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Sandia National Laboratories

SANDIA WATER AND ENERGY RESEACH, DEVELOPMENT & DEMONSTRATION

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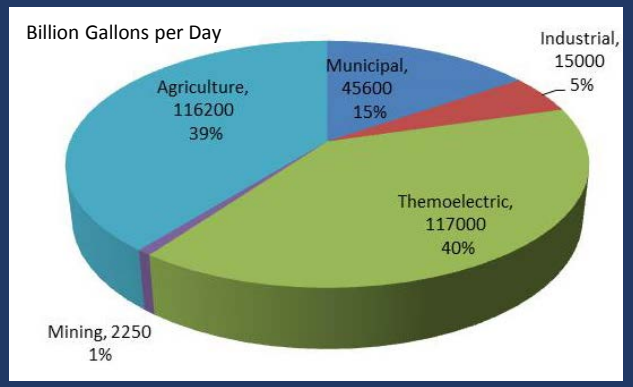
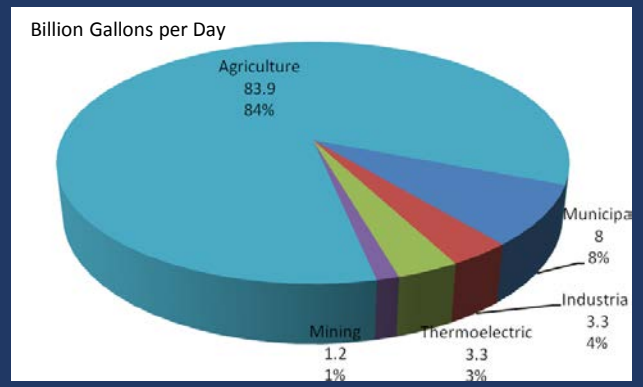
Manager, Geochemistry Department
June 20, 2017

