Paula Wilson

From: Phyllis Posy <phyllisp@atlantium.com>
Sent: Tuesday, December 06, 2011 3:29 PM
To: Paula Wilson
Subject: idaho draft rule comments email 1
Attachments: Chuck Gerba.pptx

Dear Ms. Wilson,

My Name is Phyllis Posy and head Regulatory and Strategic Affairs at Atlantium Technologies, a company that provides 3rd party validated Medium Pressure UV systems to the municipal, food and beverage, aquaculture and pharma industries. We recently won an AWWA award for the best research in 2010 for proving that Medium Pressure UV could be validated for 4 log virus credited disinfection and would be economical for use for Groundwater Compliance. We have since validated our second unit – this time for small ground water systems to use for full 4 log virus credit.

I have attached a technical presentation by Dr. Chuck Gerba to the recent Association of State Drinking Water Administrators on this topic for your consideration.

The following are our comments, in two categories – general and specific text:

General

1. The Current Draft gives dose number for UV but does not specifically invoke the appropriate constraints that the dose numbers must be calculated using a validation factor and RED Bias. This could lead to some confusion in implementing the rules that could compromise public health.

2. The current draft suggests that in all cased a disinfectant residual is expected. We recommend that, realizing that there are now 4 log validated systems that provide full source disinfection, and most disease is from source contamination rather than distribution pipe contamination (see Wather Study, Borchardt AWWA, attached in email #2 due to size)), particularly in previous undisinfected systems, this should be at the option of the Department. This will enable small systems to achieve proper source disinfection without the DPBs and other long term negative issues associated with chemical disinfection or the maintenance issues and energy expense of RO and similar technologies.

   Therefore we recommend that the following be rewritten as below:
   Current:

   > Ultraviolet (UV) light technology is a primary disinfectant typically used for Cryptosporidium, Giardia, and virus inactivation of both surface water and groundwater supplies. Reactor performance in terms of inactivation of any particular organism is a function of the delivered dose which is determined by validation testing.

   Recommended rewrite:

   > Ultraviolet (UV) light technology is a primary disinfectant typically used for Cryptosporidium, Giardia, and virus inactivation of both surface water and groundwater supplies. Reactor performance in terms of
   > inactivation of any particular organism is a function of the delivered dose which is determined by validation testing. The Department may exempt from residual disinfection those previously undisinfected systems that use full UV systems validated for 4 log virus disinfection credit in accordance with this section.

3. The provision on credit should be reworded to be clearer:

Current text:

> UV disinfection credit will be awarded for filtered systems and unfiltered systems if the system meets the requirements for unfiltered systems in 40 CFR 141.71. Systems will receive Cryptosporidium, Giardia, and virus treatment credits by achieving the corresponding UV dose values shown in Section 529.03. The target pathogen and the target log inactivation shall be used to identify the corresponding required UV dose.

Recommended rewrite:

UV Disinfection credit will be awarded for filtered systems and unfiltered systems if the system meets the requirements for unfiltered systems in 40 CFR 141.71. Systems will receive Cryptosporidium, Giardia,
and virus treatment credits by achieving the corresponding UV dose values for the appropriate target pathogen and log reduction shown in Section 529.03, calculated to take into account the validation factor and RED bias.

4. There is no general definition of UV although there are definitions of other processes. In fact, the definition of disinfection says other allowed processes but no specific reference is included.

Specific items:

1. There is the following typo on page 86:

dose delivery at the plant is equal to exceeds that utilized during
validation. Recommended approaches of the UV Disinfection Guidance

Should say:
dose delivery at the plant is equal to or exceeds that utilized during
validation. Recommended approaches of the UV Disinfection Guidance

2. The issue of how many standby UV units are needed to assure properly disinfected water should be reconsidered. The current text is self contradictory and can be unnecessarily onerous and in some cases not necessary at all for smaller systems or systems that have available storage for finished disinfected water supplies.

Currently there are two references which seem to contradict each other:

> Standby equipment. A minimum of two (2) reactors is required; each reactor must be sized to deliver the required UV dose under the operating conditions of flow and UV transmittance that occur at the plant. The conditions shall fall within the validated range of the reactor as determined during validation testing. The system must be capable of producing the plant design capacity during any component failure prior to distribution.
>
> **A** single train with a standby reactor or a sufficient number of parallel ultraviolet treatment devices shall be installed to ensure that adequate disinfection is provided when one unit is out of service. The department may approve an alternate method that provides adequate disinfection such as standby chlorination.

These two should be consolidated into a coherent policy:

> Standby equipment is required to maintain disinfection when one unit is taken out of service if there are no other options to assure a continual supply of properly disinfected water. Particularly in the case of small systems, the Department shall consider the system as a whole and how to maintain an appropriate safe water supply.

4. The issue of how multiple reactors will be considered in calculating the dose should be rewritten. The current text can be more clear.

Current text:

> Approach length

prior to the first reactor, downstream length following the last reactor, and locations of any cleaning device/ mechanism shall be based on validation testing.

This seems to indicate that distances in the middle do not have to adhere to validation parameters. This should be rewritten as follows:

> Approach length prior to each reactor included in the credited dose calculation as well as downstream length following each such reactor, and locations of any cleaning device/mechanism shall be based on validation testing.

5. The text indicates that having a UVT meter is not needed unless the UVT is a part of the dose calculation methodology. At the same time, a subsequent provision says:

   > Validated operating conditions. When UV transmittance falls outside of ranges identified in the validated operating conditions, the contingency plan shall be enacted.

   If the site is not monitoring the UVT there is no way for them to be able to determine if the UVT is within the validated conditions. We recommend that the site be advised to monitor UVT on a regular basis to assure that the unit they are using is working within the validated conditions or to do so for the first year of operation until a pattern or UVT variability has been established.

6. The rules require a low water level Alarm , but no high flow alarm. A high flow alarm is critical to assure that the unit is not operating beyond its validated conditions. This provision should be reworded to require both low water level and high flow alarms.

I hope these comments are helpful. Please be in touch if you have any questions.

Phyllis Butler Posy
Vice President
Strategic Services and Regulatory Affairs
Atlantium Technologies
347-603-5711
phyllisp@atlantium.com
cell: 054 665 1071
US VOIP: 718-770-7756

This mail was received via Mail-SeCure System.

Full Scale Validation of Ultraviolet Light Disinfection of Drinking Water using Human Adenovirus

Akrum Tamimi and Charles P. Gerba

Soil, Water and Environmental Science

and
Epidemiology and Biostatistics
Univeristy of Arizona
Tucson, AZ

THE UNIVERSITY OF ARIZONA.
Mel and Enid Zuckerman College of Public Health

Co-Investigators

- Karl Linden, University of Colorado
- Karl Scheible and Chengyue Shen, HDR/HydroQual
- Gwy-Am Shin and J-K Lee, Univ. of Washington
- Phyllis Posy, Atlantium, Bet Shemesh, Israel
- Jim Malley, University of New Hampshire

University of Colorado Boulder

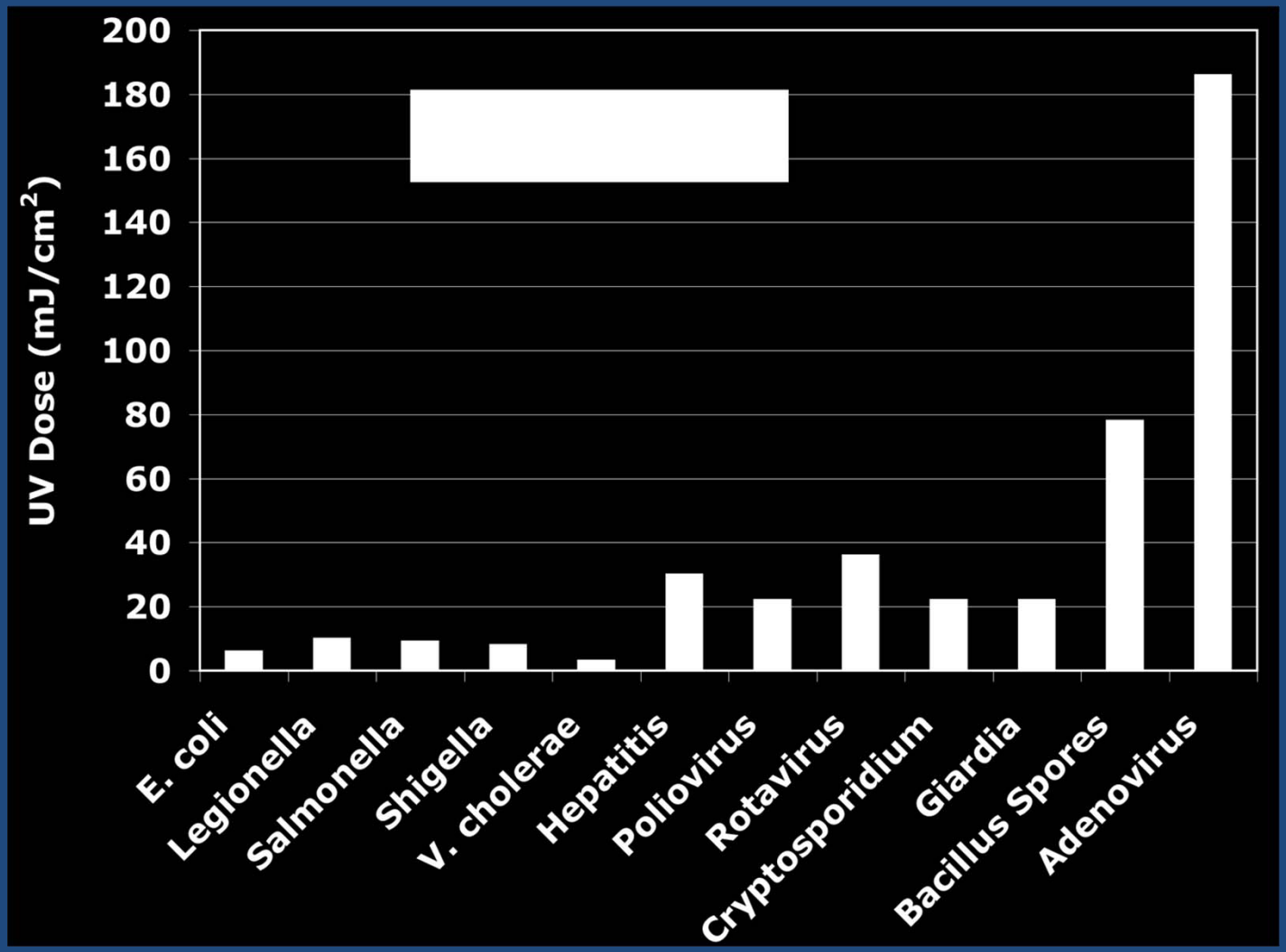
HDR | HydroQual

Atlantium
Illuminating Water Technologies

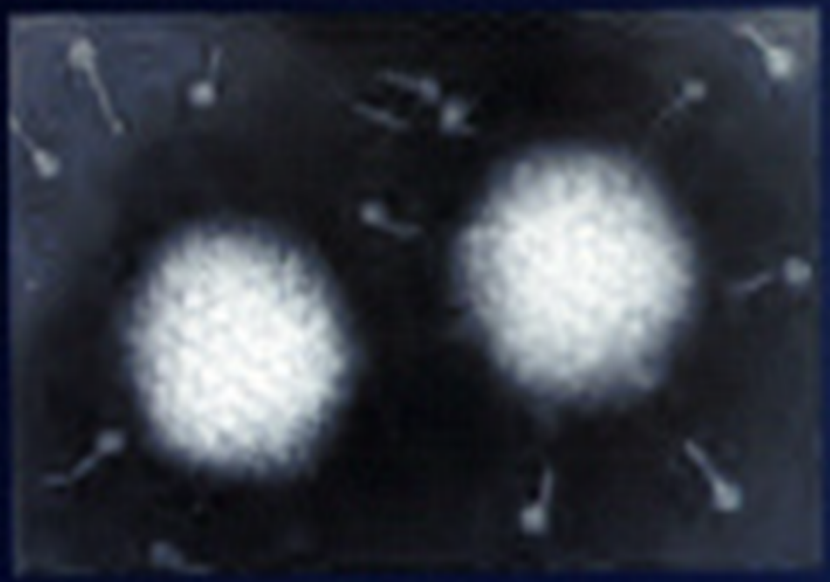
Key Topics

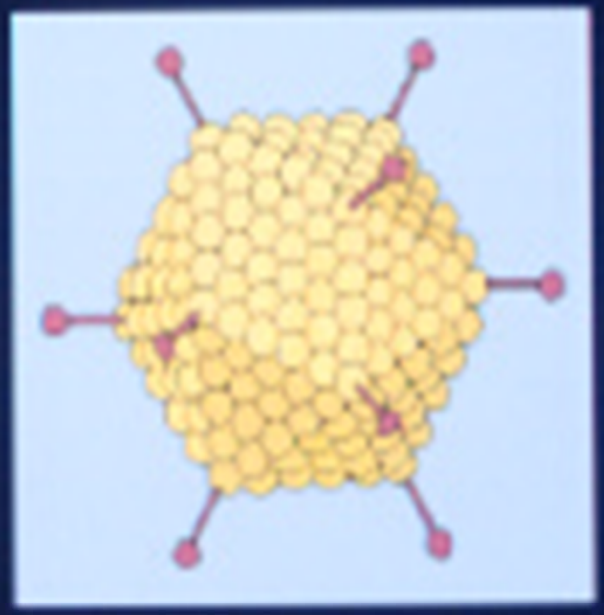
- Why is it important to public health?
- Why use live adenovirus?
- What were our results?
- Why are they significant?

