New Technology for Wastewater Control
– Cutting-Edge Treatment Technology to Reduce Odors in Biosolids –

Daniel WOLTERING[1]
Water Environment Research Foundation

1. Introduction

The overall purpose of this research is to seek ways to enhance anaerobically digested and dewatered biosolids to reduce odor intensity in biosolids cake and thereby reduce the impact on the environment of its beneficial use or disposal**.** Reduction of biosolids cake odors is one of the most important needs expressed by Water Environment Research Foundation (WERF) members. At a WERF-sponsored specialty workshop at the 2000 Water Environment Federation Technical Exposition and Conference (WEFTEC) in Anaheim, California, the WERF members voted biosolids odor issues as the highest priority for future research and specifically the influence of in-plant solids treatment processes (such as storage, thickening, anaerobic digestion, and dewatering) on biosolids odor quality. In addition, the biosolids management industry is in a state of flux as to how to properly handle, treat, dewater, and store biosolids to prevent odors while assuring compliance with present and anticipated changes to the USEPA 40 CFR Part 503 regulations governing biosolids quality.

This study focuses on the dewatering and digestion processes and equipment currently used by wastewater treatment plants (WWTPs), as well as those that are proposed to meet 40 CFR Part 503 requirements. Equipment or process vendors were invited to demonstrate their products full-scale at one or two WWTPs while the WERF team collects and analyzes data and compares results. Any promising laboratory study result will be considered for full-scale field testing in this project, in anticipation that it would lead to changes in how biosolids are digested, handled, dewatered, treated, or stored. Practical economic considerations were also be factored into the evaluation and selection of promising laboratory results to be translated to full-scale.

The conclusions of this study are intended to provide a wastewater treatment plant owner with a roadmap to develop approaches and strategies that will reduce dewatered biosolids cake odors. Biosolids cakes with minimal odors lead to better public acceptance near biosolids management sites and in neighborhoods adjacent to WWTPs. Reduced odors also could open this dewatered biosolids cake to other biosolids recycling or disposal opportunities currently not used due to odor concerns (including on-plant site composting or storage). Additionally, significant cost savings could be realized by not requiring extensive odor control or other expensive options for containment and management of biosolids.

2. Overview

This research is a multi-year study (2000–2007) conducted in three distinct phases by the same team of researchers. Different team members participated in the phases depending upon expertise required and the objectives of each phase. At the time of the January 2007 Japan-US Conference, the research team is preparing the final report including the "roadmap" to guide wastewater treatment plant owners to reduce odors associated with biosolids at their plants.

[1] 635 Slaters Lane, Suite 300, Alexandria, Virginia, 22309, USA

e-mail:dwoltering@werf.org

The first phase, conducted between 2000 and 2001 involved literature and practitioner surveys of odors in the municipal wastewater environment. The intent was to summarize information on odor characterization for wastewater treatment systems including applicable odor sampling and measurement approaches for potential sources, state-of-the-art odor control technologies and strategies, lessons learned for viable and innovative odor control strategies and technologies, and key gaps in knowledge of technology in addressing odor issues from collection through final treatment and effluent disposal including biosolids disposal. These findings were summarized in a WERF report entitled *Identifying and Controlling the Municipal Wastewater Odor Environment.*

In the second phase of research, conducted between 2002-2003, field work at 11 WWTPs lead to a better understanding of the various locations and possible causes of odors during digestion and dewatering. It was confirmed that biosolids cakes, following dewatering, typically produce the worst odors in a wastewater treatment plant. Further it was found that high shear dewatering processes such as high speed centrifugation produces more odors than pressing type processes. Biologically available protein was confirmed to be the main contributor to the odor potential of biosolids. Odorous compounds are produced as proteins degrade to form polypeptides and amino acids which are consumed by microbes. Also as part of the research, a new method for sampling and analyzing odors in biosolids cake was developed. Biosolids samples were collected and incubated (under ambient conditions) in small, air-tight sample bottles for at least 6 days. The olfactometry measurements in the bottle headspace were much higher than would be sensed by an individual onsite, or from the olfactory analysis of an air sample gathered by flux chamber or another type of field headspace (as opposed to sample-bottle headspace). While it is recognized that the bottle-headspace sampling method may not represent actual field conditions, the consistency of sampling and analytical protocols that were used for all 11 WWTPs in the study resulted in a useful and statistically valid comparison of the large number of samples collected. The complete results of the second phase are reported in a WERF publication entitled *Impacts of In-Plant Operational Parameters on Biosolids Odor Quality*.

