

Public Health Protection in DPR: Results from the DPR Demonstration Project

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Sarah Triolo



California's Big Question



Division of Drinking Water
(DDW)

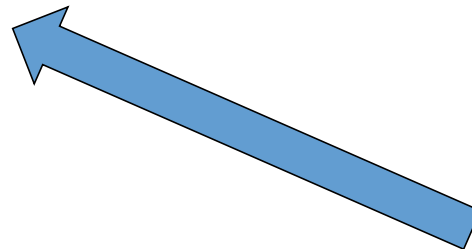
*Is it feasible to do potable reuse without
an environmental buffer (DPR)?*

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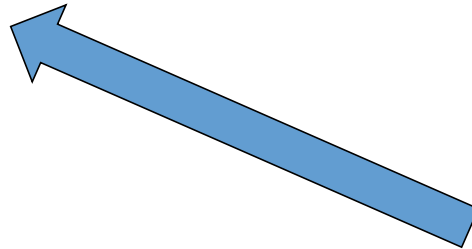


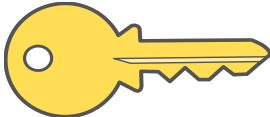
California's Big Question



Division of Drinking Water
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*Is it feasible to do potable reuse without
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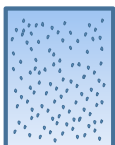
KEY  **QUESTION**

Can we do DPR safely?

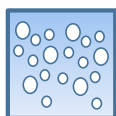


DPR Demonstration Treatment Train: Redundancy

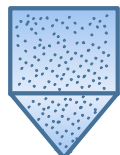
3_{ry}



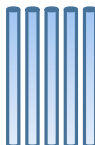
O₃



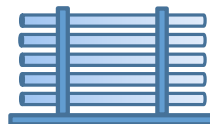
BAC



MF



RO



UV/AOP

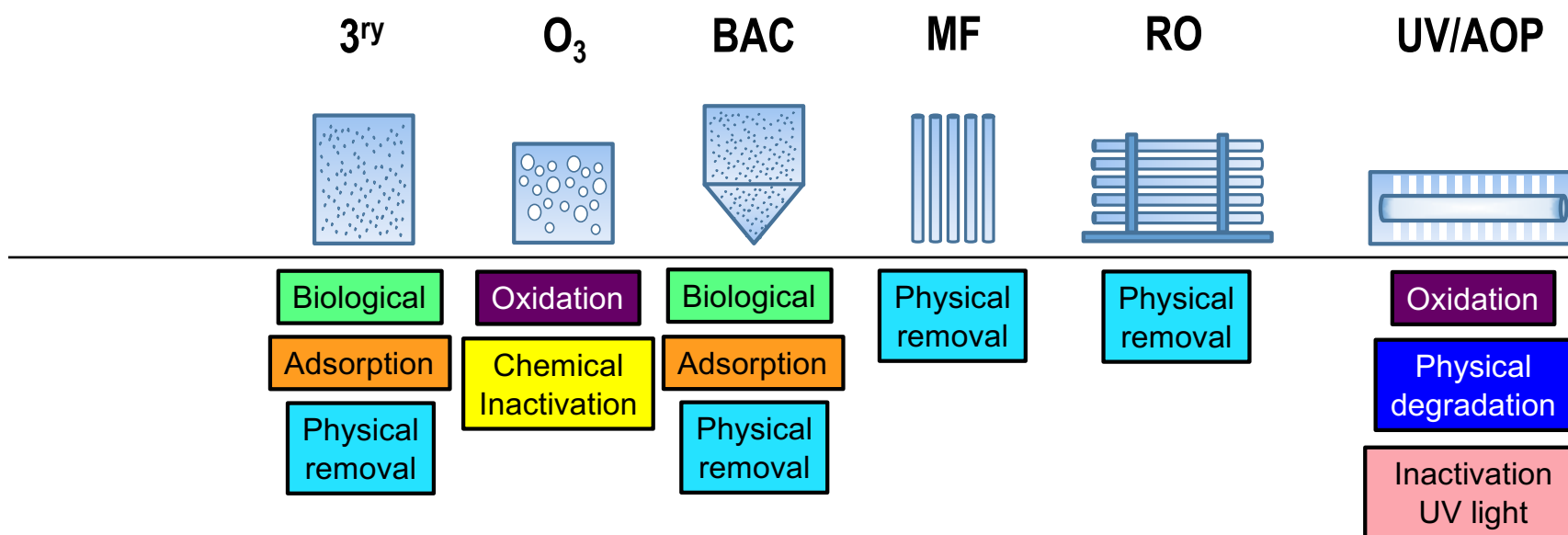


Total

Minimum

	3 _{ry}	O ₃	BAC	MF	RO	UV/AOP	Total	Minimum
Virus	2	6	-	-	2	6	16	12
<i>Giardia</i>	2	6	-	4	2	6	20	10
<i>Crypto</i>	1	1	-	4	2	6	14	10

DPR Demonstration Treatment Train: Robustness



Data management is a big deal

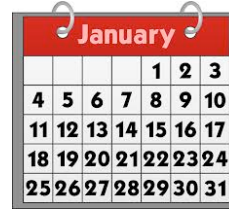


1 meter

X



One reading



> 250,000
data points



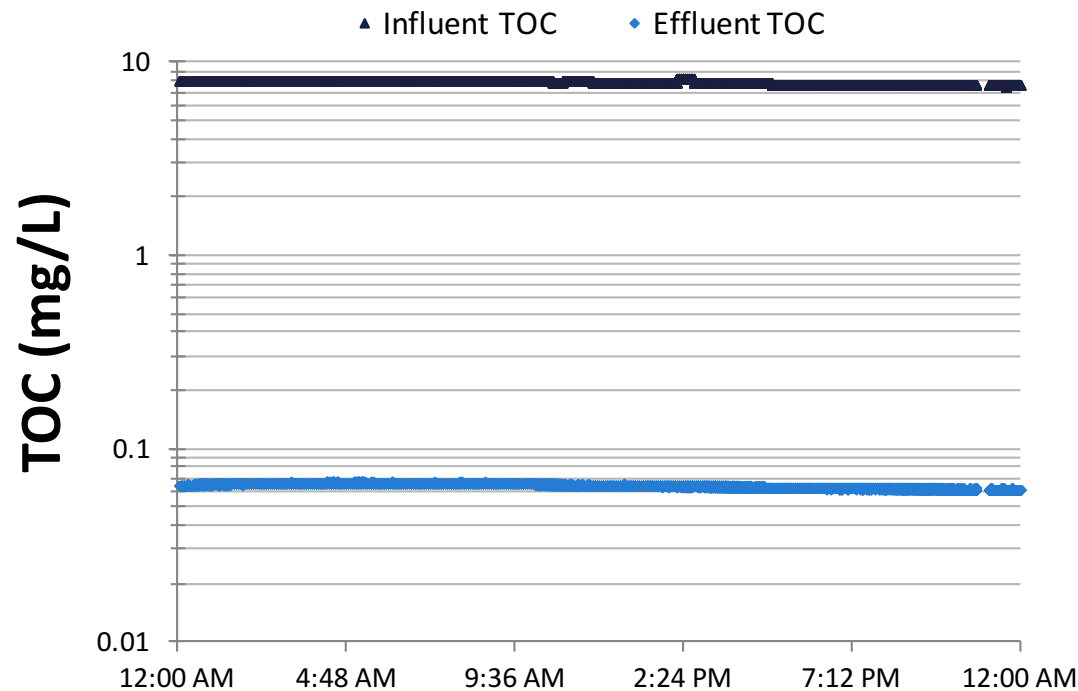
> 3,000,000
data points



Uncommon to mine this much data... 7

Quantifying Reliability

- Building probability distribution functions
 - *Collecting performance data (e.g., RO)*