ENERGY-WATER NEXUS PROGRAMS ARE NEEDED FOR A SAFE, SECURE ENERGY FUTURE

Water Withdrawal

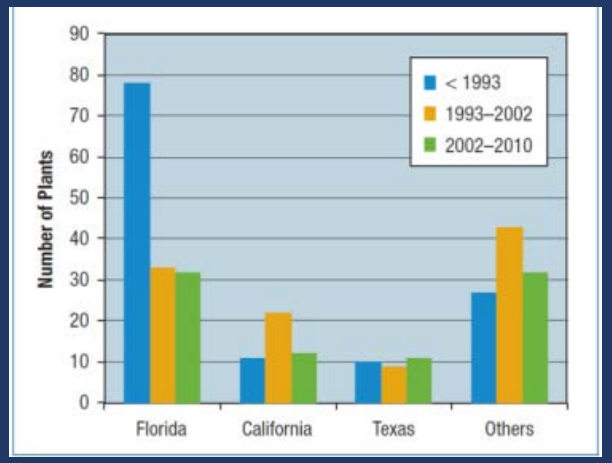


Water Consumption



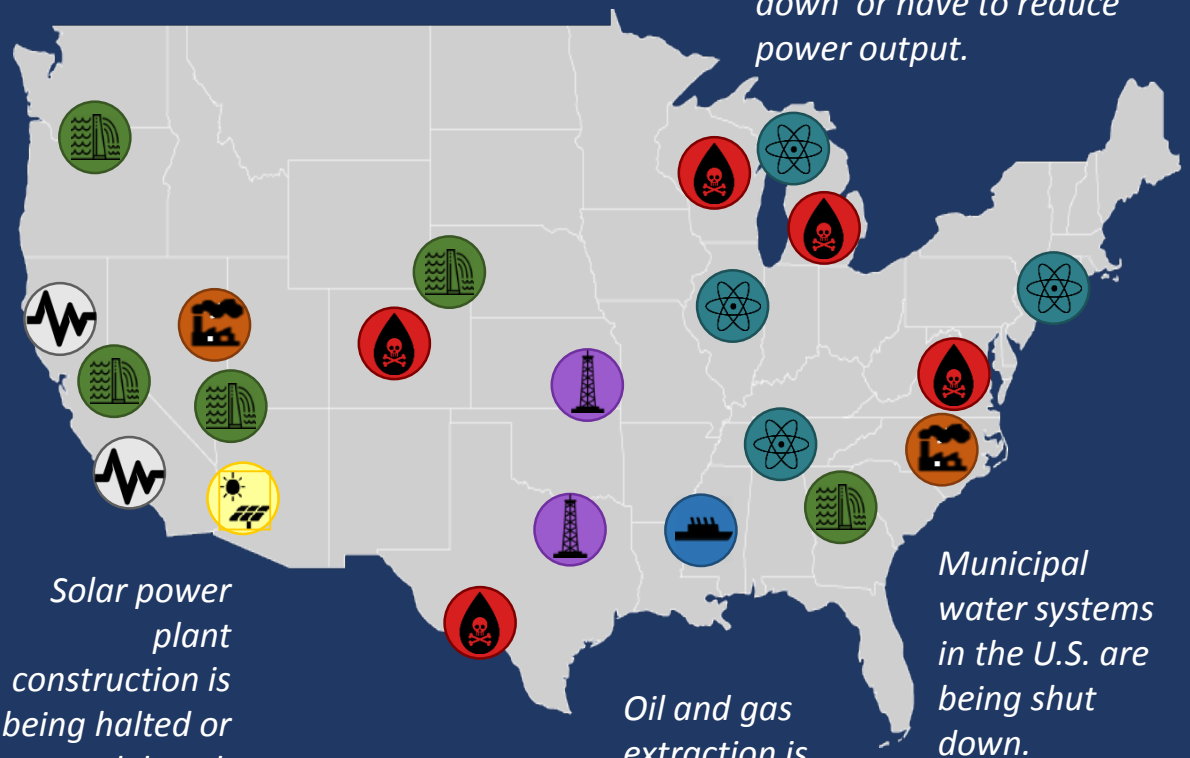
Source: USGS 1995, 2014

Thermoelectric power is the dominant user and significant consumer of water.



There are more than 300 municipal desalination plants in the U.S.

Source: Mickley (2012), Municipal Desalination Plants



Power plants are being shut down or have to reduce power output.

Solar power plant construction is being halted or delayed.

