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EPA Tools and Resources Webinar: Addressing Emerging Contaminants in Wastewater Treatment Systems

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March 19, 2025

Background and Problem

- Recognized need to address emerging contaminants (EC)
- Clean Water State Revolving Fund (CWSRF) Emerging Contaminants Capitalization Grant supports states to address ECs
- Applicants lack information on the cost and effectiveness of EC removal processes
- Comprehensive environmental impacts are unknown
- Performance and cost prediction for future unknown emerging contaminants

Objectives

Develop a web-based tool that allows users to:

- Learn more about the effectiveness of their existing treatment processes in removing emerging contaminants of concern

- Identify processes that can provide additional removal, as well as life cycle costs and environmental impacts of those processes

Approach

Initially targeting emerging contaminants (no PFAS)

- Microplastics
- Pharmaceuticals and personal care products (PPCPs)
- Harmful algal blooms
- 1,4-dioxane
- 6-PPDq

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Acetone
17β-Estradiol
17α-Ethinylestradiol
Carbamazepine
Fluoxetine
Formaldehyde
Galaxolide
Sulfamethoxazole
Trimethoprim
Triclosan

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Approach

- Existing WWTP Removal Rates
  - Compile data allowing users to estimate EC removal through existing treatment systems
- Additional Treatment Processes:
  - Compile process models suitable for contaminants of concern and user-specified conditions
  - Initial focus on short list of processes including UV advanced oxidation process (UVAOP), granular activated carbon (GAC) and ozone
  - Eventual list undefined, but could include microfiltration (MF)/ultrafiltration (UF) membranes, biological activated carbon (BAC), reverse osmosis (RO)
- Preliminary version built in Excel
- Eventual platform is web application
- Class 5 cost estimates (screening level)

6

Approach

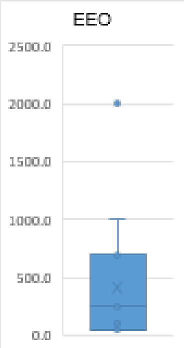
Two interrelated components:

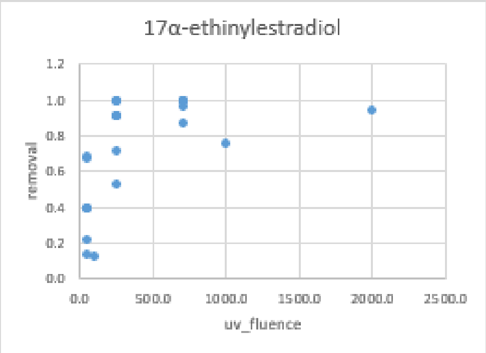
1. Performance database
   - Similar to EPA's Drinking Water Treatability Database, but with more detail
   - Goal is to express process performance as a function of important parameters such as feedwater quality, process size, process configuration, etc.
2. Unit process models
   - Standard line-item costing approach including direct and indirect cost factors
   - Life cycle inventory (LCI) and life cycle impact assessment (LCIA) of environmentally relevant components
   - Line items

Performance Database

- Detailed and standardized compilation of removal rates, as well as associated design and operating conditions
- Allows analysts to identify the influence of important process parameters on compound removal

