ADVANCES IN UV TECHNOLOGY FOR 4-LOG VIRUS DISINFECTION OF GROUNDWATER

Terry Keep

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PERFORMANCE HIGHLIGHTS

- Background
- UV for Virus Disinfection
- Validation of UV for Virus
- Case Study
- Summary

BACKGROUND

- Treatment of drinking water is carried out in various steps depending on the source of raw water

- Surface Water Treatment:
  - Primary Treatment (Coagulation)
  - Filtration
  - Primary Disinfection (SWTR)
  - Secondary Disinfection (Residual)

- Groundwater Treatment:
  - Primary Treatment and Filtration (Natural)
  - **Primary Disinfection? (Chemical or mechanical)**
  - Secondary Disinfection (Residual)

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DISINFECTION OF GROUNDWATER

- Groundwater disinfection varies
- High quality water in many locations often is not considered in need of primary disinfection.

DISINFECTION OF GROUNDWATER

Environmental Health Perspectives, September, 2012

Viruses in Nondisinfected Drinking Water from Municipal Wells and Community Incidence of Acute Gastrointestinal Illness

Mark A. Borchardt,[1] Susan K. Spencer,[1*] Burney A. Kieke Jr.,[1] Elisabetta Lambertini,[2] and Frank J. Loge[2]*

- Increasing concerns that GW supplies are exposed to pathogens
  - Leaking Septic Systems
  - Degradation of WW Collection Infrastructure

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DISINFECTION OF GROUNDWATER – CURRENT REGULATIONS

In the United States – USEPA Groundwater Rule (2006)

- Groundwater providers must actively monitor for indicators such as *E.coli* and coliphage
- Systems positive for total coliform must take corrective action
- Primary treatment of virus requires at least 4-log inactivation/removal using one or a combination of methods

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METHODS OF DISINFECTION

- Chlorine (Chemical)
  - Chlorine Gas
  - Sodium Hypochlorite (Bleach)
  - Chlorine Dioxide
- Ozone (O_3) (Chemical)
- Filtration (Mechanical)
- **UV Disinfection (Mechanical)**

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UV FOR VIRUS TREATMENT

- UV technology has a number of applications in primary disinfection:
  - Multi-barrier protection
  - Inactivation of chlorine resistant pathogens like Cryptosporidium and Giardia
  - Prevention of Disinfection By-Products
- UV for virus treatment has historically been used less frequently given the relatively higher doses compared to other pathogens

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UV FOR VIRUS TREATMENT

Table 1.4. UV Dose Requirements – millijoules per centimeter squared (mJ/cm^2) [1]

Target Pathogens	Log Inactivation							
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

[1] 40 CFR 141.720(d)(1)

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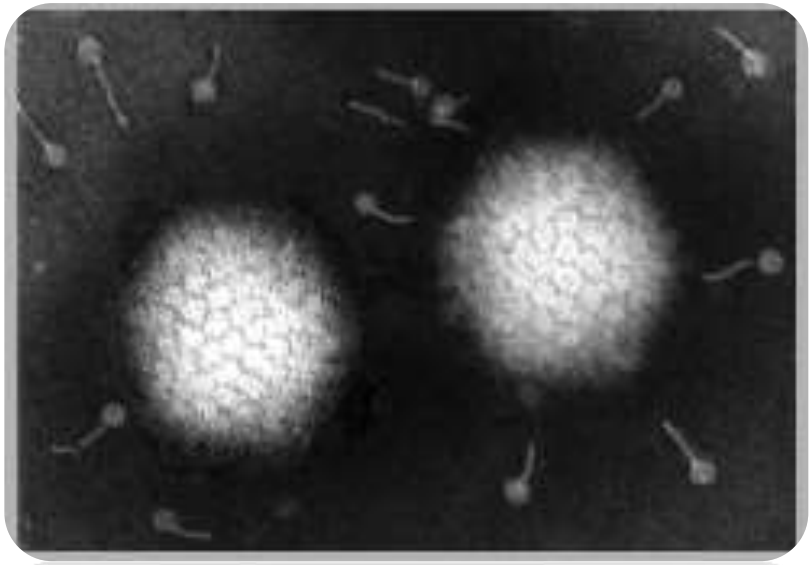
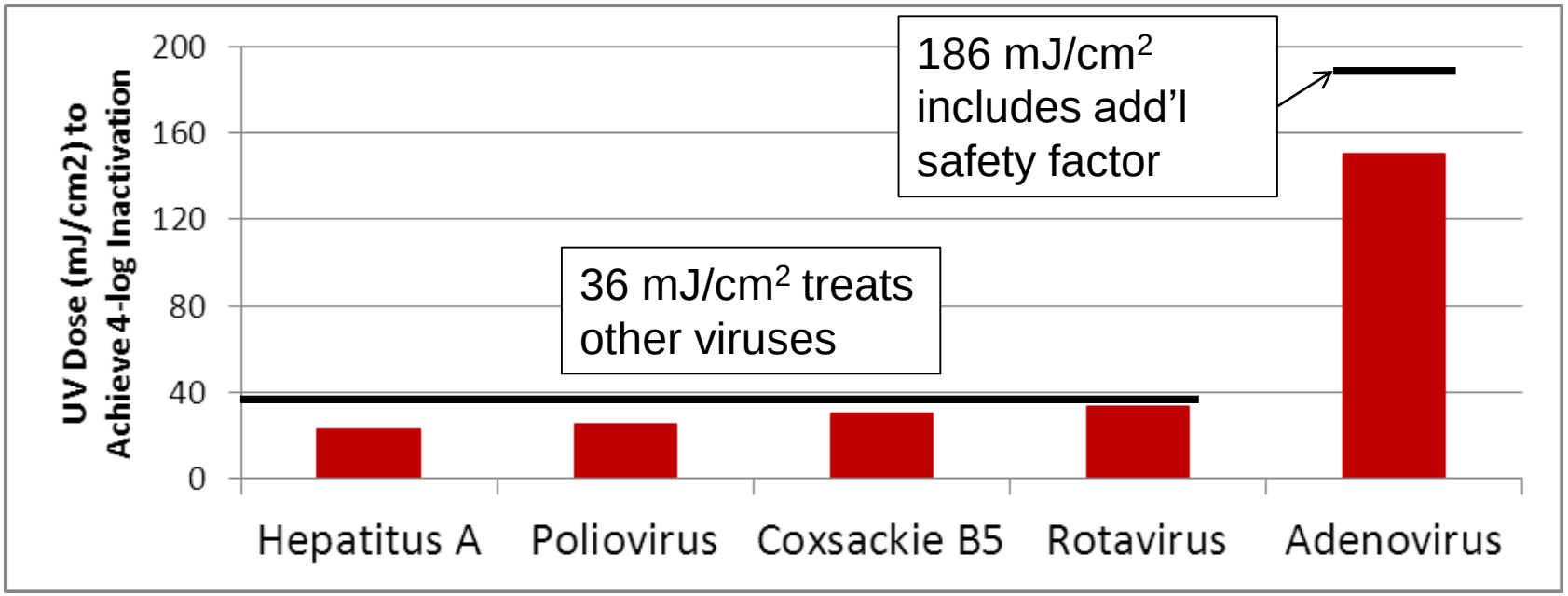
UV FOR VIRUS TREATMENT