UV Effectiveness for Waterborne Pathogens (4 log inactivation)



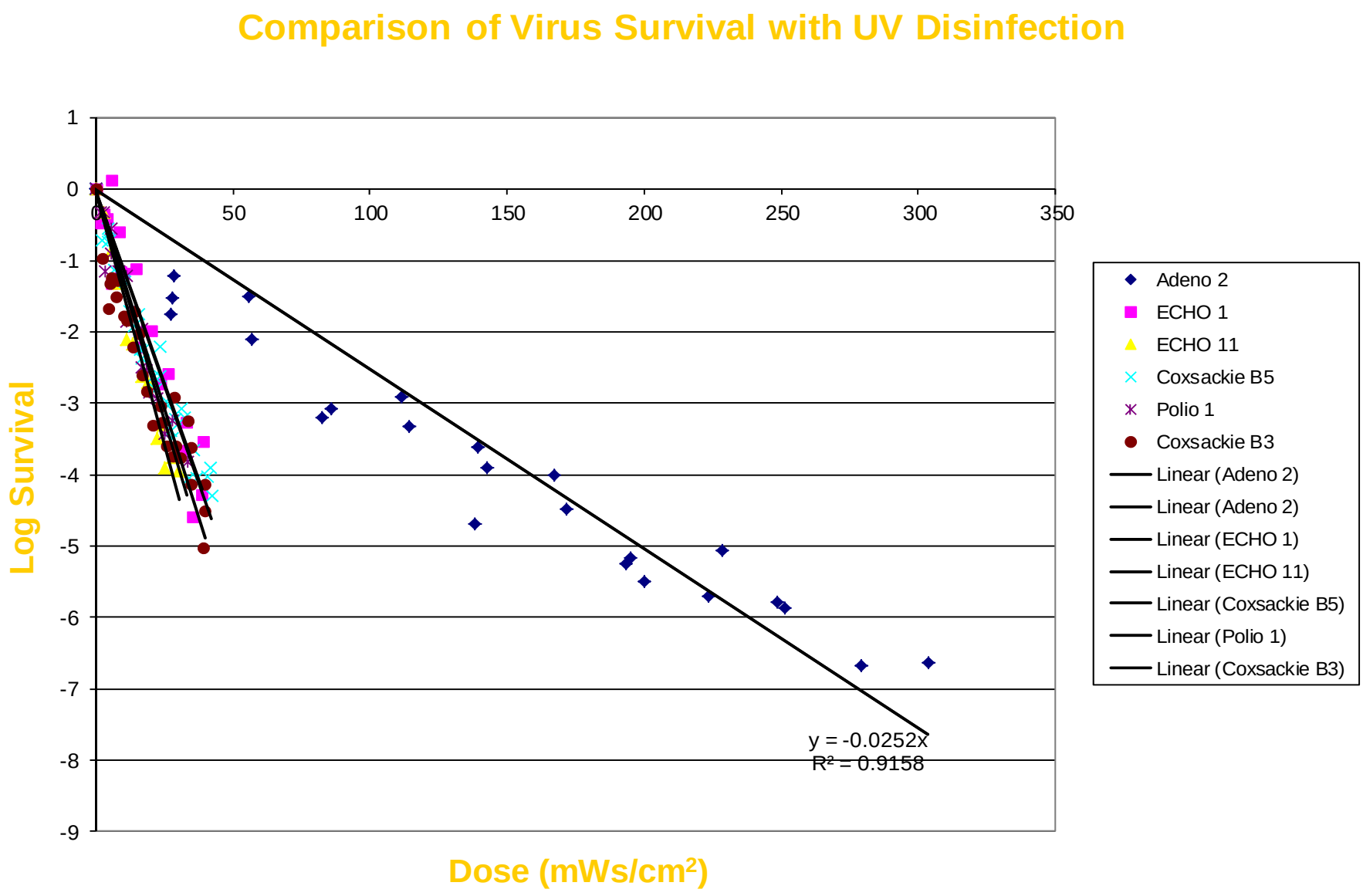
Adenovirus





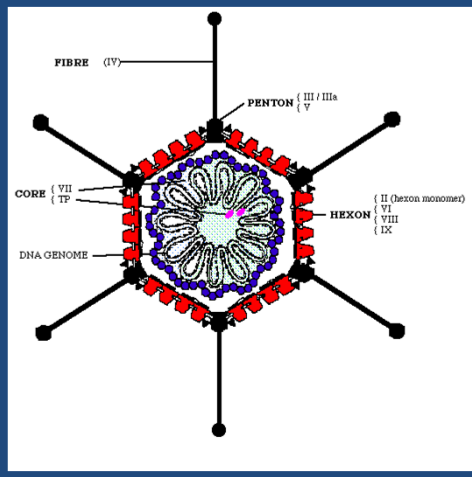
Adenovirus

- Second most common cause of childhood gastroenteritis
- Also cause of eye, throat, and respiratory infections
- Outbreaks associated with swimming pools and drinking water
- Most common enteric virus in sewage
- Typically in at-risk groundwater
- Longest surviving enteric virus in water?
- Enteric virus most resistant to UV light disinfection


Comparison of Virus Survival with UV Disinfection
Log Survival
Dose (mWs/cm²)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
50
100
150
200
250
300
350
y = -0.0252x
R² = 0.9158
Adeno 2
ECHO 1
ECHO 11
Coxsackie B5
Polio 1
Coxsackie B3
Linear (Adeno 2)
Linear (Adeno 2)
Linear (ECHO 1)
Linear (ECHO 11)
Linear (Coxsackie B5)
Linear (Polio 1)
Linear (Coxsackie B3)

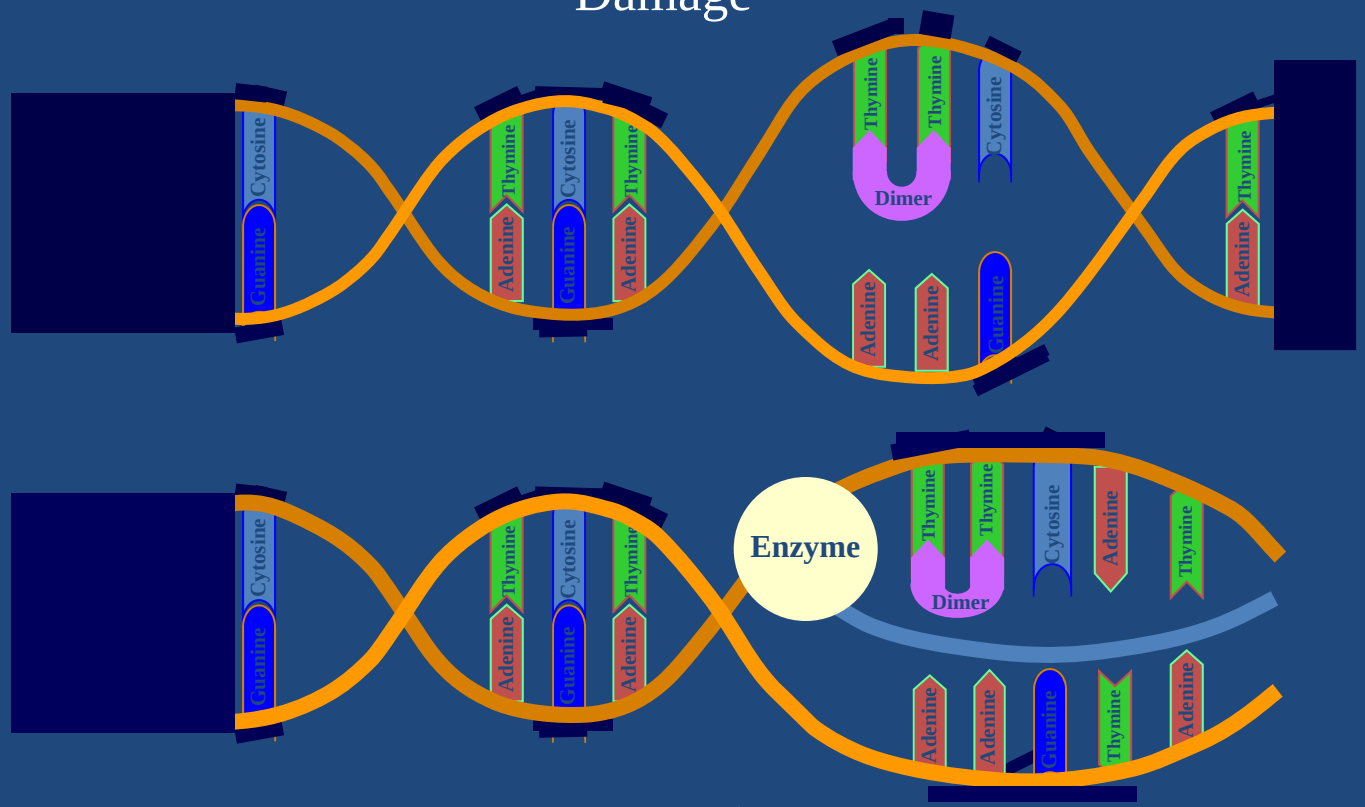
Why is Adeno so UV "Resistant"?

- Studies mostlyperformed with LP UV
- Focus on Specific DNA damage from UV 254 nm
  - Thymine dimer
- Hypotheses
  - Significant dimer-DNA damage occurs
    - Adeno is a dsDNA virus (same as host)
  - Virus enzymes call host cell repair mechanisms
  - Penton fibers unaffected
  - Infectivity is restored/DNA replicated
  - Higher UV doses required to inflict enough DNA damage to minimize repair, damage virus enzymes too.



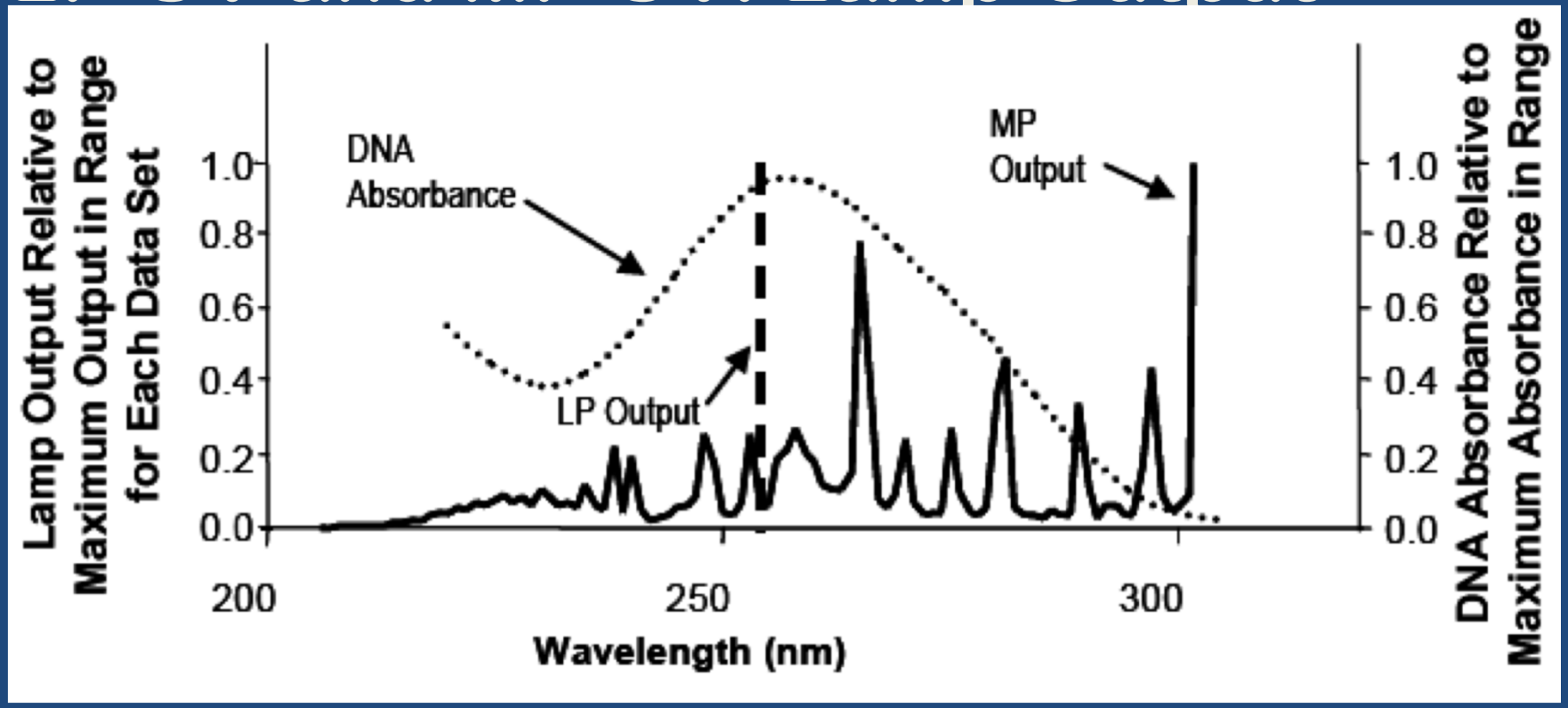
Effects of UV Irradiation on DNA

Damage



Repair

LP UV and MP UV: Lamp Output



Low Pressure (LP UV)

Mercury vapor
Monochromatic (253.7 nm)
Inactivates pathogens by damaging their DNA/RNA

Medium Pressure (MP UV)

Mercury vapor - Polychromatic
Inactivates pathogens by damaging DNA; additional macromolecules (proteins) via polychromatic

Bolton Photosciences Inc.

So, where does that put us?….

- LP UV is (apparently– requires high dose (EPA 2006)
- MP UV is much more effective – doses in line with other viruses (Malley 2004; Linden et al 2007, 2009)
- PCR studies (not in cell assays) show same amount of DNA damage occurs from LP and MP (Eischeid et al 2008)
- When assayed in repair deficient cells, MP/LP are the same, but in normal cell culture, MP is more effective than LP (Guo et al 2010)
- But can it be validated full scale according to EPA rules?