Oil and gas extraction is being curtailed.

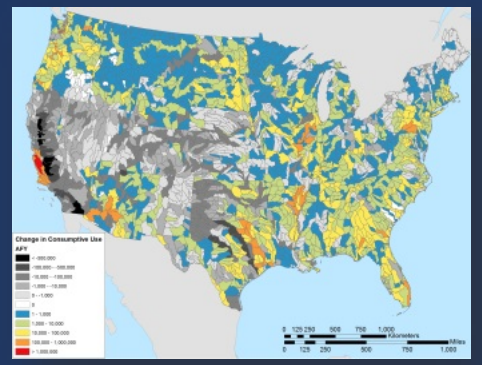
Municipal water systems in the U.S. are being shut down.

Solar Power | Earthquakes | Contamination | Nuclear Power | Hydropower | Coal-Fired Power | Hydrofracking | Barge Delivery

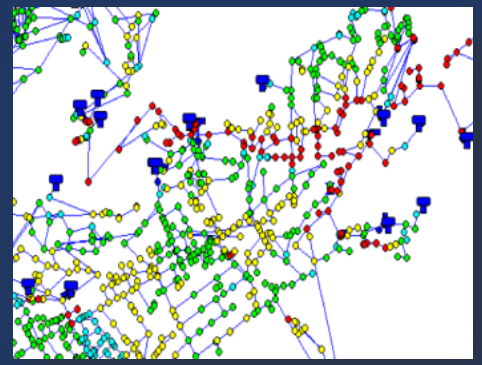
SANDIA'S ENERGY-WATER PROGRAM

Develop advanced technologies that create new water supplies, reduce thermoelectric power demand through efficient water use, and provide climate-coupled water-system planning tools.

