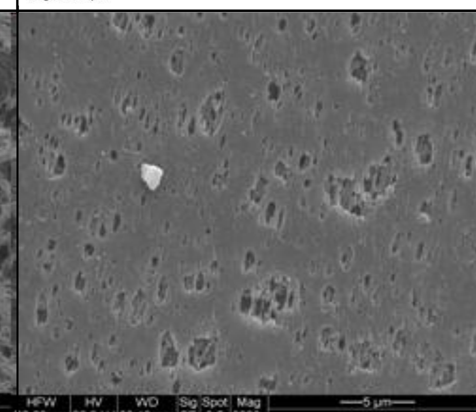
Cost Comparison

	Material Cost ($/ft^2)	Material Cost ($/vol produced)
Ceramic UF	180	60
Polymeric UF	40	20

- Fewer ceramic membranes are required to treat the same volume of water
- Ceramic membranes have higher capital cost but longer lifespan

SEM: Ceramic and Polymeric

	Membrane and Support (100x – 300x)	Support (1000 – 3000x)	Membrane Surface (5000x)
Ceramic UF Membrane			
Polymeric UF Membrane **Spintek™** www.spintek.com			

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Ceramic Membrane Manufacturers*

	Product Line(s)	Filtration Range	Support Materials	Membrane Materials	Channel Configuration
Pall	Membralox® Schumasiv®	5nm to 0.2 µm	Al_2O_3	Al_2O_3 (MF) ZrO_2 and TiO_2 (UF)	Hexagonal and round
Corning	CerCor®	5nm to 0.2 µm	Mullite ($3Al_2O_3 \cdot 2 SiO_2$)	ZrO_2 (MF) TiO_2 (UF)	Square and round
TAMI	Ceram Inside®	0.02 µm to 1.4µm	ATZ	ZrO_2 (MF) TiO_2 (UF)	Flower shaped
Atech	Atech	0.01 µm to 1.2 µm	Al_2O_3	Al_2O_3 (MF) ZrO_2 and TiO_2 (UF)	Single or multiple round
Orelis	Kerasep™	5 kDa to 0.8 µm	Al_2O_3	ZrO_2 and TiO_2	Single or multiple round

***Not a complete list**

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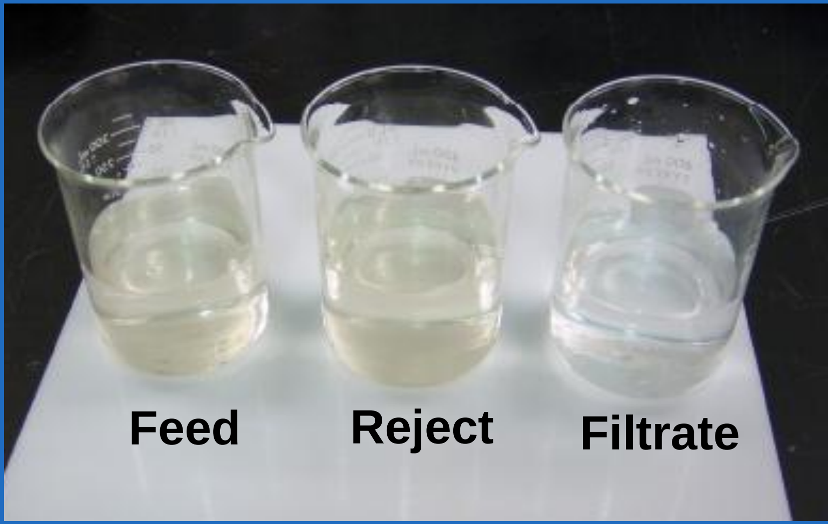
Contaminant Removal Capability

- What they will remove
  - Suspended solids
  - Oil and grease
  - Organic carbon (to some degree)
  - Metal oxides
- What they will NOT remove
  - Dissolved ions
  - Dissolved organics