Items to Consider when Validating UV Light Reactor Performance from the Microbiology Viewpoint

- Using the target organism is the ideal and provides the best public health protection and certainty
- Collimated beam data laboratory data does not reflect full scale performance
- Organisms are particulates not chemicals (solutes)
- Size of the organisms
- Structure features of the organisms (shape, appendages)
- Ability to repair damage (repair enzymes)
- Nucleic acid composition (RNA vs. DNA/double stranded vs. single stranded)
- Hydrophobicity (effects attraction to air/water/solids interfaces)
- Clumping potential
- Melanin, when present, changes cell response and UV resistance

Surrogates used to Assess UV Light Disinfection Performance

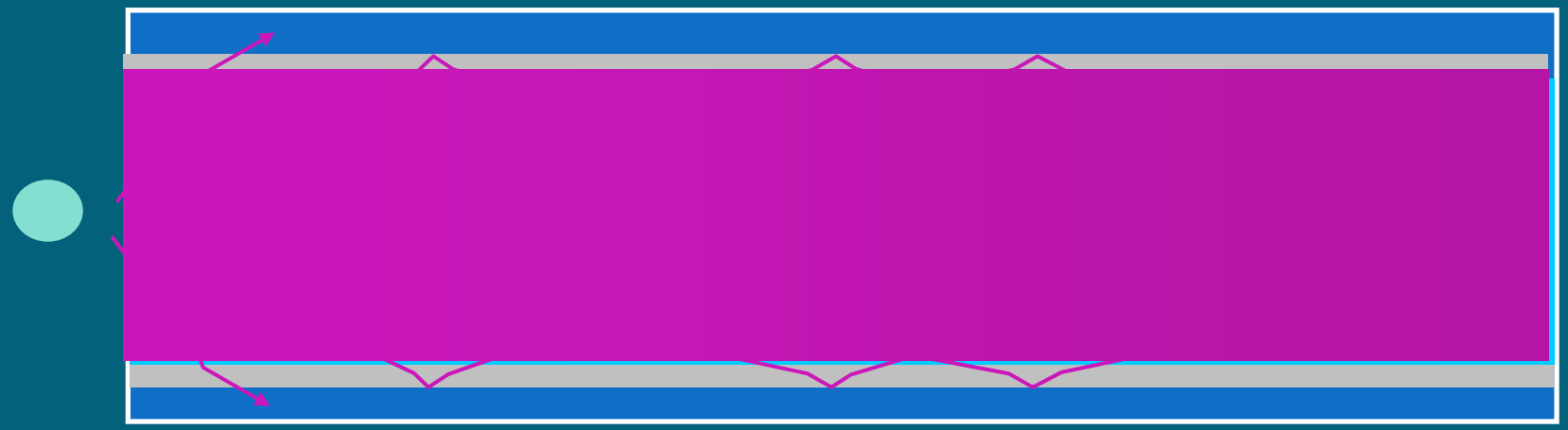
Surrogate	Advantages	Disadvantages
MS- 2 Coliphage	Easy and low cost assays; non-infectious to humans and animals	Smaller than adenovirus (23 nm vs 70 nm); very hydrophobic; ssRNA
Clostridium perfringens spores	Spore former	Much larger than viruses: need to grow and assay under anaerobic conditions
Fungal spores (*Aspergillus niger*)	Very resistant to UV light	Much larger than bacteria and viruses (35 to 50 times) and different shape; melanin changes resistance
Dyed Microspheres	Easy to assay – no microbiology lab need	Much larger (~5 microns) than bacteria and viruses
Photo reactive Chemicals	Easy to assay – no microbiology lab need	Not a particulate

Challenges for Adeno Testing

- Titer able to achieve in Reactor (1-5 x 10^5)
  - Hard to obtain high titer adenovirus stocks
- Working with a pathogenic virus
  - Required special handling and precautions
- Achieving high log reduction in reactor
  - Governed by influent titer and assay
- Meeting a dose with validation factors
  - >1 validation factor for UV reactor conditions
  - Means higher dose than 186 needs to be met

RZ 104 Optimizes UV dose delivery

- **Atlantium uses fiber-optic principles to lengthen light paths**

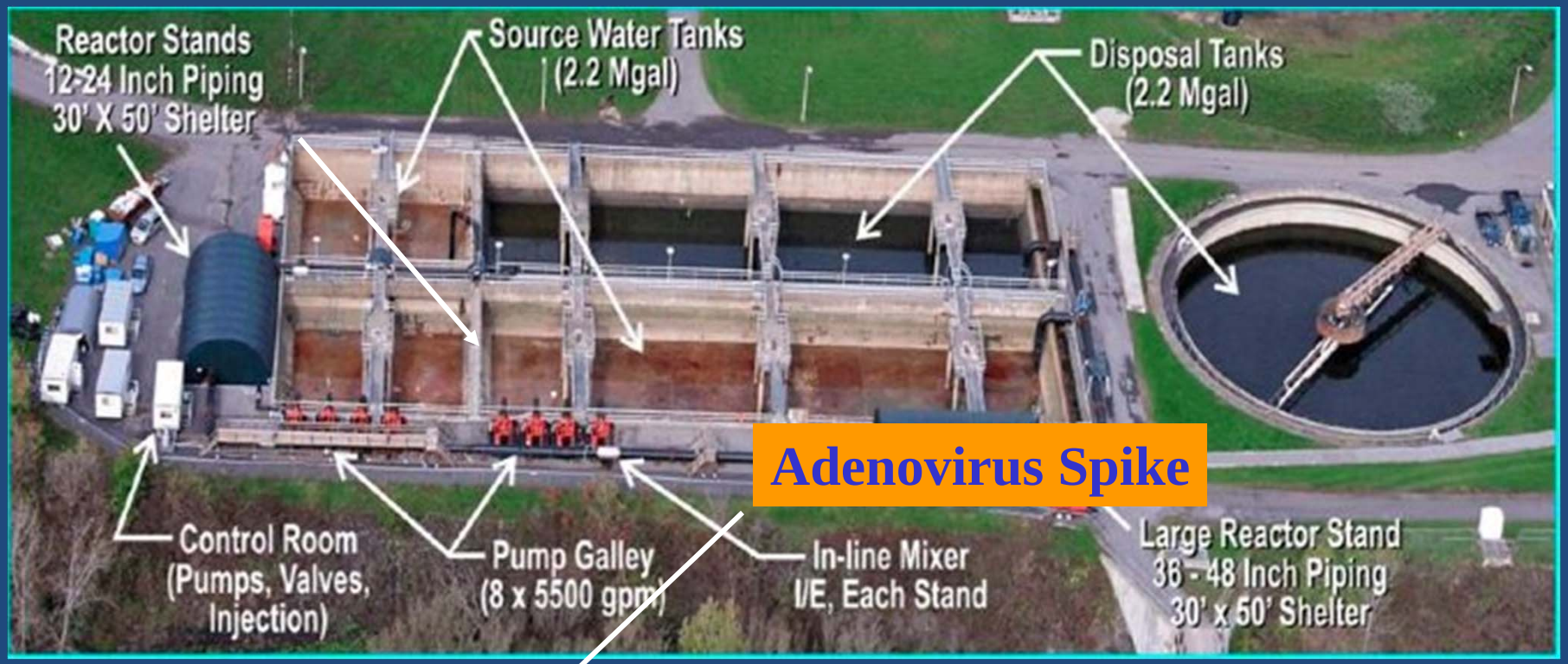


- **All Quartz Reactor with ultrasound cleaning "recycling" the UV photons**
- **No low dose tracks – pathogens cannot escape**
- **2 sensors per lamp captures real time measurement and performance**

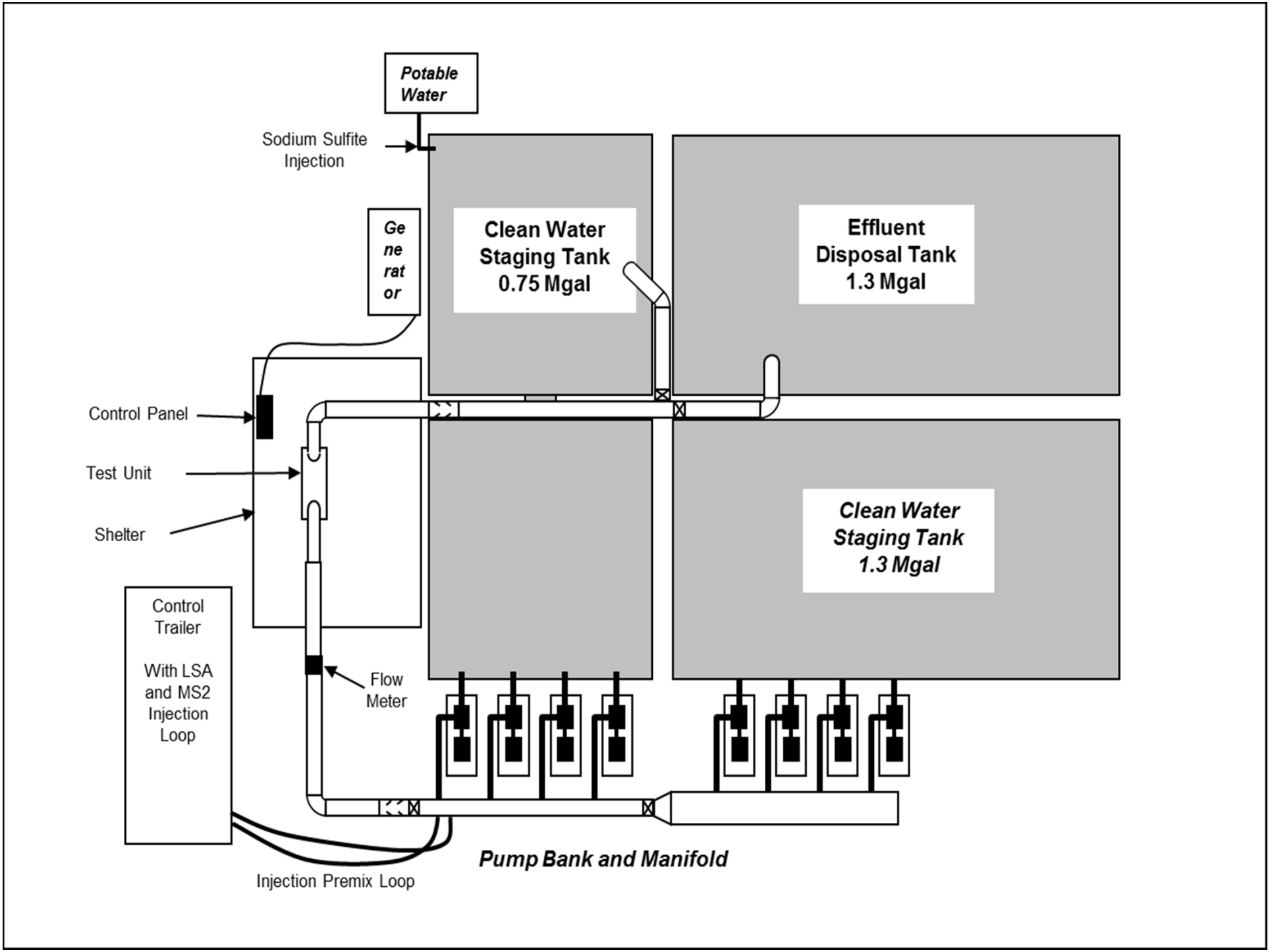
Test Unit

- Atlantium Technologies RZ-104 Hydro Optic Disinfection System
- 10 to 250 gpm
- A thick quartz tube to better control dose and added protection from fouling

