



Increased use of UV disinfection at POTWs and related issues with leachate pretreatment

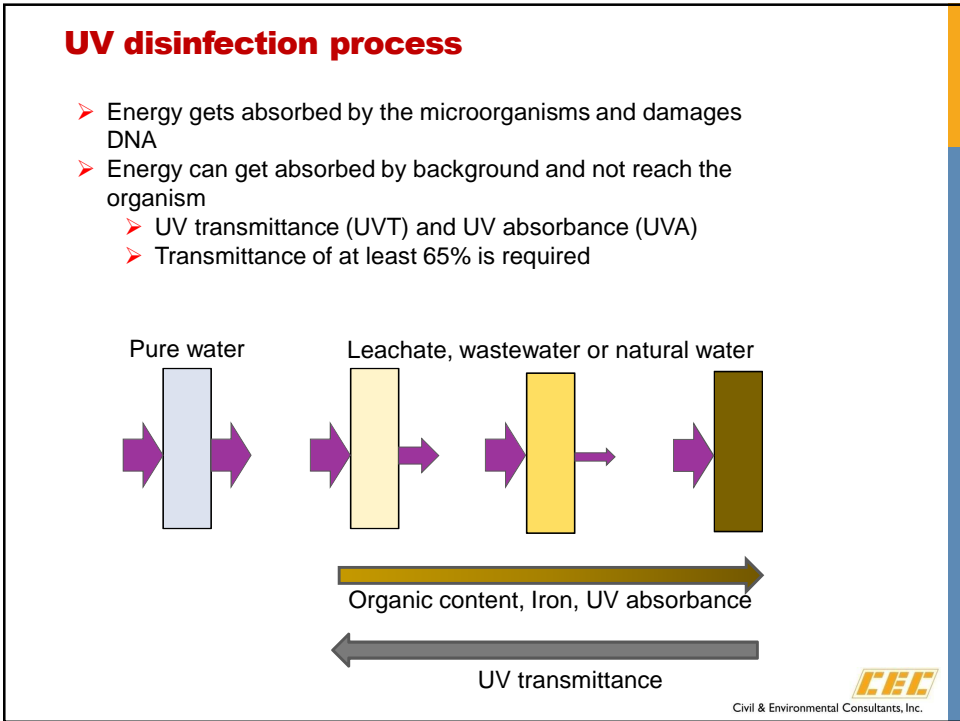
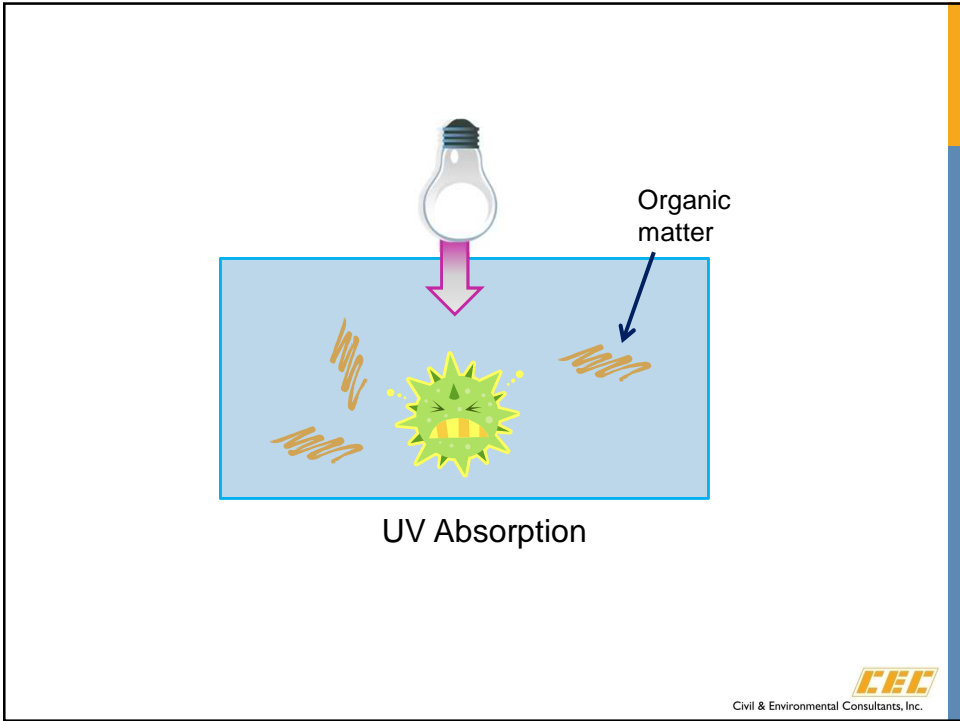
Michael Keen, E.I.
Civil & Environmental Consultants, Inc.
SC SWANA – 2014 Spring Conference