$$LRV = \log \left(\frac{\text{Influent TOC}}{\text{Effluent TOC}} \right)$$

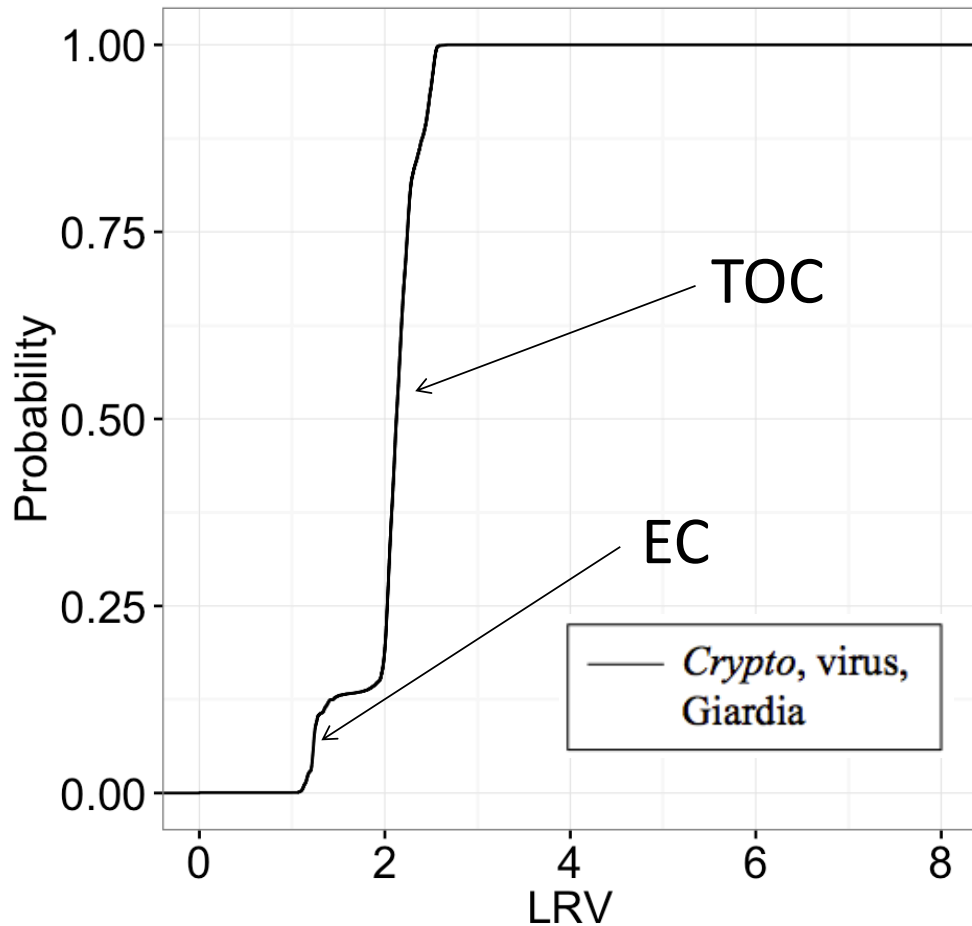
Quantifying Reliability

Rank all LRV values in ascending order

Rank	LRV	Probability
1	2.021302	0.000067
2	2.044784	0.000133
3	2.057018	0.000200
4	2.067316	0.000267
5	2.068054	0.000333
5	2.068054	0.000333
7	2.069088	0.000467
7	2.069088	0.000467
7	2.069088	0.000467
7	2.069088	0.000467
7	2.069088	0.000467
7	2.069088	0.000467
7	2.069088	0.000467
7	2.069088	0.000467
7	2.069088	0.000467
16	2.069538	0.001067
16	2.069538	0.001067
16	2.069538	0.001067
16	2.069538	0.001067
16	2.069538	0.001067
16	2.069538	0.001067

$$\text{Probability} = \frac{\text{Rank}}{\text{Total \# Points}}$$

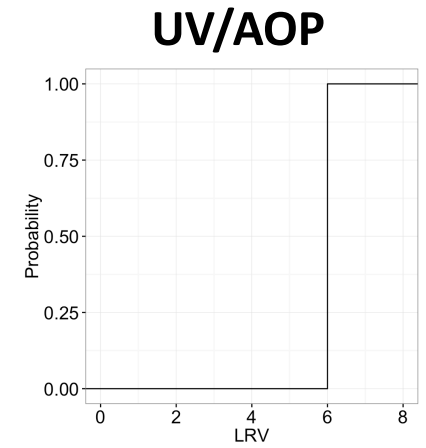
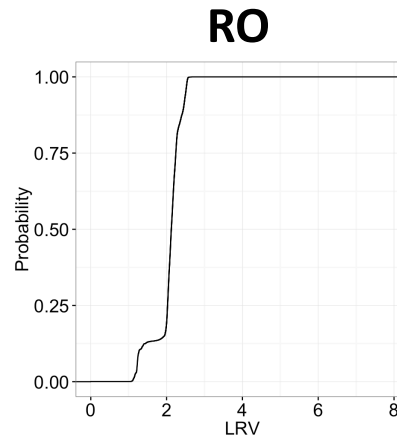
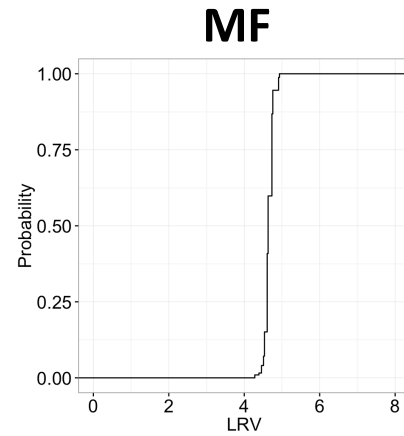
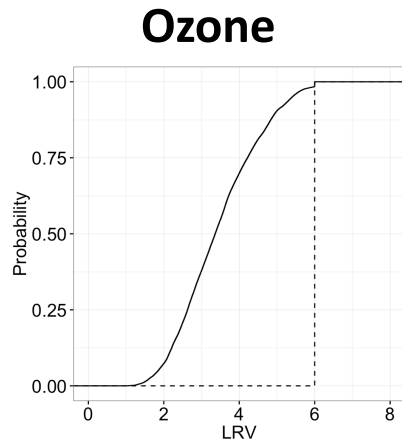
PDF: RO

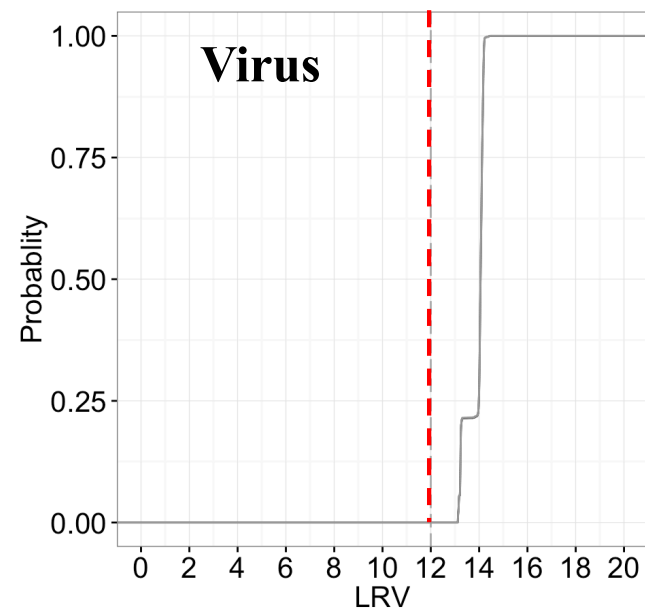
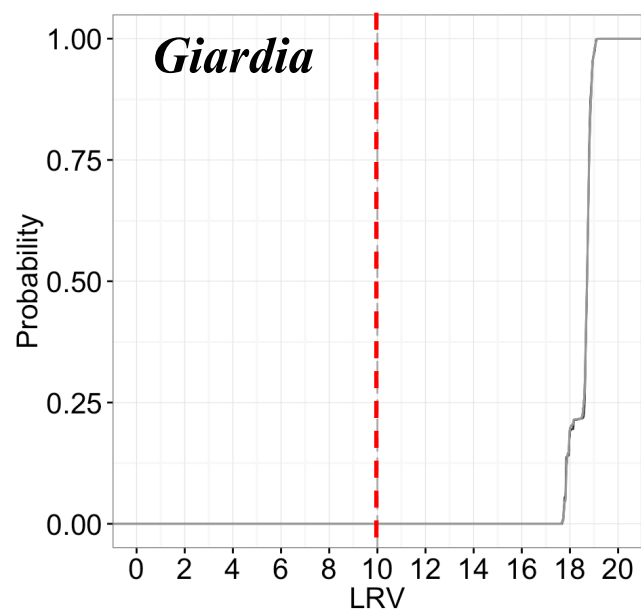
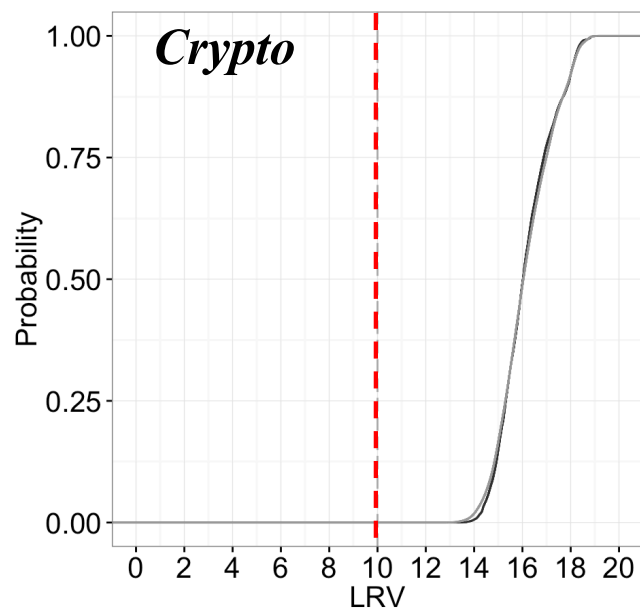


