Charting the Future of Biosolids Management

A WEF/NBP Perspective

by

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CH2M HILL Residuals Resource Recovery Leader

and

WEF RBC Chair

April 2, 2013
Biosolids is a core focus area for WEF and the NBP continues to be an important part of its overall biosolids program.

Starting in 2010, NBP began offering a series of “no charge” quarterly webcasts devoted to general biosolids management and technical topics of interest to water quality and biosolids professionals.

WEF is part of an alliance which includes NACWA and EPA that comprise the National Biosolids Partnership (NBP). The NBP sponsors a number of technical and educational programs for appropriate biosolids management including EMS training.
Overview of Workshop Objectives

- Sponsored by WEF and NBP
- December 1–2, 2010 in Alexandria, Virginia
- Encouraged open discussion among 30+ practitioners to set course of future WEF and NBP efforts
- Focus on:
  - Regulatory Drivers
  - Technology Trends
  - Operation and Management Issues
  - Training
Objectives of the Forum

To Identify regulatory and public policy drivers; trends in technology, operations and management; professional and training needs; and research needs in the coming decade.
Forum Steering-Advisory Committees

Steering Committee:
- **Mike Moore** – HDR – Steering Committee Chair
- **Bob Dominak** – North East Ohio Regional Sewer District & Co-Chair NACWA Biosolids Committee
- **Greg Kester** – California Association of Sanitation Agencies & Former State Biosolids Coordinator
- **Jim Smith** – Malcolm Pirnie & Former U.S. EPA
- **Todd Williams** – CH2M Hill & Chair WEF Residuals & Biosolids Committee

Advisory Committee:
- **Alan Hais** – Water Environment Research Foundation
- **Chris Hornback** – NACWA
- **Jim Horne** – U.S. EPA
Steering Committee Charge

Assure Balanced Representation from Biosolids Community

- Academia/Research
- State & Federal Regulatory
- Municipal Biosolids Managers
- Biosolids Service Providers
- Equipment Supplier/Manufacturer
- Consultants
Identify and Assess

- Regulatory and Public Policy Drivers
- Trends in Technology
- Trends in Operations and Management
- Outreach, Training and Research Needs

Final report - Available on NBP web page. Webcast is recorded and posted on www.biosolids.org
Concerns Regarding the 503 Rule

- **EPA Response to NAS Report**
  - Essentially complete
  - 14 Projects, including TNSSS

- **Risk Factors**
  - Arsenic
  - Dioxin

- **Validity of Indicator Organisms**
  - Emerging pathogens
  - Variety of pathogens

- **Biosolids Odor and Emissions**
  - Stability
  - Odor and health impacts

- **Phosphorus-based Management**
  - Variations in state regulations
  - P availability

- **Research and Emerging Issues**
  - Trace organics
  - Emerging pathogens, and more
Emerging Issues and Research

- **Trace Organics**
  - Fate and transport
  - Bioassays

- **Indicator Regrowth, Odors and Sudden Increase (ROSI)**

- **Emerging Pathogens**
  - Fate and transport

**Odor Research**
- Compounds associated with longer-term odorants
- Mechanisms for production
- Reducing methanogen inhibition
- Benchmark low odor product
- Targeted control

**Effect of Processes**
- Land application, storage, dewatering, digestion, upstream collection and treatment, amendments

**Inhibition of Indicator Growth**
- Factors impacting indicator regrowth

**Regrowth Research**

**Sudden Increase Research**
- New culturing method
- Time-temperature curve
- Mechanism of reactivation

Source: Higgins, et al., 2010
Public Perception: “Persistent Uncertainties” Remain

- Survey of regulators found that it is greatest pressure on biosolids programs (NEBRA, 2007)
- Survey showed only 14% of public know what “biosolids” means (NEBRA, 2004)
Need biosolids-specific, standard protocols to quantify carbon footprints
Incentives for renewable energy
Our Changing View of Beneficial Use

1991:
“Beneficial Use means any application of sludge on land specifically designed to take advantage of the nutrient and other characteristics of this material to improve soil fertility or structure and thereby further some natural resource management objective.”

Proposed 2007:
“Putting a particular biosolids product to its best and highest use by maximizing the utilization of nutrients, organic matter, moisture, and/or other qualities – including extracting the maximum amount of energy possible.”

Source: NEBRA, 2007
Our Changing View of Solids Management

- **Sludge Disposal** (1970)
- **Biosolids Beneficial Use** (1993)
- **Bioenergy** (2000)
- **2010**
Biogas: Looking Beyond Boilers and Internal Combustion Engines

- Boilers
- I.C. Engines
- Blowers
- Fuel Cells
- Heat Dryers
- Micro-Turbines
- Natural Gas
- Vehicle Fuel
Anaerobic Digestion: Focus on Optimization

- Enhanced mixing
- High temperature (Thermo. vs. Meso.)
- Dual phases
- Increased solids retention
- Pretreatment
Co-Digestion: Going Beyond the Fence Line to Optimize Biofuel Production

FOG (fats, oils, grease)

Food Waste

Biodiesel

Biogas
Other Trends

- Dewatering – simplicity, enclosed units, enhanced performance
- Nutrient harvesting (P)
- Odor minimization
- Energy optimization
- Solids minimization

Rotary Fan Press
Regulatory and Public Perception Issues

We Hold These Truths to Be Self Evident

- **Public Perception** - Frequently Drives Regulatory Policy (Strong science is not enough anymore!)

- **Regulatory Landscape** - Increasing in its Complexity (cost, achievability and common sense sometimes don’t matter anymore!)
Two overarching themes emerged from meeting discussions, both of which can be considered to be current and future drivers of solids management programs.

- **First**, the regulatory and policy landscape remains complex and is likely to become more so over time.

- **Second**, public perception will continue to be a key driver of both regulation and policy.
Multiple drivers will continue the current trend of increasing public involvement in solids management and a corresponding need for enhanced communications regarding regulations, environmental impacts, and health concerns

- Generally diminishing role of regulatory agencies communicating with the public on Part 503 rule and biosolids issues.
- The 503 rule is 20 years old - intermittent and generally local challenges to land application, most programs operate successfully under the rule directly or under similar state rules.
- Constrained federal and state resources may continue to leave biosolids managers and others in the profession as the primary educators of the public on biosolids issues and regulations.
Communication – and coordination – with EPA departments and other agencies that have not historically been involved in solids management will become increasingly important:

- For example, WEF and NACWA found branch of EPA developing sewage sludge incineration (SSI) proposed rule was unfamiliar with unique issues associated with wastewater solids incineration in the U.S.
- Considerable dialogue and data sharing was required to help the agency better understand SSI operations as they developed the proposed rule.
- SSI rule development exemplifies another trend that will complicate the regulatory landscape for solids management: cross-media issues (in this case, air quality).
Regulatory Drivers

Regulations Beyond the Part 503 Regulations

- SSI Rule
- Volatile organic compound (VOC) emission restrictions in ozone non-attainment areas
- Phosphorus land application limitations
- Organic product certification requirements from USDA
- Increasing link between biosolids and solid waste and other residuals such as animal manure
- Greenhouse gas (GHG) mitigation efforts
As the biosolids sector increasingly deals with cross-media regulatory impacts, it will be critical to emphasize the concept of “maximum environmental benefit” in regulatory development.

Participants believed it is critical for biosolids sector to promote development of a multi-agency regulatory coordination strategy, including a comparative risk, cross-media approach to regulatory development.

And last, solids managers and other experienced professionals will need to provide guidance to regulators as new products emerge from wastewater and biosolids processing, and questions arise as to how (or if) those products should be regulated.
An increasingly fragmented regulatory framework for biosolids

- A trend toward greater stringency in state level regulations, resulting in “patchwork” of different approaches to solids management nationwide and increasing departure from 503 rule.
- In some cases, new state regulations have been promulgated after years of planning but, in other cases, they have arisen suddenly (sometimes in response to a spill or other incident).
- This trend creates uncertainty for biosolids programs across the nation (especially those that operate in multiple states) and is not expected to reverse in the near term.
Public perception of biosolids management will continue to be closely associated with odors from processing, handling, and end use/disposal. Odor concerns are driving state and local regulatory activities, including odor management plans and, in some locales, “zero tolerance” approaches to biosolids odors. In addressing this issue, participants noted that compliance with 503 rule does not necessarily mean that product odor will be acceptable and suggested that modifications to current stabilization criteria might be warranted. Any modifications would need to consider product use, as product quality requirements will vary for different uses. Compost was noted as one example where modified criteria would be beneficial: carbon dioxide respiration and product curing requirements were discussed as potential methods to better ensure that a compost product is well stabilized.
The theme of biosolids as a renewable resource dominated workshop discussions and is perhaps the key to repositioning both the role and value of biosolids.

Funding and incentives will be required to fully leverage biosolids potential in this area. At present, however, biosolids do not qualify as a renewable resource under most assistance programs.

Achieving designation as a renewable resource on a federal level is deemed to be a critical step not only to expanded use of solids as a renewable fuel, but also to positioning utilities to take advantage of Renewable Portfolio Standards.

In response, the WEF Board of Trustees adopted a Renewable Energy From Wastewater Position Statement on 10/14/2011.
Participants recognized concerns regarding micro-constituents persist among the public, although research to determine the effects of biosolids-borne micro-constituents is still underway. Whole effluent toxicity testing for biosolids might address these collective impacts.

Research-based regulations are likely years away. In the interim, product stewardship is needed.

Specifically, the group cited voluntary pollution prevention programs (such as the US Department of Fish and Wildlife’s, American Pharmacists and the Pharmaceutical Manufacturers of America SMARxT Disposal program) to reduce micro-constituent disposal to sanitary sewer systems.
Participants focused substantially on the persistence of public perception issues.
Perception issues have driven local and state regulatory and policy actions.
Actions have limited biosolids management options:
- Land application bans
- “Pseudo-bans” related to complex and time-consuming permit requirements and broad community pre-notifications.
The persistence of public perception issues was linked to a complex mix of factors including the following:

- Overall sense that sector has failed to answer certain key questions related to public health risks and to build effective relationships with important stakeholders.
- Some well organized, biosolids management detractors are driven by an interpretation of the “precautionary principle” that suggests substantially constrained biosolids management options.
- Lack of data and updated methods and indicators to respond to public health and ecological concerns when they are raised, in part due to the low priority EPA has placed on biosolids, which has resulted in limited funding to conduct studies and update methods.
Public Perception Drivers

- **Absence of trusted, credible messaging sources**, with several participants expressing their sense that EPA and state regulatory bodies are now reluctant to defend the safety of biosolids management methods when public concerns are raised.
- Potentially vulnerable practice of **utilizing land application sites outside the community** where biosolids are generated (referred to as the “urban-rural divide”).
- Potential chilling impact from recent experience of San Francisco being forced to withdraw a biosolids product from urban use might have on the willingness and ability of other operators to develop and introduce certain biosolids product types.
Discussion indicated that a failure to address key biosolids concerns (odors, pathogens, microconstituents, overall public perception, phosphorus loadings) holds the potential to substantially negatively impact biosolids management in the future. Identified impacts included:

- A more fragmented, state-by-state regulatory framework that increasingly drifts from the Federal 503 baseline
- Production of more perception-oriented Exceptional Quality (EQ) product
- Introduction of more restrictive management practices such as fence line setbacks and incorporation requirements; increased legal liability
- Greater uncertainty around the mid-term viability of technology and programmatic choices
- A substantial increase in management costs
- Substantially greater complexity associated with obtaining and maintaining management options
Technology Trends And Drivers
Drivers Influencing Biosolids Trends

- Strong public support for environmental stewardship
- Increased scrutiny of land application, incineration, and landfilling
- More stringent wastewater, biosolids, and air regulations
- Increased value for soil amendment, fertilizer, and renewable energy
Technology Trends

- Nutrient recovery from side streams
- Finer influent screens and sludge screens
- Enhanced hydrolysis and anaerobic digestion
- Codigestion of additional organic wastes
- Beneficial use of biogas for combined heat and power and biomethane
- Improved biosolids composting
- Biosolids drying, gasification, and incineration
Integrated Wastewater and Solids Treatment

Wastewater → Screening → Grit Removal → Primary Clarification → Aeration → Secondary Clarification → Disinfection → Reclaimed Water

- Screenings Grit
- Primary Sludge
- Secondary Sludge

- Thickening
- Biogas
- Fertilizer
- Biosolids

- Digestion
- Dewatering
- Receiving Water
- Treated Effluent
Beneficial Use of Biosolids

Technologies producing higher quality products and recovering more energy

- Thickening
- Anaerobic Digestion
- Dewatering
- Drying
- Gasification
- Incineration with Energy Recovery

- Biosolids
- Compost
- Soil Amendment
- Fertilizer
- Char
- Ash
Beneficial Use of Biogas
Technologies with greater efficiencies and lower emissions

Biogas

Fuel
Biomethane
Heat
Power

Engines, Turbines, Fuel Cells
Co-Digestion with FOG (fats, oils, grease) and other organic wastes results in additional biogas production.

Co-Digestion of organic waste at the Des Moines Wastewater Treatment Plant, Des Moines, IA (One example of an increasing number of plants practicing co-digestion)

Bench, lab, pilot, and full-scale co-digestion research
Finer Influent Screens and Sludge Screening Technologies to produce higher quality biosolids

- Finer influent screens
- Thickened sludge screens
- Protection of downstream equipment

Photo Courtesy of Huber
Enhanced Hydrolysis
Technologies to increase digestion performance, biogas production, dewatering performance, and biosolids quality

- Thermal Hydrolysis (with pasteurization)
- Biological Hydrolysis (Acid Phase Digestion)
- Mechanical Hydrolysis
- Chemical Hydrolysis

CAMBI thermal hydrolysis installation near London, UK
Enhanced Anaerobic Digestion
Technologies to increase volatile solids reduction, biogas production, and pathogen reduction

- High Rate Mesophilic
- High Solids Loading
- Continuous Feeding
- Efficient Mixing
- Thermophilic/Mesophilic
- Acid/Gas Phased
- Extended Solids Retention
- Higher solids concentration
Anaerobic digester designs are evolving.

- Oceanside WPCP, San Francisco
- Riverside Park WRF, Spokane, WA
- South Cross Bayou WRF, Pinellas County, FL
- Rock Creek AWT, Hillsboro, OR
- F. Wayne Hill Water Resources Center, Gwinnett County, GA
Steel-wrapped, pre-stressed concrete tanks are less costly than conventional reinforced concrete.
Solids Side Stream Treatment
Technologies to recover nutrients from solids processing

- Nitrogen and Phosphorous Recovery
- Turning a Struvite Problem into a Resource
- Reduce Side Stream Loading on Biological Nutrient Removal Process Stream

Photo Courtesy of Ostara
Improved Composting

- Better process controls
- Better odor control

Photo Courtesy of Engineered Compost Systems

Spotsylvania County, Virginia
Biosolids Dryers
Technologies producing marketable products for fuel and fertilizer

Low Temperature Belt Dryer
Barcelona, Spain

Rotary Drum, Direct Dryer
Carlsbad, CA
Biosolids Gasification and Incineration

- Improved emission controls
- Increased energy recovery
- Combustion technology
- Emerging gasification technology
Technology Trends Responding to Drivers Resulting in:

- Integrated wastewater and solids treatment
- High quality marketable biosolids products
- Energy recovery from solids processing
- Sustainable environmental stewardship
- Continued options for biosolids management
- Regional solutions
Outreach, Training, and Research Needs
Research

Cost efficiency in research is critical.

- Targeted collaborative research is a growing model (used by WERF)
- Research centers (e.g. U of AZ)

Increasing communications about research:

- “State of the Science” forums
- Reviews of older research, to keep the next generation current on it.
Specific research topics that rose to the top:

- Emerging pollutants/Microconstituents
- Phosphorus limits
- Stability & odors
- Energy production & efficiency
- Greenhouse gases mitigation

Note: This forum was not a “research summit,” not a thorough prioritizing of research needs.
Training

We have talented people, *but*...we need more!

- Retirements result in experience & knowledge leaving field
- Step up peer-to-peer mentoring
- Step up recruitment
- Step up training
It’s more complex, demanding more training...

- There are more diverse options; more uncertainties
- With energy demands, biosolids are an expanding resource, requiring new skills/knowledge (do you know how to run a microturbine yet?)
- More & diverse regulations to deal with (e.g. air regulations)
- Poorly-run programs need to be weeded out. Keep the bar high with more training & certifications (ABC Land Applier certification, EMS, etc.).
Need for outreach was a constant forum topic...

Why more outreach?

Natural skepticism & uncertainty re biosolids

Increased complexity of...

- Management options
- Technologies
- Goals & objectives (maximizing resource use)
- Regulations & policies (state & local regs diverging from 503 and each other)
- Public expectations & concerns
Outreach

Why is there still public concern?

- Uncertainties: e.g. “what ifs” re chemicals
- It’s hard to communicate complex science
- Effective tapping of concerns by organized opposition to beneficial use
- Limited regulatory resources (strong state oversight boosts public confidence)
- Use of biosolids outside area where they are generated (and other outrage factors)
Outreach

- In 2004, 14% could define “biosolids.”
- Forum participants urged systematic, proactive outreach.
  - Have crisis communication materials ready to go
  - Develop school curricula
  - Increase relationships with environmental, farm, and other groups
- Build upon existing communication network of WEF, NBP, NACWA, regional member associations, utilities (a “Liquid Assets” program for biosolids?)
 Outreach

Some outreach actions/programs discussed:

• Improve easily-accessible clearinghouse(s) of info (research results, success stories, best practices)
• Leverage new media (social media, broadcasting)
• Increase “peer-to-peer” mentoring (WEF is doing with MAs; some happening with EMS programs)
• Biosolids ambassadors – working with other groups on common ground

Reality check: Outreach costs $ and time. Need to prioritize; some things are done.
Stakeholders are demanding that other criteria besides costs be evaluated.*
Outreach

Most important:

DO IT RIGHT.

MANAGE BIOSOLIDS PROPERLY.