May 7, 2014

POTW and the UV disinfection process

- Chlorination is still the most common form of disinfection
 - ~75% of all major POTWs (1->100 MGD)
- UV usage rapidly growing among major POTWs
 - 21% of all major POTWs currently use UV disinfection
 - Between 2001-2005 about 40% of all UV systems in use as of 2009 were installed
 - UV trend continuing due to safer work environment and the elimination of chlorine gas and/or chlorination/dechlorination





Typical Wastewater UV Transmittance

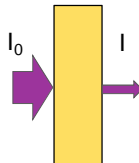
- Suspended growth processes – Activate Sludge
 - 60-65% UVT
- Fixed film processes- Trickling Filter
 - 50-55% UVT
- Sequencing batch reactor
 - 45-60% UVT
- Enhanced Primary
 - Alum – 40-50% UVT
 - Ferric- 25-45% UVT
- Tertiary filtration
 - 50-85% UVT

UNTREATED SOLID WASTE LEACHATE - HIGHLY VARIABLE



Civil & Environmental Consultants, Inc.

POTW and the UV disinfection process



Transmittance:

$$T = I / I_0$$

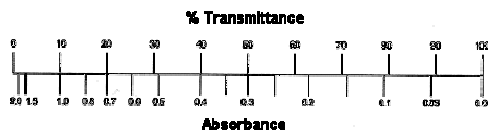
$$\% \text{ Transmittance, } \%T = 100 T$$

Absorbance:

$$A = \log_{10} I_0 / I$$

$$A = \log_{10} 1 / T$$

$$T = 10^{-A}$$



Civil & Environmental Consultants, Inc.

Landfill Pre-treatment

- Leachate traditionally high in organics, metals and nitrogen
 - Typical treatment:
 - pre-treatment includes precipitation and biological treatment
 - Co-treatment with wastewater at POTW
- After Biological treatment
 - Most organic carbon in leachate is not biodegradable further
 - Residual organic content may still be relatively high
 - POTWs typically accept pre-treated leachate with residual organics

UV disinfection is changing the STATUS QUO!



Civil & Environmental Consultants, Inc.

Solid Waste Leachate – Natural Organic Matter

- Humic Substances (HS)
- Fulvic Substances (FS)
- Hydrophilic Organic Matter (Hpi)

HS>FS>Hpi



Landfill leachate entering retention ponds for treatment.



Civil & Environmental Consultants, Inc.

Solid Waste Leachate – Humic Substances

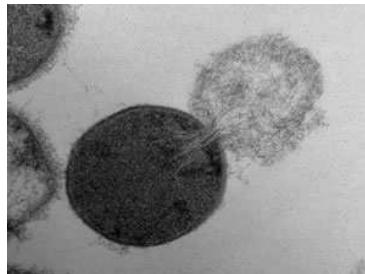
- Humic Substances = paper, wood, yard waste
- Humic Substances – not directly assessable by common analytical methods due to heterogeneous molecular structure




Civil & Environmental Consultants, Inc.

Solid Waste Leachate – Humic Substances

- Humic Substances have chromophores which absorb UV light
 - Not removed during landfill pre-treatment
 - The low UV Transmittance and non-biodegradable component of leachate
- Fulvic Substances – are organic matter with lower molecular weight and higher oxygen content
 - Usually associated with the remnants of dead cells




Civil & Environmental Consultants, Inc.

