Odour Reduction in Biosolids

Yolanta Gruchlik, Hanna Driessen, Lise Fouche, Anna Heitz, Cynthia Joll, Ina Kristiana and Jeffrey Charrois

Presentation Outline

- 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.*

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.

WERF Study Cont…

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.

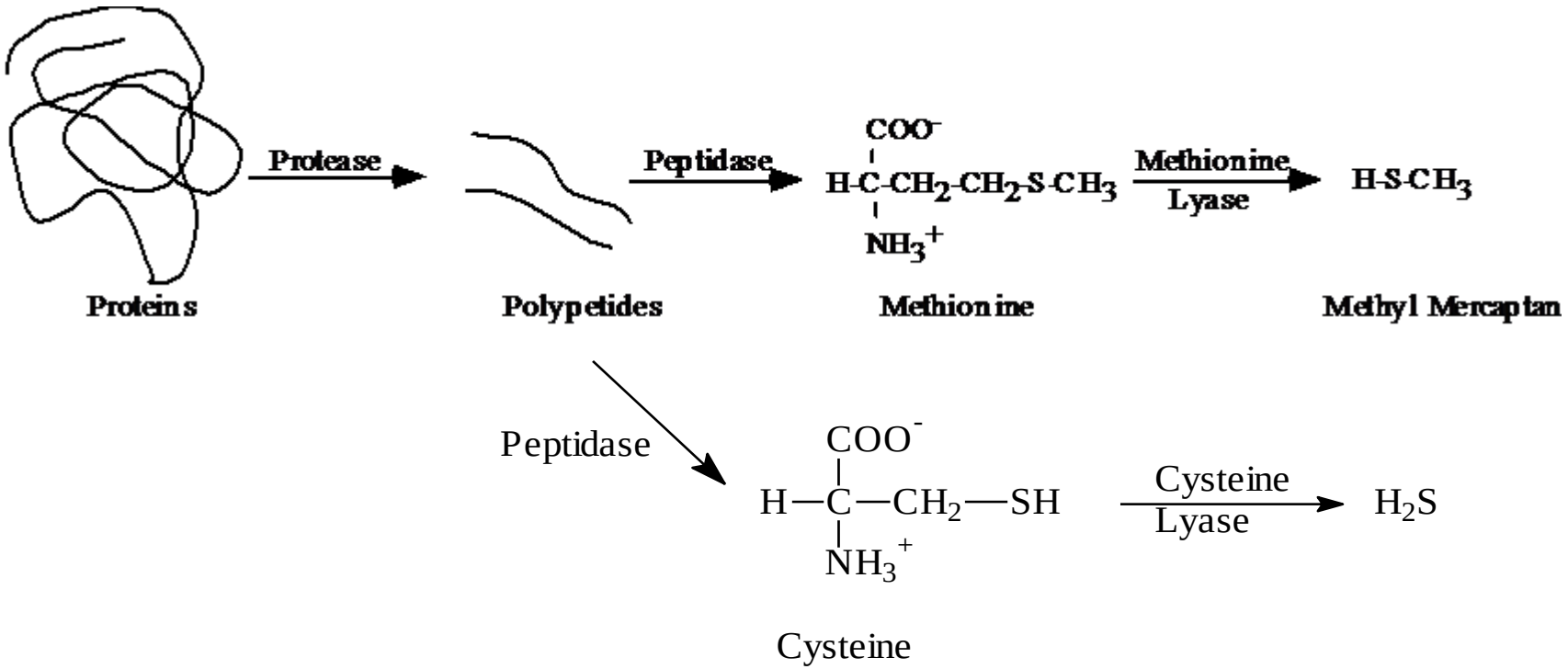
Odorous Compounds Cont…

- 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.