An ancillary part of the second phase of research was an evaluation of whether the experience of odors, i.e., odors as sensations, from biosolids at wastewater treatment plants (WWTPs) might cause illness. There exists no repository of information on the numbers of complainants with illness, their specific complaints, or the relationship between degree of exposure and complaints. Anecdotal reports nevertheless imply a pattern much like that associated with other industrial malodors. Symptoms claimed in connection to odors from biosolids in particular seem to come from olfactory rather than chemesthetic (irritating) stimulation. Although not inappropriate to the experience of malodors, the symptoms seem to occur via intermediate variables, such as annoyance, anxiety, and frustration. Persons who experience no such distress apparently experience no symptoms. Any connection between odor and illness has received little note among the large number of articles in the medical literature. This state of affairs presumably exists because odors *per se* generate no objective signs of illness in otherwise healthy persons. However, malodors may exacerbate both symptoms and signs of illness in persons with certain chronic disorders, such as asthma and migraine. Vulnerability to such effects may vary considerably from person to person. The WERF report is entitled *Health Effects of Biosolids Odors: Literature Review and Analysis.*

As a follow on to this work, WERF is currently conducting research to develop a protocol for the timely characterization of reports of adverse health effects following likely exposure to land-applied biosolids. The intent is that local health officials would use the protocol in their evaluation of reported health incidents and that the information would be used to identify and

reduce exposures if, in fact, there are any health effects or risks identified. The protocol should be available by the end of 2007.

The third and current phase of this research program began in 2004. The laboratory and field work has been completed and the data analyzed. The final report is expected to be available by the end of the first quarter of 2007. This phase is entitled *Biosolids Processing Modifications for Cake Odor Reduction.*

This phase focuses on the dewatering and digestion processes and equipment currently used by WWTPs as well as those that are proposed to meet 40 CFR Part 503 requirements. Evaluate cake odors and reduction as a function of chemical addition, and digestion and dewatering process. Eleven WWTPs across the USA were involved in the collection of information and data as well as sampling and analysis. Eight commercial vendors of agents intended to reduce biosolids odors were invited to submit their chemical, biological or enzymatic agents (CEBAs) for test demonstrations in the laboratory and at the full-scale if they showed promise in the laboratory.

The laboratory studies done at the beginning of the third phase confirmed that volatile organic sulfur compounds (VOSCs) are the main source of odors in anaerobically digested biosolids. The principal components of VOSCs and those that were monitored in the study include methyl mercaptan (MT), dimethyl sulfide (DMS) and dimethyl disulfide (DMDS). These VOSCs and odors are produced and then degraded during biosolids storage.

The effects of chemical addition before and after digestion and dewatering were evaluated for iron, aluminum sulfate (alum) and a wide range of CEBAs. More iron in wastewater leads to more VOSCs and more odor. This was demonstrated in the laboratory and confirmed in the field at one wastewater treatment plant. Eight (8) proprietary CEBAs were tested. 4 were added pre-digestion and 4 added post-digestion (either before or after dewatering). The dosage amount and frequency was done according to the directions from the vendor. Only one of the eight CEBAs tested appeared to improve cake odor reduction over the untreated controls, but that one severely inhibited the digestion process and thus was not a viable solution. One of the eight actually increased the odor in the biosolids cakes. Post-digestion alum addition showed promise for odor reduction in the laboratory. Alum field trials showed less consistent, but largely positive results in reducing odor. Peak VOSC levels were significantly reduced with the addition of both 2% and 4% alum by weight.

The evaluation of various anaerobic digester processes on odor included the study of digestion time (SRT or solids retention time), the homogenization of the sludge prior to digestion, and the configuration of the digester comparing egg-shaped digesters with two-phase (acid-gas) digesters with a more conventional mesophilic digester.

While VOSC was reduced with SRTs extended beyond 10 days up to 30 days, the levels did not get below 1000 ppmv which is still an odorous sludge. Utilizing the MicroSludge™ process before mesophilic anaerobic digestion significantly reduced cake odors. The MicroSludge System uses chemical pre-treatment and a cell disrupter to burst the microbial cells in waste activated sludge (WAS). The resulting liquefied WAS is readily converted to biogas in an anaerobic digester. The egg-shaped digester produced less odor than the two-phase (acid/gas) digester. And both of these configurations produced considerably less odor in biosolids cake than did the conventional mesophilic anaerobic digester.

A Centrifuge Scroll Test was conducted on a high speed centrifuge as part of the study to determine the effect of dewatering processes on cake odor. Several locations within the

centrifuge were sampled and the analysis of VSOC clearly indicated the level of odor was higher immediately after the digested sludge was sheared and as it left the centrifuge. The overall comparison of various dewatering processes indicated that cake produced by centrifuge had the highest odors produced followed by rotary press and then belt filter press. Centrifuge type and operation (bowl speed, torque, and feed rate) was also seen to impact odor production. The dewatering effect appears to be related to centrifugal shearing of the biosolids, which appears to make protein more bioavailable, thereby producing more TVOSC from protein decay.

In summary, the aspects of the digestion and dewatering processes that appear to have the best potential for reducing biosolids cake odor include: sludge homogenization before digestion, increased solids retention time, lower iron in the wastewater, digester configuration, and reduced shear during dewatering and handling. The addition of alum post-digestion but prior to dewatering was also found to help reduce cake odor. These aspects may work in a complementary manner, and some or all may be needed for significant odor reduction in biosolids cake. The eight commercially available CEBAs that were tested did not reduce cake odor.

While much was learned from this research program, it only forms the foundation for what will need to be numerous further trials, demonstrations and the sharing of findings by wastewater treatment plants to build a database of experience. This experience will provide guidance as to what adjustments work and are cost effective. The final report (available by the end of the first quarter of 2007) will provide an initial “roadmap” of approaches and strategies that a wastewater treatment plant owner can try in order to reduce dewatered biosolids cake odors. It will cover both the processing equipment and the chemical addition aspects of operational decisions as well as the designs of digesters and dewatering to minimize cake odors.