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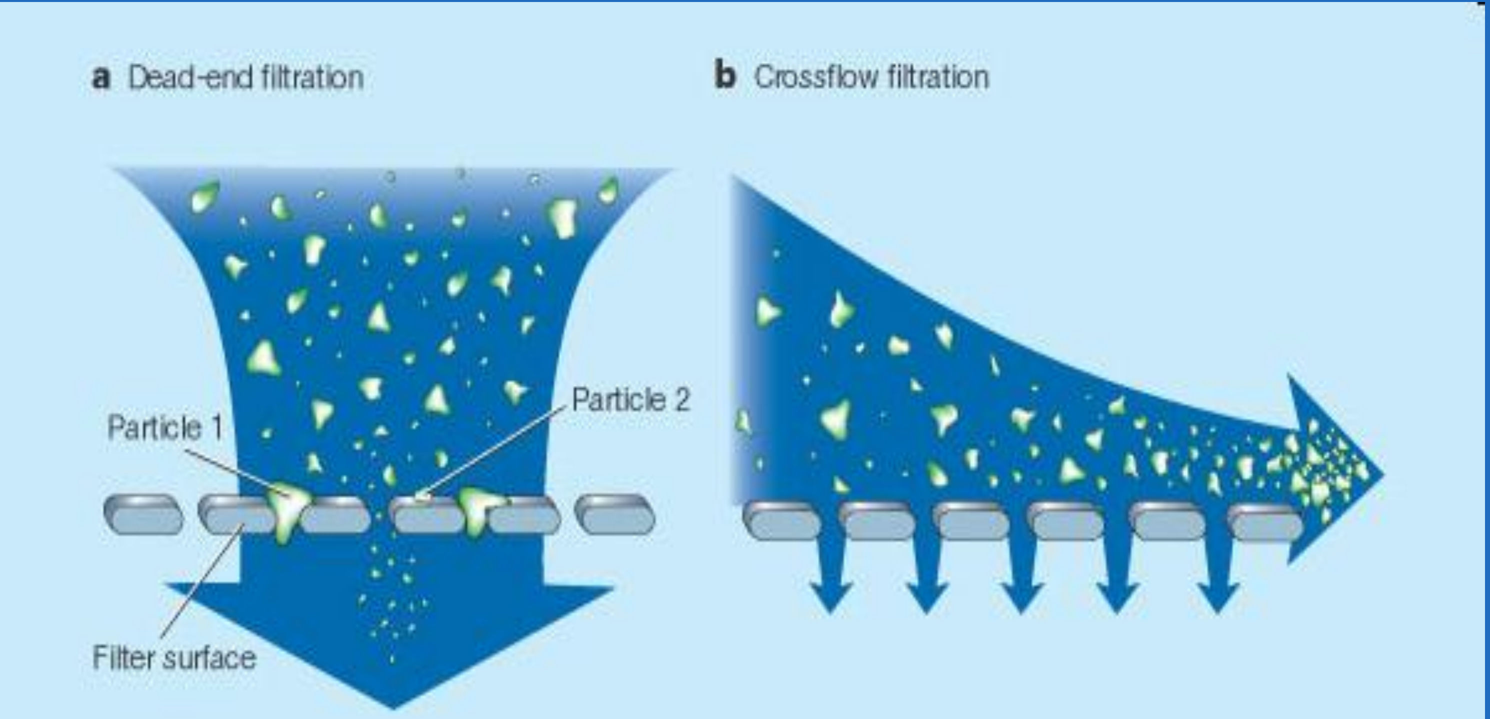
Ceramic Membrane System Operation

- Dead-end versus cross-flow filtration



Elizabeth L. Brainerd, Nature 412, 387-388(26 July 2001)

