State Water Board DPR Pathogen Research

Tools to Evaluate Microbial Risk, Plant Performance, and Reliability (DPR-1)

Raw Wastewater Pathogen Monitoring (DPR-2)

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How Much Pathogen Treatment?

Wastewater

20-log virus
14-log *Giardia*
15-log *Crypto*

Drinking Water
How Much Pathogen Treatment?

Wastewater

- 20-log virus
- 14-log Giardia
- 15-log Crypto

Drinking Water
How Much Pathogen Treatment?

DPR-1: Pathogen Treatment and Risk
How Much Pathogen Treatment?

DPR-1: Pathogen Treatment and Risk
How Much Pathogen Treatment?

DPR-1: Pathogen Treatment and Risk

DPR-2: Raw Wastewater Pathogen Monitoring
Motivation for Research

- Wastewater pathogen concentrations are key inputs
- Industry does not have sufficient high-quality data
- SOPs needed to address previous limitations
DPR-2 Technical Work Group

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DPR-2 Labs:

 cel analytical, inc.
 water, wastewater, and soil laboratory services

SCIENTIFIC METHODS

BIOLOGICAL CONSULTING SERVICES OF NORTH FLORIDA, INC.
Literature Review

- Limited number of studies
- Low method sensitivity and high frequency of non-detects
- Recovery often not measured
- QA/QC often not strictly followed

Conclusions
- Possible to measure pathogens in raw WW
- Amount and quality of data are insufficient
Method Optimization

- Used to address limitations of past studies
  - Concentration method
  - Volume of sample to process
- Require strict QA/QC
  - Matrix spikes in 75% of all samples
  - Full set of controls
- Recommendation: use DPR-2 QAPP for future studies
Sampling campaign

Pathogens and Methods
- Giardia
- Crypto
- Entero-virus
- Adeno-virus
- Noro-virus
- SARS-CoV-2

Methods:
- Microscopy
- Culture
- Molecular

14-month Monitoring Campaign
- Five facilities
- 24 samples
- Range: 30 – 275 MGD
A Closer Look: Pathogen Distributions

Cryptosporidium
A Closer Look: Pathogen Distributions

- High rate of detects across full range
A Closer Look: Pathogen Distributions

- High rate of detects across full range
- Matrix spikes used to correct for losses
- High recovery efficiency

![Graph showing Cryptosporidium concentrations with recovery-corrected and uncorrected data.]
A Closer Look: Pathogen Distributions

- High rate of detects across full range
- Matrix spikes used to correct for losses
- High recovery efficiency
- Models estimate past measured range

**Log-normal distribution**

- Mean = 1.7
- Standard Deviation = 0.4
A Closer Look: Pathogen Distributions

- High rate of detects across full range
- Matrix spikes used to correct for losses
- High recovery efficiency
- Models estimate past measured range
- Allows for comparison with IPR regs
A Closer Look: Pathogen Distributions

- High rate of detects across full range
- Matrix spikes used to correct for losses
- High recovery efficiency
- Models estimate past measured range
- Allows for comparison with IPR regs

Recommendation:
Use modeled distributions for probabilistic assessments of treatment targets
Other Key Findings

• Pathogen distributions similar across treatment plants
  – 94% of comparisons had no significant differences between facilities

• Minimal level of seasonality observed
  – Enterovirus higher in summer / adenovirus higher in winter

• No clear impact of COVID-19 on concentrations
  – Data collected before and after Stay-at-Home order showed minimal change

• Uncertainties associated with the use of molecular data
Issues with the use of molecular data

- Genome copies (GC) not always associated with *infective* virus
- Difficult to link GC with infectivity
- DPR-2 ratios span orders of magnitude:
  - 10,000:1 to 1:1 (enterovirus)
  - 100,000:1 to 1:1 (adenovirus)
When is this important?

- Norovirus not culturable
- Dose-response function makes assumptions about “infectivity” of genome copies
- If we assume 1:1, then each GC is an infectious unit (IU)
When is this important?

- Norovirus not culturable

- Dose-response function makes assumptions about “infectivity” of genome copies

- If we assume 1:1, then each GC is an infectious unit (IU)
Incorporate uncertainty in risk analyses

- DPR-1 Final Report shows how to incorporate molecular data into analysis
- Results in a “band” of potential values
Recommendations for Regulatory Development

• Use DPR-2 datasets as the raw wastewater inputs for QMRA

• Correct pathogen data for recovery using matrix spikes

• Use culture data to reduce uncertainties with molecular interpretation; follow TWG recommendations for the use of molecular data

• Model the DPR-2 distributions (and relevant literature) for use in probabilistic assessments

• Require DPR-2 QAPP/SOPs for future pathogen monitoring studies
How Much Pathogen Treatment?

DPR-1: Pathogen Treatment and Risk

DPR-2: Raw Wastewater Pathogen Monitoring

Wastewater

Drinking Water

What concentration of pathogens are we starting with?

How much treatment is needed?

