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WATEREUSE® 2023 SYMPOSIUM

MARCH 5-8, 2023 • MARRIOTT MARQUIS ATLANTA
ATLANTA, GA

REIMAGINING
WATER
TOGETHER

Panel on Treated Produced Water Risk and Toxicology Evaluation

Permian Basin Raw and Treated Produced Water Quality Analysis

Pei Xu – New Mexico State University

March 7, 2023

Produced Water Treatment and Reuse is Expanding

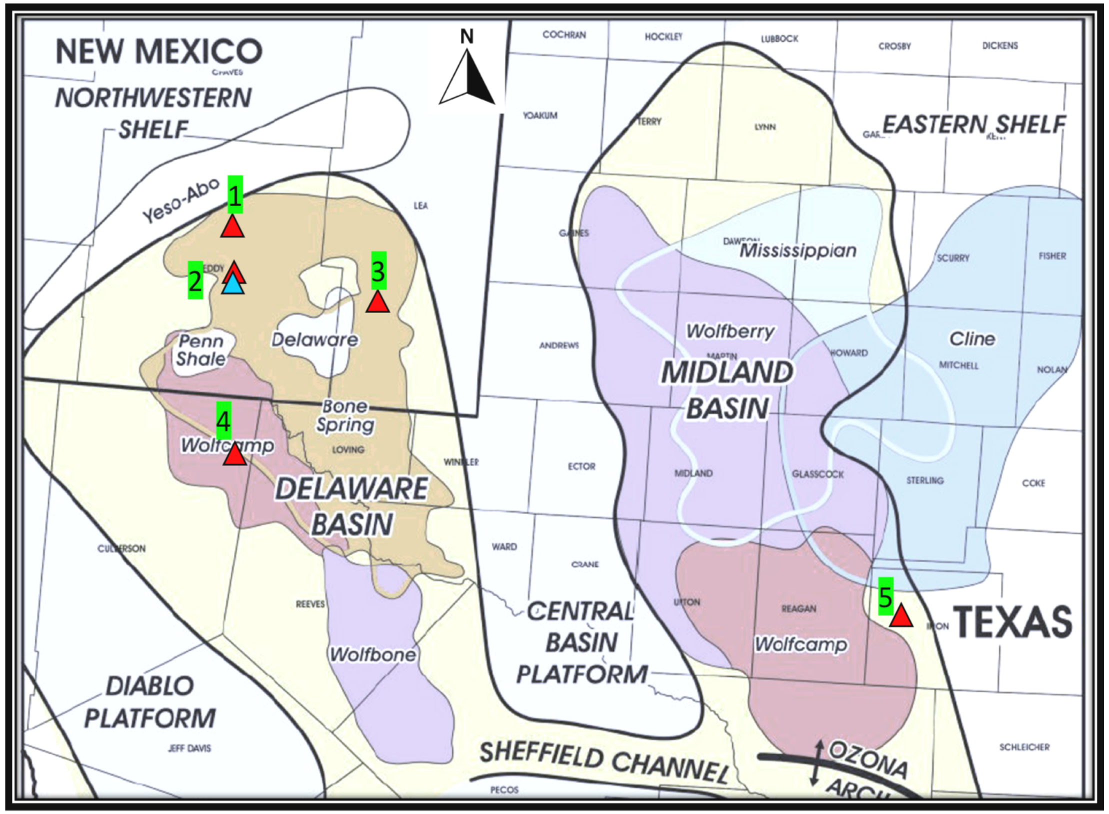
Region	PW Production (2017)	PW Disposal (Deep Well Injection)	PW Reuse Inside O&G Field	PW Reuse for EOR	PW Reuse/ Dispose Outside O&G Field	Examples of PW Reuse Outside O&G Field
Appalachian Basin	105 MMbbls (16.8×10^6 m^3)	PA: 1.1%, WV: 56%, OH: 89%.	PA: 96%, WV: 29%, OH: 9.1%.	PA: n/a, WV: 14%, OH: 1.3%.	PA: 1.6%, WV: n/a, OH: n/a.	n/a
Oklahoma	2844 MMbbls (455×10^6 m^3)	41.7%	n/a	44.9%	13.4%	n/a
Texas	9895 MMbbls (1583×10^6 m^3)	36.2%	n/a	46.1%	17.6%	n/a
California	3100 MMbbls (496×10^6 m^3)	22.4%	5.1%	59.3%	11.1%	Irrigation
Colorado	310 MMbbls (49.6×10^6 m^3)	47.1%	8.9%	32.5%	11.5%	Dust control; aquifer recharge and recovery; pits and surface water discharge.
Wyoming	1700 MMbbls (272×10^6 m^3)	14%	n/a	46%	37%	Surface water discharge; groundwater injection; dust control and road application; irrigation; land application; impoundment.
New Mexico	1240 MMbbls (196.9×10^6 m^3, 2019)	51%	10%	40%	n/a	n/a