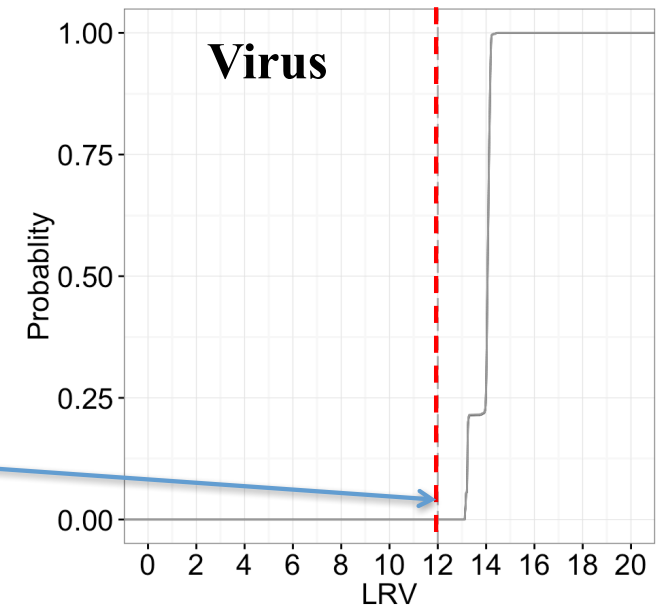
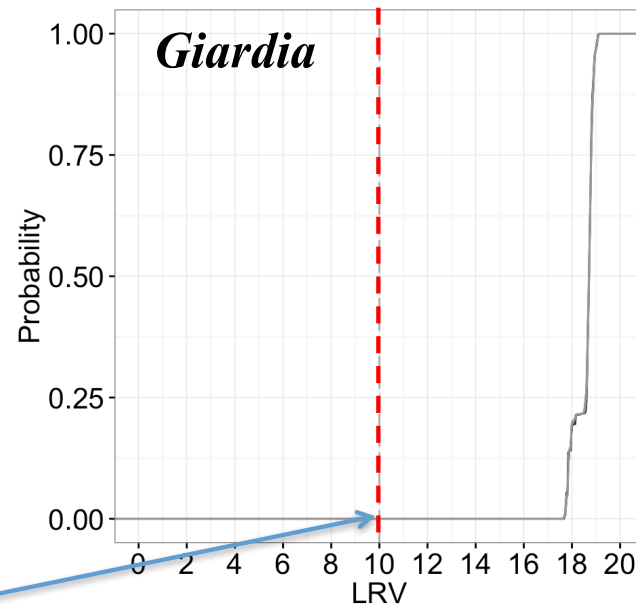
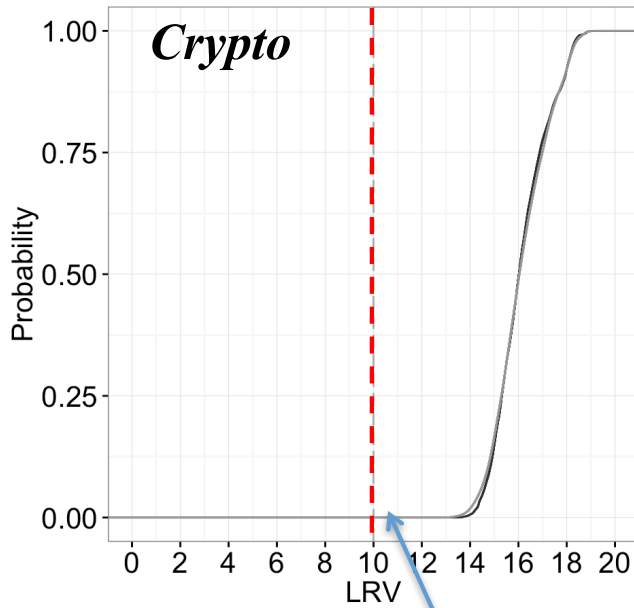
Basis for LRV Calculation:

- Continuous online TOC monitoring
- Continuous online electrical conductivity monitoring (as backup for TOC)

PDF: Treatment Train Performance







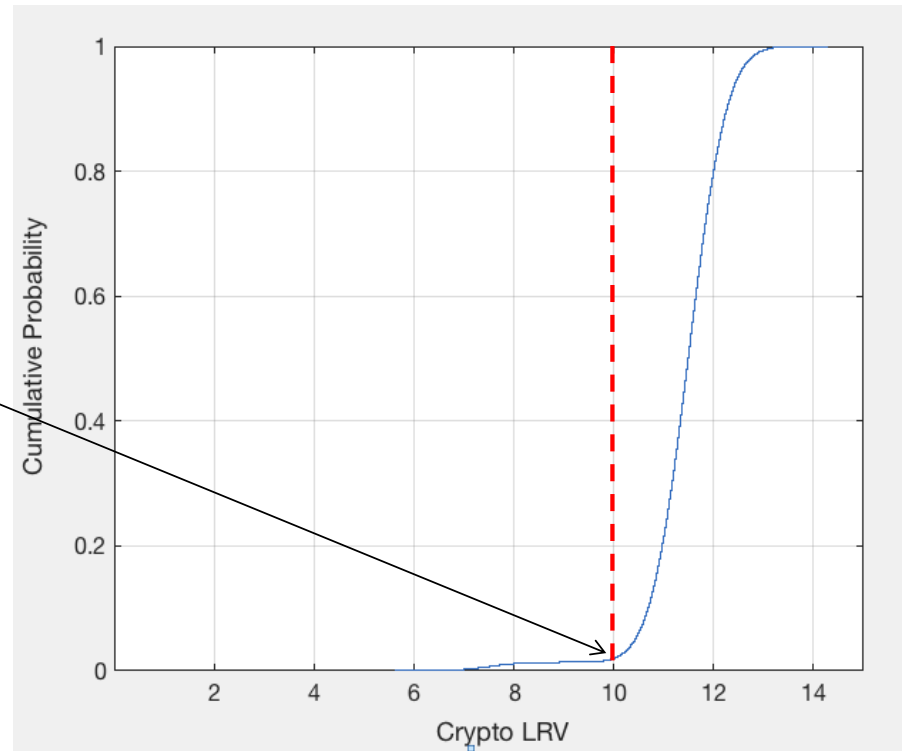
These are
obviously
protective of
public health

Our PDFs always exceed the
minimum treatment

Evaluating PDFs

- During yearlong testing, no “critical” failures occurred
- Failures may occur and significantly impact public health

If a PDF crosses the minimum treatment threshold, how can we evaluate its protectiveness?



Quantitative Microbial Risk Assessment

Goal: Quantify the probability of infection from the consumption of DPR waters and compare to goals



Quantitative Microbial Risk Assessment

1. Exposure Assessment



2. Dose-Response Analysis



3. Risk Characterization



Acceptable Risk Levels

10^{-4} infections/person/year

- U.S. EPA risk goal in Surface Water Treatment Rule
- Explicit goal of CA potable reuse regulations (groundwater + surface water)

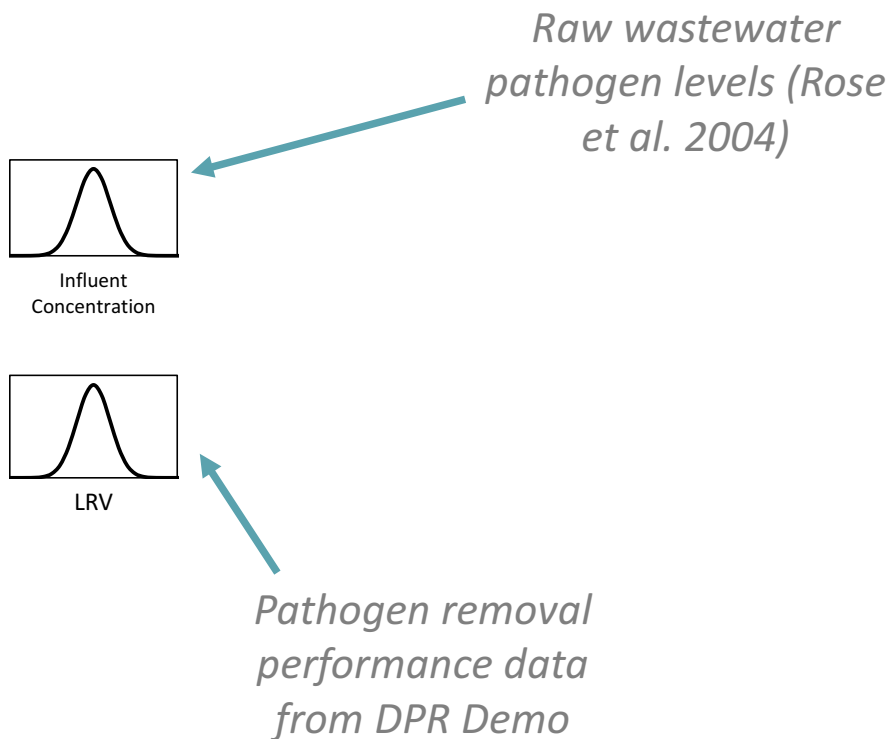
10^{-6} DALYs/person/year \approx 10^{-3} AGI / person /year

