Missouri Waste Control Coalition

July 15 – 18, 2018
Tan-Tar-A Resort
Ozark Beach, Missouri

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"Finding A Better Way"
Phyto-Utilization Systems

Update:
2 System Installations

- 4-acre vetiver system in Texas
- 15-acre poplar system in Illinois

Jeffco Results

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Leachate Volume (millions)</td>
<td>2.9</td>
<td>4.3</td>
<td>4.25</td>
<td>4.95</td>
<td>3.8</td>
<td>2</td>
<td>3.4</td>
<td>4</td>
<td>4.4</td>
<td>4.2</td>
<td>38.2</td>
</tr>
</tbody>
</table>

* 2008 - partial year, 2015-2017 - estimated

Not a single load of leachate has left the site since system startup

T&D avoided = $0.058 x 38,200,000 = >$2.2 million
W.A.I.V.

Wind Aided Intensified Evaporation

Simplified Process Flow

1 = Supply
2, 3, 4 = Distribution
5 = Wind / Evaporation
6, 7 = Circulate

Repeat

2 Systems in Permitting

• 4-unit system in Kentucky

• 2-unit system in Minnesota

for produced water from coal seam gas operations
You’re “Cut off.” Now what? – A case study of how WCA avoided permanent cut off through effective communication and technical support for strong H2S odors in leachate

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Outline

- Site Background / Problem Definition
- H₂S Formation
- Bench and Pilot Testing
- Design / Startup / Operational Results
Yarnell Landfill

Site Background

www.leachate.us
Yarnell Landfill – Site Location
Site Layout
Background

- Site in operation for many years (without problems)
- Direct connection used for years (without problems)
- Odor complaints near lift station
- Direct connection – authorization revoked
- Hauling to same WWTP in jeopardy
Outline

• Site Background / Problem Definition

• H₂S Formation

• Bench-Scale Testing

• Pilot Testing

• Design / Installation / Startup

• System Operational Results
H₂S Formation

CaSO₄ + Carbon Sources + Reducing Conditions + Water

CaSO₄

SO₄⁻² + 2C_{organic} + 2H₂O + microbial activity → ???
H₂S Formation

CaSO₄ · 2H₂O + Water + Reducing Conditions + Carbon Source + SRB = H₂S
Treatment Methods

Sulfide Removal Methods

- Physical (aeration)
- Chemical (oxidation)
- Biological

Alternate Methods

- Advanced Oxidation (O₃ w/ UV, TiO₂)
- Selective Sulfate Crystallization
- GAC
- Biofiltration
- Proprietary Chemical Compounds
Aeration

Mechanisms

- Air / Water Contact .......... Henry’s Law
- Oxidation ....................... $2H_2S + O_2 \rightarrow 2H_2O + 2S^0$

Problems

- Odors generated
- pH
- Contact time
- Incomplete treatment

Figure credit: Robert D. McVay, P.E., Florida Rural Water Association
Chemical Oxidation

- Ozone
- Hydrogen Peroxide
- Potassium Permanganate
- Hypochlorous Acid
- Chlorine Gas
- Oxygen
- Hypochlorite (bleach)
- Proprietary Compound

<table>
<thead>
<tr>
<th>Oxidizer</th>
<th>Oxidation Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>OH(^-) Radical</td>
<td>2.8</td>
</tr>
<tr>
<td>Ozone</td>
<td>2.1</td>
</tr>
<tr>
<td>Hydrogen Peroxide</td>
<td>1.8</td>
</tr>
<tr>
<td>Potassium Permanganate</td>
<td>1.7</td>
</tr>
<tr>
<td>Chlorine Dioxide</td>
<td>1.5</td>
</tr>
<tr>
<td>Hypochlorous Acid (HOCl)</td>
<td>1.5</td>
</tr>
<tr>
<td>Chlorine Gas</td>
<td>1.4</td>
</tr>
<tr>
<td>Oxygen (O(_2))</td>
<td>1.2</td>
</tr>
<tr>
<td>Hypochlorite (OCl)</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Table credit: Robert D. McVay, P.E., Florida Rural Water Association
Yarnell Landfill

Step 1 – Bench-Scale Testing

www.leachate.us
Bench Scale Testing

Methods Tested

1. Aeration
2. Chemical Oxidation (H₂O₂, Sodium Hypochlorite)
3. Aeration and Chemical Oxidation
4. Odor Control Compound

\[ \text{H}_2\text{S} + \text{H}_2\text{O}_2 \rightarrow \text{S}_0 + 2\text{H}_2\text{O} \]

\[ 4\text{H}_2\text{O}_2 + \text{H}_2\text{S} \rightarrow \text{H}_2\text{SO}_4 + 4\text{H}_2\text{O} \]
Bench Scale Testing