Note(s): PW: produced water; MMbbls: million barrels; PA: Pennsylvania; OH: Ohio; WV: West Virginia; n/a: not available.

Jiang, W., Lin, L., Xu, X., Wang, H., Xu, P. (2022) Analysis of regulatory framework for produced water management and reuse in major oil and gas producing regions in the United States. Water 14 (14), 2162. https://www.mdpi.com/2073-4441/14/14/2162

Consortium Data on Permian Produced Water Quality

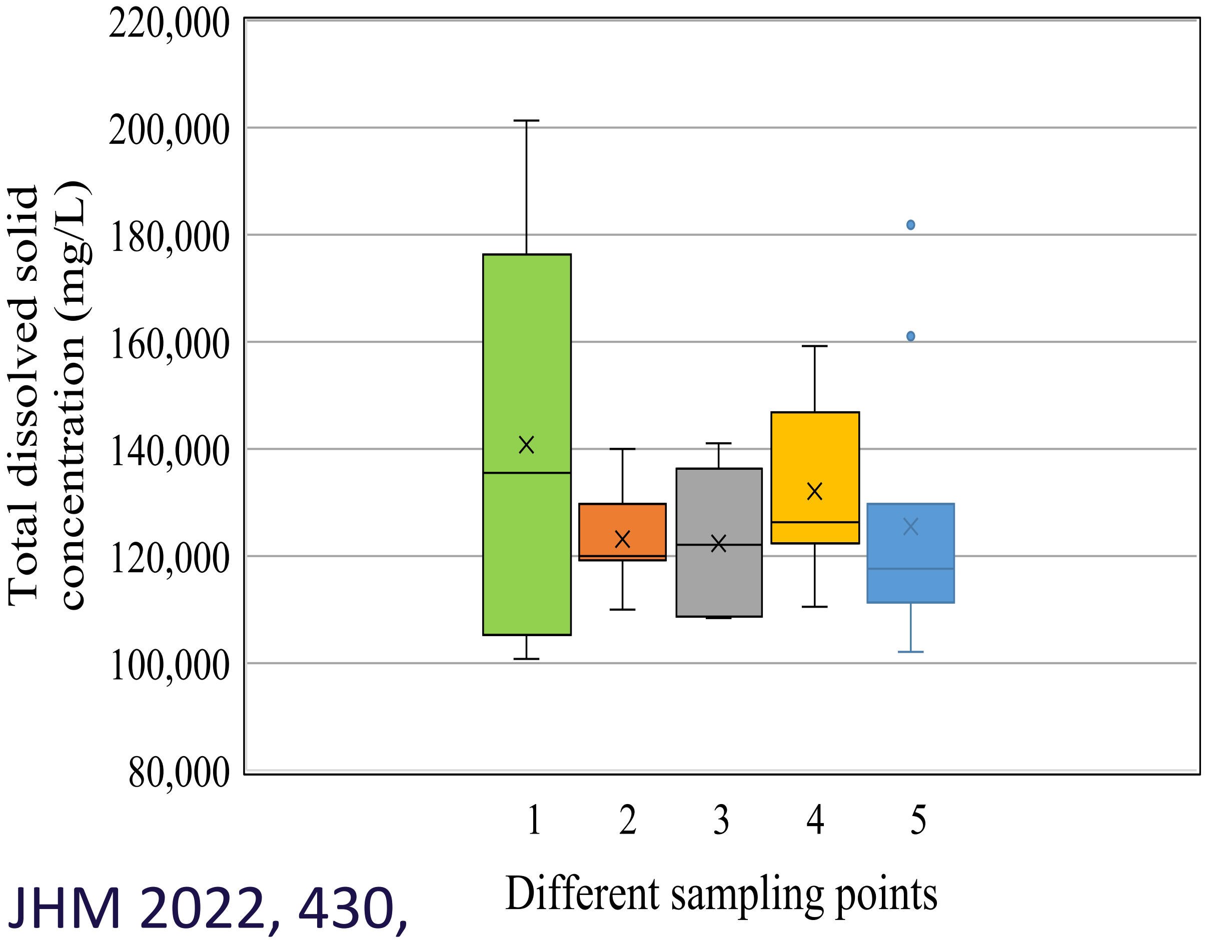
46 PW and 10 Pecos River Sampling Locations