UVAOP Data Analysis



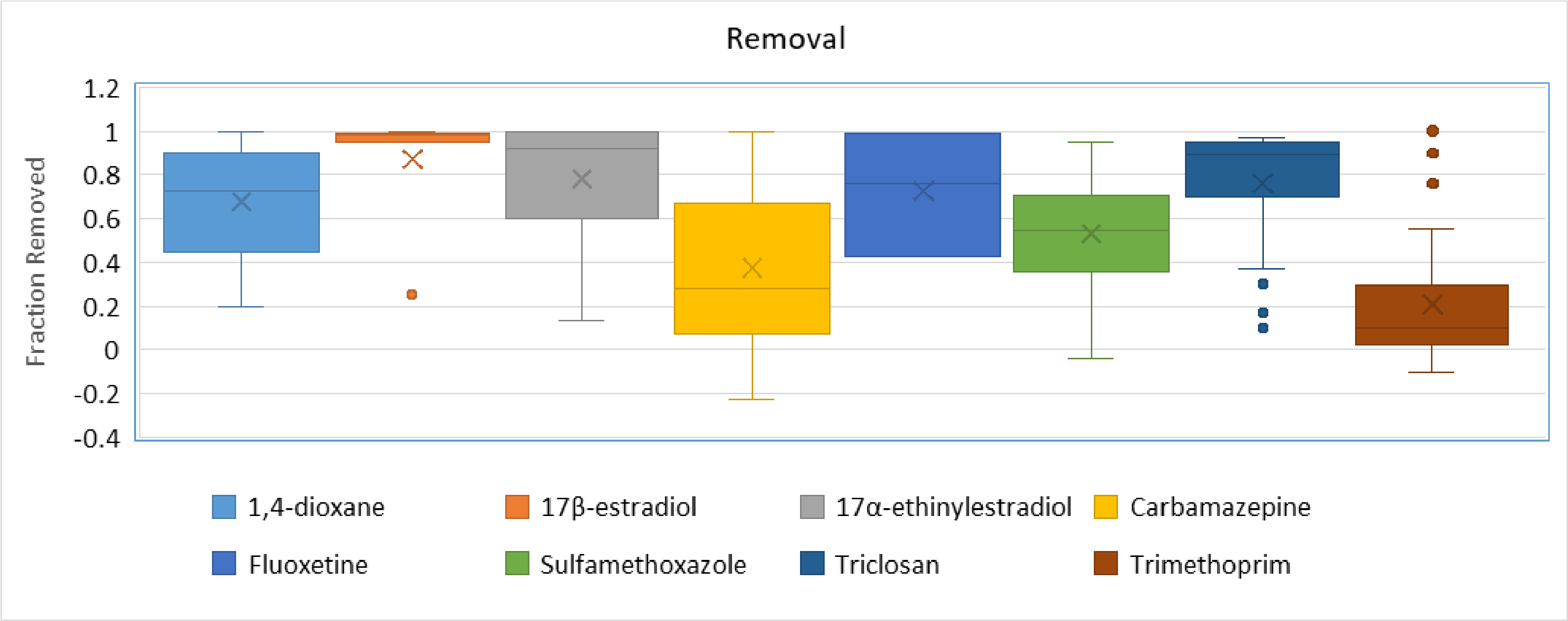


Compound	17α-ethinylestradiol
Oxidant	H2O2
WQ Parameter	k_fluence

ID	resource	compound	scenario	source_water	oc	lamp_type_sh	uv_fluence (x-axis)	removal (y-axis)
1490	Chen et al., 2007	17α-ethinylestra	Solution 2, EE2	Natural water	0.89	LP	100.0	0.1
1492	Chen et al., 2007	17α-ethinylestra	Solution 2, EE2	Natural water	0.89	LP	1000.0	0.8
1494	Chen et al., 2007	17α-ethinylestra	Solution 2, EE2	Natural water	0.89	LP	2000.0	0.9
1529	Rosenfeldt et al., 2007	17α-ethinylestra	Lab DI Water, MP 5	Lab DI water		MP	50.0	0.7
1530	Rosenfeldt et al., 2007	17α-ethinylestra	Lab DI Water, MP 10	Lab DI water		MP	50.0	0.7
1531	Rosenfeldt et al., 2007	17α-ethinylestra	Water 1, LP 5	Water 1 (natural water, water tre	3.06	LP	50.0	0.2
1532	Rosenfeldt et al., 2007	17α-ethinylestra	Water 1, MP 5	Water 1 (natural water, water tre	3.06	MP	50.0	0.4
1533	Rosenfeldt et al., 2007	17α-ethinylestra	Water 1, MP 10	Water 1 (natural water, water tre	3.06	MP	50.0	0.4
1534	Rosenfeldt et al., 2007	17α-ethinylestra	Water 2, LP 5	Water 2 (natural water, water tre	1.39	LP	50.0	0.1