Leachate Chemistry

- pH 7.61 S.U.
- ORP -306 mV
- TDS 2439 ppm
- Sulfide 44 ppm
- Total Hardness 1350 ppm as CaCO₃
- Total alkalinity 2400 ppm as CaCO₃
- Iron, total 0.93 ppm
- Sulfate 908 ppm
Aeration Testing
## Test Data - Aeration

<table>
<thead>
<tr>
<th>Time</th>
<th>Elapsed Time (minutes)</th>
<th>ORP (mV)</th>
<th>pH</th>
<th>TDS (ppm)</th>
<th>Sulfide (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20:55</td>
<td>0</td>
<td>-300</td>
<td>7.18</td>
<td>2439</td>
<td>30</td>
</tr>
<tr>
<td>20:56</td>
<td>0:01</td>
<td>-286</td>
<td>7.42</td>
<td>--</td>
<td>--</td>
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<tr>
<td>21:03</td>
<td>0:08</td>
<td>-216</td>
<td>8.03</td>
<td>--</td>
<td>12.5</td>
</tr>
<tr>
<td>21:05</td>
<td>0:10</td>
<td>-139</td>
<td>8.06</td>
<td>2077</td>
<td>1.75</td>
</tr>
<tr>
<td>21:15</td>
<td>0:20</td>
<td>12</td>
<td>7.81</td>
<td></td>
<td>0.41</td>
</tr>
</tbody>
</table>
Bench Scale Testing:
Chemical Oxidation
Sodium Hypochlorite (NaOCl) / Hydrogen Peroxide (H2O2)

Test Procedure
- 500 mL of untreated leachate
- Incrementally treated with
  - 9.75% sodium hypochlorite (bleach)
  - 3% H2O2
Test Data – NaOCl

Elapsed Time (minutes)

ORP (mV)

Sulfide (ppm)

0.24 ppm

pH

Sulfide (ppm)

ORP (mV)
Test Data – H₂O₂

Elapsed Time (minutes)

pH
Sulfide (ppm)
ORP (mV)

Sulfide (ppm)
0.96 ppm
## Summary of Bench Scale Results

<table>
<thead>
<tr>
<th>Test #</th>
<th>Description</th>
<th>ORP (mV)</th>
<th>Sulfide (ppm)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Initial</td>
</tr>
<tr>
<td>1</td>
<td>Aeration Only</td>
<td>-300</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Sodium Hypochlorite</td>
<td>-308</td>
<td>103</td>
<td>44</td>
</tr>
<tr>
<td>3</td>
<td>Hydrogen Peroxide</td>
<td>-360</td>
<td>125</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>Hydrogen Peroxide w Aeration</td>
<td>-344</td>
<td>125</td>
<td>12.25</td>
</tr>
<tr>
<td>5</td>
<td>Sodium Hypochlorite w Aeration</td>
<td>-344</td>
<td>-18</td>
<td>12.5</td>
</tr>
<tr>
<td>6</td>
<td>Odor Control Compound</td>
<td>-322</td>
<td>-275</td>
<td>30</td>
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Note: Sulfide readings < 1 ppm believed to be **false positive** from turbidity interference with instrumentation. Colorimetric tests confirmed no Sulfide.
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Note: Sulfide readings < 1 ppm believed to be false positive from turbidity interference with instrumentation. Colorimetric tests confirmed no Sulfide.
Bench Scale Testing

Conclusions

- Chemical oxidation successful
- Hydrogen peroxide preferable
  - More cost effective
  - Degradation products
  - Site personnel had some experience w H₂O₂
- Strong correlation between ORP and H₂S treatment
Yarnell Landfill

Step 2 – Pilot Testing

www.leachate.us
Pilot Testing

Leachate collection System

- Five ~1,700 gallon ASTs
- All tanks hydraulically connected
Pilot Testing

Monitoring

- Odalog H₂S Sensor
  - Continuously monitored H₂S in-tank
  - Range of 0 to 370 ppm

- YSI Flow through Cell
  - Continuously monitored: Temp, EC, DO, ORP, pH

- Sulfide Analysis
  - HACH DR 890 in field
  - Laboratory confirmation samples
Pilot Testing

- Aeration
  - Two EDI Flexair T-Series Diffusers at base of storage tank
  - Air supplied with a Rotron DR454, 1.5 HP Regenerative Blower
- Mixing = on-Site trash pump + aerator
Pilot Testing

EDI Flexair T-Series Diffusers (inside tank)
Pilot Testing

Peroxide Injection  On-site tank used.  Solution of 30% peroxide
Pilot Testing

Peroxide Injection  On-site tank used. Originally 30% peroxide, but had degraded over time to 19%
Pilot Testing

