Pennsylvania DBP Violations: Facts and Solutions
Is UV a Viable Strategy for Reducing DBPs?

by Phyllis Butler Posy
VP Strategic Services & Regulatory Affairs, Atlantium

Pennsylvania AWWA Annual Conference
April 2017
Virus Credit UV and Disinfection ByProducts

- **Context I: Disinfection By Products are Bad!**
  - Source Water is changing: impact of upstream effluents
  - Science, emerging DBPs (EDBPs) & Public perceptions are changing our world
  - Do Current CTs really give you 4 log virus kill? WRF 3134
  - Can you really predict if compliance today guarantees future compliance?

- **Context II: Do DBPs Matter in Pennsylvania?**

- **The Case for Virus Validated UV for DBP Reduction**
  - New Knowledge about microbial ecology demands new ideas
  - Why Not? / Why Yes?

- **Case Study-Strategy for Violators : Hillsborough, New Hampshire**
  - The long expensive pathway to finding a solution: Virus UV + Chloramines works

- **Case Study-Strategy for Violation Avoidance I: Ilion, New York**
  - Plan Ahead for system changes: Variable Virus UV works

- **Case Study-Strategy for Violation Avoidance II: Big Sky , Montana**
  - Avoiding Disinfection may not be necessary: 4 log Virus UV works

- **Conclusion: Engineering Leadership Can Facilitate the Right Mix of Innovative Solutions for Montana: Reduction+ Avoidance/Prevention**
Context I: Disinfection By Products (DBPs) are BAD!
Certain unregulated disinfection byproducts (DBPs) are more of a health concern than regulated DBPs. Brominated species are typically more cytotoxic and genotoxic than their chlorinated analogs. GAC treatment of drinking or reclaimed waters with appreciable levels of bromide and dissolved organic nitrogen may not control the formation of unregulated DBPs with higher genotoxicity potencies.
2 | Contaminant Candidate List Viruses: Evaluation of Disinfection Efficacy

A significant amount of research on disinfection of enteric viruses has been published over the years, primarily focusing on poliovirus, and to a lesser extent coxsackieviruses and echoviruses. However, the recommended Ct values set forth by USEPA were obtained from bench-scale inactivation experiments conducted with monodispersed hepatitis A virus (HAV) (USEPA 1990). These values may not be adequate for the CCL2 viruses for which much less information on disinfectant susceptibility is known, especially the adenoviruses and caliciviruses. The guidance is also based on disinfection in buffered, demand free water. Investigators have suggested that the ionic content of drinking water may allow for decreased disinfection efficacy, therefore the recommended Ct values may not reflect those needed in a water treatment facility (Haas et al. 1996; Liu et al. 1971; Thurston-Enriquez et al. 2003). Comprehensive research studies are needed to systematically examine disinfection efficacy of chlorine and monochloramine for CCL2 viruses in buffered, demand free water as well as source drinking water. In addition, knowledge of the effect of viral aggregation on disinfection efficacy of chlorine and monochloramine in source drinking water is needed.

1. Basis for values given in Appendix F.
Do You Know if Your Solution is Sustainable?

- There are methods of knowing if your system can comply over time
- How do small systems deal with these complicated methodologies?
- As climate change begins to affect more areas, raising DBP levels, and more smaller utilities will be in a bind
- Use a Bayesian Belief Network to evaluate DBP compliance?

Do Chemicals have to be the focus methodology to ensure public health compliance?
Context II: Do DBPs Matter in Pennsylvania?
Because PA has universal disinfection rules, most systems must monitor and keeping under the limits is getting harder.

**PA DBP Violation Trends (since rule change)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan-June</th>
<th>July-Dec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>3</td>
<td>34</td>
<td>37</td>
</tr>
<tr>
<td>2015</td>
<td>25 (833%)</td>
<td>54 (159%)</td>
<td>79 (213%)</td>
</tr>
<tr>
<td>2016</td>
<td><strong>68 (272)%</strong></td>
<td>????</td>
<td>????</td>
</tr>
</tbody>
</table>

But more scrutiny and pressure not to be in-like-Flint!

