Using UV-254 as a Surrogate to SCOD and SOC Laboratory Methods to Improve Plant Process Performance.

Authors - Matthew Brooks, Robert Angelotti, Anne Payne Bullock
Upper Occoquan Service Authority, Centreville VA.

21st Annual VA AWWA/VWEA
Good Laboratory Practices Conference
July 2015
Presentation Overview

- Background about UOSA’s Potable Reuse Scenario
- UOSA Product Water Quality
- Oxygen Demand & Organic Carbon Data Needs
- Comprehensive & Fully Engaged Laboratory
- Expensive On-line Monitoring Option
- Reasonable Process Control/Operation with Operator Field Techniques
- Study Goals
- Results of the Study
- Example Process Applications
- Future Directions
- Questions
Extent & Significance of Potable Reuse Strategy

- Population Served: 1.8 Million
- Average & Max Water Demand: 148 mgd & 240 mgd
- Two major raw sources: Occoquan Res. & Potomac River
- On average 38% of Demand from Occoquan Res.
- Annual Average UOSA inflow to Occoquan Res. is 10%
- Extreme drought condition - UOSA inflow is 90 – 95% of the reservoir inflow & 50% of withdrawal at Occoquan Plant could originate from UOSA
- UOSA contribution to raw supply is in range of 2 – 20% depending on weather conditions & water source distribution
UOSA Millard H Robbins, Jr
Water Resource Recovery Facility

42 mgd AADF
54 mgd MMDF
75 mgd PWDF
128 mgd PDF
185 mgd PIF
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>0.3 - 0.6 mg/L</td>
</tr>
<tr>
<td>TCOD</td>
<td>6 - 9 mg/L</td>
</tr>
<tr>
<td>pH</td>
<td>7.1 - 7.7</td>
</tr>
<tr>
<td>TP</td>
<td>40 - 90 ug/L</td>
</tr>
<tr>
<td>MBAS</td>
<td>10 - 50 ug/L</td>
</tr>
<tr>
<td>TKN</td>
<td>0.3 - 0.5 mg/L</td>
</tr>
<tr>
<td>Total N</td>
<td>6 – 15 mg/L</td>
</tr>
<tr>
<td>D.O.</td>
<td>Saturation @ temperature</td>
</tr>
<tr>
<td>Turbidity</td>
<td>0.1 - 0.3 NTU</td>
</tr>
<tr>
<td>Total &amp; E. Coli</td>
<td>non-detect</td>
</tr>
<tr>
<td>Contact TRC</td>
<td>0.4 - 2.6 mg/L</td>
</tr>
<tr>
<td>Effluent TRC</td>
<td>non-detect</td>
</tr>
</tbody>
</table>
Oxygen Demand/Organic Carbon Data Needs

- Need to manage 32 pressure and 16 gravity GAC contactors – 48 total
  - when to put contactors into/out of service
  - which are exhausted to go into queue for regeneration
  - predict performance for blended effluent quality
Oxygen Demand/Organic Carbon Data Needs

- Need to understand diurnal pattern of organic carbon concentration:
  - carbon substrate conc. for denitrification
  - organic substrate concentration to calibrate dynamic process operations model
  - organic substrate concentration of sidestream return flows to bioreactors
Three Options

- Could gather data thru:
  - Plant profile sampling & central lab analyses
  - Continuous on-line SCADA analyzers
  - Operator sampling & field lab analyses
Fully Engaged & Comprehensive Laboratory Monitoring Program

- 6- 900 square foot laboratories
- 14 full time staff members
- 7 days/week, 365 days/year
- FY15
  - 159,435 total analyses (samples + QC)
  - 4,163 solid samples received/collection
  - 11,289 water samples received/collection
UOSA’s Laboratory Monitoring Program

Distribution of Analyses By Type

- Nutrients: 55%
- Solids: 13%
- Other: 13%
- BOD/COD/TOC: 9%
- Metals: 6%
- Micro: 4%

UOSA’s Laboratory Monitoring Program

Distribution of Analyses By Program

- Process Control: 98%
- VPDES: 0.9%
- Water Reuse: 0.6%
- Pretreatment: 0.3%
- Biosolids & Landfill: 0.4%

UOSA’s On-line/Field Monitoring Program

• Extensive On-line instrumentation throughout the plant:
  examples: NH$_3$, NO$_3$, Orthophosphate, TSS, D.O., pH, ORP, CL$_2$, Conductivity, Temperature, Turbidity, etc.