Japan - US Governmental Conference on Drinking Water Quality Management and Wastewater Control

January 22-25, 2007, Bankoku Shinryokan, Okinawa

Treatment Technology to Reduce Odors in Biosolids

presented by

Dan Woltering, Ph.D.
Director of Research

Water Environment Research Foundation

1

Water Environment Research Foundation Top Issues for Wastewater

- Nutrient removal
- Sustainable asset management
- STP operation optimization
- Risk of trace contaminants
- Health risks of wastewater microbes
- Stormwater management
- Biosolids health risks and odors

2

Project Participants

Water Environment Research Foundation

Principal Investigators

- CH2M Hill
- Los Angeles County Sanitation Districts

Additional Research Participants

- Virginia Polytechnic Institute & State University
- Bucknell University
- Moore Engineering Consultants
- 11 participating wastewater utilities
- 8 participating commercial product vendors

3

Project Goals

- To cost-effectively produce dewatered biosolids of significantly reduced odor intensity
- Provide treatment plant owner with a “roadmap” of process modifications that can be considered to reduce dewatered biosolids cake odor
  - Focus on digestion and dewatering equipment and processes now in use to meet regulations

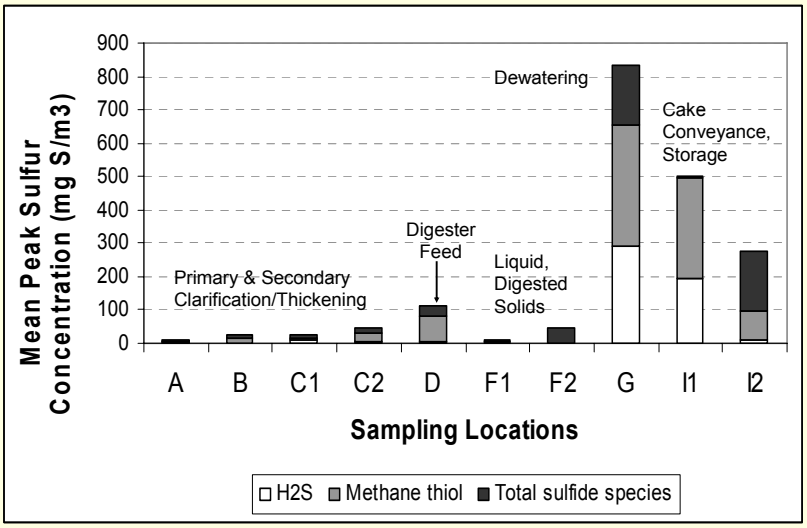
4

Project History/Overview

- **Phase 1** (2000-2001): Literature survey of odors in the municipal wastewater environment. ***Product: Literature Search, Review, & Analysis***
- **Phase 2** (2002-2003): Field work at 11 WWTPs that helped understand the various locations and possible causes of odors during digestion and dewatering. ***Product: Impacts of In-Plant Parameters on Biosolids Odors***
- **Health Effects Addendum** (2004): Review and summarize evidence surrounding potential health effects of biosolids odors. ***Product: Health Effects of Biosolids Odors: Literature Review and Analysis***
- **Phase 3** (2004-2006): Laboratory and field tests with additives to determine if odor reductions can be achieved and recommendations on what a plant can do to reduce odors. ***Product: Biosolids Processing Modifications for Cake Odor Reduction***

5

Phase 2 confirmed that biosolids cakes typically produce the worst odors in a Wastewater Treatment Plant (WWTP)



6

Phase 3 Objectives

- Evaluate cake odors and reduction as a function of:
  - Chemical addition
  - Digestion
  - Dewatering process
- Lab scale first and then try it in the field

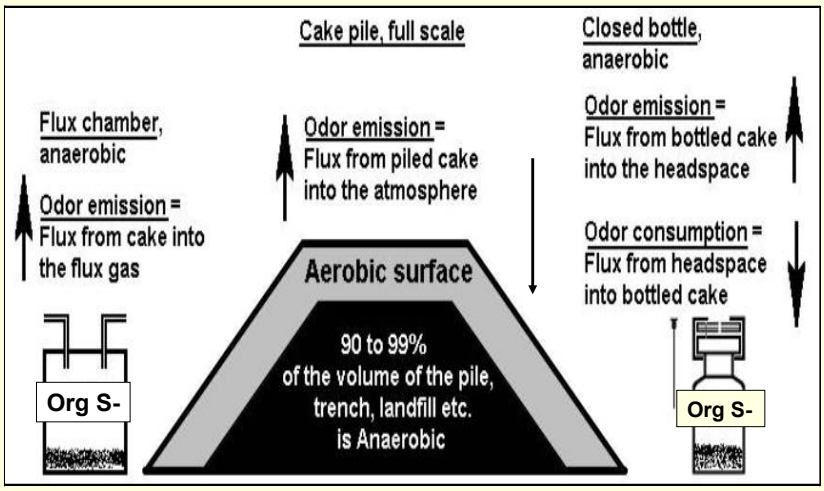
7

Components of Phase 2 Research

- Develop sampling methods for total volatile organic sulfur compound (TVOSC) as a surrogate for odors
- Confirm correlation between TVOSC and odors from biosolids