Can we meet our risk goals?
DPRisk Tool and Guidance Document

DPRisk: QMRA Tool

Quantitative Microbial Risk Assessment and Probabilistic Assessment of Treatment Train Performance for Direct Potable Reuse Scenarios

This tool is intended to facilitate quantitative microbial risk assessment (QMRA) and probabilistic assessment of treatment train performance (PATTP) for various direct potable reuse (DPR) scenarios. There are many possible analyses that you can conduct with this tool, including:

- Developing a distribution of treatment train performance for different potential DPR treatment trains.
- Evaluating daily and annual risks of infection for multiple microbial pathogens for different potential DPR treatment trains.
- Comparing different DPR treatment trains in terms of treatment performance and risk.
- Evaluating the impact of failures on treatment performance and risk.

The accompanying Guidance Document provides useful context for this tool, including:

- The background motivation for the creation of the tool.
- The historical context for the use of PATTP and QMRA in DPR.
- The project process that resulted in this tool.
- Detailed descriptions of each step of the tool, including references for default assumptions.
- Details on the computations implemented by the tool.
- Example case studies to help you get started with using the tool.

This tool was developed in the R statistical language.

DPRisk: Guidance Document

Guidance Document for DPRisk

Table of Contents

- List of Acronyms
- Project Definition and Background
- Historical Context
- Overview of DPRisk
- Step 1: Target Pathogens (Hazard Identification)
- Step 2: Raw Wastewater Pathogen Datasets
- Step 3: Raw Wastewater Pathogen Distributions
- Step 4: Identifying Unit Processes for the Treatment Train
- Step 5: Assigning Treatment Process Log Reduction Values
- Step 6: Treatment Process Failure Framework
- Step 7: Management Barriers (Blending, Dilution, and Die-off)
- Step 8: Drinking Water Ingestion (Exposure Assessment)
- Step 9: Pathogen Dose Response Models (Dose Response Assessment)
- Step 10: Risk Characterization
- Final Tool Considerations
- Case Study 1: QMRA for Enterovirus in a Default DPR Scenario
- Case Study 2: QMRA for Cryptosporidium in a FAT-Based DPR Scenario
- Case Study 3: QMRA for Adenovirus in an FAT-Based DPR Scenario
- Conclusions
- References
- Appendix 1 – Summary of Output File Headers
- Appendix 2 – Installation of DPRisk on Shinyapps.io

Also: User Input Files for 3 Case Studies
DPRisk Features

INPUTS:
- Raw Wastewater Pathogen Concentrations
- Treatment Train
- Treatment Failure
- Exposure
- Dose Response
DPRisk Features

INPUTS:
- Raw Wastewater Pathogen Concentrations
- Treatment Train
- Treatment Failure
- Exposure
- Dose Response

Target Pathogens:
- Enterovirus
- Adenovirus
- Norovirus
- Giardia Cyst
- Cryptosporidium Oocyst
- User-Defined Pathogen
INPUTS:
• Raw Wastewater Pathogen Concentrations
• Treatment Train
• Treatment Failure
• Exposure
• Dose Response
DPRisk Outputs

- Probabilistic Assessment of Treatment Train Performance (PATTP)

- Quantitative Microbial Risk Assessment
Not All DPR Projects Are Alike

TWA
- O3/BAC
- FAT
- Chlorine

RWA
- O3/BAC
- FAT
- Chlorine

RWA with Blending
- O3/BAC
- FAT
- Chlorine

RWA with Small Reservoir
- O3/BAC
- FAT
- Chlorine

Water Treatment

10:1 Blending

Buffer

1-month retention time

Water Treatment
Not All DPR Projects Are Alike

- **TWA**: O3/BAC, FAT, Chlorine
- **RWA**: O3/BAC, FAT, Chlorine
- **RWA with Blending**: O3/BAC, FAT, Chlorine
- **RWA with Small Reservoir**: O3/BAC, FAT, Chlorine

Do these projects have different risk profiles?
DPRisk Includes Management Barriers

DPRisk Inputs

**Blending**

Specify the log removal associated with blending.

Specify log removal for blending as:

- Point estimate

Log Removal:

0

**Dilution**

Specify the log removal associated with dilution.

Specify log removal for dilution as:

- Point estimate

Log Removal:

0
Risk Profiles of RWA and TWA Trains (no failures)

Daily Risk Goal

TWA Train

RWA with 10:1 Blending

RWA with 1-month Reservoir

Legend
- DPR Train 1
- DPR Train 2
- DPR Train 3
Risk Profiles of RWA and TWA with Failure Analysis

Legend:
- baseline_Pdaily
- DPR Train 1
- DPR Train 2
- DPR Train 3

DPR Train 1
DPR Train 2
DPR Train 3
TWA Train
RWA with 10:1 blending
RWA with 1-month Reservoir

Daily Risk Goal
Risk Profiles of RWA and TWA with Failure Analysis

Understanding differences in risk profiles... can allow for different DPR requirements.
Recommendations

• Select modeled distributions from DPR-2 as raw wastewater inputs

• Use DPRisk for *probabilistic* assessments of performance and risk

• Develop frameworks to incorporate the benefits of non-treatment (management) barriers in RWA and TWA
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Questions?

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