(Higgins, *et al*., 2004)

Proposed Formation Pathways for VSCs

$$R\text{-}O\text{-}CH_3 + H_2S \longrightarrow R\text{-}OH + CH_3SH \quad (1)$$

$$R\text{-}O\text{-}CH_3 + CH_3SH \longrightarrow R\text{-}OH + CH_3SCH_3 \quad (2)$$

$$CH_3SH + CH_3SH + 1/2O_2 \longrightarrow CH_3S\text{-}SCH_3 + H_2O \quad (3)$$

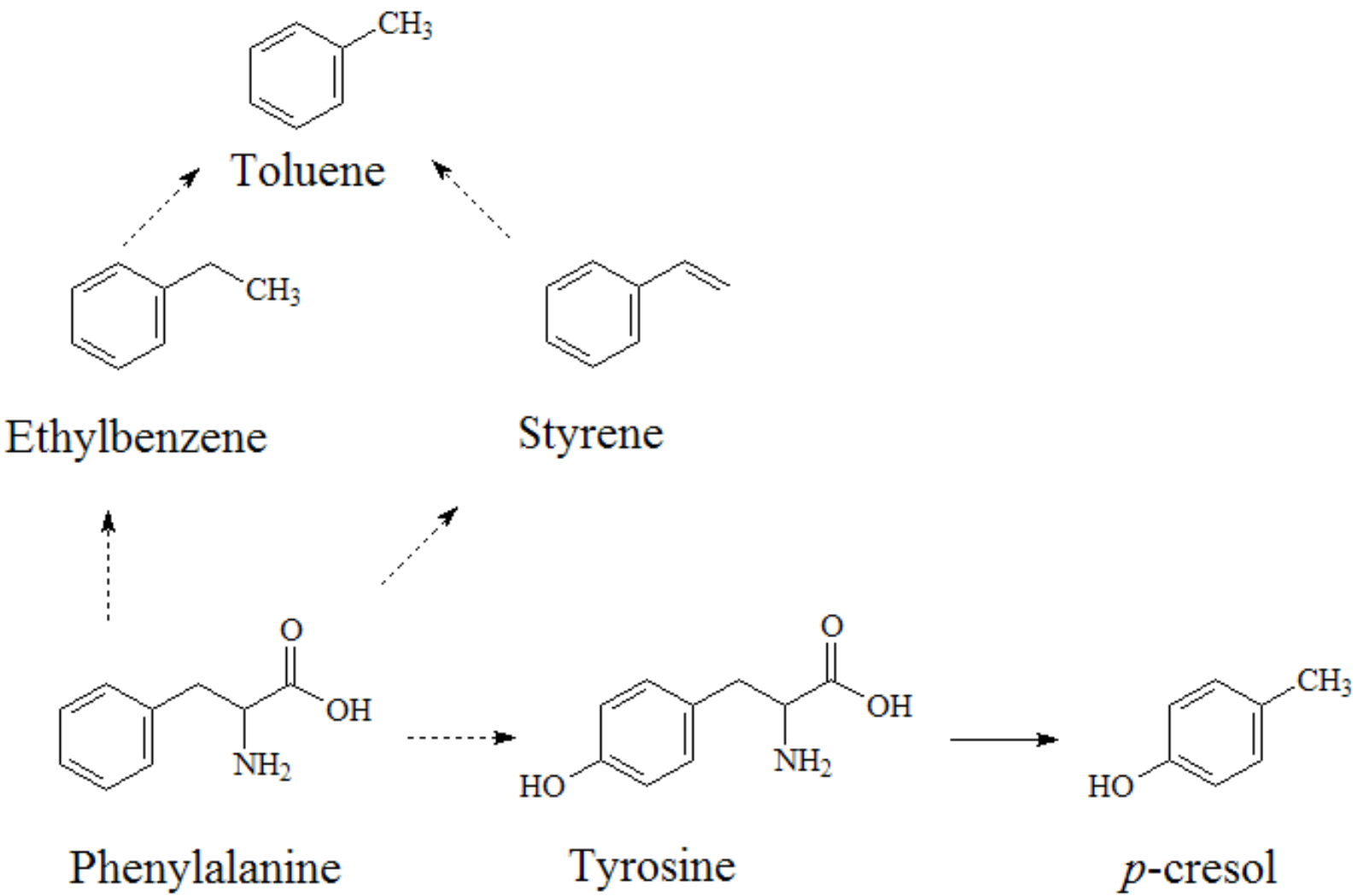
(Higgins, *et al.*, 2003, 2006)