- PA temperatures, pH, more seasonal swings
- Managing Chemical Disinfection is getting tougher
- DBP Stress – a system not there yet may be on the way!
Only a 318 PA Water Systems Avoid Disinfection

- .6% of Community Water Systems
- 28% of public water systems
- pop 25-3500
- In a dairy state like Pa with TCR detections up by 600% some of these systems are wise to consider disinfection

When It Hits The Fan…Pathogens from Human and Bovine Sources in the Environment

Mark Borchardt
USDA-Agricultural Research Service
Environmentally Integrated Dairy Management Research Unit
Marshfield, Wisconsin
Minnesota Study: What’s in “Safe Drinking Water”?

- All EPA Compliant Non-disinfecting GW systems
- 567 wells do not disinfect; 243 community; 324 NTNC
- 82 wells in study – 14.7% of the systems
- Test for and find: Human Enteric Viruses, Adenovirus Group A-F; Enterovirus; Norovirus GI & GII; Hepatitis A; Human Polyomavirus; Rotavirus; Salmonella spp.; Campylobacter jejuni; Enterohemorrhagic E. coli; Bovine Bacteroides; M3 Bacteroides-like; Bovine polyomavirus; Pepper mild mottle virus; Total coliforms and E. coli

- 66% wells positive for a target; 20% positive for salmonella; 60% TCR positive but NONE positive for E. coli (no public notice/find and fix)

- Bottom Line: Staying EPA Compliant enough to avoid disinfection is no guarantee that water is fine for all uses.
The Case for Virus Validated UV for DBP Reduction
The Case for Virus Validated UV

- Based in part on the need for a broader toolbox
- Based in part on new evidence of microbial ecology as a driver
  - Microbial balance in the distribution system is the key to microbial water quality
  - Chlorine resistant pathogens can gain upper hand; proliferate, compromise water quality.
  - Chemical Disinfection can push organisms into Viable but not culturable (VBNC) state; temperature change can resuscitate them.

- Why Not?
  - Does it really work? Can it be validated?
  - No residual – how do we know it worked this time?
  - But it is so complicated.....

- Why Yes?
  - Can be validated full scale, especially for small systems
  - Not really complicated: Critical parameters can be known upfront
  - Real time Control/documentation
  - Where a chemical residual is required, UV is effective as part of a multiple barrier scheme
  - Many states have done it...Pennsylvania is leading the pack!
2006: Final LT2 rule designated Adenovirus as the virus target benchmark, requiring doses too high to be validated with surrogates.

Validation required for credited use in municipal drinking water.

Required Piping:
- Standard 10/5 D
- The way it was done at validation or prove that the dose delivery is the same or better.

UVDGM (460 pages) sets out lots of calculations, safety factors, reporting, and maintenance.

Identify & report off-spec operation:
- Flow too high?
- UVT too low?
- All sensors calibrated?

Is it too complicated for “regular people”?

Duty UV Intensity Sensor Calibration

Prior to installation, manufacturers calibrate the UV intensity sensors. However, over time the sensor may drift out of calibration. Because these sensors are vital to assessing the UV disinfection performance, the calibration of each sensor should be checked at least monthly against the reference sensor. To assess the calibration, the following sensor calibration check protocol should be followed:

1. Measure the UV intensity with the duty sensor, and record the measurement result.
2. Replace the duty sensor with the reference sensor in the same location (i.e., port) as the duty sensor used in Step 1.
3. Measure the UV intensity with the reference sensor and record the measurement result.
4. Determine if Equation 5.1 holds true for the two UV intensity sensor readings:

\[
\left( \frac{I_{\text{Duty}}}{I_{\text{Ref}}} - 1 \right) \times 100 \leq \left( \sigma_{\text{Ref}}^2 + \sigma_{\text{Duty}}^2 \right)^{1/2}
\]

where
- \( I_{\text{Ref}} \) = Intensity measured with the reference sensor (mW/cm²)
- \( I_{\text{Duty}} \) = Intensity measured with the on-line sensor (mW/cm²)
- \( \sigma_{\text{Duty}} \) = Measurement uncertainty of the on-line UV intensity sensor (%) as stated by the manufacturer
- \( \sigma_{\text{Ref}} \) = Measurement uncertainty of the UV intensity sensor (%) as stated by the manufacturer