DATA MODELING & ANALYSIS



WATER SECURITY



WATER TREATMENT

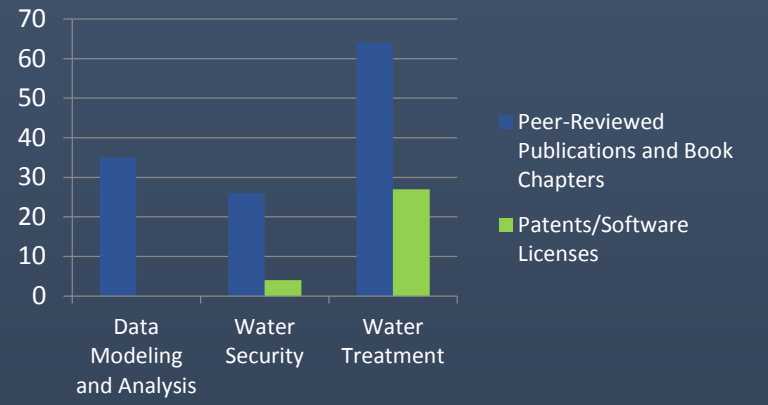
WATERLESS POWER

OUR ENERGY-WATER PROGRAM IS NATIONALLY RECOGNIZED

AWARDS

- 2003 Federal Laboratory Consortium Interagency Partnership Award for RAM-W
- 2008 Finalist for the 2008 Franz Edelman Award
- 2010 R&D100 Award - CANARY- Event Detection Software
- 2011 Federal Laboratory Consortium Interagency Partnership Award for Water Security Research Team
- 2011 R&D 100 Award: Sandia National Laboratories and the University of New Mexico, **Biomimetic Membranes for Water Purification**
- 2012 Federal Lab Consortium for Technology Transfer **National Award:** Excellence in Tech Transfer: Crystalline Silicotitanates
- 2014 Recognized in Environmental Science & Technology's Best Paper Competition
- 2008 COIN-OR INFORMS 2008 Cup award

PUBLICATIONS AND PATENTS



R&D 100

FLC
Federal Laboratory Consortium for Technology Transfer

THE FRANZ EDELMAN AWARD
Achievement in Operations Research

COIN-OR
COMPUTATIONAL INFRASTRUCTURE FOR OPERATIONS RESEARCH

For more information visit water.sandia.gov

Sandia National Laboratories

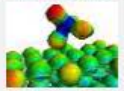
Sandia has been actively working in a broad range of water treatment technical challenges for over a decade

2000 — ADVANCED CONCEPTS WATER-TREATMENT PROGRAM BEGINS

2001 — DESALINATION TECHNOLOGY ROADMAPS

2002 — ARSENIC WATER TECHNOLOGY PARTNERSHIPS FORMS

2003 — DEVELOPMENT OF NOVEL ARSENIC TREATMENT APPROACHES



2004 — JOINT WATER REUSE & DESALINATION TASK FORCE

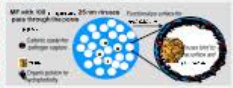
WATEREUSE

2005 — METHOD FOR SYNTHESIZING LAYERED DOUBLE HYDROXIDE CAPABLE OF SORBING ANIONIC AND IONIC CONTAMINANTS FROM FLUID

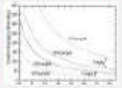
2006 — COMMERCIALIZATION OF ZERO LIQUID DISCHARGE PROCESS FOR BRACKISH WATER DESALINATION

2007 — BRACKISH GROUNDWATER NATIONAL DESALINATION RESEARCH FACILITY

2008 — MEMBRANES & SURFACES NANO-ENGINEERED FOR PATHOGEN CAPTURE & DESTRUCTION



2009 — LOW COST ARSENIC TREATMENT SYSTEM FOR SMALL COMMUNITIES



2010 — MICRO-MIXERS FOR MITIGATING MEMBRANE FOULING

2011 — NOVEL SILICA REMOVAL STRATEGIES BY WARM LIME SOFTENING

2012 — BIO-FOUILING RESISTANT CERAGENIN-MODIFIED WATER TREATMENT MEMBRANES

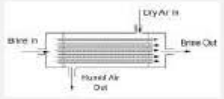
2013 — MEMBRANE TREATMENT OF SIDE-STREAM COOLING TOWER FOR REDUCTION OF WATER REUSAGE

2014 — PATENT ON METHOD FOR RECOVERING ALKALI METALS

2015 — APATITE PERMEABLE REACTIVE BARRIERS FOR IN SITU REMEDIATION OF URANIUM IN SUBSURFACE OF UMTRA SITE

2016 — WASTE WATER FOR POWER GENERATION VIA ENERGY EFFICIENT SELECTIVE SILICA SEPARATIONS

GRAPHENE OXIDE/POLYMER MEMBRANES



DEVELOPMENT OF SWEEPING GAS MEMBRANE DESALINATION USING COMMERCIAL HYDROPHOBIC HOLLOW FIBER MEMBRANES

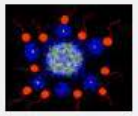
FRONTIERS OF INTERFACIAL WATER RESEARCH WORKSHOP