Solid Waste Leachate - Age

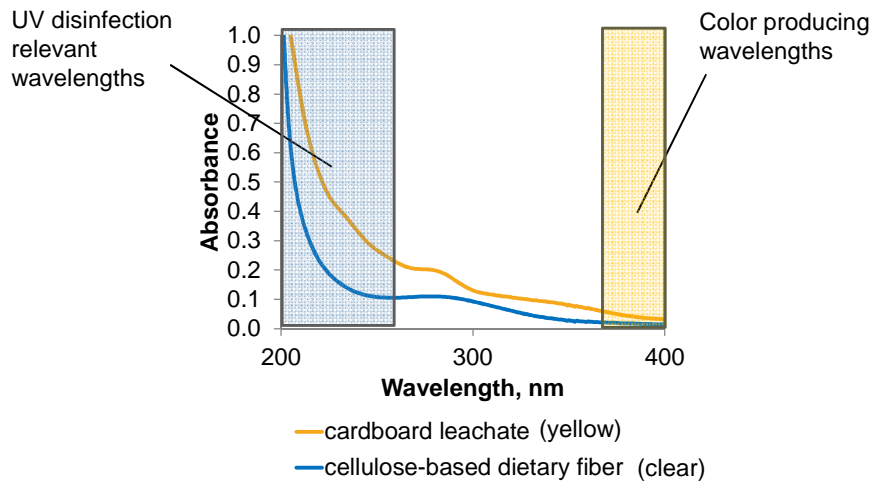
- Early Age Leachate
 - High COD, TOC and BOD
 - Higher BOD/COD ratios
- Older Leachate
 - Lower BOD/COD ratios
 - Increased concentration of higher molecular weight humic and fulvic-like constituents

Color and UV Absorbance

- You can't estimate UV Transmittance levels simply by the color of the leachate
 - Color can indicate the presence of organics such as tannins and humic material
 - Some organics and other matter that cause low UV Transmittance do not add any visible color to the leachate



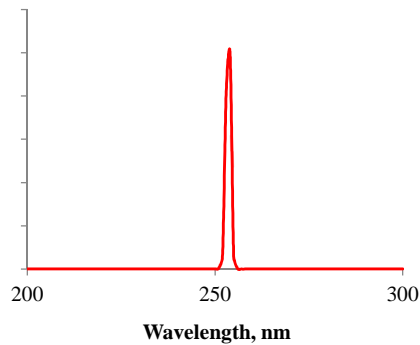
Color and UV Absorbance



CEC
Civil & Environmental Consultants, Inc.

Color and UV Absorbance

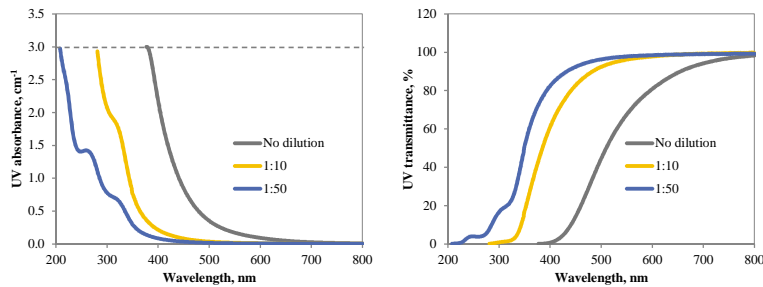
- Most common lamp type
 - Low pressure mercury vapor
 - Emission at 254 nm



CEC
Civil & Environmental Consultants, Inc.