• Field laboratory analysis –
  examples: NH$_3$, NO$_3$, D.O., % solids, pH, Alkalinity, Temperature, Turbidity, UV254, CL$_2$, etc.
Online Continuous Analyzer Solutions?

- May need 48 analyzers for GAC
- Additional analyzers for bioreactors
- Even more for sidestream returns
- Too expensive & impractical:
  - High capital cost
  - Difficult sample matrices
  - High maintenance requirements
Comparison of Central Lab vs. Field Analysis

- **Laboratory:**
  - next day turnaround for reported results thru QA
  - significant additional workload
  - rigorous SOP adherence
  - more complex instrumentation (i.e. TOC)
  - more complex sample prep/reagents (i.e. COD)

- **Field:**
  - 0-15 minutes turnaround for reported results
  - Inexpensive method & bench instrument
  - Low disruption/impact on staffing and workload
Study Goals

To provide plant operators and process engineers with:

- quick, reliable, process feedback
- improve overall plant process performance
- eliminate increased labor & analytical costs for central laboratory.
<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Sample Type</th>
<th>Sample Date</th>
<th>Filtered COD (mg/L)</th>
<th>DR5000 Filtered UV254 (cm⁻¹)</th>
<th>DR4000 Filtered UV254 (cm⁻¹)</th>
<th>Filtered TOC (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter Blank</td>
<td>Grab</td>
<td>6/17/14</td>
<td>1.03</td>
<td>-0.001</td>
<td>0.003</td>
<td>0.4</td>
</tr>
<tr>
<td>Prim Eff</td>
<td>24-hr Composite</td>
<td>6/16/14</td>
<td>126.4</td>
<td>0.480</td>
<td>0.468</td>
<td>34.8</td>
</tr>
<tr>
<td>Prim Eff/Sec Eff (50:50)</td>
<td>24-hr Composite</td>
<td>6/16/14</td>
<td>70.0</td>
<td>0.315</td>
<td>0.309</td>
<td>21.0</td>
</tr>
<tr>
<td>Sec Eff</td>
<td>24-hr Composite</td>
<td>6/16/14</td>
<td>19.1</td>
<td>0.139</td>
<td>0.143</td>
<td>5.8</td>
</tr>
<tr>
<td>Filt Inf</td>
<td>24-hr Composite</td>
<td>6/16/14</td>
<td>13.9</td>
<td>0.093</td>
<td>0.097</td>
<td>5.1</td>
</tr>
<tr>
<td>L2 CC Eff 02</td>
<td>Grab</td>
<td>6/17/14</td>
<td>11.7</td>
<td>0.069</td>
<td>0.075</td>
<td>4.8</td>
</tr>
<tr>
<td>L2 CC Eff 03</td>
<td>Grab</td>
<td>6/17/14</td>
<td>8.58</td>
<td>0.058</td>
<td>0.062</td>
<td>3.5</td>
</tr>
<tr>
<td>L2 CC Eff 03 Dup</td>
<td>Grab</td>
<td>6/17/14</td>
