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NEW MEXICO PRODUCED WATER RESEARCH CONSORTIUM

NM STATE

Research Overview and Updates on Produced Water Characterization, Treatment and Reuse

Pei Xu
Research Director, New Mexico Produced Research Consortium
PESCO Endowed Professor, Department of Civil and Environmental Engineering

2026 NMPWRC Mid-Year Review meeting
June 10th, 2026

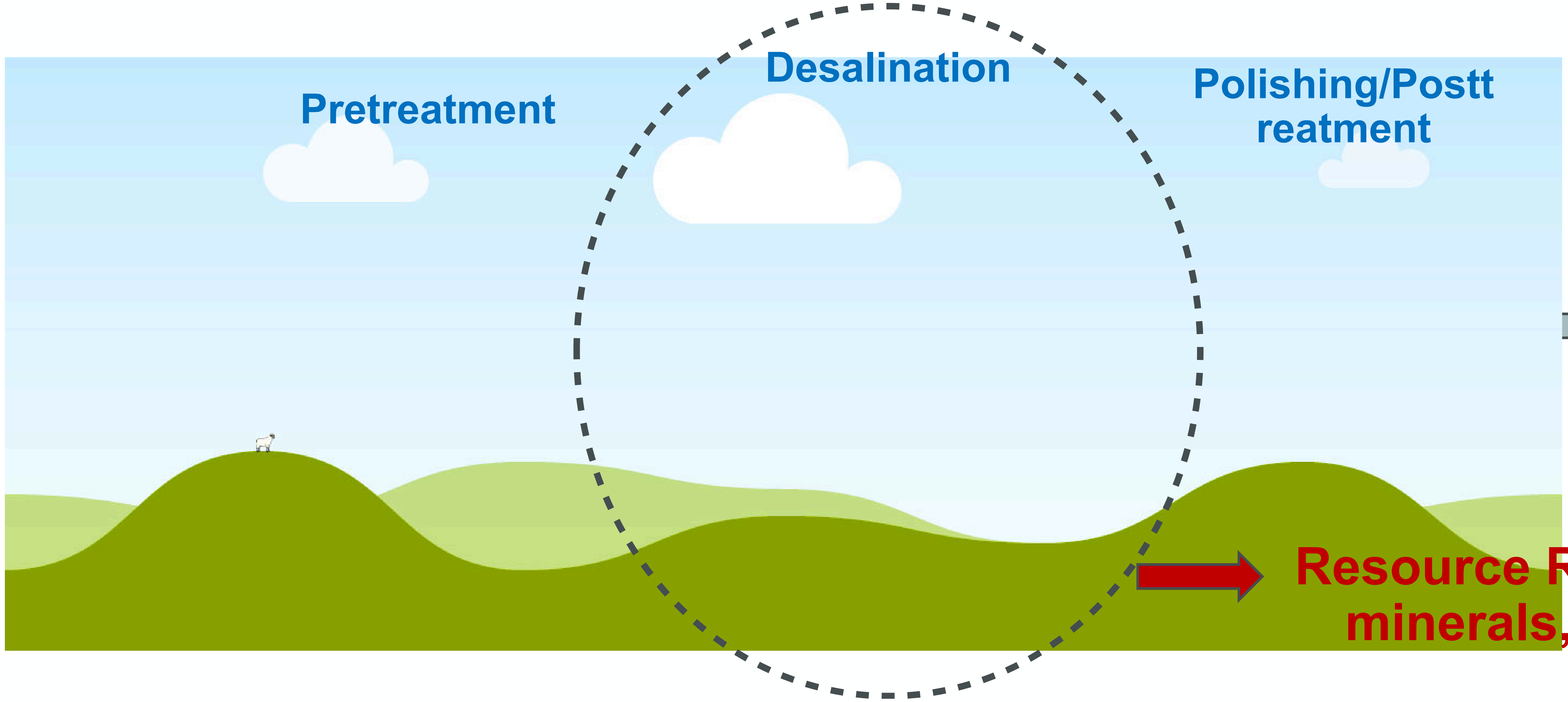
Disclaimer: The New Mexico Produced Water Research Consortium at New Mexico State University is conducting independent, science-based research to evaluate potential environmental and health effects related to the reuse of treated produced water for fit-for-purpose applications. This work is designed to generate objective data under controlled conditions, without promoting or opposing any specific reuse practices. Our goal is to provide clear, reliable information that supports informed decision-making around the safe and responsible use of produced water in New Mexico and beyond.

This presentation includes preliminary research data from the New Mexico Produced Water Research Consortium at New Mexico State University. The information presented is subject to change and has not yet undergone formal quality assurance or quality control (QA/QC) review. Distribution or sharing of this material without prior authorization from New Mexico State University is not permitted.

Advancing the Science for Produced Water Treatment and Reuse

Transforming Produced Water from a Waste to Valuable Resources through Science & Innovation

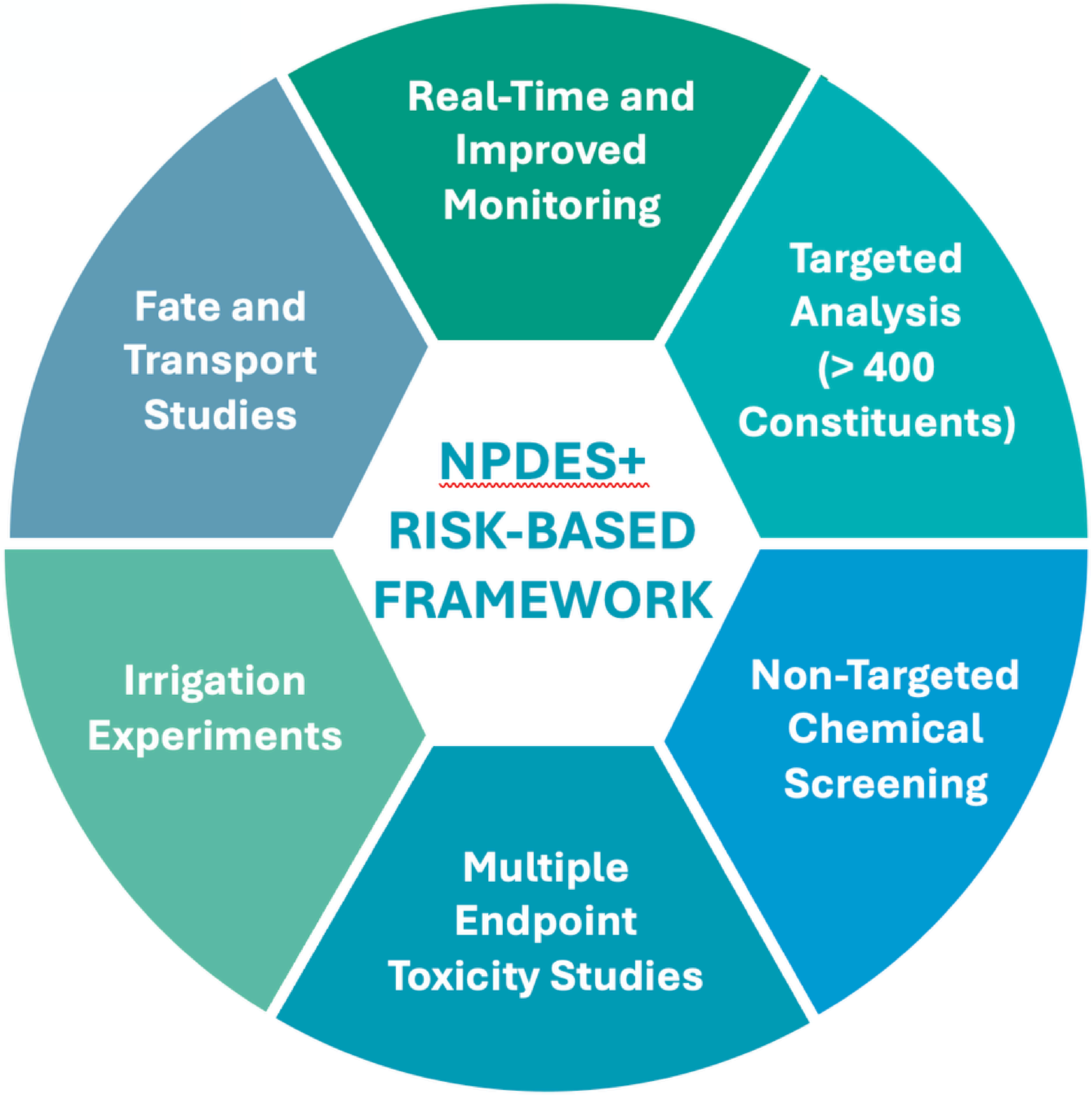
Produced Water Treatment



Fit-for-Purpose
Water Reuse

Resource Recovery (NH_3, critical minerals, H_2, acids, bases…)

PW Characterization, Toxicity Studies, and Risk Assessment



- Use a multi-tiered approach combining comprehensive chemical characterization, toxicity testing, irrigation studies, and environmental modeling to evaluate produced water quality, treatment performance, and potential reuse risks.
- Provide guidance on real-time and routine monitoring for process control and ensuring safety of reuse

The “NPDES+” Framework – Targeted Analysis

- Major product generated in ~2022 by NMPWRC + many stakeholders and members.
- This list of > 430 analytes is critical because it contains a list of compounds that are in current regulations, standards, guidance for discharge and reuse.
- Other entities like have borrowed this list and expanded upon it over the years.
- It serves as the basis for analyses of all waters coming from pilot systems.

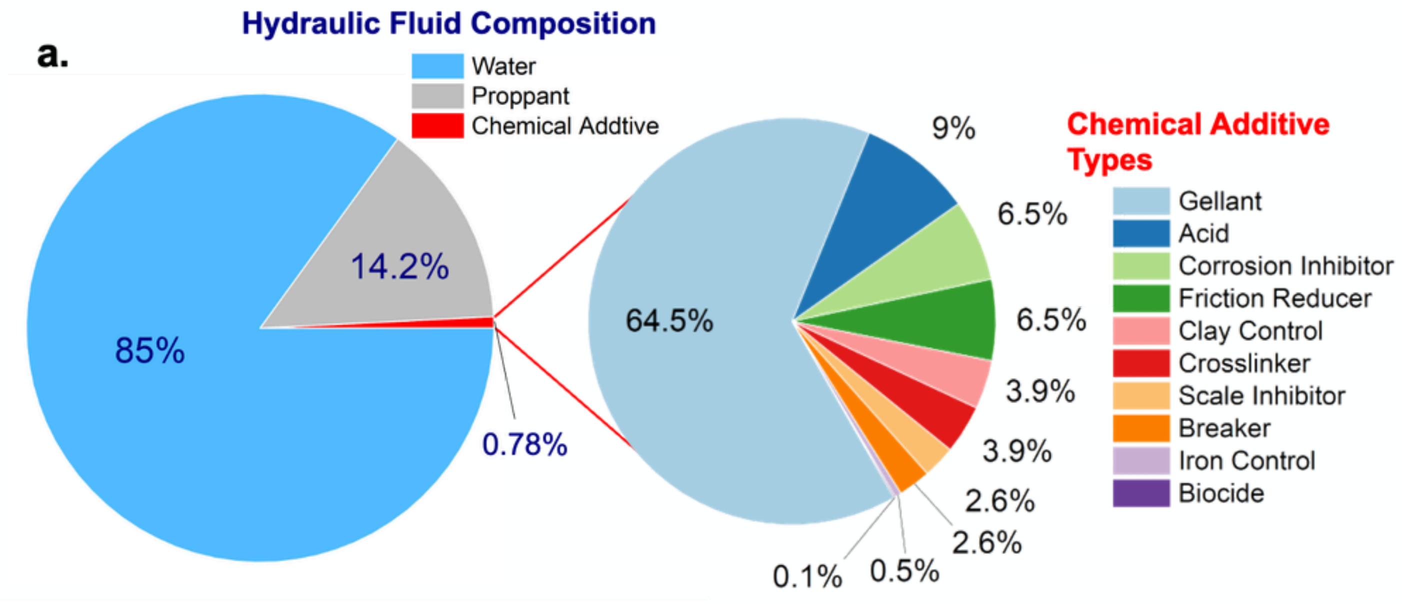
Analytical Categories (17)
Metals/Elements - speciated
Anions
Wet Chemistry, Other
Radionuclides
Organic - VOC
Organic - VOC - TPH
Organic - SVOC - General
Organic - SVOC - TPH
Organic - SVOC - Explosives
Organic - SVOC - Agent Breakdown Products
Organic - SVOC - Pesticides/Herbicides
Organic - SVOC - PCBs
Organic - SVOC - PAHs
Organic - SVOC - Organic Acids
Organic - SVOC – Dioxins
Toxicity Testing