Performance Database

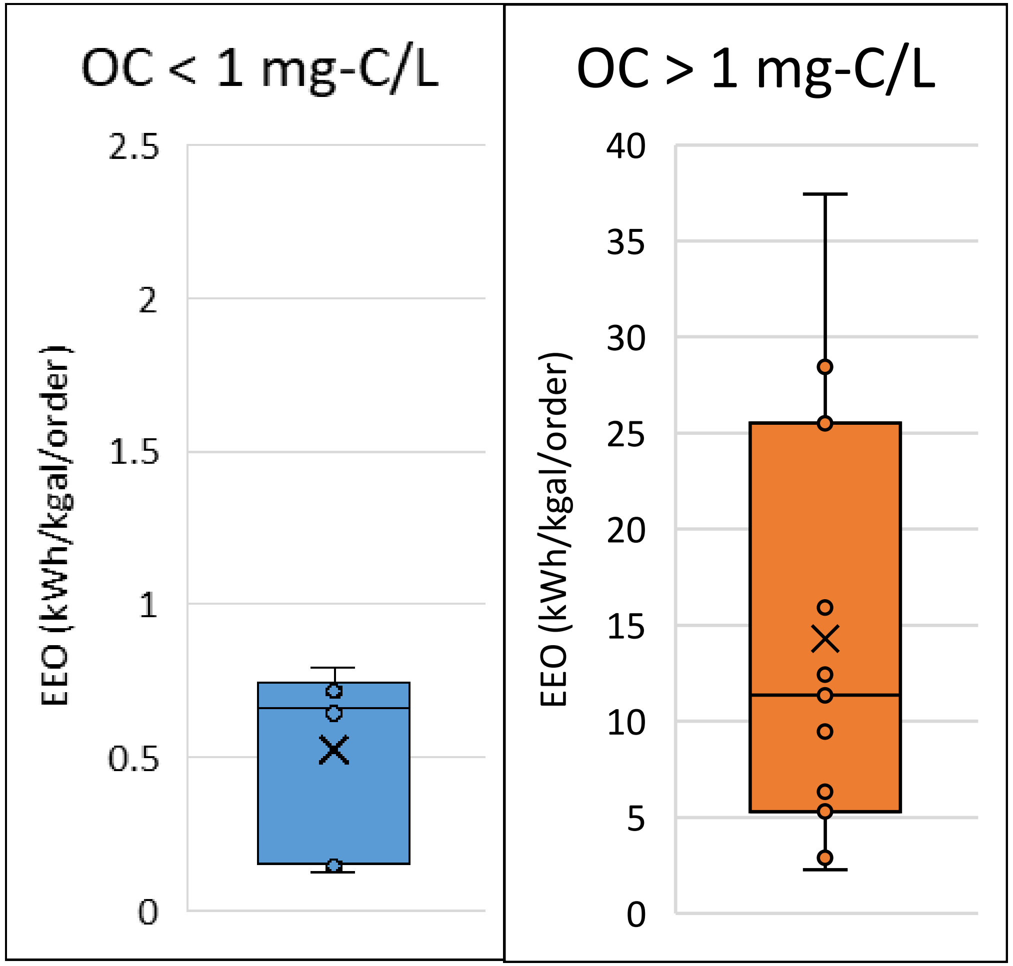
- Compiling more than just removal rate is critical
- For example, how confident can we be that UVAOP is more effective at removal of fluoxetine than carbamazepine?
- Documented removal rates typically span a wide range of design and operating conditions



Performance Database

Using 1,4-dioxane data as an example in UVAOP:

- Organic carbon, particularly effluent organic matter, can scavenge hydroxyl radicals and reduce the penetration of UV radiation
- Organic carbon concentration of 0.5 vs 5 mg/L can have an order of magnitude influence on the energy required for a fixed rate of removal