Field Testing Site: UV Center

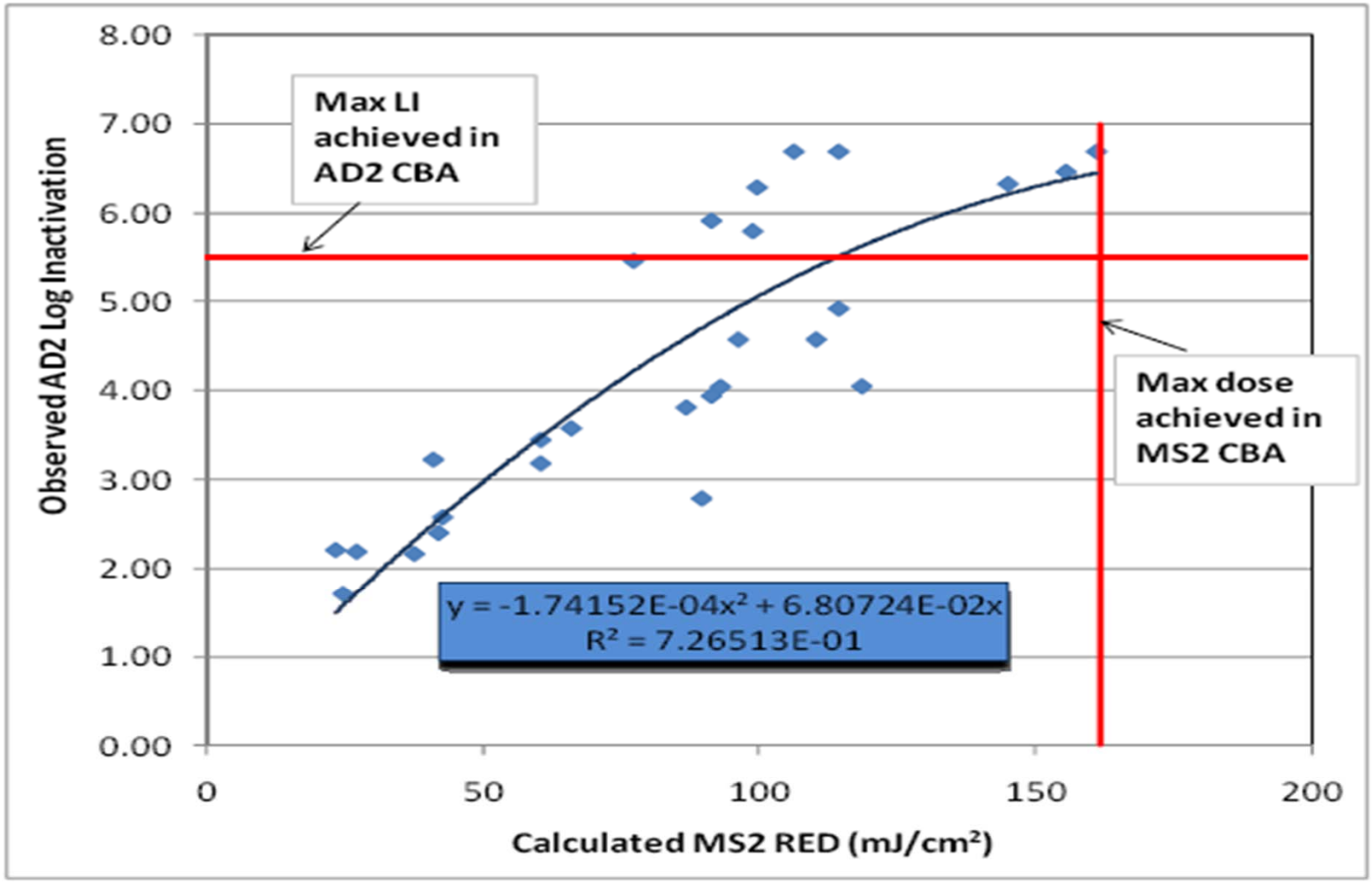


HydroQual NY State UV Validation and Research Center

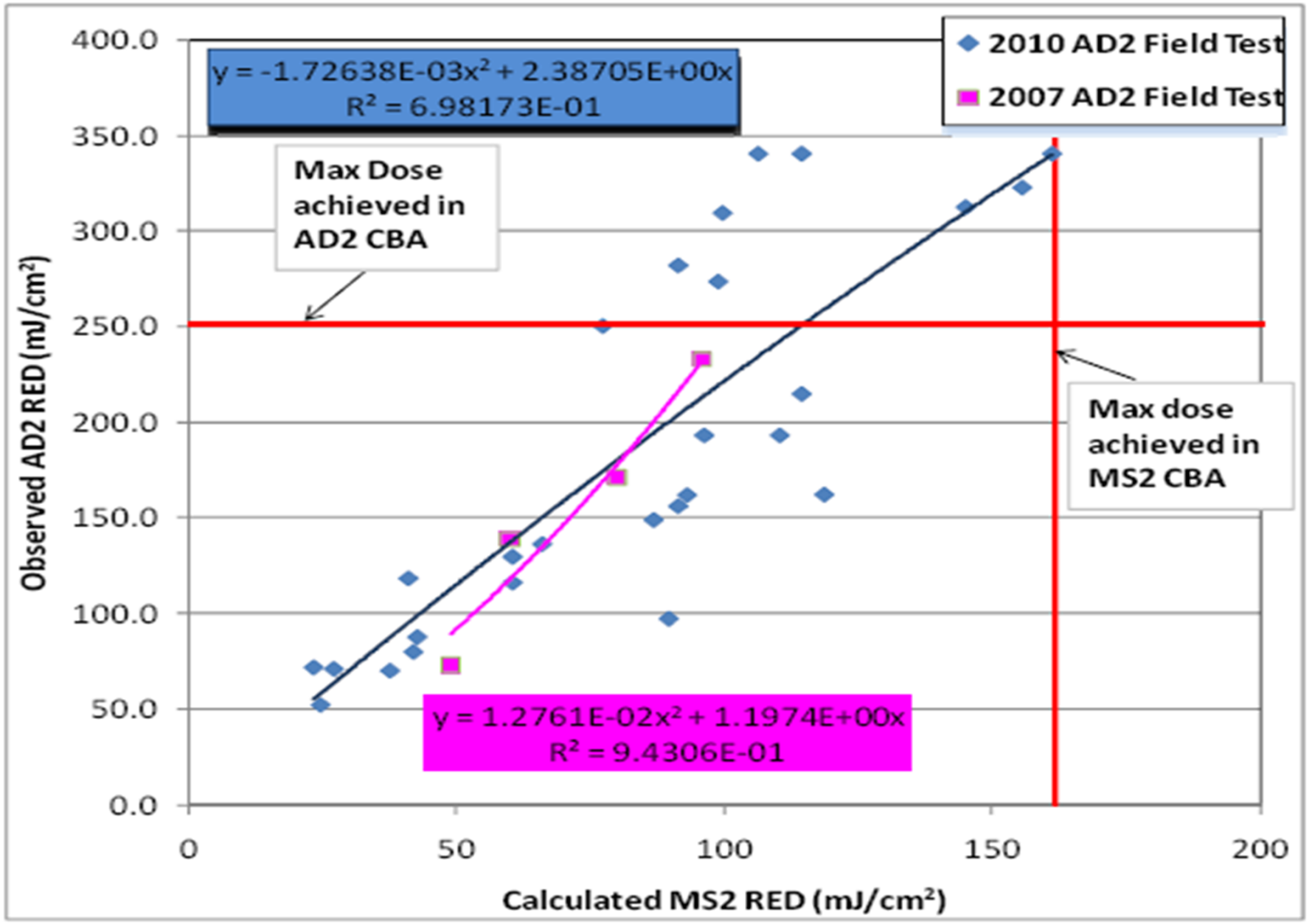

Potable Water
Sodium Sulfite Injection
Ge ne rat or
Clean Water Staging Tank 0.75 Mgal
Effluent Disposal Tank 1.3 Mgal
Control Panel
Test Unit
Shelter
Clean Water Staging Tank 1.3 Mgal
Control Trailer
With LSA and MS2 Injection Loop
Flow Meter
Pump Bank and Manifold
Injection Premix Loop

In the field – safety and accuracy

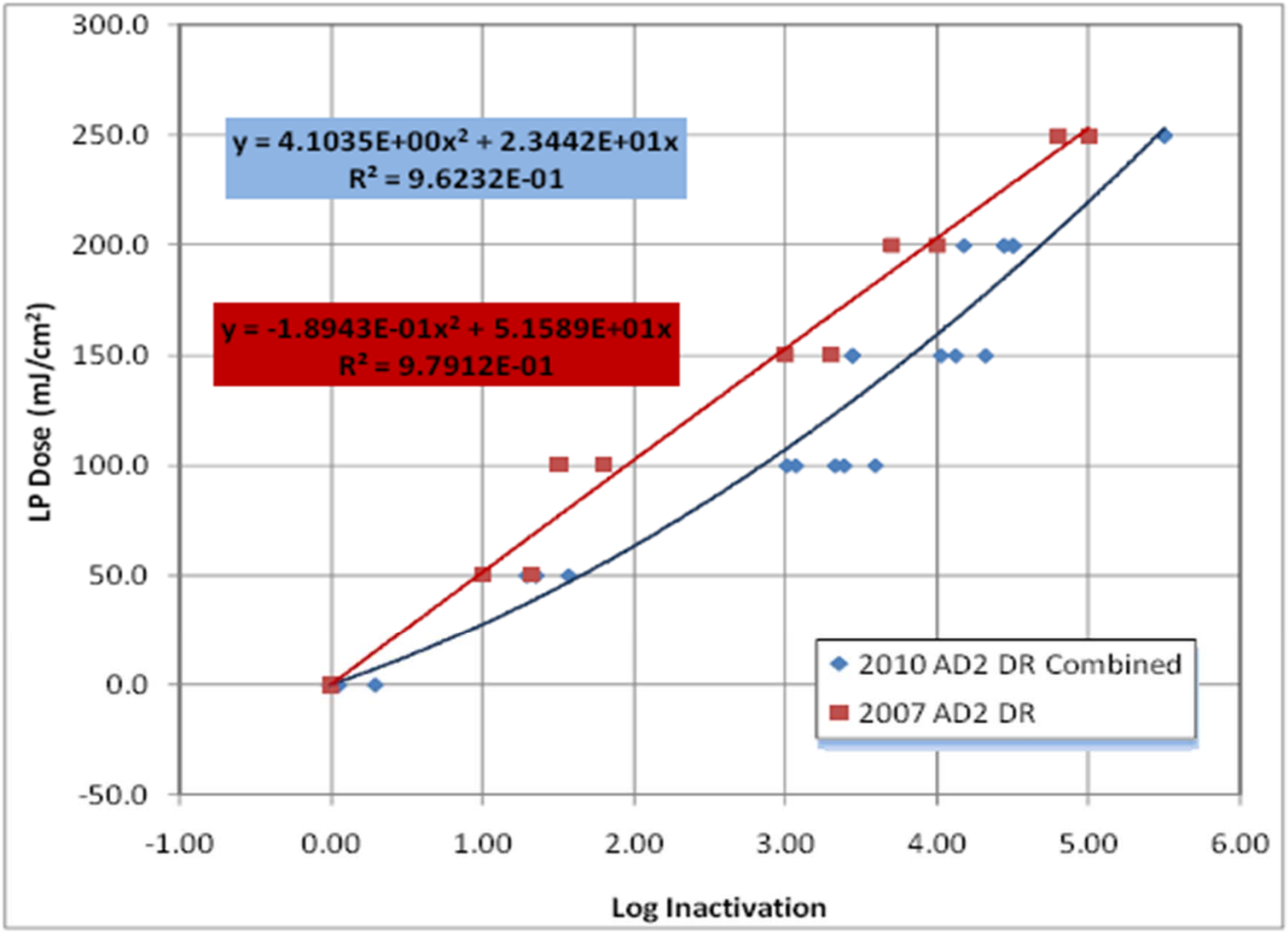
Field Measurements of AD2 and MS2 on the Medium-Pressure RZ104 Unit



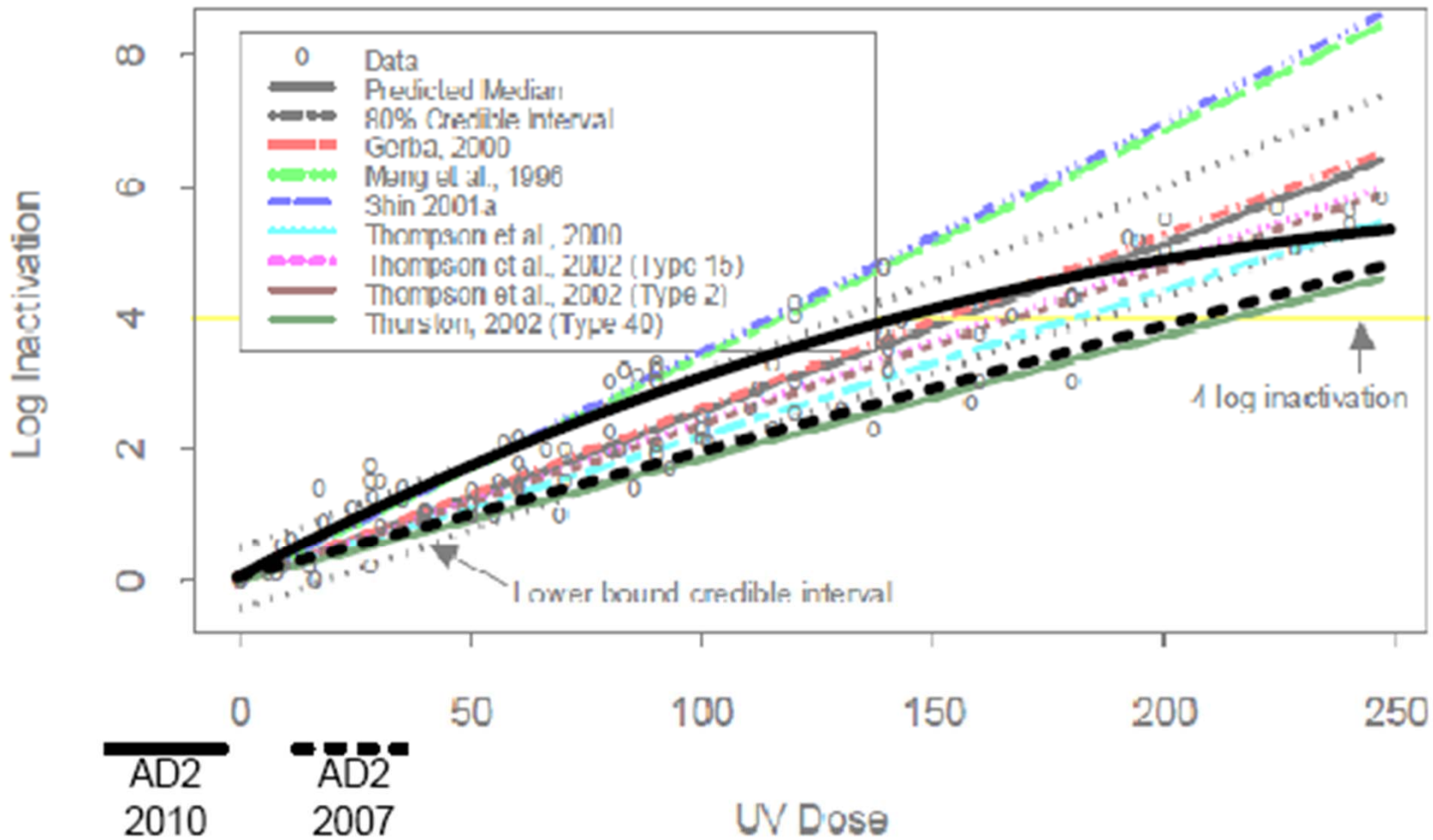
Field Measurements of AD2 and MS2 on Medium Pressure RZ104 Unit



Adenovirus 2 Dose Response Behavior - 2010



AD2 Dose-Response Behavior Curves Developed in 2007 and 2010 Compared to Literature



Bottom Line

- 118.3 mJ/cm^2 MS-2 RED = 4 log inactivation of adenovirus
- For medium vapor pressure lamp

Implications for Public Health

- MP UV definitely is more effective than traditional LP and should be recognized and validated separately with adenovirus for virus credit
- Can demonstrate dose of 186 mJ/cm^2 via LP benchmark and >4 log reduction of viruses, follows EPA Guidance
  - Adds to the body of published data that MP UV needs a lower UV dose/ less energy for adenovirus inactivation
- What about cost effectiveness?
  - We can validate UV dose and get 4 log inactivation economically – NOW accepted in NY State & PA
- Acceptance of UV for virus control in ground water
  - Should be an available tool for small systems and others to use

Conclusions

- Validated of the RZ 104 Hydro Optic Disinfection System for a 4 log adenovirus reduction credit
- Validated the use of medium vapor pressure lamp for adenovirus reduction

Wisconsin WAHTER Study

Viruses in Non-Disinfected Groundwater Supplying Municipal Drinking Water and the Human Health Risk

