Odour Reduction in Biosolids

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Key Findings from Literature Review titled: *Reduction of Odour in Biosolids*.

Overview of Current Project: *Laboratory Scale Investigations of Possible Odour Reduction Strategies in Biosolids*. 

Presentation Outline
Literature Review – Reduction of Odours in Biosolids

- Survey the available literature on various aspects of biosolids odours such as:
  - compounds associated with odours
  - process factors that affect odours
  - odour measurement and
  - how treatment processes impact odour production, especially during storage of biosolids.
Processing of Biosolids

- Anaerobic Digestion of Sludge
- Dewatering & Conveyance
- Cake Storage & End Use

Sludge → Anaerobic Digesters → Dewatered Biosolids Cake → Land Application
WERF Study

- Water Environment Research Foundation (WERF) funded a multi-phase study to better understand odours in biosolids and to develop management practices to minimise these odours.

- Study was conducted from 2000 to 2010.

- Based on in-depth sampling and analysis of biosolids and headspace samples from 11 different Wastewater Treatment Plants (WWTPs) across North America.
Study looked at various factors impacting on biosolids odours, including:

- Compounds associated with odours and their formation.
- Role of protein, amino acids and enzyme activity.
- The relationship between odours and concentrations of odorants.
- Effects of anaerobic digestion.
- Impact of biosolids dewatering and conveyance.
- Effects of chemical addition (e.g. metal salts).
Odorous Compounds

- Volatile Sulphur Compounds (VSCs), such as methyl mercaptan, dimethyl sulphide (DMS), dimethyl disulphide (DMDS).
- Nitrogen Compounds, such as trimethylamine, ammonia.
- Volatile Fatty Acids (VFAs), eg. propionic acid, butyric acid.
Odorous Compounds Cont...

- Odorous Volatile Aromatic Compounds (OVACs), such as skatole, indole, $p$-cresol, toluene, ethylbenzene and styrene.

- Terpenes, alcohols, aldehydes and ketones have been identified from biosolids composting facilities.
Proposed Formation Pathways for VSCs

- Proteins are thought to be the precursors to the volatile organic sulphur compounds, inorganic reduced sulphur compounds, nitrogenous compounds and the odorous volatile aromatic compounds.

\[
\begin{align*}
&\text{Cysteine} \\
&\text{Lyase} \\
&\text{Peptidase} \\
&\text{Polypeptides} \\
&\text{Protease} \\
&\text{Proteins}
\end{align*}
\]

(Higgins, *et al.*, 2004)
Proposed Formation Pathways for VSCs

\[ \text{R-O-CH}_3 + \text{H}_2\text{S} \rightarrow \text{R-OH} + \text{CH}_3\text{SH} \quad (1) \]

\[ \text{R-O-CH}_3 + \text{CH}_3\text{SH} \rightarrow \text{R-OH} + \text{CH}_3\text{SCH}_3 \quad (2) \]

\[ \text{CH}_3\text{SH} + \text{CH}_3\text{SH} + \frac{1}{2}\text{O}_2 \rightarrow \text{CH}_3\text{S-SCH}_3 + \text{H}_2\text{O} \quad (3) \]

(Higgins, et al., 2003, 2006)
Formation of VSCs

- Simple alkyl thiols such as methanethiol can also be produced by bacteria, molds and unicellular algae.
- DMS can be produced by higher plants, multicellular and unicellular algae and rumen microorganisms.
- DMDS can also be produced from several strains of bacteria isolated from activated sludge.
- DMDS and DMS have also been identified as products of some fungal species.
Proposed Formation Pathways for OVACs

(Chen, et al., 2004, 2006)
Proposed Formation Pathways for OVACs

(Chen, et al., 2004, 2006)
Formation of Other Odorous Compounds

- Volatile fatty acids are formed from the breakdown of starch, cellulose and hemicelluloses by acid forming bacteria.

- Aldehydes and ketones can be formed during anaerobic degradation of cellulose, starch, hemicellulose and pectins.
A strong correlation exists between the odours produced by biosolids from anaerobic digestion and the concentration of volatile sulphur compounds in the headspace of biosolids samples.

Protein concentration and, in particular, the concentration of methionine have been found to be well correlated with the production of odorous VSCs.
Other Key Findings of WERF Study

- Odour emissions from cakes dewatered by high solids centrifuges were higher than cakes dewatered by other means (e.g. low-solids centrifuges or belt presses).

- Advanced digestion processes such as multi-phased digestion, egg-shaped digesters, thermophilic digestion or a series operation of digesters all appeared to be effective to some extent in reducing biosolids odour emissions.
A pre-digestion treatment such as the MicroSludge™ process reduced the peak TVOSC emissions of digested and dewatered biosolids cake by 50% compared to conventional mesophilic digestion.

Addition of alum post-digestion and pre-dewatering resulted in lower TVOSC emissions from dewatered biosolids.

Effectiveness of iron addition in reducing odours seemed to be dependent on the characteristics of biosolids as well as other factors – more studies needed.