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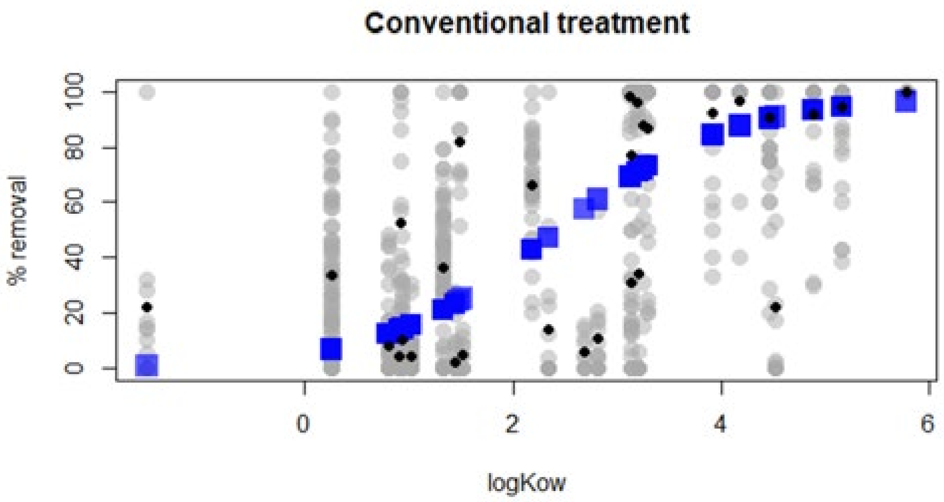
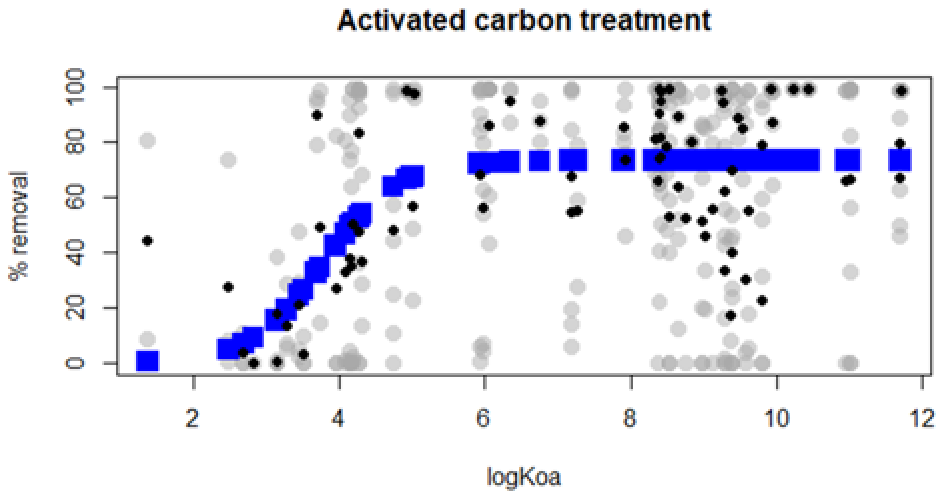
Performance Database

- Initial efforts focused on a short list of contaminants
- Chemical/physical characteristics being compiled alongside removal rates and conditions
- Future work intended to extrapolate known removal rates to other compounds on the basis of chemical/physical characteristics

Performance Database

- Relevant literature currently being reviewed
- For example, Pronk et al. (2023) used a random forest regression approach to identify dominant parameters that influence EC removal





$$P_{\text{conv}} = \frac{98}{1 + e^{-1.2 \cdot (\log K_{ow} - 2.4)}}$$

$$P_{\text{ac}} = \frac{73.4}{1 + e^{-1.99 \cdot (\log K_{oa} - 3.8)}}$$

$$P_{\text{ox}} = \frac{83.5}{1 + e^{-0.39 \cdot (\text{abonds} - 2.71)}}$$

$$P_{\text{advox}} = \frac{82.6}{1 + e^{-4.4 \cdot (\text{FeatureRingCount3D} - 0.26)}}$$

$$P_{\text{ro}} = \frac{100}{1 + e^{-2.95 \cdot (\ln(\text{Mass}) - 4.63)}}$$

Pronk, T. E., Fischer, A., van den Berg, A. E., & Hofman, R. C. (2023). Prioritization of micropollutants based on removal effort in drinking water purification treatment. *Water Quality Research Journal*, *58*(3), 184-198.

Tool Workflow

User Defines General Inputs:

- Contaminant(s) of concern
- Location
- Existing treatment system characteristics
- Effluent characteristics (e.g., TOC, nutrients)

Tool Identifies:

- Removal rates at existing treatment system
- Processes capable of providing additional treatment
- Approximate effectiveness of each
- Approximate cost ranges of each

User Selects Processes, Defines Process Model Inputs:

- Desired contaminant removal rate
- Process-specific inputs (e.g., dosage rates, retention time, material type, etc.)