Mark Borchardt and Susan Spencer
USDA – Agricultural Research Service

Burney Kieke
Marshfield Clinic Research Foundation

Elisabetta Lambertini and Frank Loge
University of California - Davis

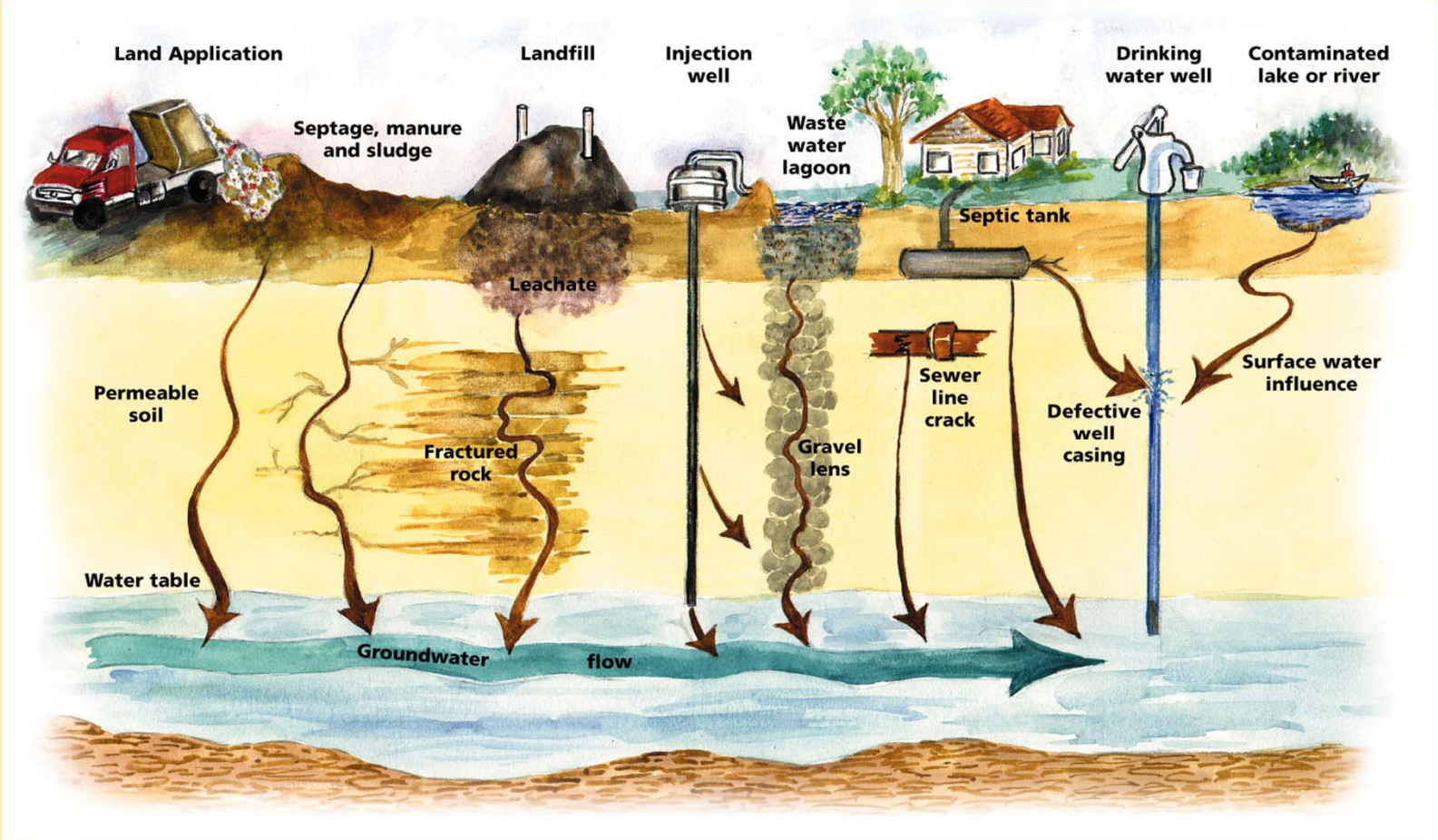
Wisconsin WAHTER Study

Virus Occurrence in USA Groundwater

- **Tested 448 municipal wells in 35 states, 31.5% positive for viruses (Abbaszadegan et al 1998)**
- **Tested 7 wells in karst/carbonate aquifer in Tennessee, 88% positive for culturable virus (Johnson & McKay et al 2011)**
- **30 municipal wells in 17 states, 23% positive for enteroviruses (Lieberman et al 1999)**
- **Tested 29 wells and 72% were virus-positive (Fout et al 2003)**
- **Viruses in Wisconsin groundwater: Private domestic wells (8%), City of La Crosse wells (83%), and City of Madison wells (66%) were virus-positive (Borchardt et al 2003, 2004, 2007)**
- **Occurrence and Monitoring Document for the Final Ground Water Rule: at some point in time 27% of public water supply wells are virus-positive (EPA 2006)**

Wisconsin WAHTER Study

Virus Sources and Infiltration Routes into Groundwater



Modified from Keswick and Gerba 1980

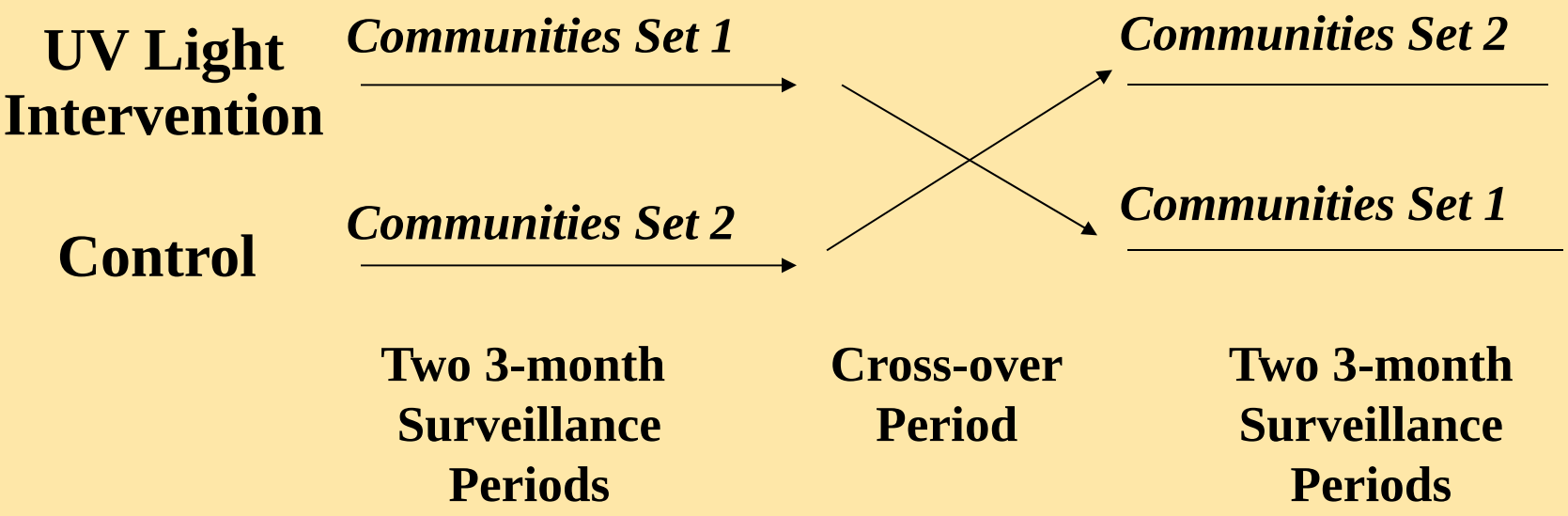
Wisconsin WAHTER Study

Health Risk or Non-Issue?

- So viruses are present in public water supply and domestic wells …
- Does it matter?
- Is there any effect on public health?

Wisconsin WAHTER Study Design

Intervention trial in 14 groundwater-source communities



Wisconsin WAHTER Study

WAHTER Study Participating Communities

Populations: 1,200 – 8,300

Number Wells: 2 – 5

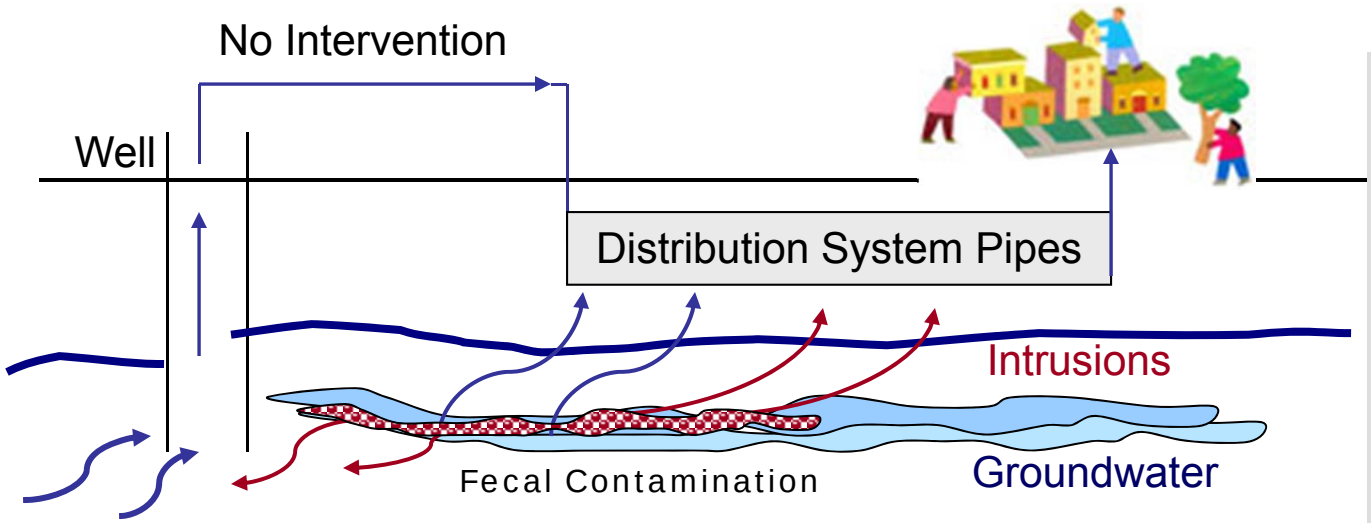
Pumpage: 0.13 – 2.1 MGD

Hydrogeology: sand, sandstone, limestone

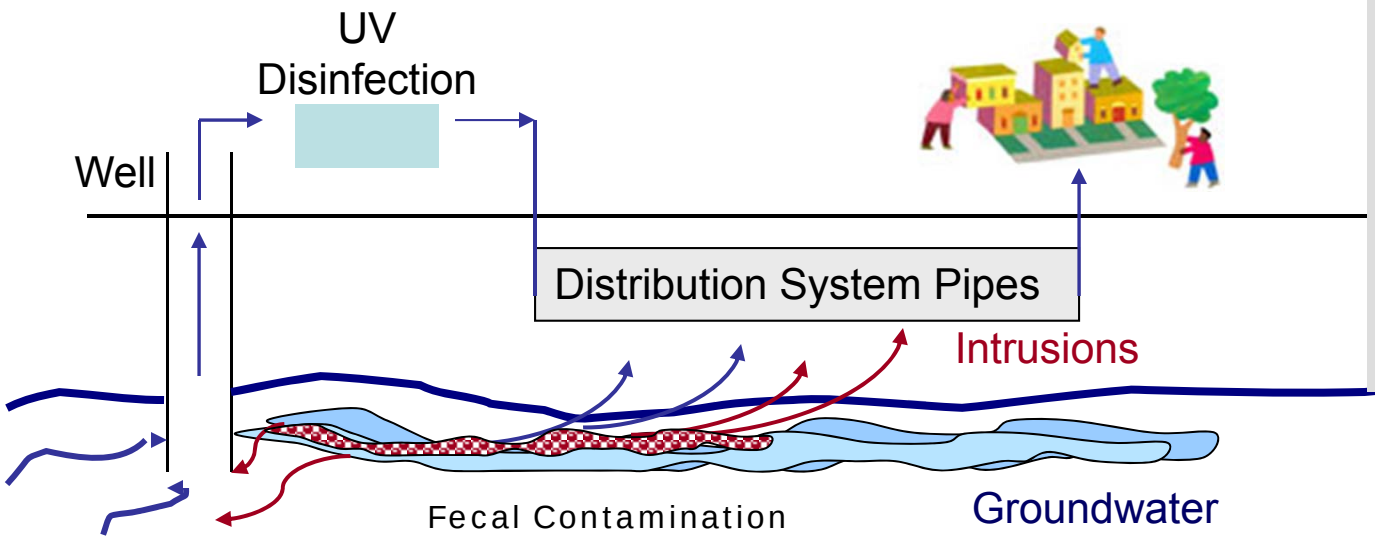
No surface water influence

No disinfection

UV Intervention Effect



Non-Intervention Communities illness due to groundwater plus distribution system



Intervention Communities illness due to distribution system only

UV dose = 50 mJ/cm2

Wisconsin WAHTER Study

Epidemiological Study Design

- Acute gastrointestinal illness (AGI) surveillance for four 12 week periods, spring and autumn 2006 and 2007
- Participants submitted an illness symptom checklist every week
- AGI defined as ≥ three episodes loose watery stools OR ≥ one episode vomiting in 24 hour period
- Person-time estimated from nights slept away from home, self-reported on symptom checklist
- Outcome measure: Number AGI episodes/person-year for each community and surveillance period

Wisconsin WAHTER Study

Participating Households' Characteristics

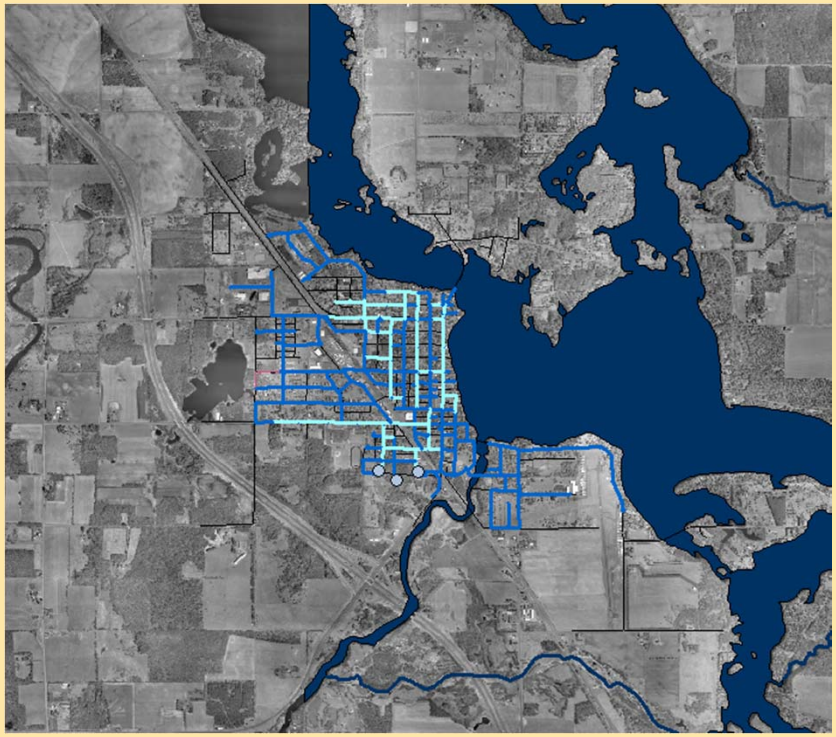
Characteristic	Number	%
Household size (no. of persons)		
2	17	(3)
3	159	(26)
4	246	(40)
5	136	(22)
≥6	63	(10)
Residence type		
Single family home	572	(92)
Apartment or condo	43	(7)
Other	6	(1)
Faucet or plumbing filtering device		
Yes	73	(12)
No	547	(88)
Don't know	1	(<1)
Primary drinking water source		
Municipal	1546	(93)
Bottled water	58	(3)
Other	1	(<1)
Missing	54	(3)