(TVOSC = total volatile organic sulphur compound)
Further Studies on Fe and Al Addition

- Evaluation of Aluminium and Iron Addition During Conditioning and Dewatering for Odour Control (Higgins, 2010).
  - Metal salts can reduce VOSC production.
  - Addition of metal salts either, before, after or simultaneously with polymer had similar effects on VOSC reduction.
  - Chemical dosage required for odorant reduction varied according to several factors, especially shear applied to the solids.
Further Studies on Fe and Al Addition

Effect of Different Forms of Al and Fe Added Directly to Cake on TVOSC Production (Higgins, et al., 2010)
Further Studies on Fe and Al Addition

Effect of Different Forms of Al and Fe Added Directly to Cake on TVOSC Production (Higgins, et al., 2010)
Further Studies on Fe and Al Addition

- Effect of Aluminium and Iron on Odours, Digestion Efficiency and Dewatering Properties (Novak, et al., 2010).
  - In lab trials, direct addition of iron to the digester feed was uniformly beneficial as iron addition:
    - Increased dewatered cake solids
    - Decreased polymer conditioning dose
    - Improved volatile solids reduction for most sludges
    - Dramatically reduced TVOSC generation (by 50 to over 95%) for most sludges
Potential Odor Reduction Measures for Biosolids Cake*

Operational Changes

Process Equipment
  - Anaerobic Digestion
    - Digester pretreatment
    - Improve mixing
    - Increase VS reduction
    - Operate in series
    - Multiple phases
    - Increase temperature
    - Other

Design Changes

Chemical Addition
  - Pre-Digestion
    - Aluminum
    - Iron
    - CEBAs
    - pH control
    - Other

Anaerobic Digestion
  - Digester pretreatment
  - Better mixing
  - Longer SRTs
  - Egg-shaped
  - Acid-Gas (multi-phase)
  - Thermophilic
  - Temperature-phased
  - Other

Dewatering & Cake Conveyance/Storage
  - Decrease centrifuge bowl speed
  - Decrease centrifuge torque
  - Increase cake moisture content
  - Consider BFPs
  - Belt Conveyors
  - Cake storage/aging
  - Other

Pre- or Post-Dewatering
  - Aluminum
  - Iron
  - CEBAs
  - pH control
  - Polymer dose and type
  - Other

Dewatering & Cake Storage
  - Belt Filter Press
  - Rotary Press
  - Variable-speed centrifuges
  - Adjust cake solids
  - Minimize conveyance
  - Belt conveyors
  - Enclose cake storage areas
  - Other

http://borr.werf.org
Current Project - Laboratory Scale Investigations of Possible Odour Reduction Strategies in Biosolids

Project objectives include:

- Identify if Total Volatile Organic Sulphur Compounds (TVOSC) are the main cause of odour in biosolids cake.
- Establish if chemical addition (i.e. aluminium sulphate or ferric chloride) reduces odour in the biosolids cake.
- Establish if reducing the speed of the high speed centrifuges has an impact on the odour.
- Investigate the effect of varying the SRT on odours in biosolids cake.
Current Project - Laboratory Scale Investigations of Possible Odour Reduction Strategies in Biosolids

Research Approach:
- Determine the most suitable methods of conducting the laboratory trials.
- Set up sampling and testing protocols for the relevant parameters to be examined.
- Develop and optimise analytical methods for the analysis of odorous compounds.
Current Project - Laboratory Scale Investigations of Possible Odour Reduction Strategies in Biosolids

Research Approach:

- Set up and conduct the laboratory trials.
- Conduct field trials if laboratory trials are successful.
Analytical method development:
- Defined list of analytes for which we plan to develop headspace SPME (solid phase micro-extraction) GC/MS methods.
- Analytes encompass 4 groups of compounds:
  - VSCs
  - Volatile nitrogen compounds
  - Volatile fatty acids
  - Other volatile organic compounds
- Initially will be developing the GC method followed by development of the SPME method for each compound group.
Acknowledgments

- Water Corporation
THANK YOU

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<table>
<thead>
<tr>
<th>Compound</th>
<th>Odour Character</th>
<th>Compound</th>
<th>Odour Character</th>
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<tbody>
<tr>
<td><strong>Nitrogen Compounds</strong></td>
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</tr>
<tr>
<td>Ammonia</td>
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<td></td>
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<tr>
<td>Methylamine</td>
<td>Fishy</td>
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<tr>
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<td><strong>Sulphur Compounds</strong></td>
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<tr>
<td>Ethyl mercaptan</td>
<td>Rotten cabbage</td>
<td>Formaldehyde</td>
<td>Unpleasant</td>
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<tr>
<td>Hydrogen sulphide</td>
<td>Rotten eggs</td>
<td>Acetaldehyde</td>
<td>Green sweet</td>
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<tr>
<td>Carbon disulphide</td>
<td>Disagree, sweet</td>
<td>Acetone</td>
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<td>Propionaldehyde</td>
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<td>Crotonaldehyde</td>
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<td>Methyl ethyl ketone</td>
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<td>Butyrldehyde</td>
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<td>Valeraldehyde</td>
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<td><strong>Odorous Volatile Aromatic Compounds</strong></td>
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