<td>8.36</td>
<td>0.057</td>
<td>0.062</td>
<td>3.4</td>
</tr>
<tr>
<td>L2 CC Eff 04</td>
<td>Grab</td>
<td>6/17/14</td>
<td>10.6</td>
<td>0.070</td>
<td>0.074</td>
<td>3.9</td>
</tr>
<tr>
<td>L2 CC Eff 07</td>
<td>Grab</td>
<td>6/17/14</td>
<td>10.9</td>
<td>0.069</td>
<td>0.074</td>
<td>3.8</td>
</tr>
<tr>
<td>L2 CC Eff 08</td>
<td>Grab</td>
<td>6/17/14</td>
<td>9.52</td>
<td>0.063</td>
<td>0.070</td>
<td>3.5</td>
</tr>
<tr>
<td>Prim Eff</td>
<td>24-hr Composite</td>
<td>7/16/14</td>
<td>127.2</td>
<td>0.460</td>
<td>---</td>
<td>31.7</td>
</tr>
<tr>
<td>Prim Eff/Sec Eff (75:25)</td>
<td>24-hr Composite</td>
<td>7/16/14</td>
<td>100</td>
<td>0.373</td>
<td>---</td>
<td>26.3</td>
</tr>
<tr>
<td>Prim Eff/Sec Eff (50:50)</td>
<td>24-hr Composite</td>
<td>7/16/14</td>
<td>67.4</td>
<td>0.285</td>
<td>---</td>
<td>16.1</td>
</tr>
<tr>
<td>Prim Eff/Sec Eff (25:75)</td>
<td>24-hr Composite</td>
<td>7/16/14</td>
<td>45.2</td>
<td>0.212</td>
<td>---</td>
<td>13.6</td>
</tr>
<tr>
<td>Sec Eff</td>
<td>24-hr Composite</td>
<td>7/16/14</td>
<td>17.0</td>
<td>0.127</td>
<td>---</td>
<td>5.6</td>
</tr>
<tr>
<td>Filt Eff</td>
<td>24-hr Composite</td>
<td>7/16/14</td>
<td>11.6</td>
<td>0.085</td>
<td>---</td>
<td>4.6</td>
</tr>
<tr>
<td>L2 CC Eff 08 (50:50)</td>
<td>Grab</td>
<td>7/16/14</td>
<td>4.76</td>
<td>0.029</td>
<td>---</td>
<td>1.8</td>
</tr>
<tr>
<td>L2 CC Eff 08 (25:75)</td>
<td>Grab</td>
<td>7/16/14</td>
<td>1.76</td>
<td>0.014</td>
<td>---</td>
<td>1.2</td>
</tr>
<tr>
<td>L2 CC Eff 08</td>
<td>Grab</td>
<td>7/16/14</td>
<td>9.24</td>
<td>0.065</td>
<td>---</td>
<td>3.5</td>
</tr>
<tr>
<td>L2 CC Eff 08 Dup</td>
<td>Grab</td>
<td>7/16/14</td>
<td>9.39</td>
<td>0.061</td>
<td>---</td>
<td>3.8</td>
</tr>
<tr>
<td>L2 CC Eff 03</td>
<td>Grab</td>
<td>7/16/14</td>
<td>9.69</td>
<td>0.057</td>
<td>---</td>
<td>3.4</td>
</tr>
<tr>
<td>L2 CC Eff 04</td>
<td>Grab</td>
<td>7/16/14</td>
<td>10.1</td>
<td>0.067</td>
<td>---</td>
<td>4.0</td>
</tr>
<tr>
<td>L2 CC Eff 07</td>
<td>Grab</td>
<td>7/16/14</td>
<td>9.96</td>
<td>0.067</td>
<td>---</td>
<td>3.9</td>
</tr>
<tr>
<td>Filter Blank</td>
<td>Grab</td>
<td>7/16/14</td>
<td>0.607</td>
<td>-0.004</td>
<td>---</td>
<td>0.7</td>
</tr>
</tbody>
</table>
Filtered COD vs DR5000 Filtered UV254