Tool Generates:

- Capital and annual cost estimates
- Life cycle impact estimates

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Process Models

General Inputs

- Location
- Cost parameters (e.g., interest rate, loan term, etc.)
- Feedwater characteristics
  - Flow rate
  - Important water quality parameters
- Contaminant of concern
- Target removal rate
- Process characteristics

General Outputs

- Cost
  - Capital and annual Operations & Maintenance
  - Present value
  - Net present value
- Environmental Impact
  - Total energy demand
  - Eutrophication
  - Water consumption
  - Water scarcity
  - Disability-Adjusted Life Year (DALY)

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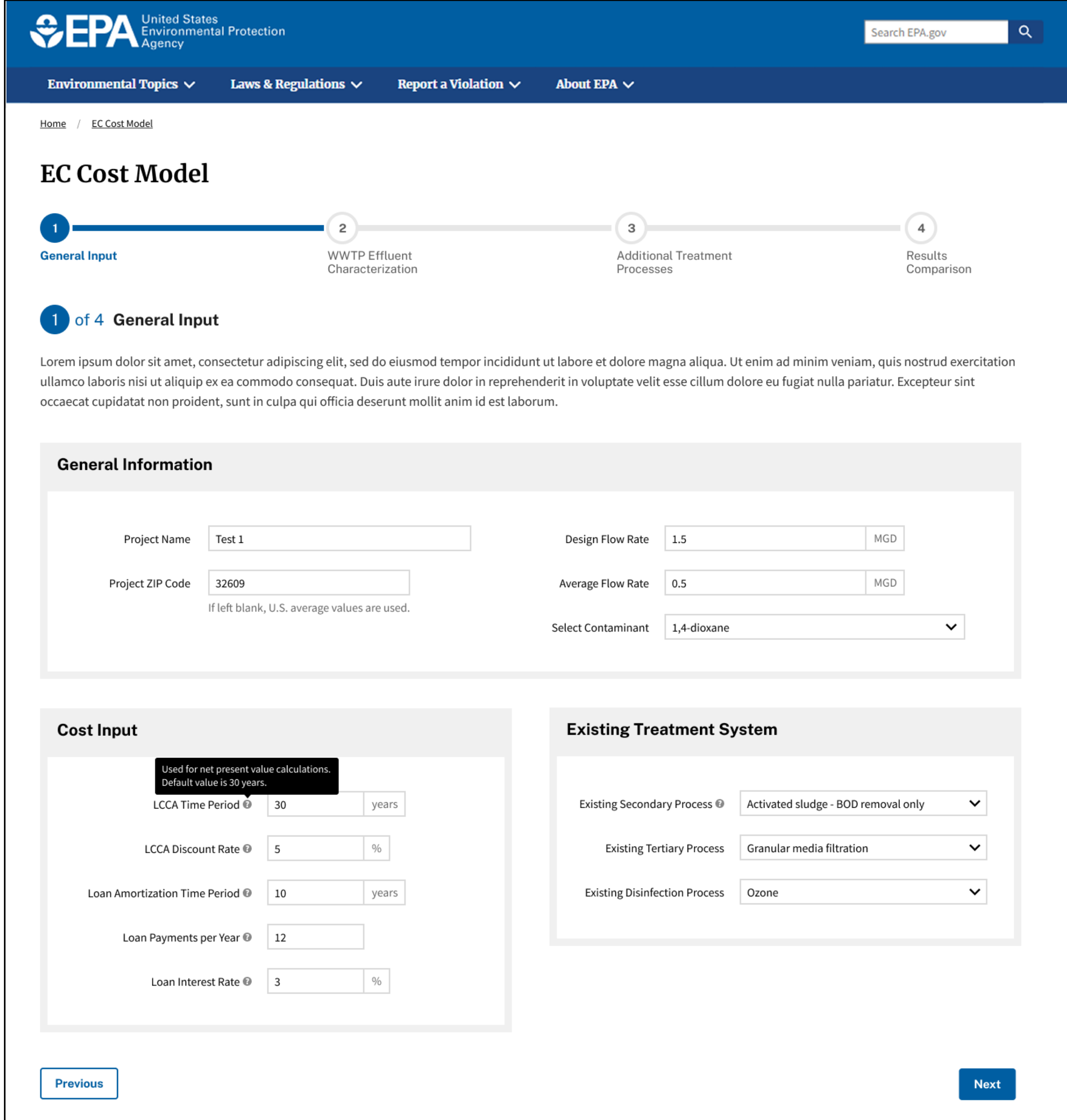
Web Application Mockup