ARSENIC PILOT DEMONSTRATION PROJECTS

UV ULTRAVIOLET WATER PURIFICATION SYSTEMS FOR RURAL ENVIRONMENTS AND MOBILE APPLICATIONS

PRODUCED WATER PILOT SAN JUAN BASIN

CAPACITIVE IONIZATION FOR COAL-BED NATURAL GAS PRODUCED WATER



PATENT FOR NEXT-GEN COAGULENT FOR THE REMOVAL OF BACTERIA AND VIRUSES

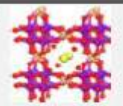
IMPLEMENTATION OF THE NATIONAL DESALINATION AND WATER PURIFICATION TECHNOLOGY ROADMAP

EXPLOITING INTERFACIAL WATER PROPERTIES FOR DESALINATION & WATER PURIFICATION APPLICATIONS

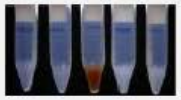
SELF-SEALING EVAPORATIVE POND LINER

BIOMIMETIC MEMBRANE R&D 100 AWARD

MEMBRANE DISTILLATION WATER TREATMENT USING POWER PLANT WASTE HEAT



CRYSTALLINE SILICOTITANATES FOR RADIOACTIVE CESIUM REMEDIATION



COAGULATION CHEMISTRIES FOR SILICA REMOVAL FROM COOLING TOWER WATER

USE OF FLUE GAS TO CONTROL SILICA AND CALCITE SCALE IN COOLING TOWERS

NMSBA

MEMBRANE DISTILLATION PROJECT FOR SMALL NEW MEXICO BUSINESS

For more information contact:

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U.S. DEPARTMENT OF ENERGY | NNSA

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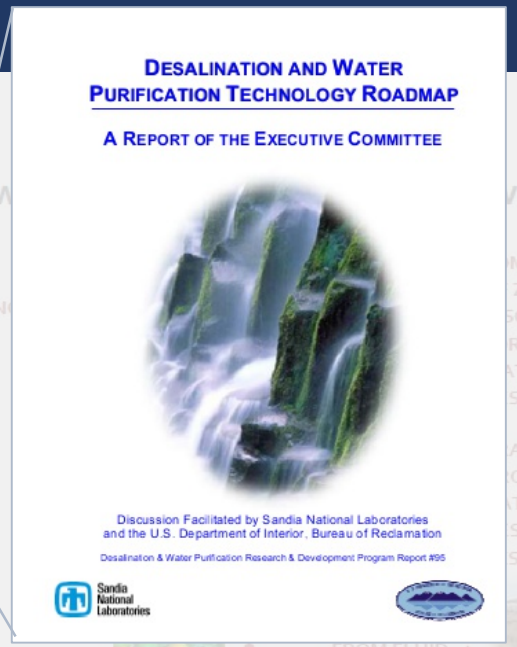
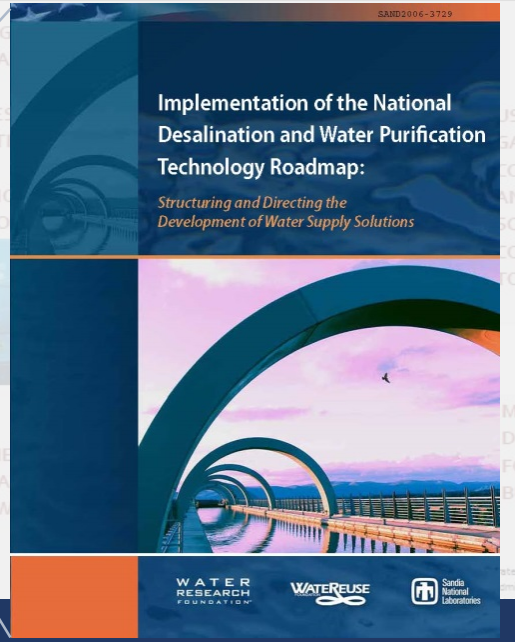
Roadmapping





ACCELERATING BRACKISH WATER DESALINATION TECHNOLOGY

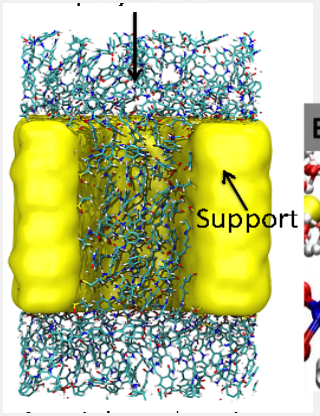
Brackish Groundwater National Desalination Research Facility (BGNDRF)
Alamogordo, NM