CWQRC

Formation of VSCs

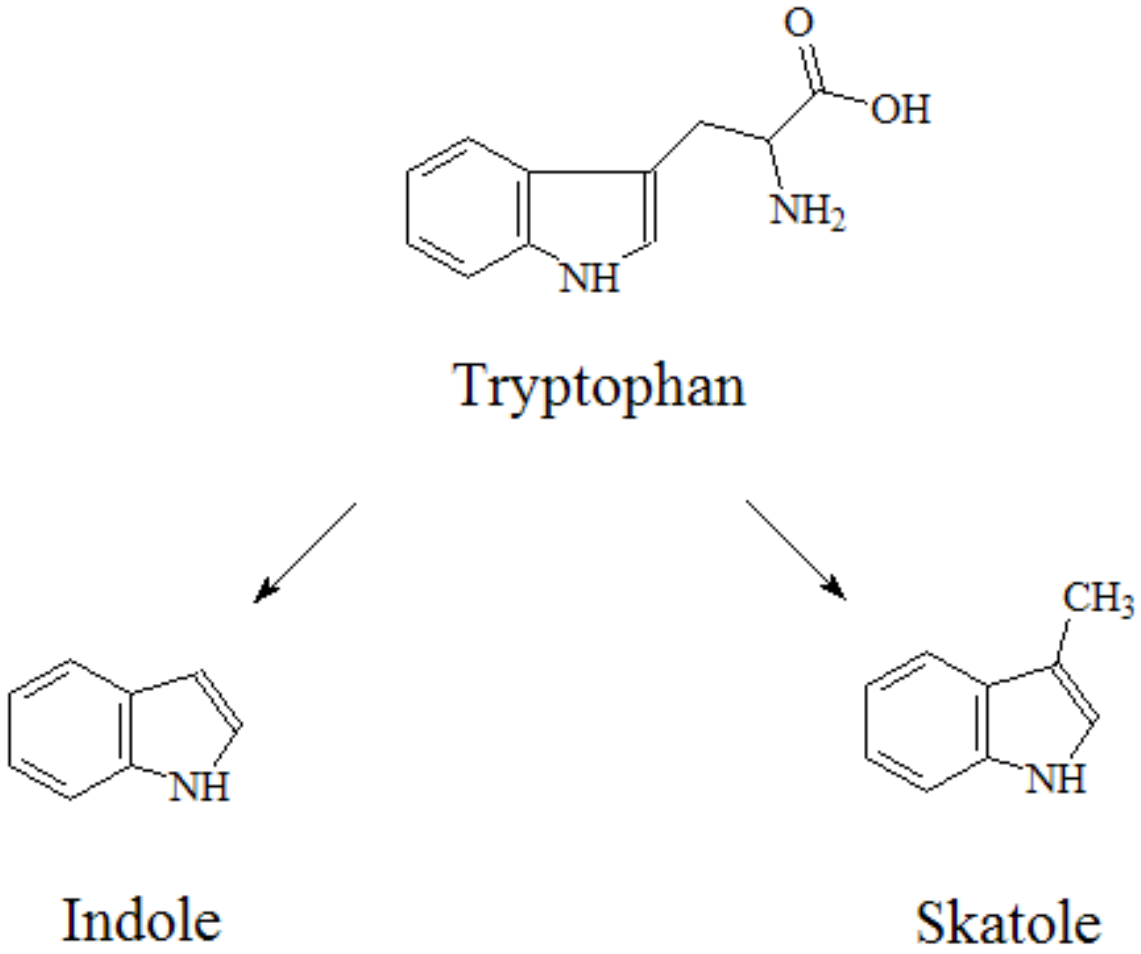
- Simple alkyl thiols such as methanethiol can also be produced by bacteria, molds and unicellular algae.
- DMS can be produced by higher plants, multicellular and unicellular algae and rumen microorganisms.
- DMDS can also be produced from several strains of bacteria isolated from activated sludge.
- 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.