LET QUALITY SPEAK FOR ITSELF.
Outreach

Existing models to build on:

- Milorganite and other heat-dried products
- NBMA / King County branding their biosolids
- Tagro products / Biosolids compost products
- WERF 2004 research on public perceptions
- WERF current research on strategic risk communications around land application programs (Tulsa and Virginia examples)
- Existing network of NBP & regional groups
Drivers
- Changing regulations, technologies
- Focus on outreach
- Limited time for travel
- Aging and diminishing work force
- Changing delivery approaches (web)

Tools
- Conferences and seminars
- Web-based delivery
- Certification programs
- Design/practice manuals
- Fact sheets/Technical Practice Updates
- “Biosolids Libraries”
- Social networking
Operations and Maintenance Trends and Drivers
Resource Utilization—"Green Factory"

- Energy generation and capture
- GHG offsets
- Value added products
- Nutrient recovery
- Others
Operations and Maintenance Trends and Drivers

More Complex Operating Environment

- More complex regulatory environment/cross-media regulatory impacts
- Interaction with “non-traditional” regulators
- Moving beyond regulatory minimum
- Focus on triple bottom line
  ◦ (social, economic, environmental benefits)
- Flexibility/Diversification
Operations and Maintenance Trends and Drivers

More Complex Operating Environment

- Public/private partnerships
- Regionalization
- Increased focus on product quality
  - More emphasis on pollution prevention/source reduction
- Shift in regulatory burden to POTWs
- Increased training
Operations and Maintenance Trends and Drivers

Emphasis on Effective Communication

- Biosolids managers as primary communicators on regulatory and risk issues

- Risk and risk management issues
  - Emerging pollutants

- Technology and related impacts

- Energy-carbon footprint, etc.
Operations and Maintenance Trends and Drivers

Workforce Considerations

- Retirements-regulators and POTW staff
  - May drive regionalization
  - POTW staff as regulators?

- Loss of institutional knowledge
  - Will drive need for more documentation, etc.
  - Increased emphasis on training
Operations and Maintenance Trends and Drivers

Funding

- Competing priorities for capital
- May increase focus on public/private partnerships
US Biosolids Management Practices

- Reuse, surface disposal and incineration governed by 40 CFR Part 503
- Incineration further covered by 40 CFR 60 (SSI MACT) – February 2011
- Landfill by 40 CFR Part 258
- States have own regulations, at least as stringent as Federal rules
- Management practices vary by Region and State
Illinois – Land application is largest practice

Landfilling is next largest category

Wisconsin has 82% land applied

Minnesota has only 31% land applied and 69% incinerated

Trend towards energy efficiency and recovery, climate change
Charting the Future of Biosolids Management

A WEF/NBP Perspective

todd.williams@ch2m.com
The History of Milorganite
Production and Marketing of a Biosolids Fertilizer
MILORGANITE
How do we make this stuff?
Milwaukee circa 1890
Milwaukee River Flushing Station

1890's
Party corruption ushers in the Sewer Socialist Era in Milwaukee

David S. Rose
Emil Seidel
Gerhard Bading
Daniel Hoan

1900’s
1910’s
Jones Island Pre-Wastewater Treatment Facility

1890’s
1915 construction Jones Island WWTP
Jones Island Circa 1927
OJ Noer- Father of Milorganite
Early Sludge Field Studies

Early Cabbage, Wm. Waters, Milwaukee.

Fertilizer as indicated 1000 lbs. per acre applied to side row,
12 heads 4-8-6 - Com'l.  65 lbs.
12 heads No fertilizer 56 lbs.
12 heads 4-8-6 sludge 63 lbs.

1920's
Early Sludge Field Studies
What shall we Name it?

MILORGANITE®

(Milwaukee-Organic-Nitrogen)

First Prize was awarded to McIver and Son of Charleston. South Carolina
First rail car of Milorganite shipped

1920’s
Milorganite Ad 1932

MILORGANITE
OVER 200,000 TONS ALREADY PRODUCED AND SHIPPED

THE PERFECT ORGANIC

MILWAUKEE MILORGANITE
ORGANIC NITROGEN

COMPLETE ANALYSIS
Made from compost of 22,000 tons produced July 1, 1931 to June 30, 1932

1. Commonly Accepted Fertilizer Elements
   Ammonia 7.5%  Available Phosphoric Acid 2.5%
   Available Potash 0.75%  Moisture less than 5.0%
   Organic Matter 75.0%

2. Other Common Mineral Elements Used by Plants %
   Calcium (Ca), as Calcium Oxide (CaO) ........... 1.61 32.2
   Magnesium (Mg), as Magnesium Oxide (MgO) ...... 1.74 34.8
   Sulphur (S), as Sulphur Trioxide (SO₃) ........... 2.79 55.8
   Iron (Fe), as Iron Oxide (Fe₂O₃) .................. 6.88 137.6

3. Rare Elements Now Considered Vital
   Copper (Cu), as Copper Sulphate (CuSO₄·5H₂O) .... 0.53 10.6
   Manganese (Mn), as Manganese Sulphate (MnSO₄·4H₂O) 0.10 2.0
   Lead (Pb), as Lead Oxide (PbO) .................... 0.22 4.4
   Arsenic (As), as Arsenic Trioxide (As₂O₃) ....... 0.013 0.3
   Chromium (Cr), as Chromic Oxide (Cr₂O₃) ....... 0.21 4.2
   Titanium (Ti), as Titanium Oxide (TiO₂) .......... 0.08 1.6
   Iodine, Zinc, Nickel, Cobalt, Boron, also present.

MANUFACTURED ONLY BY
THE SEWERAGE COMMISSION
MILWAUKEE WISCONSIN

1930’s
What’s in a Name?-Early Competitors

Akra-Soilite       Clear-O-Sludge
Hou-Actinite       Tol-e-gro       Nitrohumus
Rapidgro           Vitorganic      Pittorganite
Chi-Organic

1930’s
The ABC of Turf Culture
Composition and Properties of Individual Fertilizer Materials

By O. J. NOEB

Turf Experts

1930's
Turf Service Bureau
Marketing as a Complete Fertilizer

Even this Pest
Other golfers may swear—greenkeepers may tear their hair—but goofy golfers do have a right to live and you can’t keep them off golf courses. Be nonchalant. You won’t need to feel quite so concerned over the damage they do if your fairways are few on a diet of Milorganite.

Milorganized turf is good turf. Better root development, sturdier leaf structure, less expense for seed. Milorganite is easy, safe, inexpensive to use. Nitrogen is released gradually, continuously, ever large patches at once. Greenway applications can be made without danger of burning. High organic nitrogen content—unusually low cost per ton. Nor wonder Milorganite is used on more golf courses than any other fertilizer.

Free Bulletin "How to Use Milorganite on Fairways and Greens." mailed on request.

Outshines all other golf fertilizers

1930’s

Milorganite

E.C. F. COMMISSION
MILWAUKEE WISCONSIN

Golf courses use more
MILORGANITE
than any other fertilizer

Man’s Wastes
Plant Vigor
Purification
"Recycling" Story
Clean Water

37 1/2 LBS. OF EVERY 50 LB. BAG
IS RICH VITAL HUMUS...
THE TRUE NATURAL ORGANIC

* Never burns... safe at any temperature
* Contains all plant foods needed for growth
* Free flowing - Easy to spread
* Never a chemical additive
* Grows everything - better
* Builds stronger, healthier turf

THE SEWERAGE COMMISSION
P. O. BOX 2079 MILWAUKEE, WISCONSIN 53201
Marketing as a Complete Fertilizer

WHAT DO WE ADD TO

NOTHING!

Every nutrient known to be needed for growth is already there — naturally!

The Sewerage Commission  P.O. Box 2079  •  Milwaukee 53201

1930’s
The First Weed & Feed Product

1940's
Scotts and Milorganite via for Weed & Feed Market

TIMELY TURF TIPS

WEED CONTROL IN SPRING WITH MILARSENITE

A timely tip for home turf owners: Weed control in the spring with Milarsenite will prevent future growth of weeds and grasses. Milarsenite is the only effective weed killer for trees and shrubs and is safe for use around lawns and gardens.

SCOTTS

FEED YOUR GREENS AND FAIRWAYS

Scotts Turf Builder

FREE

at the right of the second fairway by a screen which will stop overtaking shots.

Helen Weitzel has applied to the USGA for membership as an amateur golfer, after nearly three years of preparation. The Maryland State Golf Association and the Middle Atlantic PGA will interview her in the coming months. The need for expanding the amateur membership of the USGA and eliminating much travel is hotly discussed. The American Professional Golf Association will be the Southeastern CC, Atlantic City, N. J., during May 25-31.

Sumner Reeder finally did it! The 80-year-old golfer, resident in Mobile, Fla., has set a new record for the longest flight with a single putter, a 150-yard drive. For lack of water, the Lookout CC clubhouse at Pensacola, Fla., was destroyed by fire on an undetermined date in March 30. Gracious estimates of the damage ran from $25,000 to $50,000. The initial twostory structure was burned to the ground.

April 1940
Milorganite Focuses on Recycling Story

the natural
organic fertilizer!

- LONGER LASTING
- EASIER TO APPLY
- WON'T BURN

MILORGANITE
AND ECOLOGY

The Milorganite concept is a major anti-pollution factor. Recycling is the key.

For Further information write:
Milorganite and Ecology
P.O. Box 2079
Milwaukee, Wisconsin 53201

1950's

the natural,
organic fertilizer!

MILORGANITE
AND ECOLOGY

The Milorganite concept is a major anti-pollution factor. Recycling is the key.

For Further information write:
Milorganite and Ecology
P.O. Box 2079
Milwaukee, Wisconsin 53201
Milorganite the Preferred Choice

Figure 2.

1950's
Milorganite as an Industrial Raw Material

• Extracts could be used for industrial Fermentations, including ethanol, bread dough, lactic acid, and acetone-butyl alcohol

• Activated sludge a rich source of Vitamin B-12
Milwaukee Circa 1968
Milorganite Packaging Facilities

1960’s
TWO GREAT GRASS GROWERS

With Coast to Coast Success Stories

Throughout his career, Mr. Twombly has always used Milorganite. He has adapted this unique fertilizer to Southern California grass types with as much success as he had when he worked in Long Island, N.Y.

CONTACT YOUR NEAREST WEST COAST MILORGANITE DISTRIBUTOR

Bandini Fertilizer Co., Los Angeles, California
Robinson Fertilizer Company, Orange, California
Butler’s Mill, Inc., San Diego, California
Oregon Toro Distributors, Inc., Portland, Oregon
Toro Pacific Distributing, Burlingame, California
Turf & Toro Supply, Inc., Seattle, Washington

A. R. Twombly
Golf Course Superintendent
Bel Air Country Club.
Milorganite & Pro Sports

1960’s
Heavy Metals curbs use in growing Edibles

EPA Approved For Vegetables!

1970’s
Industrial Waste Pretreatment Program
Milorganite vs. 503 EQ Standard

**MYTHS of Milorganite**

**HEAVY METALS**

**Facts about heavy metals**
- ALL fertilizers contain some level of heavy metals
- Heavy metals are naturally occurring substances found in ALL soils.
- Some heavy metals are ESSENTIAL plant nutrients such as zinc, copper and molybdenum.

**Cadmium Levels in Milorganite**

**Milorganite has strong controls**
- Milorganite is subject to DAILY and weekly laboratory analysis to guarantee safety and nutrient analysis
- Milwaukee industrial monitors regularly check what large users are sending into the waste stream, which includes metals
- Milorganite is regulated by the EPA

<table>
<thead>
<tr>
<th>Metal</th>
<th>US EPA Exceptional Quality Upper Limits</th>
<th>Milorganite Levels 2009 avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>41</td>
<td>7.5</td>
</tr>
<tr>
<td>Cadmium</td>
<td>39</td>
<td>2.9</td>
</tr>
<tr>
<td>Copper</td>
<td>1500</td>
<td>230</td>
</tr>
<tr>
<td>Lead</td>
<td>300</td>
<td>68</td>
</tr>
<tr>
<td>Mercury</td>
<td>17</td>
<td>.53</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>40</td>
<td>11</td>
</tr>
<tr>
<td>Nickel</td>
<td>420</td>
<td>26</td>
</tr>
<tr>
<td>Selenium</td>
<td>100</td>
<td>3.3</td>
</tr>
<tr>
<td>Zinc</td>
<td>2800</td>
<td>480</td>
</tr>
</tbody>
</table>

Measurements are in mg/kg.
ALS Scare

Error of Random Coincidence
49er QB Bob Waters, LB Matt Hazeltine & FB Gary Lewis suffer degenerative muscular & nerve disease, Amyotrophic Lateral Sclerosis

ALS causation still unknown

Dr. Benjamin Brooks seeks $$ to study observation via USA Today - 1987

UW Neurology closes Brooks’ motor performance lab mismanagement 2003
ALS Scare

Biosolids and Lou Gehrig’s Disease: Biosolids Fact Sheet

Executive Summary

A series of 1987 newspaper articles alleged that application of the heat-dried biosolids fertilizer Milorganite may have caused athletes to contract amyotrophic lateral sclerosis (ALS), commonly referred to as Lou Gehrig’s disease. A neurologist alleged that high rates of ALS were observed around Milwaukee, Milorganite’s largest market. Review of the data by a large group of federal, state, and local specialists dispelled all links between the fertilizer and the disease.

In addition, ALAN RUBIN, Chief of the Wastewater Solids Criteria Branch of the Environmental Protection Agency, said:

“As of now there has been no way to draw an inference that cadmium, chromium or other substances in Milorganite were linked to ALS. In the studies we have, we have never (emphasis added) seen any trends or statistics indicating a deterioration of people’s health because of the use of Milorganite.”

EPA AND WISCONSIN DNR SUPPORT: Milorganite has the backing of both the Federal Environmental Protection Agency and the Wisconsin Department of Natural Resources. Milorganite meets the fertilizer requirements for each state where it is distributed. Milorganite qualifies as a “non-hazardous” substance according to the EPA.
Product Placement
Milorganite Blues

1980's
More Communities Heat Dry Biosolids
Class A Pelletized Producers 2008

- New York, NY
- Milwaukee, WI
- Houston, TX
- Stamford, CT
- Boston, MA
- Louisville, KY
- Back River, MD
- Chicago, IL
- Patapsco, MD
- Jacksonville, FL
- Minneapolis, MN
- Ocean County, NJ
- Pinellas, FL
- Sacramento, CA
- Honolulu, HI
- Clayton County, GA
- Tampa, FL
- Greater Lawrence, MA
- Aiken, SC
- Upper Occoquan, VA
- Winston-Salem, NC
- Cary, NC
- Amherst, NY
- Sumter, SC
- Largo, FL
- Hagerstown, MD
- Bradenton, FL
- Leesburg, VA
- Waco, TX
Product Units
2007 PCB Incident
Distribution Network
Retail Outlets

- ACO Hardware
- Fleet Farm
- Hardware Hank
- Walmart
- Menards
- The Home Depot
- Lowe's
- Ace Hardware
- True Value
- Stein
- Blain's Farm & Fleet
- Rona
- AGWAY
- Busy Beaver

2010's
Co-Branded Products
Retail and Professional Lawn and Garden Sectors take a Hit in 2011

Lawn and Garden Retail Sales Down to $21.5 Billion, Study Says
Water Garden News Dec. 8, 2011

Golf Clubs Suffer in recession as Membership dwindles
8/3/2010 USA Today

Scotts Miracle-Gro 1Q Loss Widens On Sales Decline
Feb 7, 2012 Dow Jones Newswires

NGF: Record 157.5 closures in 2011
March 15, 2012 Golf Course Industry

Bad Weather Plays on Home Depot’s First Quarter Results
May 25th, 2011 Trefis Team

Lowe’s Profit Falls On Cold Rain, Chilly Weather
05/16/2011 Associated Press

UPDATE 2-Rona profit, shares tumble as customers stay away
Reuters Aug 10, 2011

Scotts Miracle-Gro Predicts Decline in 2011 Sales
October 10, 2011 Fox Business
2012 Sales by category

- Retail: 63%
- Pro: 28%
- Ag: 9%
Historic Milorganite Revenues & Expenditures

![Bar chart showing revenues and expenditures from 2005 to 2012.]

- 2005: Revenue $5.8M, Expenditures $3.0M
- 2006: Revenue $5.2M, Expenditures $2.7M
- 2007: Revenue $4.3M, Expenditures $2.5M
- 2008: Revenue $7.3M, Expenditures $3.2M
- 2009: Revenue $8.0M, Expenditures $2.9M
- 2010: Revenue $7.0M, Expenditures $3.1M
- 2011: Revenue $7.3M, Expenditures $3.2M
- 2012: Revenue $7.8M, Expenditures $2.8M
Historic Average sales Price per Ton

- 2005: $139
- 2006: $141
- 2007: $150
- 2008: $182
- 2009: $196
- 2010: $193
- 2011: $197
- 2012: $186
Promotional Expenditures

- **Web**: 30%
- **Radio**: 22%
- **Print**: 13%
- **Billboard**: 4%
- **TV**: 17%
- **Point Of Purchase**: 9%
- **PR**: 5%

2010's
Web Strategies
Once the snow clears...

Dormant feeding with Milorganite assures
- 1 to 2 weeks earlier spring green-up
- Quicker turf recovery from winter damage
- Vivid turf color and growth rates through mid-May

www.milorganite.com
1-800-287-9645

Use MILORGANITE to RELIEVE STRESSED TURF
IMPROVE COLOR & DENSITY

Research suggests that the microorganisms responsible for mineralizing the organic nitrogen in Milorganite remain active up to the time soils freeze. This means a dormant application of Milorganite in late fall, or just prior to freeze up, will work to your advantage all winter and spring.

For more information on dormant feeding with Milorganite, contact Jaime at 1-800-287-9645 | www.milorganite.com

Are your BUNKER SURROUNDS looking a little weak?
Are they covered in sand?

Applying Milorganite to these weak areas will give your turf the nutrients it needs to overcome everyday wear and tear.

www.milorganite.com
1-800-287-9645

MILORGANITE IS AN EXCELLENT SUSTAINABLE FERTILIZER FOR TURFGRASS

It contains organic nitrogen for sustained feeding without any burn potential. Milorganite phosphorus is plant available but resistant to leaching, and the iron is non-staining.