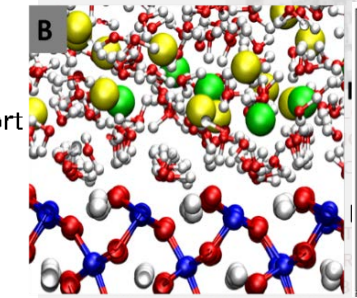
- Led effort with Bureau of Reclamation on a Report to Congress for the conceptual design of a national brackish water desalination research facility - 2003
- Supported BOR on final design, construction, and operation - 2004 - 2009

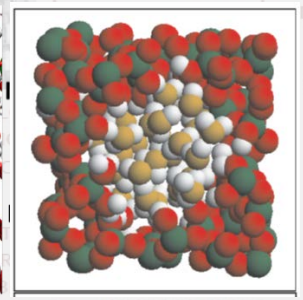
Clients:

Fundamental Research

FRONTIERS OF INTERFACIAL WATER RESEARCH WORKSHOP



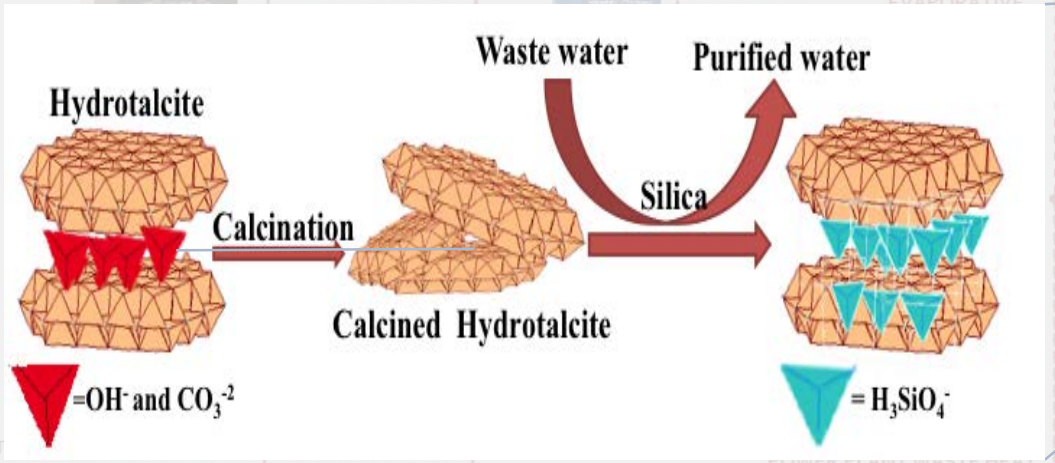




EXPLOITING INTERFACIAL WATER PROPERTIES FOR DESALINATION & WATER PURIFICATION APPLICATIONS

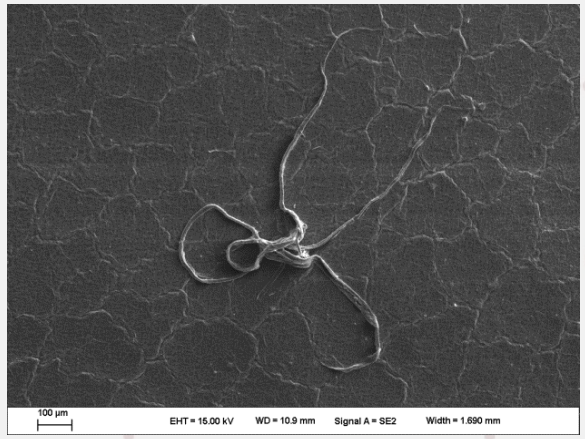
Silica Removal

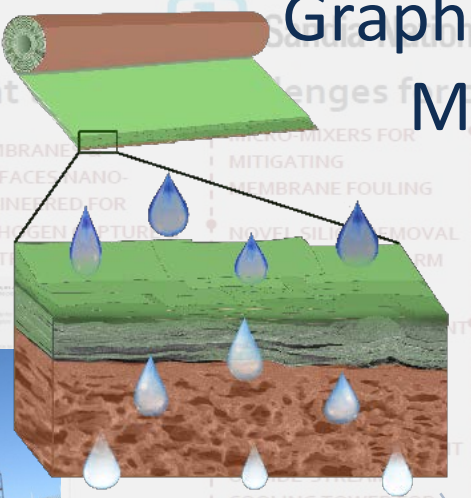
MEMBRANE TREATMENT OF SIDE-STREAM COOLING TOWER FOR REDUCTION OF WATER REUSAGE



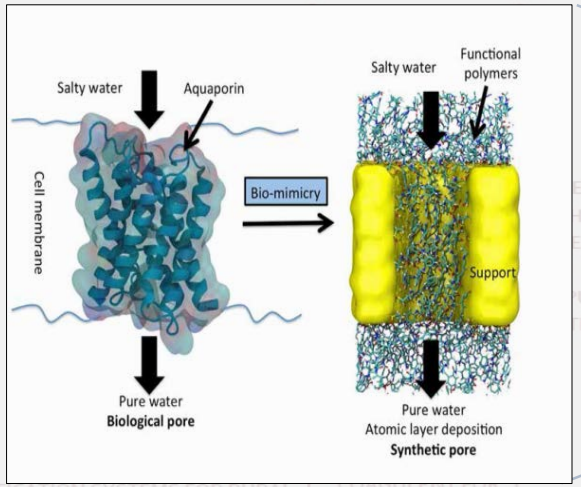
WASTE WATER FOR POWER GENERATION VIA ENERGY EFFICIENT SELECTIVE SILICA SEPARATIONS