5. Replace the duty sensor with another calibrated duty sensor if the relationship Equation 5.1 does not hold true.

The calibration of the UV intensity sensor is sensitive to the power level of the UV lamps (Swaim et al. 2002). To most effectively compare the duty sensor to the reference sensor, the power level should be set at the level typically used during routine operation (e.g., the majority of operation).
Keeping UV Simple can be Complicated!!

- Make it simple: direct full scale validation with adenovirus
- Could it be done?

2007: Dr. Karl Linden, HDR/Hydroqual and Dr. GwyAm Shin carried out full-scale validation for EPA 4-log virus using live full scale adenovirus challenge, that proved:
  - full 4 log virus performance could be validated & demonstrated full scale
  - UV can perform as well as chlorine for virus disinfection
  - Medium Pressure is much more effective than low pressure, takes much less energy
- One point does not make a line, but 3 do!

2010: Full scale adeno Validation of a second unit
2014: Full scale adeno Validation of a 12.3MGD unit
- Proven modular design means design flexibility
Case Study(SW): UV for DBP Reduction
Hillsborough, NH
Case Study: Long history of DBP Violations

- The Town of Hillsborough NH gets its water supply from the Loon Pond surface water reservoir.
- **Loon Pond has a high organic load, low UV Transmittance (UVT) especially in winter; high chlorine dose to achieve EPA 4-log virus credit**
- **1st customer is very close**
The Challenge

- Original Treatment Train:
  - Slow Sand filtration, no backwash
  - No coagulation – organics removal is biologic - shmutzdeck
  - No pumping – gravity fed
  - Chlorine disinfectant; pH adjustment
  - The water is conveyed through a 2 mile long, 16 inch diameter transmission pipeline to the distribution storage tank, with customers on the way..
  - Many years of DBP violations
  - Consent order: solve by 2015
Conventional Solutions Put to the Test

- 2005: New transmission Line; clean reservoir

PILOT TESTING

1- and 2-stage post-filtration GAC piloting was performed with 55-gal Calgon FLOWSORB 300 drums. Testing was performed at 4 gpm (1.45 gpm/sf, 12-min EBCT). The results are shown to the right and were not as promising as the bench-scale testing. Single-stage GAC TOC removals began at 56% and quickly declined—well below the target of 70% we felt necessary. The addition of a second stage did not significantly improve the results. The winter pilot results under-performed the summer and winter bench-scale results (see graph to right). Further chloramination testing confirmed the.

In summary, pilot testing indicated that GAC post-filtration would not be cost-effective and the decision was made to proceed with UV disinfection followed by chloramination.

Pilot test results were not as promising as the bench scale testing.
View from the Engineer and the User

- Using Virus UV could provide a way out: get 3 log virus credit instantaneous / no DBPs
- Follow with chloramination for secondary, residual disinfection
- Limited operator time for reporting, system operation
- Provide sustainable compliance, even if rules get stricter
- No daily waste
- Maintain gravity system
- Fit in current filter gallery with redundancy
- Loon Pond broad range of water clarity; UVT critical variable
  - Electrical demand could range by a factor of 8: from 26-3 kW/hour
- Build for worst case, be efficient at favorable conditions
The engineering firm, Hoyle, Tanner & Associates Inc., proposed the Atlantium RZ300, validated to 181mJ, 8,500 gpm, 79% UVT