[2] NPDES+ List

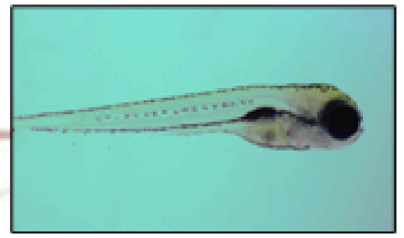
"NPDES+" Framework – Studies at NMSU

Targeted and Non-targeted Chemical Analysis

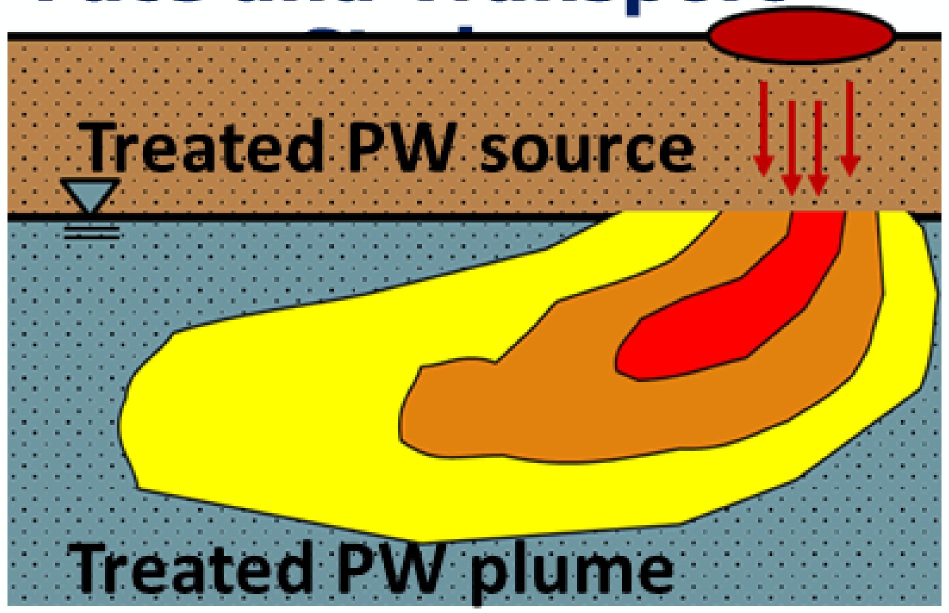
HF Chemical Analysis and Impacts on PW treatment and Reuse



Whole Effluent Testing (WET) In Vivo (Environment) & In Vitro (Human Health)



Fate and Transport



Risk Assessment of Treated Produced Water Reuse

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Example of Pilot System and Sampling Event in Permian Basin

Photos by Dr. Zhang and Dr. Xu

Targeted Analysis (75 individual samples: 65 from pilot and 10 from lab testing)

NPDES+ Analytical List + Additional Tailored Analytes

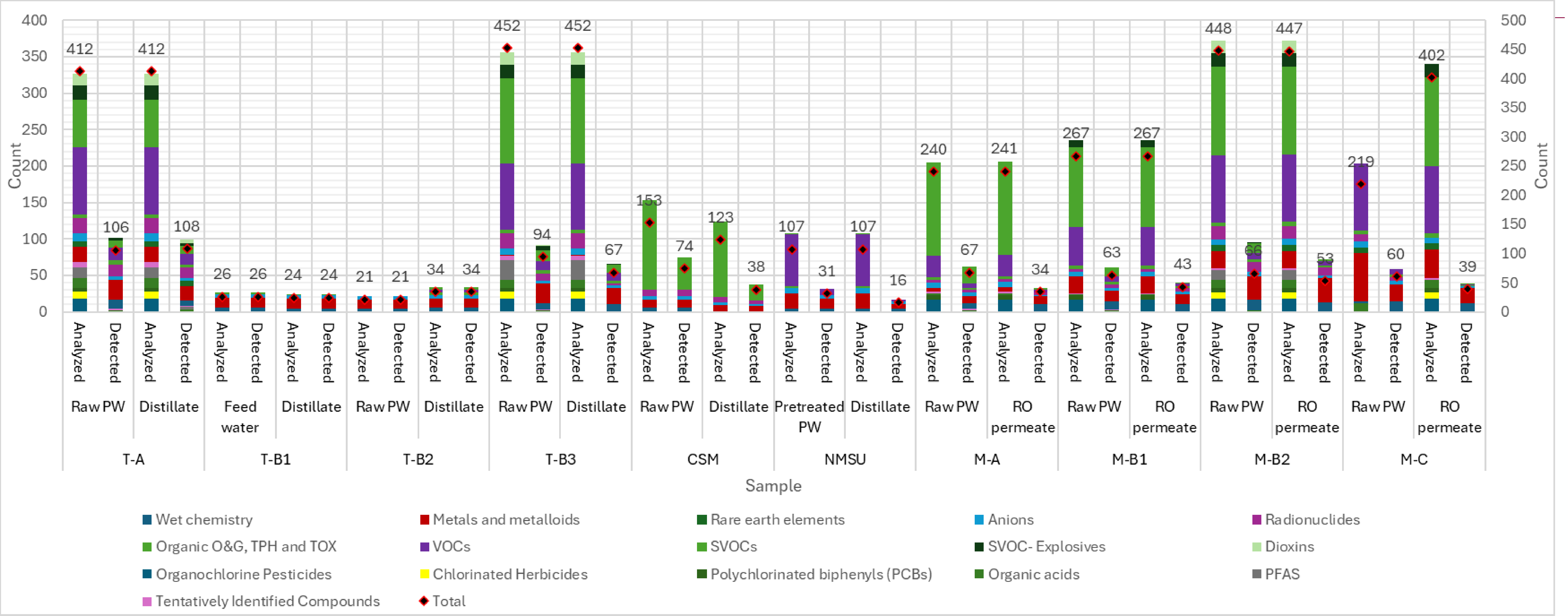
7 Thermal-based processes (55 samples)

Projects	Process
• T-A	Pilot Thermal Distillation in Midland Basin
• T-B1	Pilot Thermal Distillation in Delaware and Midland Basins
• T-B2	
• T-B3	
• T-C	Pilot Thermal Distillation in Midland Basin
• CSM	Laboratory Membrane Distillation
• NMSU	Laboratory Membrane Distillation (PMD-VMD)

4 Membrane-based processes (20 samples)

• M-A	Pilot Reverse Osmosis in Delaware Basin
• M-B1	Pilot Hybrid Desalination with Reverse Osmosis in Midland Basin
• M-B2	
• M-C	Pilot Reverse Osmosis in Delaware Basin

Analyzed vs Detected (~13,000 individual analyte measurements)



A total of 609 analytes were analyzed at least once across the 75 water samples, of which 290 analytes were detected.

Multi-Barrier Treatment Can Meet Current Water Standards

Comparison with Water Quality Standards after Post-Treatment (Thermal)

Analyte	Drinking water standards (EPA)				Post-treated (mg/L)
	Primary MCL (mg/L)	Secondary MCL (mg/L)	Min	Max	
Total Dissolved solids (TDS)		500	80	575	106 - 348
Ammonia			**3.15**	**122**	**0.247**
Boron			**0.12**	**13.4**	**BDL**
Aluminum		0.05-0.2	0.004	1.089	0.05-0.11
Barium	2		-	0.060	0.002
Chromium	0.1		0.007	0.020	0.002
Copper	1.3	1	-	-	0.004
Iron		0.3	0.004	0.259	BDL
Zinc		5	0.010	0.017	0.003
Chloride		250	1	220	27.2
Nitrate Nitrogen	10		0.087	0.087	0.12
Sulfate		250	0.120	17.661	8.86
Gross Alpha	15 pCi/L		0.513 pCi/L	0.513 pCi/L	0.827 pCi/L
Gross Beta	4 millirems per year		0.148 pCi/L	0.148 pCi/L	1.25 pCi/L
Radium-226	**5 pCi/L**		**4.595 pCi/L**	**85.3 pCi/L**	**0.0295 pCi/L**
Radium-228			**0.345 pCi/L**	**1.588 pCi/L**	**0.699 pCi/L**
Benzene	0.005		0.016	0.501	BDL
Toluene	1		0.024	0.548	0.005
Xylenes, Total	10		0.018	0.377	BDL
Perfluorohexanesulfonic acid (PFHxS)	10 ng/L		-	BDL	BDL
Perfluorononanoic acid (PFNA)	10 ng/L		-	-	BDL
Perfluorooctanesulfonic acid (PFOS)	4 ng/L		-	1.850 ng/L	0.689 ng/L
Perfluorooctanoic acid (PFOA)	4 ng/L		-	1.290 ng/L	-

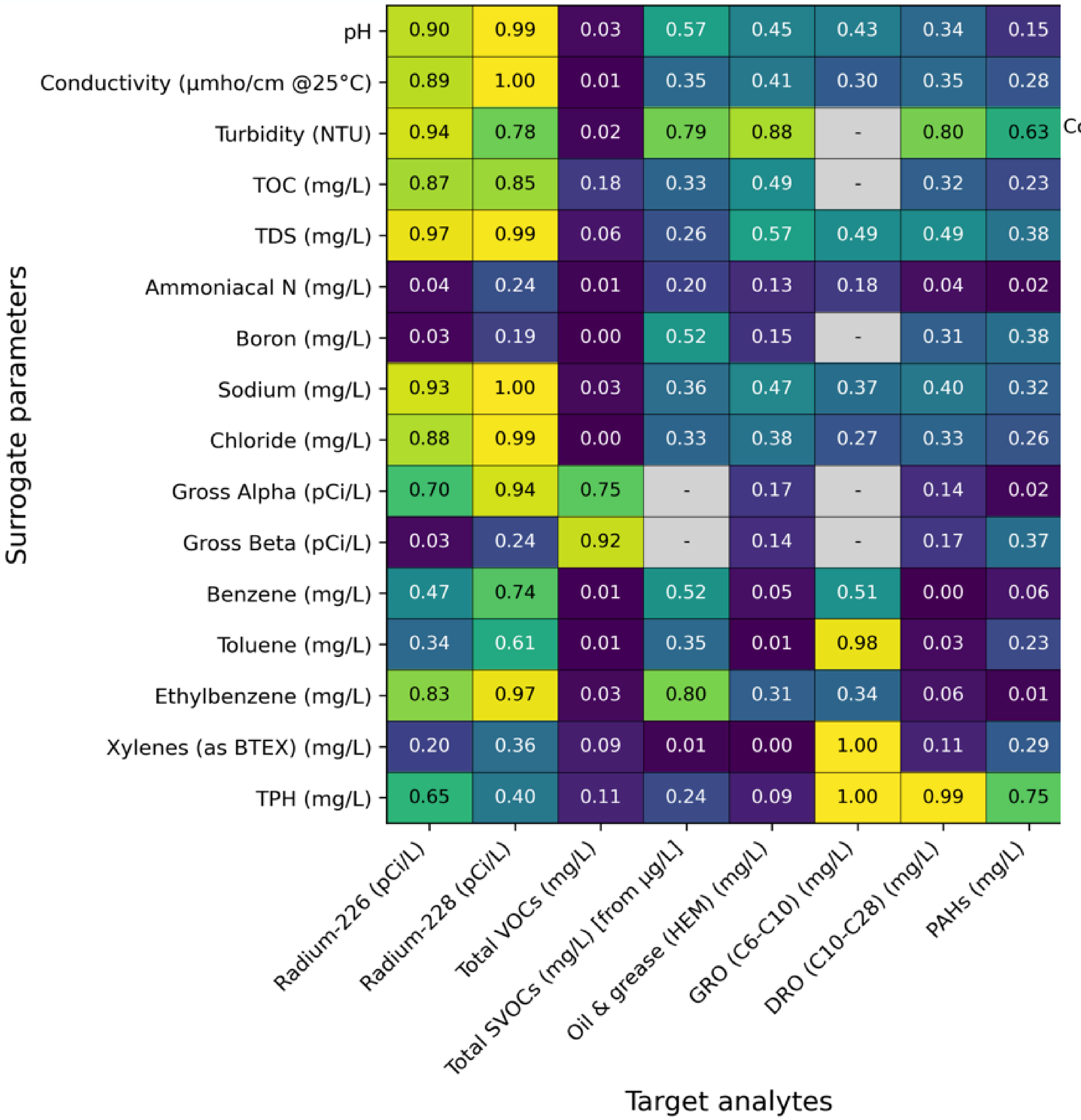
Multi-Barrier Treatment Can Meet Current Water Standards