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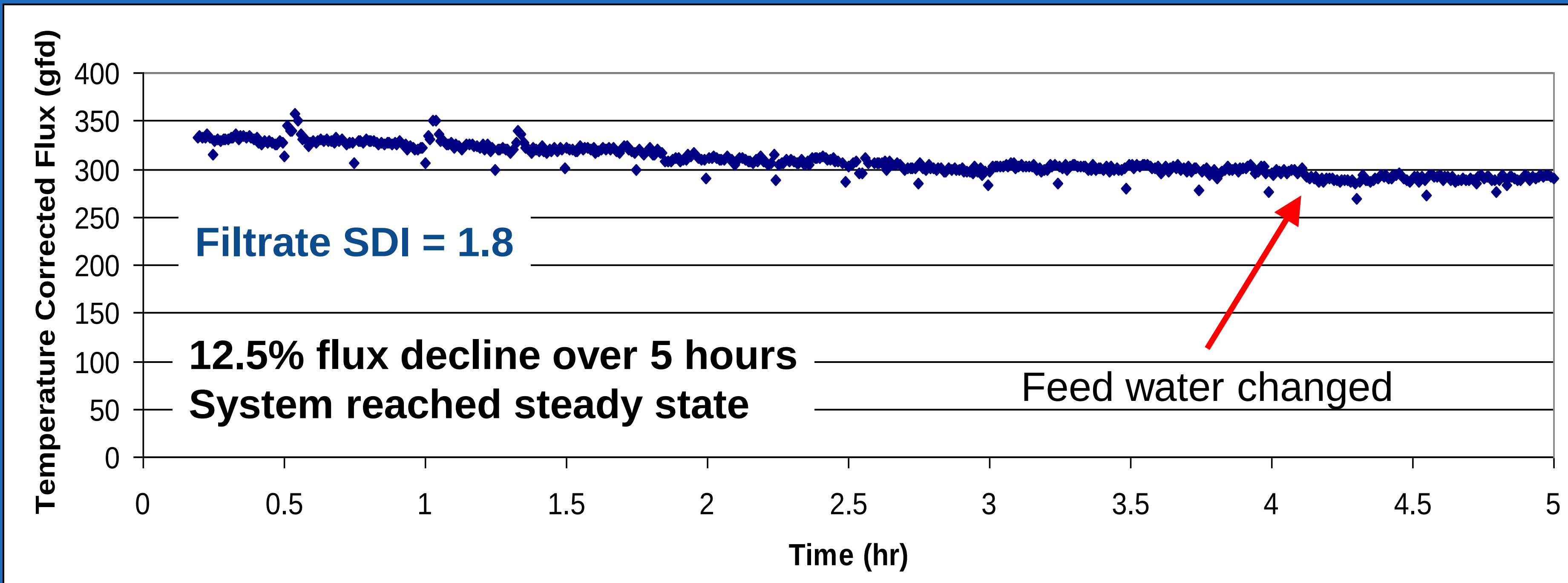
Important Operating Parameters

- Flux: volumetric flow rate of product water per area of membrane
- Trans-membrane pressure: average of feed and reject pressure minus filtrate pressure
- Cross-flow velocity: Velocity of water moving through membrane channel
- Backwash or backpulse: flow of water from the filtrate size to the feed size, rather than the feed side to the filtrate
- In-line coagulation: dose of coagulant in the feed stream with no flocculation or settling; formation of pin-sized floccs that are more easily rejected by the membrane and increase the rejection of dissolved organics

CBM Produced Water Raton Basin



Membrane Specs:	Feed Water:	Operating Conditions:
85 channels	TDS = 2300 mg/L	TMP = 60 psi
cylindrical channels	TOC = 0.27 mg/L	Crossflow = 0.46 ft/s
0.01 um pore size	TSS = 0.7 mg/L	Full recycle
	Total Fe > 0.3 mg/L	Backwash every 15 min
	SDI = 18	No coagulant

Full-Scale Ceramic Membrane Treatment of Produced Water

- Ceramic membranes used to remove organic contaminants approximately 1 to 3 um in size and as pretreatment to RO
- System configuration:
  - cross-flow velocity = 10 fps
  - backpulse every 90s
  - chemical cleaning every 24 hrs
- Filtrate SDI < 1, suitable as pretreatment for RO

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Summary

- Ceramic membranes are a viable technology for produced water treatment.
- There are a number of different ceramic membrane manufacturers with a wide variety of products to choose from.
- Ceramic membranes can remove silt, particulates, oil and grease, metal oxides, and some dissolved organic matter.
- Operational conditions of ceramic membranes still need to be optimized for different water types.
- Ceramic membranes have worked effectively at the laboratory scale and full scale for treatment of produced water.

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AQWATEC Advanced Water Technology Center

RPSEA Research Partnership to Secure Energy for America

NWRI-USA National Water Research Institute

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