Design Site conditions: 350/700 gpm; 80-92%UVT

Actual site conditions: 80-400 gpm; 79-96 UVT

**Dose required:** 143- 3 log virus credit after validation factors

Energy required: best-to-worse: 8X

Configuration: Two seven lamp units, in two parallel trains

Validated as N+1 to include a standby redundant lamp, redundant controller; each unit can be controlled independently or together to achieve dose requirements, depending on flow, UVT, lamp age

Two sensors per lamp

Full calibration utilities and reporting

All six EPA recommended reports produced automatically by the system
## Solution: Lower Cost than Conventional Wisdom

<table>
<thead>
<tr>
<th></th>
<th>Estimated Capital Cost</th>
<th>Annual Debt Service</th>
<th>Initial Year O&amp;M Cost</th>
<th>Initial Production Cost ($/1000 gal)</th>
<th>20-year Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UV / Chloramination</strong></td>
<td>$841,000</td>
<td>$53,900</td>
<td>$27,500</td>
<td>$1.01</td>
<td>$1,355,000</td>
</tr>
<tr>
<td><strong>GAC – Tanks in WTP</strong></td>
<td>$904,000</td>
<td>$58,000</td>
<td>$167,100</td>
<td>$2.80</td>
<td>$4,902,000</td>
</tr>
</tbody>
</table>
The UV/chloramination system went on-line in May 2014

### TTHM (µg/L)

<table>
<thead>
<tr>
<th></th>
<th>Clearwell Outlet</th>
<th>Reservoir Inlet</th>
<th>Reservoir Outlet</th>
<th>Distribution Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg – 13 recent samples</td>
<td>53.0</td>
<td>83.5</td>
<td>111.6</td>
<td>127.9</td>
</tr>
<tr>
<td>July 9, 2014</td>
<td>8.3</td>
<td>8.4</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Oct 8.2014</td>
<td>5.2</td>
<td>5.1</td>
<td>5.6</td>
<td>5.6</td>
</tr>
</tbody>
</table>

### HAA5 (µg/L)

<table>
<thead>
<tr>
<th></th>
<th>Clearwell Outlet</th>
<th>Reservoir Inlet</th>
<th>Reservoir Outlet</th>
<th>Distribution Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg – 13 recent samples</td>
<td>50.3</td>
<td>75.0</td>
<td>97.3</td>
<td>84.7</td>
</tr>
<tr>
<td>July 9, 2014</td>
<td>13.3</td>
<td>14.3</td>
<td>16.9</td>
<td>14.9</td>
</tr>
<tr>
<td>Oct 8, 2014</td>
<td>11.5</td>
<td>14</td>
<td>16.7</td>
<td>12.8</td>
</tr>
</tbody>
</table>
Case Study: Blended System on the Edge Violation Avoidance II: Ilion, NY
122-year-old Water Plant, Ilion NY

- Village of Ilion Filter Plant, NY, is one of the oldest plants in the country
- Serves over 9,000 people
- Processes surface water drawn from creeks and reservoirs
- Uses slow sand gravity filtration
- Uses chlorination before and after filtration
- Rated at 1.5 MGD
- Serves historic Remington Arms Plant
- Blends with ground water wells as needed

### Disinfection By Products

<table>
<thead>
<tr>
<th>Site</th>
<th>TTHM low</th>
<th>TTHM high</th>
<th>TTHM LRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>33</td>
<td>91</td>
<td>60</td>
</tr>
<tr>
<td>Site 2</td>
<td>107</td>
<td>116</td>
<td>114</td>
</tr>
<tr>
<td>Site 3</td>
<td>34</td>
<td>99</td>
<td>69</td>
</tr>
<tr>
<td>Site 4</td>
<td>22</td>
<td>99</td>
<td>58</td>
</tr>
<tr>
<td>Site 5</td>
<td>56</td>
<td>88</td>
<td>72</td>
</tr>
</tbody>
</table>