Relationship Between Odours and Odorants

- 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 extend in reducing biosolids odour emissions.

Other Key Findings Cont…

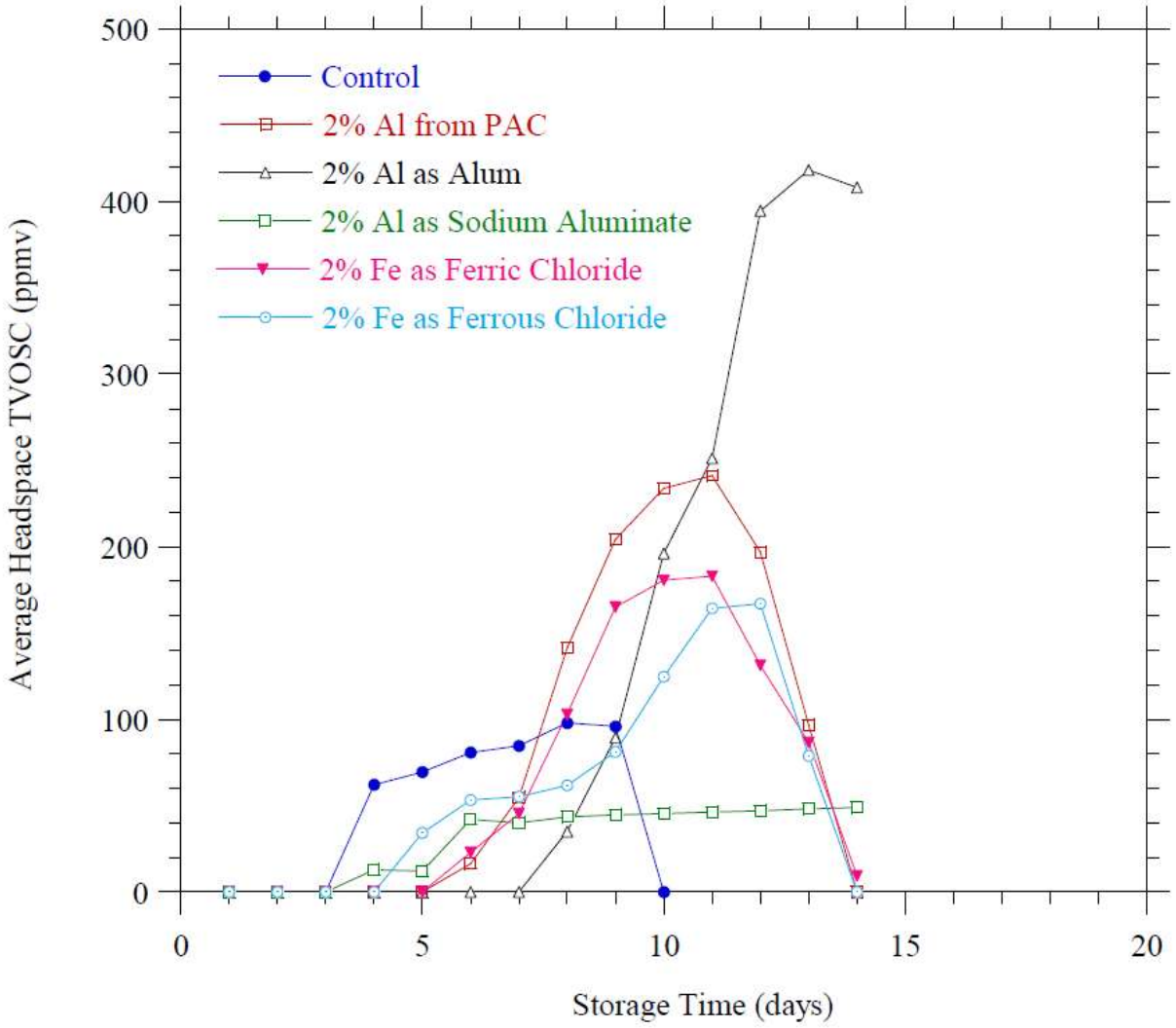
- A pre-digestion treatment such as the MicroSludge™ process reduced the peak TVOSC emissions of digested and dewatered biosolids cake by 50% compared to conventional mesophilic digestion.
- Addition of alum post-digestion and pre-dewatering resulted in lower TVOSC emissions from dewatered biosolids.
- 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