Comparison with Water Quality Standards after Post-Treatment (Membrane)

Analyte	Drinking water standards (EPA)				Post-treated (mg/L)
	Primary MCL (mg/L)	Secondary MCL (mg/L)	Min	Max	
Total Dissolved solids (TDS)		500	490	1036	156-231
Ammonia			**3.37**	**9.93**	**0.058**
Boron			**0.84**	**26.2**	**BDL**
Aluminum		0.05-0.2	BDL	0.0087	BDL
Barium	2		0.00509	0.0117	0.00847
Chromium	0.1		BDL	0.00343	BDL
Copper	1.3	1	BDL	0.00456	BDL
Iron		0.3	BDL	0.0462	BDL
Zinc		5	-	-	BDL
Chloride		250	BDL	0.0405	37.5
Nitrate Nitrogen	10		BDL	3.91	BDL
Sulfate		250	BDL	0.426	8.86
Gross Alpha	15 pCi/L		BDL	2.719	0.31 pCi/L
Gross Beta	**4 millirems per year**		**4.91 pCi/L**	**6.41 pCi/L**	**1.23 pCi/L**
Radium-226	**5 pCi/L**		**2.875 pCi/L**	**8.37 pCi/L**	**BDL**
Radium-228			**0.125 pCi/L**	**0.428 pCi/L**	**BDL**
Benzene	**0.005**		**0.28**	**16.03**	**BDL**
Toluene	1		-	BDL	BDL
Xylenes, Total	10		-	0.003282	BDL
Perfluorohexanesulfonic acid (PFHxS)	10 ng/L		-	0.00128	BDL
Perfluorononanoic acid (PFNA)	10 ng/L		-	-	BDL
Perfluorooctanesulfonic acid (PFOS)	4 ng/L		-	-	BDL
Perfluorooctanoic acid (PFOA)	4 ng/L		-	-	BDL

Surrogate Parameters and Indicator Compounds

Thermal-Based



Membrane-Based

- **EC tracks well TDS and Ra-228**
- **B and NH3 do not follow bulk trends**, so they must be measured directly.
- **TOC is not a good overall surrogate** for VOCs and SVOCs
- **Gross alpha and gross beta behave independently**, suggesting different sources/pathways.

Surrogate Parameters and Indicator Compounds

Tier 1 – daily or/and real-time monitoring (7)
• Temperature
• pH
• Electrical conductivity
• Dissolved oxygen (DO)
• Turbidity
• Total organic carbon (TOC)
Tier 2 – weekly or/and under changes in operating conditions (9)
• Total ammonia (as N)
• Boron
• Sodium
• Chloride
• Hardness (Ca and Mg)
• Gross Alpha/Beta (Radionuclides)
• Representative aromatic hydrocarbons (e.g. BTEX)
• Naphthalene
Tier 3 – [illegible]

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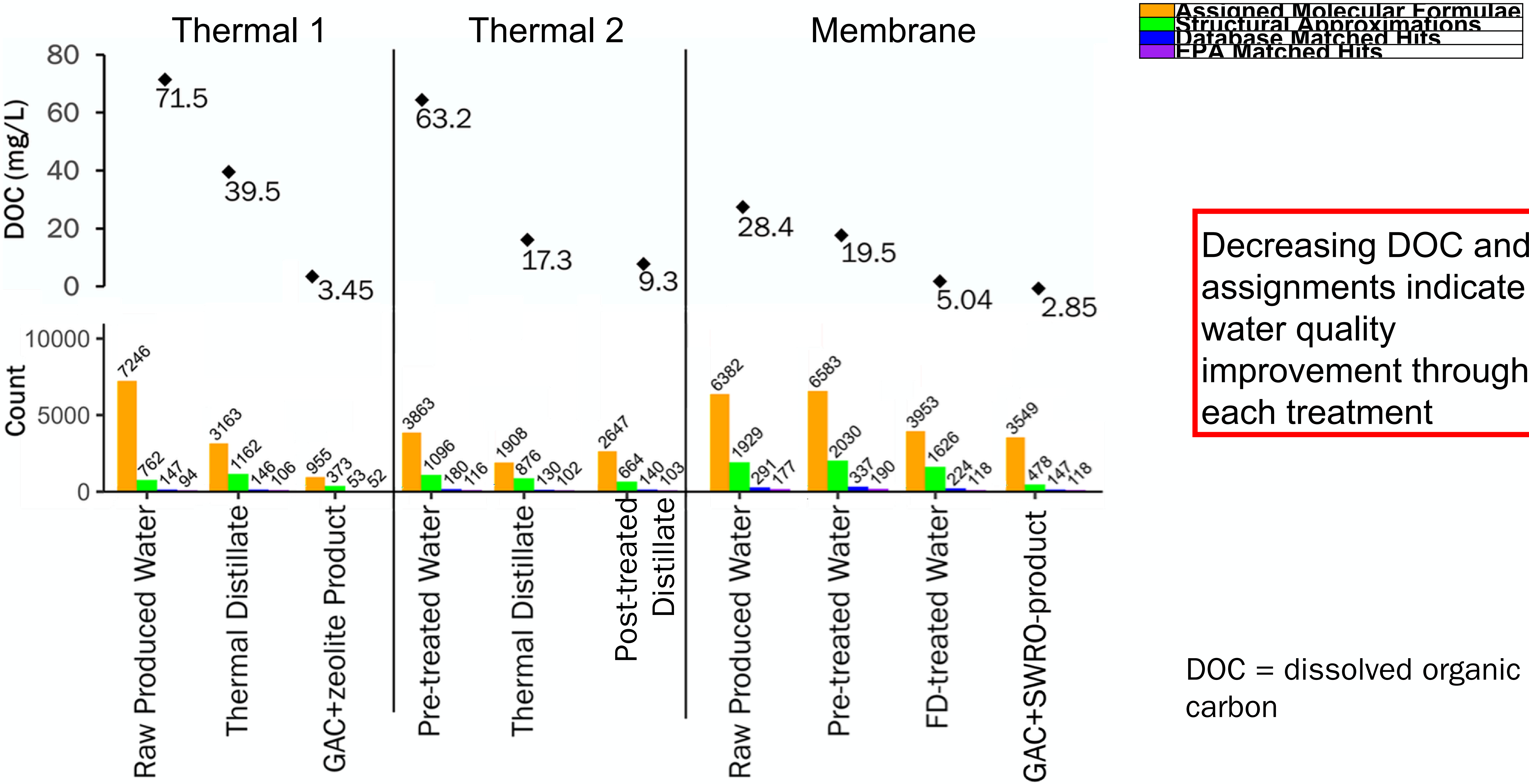
Non-Targeted Analysis



Decreasing DOC and assignments indicate water quality improvement through each treatment