For more information contact Jaime at 1-800-287-9645
www.milorganite.com

Print
Quick Response Codes
Milorganite Point of Purchase
Prominent Friends

- Paul Parent: Eastern Expert
- Walter Reeves: Southern Expert
- Will Allen: Growing a Stronger Community with Charles Wilson
- Paul Tukey: Natural Landscape Expert
- Melinda Myers: Midwest Expert
- Garden Life: A Growing Experience
Public Relations

MILOGANITE WANTS TO KEEP YOUR COMMUNITY GARDEN GROWING!

Share your community's story and you could receive a ONE YEAR SUPPLY* OF Milorganite Organic Nitrogen Fertilizer!

Visit Milorganite.com for contest details. All entries must be submitted by April 15th, 2013.

*1 year supply = 1 ton of Milorganite or 56 (36 lb.) bags.
Product Placement
TV ads
To Be Continued...
Unintended Consequences: Avoiding Nutrient Over-application When Applying Biosolids on the Farm

Richard Wolkowski
UW Extension Soil Scientist, Emeritus
Alfisol Soil Management, LLC
THE ACORN DOESN'T FALL FAR FROM THE TREE

SOURCE: WWOA WEBSITE

UNIVERSITY OF WISCONSIN
15TH SEWAGE PLANT OPERATORS SHORT COURSE, 1957
Applying Biosolids In Wisconsin

NR 204 created to regulate the use and disposal of “sewage sludge”

The intent of the code is to: “protect public health, and to protect and restore the physical, chemical, and biological integrity of the soil, air, and water”

Land application is encouraged over landfilling and incineration (NR 204.01)

Application rate is nitrogen rate based depending on crop N need

Most will be applied on private farms
Program Goals: Promote the Efficacy of Land Spreading Programs in Wisconsin

- Provide a safe and economical alternative to land filling or other disposal methods
- Protect public health
- Beneficially re-use nutrients and organic material
- Protect the quality of the soil, and surface water and groundwater
- Offer a cost-savings service to municipalities, fee payers, and farmers
Land Application is a “Gimme” for Biosolids
Biosolids and Nutrient Management

Biosolids application rate based on NR 204.
- Apply to meet crop N need
- If > 30% of crop N need; approved NMP needed
- Must account for N from legumes, manure, and other sources
- 200 and 140 lb available N/a can be applied to alfalfa and soybean, respectively

Available N equals 25% of organic-N and all ammonium-N if incorporated in year one (50 % less if surface-applied)
- 12 and 6 % of organic-N in years 2 and 3, respectively

N-based approach will result in the over-application of P
N-based Application

N balance

N

Excess P

P

N deficit

N

P balance

P

P-based Application

Biosolids Nutrient Content

Crop Nutrient Requirement
What is a Farm Nutrient Management Plan

- A field-by-field assessment of nutrient use on a farm based on soil/site factors, crop rotation, conservation requirements, and crop nutrient demand
- A strategy to obtain the maximum return from on-farm resources, commercial fertilizer, or other materials in a manner that protects water quality
- “Approved” plans must meet the USDA-Natural Resources Conservation Service Nutrient Management Standard – 590, which is adapted into NR 151 and ATCP50
- Current standard requires a P-based approach
Does Wisconsin Need Nutrient Management?
Excessive N Applications Lead to Groundwater Contamination

Nitrate detections > 10 ppm

Nitrate concentration (ppm)

Health Standard

170
170 + 120

lb N/Acre
State Average Soil Test Phosphorus

Years


Soil Test P (ppm)

Corn Optimum Soil Test P = 15-35 PPM

2000-2004 Survey

63% [< 50 ppm P], 26% [50-100 ppm P], 11% [> 100 ppm P]
Relationship between Bray P$_1$ (0-1 in) and DRP in runoff.

\[ y = -0.0025 + 0.0017x + 0.000006x^2 \]

\[ R^2 = 0.95 \quad n = 42 \]
P Loading Sources to Wisconsin Watersheds

Urban - 10%

Cropland - 70%

Barnyards - 15%

Streambanks - 5%

The USDA-NRCS 590 Standard

Establishes uniform requirements for planning, design, management, and performance

- **General criteria:**
  - Practices for all sites where nutrients are mechanically applied
  - Prescribes practices to minimize nutrient delivery to groundwater and surface water
  - Based on UW nutrient recs. and current BMP’s

- **P Based**
  - Applied N based if soil test P is “low”
  - Rotation crop removal when soil test P is “high”
  - Eliminate P when soil test P is “excessively high”
  - Alternative is to use the P Index
UWEX Nutrient Application Guidelines

**UWEX Pub. A2809**

- Based on 80+ years of research
- Uses a sufficiency approach
- Full range of crops and soils
- Revised in November 2012
- Supported by UW Soil Science
- Establishes testing methods and recommendations
- “The Bible” for NMP in Wis.
- Allows for an informed decision that makes environmental and economic sense
Alfalfa provides a significant amount of nitrogen to crops following in the rotation.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Sandy Soils</th>
<th>Other Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 8”</td>
<td>&gt; 8”</td>
</tr>
<tr>
<td>--------- lb N/a -----------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Alfalfa, &gt; 70% stand</td>
<td>100</td>
<td>140</td>
</tr>
<tr>
<td>Alfalfa, 30-70% stand</td>
<td>70</td>
<td>110</td>
</tr>
<tr>
<td>Alfalfa, &lt; 30% stand</td>
<td>40</td>
<td>80</td>
</tr>
</tbody>
</table>
**Corn after Soybean: Less N Needed**

Wisconsin N recommendations for corn use the Maximum Return for Nitrogen (MRTN) approach

<table>
<thead>
<tr>
<th>Soil and previous crop</th>
<th>Nitrogen: Corn price ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Loamy: high yield potential soil</td>
<td></td>
</tr>
<tr>
<td>Corn, forage legumes, legume vegetables, green manures</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>170 --- 210</td>
</tr>
<tr>
<td>Soybean, small grains</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>125 --- 160</td>
</tr>
</tbody>
</table>

*Source: UWEX A2809*
The Challenge of Manure
- 3.5 million cattle in Wisconsin
- Adult Holstein produces 27 tons manure/year
- 8-9 lb total N/ton, 4 lb P2O5/ton
(Sources: 2011 Wis. Ag. Stats. and UWEX A2809)
# Manure Nutrient Credits - Solid

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;</th>
<th>K&lt;sub&gt;2&lt;/sub&gt;O</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 72 hours or not incorporated</td>
<td>1 to 72 hours</td>
<td>&lt; 1 hour or injected</td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy: semi-solid (11.1–20.0% DM&lt;sup&gt;a&lt;/sup&gt;)</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Dairy: solid (&gt; 20.0% DM)</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Goat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poultry: chicken</td>
<td>24</td>
<td>27</td>
<td>29</td>
<td>35</td>
</tr>
<tr>
<td>Poultry: duck</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Poultry: turkey</td>
<td>26</td>
<td>28</td>
<td>31</td>
<td>35</td>
</tr>
<tr>
<td>Sheep</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Swine</td>
<td>7</td>
<td>9</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: UWEX A2809

<sup>a</sup> DM: Dry Matter
Soil Test P and Past Management Effects
Reducing Soil Test P Takes Years

$P_{Buffer} = (18 \text{ lb } P_2O_5 : 1 \text{ ppm soil test } P)$

- Soil P test = 100 ppm (EH)
- Optimum soil test = 20 ppm
- Removal needed for EH to Opt. = $18 \text{ lb } P_2O_5/\text{acre} \times 80 \text{ ppm} = 1440 \text{ lb } P_2O_5$
- Corn grain removes 60 lb $P_2O_5/\text{acre/year}$
- $1440/60 = 24 \text{ yrs with no added } P \text{ for EH change to optimum}$
What’s a Biosolids Manager to Do?

"Joe, all this nutrient management planning talk is making me thirsty!"
A Farmer’s “Top 10” Questions About Biosolids Application

1. What’s in the biosolids?
2. Who’s responsible for the application?
3. What else do I need to do?
4. Where can I apply my manure?
5. My soil’s phosphorus is already high
6. Will I still have to apply fertilizer?
7. Can you guarantee my livestock won’t get sick?
8. Heavy metals are bad, right?
9. Will your large trucks compact my soil?
10. You’re from the government and you’re here to help me?
Communicate with the Farmer

**Your Responsibility**

- Explain the process and who does what
- Answer their questions
- Guarantee applications are done properly
- Follow-up and trouble-shoot as needed
- You will need to know some agronomic basics
- Follow UWEX recs. and BMP’s in USDA-NRCS 590
When Are Farmers Required to Have a Farm Nutrient Management Plan

- When offered [70%] cost-share for NM
- When accepting manure storage cost-share
- When participating in Farmland Preservation or Working Lands Initiative
- When regulated under a county manure storage or livestock siting ordinance
- When regulated under a DNR WPDES permit
- If required to prevent or mitigate imminent harm to waters of the state as an emergency or interim response to a grossly negligent pollution discharge
Percentage of Cropland Reported from NM Plan Checklists 2010

1.5 million acres NM plans reported in 2010

% of Drinking Wells Exceeding the Health Std. 10 PPM Nitrate-N

Data shown were obtained between 1988 - October 2007, are from various sources, and represent the most recent nitrate concentration reported for a well.

Source: WDATCP
The Reality for Land Application Programs

- The vast majority of crop land is not managed under a “590” farm nutrient management plan
- NR 204.06 (6) outlines criteria for land application
  - “Nutrient management plan” needed if biosolids supplies more than 30% crop N
  - N-based, accounting for N from all sources
  - Your plan is for individual fields/approved sites not for the entire farm
Components of a Nutrient Management Plan

**USDA -590 (2005)**
- Current UWEX Soil Test Rec.
- Inventory of On-farm Nutrient Resources
  - Manure and legume credits
- Farm Conservation Plan
  - Crop rotation, tillage, conservation practices
  - Must meet tolerable soil loss – “T”
- Rates, times, methods that meet the NRCS 590 Standard
- Field by field
- P based

**NR 204 (1996)**
- Current UWEX Soil Test Rec.
- Account for all other N sources
- Location of the site on an approved map showing use and separation distances
- Total acreage of site
- Crop to be grown
- Analysis of material to be applied
- Rate of application (>30% of crop N, then NMP needed)
- N based
Step #1. Begin with a soil test!

WHAT SOIL TESTING TELLS US

- Crop N need
- Plant available P and K
- Crop P and K need
- Soil organic matter
- Soil pH and lime requirement
- Other tests if requested
Do a Good Job: Less than 1 oz. Will Determine the Nutrient Need for 5,000 Tons of Soil

Table 2.1. Recommended sample intensity for uniform fields.

<table>
<thead>
<tr>
<th>Field characteristics</th>
<th>Field size (acres)</th>
<th>Suggested number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fields tested more than 4 years ago OR fields testing in the responsive range</td>
<td>All fields</td>
<td>1 sample/5 acres</td>
</tr>
<tr>
<td>Non-responsive fields tested within past 4 years</td>
<td>5-10</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>11-25</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>26-40</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>41-60</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>61-80</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>81-100</td>
<td>7</td>
</tr>
</tbody>
</table>

* Collect a minimum of 10 cores per sample.
What About All That P

- Biosolids applied at the crop N rate over-apply phosphorus, elevating soil test P
- Many Wisconsin soils already test EH
- Soil test P is correlated with P in runoff

Don’t let your biosolids compound the problem
The Wisconsin Phosphorus Index

- Measures the relative potential for a field to deliver P to surface waters
- Evaluates site loading (quantity and source of P) and transport potential (erosion and runoff) from individual fields
- Field characteristics required
- Calculated by Snap-Plus software
- Agricultural management practice recommendations based on PI value
- Current recommendation is a PI<6; but we can do better
After this beer I’m going to run the Phosphorus Index
Utilize Other Soil Conservation Practices That Reduce Runoff and P Loss
Wouldn’t it be nice if there was a tool to ....

- calculate crop nutrient need
- estimate available N, P₂O₅, and K₂O from biosolids
- credit manure and legume nutrients
- calculate soil loss and the P-Index
- do all this for free !!!
- http://www.snapplus.net/
SNAP-Plus NMP Software
Farm information and cropping

[Image of SNAP-Plus software interface]
SNAP-Plus NMP Software
Set field-specific soil information

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Field group (subform)</th>
<th>FSA Tract #</th>
<th>FSA Field #</th>
<th>Size acres</th>
<th>County</th>
<th>Soil Map Symbol</th>
<th>Soil Series Name</th>
<th>Restriction Features</th>
<th>Field Slope (%)</th>
<th>Field Slope Length (ft)</th>
<th>Field Slope to Water</th>
<th>Below Field Slope to Water (ft)</th>
<th>Distance to Perennial Water (ft)</th>
<th>Rotation Start Year</th>
<th>Soil Test History for Field: 100P 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>100P 1</td>
<td></td>
<td>10</td>
<td>Wi-Dane</td>
<td>10</td>
<td></td>
<td></td>
<td>PLANO</td>
<td></td>
<td>4</td>
<td>300</td>
<td>0.2</td>
<td>0 - 300</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100P 2</td>
<td></td>
<td>10</td>
<td>Wi-Dane</td>
<td>10</td>
<td></td>
<td></td>
<td>PLANO</td>
<td></td>
<td>4</td>
<td>300</td>
<td>0.2</td>
<td>500 - 0</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100P 3</td>
<td></td>
<td>10</td>
<td>Wi-Dane</td>
<td>10</td>
<td></td>
<td></td>
<td>PLANO</td>
<td></td>
<td>4</td>
<td>300</td>
<td>0.2</td>
<td>0 - 300</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100P 4</td>
<td></td>
<td>10</td>
<td>Wi-Dane</td>
<td>10</td>
<td></td>
<td></td>
<td>PLANO</td>
<td></td>
<td>4</td>
<td>300</td>
<td>0.2</td>
<td>500 - 0</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100P 5</td>
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<td>Wi-Dane</td>
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<td></td>
<td>PLANO</td>
<td></td>
<td>4</td>
<td>300</td>
<td>0.2</td>
<td>0 - 300</td>
<td>2009</td>
<td></td>
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<tr>
<td>100P 6</td>
<td></td>
<td>10</td>
<td>Wi-Dane</td>
<td>10</td>
<td></td>
<td></td>
<td>PLANO</td>
<td></td>
<td>4</td>
<td>300</td>
<td>0.2</td>
<td>500 - 0</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100P 7</td>
<td></td>
<td>10</td>
<td>Wi-Dane</td>
<td>10</td>
<td></td>
<td></td>
<td>PLANO</td>
<td></td>
<td>4</td>
<td>300</td>
<td>0.2</td>
<td>0 - 300</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100P 8</td>
<td></td>
<td>10</td>
<td>Wi-Dane</td>
<td>10</td>
<td></td>
<td></td>
<td>PLANO</td>
<td></td>
<td>4</td>
<td>300</td>
<td>0.2</td>
<td>500 - 0</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100P 9</td>
<td></td>
<td>10</td>
<td>Wi-Dane</td>
<td>10</td>
<td></td>
<td></td>
<td>PLANO</td>
<td></td>
<td>4</td>
<td>300</td>
<td>0.2</td>
<td>0 - 300</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test Date: 5/19/2008
Sample Density (g/cm³): 1.6
Plow Depth: 4
Avg pH: 7.0
Avg N (ppm): 100
Avg P (ppm): 130
Avg K (ppm): 50
Avg Ca (ppm): 25
Avg Mg (ppm): 10
Avg Zn (ppm): 5
Avg S (ppm): 10
Avg CEC (ppm): 15
Notes: None
SNAP-Plus NMP Software

Select biosolids type
SNAP-Plus NMP Software

Set available nutrient content

This calculator converts biosolid lab analysis reports to the proper units for use in Snap-Plus. The results shown in the grid below will be inserted as the available nutrient values for this nutrient source.

**Source name: source 687 Source type: Biosolid, liquid**

<table>
<thead>
<tr>
<th>% Solids</th>
<th>Total Kjeldahl Nitrogen (TKN)</th>
<th>Ammonium Nitrogen (NH4)</th>
<th>Organic Nitrogen</th>
<th>Potassium (K), Total recoverable</th>
<th>Total Phosphorus (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.74</td>
<td>34B</td>
<td>55</td>
<td></td>
<td>8</td>
<td>4.8</td>
</tr>
</tbody>
</table>

**Available nutrients (lbs/1000 gallons)**

<table>
<thead>
<tr>
<th>Application year</th>
<th>N Surface</th>
<th>N incorporated</th>
<th>P2O5</th>
<th>K2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9</td>
<td>18.9</td>
<td>24.8</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>Second year</td>
<td>1.9</td>
<td>1.9</td>
<td>4.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Third year</td>
<td>1.0</td>
<td>1.0</td>
<td>2.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Calculation of second and third year credits depends on the "Manure Credit" setting on the farm screen.