- **Beginning enrollment: 621 households**
- **Ending enrollment: 440 households**
- **Beginning enrollment: 1,079 children, 580 adults**
- **Ending enrollment: 765 children, 413 adults**

Wisconsin WAHTER Study

Water Sampling Plan

- Every study community sampled once per month
- Sampled all operating wells before and after UV disinfection units



Distribution system samples (up to 8 per community) collected from household taps

Viruses captured by glass wool filtration; Analyzed by qPCR

Wisconsin WAHTER Study

Virus Types, Frequencies, and Concentrations in Tap Water

Virus Type	Number qPCR Positive Samples (%)	Virus Concentration Genomic Copies/L		
		Mean	Median	Maximum
Adenovirus	157 (13)	0.07	0	9.5
Enterovirus	109 (9)	0.8	0	851.1
GI Norovirus	51 (4)	0.60	0	115.7
GII Norovirus	0 (0)	0	0	0
Hepatitis A Virus	10 (1)	0.006	0	4.1
Rotavirus	1 (0.1)	$2X10^{-5}$	0	0.03
All Viruses	287 (24)	1.5	0	853.6

N = 1,204 samples

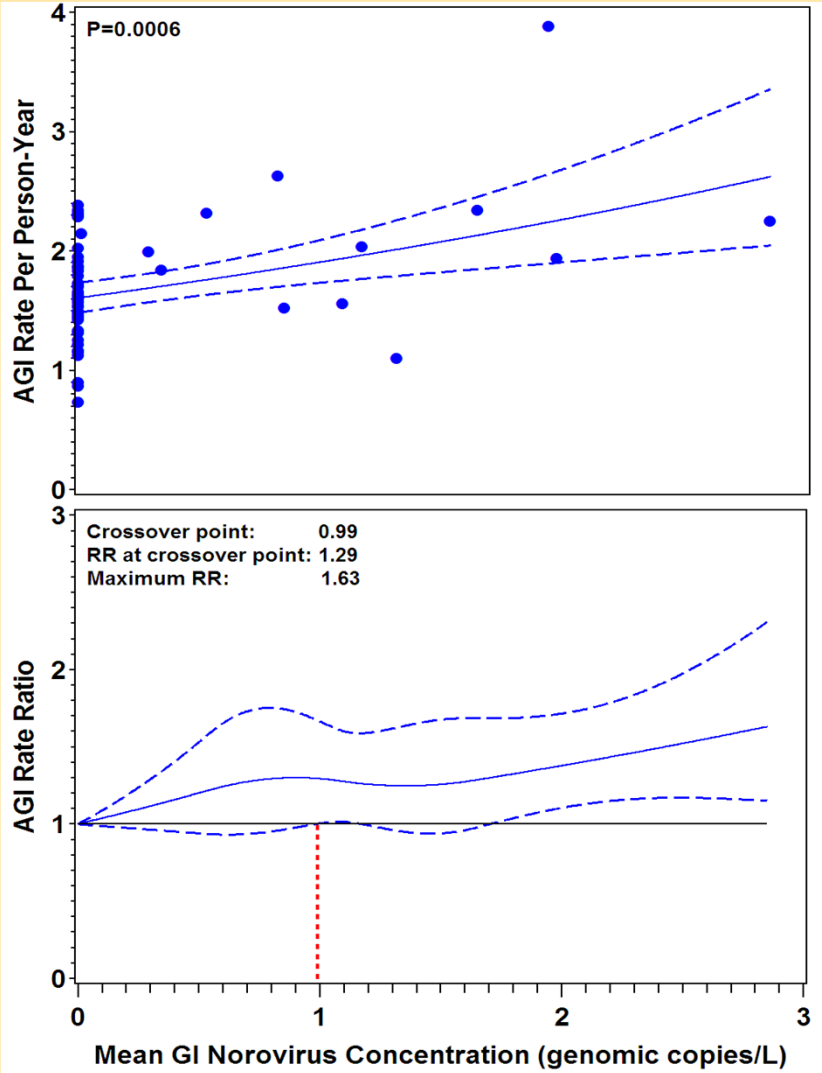
Wisconsin WAHTER Study

Objective 1

Determine the association between tap water virus concentrations and community illness rates

Wisconsin WAHTER Study

G1 Norovirus Concentration in Tap Water and AGI Incidence

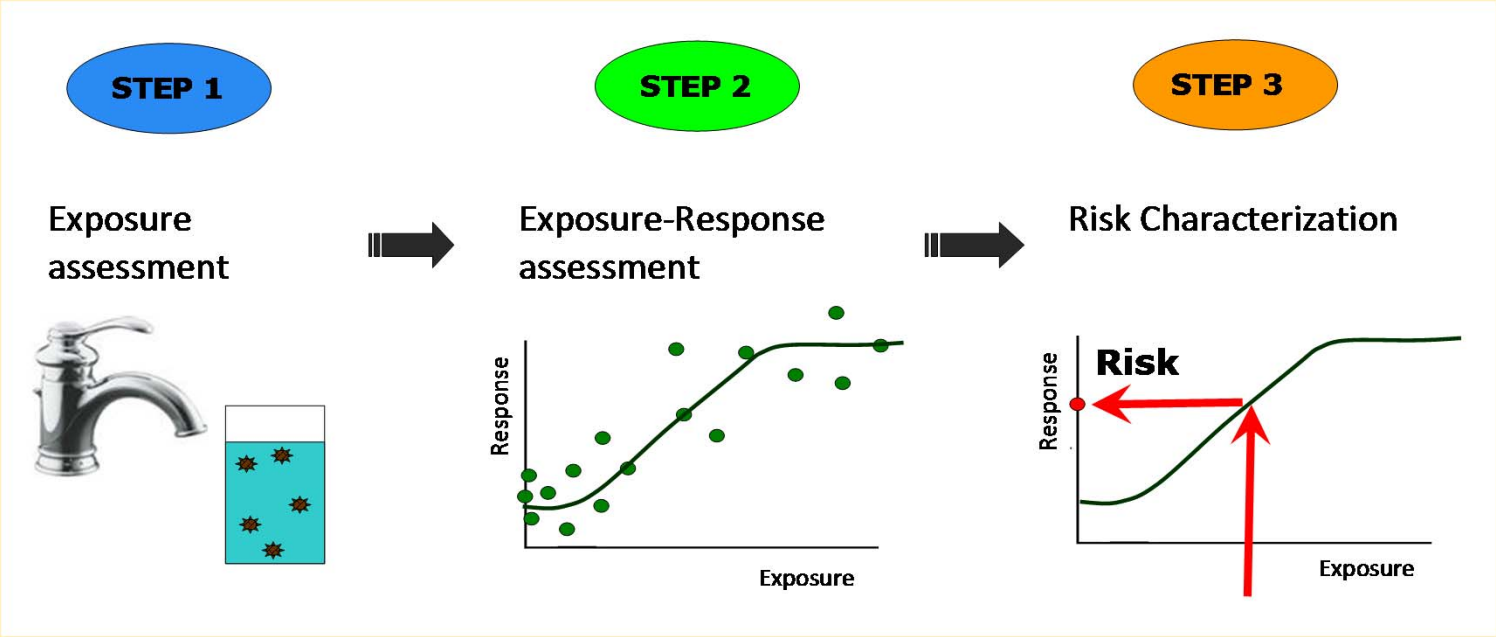


All ages

Unadjusted

Wisconsin WAHTER Study

Quantitative Microbial Risk Assessment Overview

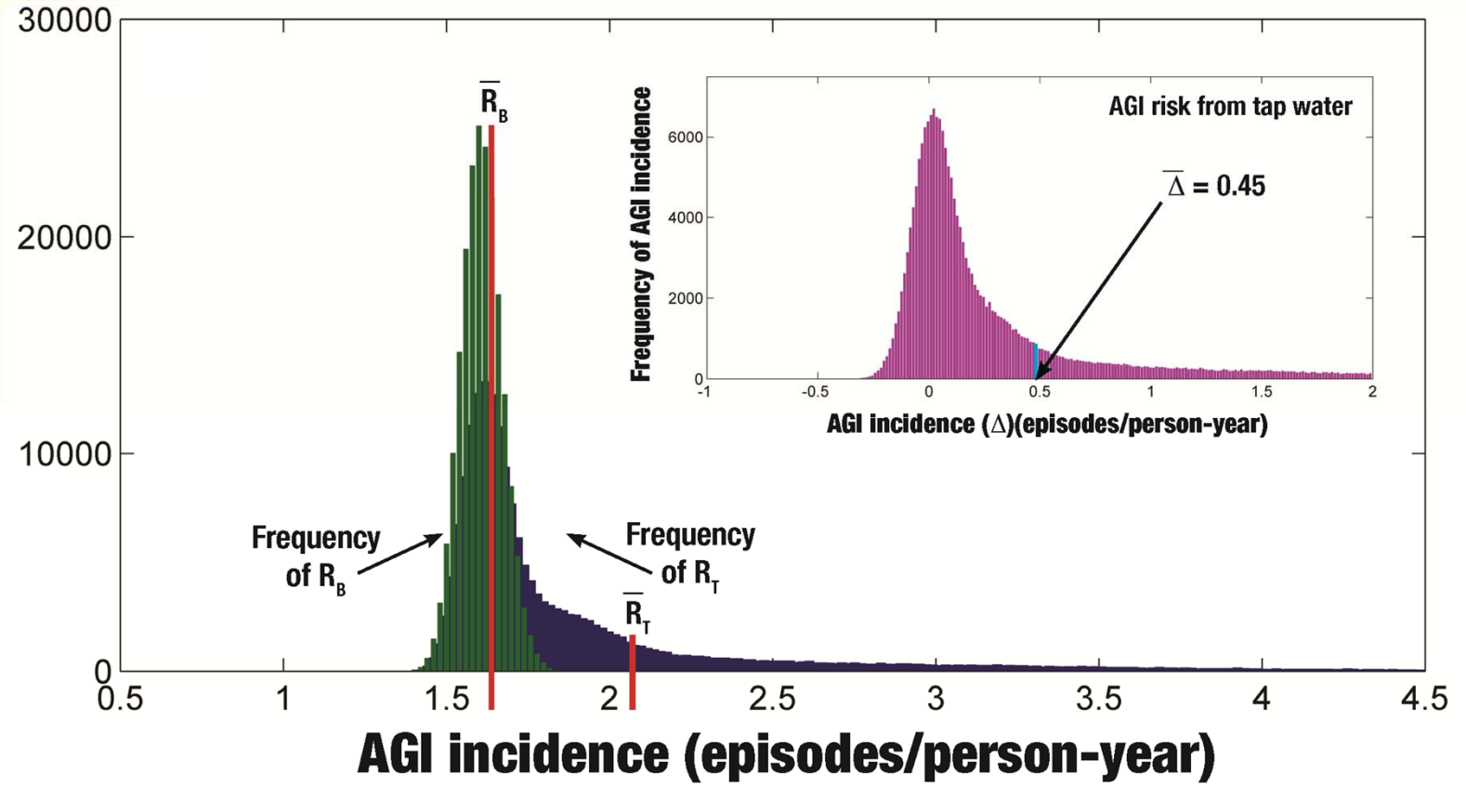


STEP 3

Risk Characterization

Virus Concentrations							
CID=1	CID=2	CID=3	CID=4	CID=5	CID=6	CID=7	CID=8
0	0.003	0	0	0	0	0.07	...
0	0	0	0	0	0	0	...
0	0.001	0	0	0	0	0	...
0	0

Estimating the Fraction of AGI from Drinking Water Using Quantitative Microbial Risk Assessment

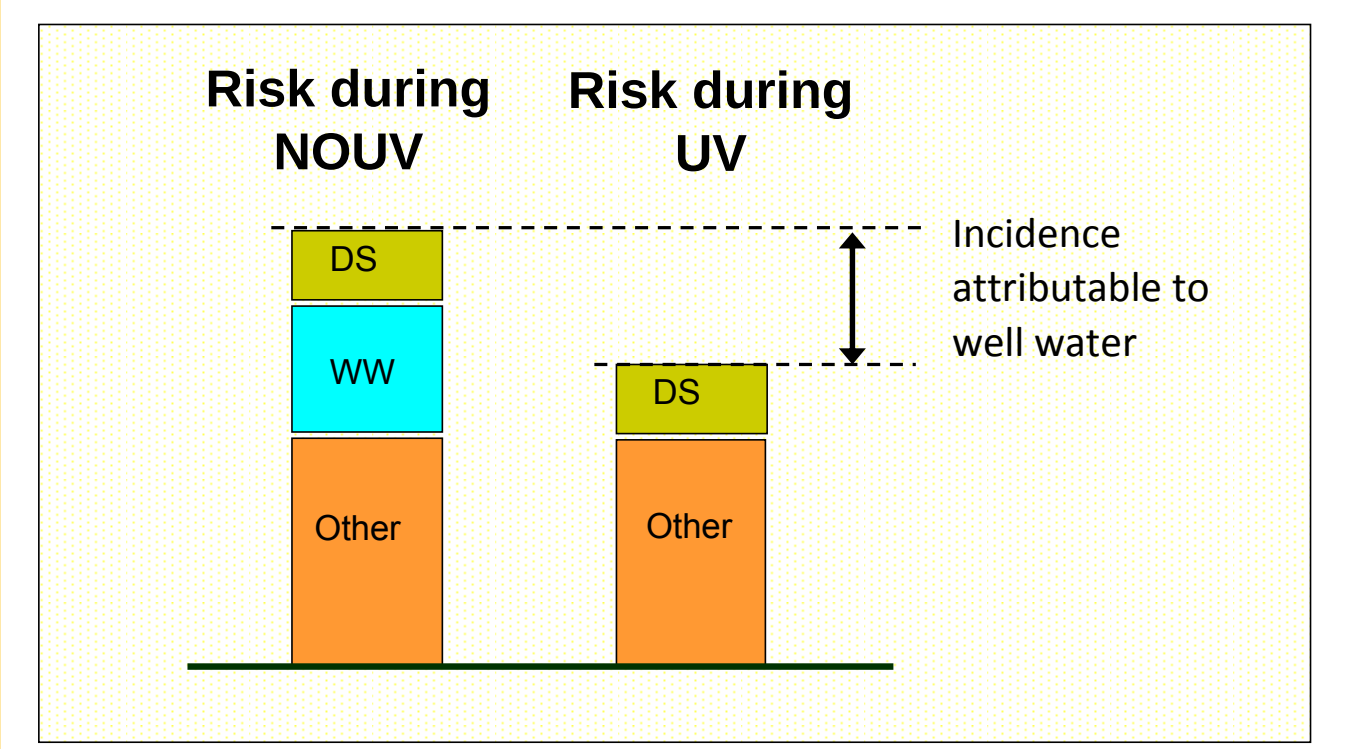


- Virus exposure – AGI model: mean concentration GI norovirus, all study subjects
- 22% of the AGI in the study communities was attributable to their virus-contaminated tap water