- Adenovirus was the basis of “virus” treatment in UVDGM
- Adenovirus is relatively resistant to UV
- Led to UV dose requirement for 4-log inactivation of 186 mJ/cm^2 (UVDGM)
- Other viruses are much less resistant



ADENOVIRUS IS RELATIVELY RESISTANT COMPARED TO OTHERS



- UV Dose of 40 mJ/cm^2, can inactivate 4-log (99.99%) of other species of virus including Rotavirus and Polio.
- Adenovirus is particularly resistant – a good standard?

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GROUNDWATER RULE ON UV TREATMENT OF VIRUSES

- GWR did not list UV as a treatment technology in the final version
- Why? (Reasons found in GWR text)
  - It recognized that adenovirus was UV-resistant
  - Validation is required for UV according to LT2
  - No methodologies existed at the time to validate to high doses necessary to demonstrate >186 mJ/cm^2
  - **EPA predicted that methods would be developed**
  - Gave flexibility to states to adapt to future developments

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VALIDATING UV FOR VIRUS TREATMENT

TROJAN'S APPROACH: A HIGH RESISTANCE SURROGATE

- To validate UV reactors to a dose of 186 mJ/cm^2, a UV-resistant surrogate was required
- Traditional surrogate organisms like MS2 and T1 are not resistant enough to measure doses of >200 mJ/cm^2
- Why use a surrogate?
  - Target organisms can be highly pathogenic
  - EPA recommends surrogates in the UVDGM
  - Validation using adenovirus itself has many difficulties