8

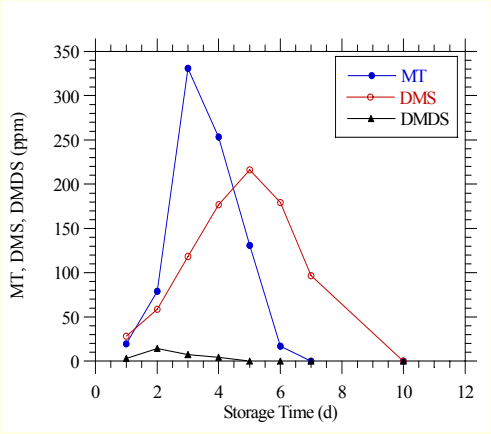
Closed cake sample bottle simulates anaerobic cake storage environment:



9

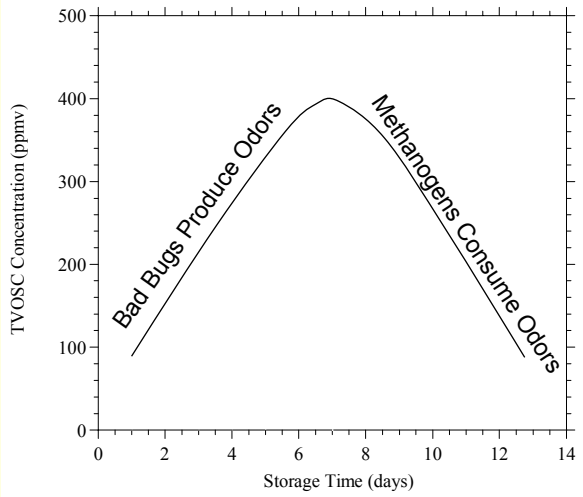
Findings from Phase 2

- Volatile organic sulfur compounds (VOSCs) are the main source of odors in anaerobically digested biosolids
- VOSCs and odors are produced and degraded during storage



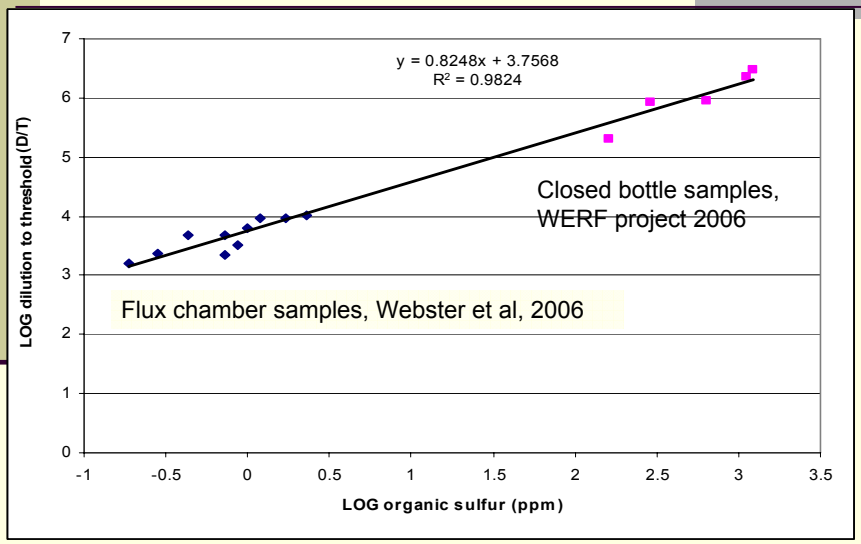
10

Why are TVOSCs and Odors Reduced ?



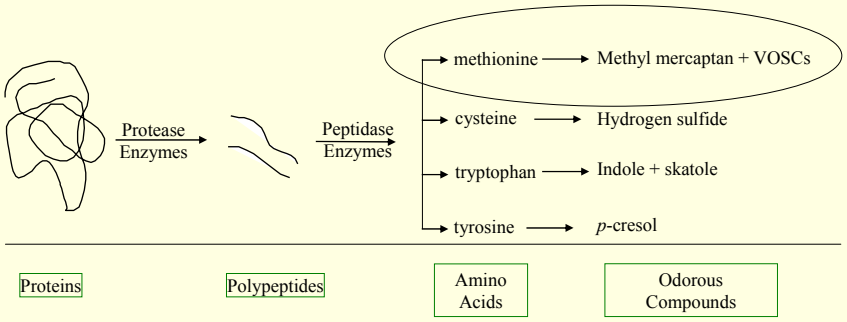
11

Correlation between TVOSC and odors as measured by dilutions-to-threshold (D/T) was corroborated