- Risk goal utilized internationally, including WHO
- Equivalent to 10^{-3} for organisms causing AGI, e.g., rotavirus and *Crypto*

Both benchmarks were used to evaluate the protectiveness of DPR train

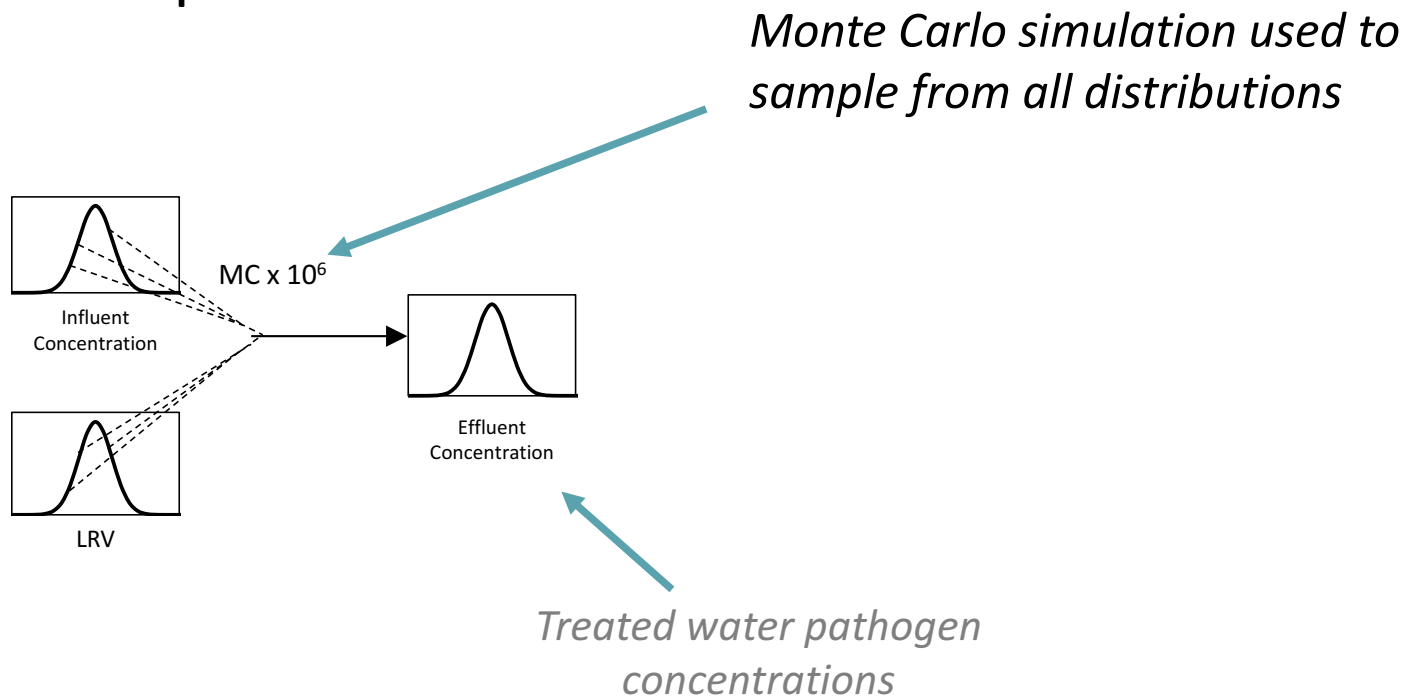
Quantitative Microbial Risk Assessment

1. Exposure Assessment



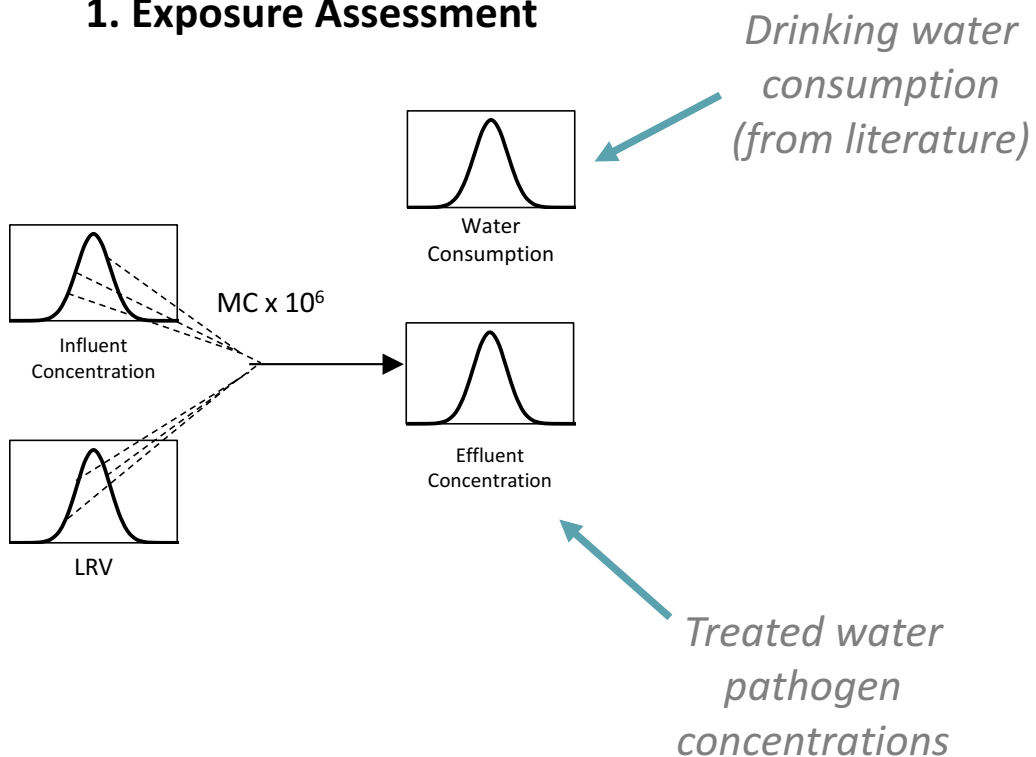
Quantitative Microbial Risk Assessment

1. Exposure Assessment



Quantitative Microbial Risk Assessment

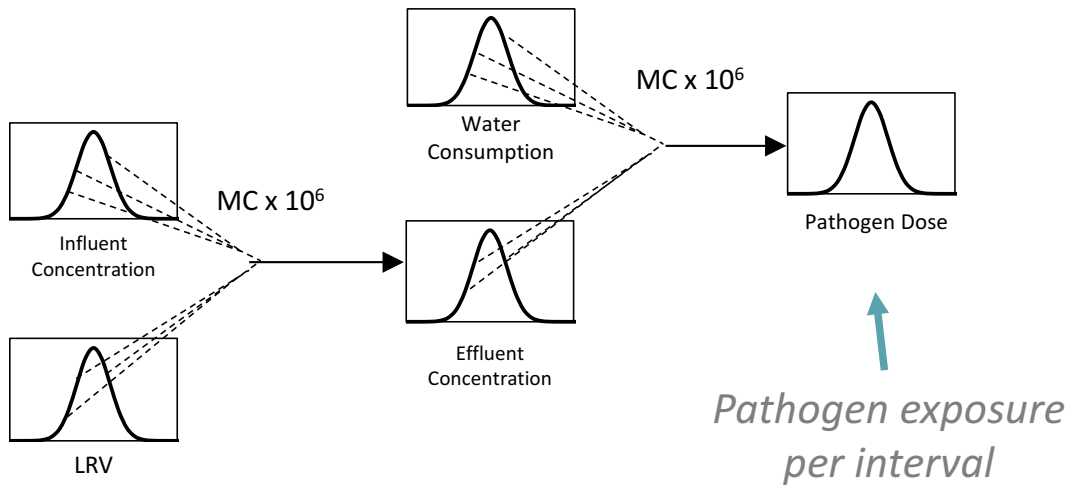