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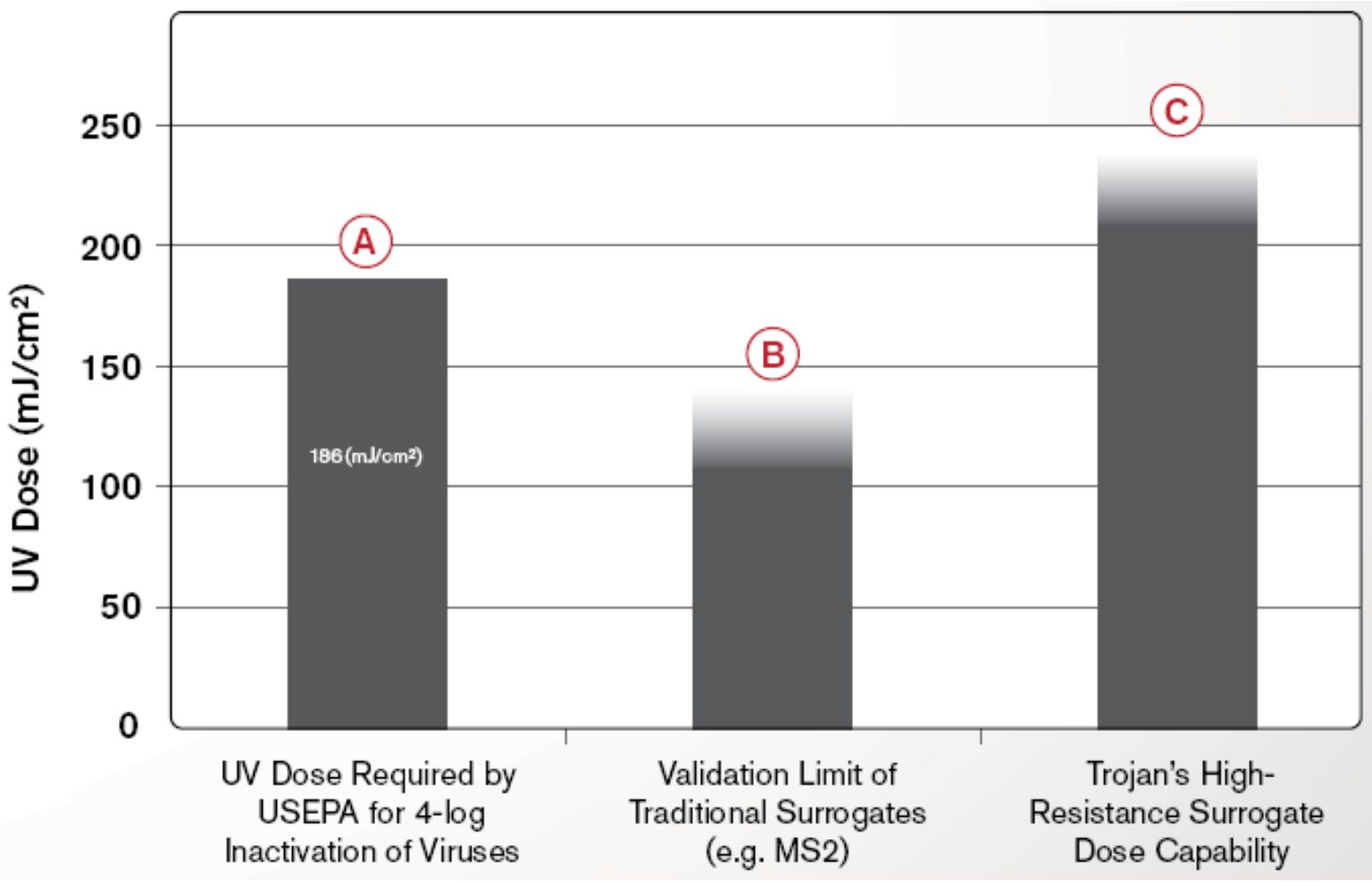
TROJAN'S APPROACH: A HIGH RESISTANCE SURROGATE



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THE SEARCH FOR A HIGH RESISTANCE SURROGATE

Characteristics of an Effective, Highly UV Resistant Surrogate Organism:

1. Easily cultured to high concentrations (full scale tests)
2. Easily managed to ensure good repeatability in validation tests
3. Non-pathogenic (safe test procedures)
4. Good stability (shipping, lab handling)
5. High UV resistance (measure high UV doses > 186 mJ/cm^2)