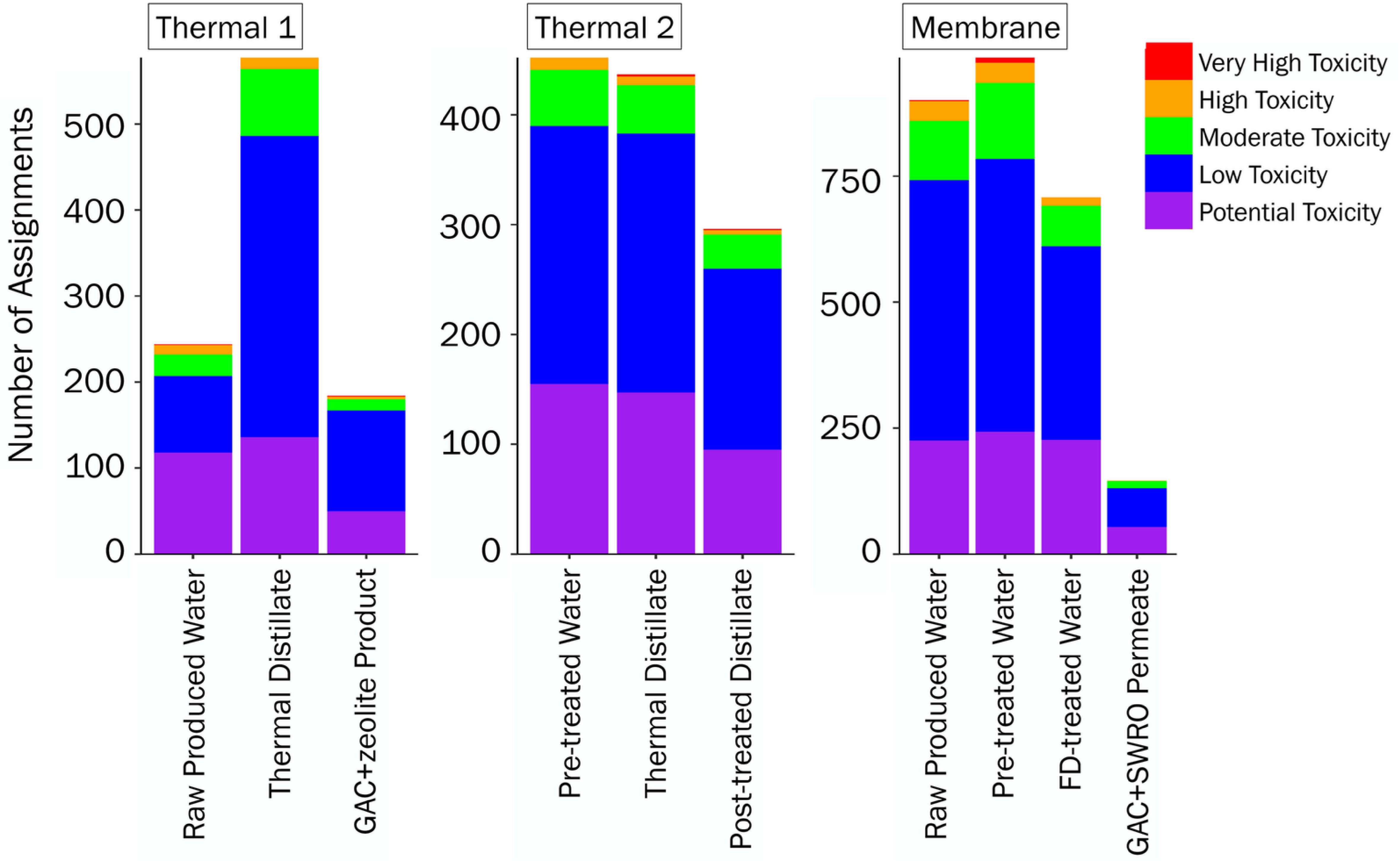
DOC = dissolved organic carbon

Features with Predicted Toxicity Diminish Following Treatment

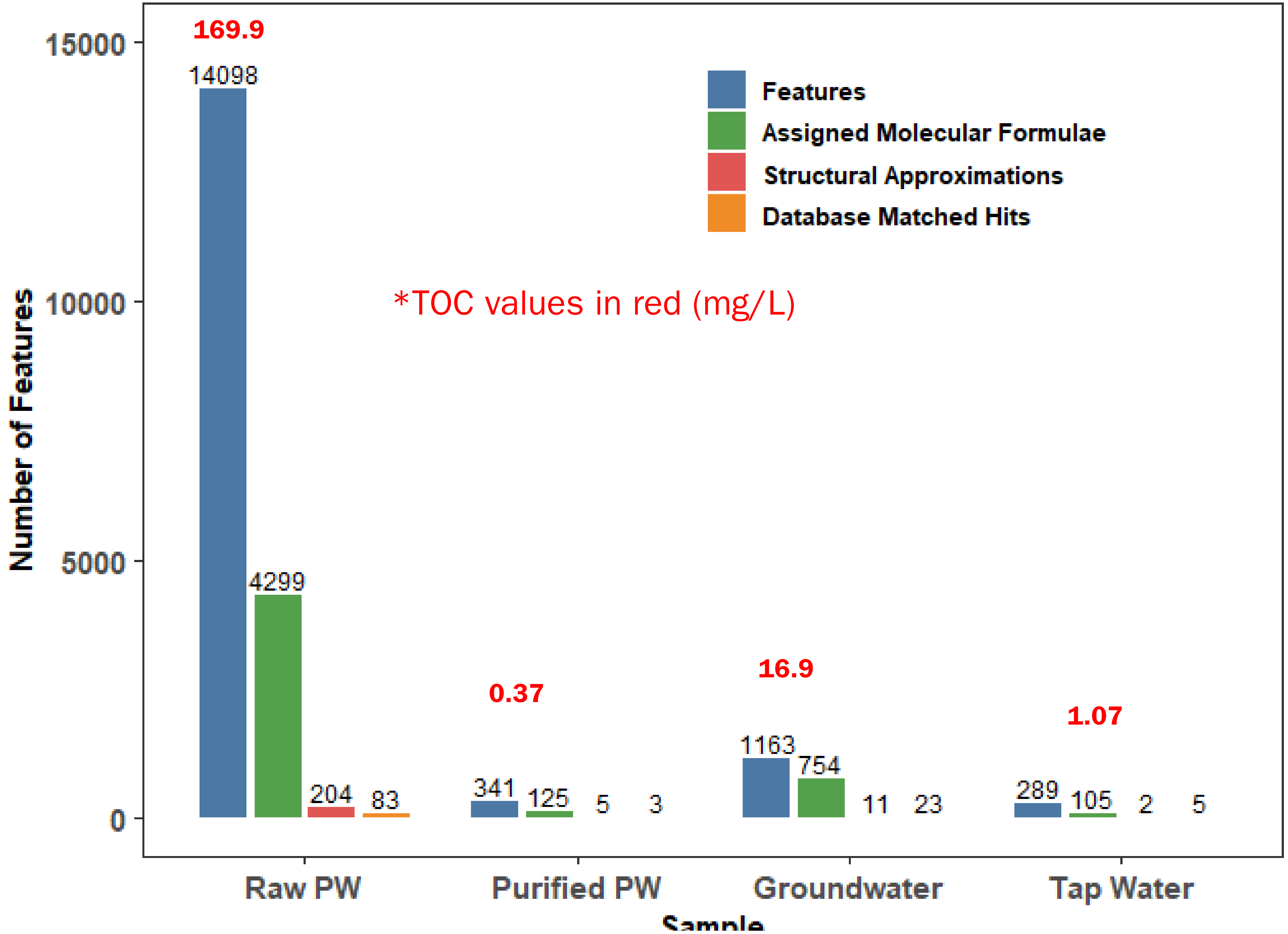
- EPA Toxicity Estimation Software Tool (TEST) to predict toxicity of a compound based on structure

- Very high, high, and moderate toxicity feature predictions decrease the most from initial to final product waters:
  - Thermal 1: 37 → 17
  - Thermal 2: 62 → 36
  - Membrane: 159 →15

Residues remaining in the final product waters are fewer and of lower toxicity compared to initial waters



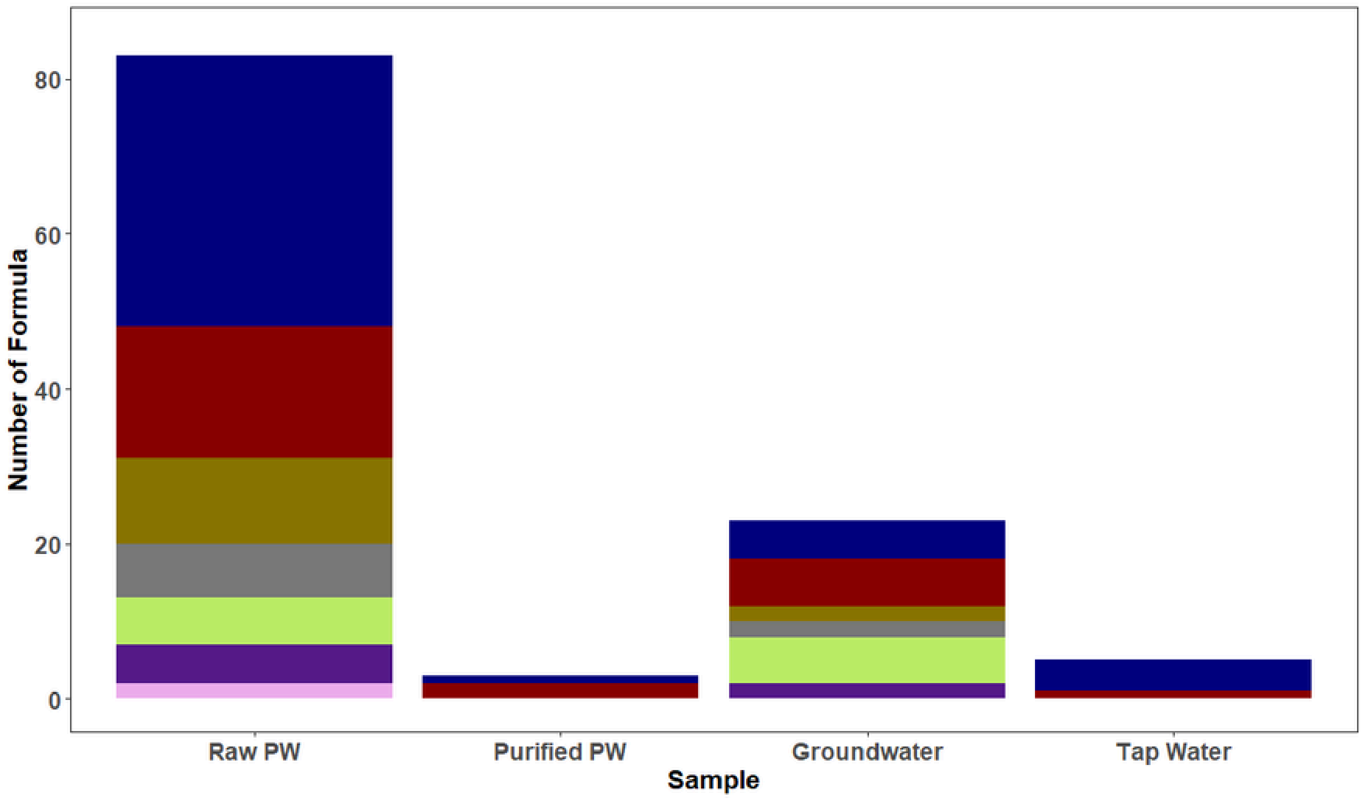
Comparison of PW with Groundwater and Tap water in Midland



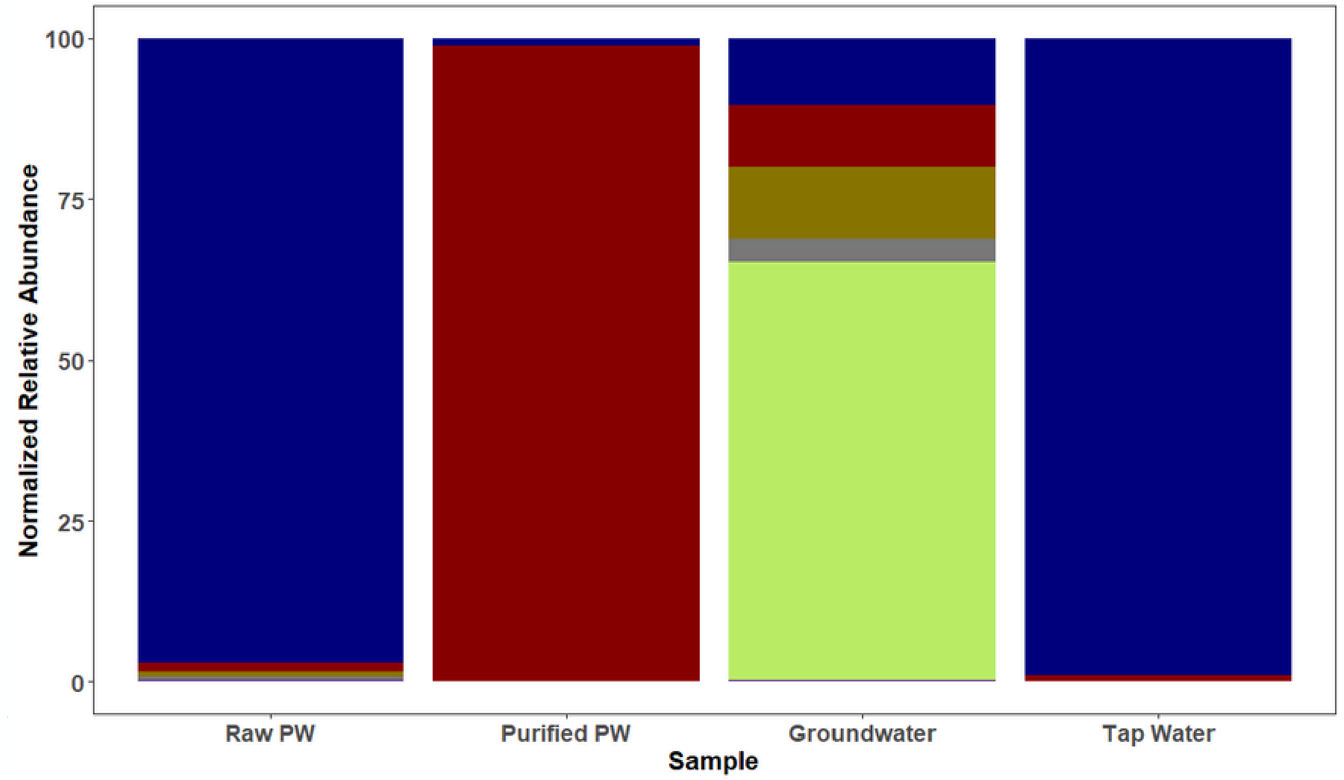
- Raw PW showed the highest number of detected features
- A substantial reduction in the number of features can be seen after the purification
- Groundwater also showed a relatively higher number of features
- The number of detected features was consistent with the TOC values of each sample

Classification of Tentatively Identified Molecules

With respect to the number of formulas

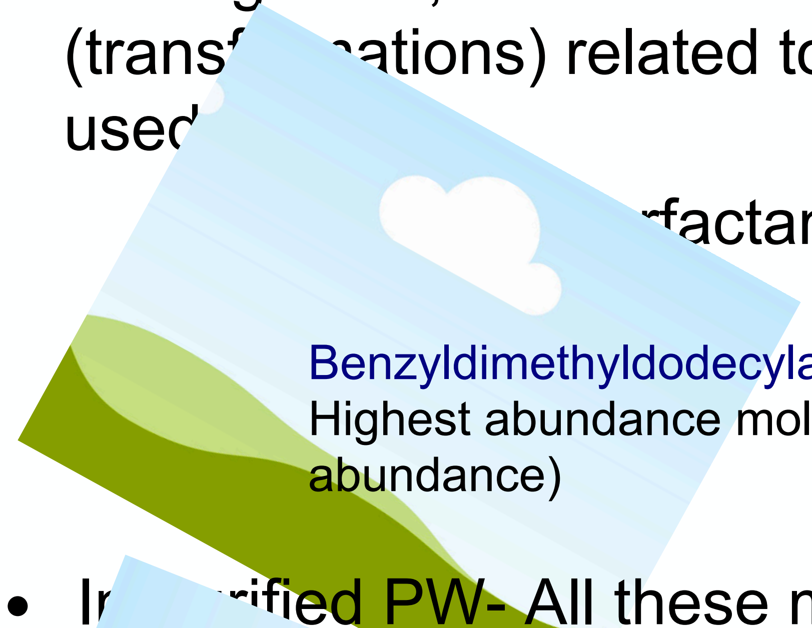


With respect to normalized relative abundances (NRA)