Wisconsin WAHTER Study

Objective 2

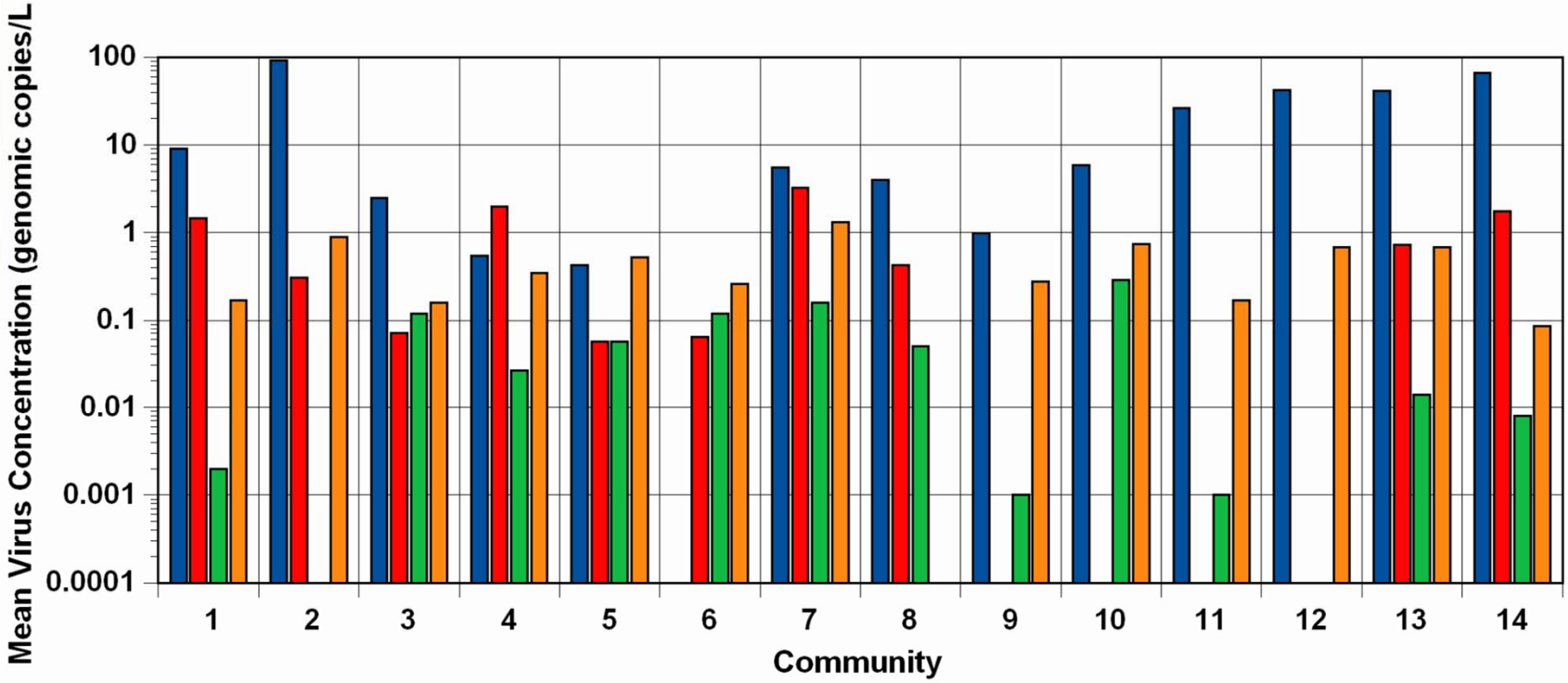
Estimate the risk of acute gastrointestinal illness (AGI) from drinking non-disinfected municipal water from groundwater sources



Wisconsin WAHTER Study

Viruses in the Study Wells

In the 14 study communities, of all 36 wells tested, 34 were virus-positive (139 positive samples out of 392 (36%))



Wisconsin WAHTER Study

Attributable Risk Percent for Groundwater-borne AGI

Adults, Periods 3 and 4

AR% = 13%
95% Confidence Interval: - 5% - 22%

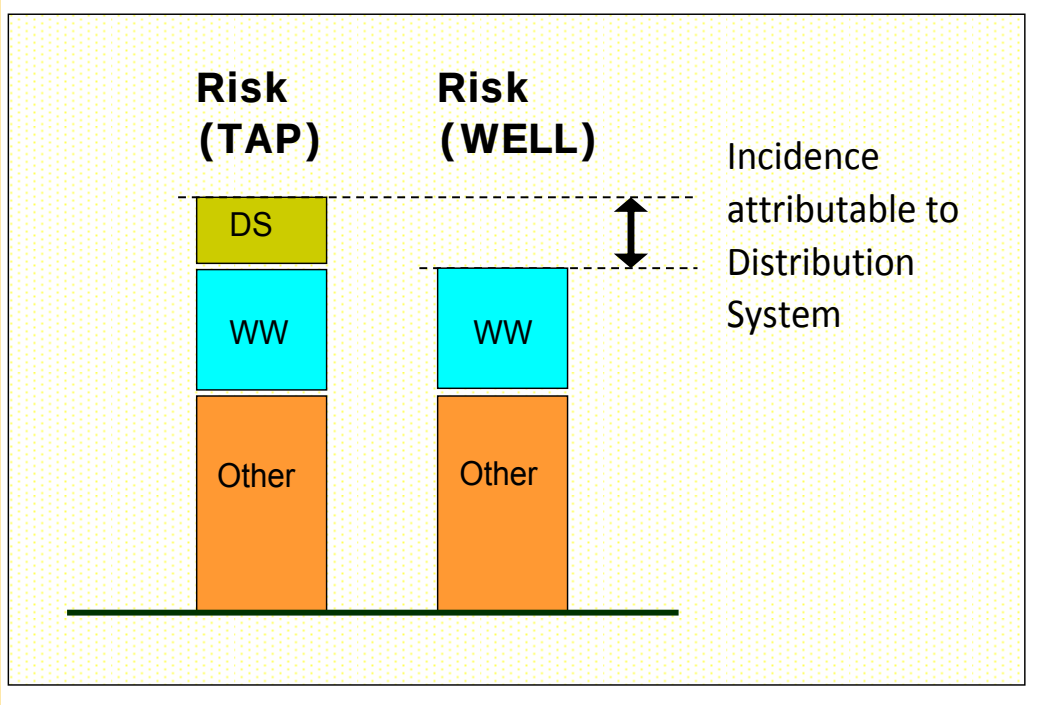
Children <5, Period 1

AR% = 13%
95% Confidence Interval: - 12% - 41%

Wisconsin WAHTER Study

Objective 3

Estimate the AGI risk contributed solely by contaminated distribution systems



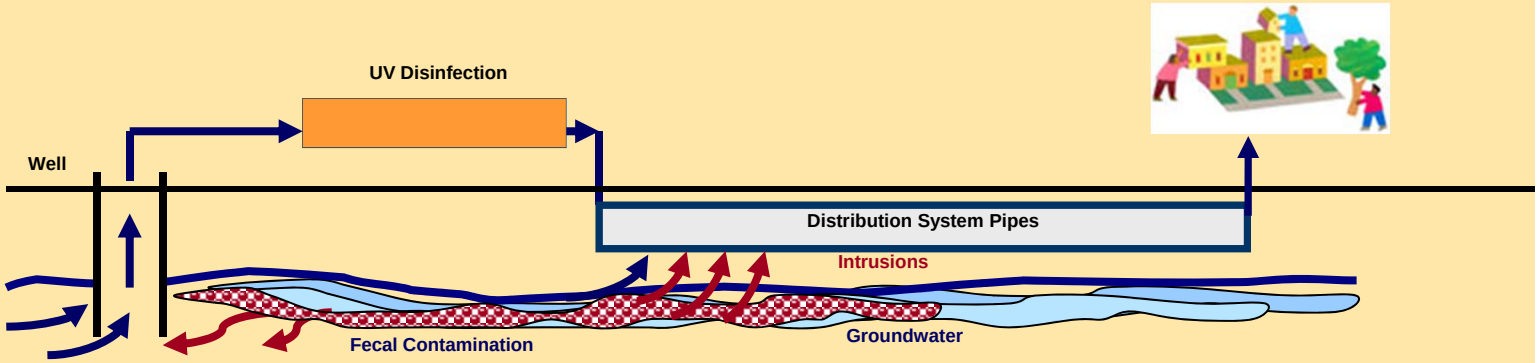
Wisconsin WAHTER Study

AGI Incidence due to Distribution Systems

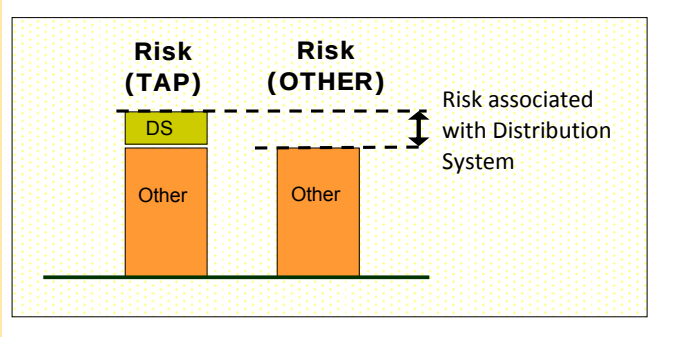
Approach 1:

With UV Disinfection, Viruses Contributed only by Distribution Systems

Community-Wide Intervention with UV Disinfection

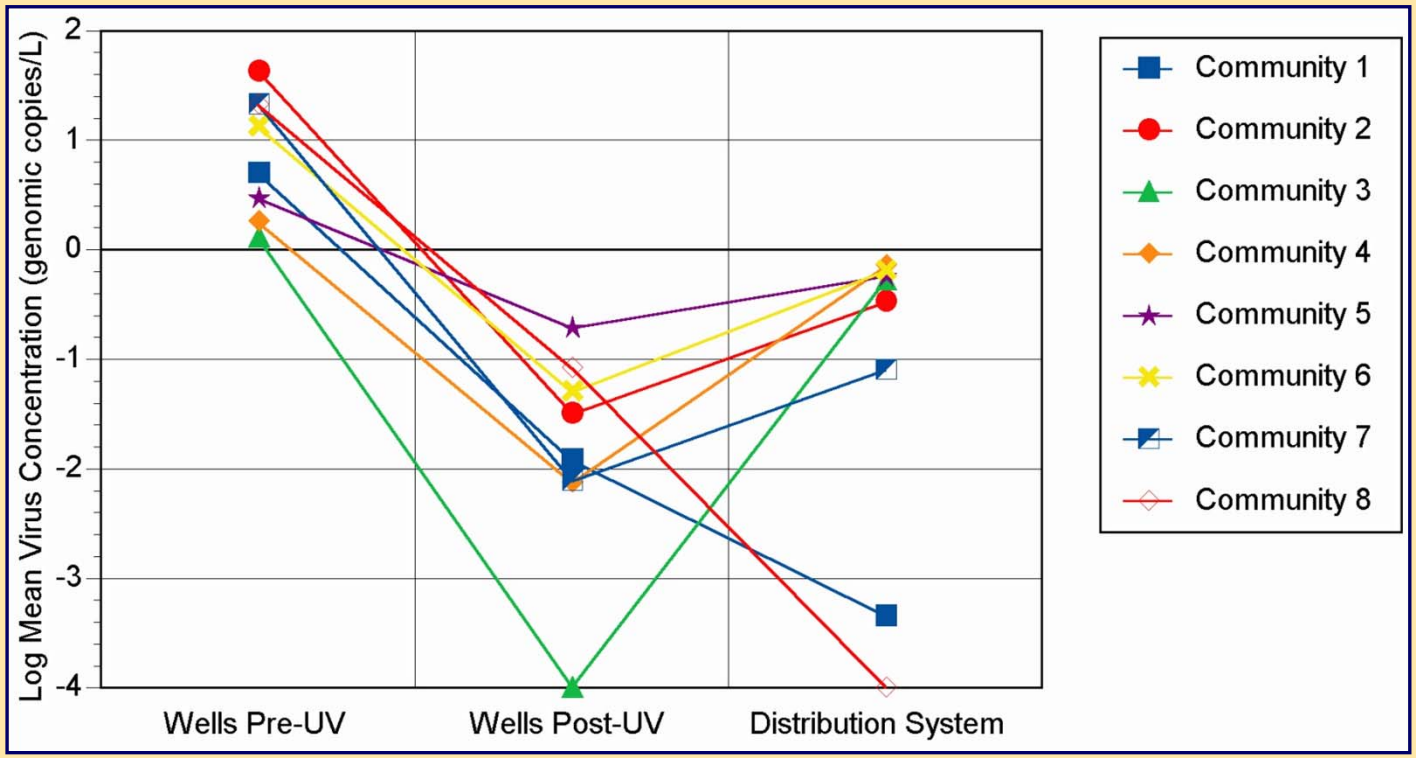


- Without a chlorine residual, to the extent UV disinfection is effective, all viruses detected at household taps must have entered through the distribution system



Wisconsin WAHTER Study

Virus Concentrations from Source to Tap, Year 1 UV Communities



Wisconsin WAHTER Study

Estimating the Fraction of AGI from Distribution Systems Using Quantitative Microbial Risk Assessment

Approach 1 – With UV

Virus Concentration – Illness Relationship	Median Attributable Risk[a] (AGI episodes/person-year	Attributable Risk %[b]
All viruses, All ages	0.031	1.8
All viruses, Adults	0.067	3.9
Enteroviruses, Adults	0.044	2.6
GI Norovirus, All ages	0.024	1.4
GI Norovirus, Adults	0.035	2.1
GI Norovirus, Children	0.018	1.1
GI Norovirus, Child<5	0.043	1.6

a. Number of Monte Carlo runs: n=100,000.
b. Denominator AGI incidence from the simulated "No UV" periods when contributions to illness included distribution system, well water, and other sources (e.g., person to person). Denominator varies by age group.