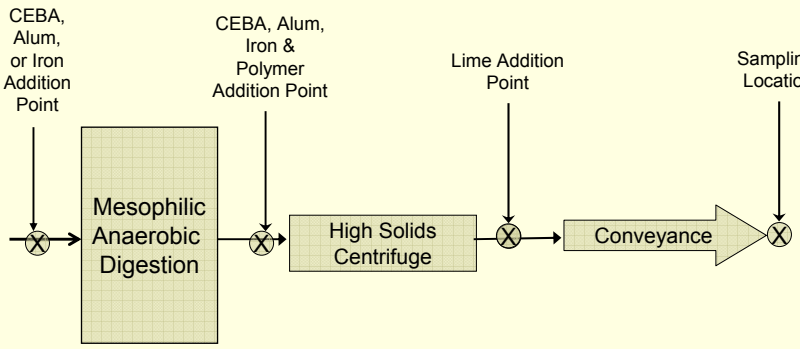
12

Cause of Biosolids Odor: Odorants are produced from protein degradation



13

Effect of Chemical Addition

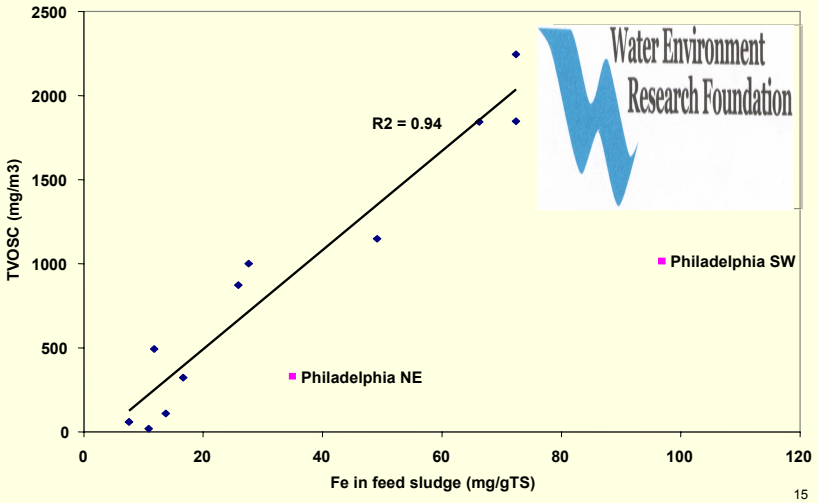


CEBA = chemical, enzymatic or biological agent

Alum = aluminum sulfate ($Al_2(SO_4)_3$

14

More iron in the wastewater leads to more TVOSC - blue are lab and pink are field data



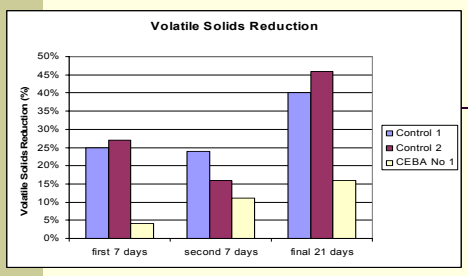
15

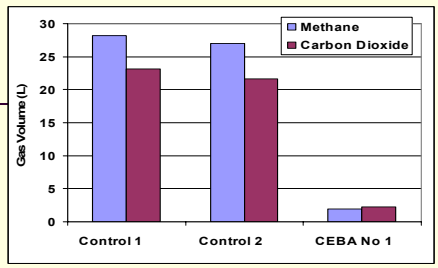
Tests of Chemical, Enzymatic, and Biological Agents (CEBAs)

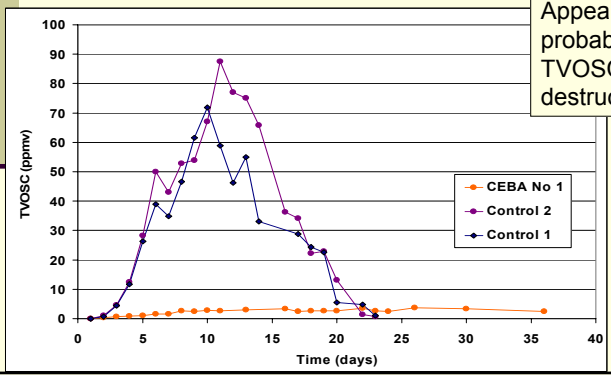
- Eight (8) proprietary CEBAs were tested, 4 added pre-digestion and 4 added post-digestion
- The dosage amount and frequency was according to the directions from the Vendor
- Digestion was batch-wise with two different 50% exchanges of fresh sludge on days 7 and 14 with an additional 21 days of digestion
- An initial 20% seed of digested sludge and a balance of 50/50 mix of primary/secondary sludge was used
- Post-digestion CEBAs were added before & after dewatering
- Only one of the eight (8) CEBAs tested appeared to improve cake odor reduction over the untreated controls, but that one severely inhibited the digestion process…

16

CEBA No. 1: Added Pre-digestion







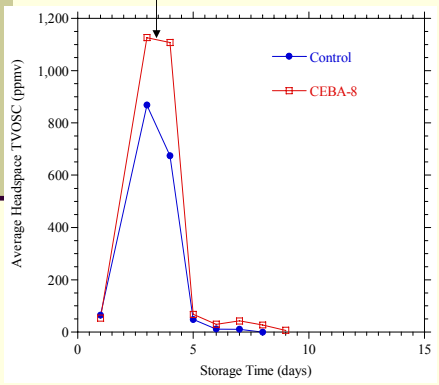
Appeared to be inhibitory, probably due to low pH. Low TVOSC but also low VS destruction and gas production