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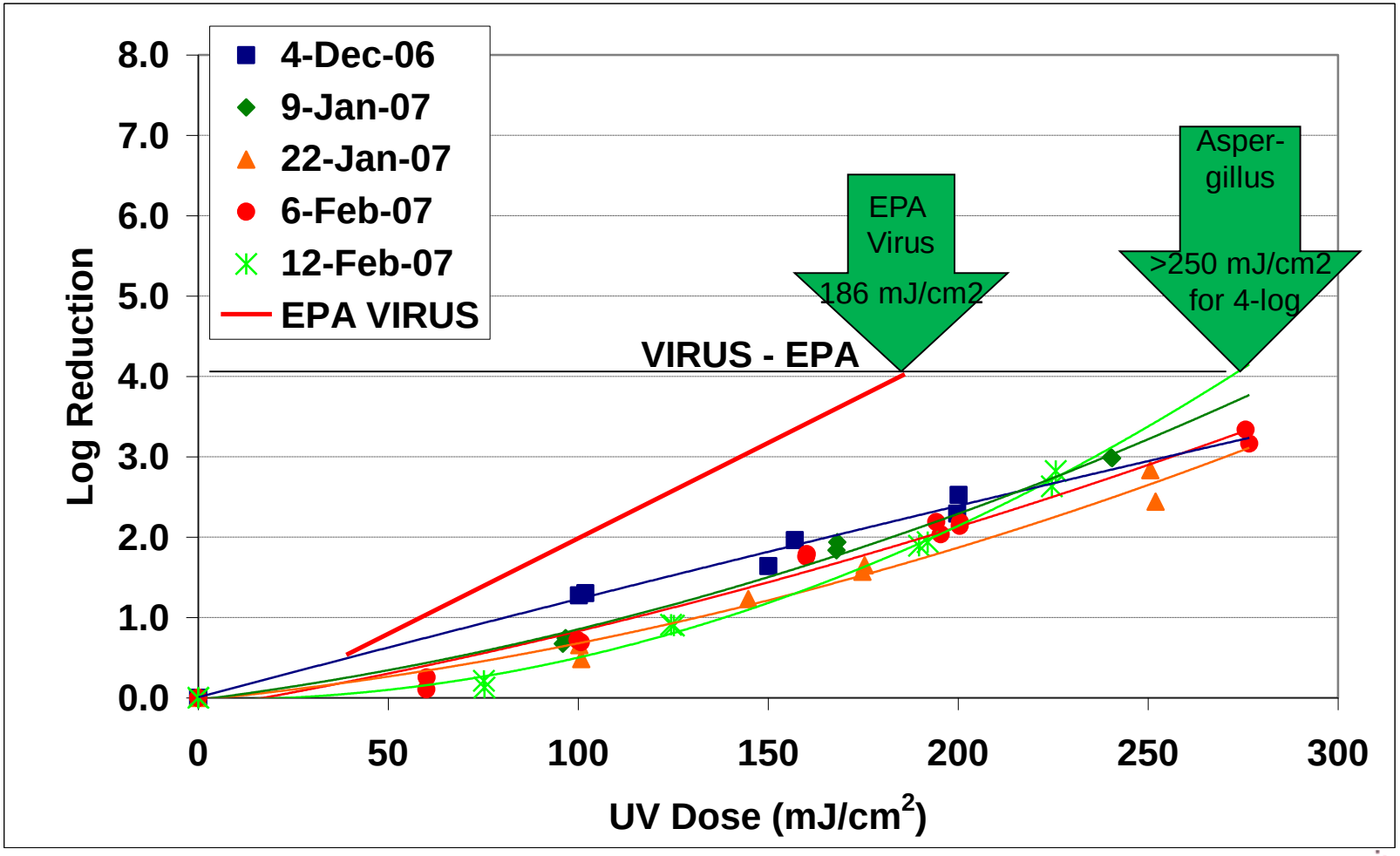
ASPERGILLUS BRASILIENSIS ATCC 16404 SELECTED

- Fungal spore
- Ubiquitous in nature
- Used for commercial processes (fermentation for organic acids and enzymes)
- Pathogenicity: Minor
- **Meets <u>all</u> EPA recommendations regarding an acceptable surrogate**

A. BRASILIENSIS SPORES: EASY TO WORK WITH

A. BRASILIENSIS SPORES: HIGH UV RESISTANCE



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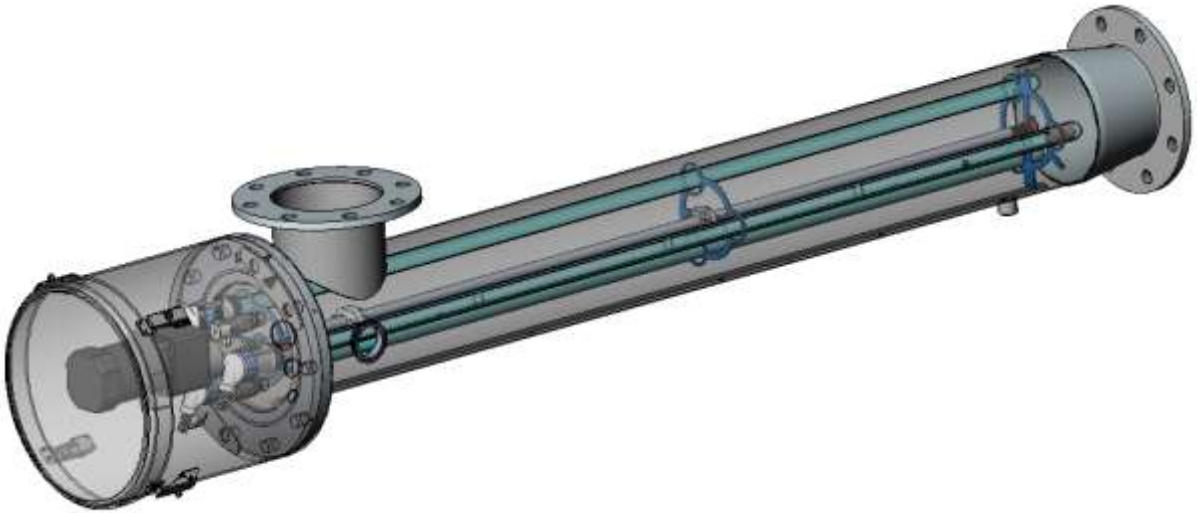
RESULT – UV SYSTEMS VALIDATED FOR VIRUS TREATMENT

- Trojan has validated four LPHO TrojanUVSwift™SC D-Series reactors
  - *Aspergillus brasiliensis* – For Virus
  - MS2, T1, T7 – For *Cryptosporidium*/*Giardia*
  - Validation reports ready – Equations bracket MS2 and *Aspergillus*
- Performed at Hydroqual UV Validation Center Johnstown, NY