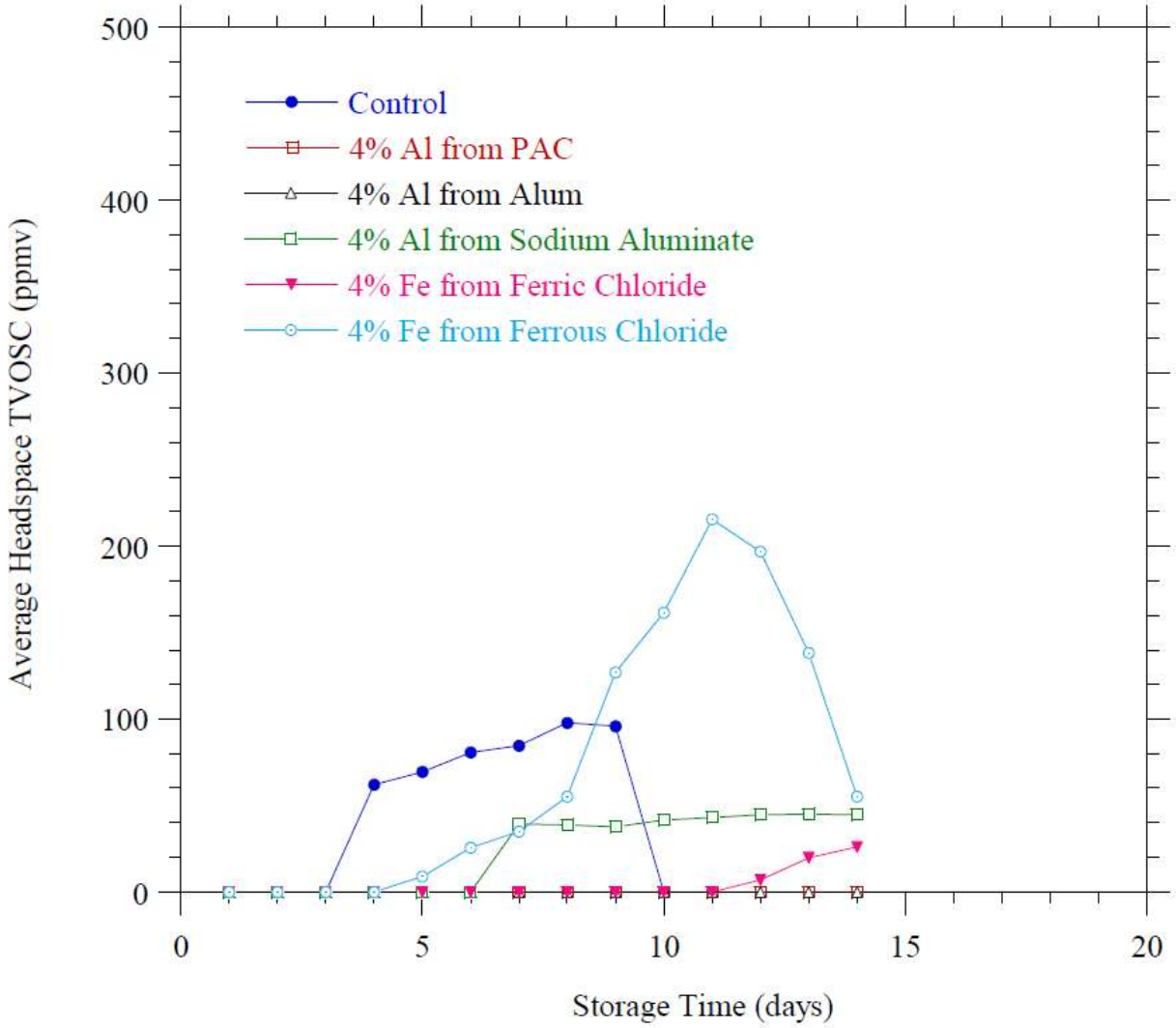
- Evaluation of Aluminium and Iron Addition During Conditioning and Dewatering for Odour Control (Higgins, 2010).
  - Metal salts can reduce VOSC production.
  - Addition of metal salts either, before, after or simultaneously with polymer had similar effects on VOSC reduction.
  - Chemical dosage required 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)