Dilution as Solution

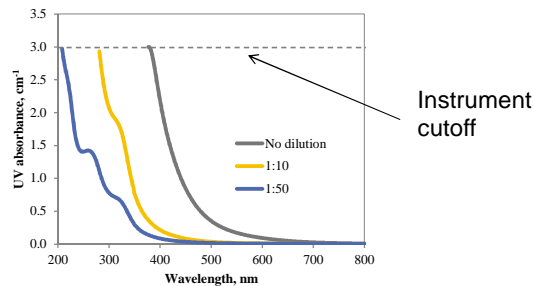
- High strength leachate can have zero transmittance even after MBR treatment
 - Can constitute 1/200th of the wastewater flow or less to comply with UVT requirements of POTW
- Absorbance changes linearly with dilution (Beer-Lambert Law)
 - Sample with A=1.0 will have A=0.1 at 1:10 dilution
- A=1 → 90% of UV is absorbed in 1 cm of depth
- A=2 → 99%; A=3 → 99.9%, etc.
- Transmittance does not change linearly



CEC
Civil & Environmental Consultants, Inc.

Dilution as Solution

- Leachate shown has absorbance of 40
 - 99.999999.....999% of light absorbed
- Spectrophotometers have a measuring limit of 3-4
 - Only reliably report 99.9% or 99.99% absorbance
 - Sample with 99.99999999999999% absorbance will read as 99.99% because this is the instrument max
 - Samples need to be diluted until absorbance is <99% and undiluted absorbance is back calculated



CEC
Civil & Environmental Consultants, Inc.

Treatment options

- Oxidation
 - Fenton's
 - Ozone
 - Ozone + hydrogen peroxide
- Adsorption
 - Zeolite
- Membrane filtration
 - Nanofiltration
 - Reverse osmosis



Civil & Environmental Consultants, Inc.

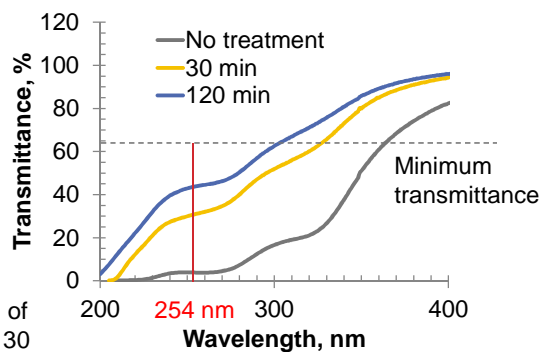
Treatment options

- Fenton's
 - Limited effectiveness
 - Sludge generation
 - Addition of high amounts of iron and H_2O_2
 - Potential COD removal (was not measured)



Biologically treated leachate before Fenton's

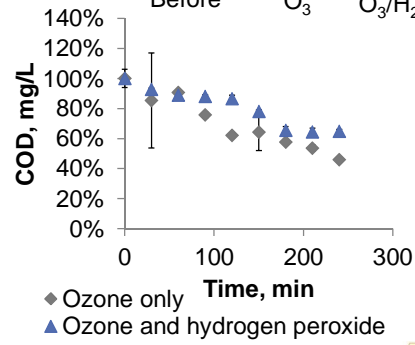
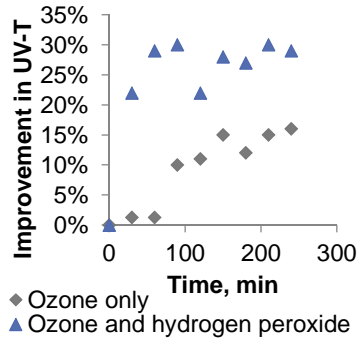
After 120 min of Fenton's and 30 min of settling



Civil & Environmental Consultants, Inc.

Treatment options

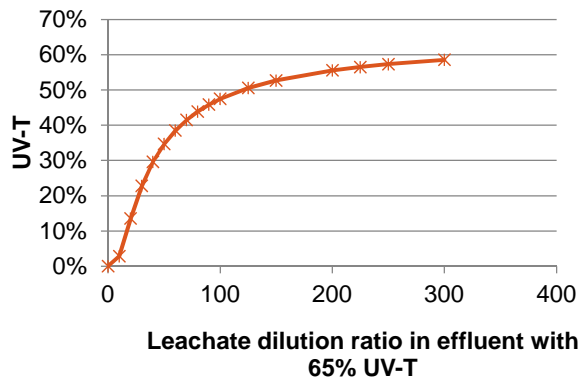
- Ozone and Ozone/H₂O₂
 - Limited effectiveness
 - Improvement with H₂O₂ addition
 - Bonus COD removal
 - Still not enough improvement in high volume, high strength leachate



Civil & Environmental Consultants, Inc.