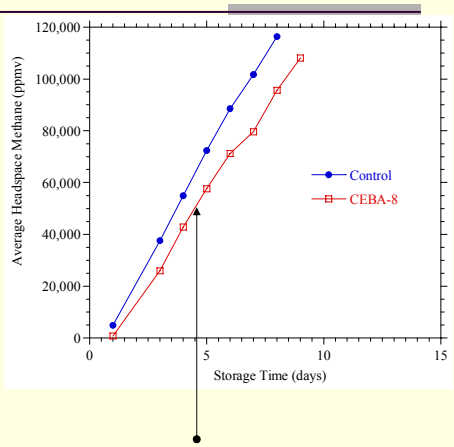
We would expect that, if the inhibition were eliminated, TVOSC would be generated

17

CEBA No. 8: Added post-digestion, prior to dewatering

CEBA No. 8 produced higher odor…

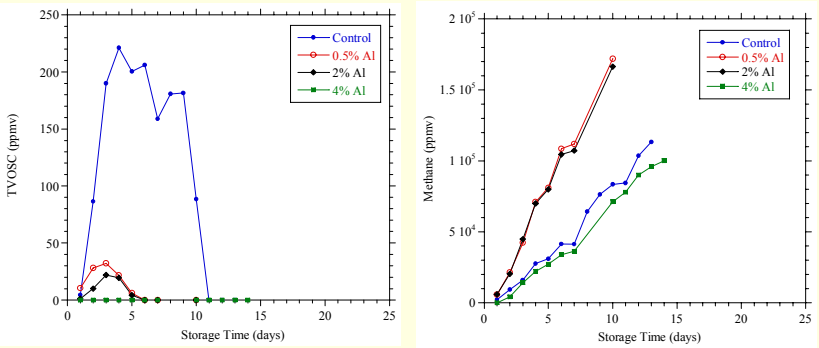




…and had lower methane production

18

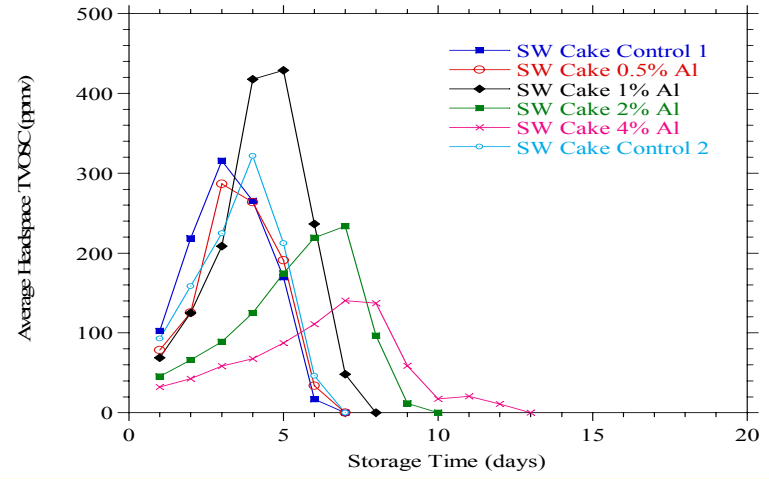
Post-digestion Alum Addition Showed Promise for Odor Reduction in the Lab



TVOSC and Methane Production vs. Cake Storage Time at Varying Alum Doses (Optimum Polymer Dose)

19

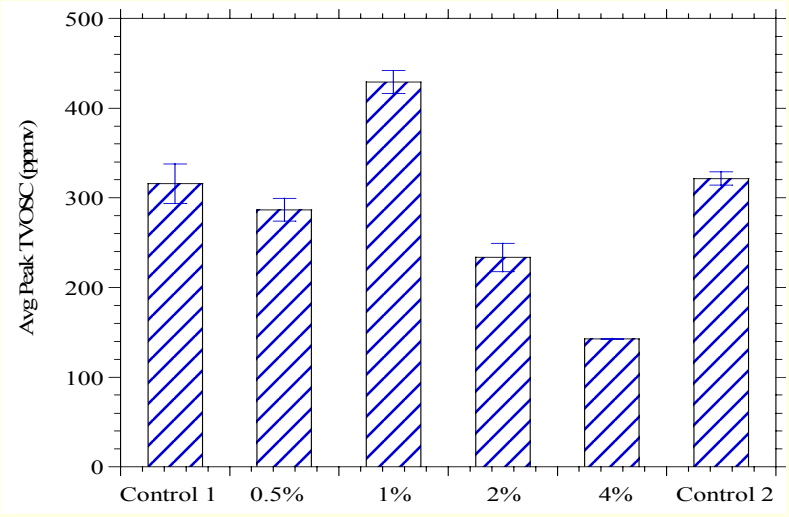
Alum Field Trials showed less consistent, but largely positive results



Digested solids dewatering from Philadelphia WWTP

20

Same Alum Field Trial Results as a Bar Chart, Comparing Peak TVOSC at Different Alum Doses