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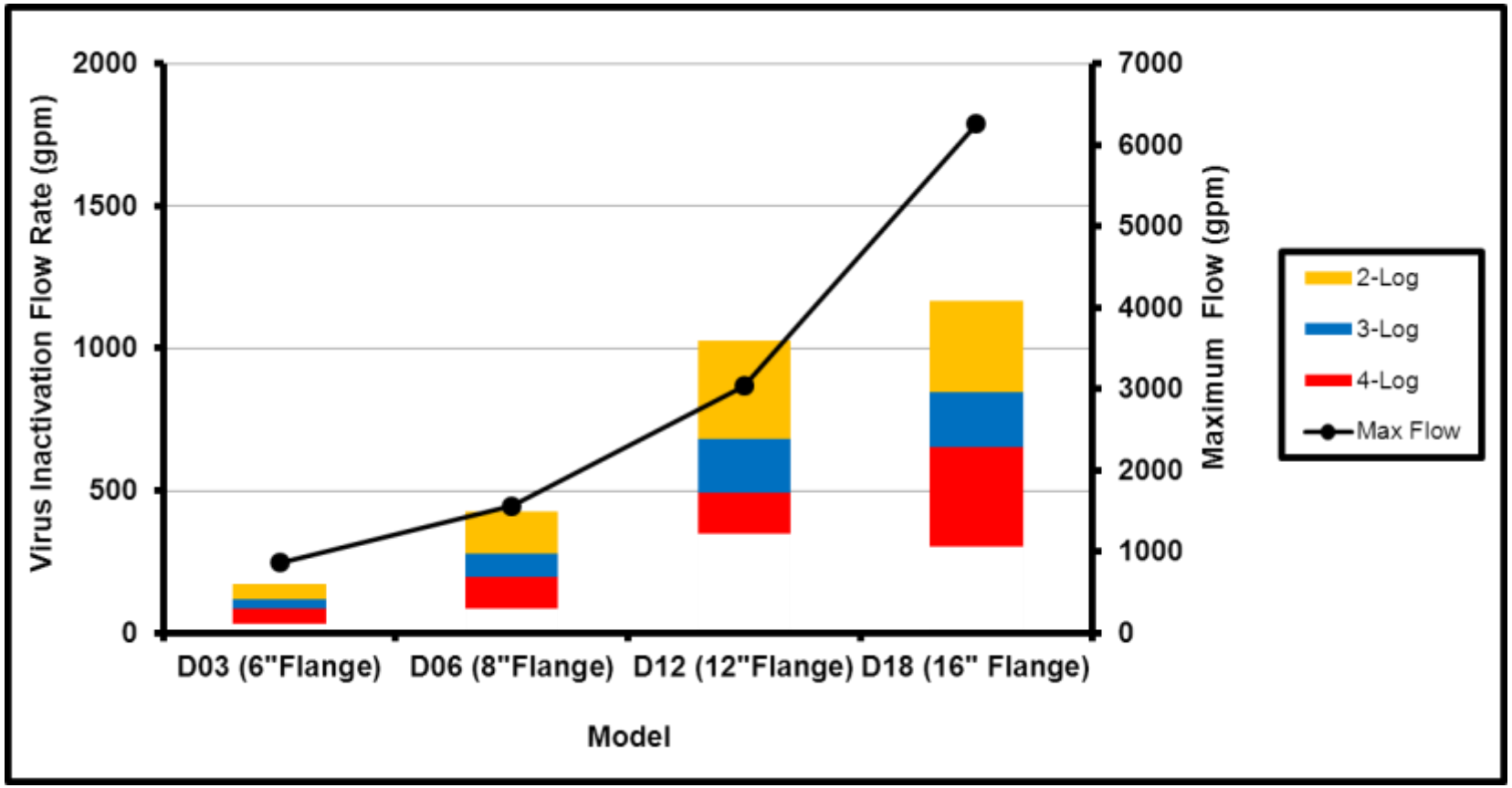
RESULT – UV SYSTEMS VALIDATED FOR VIRUS TREATMENT

Virus Inactivation Flow Ranges (gpm)