**Source name: source 687 Source type: Biosolid, solid**

<table>
<thead>
<tr>
<th>% Solids</th>
<th>Total Kjeldahl Nitrogen (TKN)</th>
<th>Ammonium Nitrogen (NH4)</th>
<th>Organic Nitrogen</th>
<th>Potassium (K), Total recoverable</th>
<th>Total Phosphorus (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.5</td>
<td>6.51</td>
<td>1.52</td>
<td></td>
<td>0.00</td>
<td>2.44</td>
</tr>
</tbody>
</table>

**Available nutrients (lbs/cubic yard)**

<table>
<thead>
<tr>
<th>Application year</th>
<th>N Surface</th>
<th>N incorporated</th>
<th>P2O5</th>
<th>K2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3</td>
<td>12.8</td>
<td>21.7</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Second year</td>
<td>2.4</td>
<td>2.1</td>
<td>3.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Third year</td>
<td>1.0</td>
<td>1.0</td>
<td>1.8</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Calculation of second and third year credits depends on the "Manure Credit" setting on the farm screen.
SNAP-Plus NMP Software
Select field-specific management

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield Goal</th>
<th>Tillage</th>
<th>Soil Test Date</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn grain</td>
<td>151-170</td>
<td>Fall Chisel, disked</td>
<td>3/9/2012</td>
<td>165</td>
<td>0</td>
<td>25</td>
<td>170</td>
</tr>
<tr>
<td>Corn grain</td>
<td>151-170</td>
<td>Fall Chisel, disked</td>
<td>3/9/2012</td>
<td>170</td>
<td>0</td>
<td>25</td>
<td>170</td>
</tr>
<tr>
<td>Corn grain</td>
<td>151-170</td>
<td>Fall Chisel, disked</td>
<td>3/9/2012</td>
<td>166</td>
<td>0</td>
<td>282</td>
<td>156</td>
</tr>
<tr>
<td>Corn grain</td>
<td>151-170</td>
<td>Fall Chisel, disked</td>
<td>3/9/2012</td>
<td>166</td>
<td>0</td>
<td>282</td>
<td>156</td>
</tr>
</tbody>
</table>

Rotation Summary Results 2010 - 2013

- Avg soil loss: 1.8 b/acre/yr
- Field "T": 5 b/acre/yr
- Avg P Index: 3
- P205 removal: 240 b/acre
- K20 removal: 110 b/acre
- P205 balance: 62 b/acre
- K20 balance: 175 b/acre

Soil test P is greater than 50 ppm so P205 balance should be less than zero b/acre.
With Smart Decisions We Can Properly Land-Apply Biosolids
Summary

- Meet NR204 requirements, but integrate NRCS 590 guidelines
- Consider managing P over the rotation
  - Apply to lower testing fields
  - Grow crops that remove large amounts of P
  - Monitor with more frequent soil testing
  - Don’t apply annually to the same field
- Identify and avoid situations that create a risk of P loss
  - Work within the farm’s conservation framework
  - Stay away from “risky” fields
- Communicate with farmers and their crop advisors to optimize management
  - Use SNAP-Plus to evaluate scenarios
  - Calibrate equipment and do a good job of application
MANAGE BIOSOLIDS PROPERLY TO AVOID WASTE !!
Biosolids dewatering at the Empire WWTP following conversion to bio-P and influent wastewater changes

George Sprouse MCES

CSWEA 18th Annual Education Seminar
Biosolids: Resource or Refuse?
April 2, 2013
Project Team/Acknowledgments

• Empire
  – Pat Oates, Cammy Johnson, Terry Mitchell
  – All the operators and unit coordinators

• SSBU
  – Rebecca Alm, Adam Sealock, Alex Koo, Nick Davern, Mike Rieth, Larry Rogacki

• Technical Services
  – Bill Cook, Rene Heflin
  – Solids project team consultant members

• IWPP
  – Mark Pierson, Bob Golden

• Others
  – Matt Higgins, Bucknell University
  – Expansion design project team consultant members
Outline

- Empire Background
- Dewatering Performance History
- Investigations to Date
- Current Ideas and Next Steps
- Summary and Conclusions
Empire WWTP

- 24 mgd liquid capacity
- <18 mgd solids capacity
- Current influent flow ~ 10 mgd
Empire WWTP - 2004 to 2008

• Plant Expansion, conversions and upgrade

• Activated Sludge: 2 sludge high rate AS + nitrifying AS to 1 sludge Bio-P

• Thickening: Co-gravity thickening to gravity thickening PS, GBT thickening of WAS

• BFP equipment changed
Dewatering and Project Events

Conversion from 2 Sludge to 1 Sludge System

Anaerobic Basins On-Line

New BFPs Start-Up

GBT Started, Co-Thickening Discontinued

Cake Solids (%)

Belt Press Cake Total Solids
Dewatering – Bio-P Startup

Conversion from 2 Sludge to 1 Sludge System

Anaerobic Basins On-Line

Effluent Total P (mg/l)

Cake Solids (%)

Belt Press Cake Total Solids

Plant Effluent Total Phosphorus

Jan-05 Apr-05 Aug-05 Dec-05 Mar-06 Jul-06 Nov-06 Feb-07
Dewatering – Influent Changes

2005 Industrial Contributor Changes

- Belt Press Cake Total Solids
- Plant Influent COD
### Dewatering – Influent Changes

**Graph Details:**
- **Y-axis:** Cake Solids (%)
- **X-axis:** Months from Jan-05 to Feb-07
- **Data:**
  - **Primary Effluent COD (mg/l)**: Range from 200 to 700
  - **Cake Solids (%):** Range from 0 to 25

**Legend:**
- **Belt Press Cake Total Solids**
- **Primary Effluent COD**

**Notice:**
- **2005 Industrial Contributor Change**

---

**Notes:**
- The graph illustrates the changes in cake solids and primary effluent COD over time.
- The industrial contributor change is highlighted in the graph, indicating a significant impact on the data.
## Implications

<table>
<thead>
<tr>
<th>Item</th>
<th>2011 Conditions</th>
<th>Project Planning Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dewatered Cake Solids</td>
<td>11.8%</td>
<td>18.0%</td>
</tr>
<tr>
<td>Implications for current production:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-Month Storage Pad Coverage</td>
<td>75%</td>
<td>48%</td>
</tr>
<tr>
<td>Annual Land Application Trips</td>
<td>1,650</td>
<td>1,060</td>
</tr>
</tbody>
</table>

~on the order of $100,000/yr higher cost
Investigations

• Goals:
  – Evaluate potential methods of improving dewatering performance
  – Better understand parameters influencing dewatering performance
Methods

- Bench scale
- Pilot scale
- Full scale
Methods - Crown Press

• Preliminary evaluation of CST, SRF and Crown Press
• Based on results, used the Crown Press
Investigated to date:

- Belt Press Optimization
- Longer Digestion Time
- Digester Feed Stream Conditioning
  - Feed Sludge Homogenization
  - TWAS Lysis
  - Pre-Aeration of TWAS
- Pre-dewatering treatment
  - Post-Aeration of Digested Sludge
  - Pre-thickening before dewatering
  - Temperature of dewatering
  - Ferric chloride addition
  - Polymers and polymer dose
Investigated to date:

• Impact of the industrial contribution
  – Redirected from Empire for ~6 months

• Influence of relative amounts of TPS and TWAS in the digester feed

• Biopolymer and cation concentrations

• Chemical addition to the digester
Ind Discharge – Cake Solids

Cake Solids (%)

May-11 to Jul-13

Redirected

Reintroduced

BFP 3

BFP 4
Is it the Ind Discharge or the Amount of TWAS it Creates?

• Pilot Tests
  – During redirection, pilot feed blend was maintained at typical blend of TPS and TWAS
  – As a second pilot task, the dewatering performance for range of blends were investigated

• Modeling
  – Can one set of characteristics describe the observed variations over time?
Pilot and Full-Scale Findings

**Pilot Data:** Feed From Ind Discharge Redirected

**Full Scale:**
- Ind Discharge Redirected
- Ind Discharge in Influent

---

**Model - One Set of Characteristics fit to Full Scale Transition Data**

- **Pilot**
- **Full Scale**
Modeling Findings

Cake Solids (%)

- Actual Cake Solids
- Used in Parameter Fitting
- Model

Dates:
- Jan-08 to Jul-13

Markings:
- Reintroduced
- Redirected

Data points from Jan-08 to Jul-13 for cake solids percentage.
## Model Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Thickened Primary Sludge</th>
<th>Thickened Waste Activated Sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodegradable VS Fraction</td>
<td>lb BVS/lb VS</td>
<td>0.73</td>
<td>0.42</td>
</tr>
<tr>
<td>Biodegradable VS First Order Decay Rate</td>
<td>d⁻¹</td>
<td>&gt;2.7</td>
<td>0.80</td>
</tr>
<tr>
<td>FS First Order Deposition Rate</td>
<td>d⁻¹</td>
<td>0.0014</td>
<td>0.012</td>
</tr>
<tr>
<td>Water Retained by VS through Dewatering Step</td>
<td>lb H₂O/lb VS</td>
<td>6.4</td>
<td>14.1</td>
</tr>
</tbody>
</table>
Current Focus on

(1) TWAS

• Divalent Cation Bridging (DCB)
• Bio-P, potassium and magnesium, and anaerobic digestion

Matt Higgins of Bucknell University and Charles Bott of Hampton Roads SD

(2) Belt Blinding

• Washout blinding material with elutriation

MCES staff: Mike Rieth and Adam Sealock
Divalent Cation Bridging (DCB)

Extracellular Biopolymers with (-) Functional Groups

More Interstitial water

Divalent Cations

Monovalent Cations

Sobeck and Higgins (2002) Examination of three theories of cation-induced bioflocculation
K, Mg: Bio-P and Digestion

**Bio-P**

**Aerobic Phase**

- $\text{PO}_4^{3-}$
- Poly P
- $\text{Mg}^{2+}$
- $\text{K}^+$
- $\text{Ca}^{2+}$
K, Mg: Bio-P and Digestion

Anaerobic Digestion

Struvite

NH₄⁺ → PO₄³⁻ → Mg²⁺ → K⁺

Poly P

~Release and Uptake Stoichiometry*

<table>
<thead>
<tr>
<th>Component</th>
<th>Stoichiometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>K⁺</td>
<td>0.34 mole K/mole P</td>
</tr>
<tr>
<td>Mg⁺</td>
<td>0.30 mole Mg/mole P</td>
</tr>
<tr>
<td>Ca⁺</td>
<td>~0.07 mole Ca/mole P</td>
</tr>
</tbody>
</table>

M/D = 0.34/(2*0.30) = 0.57

* Pattarkine et al. (1990)
Conversion from 2 Sludge to 1 Sludge

Bio-P Anaerobic Basins On-Line
Dewatering - Potassium

Graph showing the relationship between digested sludge potassium (mg/kg) and cake solids (%) for the 1 Sludge System after Bio-P.
Dewatering - Potassium

Cake Solids (%) vs. Digested Sludge Potassium (mg/kg)

- ▲ 2-Sludge System
- ★ 1-Sludge System/Start-Up Prior to Bio-P
- ● 1-Sludge System After Bio-P
## Cations

<table>
<thead>
<tr>
<th>Cation (meq/l)</th>
<th>Before Redirection</th>
<th>During Redirection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg$^{2+}$</td>
<td>3.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Ca$^{2+}$</td>
<td>7.7</td>
<td>4.8</td>
</tr>
<tr>
<td>K$^+$</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Na$^+$</td>
<td>21.9</td>
<td>12.1</td>
</tr>
<tr>
<td>NH$_4^+$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M/D w/o Amm.</td>
<td>2.0</td>
<td>2.1</td>
</tr>
<tr>
<td>M/D w Amm.</td>
<td>2.0</td>
<td>2.1</td>
</tr>
</tbody>
</table>

## Digested Sludge

<table>
<thead>
<tr>
<th>Cation (meq/l)</th>
<th>Before Redirection</th>
<th>During Redirection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg$^{2+}$</td>
<td>1.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Ca$^{2+}$</td>
<td>3.7</td>
<td>1.8</td>
</tr>
<tr>
<td>K$^+$</td>
<td>26.5</td>
<td>11.9</td>
</tr>
<tr>
<td>Na$^+$</td>
<td>32.8</td>
<td>14.6</td>
</tr>
<tr>
<td>NH$_4^+$</td>
<td>85.5</td>
<td>51.0</td>
</tr>
<tr>
<td>M/D w/o Amm.</td>
<td>11.6</td>
<td>9.2</td>
</tr>
<tr>
<td>M/D w Amm.</td>
<td>29.1</td>
<td>28.5</td>
</tr>
</tbody>
</table>
## Biopolymers

<table>
<thead>
<tr>
<th>Biopolymer (mg/l)</th>
<th>Before Redirection</th>
<th>During Redirection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Polysaccharides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soluble</td>
<td>4.1 (5%)</td>
<td>4 (5%)</td>
</tr>
<tr>
<td>Bound</td>
<td>7.2 (8%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Tightly Bound</td>
<td>78 (87%)</td>
<td>84 (95%)</td>
</tr>
<tr>
<td><strong>Proteins</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soluble</td>
<td>19 (7%)</td>
<td>16 (1%)</td>
</tr>
<tr>
<td>Bound</td>
<td>128 (52%)</td>
<td>295 (25%)</td>
</tr>
<tr>
<td>Tightly Bound</td>
<td>101 (41%)</td>
<td>886 (74%)</td>
</tr>
</tbody>
</table>

## Digested Sludge

<table>
<thead>
<tr>
<th>Biopolymer (mg/l)</th>
<th>Before Redirection</th>
<th>During Redirection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Polysaccharides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soluble</td>
<td>270 (37%)</td>
<td>216 (35%)</td>
</tr>
<tr>
<td>Bound</td>
<td>103 (14%)</td>
<td>57 (9%)</td>
</tr>
<tr>
<td>Tightly Bound</td>
<td>348 (48%)</td>
<td>346 (56%)</td>
</tr>
<tr>
<td><strong>Proteins</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soluble</td>
<td>1840 (29%)</td>
<td>1791 (25%)</td>
</tr>
<tr>
<td>Bound</td>
<td>330 (5%)</td>
<td>136 (2%)</td>
</tr>
<tr>
<td>Tightly Bound</td>
<td>4263 (66%)</td>
<td>5063 (73%)</td>
</tr>
</tbody>
</table>
### Biopolymers

<table>
<thead>
<tr>
<th>Biopolymer (mg/l)</th>
<th>Before Redirection</th>
<th>During Redirection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polysaccharides</td>
<td></td>
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<td></td>
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<td>Bound</td>
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</tr>
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<td>Tightly Bound</td>
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</tr>
</tbody>
</table>

### MLSS

<table>
<thead>
<tr>
<th>Biopolymer (mg/l)</th>
<th>Before Redirection</th>
<th>During Redirection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polysaccharides</td>
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<td></td>
</tr>
<tr>
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<td>Bound</td>
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</tr>
<tr>
<td>Tightly Bound</td>
<td>348 (48%)</td>
<td>346 (56%)</td>
</tr>
</tbody>
</table>

### Can we accomplish something at the digestion step or is dewaterability decided in the activated sludge system?
Digestion’s Impact - Dewatering

- **Cake Solids (%)**
  - **Undigested TWAS**
  - **Digested TWAS**

- **TPS**
  - **Undigested TPS**
  - **Digested TPS**
Digestion Impact?

The graph illustrates the impact of volumetric blend, TPS/Total (%), on cake solids (%). It compares initial models and models with pre-digestion cake solids, showing data from pilot and full scale tests.

Key observations:
- The initial model starts with a lower cake solids percentage and increases as the volumetric blend increases.
- Models with pre-digestion cake solids show a higher initial cake solids percentage and a steeper increase as the blend increases.
- The pilot data points are represented by orange diamonds, while the full scale data points are represented by green circles.
- The graph highlights the difference in performance between the initial model and models with pre-digestion cake solids, especially at higher volumetric blends.
Pilot Tests Planned for 2013

• Provide more multi-valent cations in digesters
  – Mg addition to digestion
  – Ferric (or Ca) addition to digestion
  – Target M/D w/o Amm. < 7
  – Subsequent phase of potassium addition

• Remove potassium upstream of digestion
  – Release of WAS potassium (magnesium and phosphorus) upstream of thickening using unaerated storage so potassium is diverted from digestion
Mg Addition - 2012 Pilot Results

Cake Solids (%)

- No Mg Added
- 2.1 SRTs
- 2.4 SRTs
- 2.8 SRTs
- 3.2 SRTs

CHEMICAL FEED PUMP FAILURE
# Fe Addition – Indirect Comparison

<table>
<thead>
<tr>
<th>Plant</th>
<th>~<strong>Ferric Dose</strong> (lb Fe/ dt digester feed solids)</th>
<th>Digester Gas H₂S (ppm)</th>
<th>Dewatering Return Total P (mgP/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Lake</td>
<td>33 directly to digesters</td>
<td>130 to 205 ppm</td>
<td>124 mg/l</td>
</tr>
<tr>
<td>Empire</td>
<td>16 added at primary clarification</td>
<td>112 to 368 ppm</td>
<td>350 mg/l</td>
</tr>
</tbody>
</table>
Fe Addition - Preliminary

Blue Lake using Standard Crown Press Procedures

Cake Solids (%) vs Volumetric Blend, TPS/Total (%)

Model  | Pilot  | Empire | Blue Lake - Comparative Crown Press
Pre-Digestion K Release Pilot

Secondary Process

Primary Process

GBT

TWAS

TPS

Plant

Pilot

Pilot Digester
Pre-Digestion K Release Full Scale?

Secondary Process

Unaerated Storage

Thickening

TWAS

NH$_4^+$

NH$_4^+$

PO$_4^{3-}$

Mg$^{2+}$

Struvite

Struvite System

GT

TPS

Primary Process

Pilot Digester
Summary and Conclusions

• Empire’s cake solids are low: ~ 11 to 12%
  – Initial degradation:
    • Coincided with conversion from 2-sludge to 1-sludge AS
      – did not appear directly related to the startup of Bio-P
    • May have coincided with increase in influent soluble COD
    • May have been a result of start-up conditions and disruption from expansion/construction activities
  – Dewatering performance continues to be below expectations well into the period of stable conditions at the plant

• A range of potential methods of improving cake solids have been investigated at the bench, pilot and full scales
  – Nothing to date has shown the potential to meet target (18%)
  – Reduction in the plant influent soluble COD with the resulting reduction in the amount of TWAS has had the largest improvement (13.6%)
  – Some methods have shown the potential for minor improvement
Summary and Conclusions

• One current school of thought (Higgins and Bott, et al.) focuses on the role of cations in the structure and water retention of a biomass and on the interaction of Bio-P and anaerobic digestion – MCES will conduct pilot tests on this concept summer 2013 with focus on the M/D cation ratio at a target parameter

• Some preliminary information suggests that other mechanisms and methods beyond cation addition/adjustment should continue to be developed and investigated. MCES is:
  – developing a testing program for the impact and the potential removal of belt blinding components
  – investigating alternative dewatering aids
  – considering digester additives (peat extract?)
  – INTERESTED IN LEARNING OF OTHER IDEAS
Thank you
CH2M HILL Acknowledgements

- Dru Whitlock, PE
- Julian Sandino, PhD, PE
- Bruce Johnson, PE
- Glen Daigger, PhD, PE
- Barry Rabinowitz, PhD, PE
- Tania Datta, PhD
Why Reduce Waste Solids Production?