1. Exposure Assessment



Quantitative Microbial Risk Assessment

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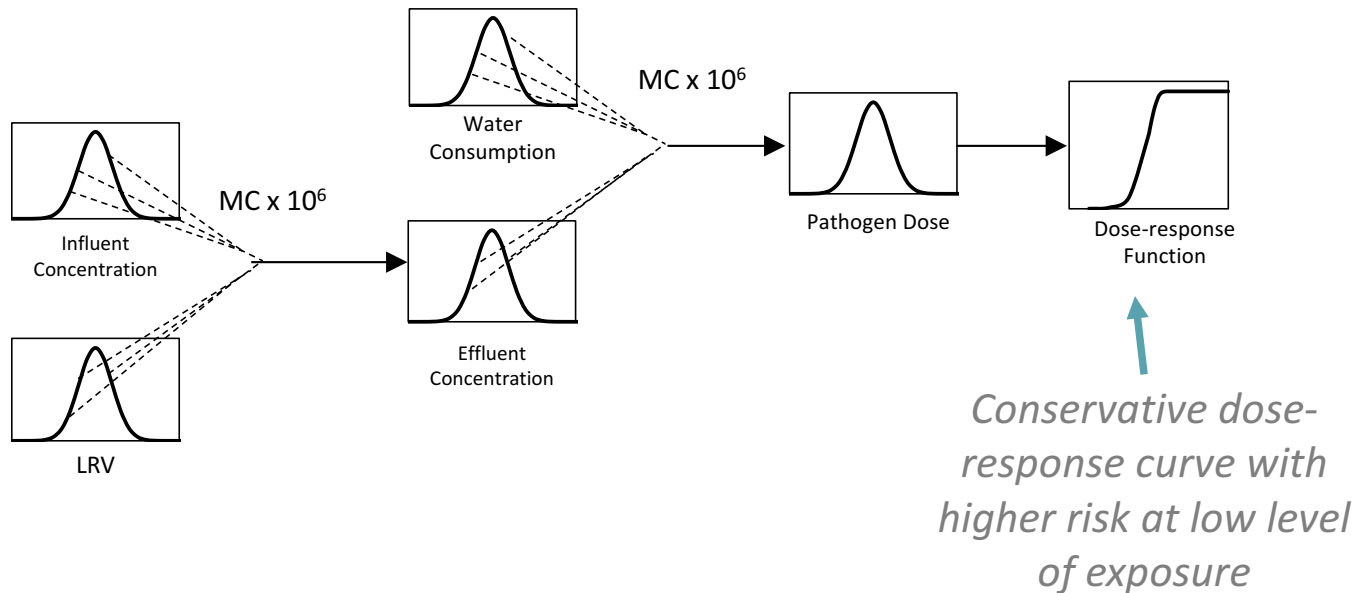
2. Dose-Response Analysis



Quantitative Microbial Risk Assessment

1. Exposure Assessment

2. Dose-Response Analysis

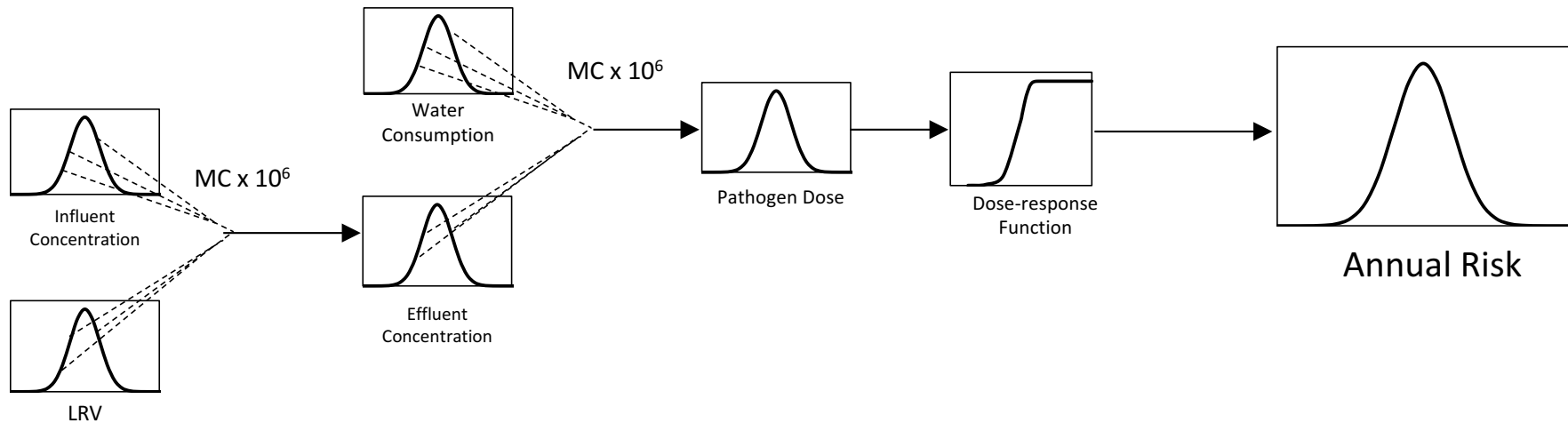


Quantitative Microbial Risk Assessment

1. Exposure Assessment

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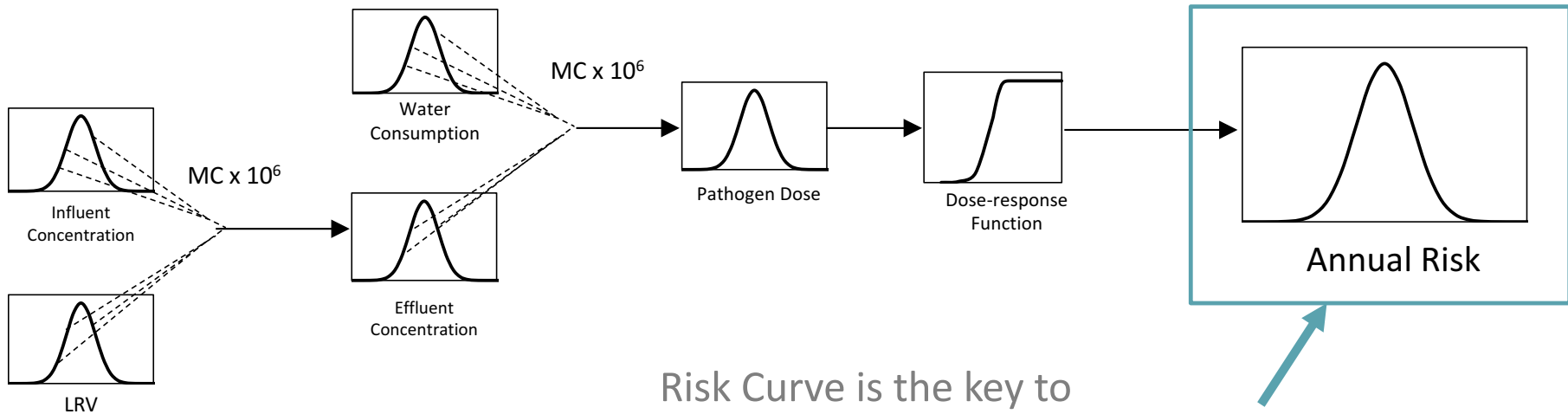