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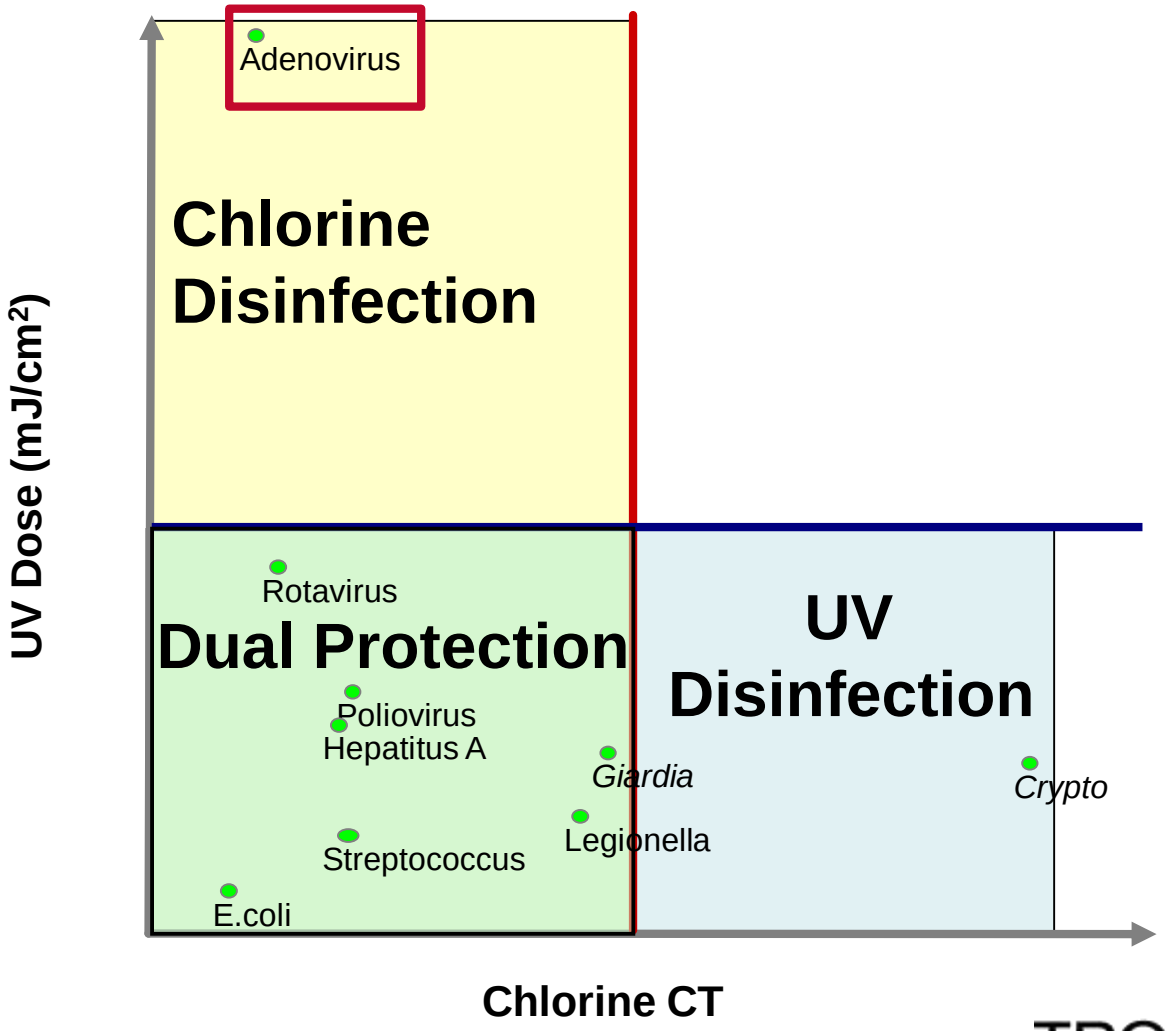
DISINFECTION APPROACHES - BEFORE



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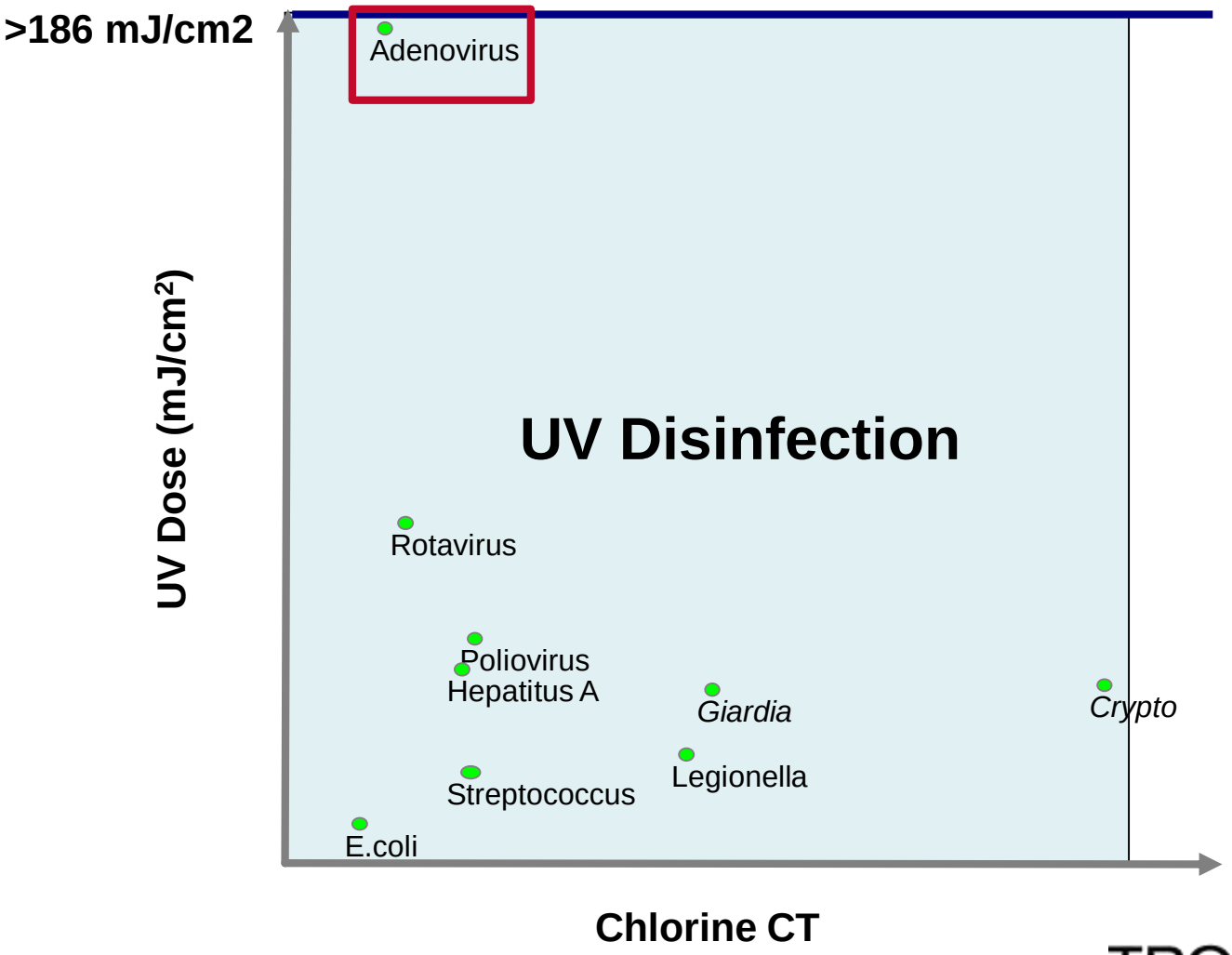
DISINFECTION APPROACHES - AFTER