Graphene Oxide Membranes

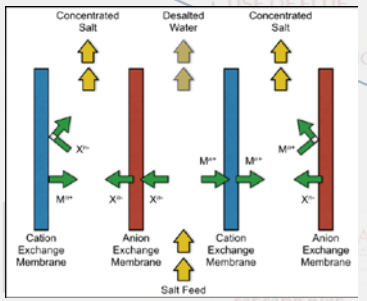




2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016



BIOMIMETIC MEMBRANE R&D 100 AWARD



GRAPHENE OXIDE/POLYMER MEMBRANES

BIO-INSPIRED ION-SELECTIVE ED MEMBRANES

Bio-Inspired Membranes

Pilot Testing

LOW COST ARSENTIC TRATMENT FOR SMALL COMMUNITIES

MEMBRANE TREATMENT OF SIDE-STREAM COOLING TOWER WATER FOR REDUCTION OF WATER USAGE

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

ARSENIC PILOT DEMONSTRATION PROJECTS

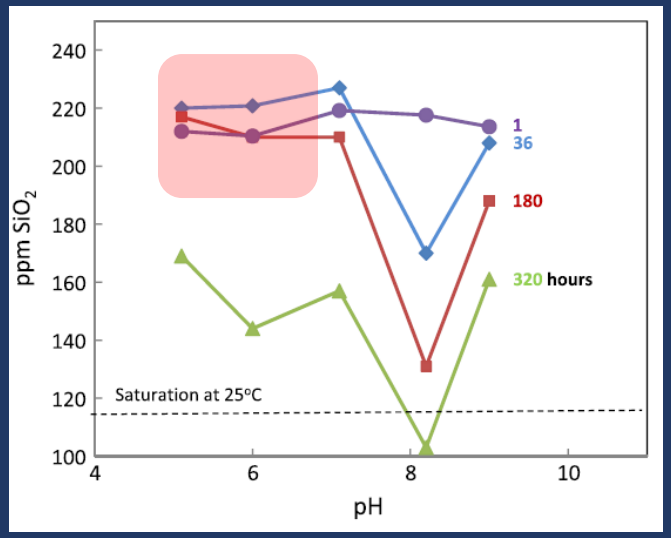
PRODUCED WATER PILOT SAN JUAN BASIN

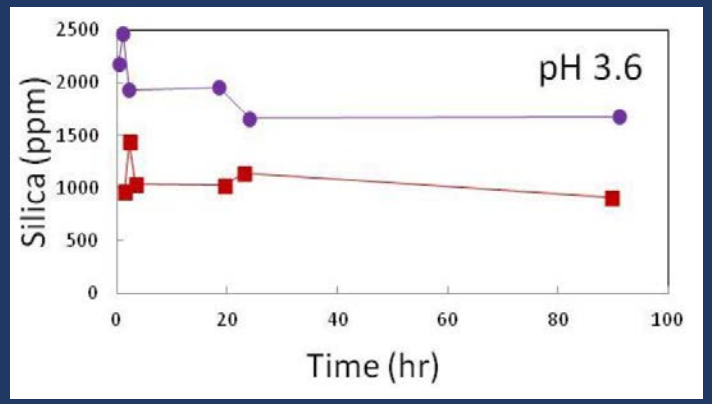
GRAPHENE OXIDE/POLYMER MEMBRANES

SANDIA AND SILICA REMOVAL

SILICA SCALE INHIBITION

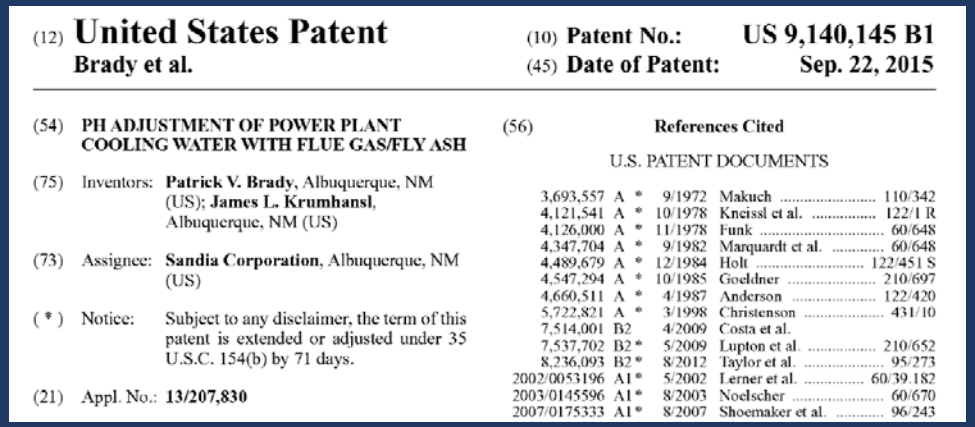
From: Brady, Patrick V., Susan J. Altman, Lucas K. McGrath, James L. Krumhansl, and Howard L. Anderson. "pH modification for silica control." *Desalination and Water Treatment* 51, no. 31-33 (2013): 5901-5908.





Highly supersaturated silica solutions (> 2000 ppm) can be made stable with low pH.

At pH ~6, supersaturated silica solutions (> 120 ppm) are stable for ~ 200 hours, long enough to backwash membranes, or discharge blowdown.



(12) **United States Patent**
Brady et al.

(10) **Patent No.: US 9,140,145 B1**
(45) **Date of Patent: Sep. 22, 2015**

(54) **PH ADJUSTMENT OF POWER PLANT COOLING WATER WITH FLUE GAS/FLY ASH**

(75) Inventors: **Patrick V. Brady**, Albuquerque, NM (US); **James L. Krumhansl**, Albuquerque, NM (US)

(73) Assignee: **Sandia Corporation**, Albuquerque, NM (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 71 days.