**Test 1: H2O2 Only (no aeration)**

<table>
<thead>
<tr>
<th>Test 1 Data</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Leachate volume</td>
<td>1040</td>
<td>gallons</td>
</tr>
<tr>
<td>Leachate Mass</td>
<td>8,674</td>
<td>lbs</td>
</tr>
<tr>
<td>Dosing Rate</td>
<td>0.08</td>
<td>l/min</td>
</tr>
<tr>
<td>Total Dosing Time</td>
<td>40</td>
<td>min</td>
</tr>
<tr>
<td>Volume Peroxide Dosed</td>
<td>3.2</td>
<td>liters</td>
</tr>
<tr>
<td>Peroxide Concentration</td>
<td>19</td>
<td>%</td>
</tr>
<tr>
<td>Peroxide Density</td>
<td>1.11</td>
<td>g/mL</td>
</tr>
<tr>
<td>Mass Peroxide Dosed</td>
<td>3,552</td>
<td>g</td>
</tr>
<tr>
<td></td>
<td>7.8</td>
<td>lbs</td>
</tr>
<tr>
<td>Peroxide Concentration</td>
<td>172</td>
<td>ppm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test 1 Results</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting Concentrations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfide</td>
<td>41</td>
<td>mg/L</td>
</tr>
<tr>
<td>ORP</td>
<td>-232</td>
<td>mV</td>
</tr>
<tr>
<td>pH</td>
<td>7.07</td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>1.58</td>
<td>mg/L</td>
</tr>
<tr>
<td>End Concentrations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfide</td>
<td>0.7</td>
<td>mg/L</td>
</tr>
<tr>
<td>ORP</td>
<td>45.3</td>
<td>mV</td>
</tr>
<tr>
<td>pH</td>
<td>7.16</td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>6.51</td>
<td>mg/L</td>
</tr>
</tbody>
</table>

Peroxide injected at 10-min intervals at a rate of 0.08 l/min. 3.2 liters used over 3-hour period.
Pilot Testing – Test 2 – H$_2$O$_2$ and Aeration

H$_2$O$_2$ Dosing

H$_2$S (ppm)

ORP (mV)

Pulse Aeration

Elapsed Time (Hours:Minutes:Seconds)

0:00:00 1:12:00 2:24:00 3:36:00 4:48:00

H$_2$S Gas Concentration in Tank (ppm)

ORP (mV)

H$_2$S Gas (ppm)
Peroxide Dosing (0.08 L/min)
Blower Operating
Leachate: ORP (mV)
Pilot Testing – Test 2 – H₂O₂ and Aeration

Elapsed Time (Hours:Minutes:Seconds)

- H₂O₂ Dosing
- H₂S (ppm)
- Pulse Aeration

- ORP (mV)

H₂S Gas Concentration in Tank (ppm)

- H₂S Gas (ppm)
- Peroxide Dosing (0.08 L/min)
- Blower Operating
- Leachate: ORP (mV)
Pilot Testing – Test 3 – H₂O₂ and Aeration

H₂S Gas Concentration in Tank (ppm)

ORP (mV)

H₂S (ppm)

H₂O₂ Dosing

ORP (mV)

Aeration

H₂S Gas (ppm)

H₂O₂ Dosing (0.16 L/min)

Blower Operating

Leachate: ORP (mV)
Pilot Testing – Test 4 – Aeration Only

- Short test conducted
- H2S levels jumped >370 ppm
- Noticeable odor
- Test stopped after presence of ambient odor issue was obvious
Pilot Testing

Conclusions

- Aeration alone is not a viable option due to odor
- ChemOx w/ H₂O₂ + Aeration is best match
- ORP is excellent indicator of sulfide concentration
- Peroxide to sulfide ratio on mass basis for removal ranges from 4:1 to 13:1
Yarnell Landfill

Step 3 to 5 – Design, Installation, & Operation

www.leachate.us
Full Scale System Design

Design Framework

- H₂O₂ + Aeration system
- ORP monitoring to verify H₂S treatment
  - ORP of -200 to -300 mV to positive
- Automated treatment system
- Remote access for control and monitoring
Treatment System Components

- A new 12,500 gal storage tank
- Steel framed treatment building
- Centrifugal pump to recirculate and discharge leachate
- H2S sensor (Odalog)
- Flowmeter
- ORP sensor
Treatment System Components

- Chemical feed tank (peroxide) and feed pump
- Aeration blower
- Motorized ball valves
- Level sensors and floats
- Programmable logic controller (PLC) and human-machine interface (HMI)
System Installation