Quantitative Microbial Risk Assessment

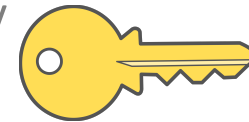
1. Exposure Assessment

2. Dose-Response Analysis

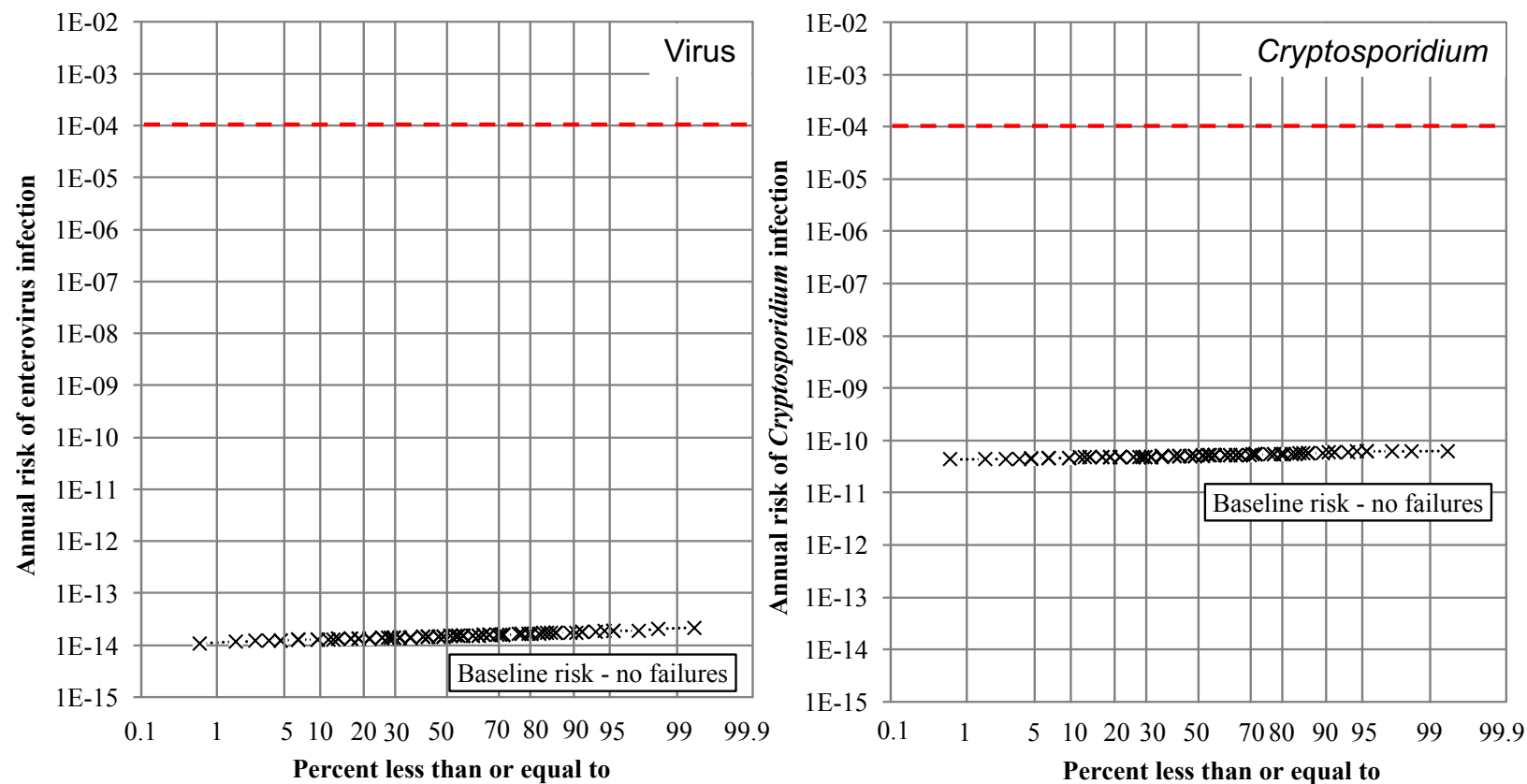
3. Risk Characterization



Risk Curve is the key to understanding Reliability – how consistently do you meet 10^{-4} risk goal?

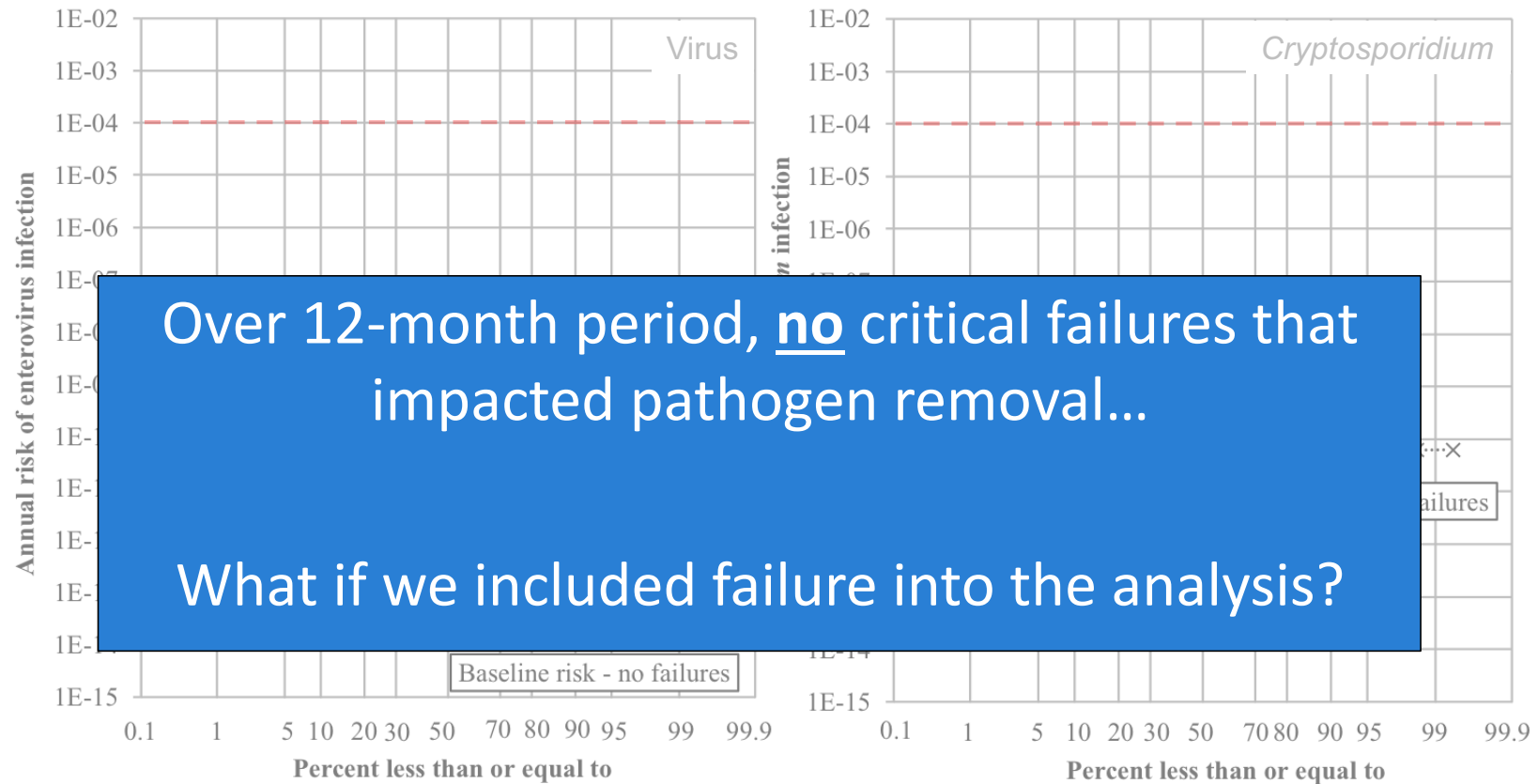


DPR Train Provides Superior Risk Control



B. Pecson, S. Triolo, S. Olivieri, E. Chen, A. Pisarenko, C. Yang, A. Olivieri, C. Haas, S. Trussell, R. Trussell (2017) Reliability of pathogen control in direct potable reuse: Performance evaluation and QMRA of a full-scale 1 MGD advanced treatment train. *Water Research* 122: 258-268.

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QMRA with failures incorporated

Failure Frequency

- Each unit has one failure per process per year
- Highly conservative

Failure Duration

- 15 min minimum based on rapid monitoring
- Also 1-h, 8-h, and 24-h failure durations