Established 1893
Thinking UV for Crypto but Hard Site Constraints

- Needed Crypto/Giardia...DBPS rising
- Very small footprint plant
2. The installation of the UV reactor and associated piping does not appear to meet the requirements of the UV Policy Statement, 2012 RSWW, Section C.2 and the Ultraviolet Disinfection Guidance Manual (UVDGM) Section 3.6.2. The proposed upstream straight pipe length shown is 36" for UV Layout “A” (sheet 4A), and 24" for UV Layout “B” (sheet 4B), both of which are less than the required length of 5 times the pipe diameter (50’). Additionally, the UV inlet piping shown in UV Layout “B” contains an expansion within 10-ft upstream of the reactor, which is not in accordance with UVDGM 3.6.2. Can the layout be revised to provide additional upstream pipe length? If not, please explain how the current proposed design will provide adequate stability of flow entering the UV reactor and deliver a UV dose that is equal to or greater than the validated dose.
Simulations Give Proof of Performance

- Compared 3-lamp unit with only two lamps operating
- Same dose delivery performance as determined by validation for an equivalent 2 lamp unit with pipe lengths
- The additional lamp and disinfection module act as a hydraulic baffle & duplicate the impact of the upstream straight pipe
- The flexibility of having 3 lamps provides safety factor and can be used as redundancy.

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Power (%)</th>
<th>UVT (%/cm)</th>
<th>Flow (gpm)</th>
<th>Flow (m³/h)</th>
<th>Validation RED (mL/cm²)</th>
<th>RED per Simulation (mL/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS2</td>
<td>40</td>
<td>92.1</td>
<td>602</td>
<td>139</td>
<td>55.1</td>
<td>54.8</td>
</tr>
<tr>
<td>MS2</td>
<td>100</td>
<td>92.1</td>
<td>639</td>
<td>147</td>
<td>160.4</td>
<td>179.6</td>
</tr>
<tr>
<td>MS2</td>
<td>40</td>
<td>97.0</td>
<td>682</td>
<td>157</td>
<td>121.2</td>
<td>120.5</td>
</tr>
<tr>
<td>QB</td>
<td>40</td>
<td>92.3</td>
<td>1221</td>
<td>281</td>
<td>24.2</td>
<td>25.9</td>
</tr>
<tr>
<td>MS2</td>
<td>100</td>
<td>92.1</td>
<td>1221</td>
<td>281</td>
<td>85.0</td>
<td>85.4</td>
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<tr>
<td>MS2</td>
<td>40</td>
<td>97.3</td>
<td>1251</td>
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<td>85.0</td>
<td>78.9</td>
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<tr>
<td>MS2</td>
<td>40</td>
<td>96.3</td>
<td>1271</td>
<td>292</td>
<td>80.6</td>
<td>79.2</td>
</tr>
<tr>
<td>MS2</td>
<td>65</td>
<td>97.0</td>
<td>1277</td>
<td>294</td>
<td>123.3</td>
<td>125.0</td>
</tr>
</tbody>
</table>

**Measured RED in Validation versus Simulation Predicted RED on Selected Validation Test Conditions**
The Third Lamp Actually Improves Hydraulics

- The extra lamp acts as a baffle to compensate for potential hydraulic impairments.
- Validation and simulation data verified that Ilion would be able to get the required dose and log disinfection performance.

100-13 unit (with only two set/out piping configurations determined by the validation stream lamp (Lamp1) in the loss of dose delivery with the Lamp1 provides additional

Validation Report to size the slightly conservative than the demonstrated by the simulation

Chu
Project Manager
Manager, the HDR Technology Validation Center

The validator and the engineering company give the green light to 3 lamp unit configuration proposed by the vendor
Challenge: Simplifying Operating & Reporting

- Climbing down all the ladders is a challenge!
- Control abilities next to the unit and at Ground Level
- No need to go there to check up on current data status
- Controller synchronized with laptop via single Ethernet cable/ plug & play!
- External on-off synchronizes the unit with upstream processes
- Password-protected remote control module provides real-time access and control from PC and mobile phone
Not simple!