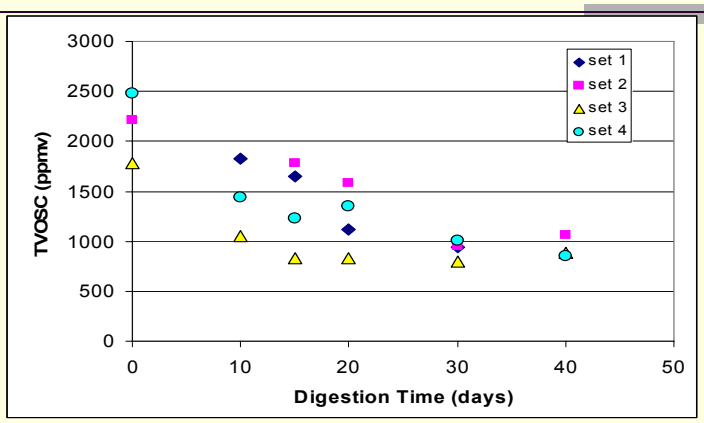
21

Effects of Anaerobic Digestion Processes on Cake Odor

- The next three slides show:
  - Effect of Mesophilic Anaerobic Digestion Time (SRT) on Volatile Solids Reduction and TVOSC
  - Effect of Activated Sludge Homogenization prior to Anaerobic Digestion on TVOSC
  - Effects of Egg-shaped Digesters and Two-phase (Acid-gas) Digestion compared with Conventional Mesophilic Anaerobic Digestion

22

Lab digestion – the SRT study

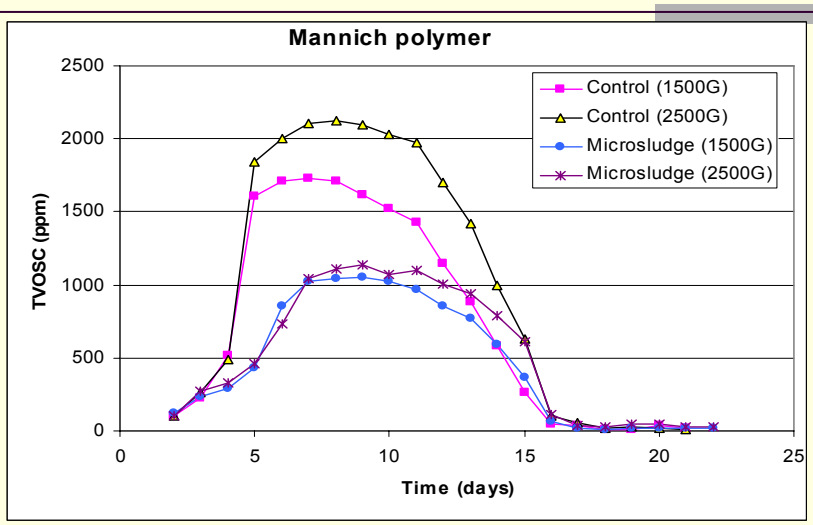


What do we see?

- Improved TVOSC reduction to 30 days
- Can't seem to get below 1000 ppmv
- This is still an odorous sludge after 40 days digestion time

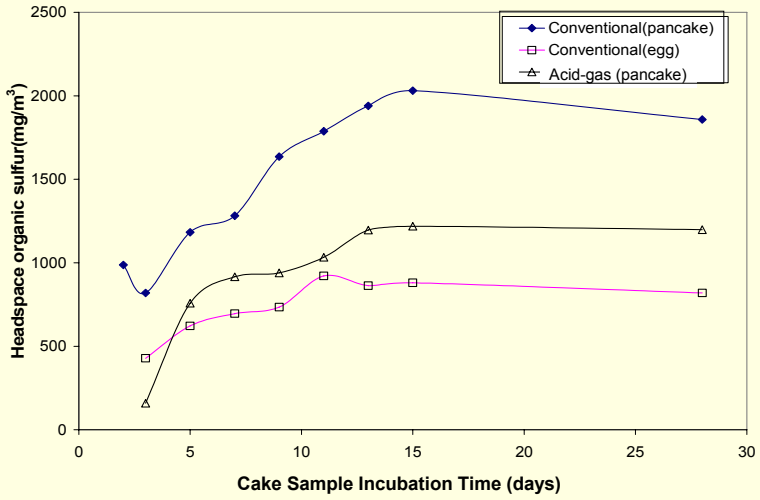
23

The MicroSludge™ Process before Mesophilic Anaerobic Digestion Reduced Cake Odors



24

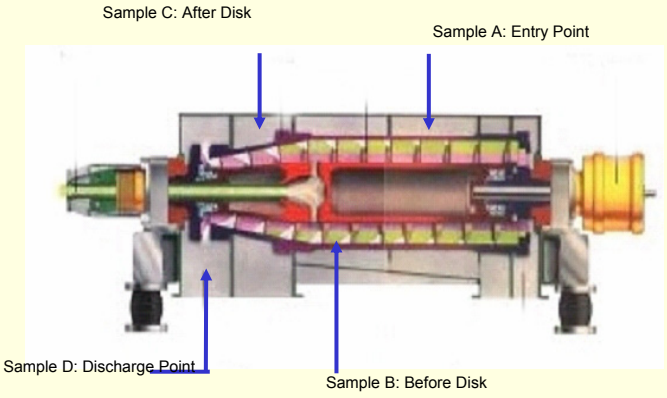
Two-phase (Acid/gas) & Egg-shaped Digesters are Better than Mesophilic Anaerobic Digestion For Odor Reduction