Limited reuse/disposal paths and more constraints

- **Landfill 38%**
  - restrictive regulations
  - lower public acceptance
  - restricted access for organic wastes

- **Agriculture 51%**
  - restrictive regulations
  - lower public acceptance
  - competition with manure
  - restricted available land

- **Incineration 11%**
  - restrictive regulation (air emission)
  - lower public acceptance
  - potential regulatory changes

Hence, **US Biosolids production is approximately 7 million dry tons per year...WAS is ~50% of this**

**Favorable drivers for solids reduction technologies**
Why Optimize Waste Solids Processing?

- Reduce capital and O&M costs
- Maximize potential benefits of solids processing (e.g. optimized energy balance in WWTP)
- Reduce carbon footprint – GHG management
- Improve reliability/viability of biosolids management
Specific Mechanisms Affect Differently the Rate and Extent of Sludge Reduction

Waste Solids

- Biodegradable
  - Fast
  - Slow
  - Very Slow

- Non-Biodegradable
  - Organic
  - Inorganic

WSR Rate
WSR Extent
Waste Solids Digestion Pretreatment Key Points

- Many new products in the market
- Few full-scale installations; many outside US
- Many benefits claimed in literature
- Carbon augmentation potential for BNR
- Empirical sizing methods
- Little is known on impact of raw feed characteristics and/or process operational parameters – pilot studies are recommended
WERF 05-CTS3 Evaluation of Processes to Reduce Activated Sludge Generation and Disposal

- Develop evaluation methodology for WAS reduction technologies.
- Important for industry and municipalities
- CH2M HILL-led team. Dr. Julian Sandino, principal investigator, Dru Whitlock, project manager
- Key role played by Dr. John Novak, Virginia Tech
- 3-year assignment, started Spring 2007
- Final Report to be Released by WERF this Summer
Selection of Reference Technologies: Collection and Evaluation of Laboratory and Field Data

- **Biological: Cannibal™**
  - Peru, IN
  - Emporia, VA
  - Big Bear, CA
  - Morongo, CA

- **Physical: Cambi™ Thermal Hydrolysis**
  - Naestved, Denmark
  - DC Water and Sewer Authority pilot plant operated at Virginia Tech.

- **Physical: Crown Disintegrator™ Pressure Release:**
  - Rosedale WWTP, New Zealand

- **Chemical/Physical: MicroSludge™ Homogenization:**
  - Des Moines, IA
Physical Processes – Key Mechanisms

- Focused on floc disintegration and cell lysis
- From cell wall damage to full cell disruption depending on energy intensity
- Sized on volume basis – the thicker the better
- Several mechanisms: cavitation, temperature, pressure release, shear, pulsed electric fields
Physical Processes – Claimed Benefits

- Increased digestion rates & stability
- Increased volatile solids reduction (VSr)
- Increased biogas production
- Reduced solids for dewatering & reuse/disposal
- Reduced filamentous foaming
- Reduced viscosity
- Improved dewatering (higher cake; lower polymer)
- Increased hydrolysis of complex organics and production of VFAs – BNR carbon augmentation
- Reduced odors
- Heat addition
Cell Lysis Technologies

- **Homogenization**
  - MicroSludge™

- **Pressure Release**
  - Siemens Crown™ BioGest

- **Ultrasound**
  - Ovivo/UltraWaves

- **Pulse Power**
  - OpenCEL™
  - Volgelsang BioCrack

- **Thermal Hydrolysis**
  - Cambi®
  - Kruger Exelys™
  - Lysotherm®
Homogenization - MicroSludge™

- 1999-2001 - Vancouver, B.C. lab testing
- 2002-2003 - Vancouver WWTP pilot
- 2004 - Chilliwack, B.C. alpha test
- June 2005 - Strategic partnership, Invensys plc
- 2005-2006 - JWPCP, LA County 12 month beta test
- May 2007 - Des Moines commercial installation

- Includes Pilot Scale Digesters

- Over ten years of development
Homogenization - MicroSludge™

Developed by Paradigm Environmental Technologies Inc., BC

- NaOH to weaken cell membranes and reduce viscosity (pH 9 to 10)
- Chopper pump to break up agglomerates
- Screen to 800 µm to remove non-cellular debris
- Homogenizer pressure 82,700 kPa (12,000 psig) for cell lysis
Homogenization - *MicroSludge™*

Homogenizer Valve

- Raw WAS
- Homogenized WAS

Cell Disruption Valve

Impact Ring

Valve Stem
**MicroSludge™ Installations**

- Bench-scale tests
- Field tests at Chilliwack WWTP, BC
- Large demonstration at LACSD – vendor tests and WERF Project (03-CTS-9T)

BEFORE

*MicroSludge*

AFTER

*MicroSludge*
Homogenization - *MicroSludge™*

Odor Reduction Benefits – WERF/LACSD/CH2M HILL Field Tests
### Des Moines Study

<table>
<thead>
<tr>
<th>Digester Number</th>
<th>Digester Feed (TS Basis)</th>
<th>HRT (Days)</th>
<th>Organic Loading Rate (Kilograms Volatile Solids/m³ day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56% TWAS + 44% PS</td>
<td>20, 15, 10, 7</td>
<td>1.45, 1.76, 2.68, 4.10</td>
</tr>
<tr>
<td>2</td>
<td>56% MicroSludge™ TWAS + 44% PS</td>
<td>20, 15, 10, 7</td>
<td>1.45, 1.76, 2.68, 4.10</td>
</tr>
<tr>
<td>3</td>
<td>100% raw TWAS</td>
<td>15</td>
<td>1.83</td>
</tr>
<tr>
<td>4</td>
<td>100% MicroSludge™ TWAS</td>
<td>15</td>
<td>1.83</td>
</tr>
</tbody>
</table>
## Des Moines, Pilot Study

<table>
<thead>
<tr>
<th>HRT</th>
<th>Testing Period (2009)</th>
<th>No. of days</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 days</td>
<td>Dec 20 – Mar 15</td>
<td>86</td>
</tr>
<tr>
<td>15 days</td>
<td>March 16 – April 1</td>
<td>17</td>
</tr>
<tr>
<td>10 days</td>
<td>April 2 – May 22</td>
<td>51</td>
</tr>
<tr>
<td>7 days</td>
<td>May 23 – August 7</td>
<td>77</td>
</tr>
</tbody>
</table>
Volatile Solids Reduction in Control and Test Digesters

![Graph showing VS Reduction vs. Digester HRT in Days]

- **Control VSr**
- **Test VSr**

Digester HRT [Days]

VS Reduction [%]
COD Reduction in Control and Test Digesters

![Graph showing COD reduction in control and test digesters over varying HRT (days).]

- **Control COD Reduction**
- **Test COD Reduction**
## Total Volume of Biogas Produced

<table>
<thead>
<tr>
<th>HRT</th>
<th>No. of days of operation</th>
<th>Total Biogas Production in Control (L)</th>
<th>Total Biogas Production in Test (L)</th>
<th>% Increase in Biogas Production in Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>86</td>
<td>20,392</td>
<td>24,045</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>17</td>
<td>5,376</td>
<td>6,093</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>51</td>
<td>21,954</td>
<td>26,796</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>77</td>
<td>22,619</td>
<td>25,304</td>
<td>11</td>
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</table>
VFA Production

**TWAS**

```
<table>
<thead>
<tr>
<th>Incubation day</th>
<th>HAc</th>
<th>HPr</th>
<th>HBu</th>
<th>Total VFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

```
mg/L as HAc
```

```
20000
15000
10000
5000
0
```

**Micro sludge**

```
<table>
<thead>
<tr>
<th>Incubation day</th>
<th>HAc</th>
<th>HPr</th>
<th>HBu</th>
<th>Total VFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

```
mg/L as HAc
```

```
20000
15000
10000
5000
0
```

- HAc
- HPr
- HBu
- Total VFA
Results from Des Moines Study

- Lower odor generation potential for MicroSludge™ treated TWAS.
- Direct formation of VFAs; Higher methanogenic activity for MicroSludge™ treated TWAS.
- Little VSr and CODr improvement at 20d SRT, but significant difference at shorter SRTs.
  - This equates to smaller quantities of solids requiring subsequent handling
- Biogas yields higher
  - Yields increased the most at lower SRT’s
- Filamentous organism control.
  - Reduces digester foaming
- No significant impact on pathogen reduction ahead of digestion
Homogenization – MicroSludge™ Summary

 Advantages

- Established theory (food processing industry)
- Waste solids reduction (7-15%) & biogas increase
- Odor reduction potential (30-50%)
- Foam reduction
- Processing and hauling costs reduction (site specific)

 Disadvantages

- Single vendor
- Emerging system in development stages
- Equipment/materials problems
Pressure Release - Crown™ Biogest

- Macerate sludge to homogenize
- Increase pressure (12 Bar) with progressive cavity pump
- High pressure mixer, flow into disintegration nozzle.
- As the flow exits the nozzle, cavitation occurs rupturing cell structure
- Sludge can be passed through system three times before discharge to the digesters.
Pressure Release – Crown™ Biogest

Vendor claims
- A minimum 20% increase in Biogas production.
- A minimum 15% reduction in dehydrated sludge volume.
- Carbon augmentation for BNR.

Crown Disintegrator
Wiesbaden WWTP - 60m3/hr
Crown™ Biogest Installations

Several installations on line

- Ingelheim, Germany 2002
- Oppenheim, Germany 2004
- Viby, Denmark 2006
- Rosedale, New Zealand 2006
- Weisbaden, Germany
- Danzig, Poland
- Bjermaken, Denmark
Crown™ Biogest Summary

Advantages
- Improved volatile solids destruction & digester biogas increase
- Foam reduction in digester
- Reduce quantity of solids requiring further handling
- Improved dewatering performance

Disadvantages
- High wear parts due to extreme pressure cavitation
- No systems on line in North America (although one system being installed in Visalia, CA in mid 2013)
Ultrasound – Ovivo Sonolyzer™

- Treats all or portion of TWAS
- 5 Oscillators in each module (1 kW each)
- Frequency is 20 kHz
- Energy input is 5 kW
- Intensity 25 to 50 W/cm²
- Sonication dose 1-9 kWh/m³
Ultrasound – Sonolyzer™: Where Applied

Ultrasound systems on wastewater treatment plants

Areas of use and advantages

- Primary Sedimentation
- Aeration Tank
- Secondary Sedimentation
- Return Activated Sludge
- Thickening
- Waste Sludge
- Digester
- Digested Sludge
- Dewatering
Ovivo Sonolyzer™ Installations

Several Plants on Line in Germany

- Leinetal 2003
- Bamberg 2004
- Meldorf 2005
- Ahrensburg 2009
- Bunde
- Centrum, Poland 2009
Ultrasound - Sonolyzer™ Summary

Advantages
- Improved volatile solids destruction & digester biogas increase
- Foam reduction and improved settleability (reduced SVI)
- Reduce quantity of solids requiring further handling
- Can provide supplemental carbon source for BNR
- Potentially increase loading to digester

Disadvantages
- No systems on line in North America
- Sonotrodes must be replaced every 1.5 - 2 years
How Pulsed Power Technology Works

The underlying technology, Pulsed Electric Fields (PEF), has applications in the food and biotechnology arenas.
## Main Applications of Pulsed Electric Fields

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food technology</td>
<td>- FDA-approved alternative to pasteurization for liquid food products</td>
</tr>
<tr>
<td></td>
<td>- Scaled for food processing operations</td>
</tr>
<tr>
<td></td>
<td>- Significant research history (led by Ohio State University)</td>
</tr>
<tr>
<td>Medical/Biotechnology</td>
<td>- “Electroporation” used for gene and drug transfer in bio systems</td>
</tr>
<tr>
<td></td>
<td>- Typically bench scale systems</td>
</tr>
<tr>
<td></td>
<td>- Multiple manufacturers of lab electroporation equipment</td>
</tr>
<tr>
<td>Waste/water/energy</td>
<td>- Acceleration of biotech processes by disrupting cellular membrane</td>
</tr>
<tr>
<td></td>
<td>- Industrial scale equipment designed for 24/7 operation</td>
</tr>
<tr>
<td></td>
<td>- OpenCEL FP equipment, IP (incl OSU license), and know how</td>
</tr>
</tbody>
</table>
1. Main TWAS line
2. TWAS input
3. Pump/grinder
4. FP modulator
5. Treated TWAS return
6. FP high-voltage PS
7. Cooling water
8. 3-Phase 480V
# OpenCEL™ Pulse Power operational summary

## OpenCEL FP technology progress at bench, pilot, and full scale

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
</table>
| Lancaster, OH     | - Pilot-scale demonstration at an all-aerobic facility  
                     - Treatment of recycle stream showed nearly 80% reduction in solids  
                     - Significant reduction in pathogen counts after treatment |
| ASU Biodesign     | - Two lab-scale anaerobic digesters and a Focused Pulsed unit  
                     - Applied research for parameter optimization  
                     - Basic research to investigate advanced applications of technology |
| Mesa, AZ          | - Full-scale installation at anaerobic facility; started first quarter 2007  
                     - Innovative savings-share commercial terms  
                     - ASU and CH2M HILL providing technical support to monitor progress |
Lancaster, OH pilot results (con’t)

…and resulted in greater destruction of biosolids during aerobic treatment

Biosolids production
Ton biosolids/kg VSS

2-month average: 1.56
Treated actual: 1.19
Treated normalized: 0.47

Biosolids production decreased significantly after treatment of only 34% of RAS flow; normalized reduction in biosolids volume for treatment of total WAS volume estimated at 70 to 80%
Mesa anaerobic digesters

Operating data:
• Plant flow rate between 10-12 MGD
• Continuous treatment of up to 60,000 gpd of PS/WAS
• Solids content of PS/WAS material between 4% and 6%

Project notes:
• Full-scale municipal installation
• Equipment installed with minimal impact to ongoing operations
• Unique savings-share commercial terms
Mesa NWWRP process flow

- PS
- WAS
- Thickened Sludge Wet Well
- Thickened Sludge Pumps
- Anaerobic Digesters
- FP System Installed Here
- Dewatering Centrifuges
- Biosolids (Landfill or Land App)
Mesa NWWRP installation details

1. FP Modulator
2. Treatment chamber
3. FP High-voltage power supply
4. OpenCEL control system

Supplied by OpenCEL

5. Pump/grinder
6. Grinder control panel
7. Feed pump control panel
8. Power monitor

Supplied by Client and/or OpenCEL
Mesa Plant performance trends since OpenCEL installation

Summary:
- OpenCEL treatment has increased steadily since startup
- Biosolids trucked from the plant have decreased as more material is treated
- Biogas production has increased in response to additional treatment
- Natural gas consumption for sludge heating has been reduced in the winter months and eliminated in the summer
- In early 2009, FP-treated material has replaced methanol for denitrification and digester performance continues to improve

Source: NWWRP operating data
Mesa NWWRP 2008 summary results

biosolids quantity requiring handling

Normalized weight of biosolids trucked from the Mesa NWWRP as compared to a 3-month moving average of the digester influent sludge volume fraction treated by the OpenCEL FP unit. The dashed horizontal line represents the baseline period average (502 tons per million gallons); the solid horizontal line represents the 2008 corrected average (417 tons per million gallons).

Source: NWWRP operating data
Normalized biogas generation at the Mesa NWWRP as compared to a 3-month moving average of the digester influent sludge volume fraction treated by the OpenCEL FP unit. The dashed horizontal line represents the baseline period average (2.14 scf per gallon); the solid horizontal line represents the 2008 average (2.83 scf per gallon).
Normalized natural gas consumption at the Mesa NWWRP as compared to the digester influent sludge volume fraction treated by the OpenCEL FP unit. The dashed horizontal line represents the baseline period average (2,208 therm/gallon-month); the solid horizontal line represents the 2008 average (923 therm/gallon-month).

Source: NWWRP operating data
OpenCEL Performance at Mesa Arizona 2008

<table>
<thead>
<tr>
<th></th>
<th>Flow to Digester through OpenCEL Unit</th>
<th>Adjusted to 95% flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Solids Trucked</td>
<td>16.8%</td>
<td>52.7%</td>
</tr>
<tr>
<td>Percent Reduction over baseline</td>
<td>16.8%</td>
<td>52.7%</td>
</tr>
<tr>
<td>Biogas</td>
<td>31.9%</td>
<td>52.7%</td>
</tr>
<tr>
<td>Percent Improvement over baseline</td>
<td>31.9%</td>
<td>52.7%</td>
</tr>
<tr>
<td>Natural gas consumption</td>
<td>58.2%</td>
<td>N/A</td>
</tr>
<tr>
<td>Percent reduction over baseline</td>
<td>58.2%</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Since its April 2007 startup the OpenCEL FP unit has:

- Demonstrated an effective increase in biogas production of nearly 60% in 2008
- Demonstrated an effective reduction in the weight of wet biosolids trucked from the plant of 30%
- Operated continuously and unattended since the beginning of September 2007
- Caused no disruption to Mesa operations

1. The Mesa NWWRP produces a 60/40% (or leaner) blend of primary and waste activated sludge. Benefits should be proportionately higher at plants were the OpenCEL unit treats 100% WAS.
Advantages

- Improved volatile solids destruction & digester biogas increase
- Foam reduction and improved settleability (reduced SVI)
- Reduce quantity of solids requiring further handling
- Can provide supplemental carbon source for BNR
- Potentially increase loading to digester

Disadvantages

- Significant energy requirement
- Only one vendor so far
- Only two systems on line in North America (Mesa and Racine) but a third in Orange County, CA is going on line in 2013
Thermal Hydrolysis

- High pressure-high temperature process: thermal hydrolysis of dewatered sludge under pressure using live steam.
- Hydrolyzed and pasteurized sludge digested at greater VSLRs (smaller vessels).
- Heat recovery minimizes the energy consumption.