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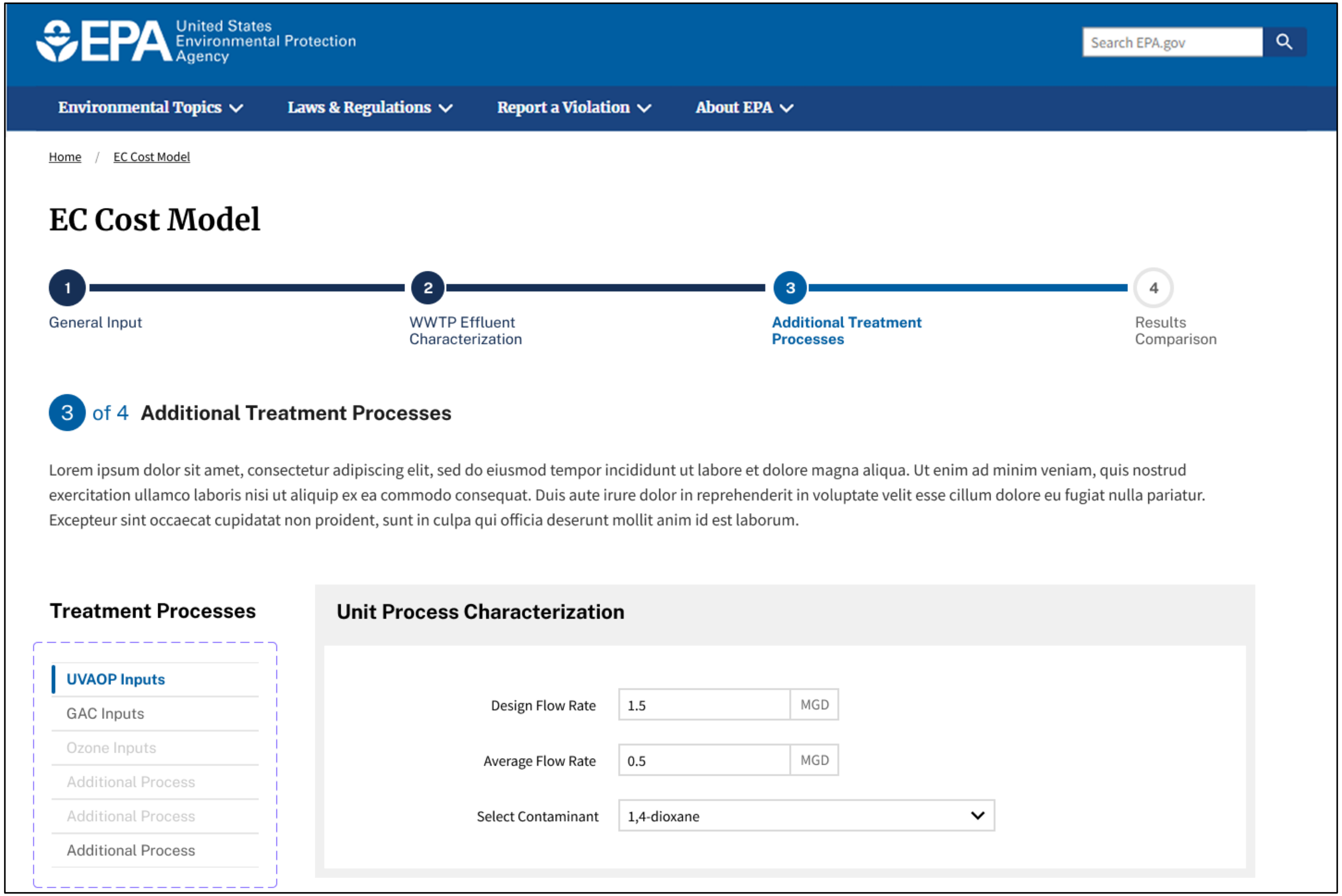