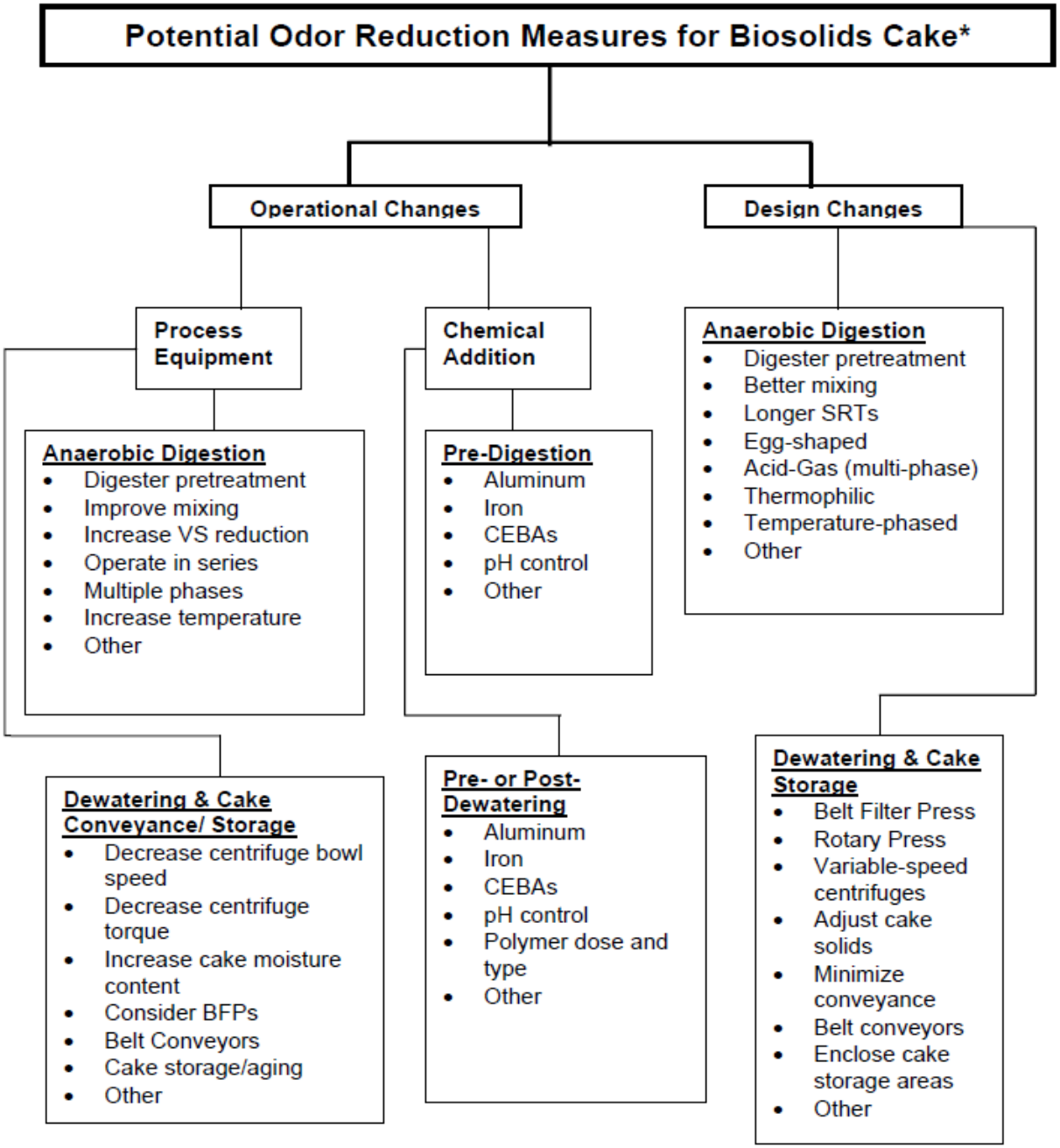
Further Studies on Fe and Al Addition



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



http://borr.werf.org

Current Project - Laboratory Scale Investigations of Possible Odour Reduction Strategies in Biosolids

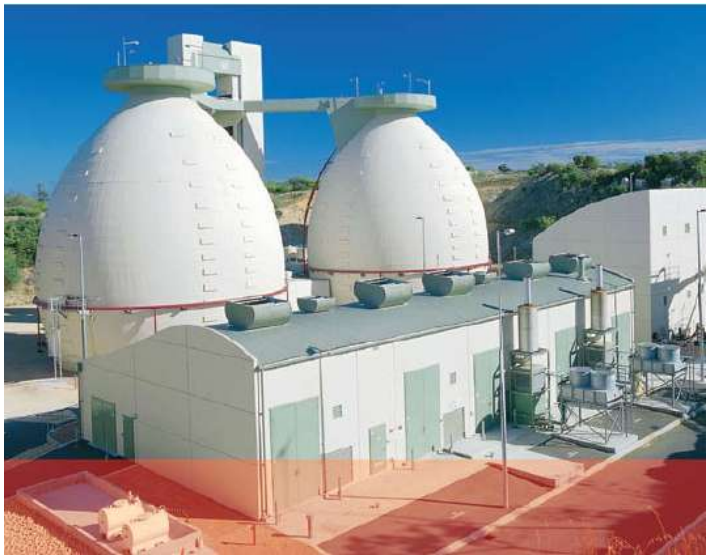
Project objectives include:

- 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.

Current Project - Laboratory Scale Investigations of Possible Odour Reduction Strategies in Biosolids

- 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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Odorous Compounds Associated with Biosolids (Rosenfeld & Suffet, 2004)

Compound	Odour Character	Compound	Odour Character
Nitrogen Compounds			
Ammonia	Pungent		
Methylamine	Fishy		
Triethylamine	Fishy		
Trimethylamine	Fishy		
Sulphur Compounds		***Aldehydes and Ketones***	
Ethyl mercaptan	Rotten cabbage	Formaldehyde	Unpleasant