Source Related Categories
- Industrial_formulation_chemicals
- Biocidal_pharmaceutical_related
- Degradation_transformation_products
- Petroleum_solvent_related
- Plant_algal_derived_organic_matter
- Microbial_metabolites
- Fragrance_consumer_related

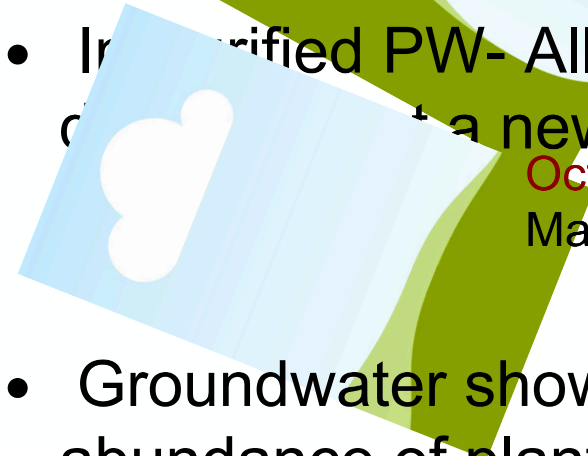
- A higher number of molecules detected in Raw PW.
- Among them,19 were directly, and 5 were indirectly (transf ations) related to the fracking chemicals used



rfactant-disinfectant/biocide

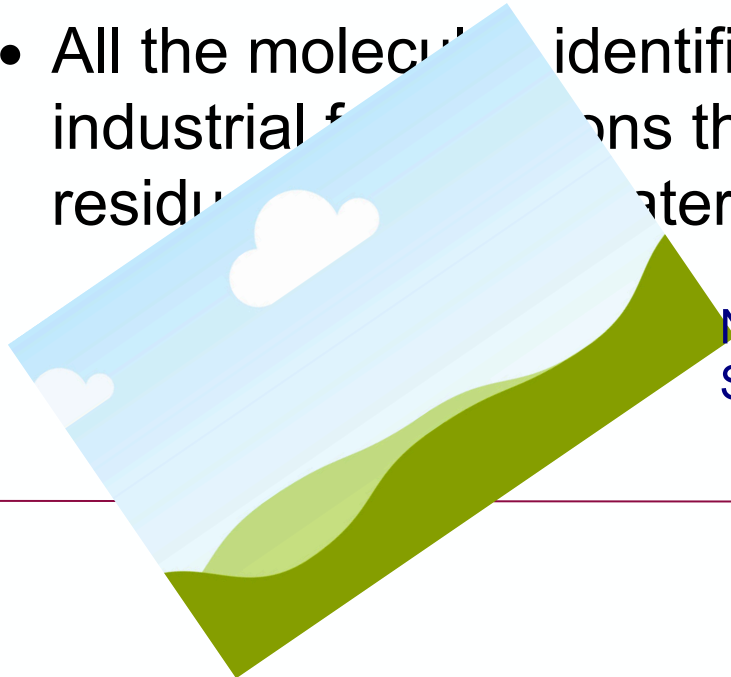
Benzyldimethyldodecylammonium cation
Highest abundance molecule -(more than 70% of total abundance)

- In rified PW- All these molecules were not d t a new



Octhilinone (biocide)
May appear due to low matrix effect

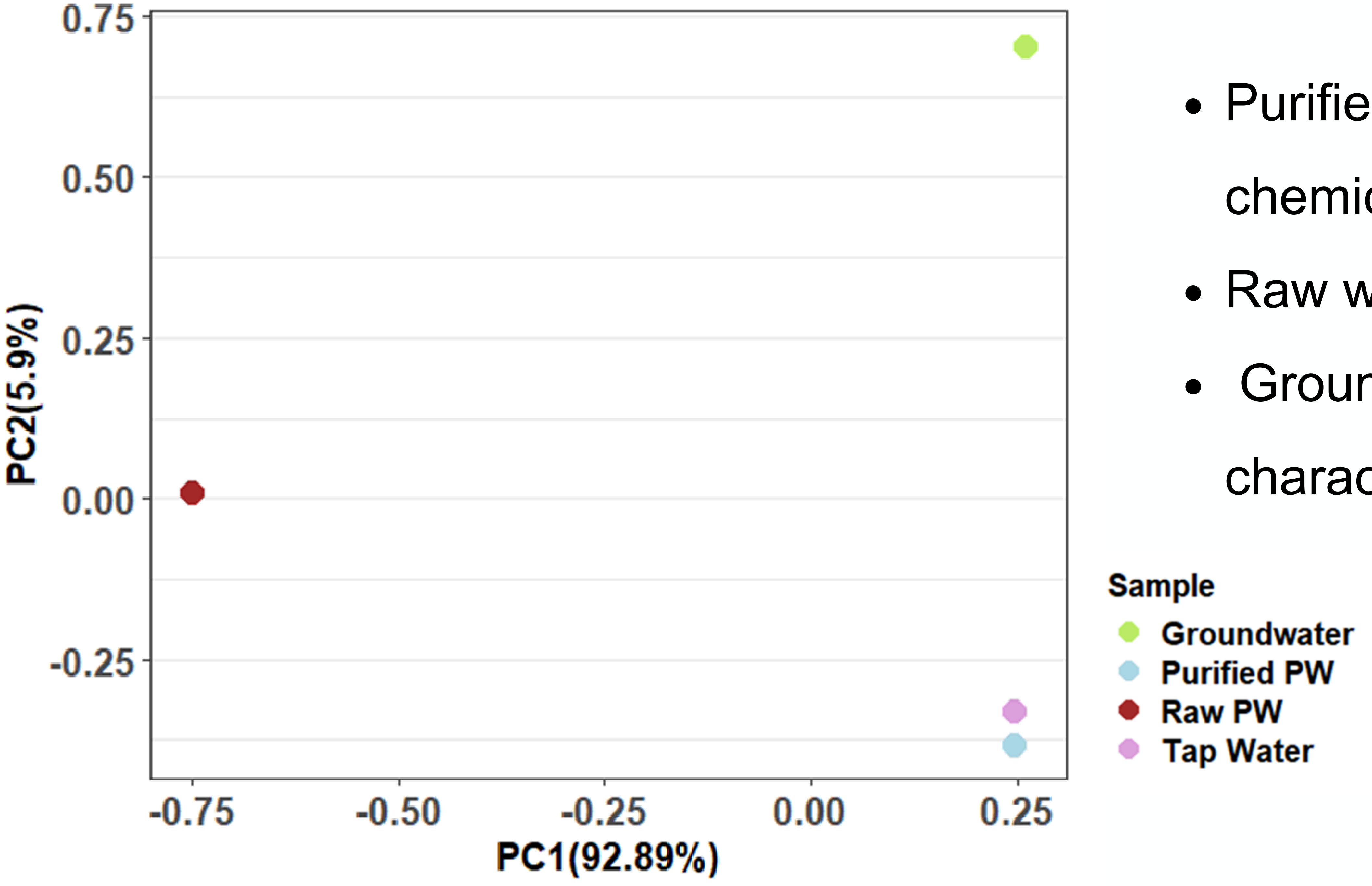
- Groundwater showed a relatively higher abundance of plant-derived organic matter
- All the molecu identified in tap water are industrial f ons that may be related to residu ter treatment or contaminants



N,N-Dimethyldodecylamine N-oxide
Surfactant (DDOA)

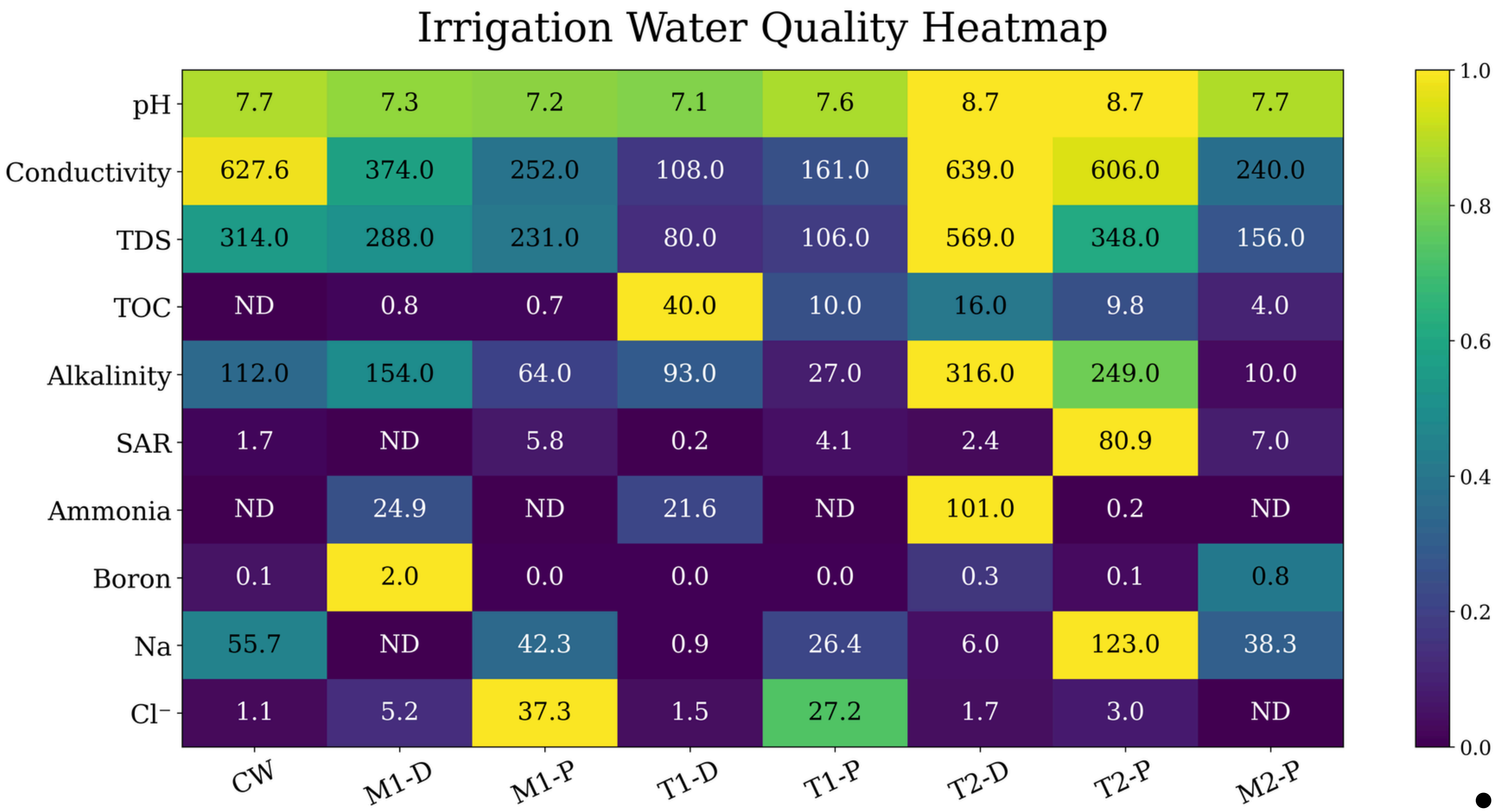
Principal Component Raw and Purified PW, Groundwater and Tap Water