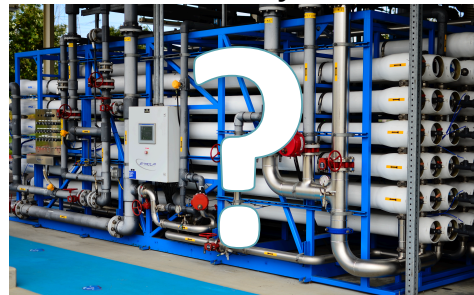
Failure Impact

- Drops unit process LRV to 0
- Highly conservative

Ozone generator failure



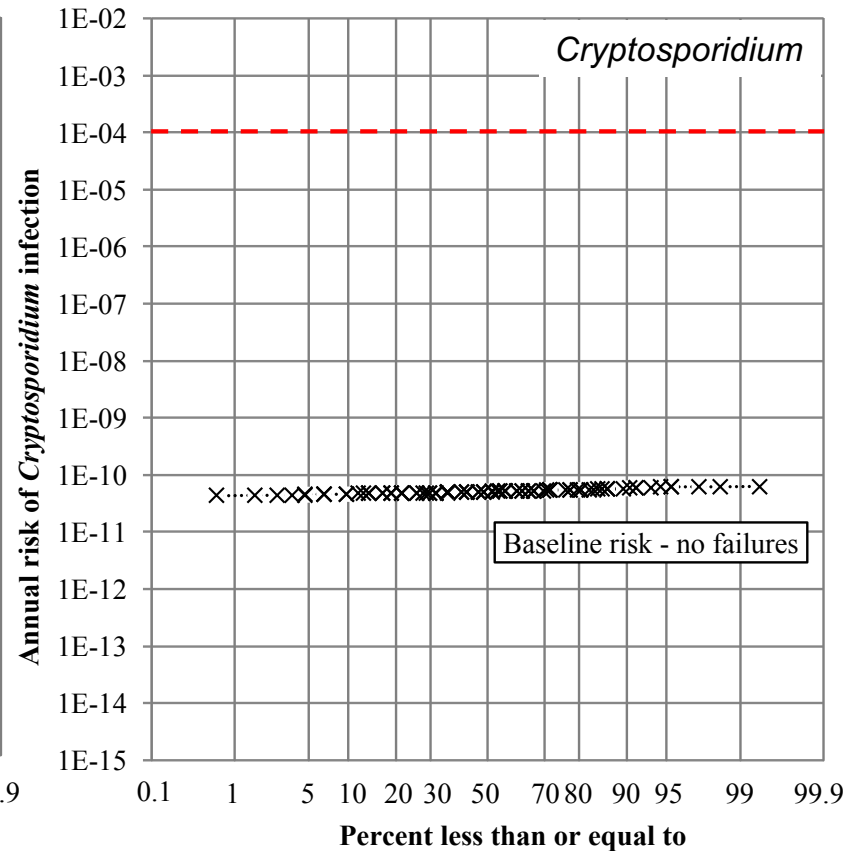
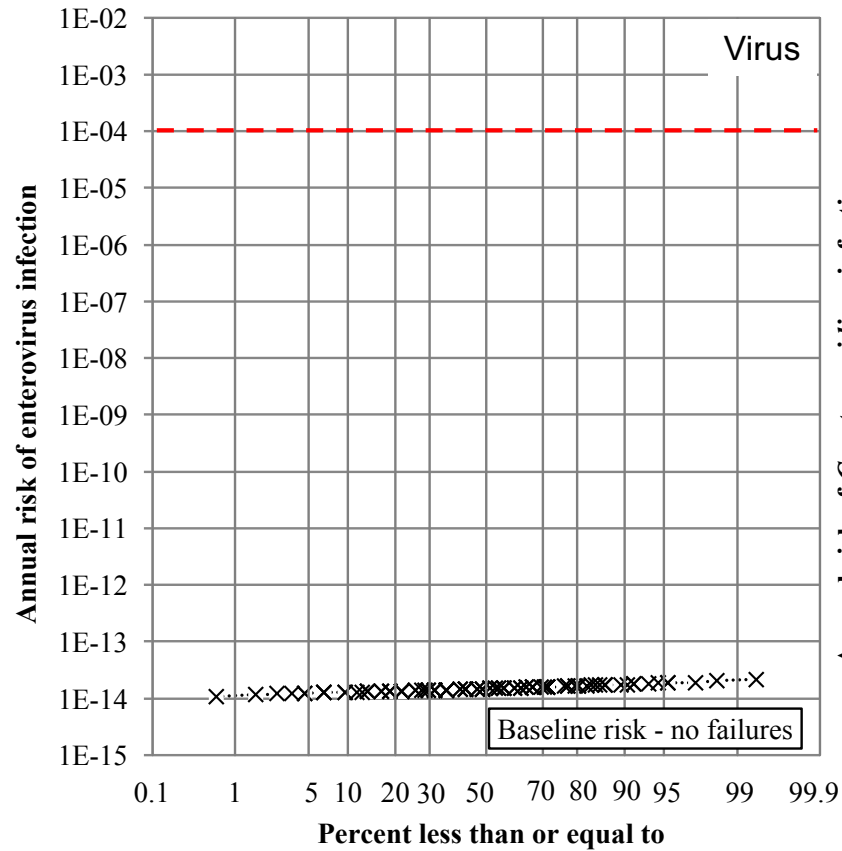
RO meter failure



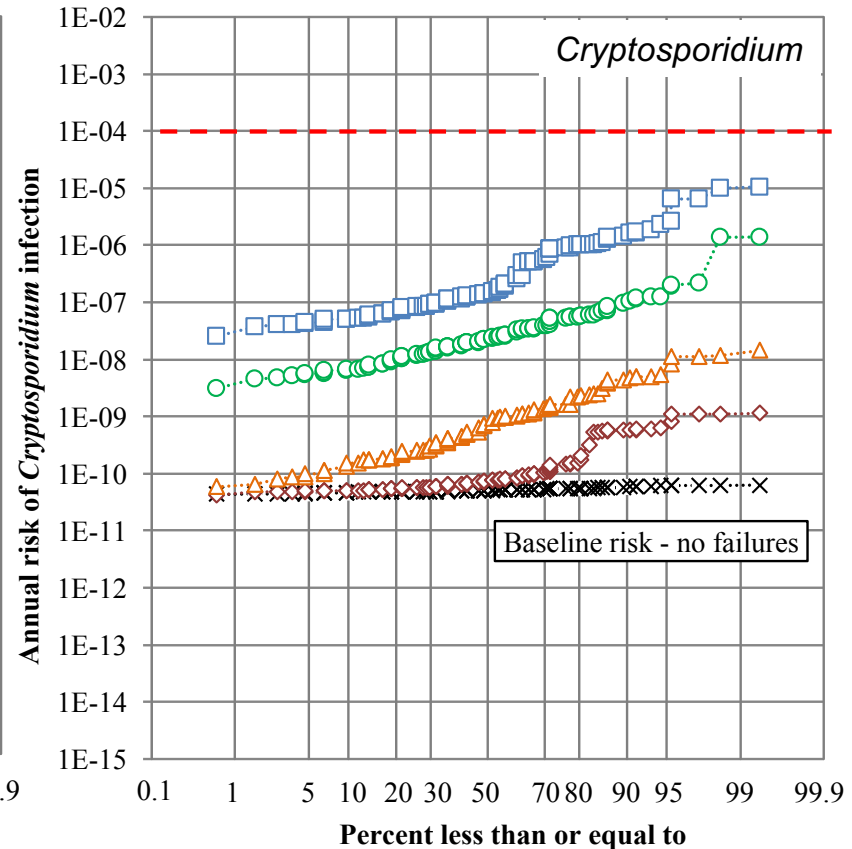
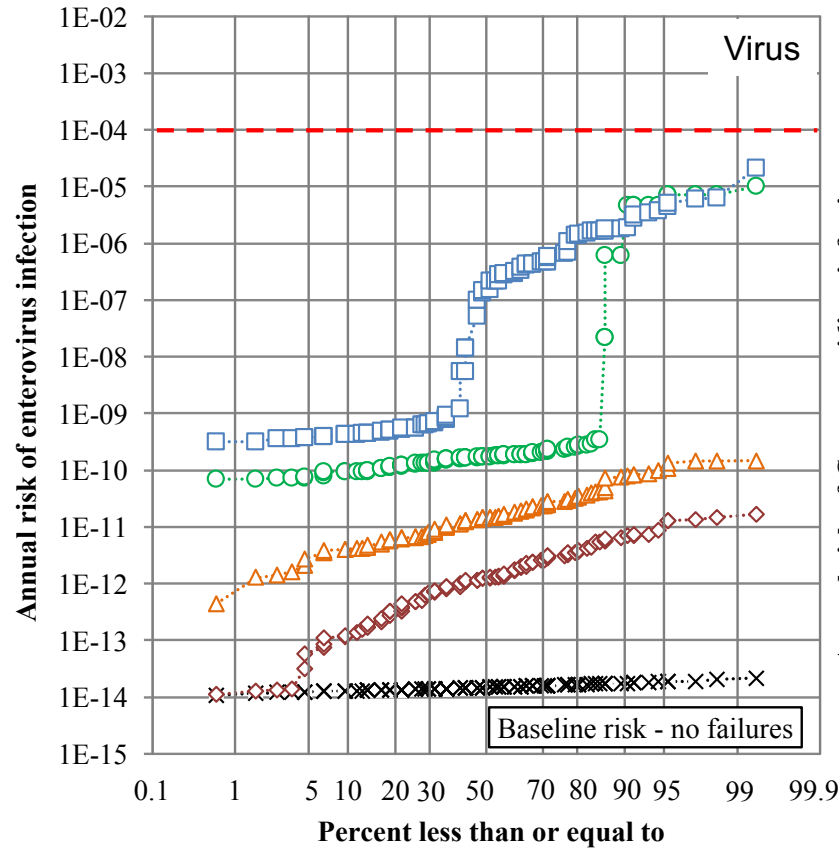
Operator error