- Diver has to isolate the piping in the clearwell to install new isolation valves
- Bypass to avoid service interruption
- Custom fabrication to match old pipes
- Cantilevered rigging to remove the old pipes, put in the new unit
- Deadlines for funding expiration
- Work started in May 2015 – DOH approval and unit in service August
2015 After 4 months of operation

<table>
<thead>
<tr>
<th>Year: 2014</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
<th>Site 4</th>
<th>Site 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTHM low</td>
<td>33</td>
<td>107</td>
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</tr>
<tr>
<td>TTHM high</td>
<td>91</td>
<td>116</td>
<td>99</td>
<td>99</td>
<td>88</td>
</tr>
<tr>
<td>TTHM LRA</td>
<td>60</td>
<td>114</td>
<td>69</td>
<td>58</td>
<td>72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year: 2015</th>
<th>Site 1</th>
<th>Site 2</th>
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<th>Site 4</th>
<th>Site 5</th>
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<tbody>
<tr>
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<tr>
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<td>83</td>
<td>90</td>
<td>60</td>
<td>41</td>
<td>62</td>
</tr>
<tr>
<td>TTHM LRA</td>
<td>52</td>
<td>57</td>
<td>47</td>
<td>21</td>
<td>42</td>
</tr>
</tbody>
</table>

2016 results: .05-72.7 Total LRA: 64.4 and falling!
Case Study (GW): DBP Avoidance for Big Sky Montana
- Big Sky, Montana covers a large area of pristine nature and sky slopes
- Water supply comes from groundwater wells
- Expanding wells meant they needed 4 log virus disinfection
The Challenge

- The tastiest tap water in the US award: 2015

They didn’t want to spoil the quality and taste by using chemicals
The Solution

- Target Disinfection: 4-log virus inactivation of groundwater well supply from 5 wells feeding into a common manifold.
- One system for the full Flow at the lowest UVT; backup for lead/lag operation
- Validated to EPA and state regulations
Conclusion: Engineering Leadership Can Facilitate the Right Mix of Innovative Solutions for Pennsylvania: Reduction+ Prevention
Engineering Leadership

1. Look at it more than 1 way: Overlay at least 2 options and your needs

2. Make Friends: Partner with the regulators early, but give them a pathway!

3. Real people= Real results: Involve operators throughout the process

4. Big Tent: Include a vendor you never worked with

5. Try: They can only say yes if you ask!

- Nobody wants to waste resources on solutions that won’t work over time, but a forgone conclusion can rob you of choices

- Virus Validated UV provides an immediate, cost effective solution
Questions?

**Phyllis Butler Posy**
Vice President
Strategic Services & Regulatory Affairs
Atlantium Technologies
C: 972 54 665 1071
Skype: Phyllis.posy

Atlantium Technologies Ltd.
Har Tuv Industrial Park  POB 11071, Israel 99100
Tel: +972-2-992 5001
phyllisp@atlantium.com  www.atlantium.com
The Company

Product in market since 2004

More than 2,500 units in the field

Major shareholders:

- BK Holding
- aster capital
- Solvay
- Schneider Electric
- ALSTOM

Technology

Disruptive fiber-optic UV system

Achieves disinfection levels equal+ to chemicals, recycling photons for lower energy inspires new applications

Automatically adjusts to conditions in real-time; verifies performance

The only system validated full-scale with real adenovirus; credits for US EPA compliance incl. full 4-log virus

Market Segments & Customers

100+ Fortune 500 customers

- Municipal
- Power & Energy
- Food & Beverage
- Bio-Pharma
- Aquaculture

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Hydrozoa, Zebra & Quagga Mussel Control

- Proven macrofouling control in cooling water
- While screens catch large organisms, the veligers settle, grow and block pipes, compromise cooling efficiency
- US Bureau of Reclamation 3 year pilot concludes: Atlantium Hydro-Optic UV the most sustainable solution

Intake pipes with & without Atlantium