INSTALLING UV FOR VIRUS TREATMENT

HALL ROAD, PENNSYLVANIA UV INSTALLATION

Background

- Groundwater Extraction
- 1.5 MGD Design Flow
- Operated by Aqua Pennsylvania (Aqua PA)
- In 2009 PA State Regulators passed legislation mandating ALL groundwater providers install 4-log virus inactivation

HALL ROAD, PENNSYLVANIA UV INSTALLATION

OPTION #1 – IMPROVE CHLORINE TREATMENT

- Chlorine is an effective method for the disinfection of virus BUT
- This often required increasing contact time (CT)
- Increasing CT involved installing/expanding pipeline
  - Can drastically increase plant footprint

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HALL ROAD, PENNSYLVANIA UV INSTALLATION

OPTION #2 – UV DISINFECTION

- Disinfection is instantaneous
  - No extensive CT required
- Minimal additional piping required
  - Lower capital expense
  - Much smaller footprint
- No risk of DBP formation

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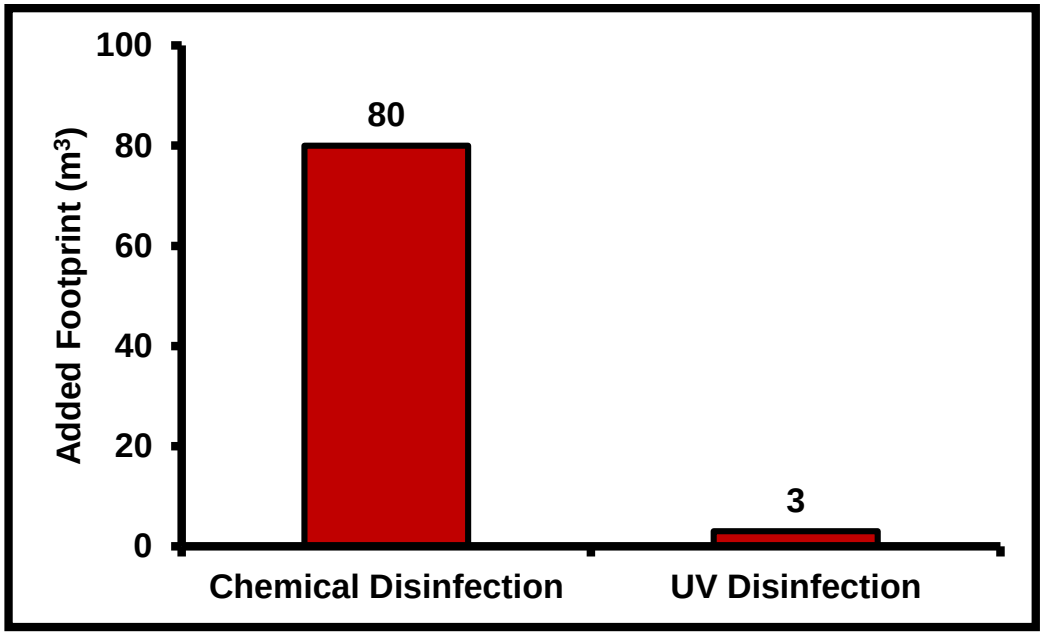
HALL ROAD, PENNSYLVANIA UV INSTALLATION