QMRA: Results

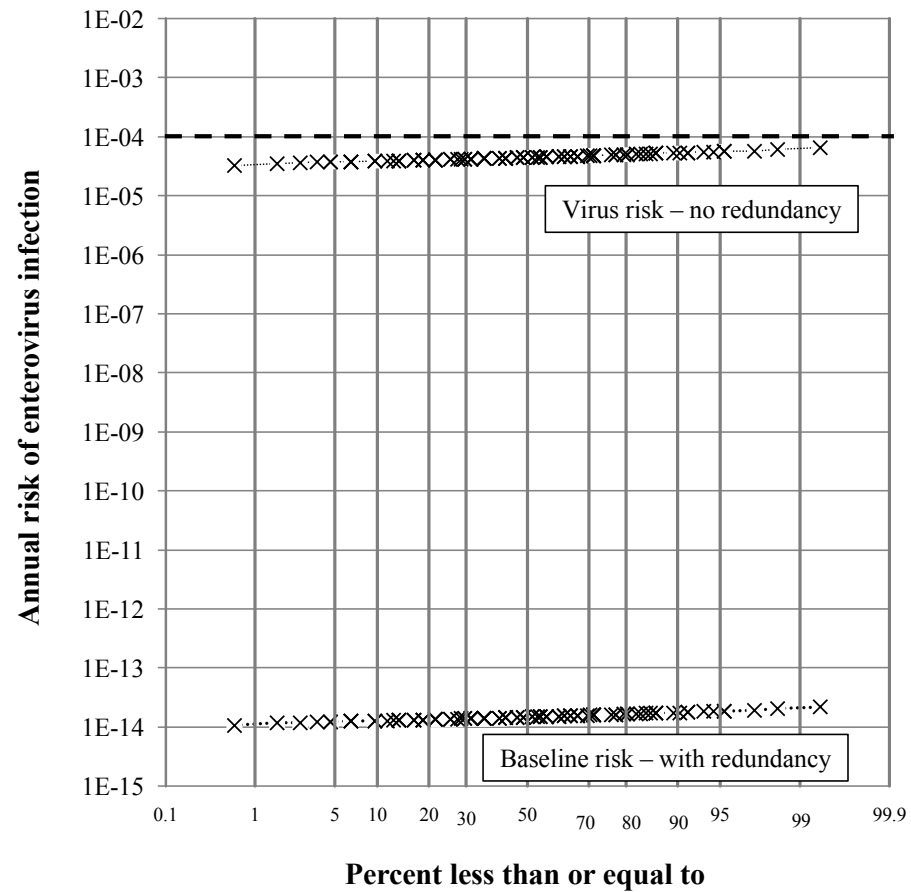


Safety ensured even under extreme failure

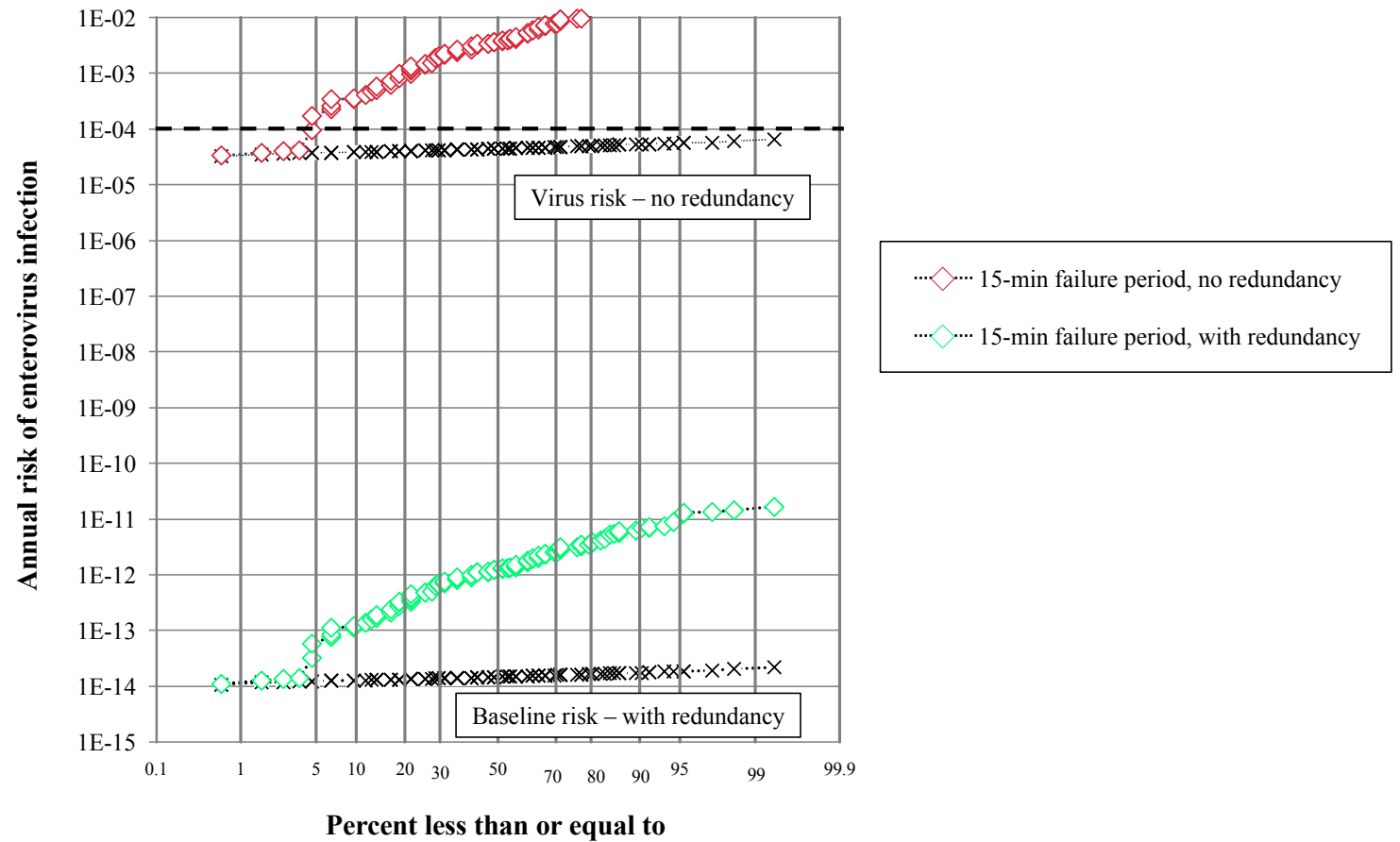


.....◇..... 15-min failure period △..... 1-hr failure period
.....○..... 8-hr failure period □..... 1-day failure period

Failure prevention vs. failure response

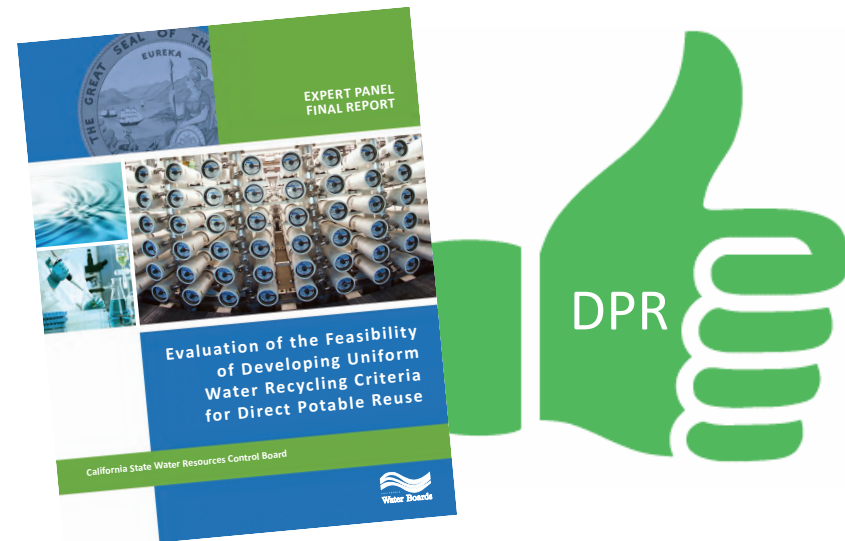


Failure prevention vs. failure response



Conclusions

- DPR can provide public health protection equivalent to or greater than conventional supplies
- QMRA shows pathogen risk significantly below acceptable risk level, even under failure conditions
- Design DPR with strong failure prevention features



Additional Information

- B. Pecson, S. Triolo, S. Olivieri, E. Chen, A. Pisarenko, C. Yang, A. Olivieri, C. Haas, S. Trussell, R. Trussell (2017) Reliability of pathogen control in direct potable reuse: Performance evaluation and QMRA of a full-scale 1 MGD advanced treatment train. *Water Research* 122: 258-268.
- Open Access (free!)



Acknowledgements

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- Rodrigo Tackaert
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- Aviv Kolakovsky



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