- AGI incidence higher than zero in all scenarios
- Low attributable risk %

Wisconsin WAHTER Study

Does Groundwater-borne Illness Risk Meet EPA Standards?

- Acceptable EPA risk for waterborne disease is 1 infection in 10,000 people/year
- Assume every infection leads to an illness, then the acceptable illness rate is 0.0001 illness/person-year
- In the fall of 2006 the WAHTER Study measured 0.44 illness/person-year in children < 5 years old that was attributed to groundwater
- 4,400 times higher than EPA acceptable risk

Wisconsin WAHTER Study

Summary

- Virus levels in tap water were significantly associated with community rates of AGI; the higher the virus concentration, the more illnesses in the community
- From quantitative microbial risk assessment, virus-contaminated tap water was responsible for 10% to 20% of the AGI in the study communities.
- From the UV experiment, UV disinfection inactivated viruses in groundwater, reducing AGI by 13% in adults and 13% in children <5 , depending on the study period.
- Distribution system virus contamination was responsible for 1.2% to 3.5% of AGI in the communities, depending on the virus exposure-illness model used in the QMRA.

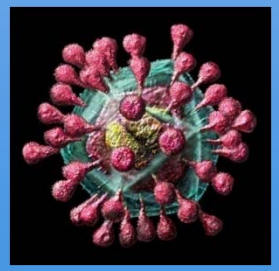
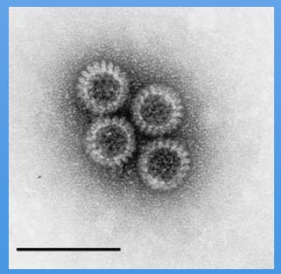
Wisconsin WAHTER Study

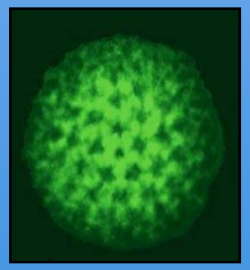
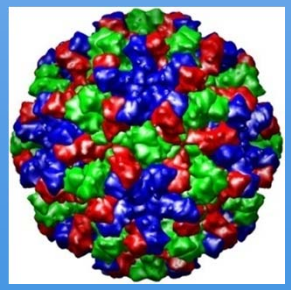
WI Drinking Water Code Science and Politics

- WI Code NR 810 revised to require disinfection of municipal water supplies
- Public hearings completed October, 2009
- DNR Board approved on April 28 2010
- Legislative approval, Final Rule filed with the Legislative Reference Bureau in July 2010
- November 2010 Election brings new party to power in Wisconsin
- WI Governor signs law prohibiting DNR from requiring disinfection of groundwater used for municipal drinking water, May 2011

Questions?

Comments?

Wisconsin WAHTER Study

Acknowledgments

Laboratory

Susan Spencer
Phil Bertz
Matt Volenec

Epidemiology

Ed Belongia, M.D.
Sandy Strey
Vicki Allison
Carol Beyer
Jordon Ott
Marilyn Bruger
Deb Kempf
Cathy Schneider
Amy Kieke

Biostatistics

Burney Kieke, Jr.
Carla Rottscheit
Richard Berg

Risk Assessment

Frank Loge, Ph.D.
Elisabetta Lambertini

EPA

Angela Page
Cynthia Nolt-Helms
Shay Fout, Ph.D.
Phil Berger

Wisconsin WAHTER Study

Enteric Viruses – Clinical Significance

- **Enteroviruses:** fever, “summer cold”, diarrhea, hand, foot, mouth disease, conjunctivitis, meningitis, myocarditis, poliomyelitis, diabetes? chronic fatigue syndrome?
- **Rotavirus:** severe diarrhea and vomiting, 50,000 hospitalizations/year in US
- **Hepatitis A virus:** gastroenteritis, hepatitis, fatality rate of 2.7% in people > 49 years of age
- **Noroviruses:** gastroenteritis, “the flu”
- **Adenoviruses:** diarrhea, acute respiratory illness, pneumonia, conjunctivitis, neurological diseases, obesity?

Wisconsin WAHTER Study

Wisconsin WAHTER Study

Funded by the US EPA STAR Program

Study Period: 2005 – 2009

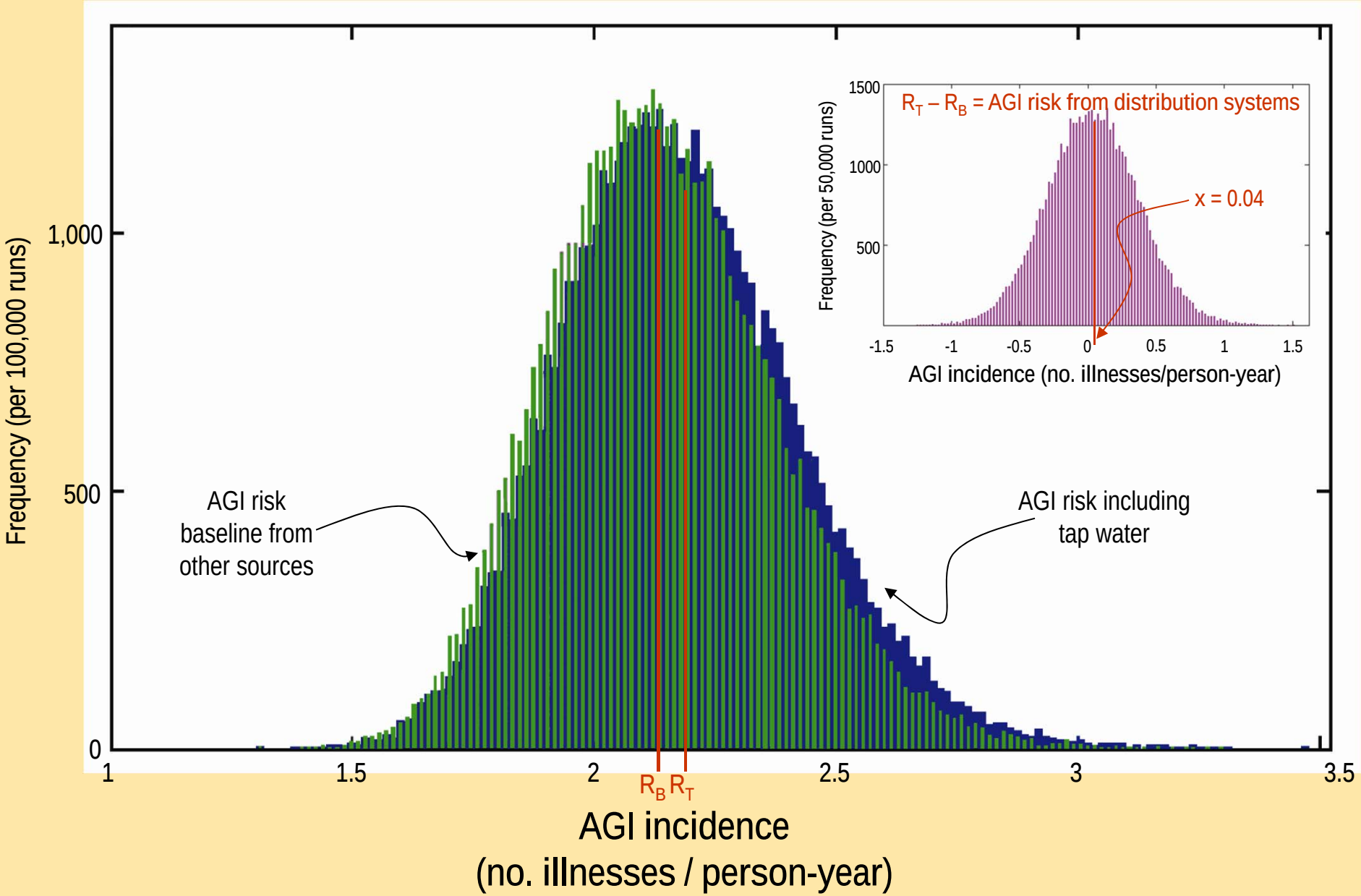
Collaborators include UC-Davis and UW-Madison

Wisconsin WAHTER Study

Study Objectives

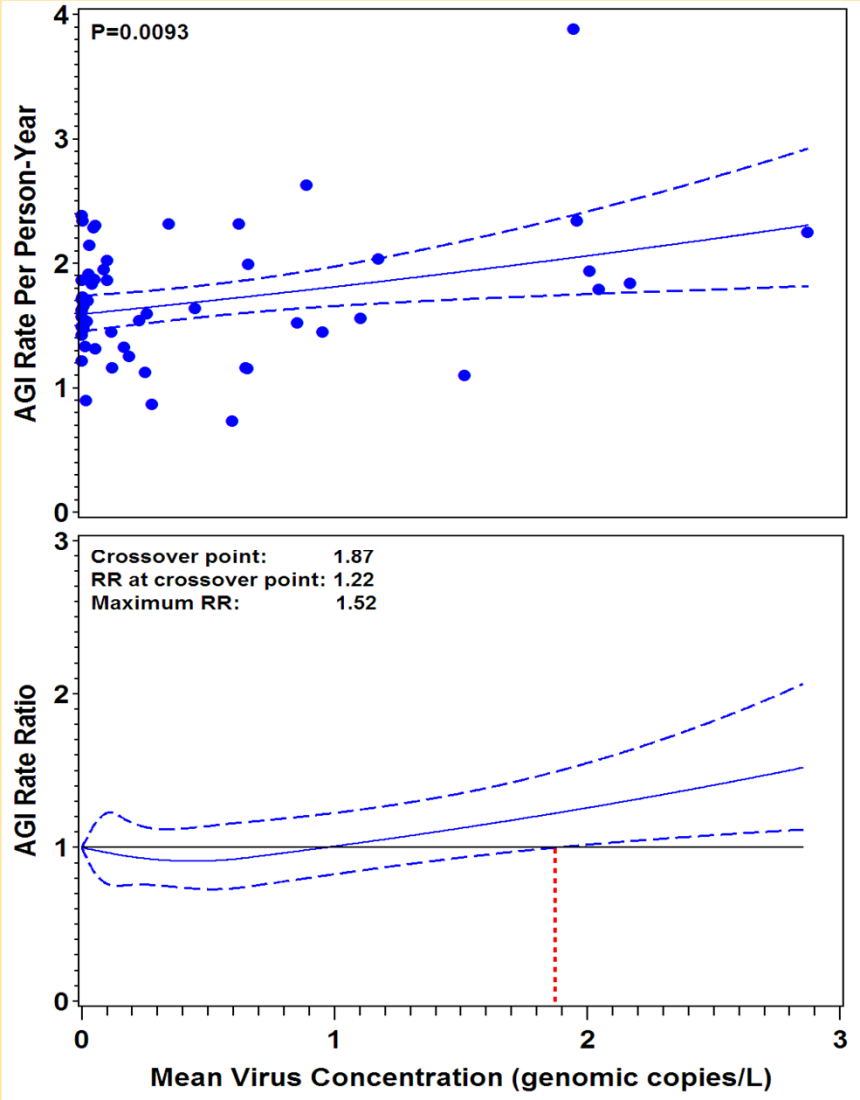
1. Determine the association between tap water virus concentrations and community illness rates
2. Estimate the risk of acute gastrointestinal illness (AGI) from drinking municipal water from groundwater sources
3. Accounting for any risk contributed by groundwater, estimate the AGI risk contributed solely by contaminated distribution systems
4. Determine the association between viruses in distribution systems and utility operation and maintenance procedures

Distribution System Risk – Approach 1 With UV



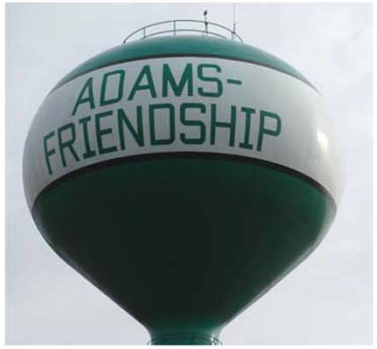
Wisconsin WAHTER Study

Total Virus Concentration in Tap Water and AGI Incidence



All ages

Unadjusted


ADAMS-
FRIENDSHIP

BALDWIN

BARRON BEARS

CAMERON
COMETS

CHETEK
BULLDOGS

CRANDON

UMBERLAND

Thank You

FALL RIVER

LADYSMITH

LAKE HALLIE

PRAIRIE DU SAC

RICE LAKE
UTILITIES

SPRING GREEN

TOMAHAWK

ANNISTON

Association between distribution system events and virus concentration. Analysis by sampling period.

	Mean Virus Concentration	
Event	**p-value**	**Outcome ratio (event occurred / no event)**
Chlorination	0.61	1.59 (0.269 / 0.168)
Well shut-down	0.26	0.42 (0.086 / 0.208)
Main breaks	0.54	1.78 (0.289 / 0.162)
Pipe replaced	0.26	4.21 (0.625 / 0.148)
Pipes added	**0.01**	7.04 (0.615 / 0.087)
Pipe replaced or added	**0.01**	6.86 (0.577 / 0.084)
Main cut open	0.18	4.10 (0.56 / 0.136)
Reservoir maintenance	0.18	3.20 (0.416 / 0.13)
Valve exercising	0.85	0.85 (0.163 / 0.192)
Total Coliform positives	0.20	0.32 (0.073 / 0.230)
Hydrant flushing	0.82	0.86 (0.174 / 0.203)
Hydrant flushing (days)	**0.008**	0.78