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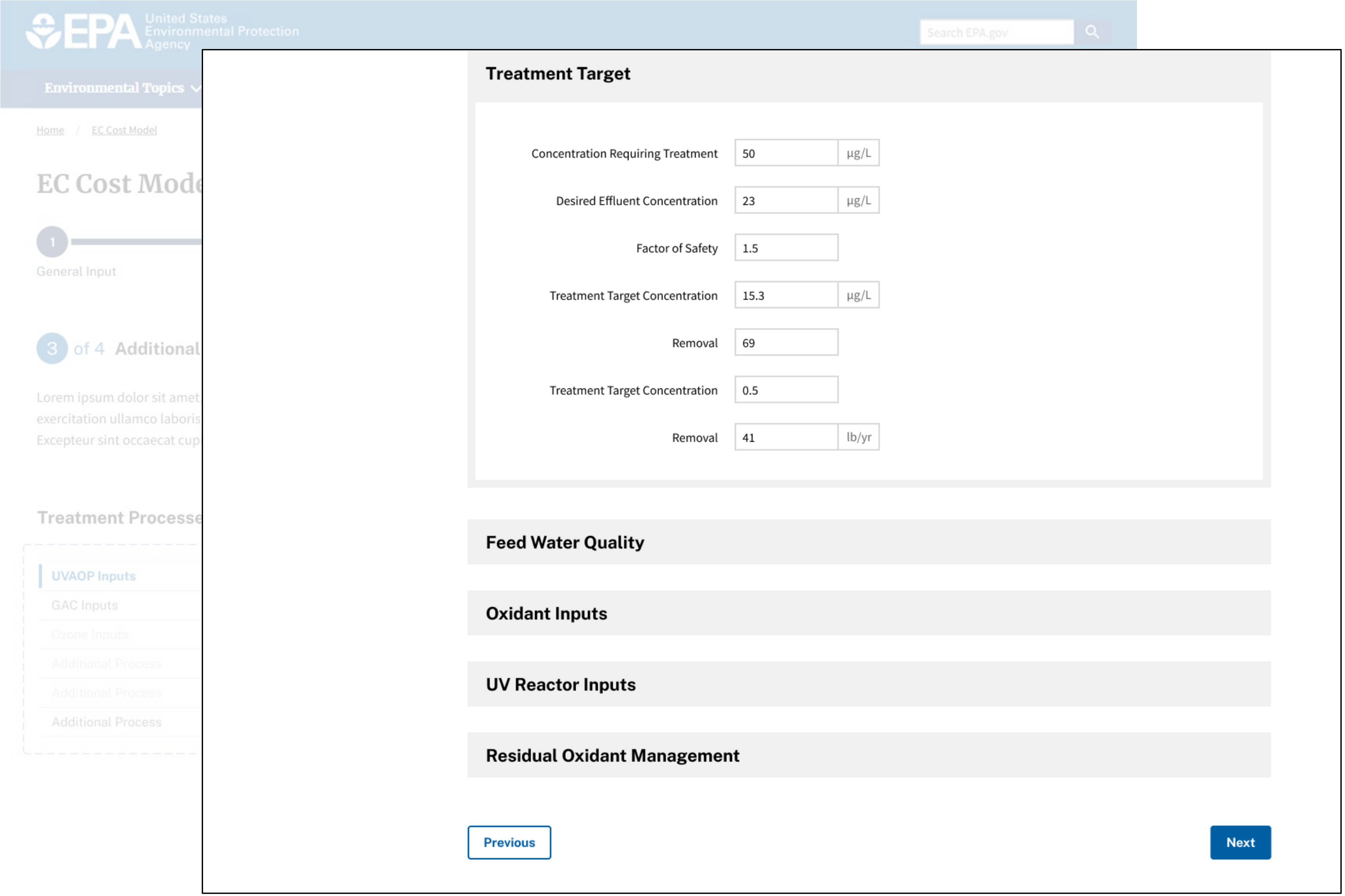