- Three systems suppliers:
  - Cambi® Thermal Hydrolysis Process (THP)
  - Kruger Exelys® Process
  - Lysotherm® Process
• Class A biosolids
• Reduced volume
  • >35% solids
  • 60 V.S. destruction

1. Solids are dewatered
   To ~15%

2. Solids mixed with
   return steam and
   Water, so about 12%

3. Solids are heated by
   direct steam addition to
   320° F and 90 psi for
   45 minutes
   • Class A time v. temp.
   • Organic compounds are
     solubilized

4. Pressure in reactor is
   reduced to 60 psi.
   • Steam is returned to Pre-Heat

5. Reactor pressure is
   rapidly released, flashing
   solids to the flash tank.
   • Flashing causes cells to
     rupture
   • Steam is returned to
     Pre-Heat
   • Hydrolyzed solids have reduced
     viscosity

8-10% solids
Digester feed
at 100° F

60% C.O.D. conversion
50% reduction in digester volume
Increased gas production
Foaming eliminated

Dewatering
30 - 37% DS

Methane

Pre-Heat
Tank

Reactor

Flash
Tank

Anaerobic
Digester
# CAMBI Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mesophilic AD</th>
<th>CAMBI + Meso AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digester Feed (%TS)</td>
<td>4-6</td>
<td>12-15</td>
</tr>
<tr>
<td>VSLR (kg VS/m$^3$/d)</td>
<td>1.5</td>
<td>3.5</td>
</tr>
<tr>
<td>VS Destruction (%)</td>
<td>40-55</td>
<td>55-65</td>
</tr>
<tr>
<td>Pathogen content</td>
<td>Class B</td>
<td>Class A</td>
</tr>
<tr>
<td>Dewatered Cake TS (%)</td>
<td>20-25</td>
<td>30-35</td>
</tr>
</tbody>
</table>
**Cambi - Conventional THP (MARK I):**

**Batch cycle conventional:**
- 15 min. Sludge filling.
- 15 min. Steam filling.
- 20 - 30 min. Retention time.
  - Temp. set point at 150 to 180 °C (302 – 356 °F).
- 15 min. Flash from reactor to pulper.
  - (6 barg to 2 barg*). No steam explosion.
- 15 min. Blow down from reactor to flash tank.
  - (2 barg to 0.2 barg**). Steam explosion

**Total cycle time : 90 minutes (Typical)**

* 87 PSI to 29 PSI
** 29 PSI to 3 PSI
What is Cambi MK-II?

• Allow sludge filling and steam filling at the same time:
  • Modification in the control philosophy
  • Use special developed equipment.

• Better use of available reactor volume:
  • Full blow down from reactor to flash tank.
    • Use of patented internals in the flash tank.

• Retention time reduction to 20 minutes.
Cambi - MK-II THP:

Batch cycle for B12:

- 29 min. Sludge and steam filling.
- 20 min. Retention time
  Temp. set point at 150 to 180 °C.
  (302 – 356 °F).
- 0 min. Flash from reactor to pulper.
- 15 min. Blow down from reactor to flash tank.
  Full blow down (6 barg to 0.2 barg*)

Total cycle time: 64 minutes

* 87 PSI to 3 PSI
Improving Digester Performance with enhanced steam explosion at Chertsey

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>22 tDS/d</td>
<td>Average</td>
</tr>
<tr>
<td>Practical limit</td>
<td>30 tDS/d</td>
<td>30 tDS/d</td>
</tr>
<tr>
<td>OLR max</td>
<td>7kgVS/m3/d</td>
<td>OLR max</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8kgVS/m3/d</td>
</tr>
</tbody>
</table>

Peak 35tDS/d
Odor Reduction with Cambi Cake

![Graph showing TVOS concentration vs storage time with different methods: Pre-Pasteurization, Thermo in Series, TPAD, Conventional Meso, Thermophilic, Cambi Thermal Hydrolysis.](Source: WERF ROSI Project)
# CAMBI PLANTS (in operation)

<table>
<thead>
<tr>
<th>Customer/project</th>
<th>Location</th>
<th>Design capacity (TDS/year)</th>
<th>THP reactors</th>
<th>TYPE</th>
<th>Completed</th>
<th>No. of plants</th>
<th>Application</th>
<th>Product end-use</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIAS (1)</td>
<td>Hamar, Norway</td>
<td>3,600 tonnes</td>
<td>1</td>
<td>WWTP</td>
<td>1996</td>
<td>1</td>
<td>F</td>
<td>A</td>
</tr>
<tr>
<td>Thames Water (2)</td>
<td>Chertsey, UK</td>
<td>9,600 tonnes</td>
<td>2</td>
<td>WWTP</td>
<td>1999</td>
<td>2</td>
<td>F</td>
<td>A</td>
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<tr>
<td>Borregaard Industries</td>
<td>Sarsborg, Norway</td>
<td>4,000 tonnes</td>
<td>1</td>
<td>PAPER</td>
<td>2000</td>
<td>3</td>
<td>W</td>
<td>I</td>
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<tr>
<td>The Municipality of Næstved*</td>
<td>Næstved, Denmark</td>
<td>1,600 tonnes</td>
<td>1</td>
<td>WWTP*</td>
<td>2000</td>
<td>4</td>
<td>W</td>
<td>A</td>
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<tr>
<td>Nigg Bay</td>
<td>Aberdeen, UK</td>
<td>16,500 tonnes</td>
<td>4</td>
<td>WWTP</td>
<td>2001</td>
<td>5</td>
<td>F</td>
<td>A</td>
</tr>
<tr>
<td>&quot;Mjøsanlegget&quot;, Biowaste Plant</td>
<td>Lillehammer, Norway</td>
<td>4,600 tonnes</td>
<td>2</td>
<td>OFMSW</td>
<td>2001</td>
<td>6</td>
<td>B</td>
<td>A</td>
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<tr>
<td>Ringsend Sewage Treatment Works</td>
<td>Dublin, Ireland</td>
<td>36,000 tonnes</td>
<td>8</td>
<td>WWTP</td>
<td>2002</td>
<td>7</td>
<td>F</td>
<td>D, A</td>
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<tr>
<td>The Municipality of Fredericia</td>
<td>Fredericia, Denmark</td>
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<td>2</td>
<td>WWTP</td>
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<td>Kobelco Eco-Solutions</td>
<td>Niigata, Japan</td>
<td>1,200 tonnes</td>
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<td>Spolka Wodna Kapusciska</td>
<td>Bydgoszcz, Poland</td>
<td>8,000 tonnes</td>
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<td>Thames Water</td>
<td>Chertsey, UK</td>
<td>Included in (2)</td>
<td>0</td>
<td>Operations</td>
<td>2005 - 2012</td>
<td>Part of 2</td>
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<tr>
<td>HIAS, additional digester</td>
<td>Hamar, Norway</td>
<td>Included in (1)</td>
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<td>New digester</td>
<td>2005</td>
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<td>Oxley Creek</td>
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<td>12,900 tonnes</td>
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<td>11</td>
<td>W</td>
<td>A</td>
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<tr>
<td>Bruxelles Nord</td>
<td>Bruxelles, Belgium</td>
<td>20,000 tonnes</td>
<td>5</td>
<td>WWTP</td>
<td>2007</td>
<td>12</td>
<td>W</td>
<td>O</td>
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<tr>
<td>HIAS- Expansion</td>
<td>Hamar, Norway</td>
<td>2,000 tonnes</td>
<td>1</td>
<td>WWTP</td>
<td>2007</td>
<td>Expanding 1</td>
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<td>A</td>
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<tr>
<td>Cotton Valley (Anglian Water)</td>
<td>Milton Keynes, UK</td>
<td>20,000 tonnes</td>
<td>4</td>
<td>WWTP</td>
<td>2008</td>
<td>13</td>
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<tr>
<td>Ecopropro, multi-waste** plant</td>
<td>Verdal, Norway</td>
<td>8,000 tonnes</td>
<td>2</td>
<td>OFMSW***</td>
<td>2008</td>
<td>14</td>
<td>B + F</td>
<td>A</td>
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<tr>
<td>Whittingham WWTW (Anglian Water)</td>
<td>Norwich, UK</td>
<td>19,000 tonnes</td>
<td>4</td>
<td>WWTP</td>
<td>2008</td>
<td>15</td>
<td>F</td>
<td>A</td>
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<tr>
<td>Biowakka Oy</td>
<td>Åbo/Turku, Finland</td>
<td>14,000 tonnes</td>
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<td>WWTP</td>
<td>2008</td>
<td>16</td>
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<td>A</td>
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<tr>
<td>Nigg Bay, upgrade</td>
<td>Aberdeen, UK</td>
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<td>0</td>
<td>WWTP</td>
<td>2009</td>
<td>Expanding 5</td>
<td>F</td>
<td>A</td>
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<tr>
<td>Bran Sands (Aker-Kværner/NWL)</td>
<td>Åbo/Turku, Finland</td>
<td>37,000 tonnes</td>
<td>8</td>
<td>WWTP</td>
<td>2009</td>
<td>17</td>
<td>F</td>
<td>A</td>
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<tr>
<td>Ampereverband, Cambi THP-C*</td>
<td>Geiselbullach, Germany</td>
<td>2,000 tonnes</td>
<td>1</td>
<td>WWTP</td>
<td>2009</td>
<td>18</td>
<td>H</td>
<td>I</td>
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<tr>
<td>Ringsend STW (New THP line)</td>
<td>Dublin, Ireland</td>
<td>20,000 tonnes</td>
<td>4</td>
<td>WWTP</td>
<td>2010</td>
<td>Expanding 7</td>
<td>F</td>
<td>D, A</td>
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<tr>
<td>Cardiff, Welsh Water (Imtech)</td>
<td>Wales, UK</td>
<td>30,000 tonnes</td>
<td>6</td>
<td>WWTP</td>
<td>2010</td>
<td>19</td>
<td>W</td>
<td>A</td>
</tr>
<tr>
<td>Afan, Welsh Water (Imtech)</td>
<td>Wales, UK</td>
<td>20,000 tonnes</td>
<td>4</td>
<td>WWTP</td>
<td>2010</td>
<td>20</td>
<td>F</td>
<td>A</td>
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<tr>
<td>Riverside, Thames W (Interserve)</td>
<td>London, UK</td>
<td>40,000 tonnes</td>
<td>8</td>
<td>WWTP</td>
<td>2011</td>
<td>21</td>
<td>F</td>
<td>A</td>
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<tr>
<td>Vilniaus Vandensys/ Vilnius Water Co.</td>
<td>Vilnius, Lithuania</td>
<td>23,000 tonnes</td>
<td>5</td>
<td>WWTP</td>
<td>2011</td>
<td>22</td>
<td>F</td>
<td>D, A</td>
</tr>
<tr>
<td>Mapocho WWTP (Degremont)*</td>
<td>Santiago, Chile</td>
<td>25,000 tonnes</td>
<td>6</td>
<td>WWTP</td>
<td>2012</td>
<td>23</td>
<td>H</td>
<td>A</td>
</tr>
<tr>
<td>Lindum, Cambi Compact</td>
<td>Drammen, Norway</td>
<td>6,000 tonnes</td>
<td>2</td>
<td>WWTP</td>
<td>2012</td>
<td>24</td>
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<td>A</td>
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<tr>
<td>Dawhulme, UU (B&amp;V)</td>
<td>Manchester, UK</td>
<td>91,000 tonnes</td>
<td>20</td>
<td>WWTP</td>
<td>2012</td>
<td>25</td>
<td>F</td>
<td>A, I</td>
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<tr>
<td>Howdon (Imtech/NWL)</td>
<td>Newcastle, UK</td>
<td>40,000 tonnes</td>
<td>8</td>
<td>WWTP</td>
<td>2012</td>
<td>26</td>
<td>F</td>
<td>A</td>
</tr>
</tbody>
</table>
CAMBIA PLANTS (in design/construction)

Ordered Plants / Under design/construction

<table>
<thead>
<tr>
<th>Plant</th>
<th>Location</th>
<th>Country</th>
<th>Capacity (tonnes)</th>
<th>Application</th>
<th>Start Year</th>
<th>Code</th>
<th>End-Use</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>Oslo EGE</td>
<td>Oslo</td>
<td>Norway</td>
<td>15,000</td>
<td>OFMSW***</td>
<td>2012</td>
<td>27</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Heijmans, STC Tilburg</td>
<td>Tilburg</td>
<td>Holland</td>
<td>23,000</td>
<td>WWTP</td>
<td>2013</td>
<td>28</td>
<td>F</td>
<td>I</td>
</tr>
<tr>
<td>Crossness, Thames Water</td>
<td>London</td>
<td>UK</td>
<td>36,500</td>
<td>WWTP</td>
<td>2013</td>
<td>29</td>
<td>F</td>
<td>I</td>
</tr>
<tr>
<td>Beckton, Thames Water</td>
<td>London</td>
<td>UK</td>
<td>36,500</td>
<td>WWTP</td>
<td>2013</td>
<td>30</td>
<td>F</td>
<td>I</td>
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<tr>
<td>DC Water</td>
<td>Washington DC</td>
<td>USA</td>
<td>130,000</td>
<td>WWTP</td>
<td>2014</td>
<td>31</td>
<td>F</td>
<td>A</td>
</tr>
</tbody>
</table>

**Total:** 768,000 tonnes 159

TDS = Total dry solids (1000 kg = 1 tonne)

Applications:

- **H:** Cambi Hybrid (WAS only TH mixed with untreated P), not Class A
- **W:** WAS, biological sludge, only (usually extended aeration)
- **F:** Full Cambi, TH of both P and WAS sludge, Class A
- **B:** Biowaste
- **O:** Wet-air oxidation

Product end-use:

- **A:** Use of end product in agriculture
- **D:** Drying of end-product
- **I:** Incineration of end-product

**WWTP = sludge from municipal wastewater treatment plant,** biological sludge/WAS only (Næstved is extended aeration plant)

*PAPER = bio-sludge/waste activated sludge from paper factory wastewater treatment plant*

***OFMSW = Organic Fraction of Municipal Solid Waste, **mix of sludge, OFMSW, and animal by-products (wet: 30,000 - 40,000 t/y)

Pop. Equiv. 26,301,000
Kruger EXELYS™

- Continuous energy efficient thermal hydrolysis

Heats solids
Not water!

 guarantened performance

Steam mixer + condenser

Sludge: 165°C, 9 bar, ~60-100°C
~20% DS

To digester Hydrolyzed Sludge
60-35°C
8-15%DC
Hillerød, Denmark

- **Size:**
  - Dimensioned for 8 MGD
  - Loaded with 4 MGD

- **Treatment line**
  - Primary sludge
  - Activated sludge BNR
  - **AND NOW EXELYS™-DLD**
    - 1 EP250 – 4,000 kg-DS/d
**Kruger Exelys™- LD**

- Double digester capacity & enhance performance

---

![Diagram of Kruger Exelys™- LD process]

1. **Primary + Secondary sludge**

2. **1st dewatering**
   - Sludge: ≥ 20%DS

3. **Steam mixer + condenser**

4. **Reactor**
   - Sludge: 165°C, 9 bar, ~20%DS, t ≥ 30 min

5. **Heat exchanger**

6. **Recovered heat**

7. **Biogas**

8. **Electricity + Heat**

9. **CHP unit**

10. **Digester**
    - More Biogas!
    - +100% capacity
    - Less sludge!

---

To digester
- Hydrolyzed Sludge
  - 35-40°C
  - 8-10%DS

---

**Legend:**
- **Steam Generator**
- **Dilution water**
- **To digester**
- **Final dewatering**
October 2011: Chosen as technology supplier for Vigo WWTP upgrade. 23,000 t-DS/y with Exelys + BioCon. Biogas production used to offset natural gas import for drying.
Advantages

• Allows significantly increased loading to digester
• Lower viscosity liquid sludge (easier to pump)
• Improved volatile solids destruction & digester biogas increase
• Improved dewatering performance
• Reduce quantity of solids requiring further handling
• Lower odor product without pathogen regrowth
• Produces Class A Biosolids

Disadvantages

• Complex systems with high pressure steam
• High strength side stream requiring treatment
Waste Solids Digestion Pretreatment Key Points

- Many new products in the market
- Many benefits claimed in literature
- Generally all provide some benefit
- Carbon augmentation potential for BNR
- Little is known on impact of raw feed characteristics and/or process operational parameters
- Pilot studies are recommended for most of these systems
- Energy balance needs to be carefully evaluated
- Few full-scale installations; many outside US, but the number of installations is rapidly increasing
Sludge Reduction and Cell Lysis Technology Practices

QUESTIONS?

Todd O. Williams, P.E., BCEE
todd.williams@ch2m.com
Janesville’s Renewable Energy Initiative

Biosolids: Resource! or Refuse?