Existing tank removal

Shed off-loading and placement
System Installation

New tank placement

Piping connections and pump install
Process Flow

- Influent
- Flow Meter
- PLC
- ORP Meter
- Aeration Blower
- Automated Valves
- Pump
- Wet Well w Odalog
- 12,500 gal AST w Diffusers
- H2O2 Addition
12,500 gal AST w Diffusers

Flow Meter

PLC

ORP Meter

Aeration Blower

Wet Well w Odalog

Process Flow
Influent

Pump

12,500 gal AST w Diffusers

Flow Meter

PLC

ORP Meter

Aeration Blower

H2O2 Addition

Automated Valves

Wet Well w Odalog

Process Flow
Influent

Flow Meter

PLC

ORP Meter

Aeration Blower

H₂O₂ Addition

Automated Valves

Wet Well w Odalog

12,500 gal AST w Diffusers

Pump

Process Flow
Influent

12,500 gal AST w Diffusers

Pump

H₂O₂ Addition

Automated Valves

ORP Meter

Aeration Blower

Wet Well w Odalog

Process Flow
12,500 gal AST w Diffusers

H₂O₂ Addition

Automated Valves

Wet Well w Odalog

Process Flow
12,500 gal AST w Diffusers

Influent

Flow Meter

PLC

ORP Meter

Aeration Blower

H2O2 Addition

Automated Valves

Pump

12,500 gal AST w Diffusers

Process Flow

Wet Well w Odalog
Multiple HMI setpoints = flexibility, adjustable
System Operation

- On-site meeting with WWTP on July 21, 2016
  - Demonstrated system operation
  - Verification of treatment
System Testing and Operation

Proof of Performance

- Still hauled by tanker truck
- Operated and verify no odor at WWTP
- Confirmation Lab Sampling
System Testing and Operation

Proof of Performance

- Still hauled by tanker truck
- Operated and verify no odor at WWTP
- Confirmation Lab Sampling
- **FAILED** sulfide analysis
System Testing and Operation

Proof of Performance

- Still hauled by tanker truck
- Operated and verify no odor at WWTP
- Confirmation Lab Sampling
- **FAILED** sulfide analysis
  - Interference, detection limit
  - Resampled, alternate method
  - Results $<0.10$ mg/L (bdl)
System Testing and Operation

Proof of Performance

- Still hauled by tanker truck
- Operated and verify no odor at WWTP
- Confirmation Sampling = Passed

- Final Approval to commence direct sewer discharge!!!
  Sept 1, 2016
System Operation

- Direct discharge re-established on September 1, 2016
  - Sulfide monitored semi-annually – limits met
  - Maximum daily flow
    - 15,000 gallons/day
    - Renegotiated increase to 25,000 gallons/day
What was the most important part of this successful project???
Effective Communication

- Owner
- Site
- Region
- Corporate
- Regulator
- Supervisors
- Permit writers
- Consultant
- Subcontractors
  - Electricians, plumber, equipment suppliers, system integrator, etc.
Effective Communication

- Electronic
- Phone conversations
- In person meetings at WWTP office
- Invitations and having WWTP personnel on site to
  - Understand Site
  - Observe testing
  - Observe installation
  - Observe full-scale operation
- Key WCA staff on Site

BUILT TRUST AND CONFIDENCE
Project Accomplishments

Results

- Write a permit app which had high likelihood of approval
- Approval received
- System installed
- Direct discharge reestablished

BUILT TRUST AND CONFIDENCE
Results

- Reestablished Direct Discharge
  - 2,879,981 gallons (7/14/18)
- System cost $150,000
- $432,000 T&D avoided
- Clear path ahead for long-term leachate treatment and disposal
THANK YOU!

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"Finding A Better Way"
Costs

- Bench Scale Testing – $3,300
- Pilot Testing – $15k + ~$2-3k for local supplies
- Design – Installation $130k (design, installation oversight, equip., tank, PLC, shed, delivery, contractor installation plumbing / mechanical and elect., system startup, sampling
- Total ~ $150k
**Project Timeline**

- Local POTW cuts off a direct disposal connection to a sewer due to odors caused by hydrogen sulfide (H₂S) in leachate, allows hauling by truck but under strict conditions, and threatened to end acceptance altogether.
- May 2015 – Bench scale testing done to determine potential H₂S treatment options
- June 2015 – Pilot testing conducted on site to verify efficacy of H₂S treatment with aeration and hydrogen peroxide
- September 2015 – Permit negotiations and design initiated. Budgets proposed for 2016
- December 2015 – Budget approved. Begin bidding out contractor portions of project
- May 2016 – System installation
- June 2016 – System testing and operation
- July 2016 – On-site meeting with WWTP for permit completion
- September 1, 2016 – Direct discharge under new WWTP permit