EC Cost Model

1 General Input — 2 WWTP Effluent Characterization — 3 Additional Treatment Processes — 4 Results Comparison

4 of 4 Results Comparison

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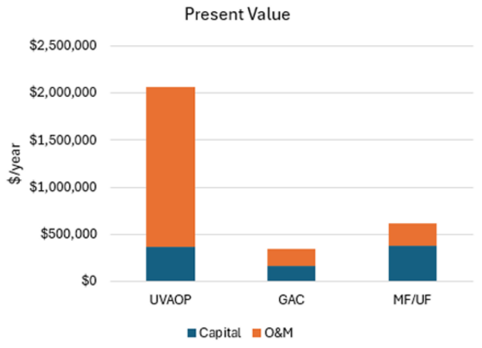
Capital Cost | **Present Value** | Net Present Value | Environmental Impact

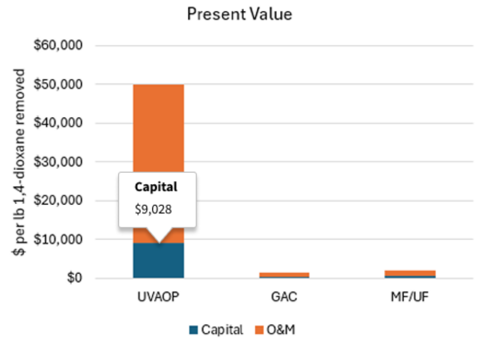
$/year

	UVAOP	GAC	MF/UF
Capital	$371,611	$167,000	$384,100
O&M	$1,684,237	$183,700	$229,625



$ per lb 1,4-dioxane removed

	UVAOP	GAC	MF/UF
Capital	$9,028	$501	$802
O&M	$40,919	$895	$1,205



Previous

New Calculation

Impact

- The Integrated Framework tool is designed to:
  - Provide clear and data-driven guidance to environmental and public health decision makers responsible for allocating and spending SRF funds
  - Provide easy access to an otherwise vast, variable and complex body of data describing EC fate and transport
  - Identify the most cost-effective technologies for addressing a range of ECs
  - Identify environmental tradeoffs in technology selection – e.g., does cheaper treatment come at the cost of greater life cycle environmental impact?

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Ongoing Work

- Contractors working to finalize preliminary process models and framework construction
- Upcoming year will be spent expanding to additional contaminants and processes (data sharing is welcome)
- Longer term, platform lends itself to expand to other problematic contaminants for the wastewater community, such as chloride, sulfate and nitrate
- Initial Excel-based web application to be launched by the end of 2026
- Long-term goal – Wastewater Treatability Database

Collaborators

- USEPA Office of Water/Office of Wastewater Management: Smiti Nepal, Heather Strathearn, Jacob Adler
- USEPA ORD: Cissy Ma, Jay Garland, Michael Jahne, Tao Li, Bruce Smith, Sean Thimons
- Eastern Research Group, Inc.: Sam Arden, Hiroko Yoshida, Steve Geil, Annie Dubner
- Oklahoma, Washington, Arizona, Florida, and Iowa agreed to share data for the framework
  - Oklahoma – PPCPs, microplastics and PFAS in biosolids demonstration at WWTP
  - Washington – 6-PPD, microplastics, PPCPs, and PFAS in stormwater
  - Arizona (utility for reuse) – 1,4, Dioxane
  - Florida (pilot at WWTP) – PFAS
  - Iowa (WWTP)- PFAS

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Take Home Messages

- Effectiveness of existing treatment processes in removing ECs
- Identify the removal rates for unit processes that can potentially provide additional removal
- Provide the basis for fit-for-purpose targets
- Balance treatment performance with cost and environmental impacts
- Holistically manage the cost-effective removal of ECs to meet Clean Water Act water quality goals

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Disclaimer: The research described in this presentation has been funded in part by the US EPA under contract 68HERC20D0029. It has been subjected to review by ORD and approved for publication. Approval does not signify that the contents reflect the views of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.