18th Annual Education Seminar

Dan Lynch, P.E., BCEE and Jay Kemp, P.E., BCEE
Presentation Outline

- City of Janesville
- Renewable Energy Systems
- Biogas Utilization Overview
- Grants and Funding
- Costs and Revenues
- Gas Treatment Systems
- CNG Vehicles and Fueling
- System Performance
Janesville WWTP Facts

- Design Capacity of 19.8 million gallons of sewage per day (MGD)
- Serves a population of over 60,000.
- Thermophilic-mesophilic anaerobic digestion
- Produces 100,000 to 130,000 ft$^3$ per day of digester gas.
- Generates 1,600 dry tons of biosolids per year
Renewable Energy Features

- Electricity generated from biogas
  - Microturbines with heat recovery

- Solar energy
  - Photovoltaic cells on Administration Building

- Effluent-source heat pump

- BioCNG for Vehicle Fuel

- Grants and Funding
  - Focus on Energy
  - Alliant Energy
  - State of WI Energy Office
Renewable Energy System Not Implemented

- Effluent hydroturbine generator
  - Hard to find a good turbine fit
  - No funding available

- Wind Turbines (airport conflict)

- Additional solar electric
  - Phase II WWTP
  - Water Admin.
  - Feed-in tariff no longer available, incentives reduced
Biogas-to-Energy System (Phase I)

- Digester upgrades
- Sludge-to-sludge heat exchanger
  - Recovers heat from thermophilic digested sludge
- Gas Storage System
  - New dual membrane system
  - 107,000 cu ft capacity
- Gas conditioning and compressor system
  - Moisture and particulate removal
  - Siloxane removal
- (4) 65kW microturbines with integral heat recovery
  - Grid connect mode
  - WWTP has power purchase agreement with the electric utility
  - $0.12 /kWh on peak
Gas Storage System

- Completed in early July 2011
- Holds 107,000 cubic feet or one day of gas production
- Allows for maximizing of on-peak power production.
- Delays or prevents flaring of valuable gas resource in the event of gas conditioning system or microturbine downtime.
(4) 65kW ICHP Microturbines

- Recovered thermal energy heats digesters, reducing the need for natural gas-fired boilers
- Electricity sold to Alliant Energy at premium rate
- Low maintenance due to one moving part
• 200kW microturbine
• High Strength Waste Receiving
• CO₂ Removal Module for BioCNG production
• CNG compressor
• CNG Fuel Dispenser
• CNG high pressure storage spheres
Phase II Energy Projects

- Surplus gas will be used in a 200kW Microturbine.
- Allow for further maximizing of on-peak production.
- $+120,000 – $175,000 in additional yearly revenue depending on rate.
### Incentives for Energy Projects

<table>
<thead>
<tr>
<th>Provider</th>
<th>Project Description</th>
<th>Incentive Amount</th>
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</thead>
<tbody>
<tr>
<td>Focus on Energy</td>
<td>Turblex Aeration Blowers</td>
<td>$17,672</td>
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<tr>
<td>Focus on Energy</td>
<td>Biogas Project 95%</td>
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<td>Focus on Energy</td>
<td>Admin Building Solar Array</td>
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<td>Alliant Energy</td>
<td>Admin Building Solar Array</td>
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<tr>
<td>Focus on Energy</td>
<td>Building 35 Lights</td>
<td>$393</td>
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<td>Focus on Energy</td>
<td>Other WWTP Lights</td>
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<td>Focus on Energy</td>
<td>WWTP VFDs</td>
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<td>Biogas Project 5%</td>
<td>$6,922</td>
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<td>Admin. Building HVAC</td>
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<td>Focus on Energy</td>
<td>Operations Building HVAC</td>
<td>$1,500</td>
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<td>State Energy Office</td>
<td>Bio-CNG Project-Gas Storage</td>
<td>$125,000</td>
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<tr>
<td><strong>Wastewater Total</strong></td>
<td><strong>Wastewater Total</strong></td>
<td><strong>$373,472</strong></td>
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## Janesville Water Utility Grants

<table>
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<th>Focus on Energy</th>
<th>Water Admin Building HVAC</th>
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<tr>
<td>Focus on Energy</td>
<td>Pumping Station VFDs</td>
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<td><strong>Water Total Grants</strong></td>
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<tr>
<td>Total Energy Grants</td>
<td></td>
<td>$512,003</td>
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</table>
Renewable Revenue

• 1,672,000 kWh generated in 2011 from biogas
  –$ 154,000 in electricity sales
  –$ 77,665 thru June 2012 ($ 155,330 annually)

• 64,300 therms of recoverable heat
  –$ 47,600 in purchased energy savings

• 22,000 kWh of solar electricity generated in 2011
  –$ 1,100 in revenue*

• 1,800 GGE of BioCNG annually @ $4.00 gal=$7,200/yr
  –Use will grow as vehicles are added.

* Feed-in tariff not available
Janesville WWTP Electric & Transportation Fuel Cost/Revenue Projections
## Return on Investment

<table>
<thead>
<tr>
<th>Project Element</th>
<th>Capital Cost</th>
<th>10 yr Cumulative Revenue</th>
<th>10 yr Cumulative O&amp; M</th>
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<tbody>
<tr>
<td>65 kW Microturbine System*</td>
<td>$750,000</td>
<td>$1,949,000</td>
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<tr>
<td>200kW Microturbine</td>
<td>$300,000</td>
<td>$2,287,000</td>
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<td>Gas Conditioning</td>
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<td>CO2 Removal Module</td>
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<td>$453,000</td>
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<tr>
<td>CNG Fueling</td>
<td>$200,000</td>
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<td>$453,000</td>
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<td>CNG storage</td>
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<td>Grants</td>
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<td>$1,663,000</td>
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<tr>
<td></td>
<td></td>
<td>$4,943,000</td>
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</table>

Includes building addition and modifications
Biogas Treatment Requirements/Considerations

- Hydrogen Sulfide Removal (Existing iron sponge)
- Gas Compression
- Moisture Removal
- Siloxane/VOC Removal
Gas Conditioning System

- Began operation November 2010
- Removes moisture, particulates, and siloxane from digester gas
- Compresses gas to pressure required by microturbines
- 140 cfm capacity
• Chiller- Cools gas to 35F to remove moisture and some siloxane and other impurities.

• Compressor- pressurizes gas for application to microturbines

• Adsorptive media filters: Silica Gel and activated carbon provide siloxane and VOC removal to protect microturbines and CO₂ removal membranes
Biogas Treatment Requirements/Considerations

✓ Hydrogen Sulfide Removal
✓ Gas Compression
✓ Moisture Removal
✓ Siloxane/VOC Removal

☐ Carbon Dioxide Removal

☐ Fuel Requirements:
  – Engine Manufacturers Specifications, SAE J1616
CO$_2$ Removal System

- Concentrates methane from 60% to more than 90% by removing CO$_2$ and other gases.
- Required to make digester gas suitable for vehicle fuel.
1,000 ft$^3$ Digester Gas
600 ft$^3$ Methane
400 ft$^3$ CO$_2$

300 ft$^3$ Methane
370 ft$^3$ CO$_2$

300 ft$^3$ Methane
30 ft$^3$ CO$_2$

40 cfm

20 cfm

60 cfm

2.5 Gallons Gasoline

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Phase II Energy Projects

- 5 Vehicles planned for 2012
- Up to 50 vehicles in 10 years

- BioCNG for Vehicle Fuel
CNG Storage and Fueling Station

- 100 gallons gasoline equivalent storage sphere.
- Includes further drying and compression of gas before entering sphere (4500 psi).
- Fill-up time comparable to conventional fuel station.
CNG Vehicles

- Handle the same as conventional vehicles.
- Use the same engine with few modified components.
- Can switch from petroleum to CNG at push of a button.
- Bi-Fuel vehicles have additional tanks which can limit storage space.
CNG Vehicle Layout

Ford F-150 Engine

CNG Fuel Rail

- CNG shut-off valve
- Dashboard with CNG fuel gauge
- Common refueling location
- Gasoline tank
- CNG tank
- Gasoline fuel rail
- Intake air manifold with CNG fuel rail
- CNG engine management system

Source: Fiat Powertrain
© 2010 Chrysler Group LLC
Gasoline Equivalent Gallons per Month for BioCNG (2012-2013)
CNG is highest value use for Digester Gas

Relative Value of 100 cuft of Digester Gas by Usage

- Microturbine 200 off peak
- Natural Gas Equivalent ($0.70/therm)
- Heat Value of DG (80% efficiency)
- Microturbine 65 off peak (heat recovery)
- Microturbine 200 off peak (heat recovery)
- Microturbine 200 on peak
- Microturbine 65 on peak (heat recovery)
- Microturbine 200 on peak (heat recovery)
- Gasoline (as CNG)
• 107,000 cu ft Gas Storage
• High Strength Waste- up to 20,000 gal/ day
• 4-65 kW microturbines with heat recovery
• 1- 200kW microturbine
• 60 scfm biogas to 20 scfm BioCNG modules
• 50 scfm CNG compressor with 100 GGE storage sphere
• CNG fuel dispenser
Thank You
Bursting the Foam Bubble
Causes, Effects, and Prevention/Control of Anaerobic Digester Foaming

Krishna Pagilla, Ph.D., P.E., BCEE
Illinois Institute of Technology

CSWEA Education Seminar,
April 2, 2013

The Battle of the Foaming Digesters
(Holy!) Rivers of AD Foam....
Possible Factors and Relationships Leading to Bubble and Foam Formation

AD Foam - Three Phase Foam

- Liquid-Solids-Gas
  - Bubbles Stabilized by Filaments, Surfactants and Solids
  - Dissolved/Dispersed Flotation Effects of Biogas
  - Sludge Particles are Accumulated in Foam

Solids-liquid-gas volume in foam?
Thresholds of surfactants and solids in foam?
Types of digester foams?
### Foaming Causes and Contributors

<table>
<thead>
<tr>
<th>Classification</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge feed characteristics</td>
<td>Surface active agents in feed</td>
</tr>
<tr>
<td></td>
<td>Foam causing filaments in feed sludge</td>
</tr>
<tr>
<td>Digestion process-related characteristics</td>
<td>Organic loading aspects – overload and inconsistent loading</td>
</tr>
<tr>
<td></td>
<td>VFA production - Imbalances between the successive hydrolysis, acidogenesis and methanogenesis</td>
</tr>
<tr>
<td></td>
<td>Gas production</td>
</tr>
<tr>
<td>Digester operating conditions</td>
<td>Temperature, pressure, pH, alkalinity</td>
</tr>
<tr>
<td></td>
<td>Mixing</td>
</tr>
<tr>
<td>Digester configuration, shape and physical features</td>
<td>Digester shape and configuration</td>
</tr>
<tr>
<td></td>
<td>Sludge withdrawal and gas piping</td>
</tr>
</tbody>
</table>

**Primary Cause vs. Contributing Factor?**

**Cause vs. Consequence?**

### Filaments and AD Foaming

- *Gordonia (Nocardia) amarae*
- *Microthrix parvicella* (BNR)
- Thresholds for AS and AD Foaming are Different
- Stable Foam (Stable for Hours)
- High Solids Content
- Definite Primary Cause of AD Foaming
- Possibly the Only Primary Cause??

**What are the threshold levels?**
Prevention and Control of Foaming – Existing Information

- Physical Break-up by Sludge Sprays
- Chemical Addition (Defoamants, No Cl₂)
- Sludge Pre-Treatment Technologies
- Prevention
  - Uniform Sludge Feeding (flow and load)
  - Optimized Mixing
  - Control of Foaming in Liquid Treatment
  - Change in Digester Cover/Piping/Shape

How to select one or more?

WERF Survey Results

39 US Plants (Responses)

- 32 have AD Foaming
- All Seasons
- Both Intermittent and Persistent
- All AS Configurations
- Filaments Common
- Cited Surfactants/FOG
- Foaming AD Mix Continuously
- Defoamers, Uniform Loading, “Optimum Mixing”, WAS Chlorination (?), Thickening (?) are Top Solutions Tried

- No specific relationships between process parameters and causes of foaming
- Gaps and needs from earlier knowledge still remain
- Full scale investigations at select plants way forward
Full Scale Studies – Topics Investigated

- Filaments Presence in Feed
- PS:WAS Solids Ratio Effects
- Organic Loading Rate (OLR) and OLRvariation Effects
- Effects of Mixing on Foaming and Performance
- Feed Sludge Holding Effects
- Foam Destroyer or Sludge Spray Use
- Defoamer Application Effectiveness
- Methods for Foam Detection

Full-Scale Study Plants

- SF Oceanside Plant, California
- NYC Hunt’s Point Plant, New York
- Marquette WRF, Michigan
- City of Elmhurst, Illinois
- City of Crystal Lake, Illinois
- Columbus Southerly & Jackson Pike, Ohio
**Filament Presence and Foaming in Full-Scale Study Plants**

<table>
<thead>
<tr>
<th>Name of Plant</th>
<th>Reported Cause of AD Foaming</th>
<th>Filament Presence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elmhurst WWTP, IL</td>
<td>Overloading of digesters</td>
<td>None</td>
</tr>
<tr>
<td>Crystal Lake WWTP-2, IL</td>
<td>Primary sludge levels in feed</td>
<td><em>G. amarae</em> and <em>M. parvicella</em></td>
</tr>
<tr>
<td>Marquette City WRF, MI</td>
<td>High levels of gas production with insufficient surface area for gas to escape the liquid volume</td>
<td><em>M. parvicella</em> (intermittent presence)</td>
</tr>
<tr>
<td>Oceanside WWTP, CA</td>
<td>Filamentous foaming</td>
<td><em>G. amarae</em></td>
</tr>
<tr>
<td>Hunts Point WWTP, NY</td>
<td>Filamentous foaming</td>
<td><em>G. amarae</em></td>
</tr>
<tr>
<td>Southerly WWTP, OH</td>
<td>Unknown</td>
<td><em>M. parvicella</em> (intermittent presence)</td>
</tr>
<tr>
<td>Jackson Pike, OH</td>
<td>High WAS levels in feed</td>
<td>None</td>
</tr>
</tbody>
</table>

- Most of the plants did not experience any foaming during the duration of the study.
- Difficult to conclude that filaments were the primary foaming cause and to determine any filament thresholds for AD foaming.

**Gram Stain and FISH Images from Full Scale Study Sludge Samples**

- **Gram positive *M. parvicella***
- **FISH of *M. parvicella***
- **Gram Stain of *G. amarae***
- **FISH of *G. amarae***
Crystal Lake PS:WAS Solids Ratio Effects

Historical PS:WAS Ratio in Feed

- The digester was fed either PS or WAS on several occasions.
- Yearly average for 2011, 76% PS and 24% TWAS was fed to the digester.
- During a foam episode, the digester seems to have been fed all PS and no TWAS (accompanied by overloading).

PS:WAS Trending for Phase 1 Full Scale Study

- Feeding all PS to the digester during our full scale study did not result in a foam episode.
- The OLR to the digester during these days ranged between 0.07 – 0.09 VS per cubic feet per day, which is lesser than the OLR during the foam event.

Crystal Lake PS:WAS Solids Ratio – Foaming Potential Results

Unstable Foam Ratio during Full Scale Study

- Foam potentials are not significantly high.
- Filaments are present.
- The highest unstable foam ratios were exhibited by PS and digester contents, and were nearly 1.6 and 1.2 respectively.
Full Scale Mixing Studies (and OLR Effects)

• Modifying mixing frequency/patterns in the digesters
  – Gas and mechanically mixed
  – Both cylindrical and ESD
• Evaluating gas production and digester depth profiles
  – Detection of presence/absence of foam by plant-specific methods and/or visual observation

Elmhurst Gas Mixed Cylindrical Digesters
OLR and Mixing Study - Introduction

• 2 Digesters – SD and ND
  – SD has Pearth gas mixing.
  – ND has confined gas mixing system with an eductor tube.
• Full – Scale Study:
  – Phase 1: Mixing only a total of three hours a day – one hour each, morning, noon and evening.
  – Phase 2 A: Each digester was fed on alternate days (Baseline).
  – Phase 2 B: ND fed approx. twice the OLR compared to SD, while continuing to mix three hours a day.
Elmhurst Gas Mixed Cylindrical Digesters
OLR and Mixing Study

Historical OLR Data (2009 – 12)

- Max OLR for 2009 to ND was 76 lb volatile solids per thousand cubic feet of digester volume (lb VS/kcf/d).
- Shock load of 141 lb VS/kcf/d in 2010.
- ND is more prone to foaming.

Full Scale Study OLR Variations to Digesters

- From Jan 1, 2012 through April 30, 2012, the ND was double that of SD.
- Baseline OLR ranged between 20 – 30 VS/kcf/d for both ND and SD
- The average feed to ND was 58 lb VS/kcf/d and the maximum was 84 lb VS/kcf/d.

Elmhurst Mixing Study Results

- Mixing was reduced from 11 hours a day to 1 hour each, morning, noon and evening.
- Digester contents are homogeneous after mixing reduction.
- Digester depth profiles measured with sludge judge before and after mixing.

TS Variation at Bottom Level of the Digester before and after Mixing

TS Variation at Top Level of the Digester before and after Mixing
Elmhurst Results – Increased OLR and Reduced Mixing

**Measured Foam Levels**

- Digester depth profiles measured with sludge judge before and after mixing.
- No foam was measured in North Digester.

**Gas Production**

- Average gas production in 2010 and 2011 was 30 kcfd. In 2012, it was 26 kcfd.
- After increased OLR and mixing reduction, gas production is within the margin of error of measurement.
OSP Mechanically Mixed ESDs
Different Digester Mixing Modes

A. Foam Abatement Mixing
- Sludge mixing and heat recirculation - 2,500 gpm centrifugal pumps and 600 gpm recirculation pumps.
- Both pumps provide approximately 6 mixing turn-overs per day.
- With the intended mixing system partly or completely off, mixing by the heat recirculation loop provides 1.15 turn-overs per day.

B. Normal Mixing

OSP Mechanically Mixed ESDs
Full Scale Mixing Studies

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Mixing Frequency (% of the time)</th>
<th>FOG Injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Since Plant Start-up</td>
<td>100% 100% 100%</td>
<td></td>
</tr>
<tr>
<td>Phase 1</td>
<td>Jan-Apr 2012 100% 75% 50%</td>
<td>FOG injection in all 3 digesters (even feed)</td>
</tr>
<tr>
<td>Phase 2</td>
<td>May-Sep 2012 100% 50% 25%</td>
<td>Interrupted from August 15th, 2012 to January 16th, 2013</td>
</tr>
<tr>
<td>Phase 3</td>
<td>Oct-Nov 2012 25% 25% 0%</td>
<td>Interrupted from August 15th, 2012 to January 16th, 2013</td>
</tr>
<tr>
<td>Phase 4</td>
<td>Dec. 2012 0% 25% 0%</td>
<td>Interrupted from August 15th, 2012 to January 16th, 2013</td>
</tr>
<tr>
<td>Phase 5</td>
<td>Starting Jan. 2013 0% 0% 0%</td>
<td>FOG injection in digester #1 only</td>
</tr>
</tbody>
</table>
**OSP Mixing Study Results**

- Despite interrupting mixing totally for more than 50 days, digester 4 contents are almost homogeneous. (Digester 1&2 have been mixed for 25% of the time).
- Temperature difference between top and bottom depth of all digesters is less than 2 °F.