\[ y = 0.0035x + 0.0348 \]

\[ R^2 = 0.9846 \]
UV High Level Data

Filtered COD vs Filtered TOC

\[ y = 0.2526x + 1.262 \]

\[ R^2 = 0.9921 \]
UV High Level Data

Filtered COD vs DR4000 Filtered UV254

$R^2 = 0.9863$
UV High Level Data

DR5000 Filtered UV254 vs Filtered TOC

\[ y = 70.73x - 1.1078 \]

\[ R^2 = 0.9849 \]
UV Data Older vs Newer Instrument Check

\[ y = 0.958x + 0.008 \]
\[ R^2 = 0.9999 \]
High Level UV Data Older Instrument

![Graph of DR4000 Filtered UV254 vs Filtered TOC]

The graph shows a strong linear relationship between DR4000 Filtered UV254 and Filtered TOC, with an $R^2$ value of 0.9864.
# Raw Study Data
## Low Range

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Sample Type</th>
<th>Sample Date</th>
<th>Filtered COD (mg/L)</th>
<th>DR5000 Filtered UV254 (cm⁻¹)</th>
<th>Filtered TOC (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sec Eff</td>
<td>24-hr Composite</td>
<td>6/16/14</td>
<td>19.1</td>
<td>0.139</td>
<td>5.8</td>
</tr>
<tr>
<td>Filt Inf</td>
<td>24-hr Composite</td>
<td>6/16/14</td>
<td>13.9</td>
<td>0.093</td>
<td>5.1</td>
</tr>
<tr>
<td>L2 CC Eff 02</td>
<td>Grab</td>
<td>6/17/14</td>
<td>11.7</td>
<td>0.069</td>
<td>4.8</td>
</tr>
<tr>
<td>L2 CC Eff 03</td>
<td>Grab</td>
<td>6/17/14</td>
<td>8.58</td>
<td>0.058</td>
<td>3.5</td>
</tr>
<tr>
<td>L2 CC Eff 03 Dup</td>
<td>Grab</td>
<td>6/17/14</td>
<td>8.36</td>
<td>0.057</td>
<td>3.4</td>
</tr>
<tr>
<td>L2 CC Eff 04</td>
<td>Grab</td>
<td>6/17/14</td>
<td>10.6</td>
<td>0.070</td>
<td>3.9</td>
</tr>
<tr>
<td>L2 CC Eff 07</td>
<td>Grab</td>
<td>6/17/14</td>
<td>10.9</td>
<td>0.069</td>
<td>3.8</td>
</tr>
<tr>
<td>L2 CC Eff 08</td>
<td>Grab</td>
<td>6/17/14</td>
<td>9.52</td>
<td>0.063</td>
<td>3.5</td>
</tr>
<tr>
<td>Sec Eff</td>
<td>24-hr Composite</td>
<td>7/16/14</td>
<td>17.0</td>
<td>0.127</td>
<td>5.6</td>
</tr>
<tr>
<td>Filt Eff</td>
<td>24-hr Composite</td>
<td>7/16/14</td>
<td>11.6</td>
<td>0.085</td>
<td>4.6</td>
</tr>
<tr>
<td>L2 CC Eff 08 (50:50)</td>
<td>Grab</td>
<td>7/16/14</td>
<td>4.76</td>
<td>0.029</td>
<td>1.8</td>
</tr>
<tr>
<td>L2 CC Eff 08 (25:75)</td>
<td>Grab</td>
<td>7/16/14</td>
<td>1.76</td>
<td>0.014</td>
<td>1.2</td>
</tr>
<tr>
<td>L2 CC Eff 08</td>
<td>Grab</td>
<td>7/16/14</td>
<td>9.24</td>
<td>0.065</td>
<td>3.5</td>
</tr>
<tr>
<td>L2 CC Eff 08 Dup</td>
<td>Grab</td>
<td>7/16/14</td>
<td>9.39</td>
<td>0.061</td>
<td>3.8</td>
</tr>
<tr>
<td>L2 CC Eff 03</td>
<td>Grab</td>
<td>7/16/14</td>
<td>9.69</td>
<td>0.057</td>
<td>3.4</td>
</tr>
<tr>
<td>L2 CC Eff 04</td>
<td>Grab</td>
<td>7/16/14</td>
<td>10.1</td>
<td>0.067</td>
<td>4.0</td>
</tr>
<tr>
<td>L2 CC Eff 07</td>
<td>Grab</td>
<td>7/16/14</td>
<td>9.96</td>
<td>0.067</td>
<td>3.9</td>
</tr>
</tbody>
</table>
Low Level UV Data

Filtered COD vs DR5000 Filtered UV254

$y = 0.0074x - 0.0066$

$R^2 = 0.9708$
Low Level UV Data

Filtered COD vs Filtered TOC

\[ y = 0.2846x + 0.9085 \]

\[ R^2 = 0.941 \]
Low Level UV Data

\[ y = 36.86x + 1.277 \]

\[ R^2 = 0.8895 \]
UOSA GAC Performance

COD Removal

mg/L COD


CC Infl Effl1 Effl32 Effl3 Effl4 Effl5
UOSA GAC Performance

TOC Removal

CC Infl | Effl 1 | Effl 2 | Effl 3 | Effl 4 | Effl 5

mg/L TOC

0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00

UOSA IVewOps Dynamic Process Model Calibration
• UOSA is undertaking a pilot study to investigate if adding ozone ahead of activated carbon is advantageous
  – Extend exhaustion cycle & reduce regeneration frequency
  – Reduce life cycle cost of TCOD & TOC removal
  – Improve water quality with respect to TOrCs and organics character

Fluorescence Excitation Emission Matrices (EEM)
Benefits realized from field monitoring of process parameters

- Significant reduction in delay of sample analysis results.
- Provides real time operating data to engineers and operations in order to make process changes related to operation of plant.
- Reduces Laboratory workloads.
- New Bench Method will be particularly effective for the Ozone/BAC pilot study.