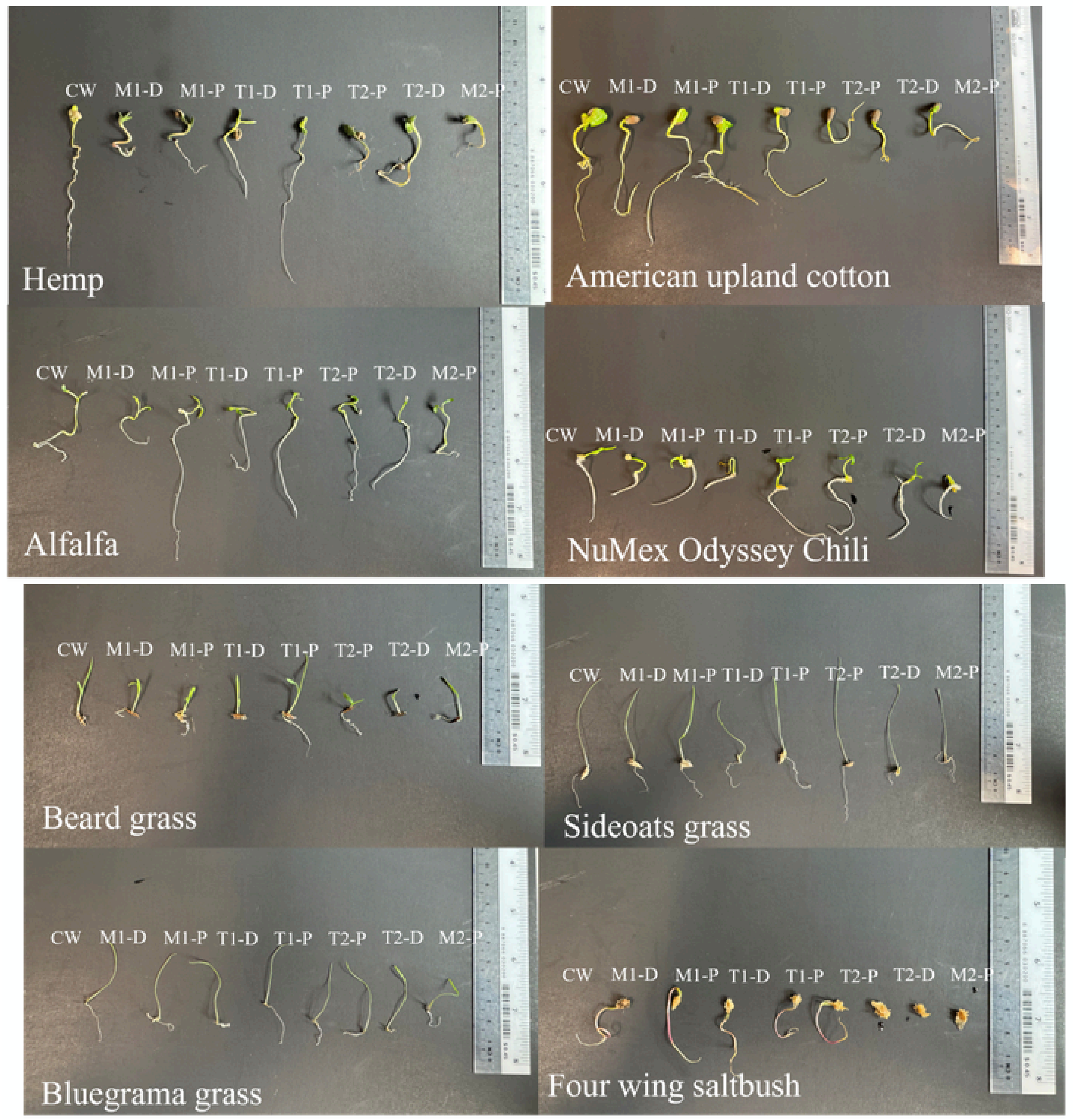
PCA comparing all the detected features, including unidentified ones

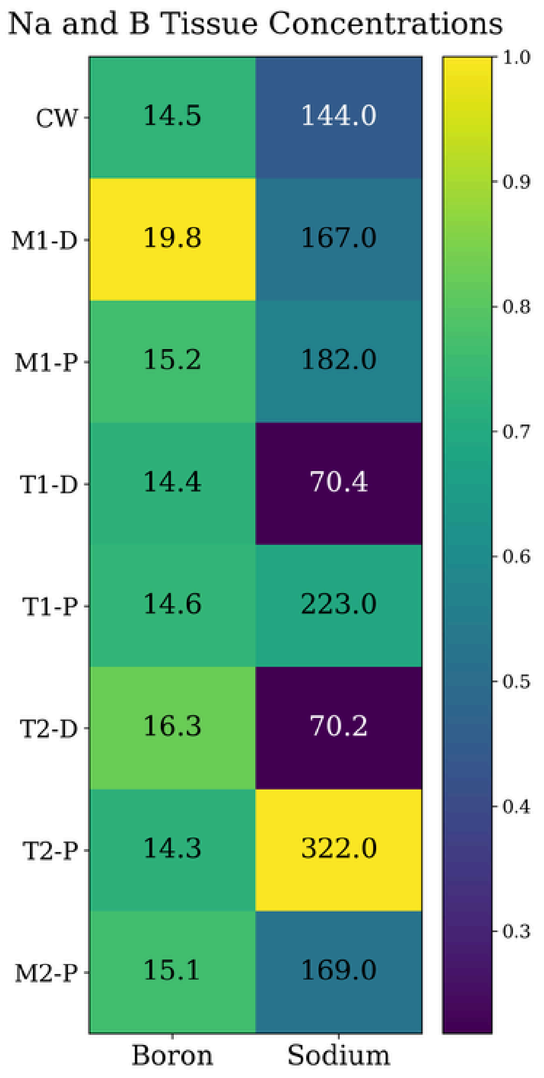


- Purified PW water and Tap water have similar chemical profiles
- Raw water is distinctly different from others
- Groundwater also has unique chemical characteristics compared to the Tap and Purified