Hydrogen sulphide	Rotten eggs	Acetaldehyde	Green sweet
Carbon disulphide	Disagree, sweet	Acetone	Sweet, minty
Dimethyl sulphide	Rotten cabbage	Acrolein	Burnt, sweet
Dimethyl disulphide	Rotten cabbage	Propionaldehyde	Sweet, ester
Dimethyl trisulphide	Rotten cabbage	Crotonaldehyde	Pungent, suffocating
Methyl mercaptan	Rotten cabbage	Methyl ethyl ketone	Sweet, minty
Allyl mercaptan	Garlic coffee	Butyrladehyde	Sweet, rancid, sweaty
Propyl mercaptan	Unpleasant	Valeraldehyde	Pungent
Amyl mercaptan	Putrid		
Benzyl mercaptan	Unpleasant		
Sulphur dioxide	Irritating		
Odorous Volatile Aromatic Compounds		***Volatile Fatty Acids***	
Indole	Faecal nauseating	Formic acid	Biting
Skatole	Faecal nauseating	Acetic acid	Vinegar
p-cresol	Medicine	Propionic acid	Rancid, pungent
Toluene	Sweet, pungent	Isobutyric and butyric acid	Rancid
Ethylbenzene	Gasoline	Isovaleric acid	Unpleasant
Styrene	Sweet	Valeric acid	Unpleasant