(21) Appl. No.: **13/207,830**

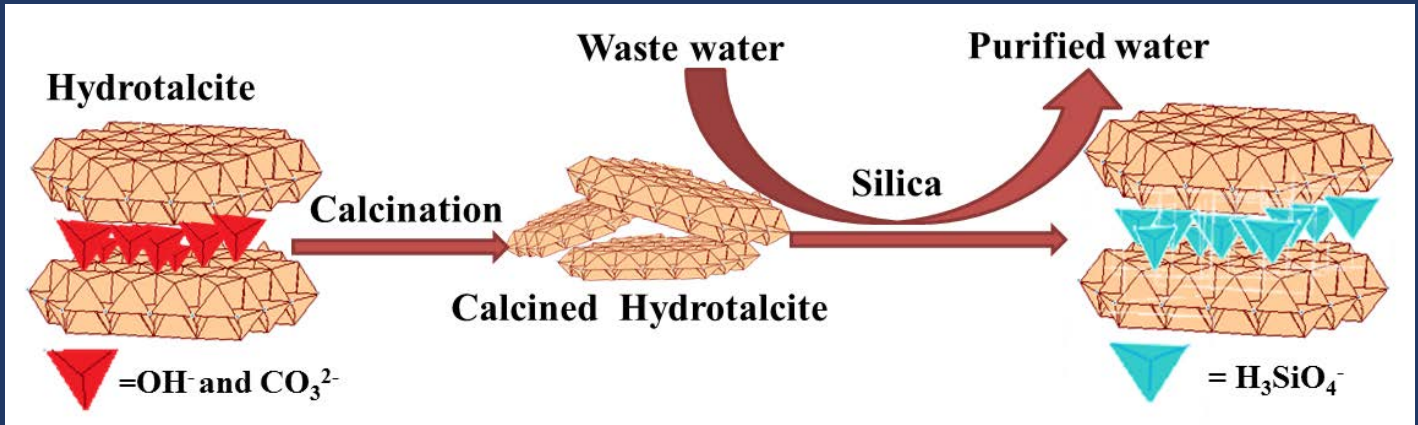
(56) **References Cited**

U.S. PATENT DOCUMENTS

3,693,557	A *	9/1972	Makuch	110/342
4,121,541	A *	10/1978	Kneissl et al.	122/1 R
4,126,000	A *	11/1978	Funk	60/648
4,347,704	A *	9/1982	Marquardt et al.	60/648
4,489,679	A *	12/1984	Holt	122/451 S
4,547,294	A *	10/1985	Goeldner	210/697
4,660,511	A *	4/1987	Anderson	122/420
5,722,821	A *	3/1998	Christenson	431/10
7,514,001	B2	4/2009	Costa et al.	
7,537,702	B2 *	5/2009	Lupton et al.	210/652
8,236,093	B2 *	8/2012	Taylor et al.	95/273
2002/0053196	A1 *	5/2002	Lerner et al.	60/39.182
2003/0145596	A1 *	8/2003	Noelscher	60/670
2007/0175333	A1 *	8/2007	Shoemaker et al.	96/243

How to inexpensively make the pH adjustments that stabilize dissolved silica.

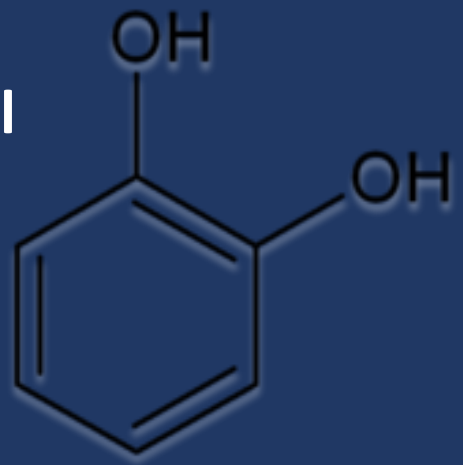
NOVEL MATERIALS FOR SILICA REMOVAL



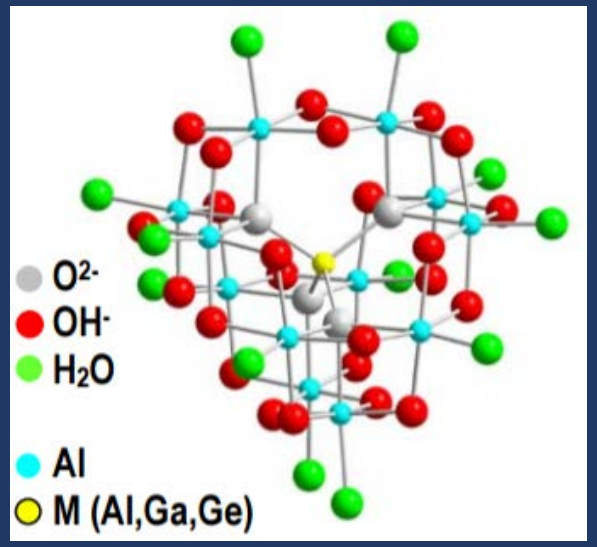
Sasan, Koroush, Patrick V. Brady, James L. Krumhansl, and Tina M. Nenoff. "Removal of dissolved silica from industrial waters using inorganic ion exchangers." *Journal of Water Process Engineering* 17 (2017): 117-123.

Silica: Chloride Ratio	% Silica Removed		Silica: Sulfate Ratio	% Silica Removed
1:1	99.0		1:1	99.0
1:5	98.8		1:5	97.0
1:10	98.5		1:10	95.8
1:15	97.9		1:15	95.2
1:20	97.6		1:20	94.8

Catechol



Keggin's Ion



Stewart, Tom, May Nyman, and Susan J. Altman. "Coagulation chemistries for silica removal from cooling tower water." In *Sandia Report SAND2011–0800*. 2011.

SANDIA ENERGY-WATER PARTNERS: PAST & PRESENT