FOOTPRINT COMPARISON



- Chlorine Disinfection – 430 feet of 36” pipe required to increase CT for 4-log virus treatment
- UV Disinfection – 2 UV reactors plus control panels

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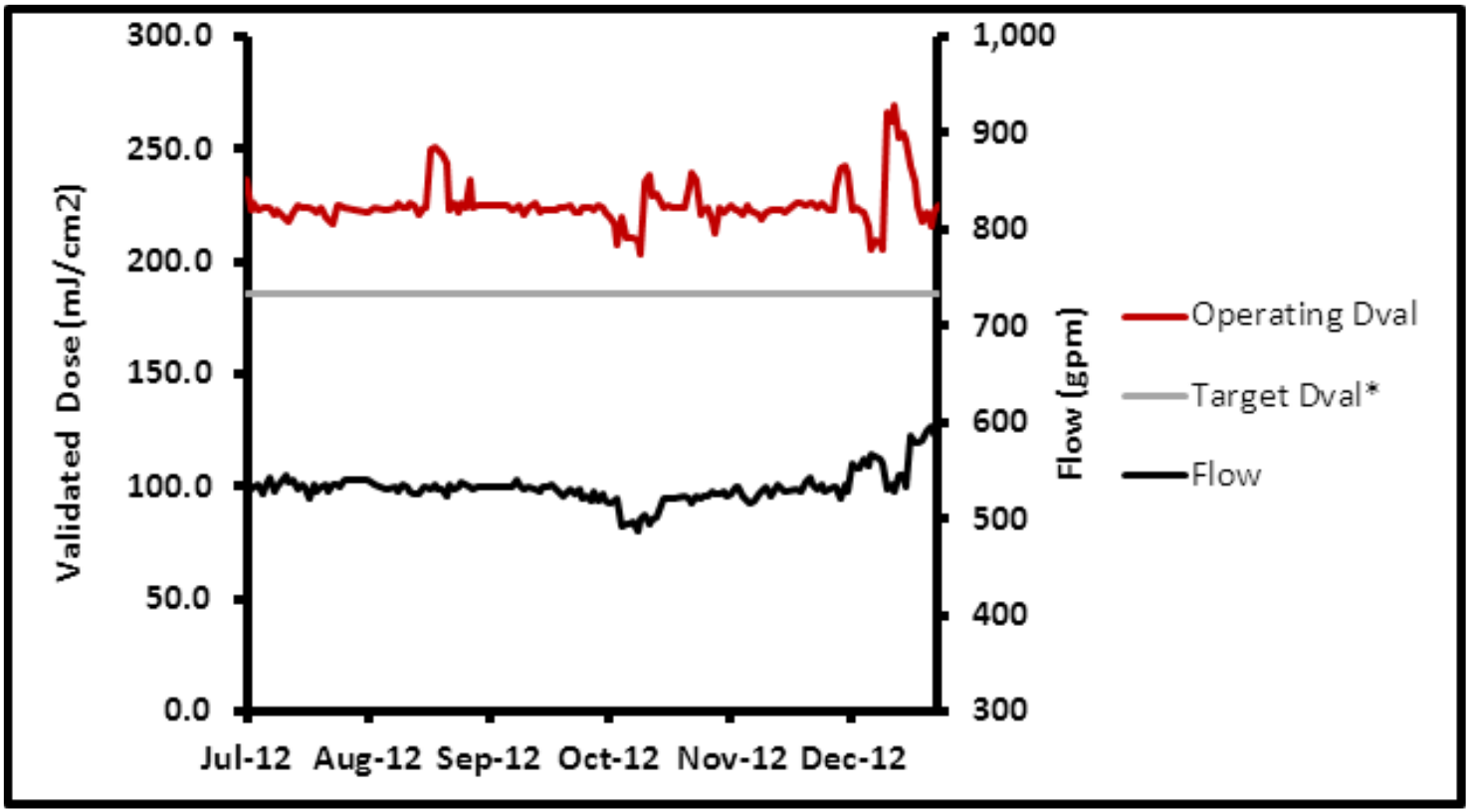
HALL ROAD, PENNSYLVANIA UV INSTALLATION

PERFORMANCE



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SUMMARY

- Increasing demand for groundwater providers to carry out 4-log virus primary disinfection
- UV systems are now third-party validated to inactivate 4-log virus in accordance with USEPA standards
- Use of a high-resistance surrogate to validate UV systems is a preferred approach and is backed by USEPA

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SUMMARY

- UV disinfection is instantaneous and does not require a large footprint
- Current installations chose UV as it required less than 5% of the footprint required to increase chlorine CT
- Performance data demonstrates that UV can maintain 186 mJ/cm2 USEPA mandated dose for 4-log virus treatment

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Questions?

Terry Keep
ECT Sales Manager
TrojanUV
(519) 457-3400
tkeep@trojanuv.com

www.trojanuv.com