25

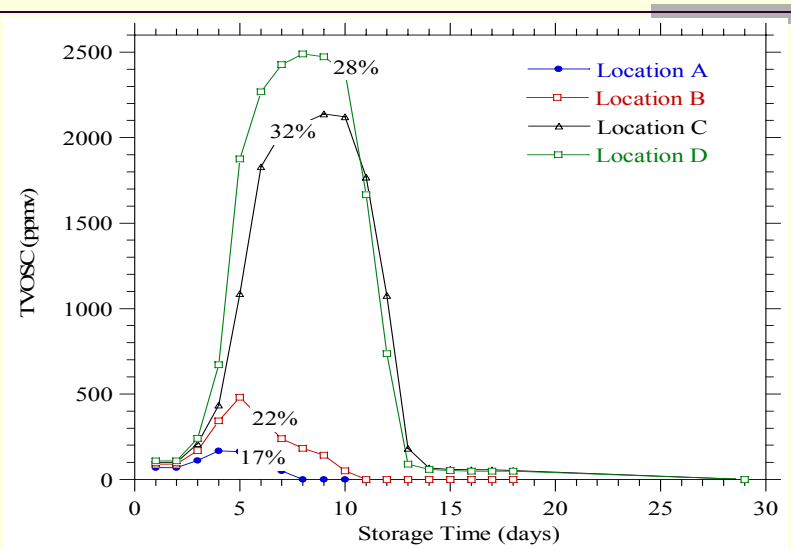
Effect of Dewatering Processes on Cake Odor

Centrifuge Scroll Test – Sample locations



26

Centrifuge Scroll Test: odor results by sample location



27

Dewatering Conclusions

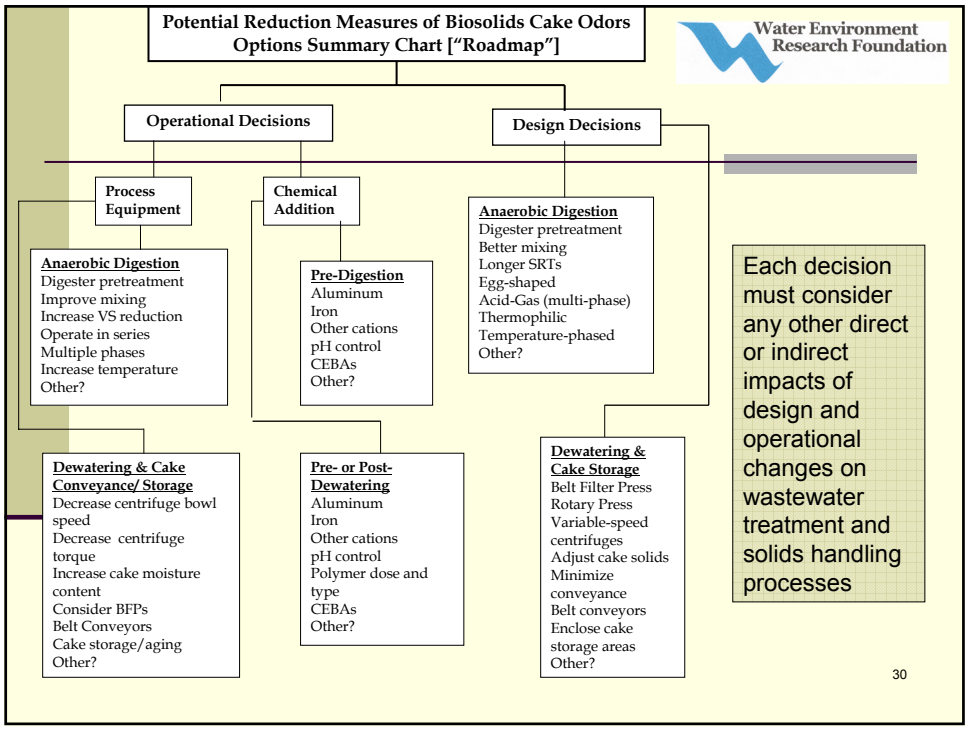
- Dewatering process has significant impact on odor production:
  - Centrifuge >> Rotary Press > Belt Filter Press, in terms of cake odors produced
- Centrifuge type and operation (bowl speed, torque, feed rate) can also impact odor production
- Main effect appears to be related to centrifugal shearing of the biosolids, which appears to make protein more bioavailable, thereby producing more TVOSC from protein decay

28

Phase 3 - Overall Observations

- Sludge homogenization before digestion can reduce odor
- Increased solids retention time can reduce odor
- Higher iron in the wastewater can lead to increased odor
- Digester configuration can affect cake odor
- Addition of alum post-digestion but prior to dewatering can reduce odor
- Reduced shear during dewatering and handling can reduce odors
- These aspects may work in a complementary manner, and some or all may be needed for significant odor reduction in biosolid cake
- The commercially available CEBAs that were tested did not reduce odor

29



30

Thank you

The final report, which will include the “roadmap” is expected in Q1 of 2007

Contact information:
Dr. Dan Woltering
dwoltering@werf.org

31