Produced water sampling point

Pecos River water sampling point

Produced Water TDS Distribution



Source: Jiang et al., JHM 2022, 430, 128409

Chemical Analysis

More than 300 targeted analytes were quantitatively analyzed, including wet chemistry, inorganics, radionuclides, organics such as VOCs, SVOCs, total petroleum hydrocarbons, organic acids, oil and grease, pesticides/herbicides, dioxins, and tentatively identified compounds, and per- and polyfluoroalkyl substances (PFAS).

For 10 produced water samples collected in 2020, 91 analytes were quantified and 218 analytes were not detected (309 in total)

For 10 Pecos River samples collected in 2020, 67 analytes were quantified and 242 analytes were not detected (309 in total)

Source: Jiang et al., JHM 2022, 430, 128409

Produced Water and Waste Water Quality Evaluation

Raw Municipal Waste Water

~60 major constituents

(~20 TICs)

Raw Pecos River Water

~70 major constituents

(~10 TICs)

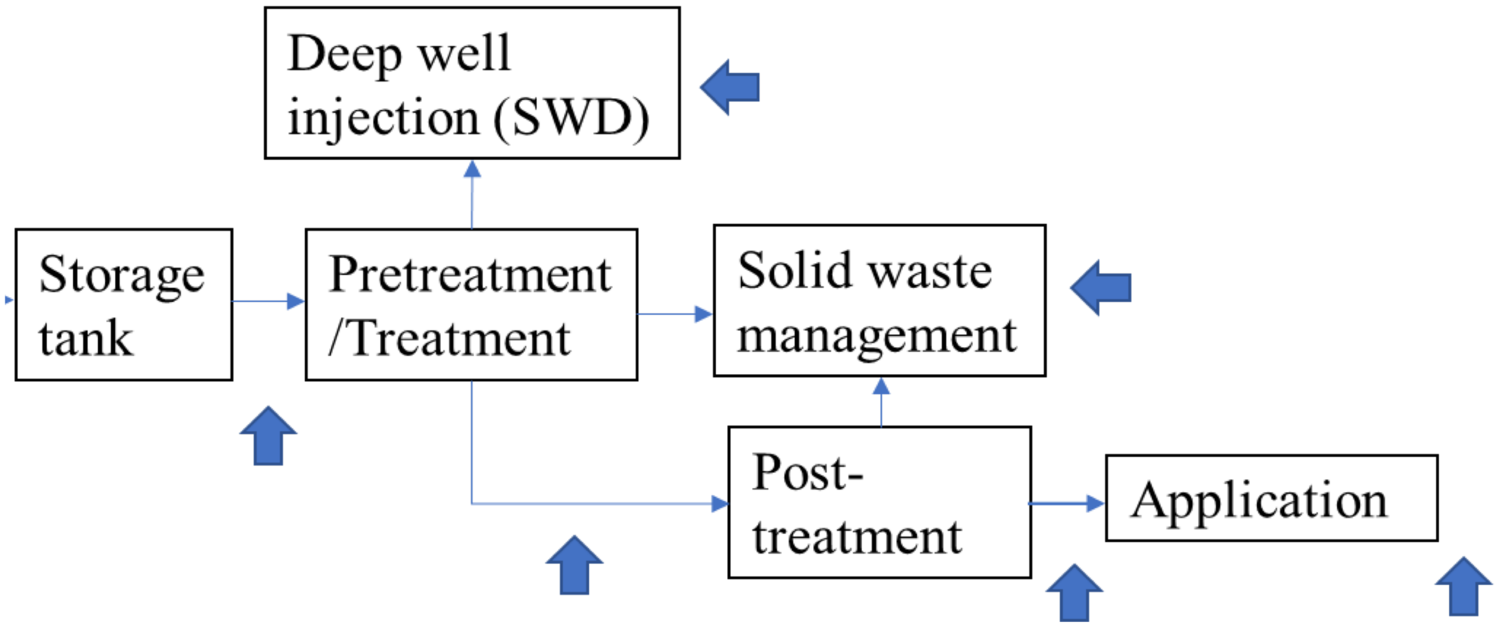
Permian Raw Produced Water