Treatment options

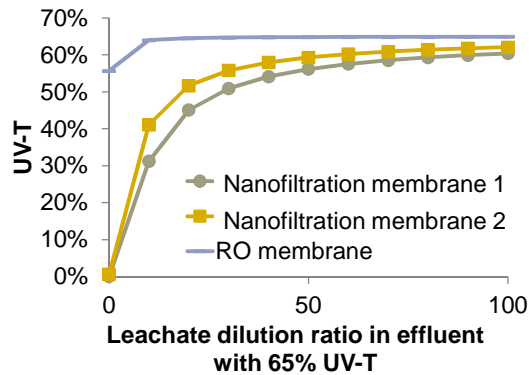
- Zeolite (Ahlstrom Disruptor)
 - Limited effectiveness



Civil & Environmental Consultants, Inc.

Treatment options

- Membrane filtration
 - Nanofiltration
 - Reverse osmosis
- RO is highly effective
- Energy expenditures
- Membrane fouling
- Concentrate management



Raw leachate After nanofiltration



CEC
Civil & Environmental Consultants, Inc.

Conclusions

- Leachate reduces the POTW UV Transmittance even after pre-treatment
- Most current pre-treatment are not effective in removing or reducing humic acids
- Pre-treatment of landfill leachate may be required for POTW to meet NPDES permit requirements or for their UV disinfection process to work effectively
- No one-size-fits-all solution currently available

CEC
Civil & Environmental Consultants, Inc.

References

1. Leong, Lawrence Y.C., Kuo, Jeff, Tang, Chi-Chung **2009**. Disinfection of Wastewater Effluent: Comparison of Alternative Technologies, Executive Summary: Water Environment Research Foundation.
2. Renou, S.; Givaudan, J. G.; Poulain, S.; Dirassouyan, F.; Moulin, P., Landfill leachate treatment: Review and opportunity. *Journal of Hazardous Materials* **2008**, 150 (3), 468-493.
3. Zhao, R.; Gupta, A.; Novak, J. T.; Goldsmith, C. D.; Driskill, N., Characterization and treatment of organic constituents in landfill leachates that influence the UV disinfection in the publicly owned treatment works (POTWs). *Journal of Hazardous Materials* **2013**, 258–259 (0), 1-9.
4. Campagna, M.; Çakmakçı, M.; Büşra Yaman, F.; Özkaya, B., Molecular weight distribution of a full-scale landfill leachate treatment by membrane bioreactor and nanofiltration membrane. *Waste Management* **2013**, 33 (4), 866-870.
5. US Environmental Protection Agency, Municipal solid waste in the United States: 2011 facts and figures. **2013**.
6. UV photo online source: <http://www.wedeco.com/us/expertise/uv-technology/uv-disinfection.html>
7. Humic Substance photo online source: <http://www.xsyagri.com/portfolio/potassium-humate/>
8. Bacteria photo online source:
9. Credit: Daniel Nelson, UMD: <http://www.cos.gatech.edu/news/Study-Quantifies-the-Size-of-Holes-Antibacterials-Create-in-Cell-Walls-to-Kill-Bacteria>
10. Landfill Leachate photo online source: <http://www.reading.ac.uk/geographyandenvironmentalscience/Postgraduate/taught/ges-pgt-msc-soils-environmental-pollution.aspx>



Civil & Environmental Consultants, Inc.

Questions?

Michael Keen, E.I.
Civil and Environmental Consultants
Voice: (980) 237-0373
mkeen@cecinc.com
www.cecinc.com



Civil & Environmental Consultants, Inc.