Seed Germination



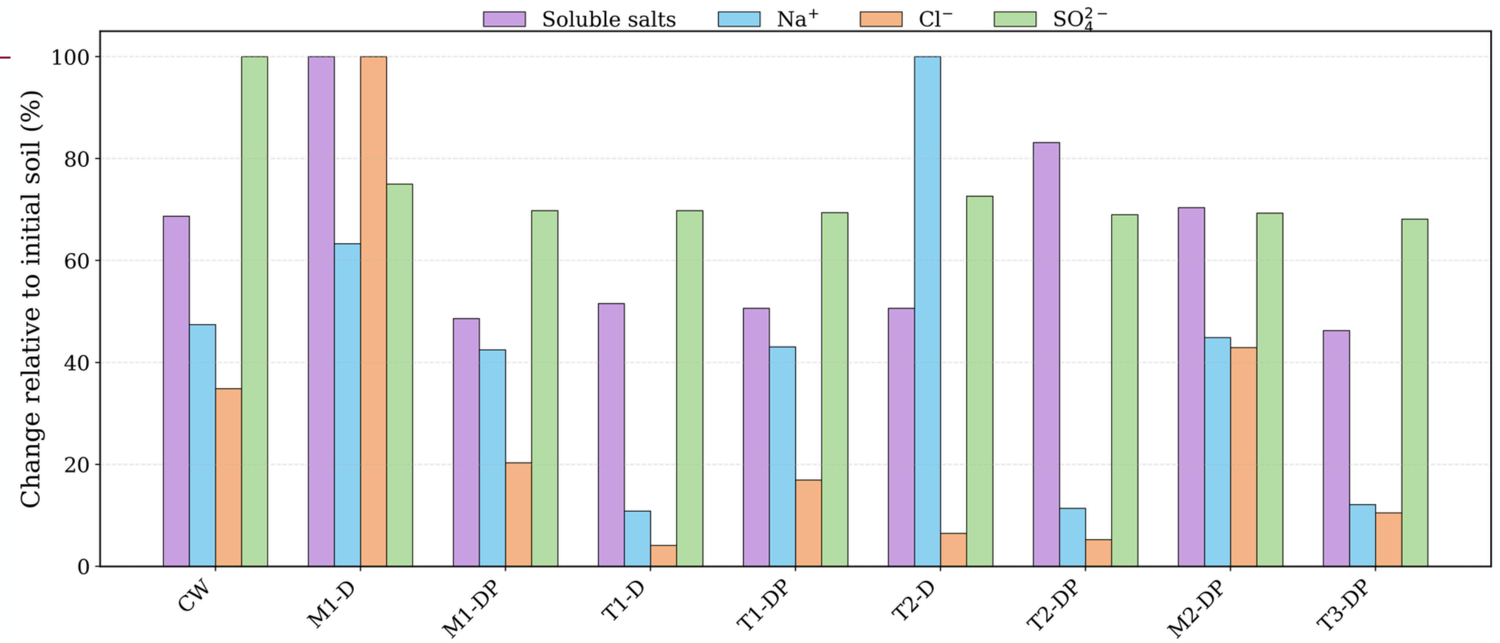


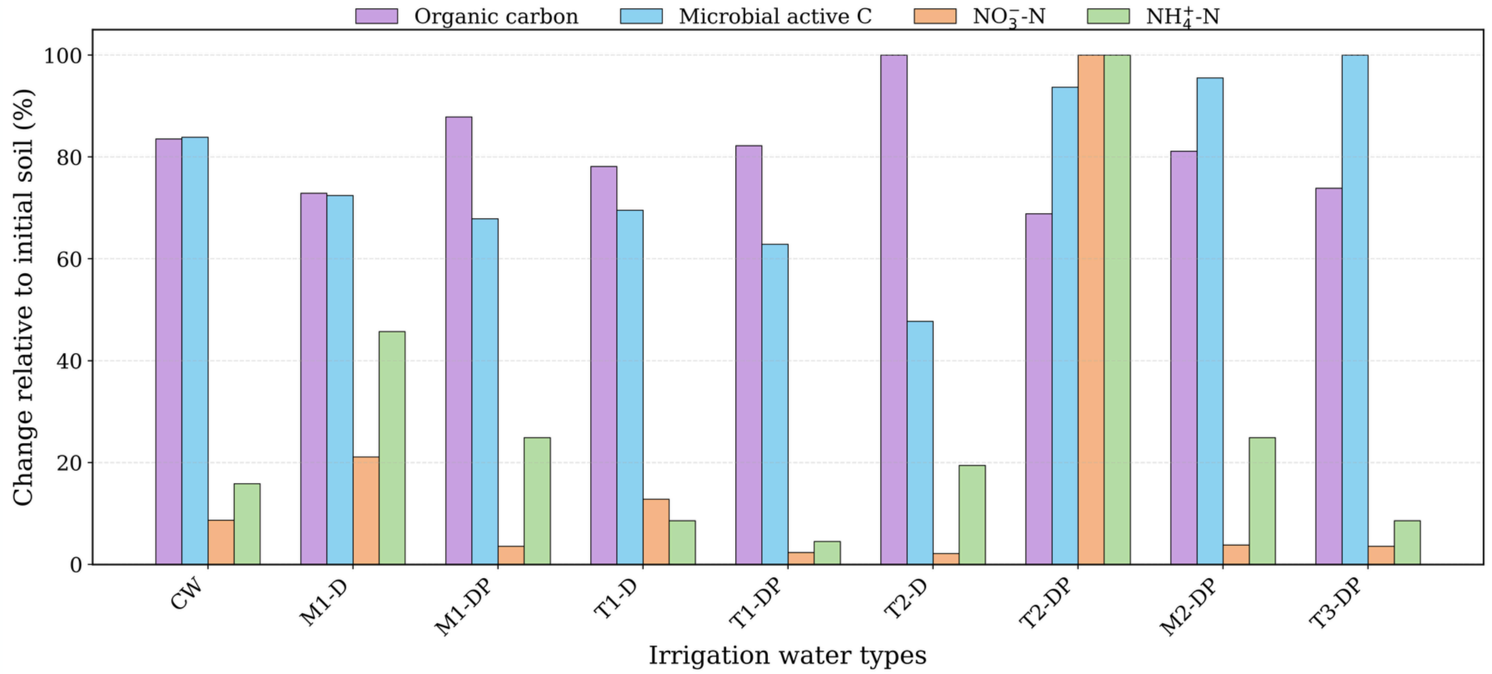


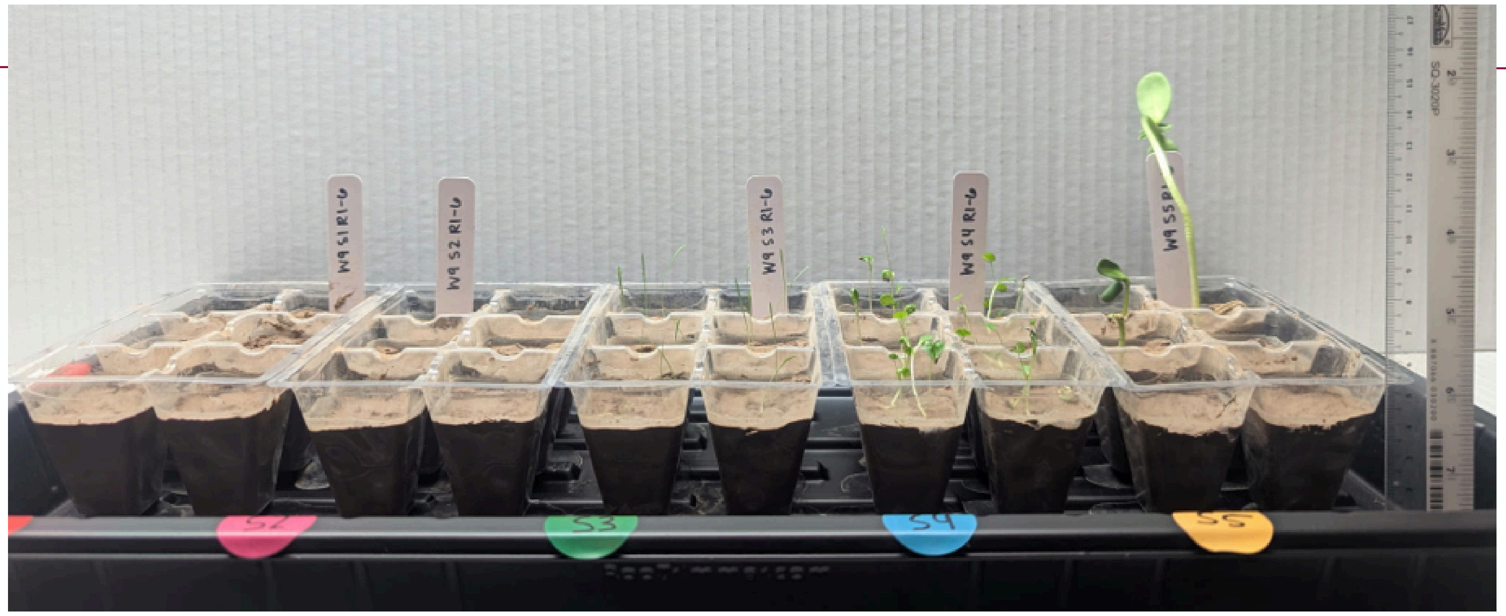
- 8 native plants and crops were irrigated
- 7 desalted and post-treated PW with different levels of salts, SAR, ammonia, TOC, and B were tested against tap water (CW)

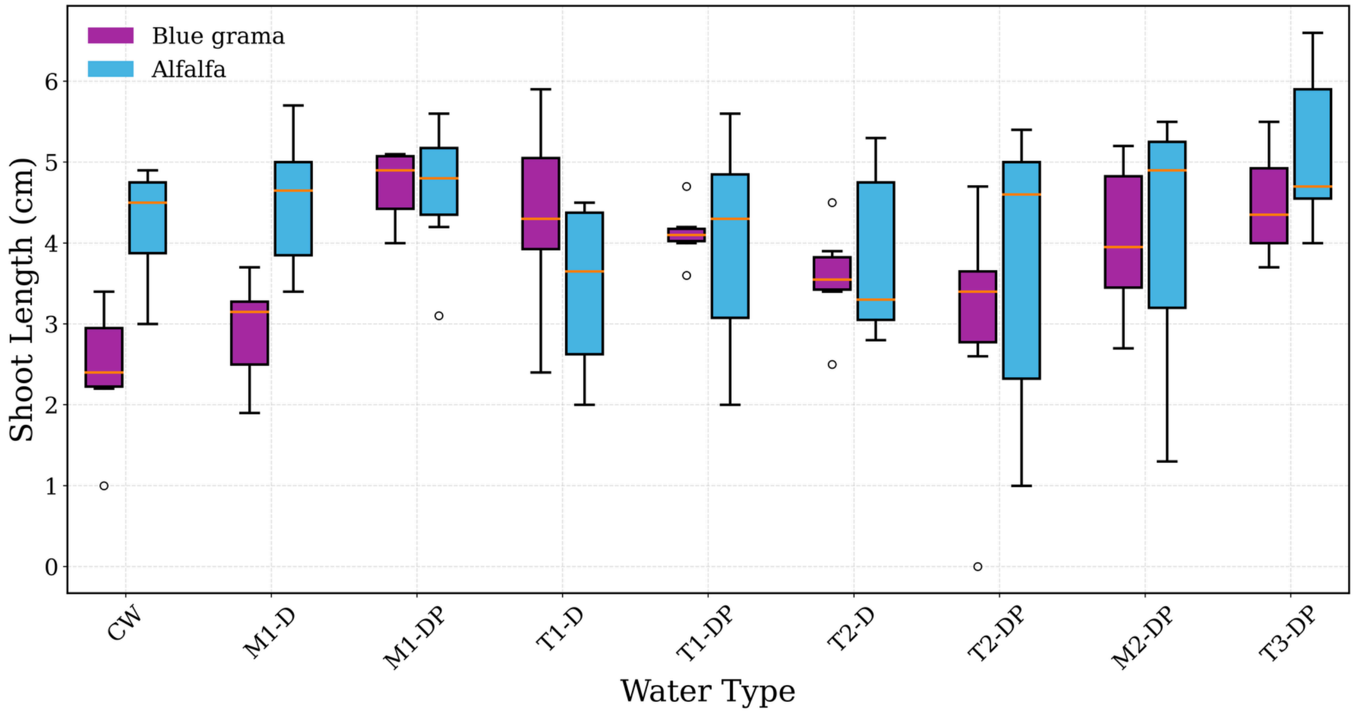
- Post-treated desalinated PW (M1-P, T1-P) generally performed best for root and shoot growth.
- Desalting alone was not sufficient; residual constituents (B, NH_3-N) affected plant responses – root growth.
- No single water type was best for all species; responses were species-dependent.

Seedling emergence under native soil conditions (Artesia soil)





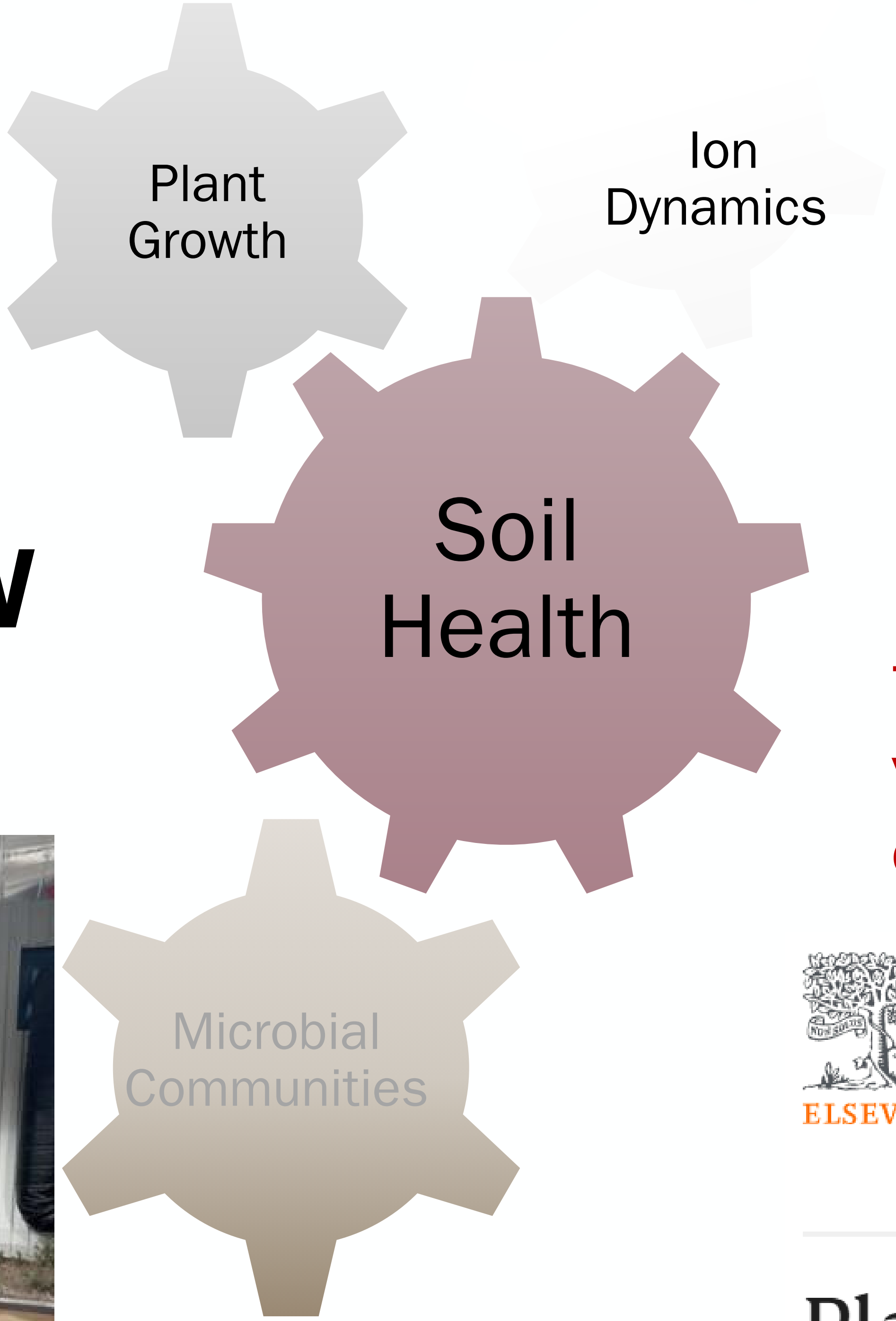




- Post-treated waters generally reduced soil salinity buildup (Na^+, Cl^-, soluble salts, and SO_4^{2-}) while maintaining improved soil health and nutrient dynamics relative to several desalination-only treatments.
- M1-DP, M2-DP, and T3-DP showed the most favorable overall responses, including improved soil quality indicators and enhanced shoot growth of Blue grama and Alfalfa.
- Organic carbon, microbial activity, NH_4^+-N, and NO_3^--N results indicated better maintenance of biological activity and nutrient balance under purified irrigation waters.

9-month Greenhouse Irrigation Study

Using Treated PW for Agricultural Irrigation



The project was designed to study the influence of tPW (500, 1000, 1500 mg/L TDS) vs. control (12 mg/L TDS) on:

- Soil health (SQI: chemical & physical)
- Ion transport & organics in soil profile
- Microbial communities (bacteria/fungi)
- Alfalfa forage quality (Crude protein, fiber, digestibility)

Treated produced water with TDS ≤ 1000 mg/L is a viable irrigation source that matches or exceeds control water for soil health and forage quality.

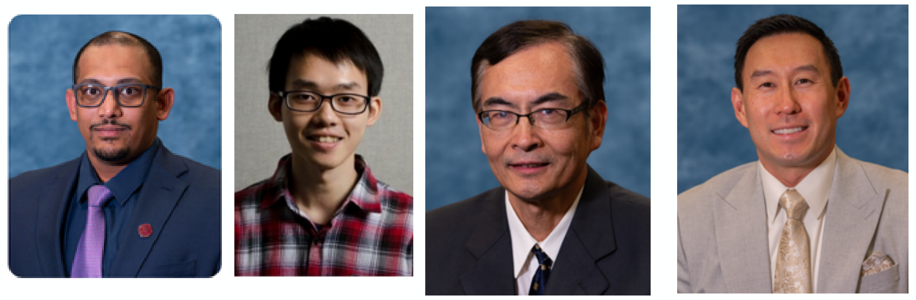
ELSEVIER
Science of The Total Environment
Volume 1001, 25 October 2025, 180520

Plant growth, ion dynamics, and microbial communities in soils irrigated with treated produced water for sustainable agriculture

What do the results show?