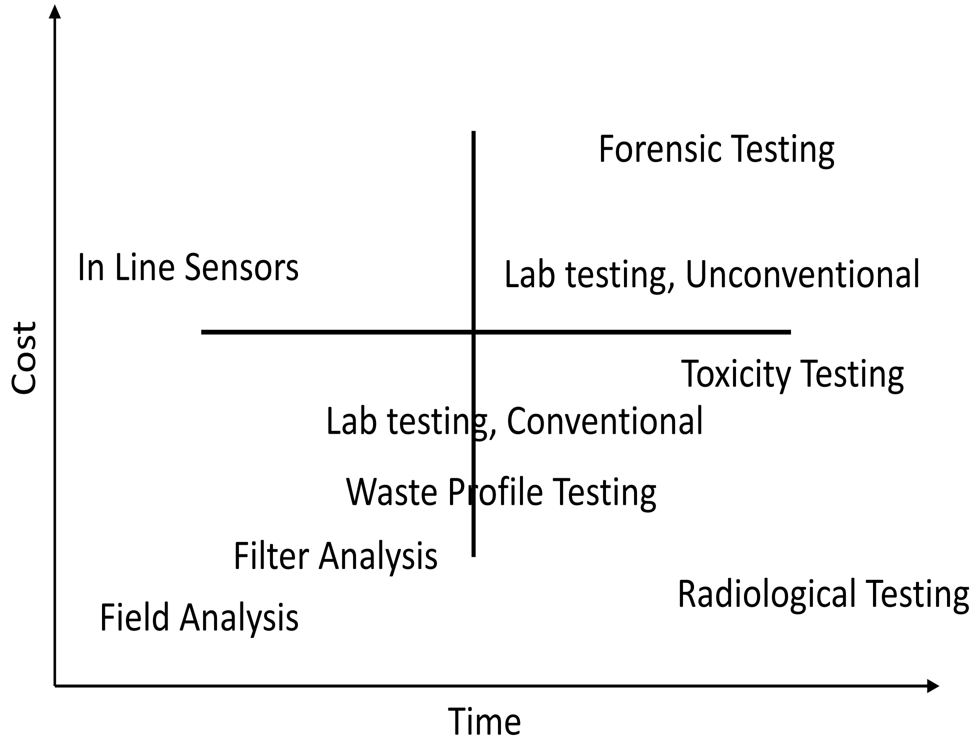
~90 major constituents

(~3-4 TICs)

- Extensive sampling and analysis program in 2020 – assessed 300 constituents
- Evaluation suggests that produced water in most basins has ~100 +/- 20 constituents
- Did identify tentatively identified compounds (TICs) in all waters (i.e. unknowns)
- Identified analytical method for unknowns using NMSU HR LCMS
- In 2022 hired a full-time HRLCMS analyst focused on treated produced water, with analytical evaluations already underway
- With NMED and Consortium established sampling protocol (NPDES+) and (Tiered) monitoring protocol
- Sampling and analysis is driven by Risk and Tox Protocol – but supports treatment and application selection

Multi-tiered Produced Water Characterization





Source: Jiang et al., JHM 2022, 430, 128409

The cost and turnaround time of produced water analysis

Water Quality Drives Toxicity and Treatment Selection

Results of general quality of 46 PW samples from Delaware and Midland Basins – Some Challenges will Drive Pre-, Post-, and Treatment

		Mean	Max	Min	25th percentile	50th percentile	75th percentile
Alkalinity	mg/L as $CaCO_3$	272	870	100	128	207	336
Ammonia	mg/L	432	750	320	330	400	495
COD	mg/L	1,626	3,100	930	1,250	1,400	1,950
pH	SU	6.6	8.1	3.9	6.3	6.7	7.0
TDS	mg/L	128,641	201,474	100,830	113,441	122,280	134,525
TOC	mg/L	103.5	248.1	2.4	28	90.6	173.3
TSS	mg/L	342.9	790	85	142.5	375	422.5
Turbidity	NTU	116.4	200	23	36	110	200
MBAS	mg/L	1.10	2.1	0.047	0.92	0.97	1.33

Source: Jiang et al., JHM 2022, 430, 128409

Nontargeted Analysis Led by Dr. Robert Young

LC-Orbitrap MS

	Sample Preparation	Instrumental Analysis	Data Analysis
Targeted Analysis	• Optimized for targets • Selective	• Optimized for targets • Sensitive • Focuses completely on targets	• Quantitative • Focuses on accuracy, precision, & reproducibility
Nontargeted Analysis	• More "universal" • Still doesn't work for all analytes	• Aims to collect as much data as possible • Needs high chromatographic and/or mass resolution • Still doesn't work for all analytes	• Semi-quantitative • Focuses on confidence in identification

ThermoFisher SCIENTIFIC

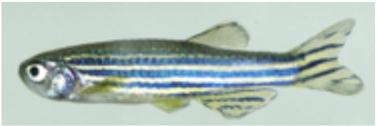
Nontargeted analysis is most useful for identifying what to target

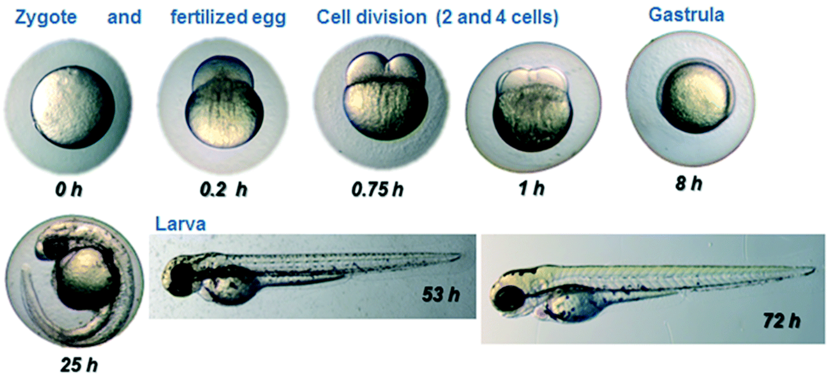
Laboratory Toxicity Assays Led by Dr. Yanyan Zhang

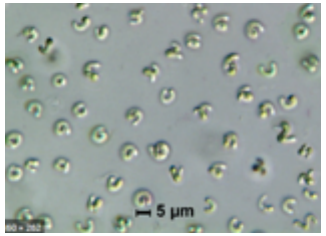
- Acute toxicity test with *Daphnid*
  - Immobilization of *Ceriodaphnia dubia*
  - *EPA-821-R-02-012,Method 2002.0*
- Fish Embryo Acute Toxicity (FET) Test
  - Based on the development of fish embryos
  - OECD, Test No. 236
- Chronic toxicity with *Daphnid*
  - Based on survival/reproduction of *Ceriodaphnia dubia*
  - *EPA-821-R-02-013, Method 1002.0*
- Chronic toxicity with freshwater green algae
  - Chronic toxicity of *Selenastrum capricornutum*
  - *Algal growth*
  - *EPA-821-R-02-013, Method 1003.0*

https://pubs.rsc.org/en/content/articlelanding/2019/ew/c9ew00411d/unauth

http://cfb.unh.edu/cfbkey/html/Organisms/CCladocera/FDaphnidae/GCeriodaphnia/Ceriodaphnia_dubia/







Algae: **primary producers**
Invertebrates: **primary consumers**
Fish: **secondary consumers**

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