Test (End-Use)	Raw PW	Pretreated	Desalinated	Post-Treated
WET (Surface Discharge)	Toxic	Toxic	Signif. Reduced Toxicity	No Toxicity
Bioassays (Human Exposure)	Cytotoxic	Cytotoxic	Signif. Reduced Cytotoxicity	No Cytotoxicity
Greenhouse (Ag/Irrigation)	[Did not test]	[Did not test]	Minimal Impacts*	No Adverse Impacts

Other Big, Outstanding Questions (Currently Being Researched)

Question	Research Approach	Lead Researchers
Are there any "unknowns" in the raw, treated PW, and bioaccumulations in soil and plants?	In conjunction with targeted analysis, conduct Non-Targeted Analysis to screen for transformation by-products and TICs.	
What about potential chronic impacts to organisms exposed to tPW over long durations?	Conduct long-term zebrafish toxicity testing (98 day), mouse toxicity (100 days) and reproduction studies, and mosquito studies to probe health and ecological impacts of long-term exposure.	
Do chemical additives in fracking fluids have an impact on the treated PW?	Use FracFocus data to compare fracking chemical footprints and assess how these additives may influence produced water chemistry, toxicity, and treatment complexity.	
What is the fate and transport of the (organic) compounds that make it through treatment?	Build off existing F&T models to model and predict if compounds pose a risk to human health & environment.	
What are the economics of Permian Basin PW treatment?	Conduct a technoeconomic analysis and calculate levelized cost of water of a conventional treatment train, w/ focus on understanding where R&D is needed to reduce costs.	

Techno-Economic Analysis (TEA) Framework

A modular workflow for estimating cost, performance, and levelized cost of water.

Scenario definition

- Feed flow and quality
- Application scenario

>

Treatment train specifications

- Chemistry-informed decision making

>

Unit technical/cost models

- Recovery and removal rate
- Capital cost and O&M
- Sizing and financial assumptions

>

System aggregation

- Annualized CAPEX + OPEX
- LCOW normalized to feed volume
- Unit-level cost breakdown

Data source:

- **Raw and treated water quality:** NMSU's Water quality characterization
- **Technical models:** Pilot-validated physical/empirical models, established models from publications
- **Cost models:** Industrial insights, publications

Planned PW Treatment Technologies for Integration

Intake/distributio	Pretreatment	Desalination	Posttreatment	Brine valorization	Waste disposal
Well	3-phase	RO	GAC	Chemical	SWD
Raw water	DAF	MVC	Ammonia	Brine	Evaporation
	Walnut shell	MD (VMD,	Zeolite	Crystallizer	
	Cartridge	LSRRO	Ion exchange	Selective ED	
	Ultrafiltration		Remineralization	Bipolar ED	
	Electrocoagulatio				
	Chemical				
	Antiscalant				
	GAC				
	Air stripping				
	Nanofiltration				

Produced Water TEA

localhost:8501

Deploy

TEA GUI

Treatment Scenarios

Treatment Trains

System Design

TEA Results

Extensions

Techno-Economic Analysis — Fit-for-Purpose Water Treatment

Welcome to the NMPWRC TEA Tool 😊.

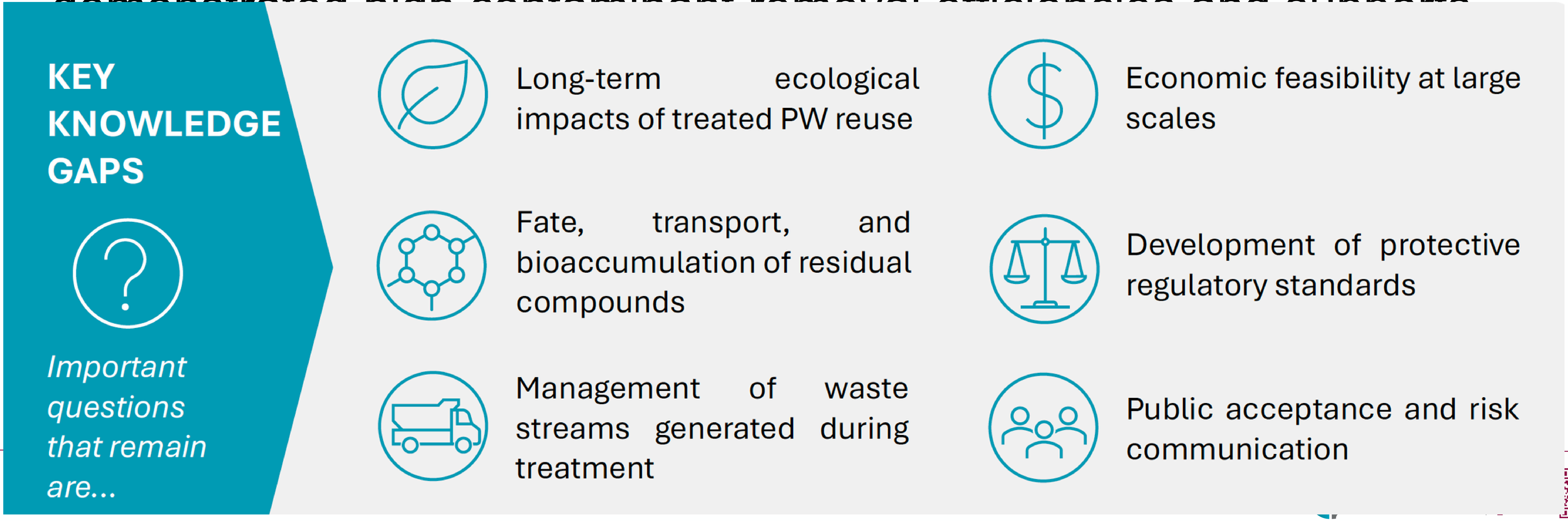
Use the sidebar to navigate between different steps:

- **Treatment Scenario:** Select treatment scenario
- **Treatment Train:** Configure treatment train
- **System Design:** Set up unit parameters
- **TEA Results:** View cost analysis
- **Extensions:** Explore planned GIS, socio-economic, optimization, and sensitivity modules

Start →

Summary on State of the Science

- Through **collaborative** research and **independent** evaluation, the science of produced water treatment and reuse has advanced significantly in recent years.
- Peer-reviewed studies and pilot-scale evaluations provide growing evidence that advanced multi-barrier treatment systems have demonstrated high contaminant removal efficiencies and supports



2026 Research Priorities

1. Evaluate the technical, economic, and environmental performance of treatment systems
2. Conduct comprehensive toxicological assessments of treated produced water
3. Improve the understanding of the relationships between water chemistry and observed bio-logical effects
4. Develop surrogate parameters and indicator compounds for routine water quality monitoring
5. Compile chemical and toxicological reference values and ecotoxicity data for reuse scenarios
6. Establish risk-based benchmarks to support the development of scientifically defensible regulatory standards

Acknowledgement – Great Collaborations!

- NMPWRC – ALL Members
- NMSU (Students, researchers, faculty, and administrators)
- State of New Mexico (NMED, HED, EDD, OCD, OSE, NMDA, DH…)
- Federal agencies: USEPA, BoR, DOE, USGS
- All Collaborators, TxPWC, CPWC….

Contact Information

New Mexico State University

New Mexico Produced Water Research Consortium (NMPWRC)

College of Engineering Outreach | (575) 646-2913 |

nmpwrc@nmsu.edu

Dr. Patricia A. Sullivan
Associate Dean
Office of Engineering Extension and Outreach
Patsulli@nmsu.edu

Dr. Pei Xu
Chief Technology Officer and Research Director
Professor, Civil and Environmental Engineering
pxu@nmsu.edu

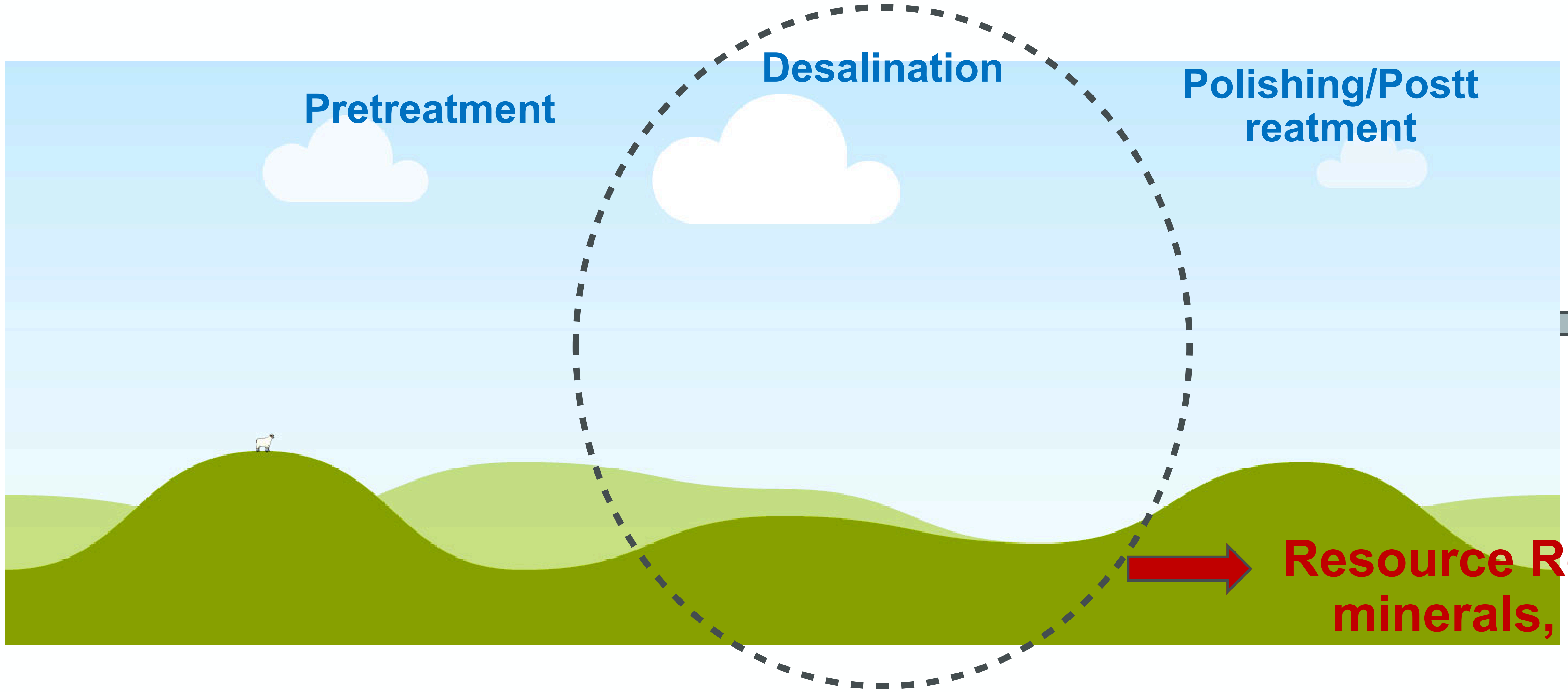
Dr. Zach Stoll
Assistant Director
zstoll@nmsu.edu

Research Priorities - strong consensus

- **Provide science to enable policy/standards for regulations:**
  - Need a clearer PW reuse policy/regulatory framework
  - Provide protective water quality standards/limits that regulators and industry can reference
- **Build credibility through risk assessment + fate/transport:**
  - Risk assessment on human health and environment is central for public acceptance
  - Fate & transport study is important for regulators and permitting: needs credible fate/transport evidence for residual compounds in receiving environments (soil, surface water, crops, etc.)
- **Support implementation with monitoring and transparent data:**
  - Open access to data (e.g., on the website)
  - Real-time/near-real-time monitoring systems that can support discharge and reuse without requiring impractical sampling burdens.
- **Use TEA strategically (comparative + sensitivity) while acknowledging private cost data limitations**
- **Evaluate long-term field testing and impacts on fit-for-purpose reuse not just near-term lab results.**

Water Quality-Driven Technoeconomic Analysis (TEA) validated by experimental data

Produced Water Treatment



Fit-for-Purpose Water Reuse

Water quality requirements:
- **Drinking water**
- **Ag Irrigation**
- **Land application**
- **Pure water for industry**

Resource Recovery (NH_3, critical minerals, H_2, acids, bases…)

Levelized Cost of Water:
- Costs: CaPX, OPEX (energy, chemicals, labors, replacement, maintenance)
- Energy sources
- Waste management and disposal (liquid, solids)
- Sensitivity analysis (cost of materials, life cycle time)
- Benefits: water uses, resources recovery and valorization