**Marquette Foam Suppression Mixing**

- (Foam Buster) Nozzle connected to recirculation pumps
- Mixing studied in conjunction with bypass of downstream high HRT aerated WAS storage tank:
  - Phase 1 – Bypassing the WAS storage tank
  - Phase 1A – Foam suppressors on in Digester 2 while keeping them off in digester 1.
  - Phase 1A (No bypass) – Foam suppressors on in Digester 2 while keeping them off in digester 1; with no bypass of the aerated WAS tank.
• The content of the digester 2 is not homogeneous but digester 1 that is currently not mixed is homogenous.
• Switching off foam suppression did not allow the contents of 1 to settle; though both digesters are loaded uniformly
Marquette Gas Production – WAS Storage Tank Bypass/No Bypass

The average gas production for:
- Baseline - Years 2010 and 2011 - 30755 CF/day ± 13576 (mean ± standard deviation).
- WAS tank bypass only - 50901 CF/day ± 8343.
- WAS tank bypass + foam suppression (off in digester 1/On in 2) - 46907 CF/day ± 8356.
- Foam suppression (off in digester 1/On in 2) - 52610 CF/day ± 5027.

- Overall gas production was not impacted by turning off the foam suppression mixing.
- Bypass of the aerated WAS tank has resulted in lesser undigested matter reaching the digesters, thus reducing particulates that could potentially stabilize the foam and improve volatile solids destruction leading to enhanced biogas production.

Marquette Foaming Potential Results

- The unstable foam ratios were higher than the stable foam ratios.
- The highest unstable foam ratios were exhibited by digester 2.
- Any foam formed would be short lived.

- The stable foam ratios for most samples were less than 1; except in 1 baseline sample.
- The highest values were exhibited by digester 2 samples.
- Insignificant variations in foam potential in all samples across all scenarios.
Hunt`s Point Full-Scale Defoamant Addition – Introduction

- The full-scale defoamant addition was carried out on Digesters 2 and 3 at the Hunt`s Point WPCP from August 8, 2011 through August 15, 2011.
- Commercially available FC Rel defoamant was tested.
- Digester 2 was the test digester while Digester 3 was the control which did not receive defoamant.

Hunt`s Point Full-Scale Defoamant Addition – Study Background

<table>
<thead>
<tr>
<th>Foam Rating</th>
<th>Stable Foam</th>
<th>Unstable Foam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Foaming</td>
<td>0-0.1</td>
<td>0-1.0</td>
</tr>
<tr>
<td>Mild Foaming</td>
<td>0.1-0.3</td>
<td>1.0-2.0</td>
</tr>
<tr>
<td>Foaming</td>
<td>0.3-0.5</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td>Severe Foaming</td>
<td>&gt; 0.5</td>
<td>&gt; 3.0</td>
</tr>
</tbody>
</table>

Rating system of foaming severity generated based on multiple foaming potential experiments and observations.
Hunt`s Point Full-Scale Defoamant Addition - Results

Unstable Foam Potential Results

Stable Foam Potential Results

Unstable Foam Ratio = Maximum Foam Height / Initial Ht. of Sludge
Stable Foam Ratio = Settled Foam Height / Initial Ht. of Sludge

- Prior to defoamant addition on Day 1, both Digesters 2 and 3 exhibited foam ratios in the ‘foaming’ to ‘severe foaming’ range for stable and unstable foam.
- Digester 2 shows a lower foam ratio than Digester 3 for both stable and unstable foam.
- Use of defoamant in Digester 2 was responsible for the observed reduction in foaming potential.

Methods for Foam Detection - Background

1. Monitoring and detecting digester foam - practical challenge.
2. Conditions inside digesters and the nature of the foam - problems with detection.
   - Monitoring and testing of digesters or its contents.
   - Sensors and associated instrumentation.
3. Cases of Specific Foam Detection Strategies

<table>
<thead>
<tr>
<th>Utility</th>
<th>Foam Monitoring/Detection Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceanside Plant, CA</td>
<td>Temperature differential between foam separator and condenser.</td>
</tr>
<tr>
<td>Marquette City WRF, MI</td>
<td>Level transducer monitoring.</td>
</tr>
<tr>
<td>Crystal Lake WWTP, IL</td>
<td>Level transducer monitoring.</td>
</tr>
</tbody>
</table>
Foam Detection - OSP Mixing Study Results

Foaming Occurrence

Digester Gas Line Scum Separator Drainage Temperature (Greater than 72 °F Indicates that Foam / Sludge is Reaching the Digesters Gas Line)

Digester 4 experiences intermittent foaming and events are relatively fewer and shorter than in digester 1.

Foam Detection - Crystal Lake

The transducer level does not sense the foam layer on top of the liquid layer.
Foam Detection - Marquette City
Process Snap Shot of Level Transducers in Marquette City WTF

The yellow line indicates that foam had expanded into the digester domed ceiling.

Foam Detection Methods Summary

• Patterns in operational data or other signs in digester operation prove to be effective in foam monitoring.
• Careful monitoring of digester performance is necessary.
• In spite of several shortcomings, the aeration test is one of the few available to detect foaming potential/stability.
• Foam potential data needs to be collected long term to evaluate threshold foam ratios and to determine if high foam potential values represent full scale digester foam episodes.
• Foam potential ratios are specific to each plant.
Full-Scale Studies Summary

- The popular opinion that all foaming has to be filamentous seems to be unfounded.
  - Though the most common cause of foaming, it is not conclusive if it is the only established primary cause of foaming - insufficient full scale literature.
- OLR values are specific for each digester.
  - Case specific OLR thresholds signify that the digestion process is overloaded not by just the absolute quantity of feed but a combination of the digestion process, operational factors (mainly mixing and temperature). OLR was a likely major contributor to foaming in the case of Elmhurst.
- PS:WAS Solids Ratio is only a supplementary cause of foaming.

Full-Scale Studies Summary

- Mixing is viewed as a contributor to foaming
  - Over or under mixing are ambiguous terms. Improper mixing, though it cannot be given a universal definition, is a supplementary cause of foaming (exacerbating the foam episode when a primary cause exists), but not necessarily a cause of the foam.
  - The most important function of mixing seems to be to maintain a homogeneous environment in the digester
    - Can be achieved without mixing 24x7, in most cases, due to contribution of the various sources natural mixing in the digesters.
Acknowledgements

Derek Wold, Amanda Poole and Sean O`Dell

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Curt Goodman, Tom Asmus and Harold Hayes

City of Marquette, MI

Alexandre Miot,

San Francisco Public Utilities Commission, CA

Jackson Pike WWTP & Southerly WWTP,
Columbus, OH.
Overview of Facilities
Marquette Process Schematic

Marquette Full-Scale Study

WAS Tank Bypass
Overview of Facilities
Crystal Lake Process Schematic

Overview of Facilities
Elmhurst Process Schematic
Overview of Facilities
OSP Process Schematic

Overview of Facilities
Hunt`s Point Process Schematic
DEVELOPMENT OF AN INTEGRATED HAULED WASTE PROGRAM

Royce Hammitt, Des Moines Wastewater Reclamation Authority (WRA)
Des Moines Wastewater Reclamation Authority
Altoona - Ankeny - Bondurant - Clive - Cumming - Des Moines -
Greenfield Plaza/Hills of Coventry - Johnston - Norwalk - Pleasant Hill –
Polk City - Waukee - West Des Moines - Polk and Warren Counties -
Urbandale/Windsor Heights and Urbandale Sanitary District

Working together to protect public health and enhance the environment by recycling wastewater and being the preferred treatment facilities for hauled liquid wastes

Operating Contractor - City of Des Moines
- The Des Moines WRF serves a population of 500,000
- Treated nearly 26 billion gallons of wastewater or about 72 million gallons per day in 2009
- Actively seeks to improve efficiency in use of resources
Water and Wastewater Demands Energy

Typical Large City Electrical Usage

Source: Texas Comptroller of Public Accounts
Wastewater Plants Can Produce Enough Electricity to Meet Demands

Source: David L. Parry, CSWEA, Oct. 2010
Hauled organic wastes account for 42% of the feed to the anaerobic digesters

Des Moines Wastewater Treatment Plant, Des Moines, IA
2010 WERF Interim Report – Waste Characterization

CO-DIGESTION OF ORGANIC WASTE PRODUCTS WITH WASTEWATER SOLIDS

INTERIM REPORT

Principal Investigator:
David Perry, PhD, P.E.
CDM
## Waste Composition Effect on Biogas Energy Production

<table>
<thead>
<tr>
<th></th>
<th>Gas yield per unit solids destroyed, m³/kg (cu ft/lb)</th>
<th>Methane content of biogas (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>1.2–1.6 (19–26)</td>
<td>62–72</td>
</tr>
<tr>
<td>Grease</td>
<td>1.1 (17.6)</td>
<td>68</td>
</tr>
<tr>
<td>Scum</td>
<td>0.9–1.0 (14.4–16)</td>
<td>70–75</td>
</tr>
<tr>
<td>Crude fibers</td>
<td>0.8 (12.8)</td>
<td>45–50</td>
</tr>
<tr>
<td>Protein</td>
<td>0.7 (11.2)</td>
<td>73</td>
</tr>
<tr>
<td>PS + WAS blend (typical)</td>
<td>0.8–1.1 (13–18)</td>
<td>60–70</td>
</tr>
</tbody>
</table>

Source: Design of Municipal Wastewater Treatment Plants, WEF, 2009
# Characteristics of Selected High Strength Organic Feedstocks

<table>
<thead>
<tr>
<th>Component</th>
<th>Restaurant interceptor grease</th>
<th>Biodiesel glycerin</th>
<th>Polymer dewatered FOG</th>
<th>Lime dewatered FOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids, % solids</td>
<td>1.8–21.9</td>
<td>14.7</td>
<td>42.4</td>
<td>49.1</td>
</tr>
<tr>
<td>Volatile solids/total solids, %</td>
<td>88.9–98.6</td>
<td>95.2</td>
<td>96.5</td>
<td>76.5</td>
</tr>
<tr>
<td>Chemical oxygen demand, g/L</td>
<td></td>
<td>1,160</td>
<td>1,211</td>
<td>1,030</td>
</tr>
<tr>
<td>Total nitrogen, g/L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total phosphorus, g/L</td>
<td>0.128</td>
<td>0.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>4.3–4.8</td>
<td>8.4</td>
<td>4.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Volatile solids destruction potential(^{(1)}), %</td>
<td></td>
<td></td>
<td>70.8</td>
<td>78.3</td>
</tr>
<tr>
<td>Methane content of generated gas, %</td>
<td></td>
<td></td>
<td>75.0</td>
<td>74.6</td>
</tr>
<tr>
<td>Methane (CH(_4)) potential yield(^{(2)}), m(^3)/kg (scf/lb) feedstock volatile solids</td>
<td>1.048 (16.8)</td>
<td></td>
<td>0.927 (14.8)</td>
<td></td>
</tr>
<tr>
<td>Biogas potential yield(^{(2)}), m(^3)/kg (scf/lb) feedstock volatile solids</td>
<td>1.398 (22.4)</td>
<td></td>
<td>1.242 (19.9)</td>
<td></td>
</tr>
</tbody>
</table>

\(^{(1)}\) Maximum potential volatile solids destruction and yield based on long-term (120 days batch) testing.

\(^{(2)}\) At 60°F and 1 atm.
Feedstocks

- High strength organic wastes that are easily degradable
- Examples:
  - Fats, oils, and grease (FOG)
  - Restaurant wastes
  - Food processing wastes
  - Solid wastes
Hauled Wastes

- **Sources**
  - Sludges from regional WWTP’s
  - Industrial and food processing wastes

- **Issues**
  - Spikes in biogas
  - Foaming

- **Received 24/7!**
WRA’s Existing Program

Original Trucked Liquid Waste (TLW)

- Little storage
- Loads transferred to digester as they arrive and unload

New TLW Facility

- Storage
- 160,000 gallons
- Carry over of wastes through weekend
- Costs less to store feed stock than to store gas
COMBINED HAULED WASTE PROJECT

OLD UNLOADING FACILITY

NEW UNLOADING FACILITY
Trucked Liquid Waste Storage
COMBINED HAULED WASTE PROJECT RESULTS

• Tanker unloading time reduced by 50%

• Areas of congestion eliminated

• Customers (haulers) give positive comments
WRF Hauled Waste -- Regional
“If you build it – they’ll come”

FOG & Digester Loads by Month

Million of Gallons

Jan-09 | Mar-09 | May-09 | Jul-09 | Sep-09 | Nov-09 | Jan-10 | Mar-10 | May-10 | Jul-10 | Sep-10 | Nov-10 | Jan-11 | Mar-11 | May-11 | Jul-11 | Sep-11 | Nov-11 | Jan-12 | Mar-12 | May-12 | Jul-12 | Sep-12 | Nov-12 | Jan-13

FOG

Digester - Hauled Waste
Existing Facilities

West view of Digestor Complex
Tasks & Objective of the BioEnergy Master Plan

- Improve digester facilities
- Enhance biogas production
- Maximize use of biogas
- Develop Economic Model

Evaluation Process

Reliable, Flexible System for the Future
WRA’s Existing Program

Primary and Secondary Treatment
- 50 MGD

Anaerobic Digestion
- Sludges
- Hauled Wastes
- 0.14 MGD
- > 30 loads/day
- Biosolids to Land Application

Biogas Storage

Process Heating
Building Heating
Power Generation
Industrial User
Daily Biogas Production and Usage

Objective < 5% loss

Date

Cu.Ft / Day

Total Production
Total Usage
Evaluation Process

- 11 economic and noneconomic criteria
- WRA staff developed weighting

- Ease of O&M
- Proven and Reliable
- Lifecycle Costs
Task 1

Improve digester facilities

Evaluation Process

Reliable, Flexible System for the Future
Required Digester Improvements

- Covers Evaluated

- Submerged Fixed Concrete
- Fixed Steel
- Floating
- Gas Membrane
Submerged Fixed Cover Gas Dome

- Recirculation from Tank Bottom
- Spray Nozzles
- Transflow 3-Way Valve
- Pressure Vacuum Relief
- Gas Withdrawal
- Gas Dome
- Normal Overflow to Standpipe (Embedded in Cover)
- Emergency Liquid Level
- Emergency Overflow Pipe to U-Tube Gas Seal
- Normal Operating Level
Digester Covers Selected

- Primaries – Submerged Fixed Covers
  - Ease of O&M
  - Foam control
  - Increased capacity (~8%)

- Secondary – Gas Membrane
  - Biogas storage
  - Biosolids storage
  - Dewatering operations flexibility
Examples of Covers
Required Digester Improvements

• Mixing Systems Evaluated

- Gas Bubble
- Mechanical
- Pumped Recirculation
Computational Fluid Dynamics (CFD) Modeling

Pathlines colored by velocity (fps)

Mechanical Mixing

Gas Mixing

Pumped Mixing
Digester Mixing Systems Selected

• Primaries – Mechanical Draft Tube
  • Reliability
  • Accomodate
    • Thick feed
    • Scum & foam

• Secondary – Pumped Recirculation
  – Compatible with gas membrane & fluctuating sludge levels
Computational Fluid Dynamics (CFD) Modeling

- Recommended 24-inch diameter draft tubes
- Cost savings:
  - $700K in capital (4% of total project construction cost)
  - $36K/yr in O&M (800,000 kWh/yr in energy consumption)
Task 2

- Improve digester facilities
- Enhance biogas production

Evaluation Process

Reliable, Flexible System for the Future
Methods Evaluated for Increasing Biogas Production

• WAS pretreatment
  – MicroSludge®
  – OpenCEL

• Advanced digestion
  – Extended thermophilic
  – Temperature phased (TPAD)
Conclusions for Enhancement Evaluation

- **WAS Pretreatment**
  - Limited benefit due to small fraction of TWAS
  - Potential increase in biogas production ~ 7%
  - Payback > 20 years

- **Advanced Digestion**
  - Increased capacity & Class A product
  - Potential increase in gas production ~ 10-15%
  - Payback >15 years
Task 3

- Improve digester facilities
- Enhance biogas production
- Maximize use of biogas

Evaluation Process

Reliable, Flexible System for the Future
Model Biogas Storage and Use
## Biogas Storage Evaluation

<table>
<thead>
<tr>
<th>Capacity (cf)</th>
<th>% of Biogas Flared</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current</td>
</tr>
<tr>
<td>475,000</td>
<td>6.1</td>
</tr>
<tr>
<td>805,000</td>
<td>5.8</td>
</tr>
</tbody>
</table>

*Increased storage is important, but not the key!*
Alternatives for Increasing Use

- Replace natural gas use at plant
  - Supply additional boilers
  - Produce biomethane for plant-wide use
- Sell to gas utility
- Increase volume sold to industry
Natural Gas Usage in Plant Boilers
Compressed Biogas (CBG) Production Options

- **Pressure Swing Absorption (PSA)**
  - Low energy (~60KW)
  - Experience with biogas
  - Operational flexibility

- **CO2 Wash**
  - High energy (~300KW)
Use of Biogas by Local Industry

• Averaging 700,000 cfd
• Capacity of 1,200,000 cfd
• Conveyance system limits
• Potential for 1,700,000 cfd in future
Staged Approach to Expanding Biogas Use

• Increase industry use preferred
  • Proven, reliable
  • Minimal affect on O&M

• Backup power generation associated with High Rate Treatment Facility (separate project)
  • Add 4 new 1.4 MW engine generators (2 CHP biogas, 2 Emergency)

• Use in boilers possible in future
  • Proven, reliable system
  • Reduces natural gas dependence
  • Payback ~ 12 years
Task 4

- Improve digester facilities
- Enhance biogas production
- Maximize use of biogas

Evaluation Process

Reliable, Flexible System for the Future

Develop Economic Model
Process & Economic Model

Input Parameters

Output

Primary & WAS

Monthly Biogas Balance

Present Worth

4 Different Wastes

Model

Digestion process parameters

Biogas Options

Power
Natural Gas
Tip Fees
Treatment Costs
Land Application
Dewatering

$
Example of Economic Model Output

Avg. Monthly Gas Balance

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Surplus Gas for Sale</td>
<td>775,000</td>
<td>784,000</td>
<td>821,000</td>
<td>862,000</td>
<td>1,291,000</td>
<td>1,313,000</td>
<td>1,330,000</td>
<td>1,332,000</td>
<td>1,323,000</td>
<td>915,000</td>
<td>860,000</td>
<td>822,000</td>
</tr>
<tr>
<td>DG Usage in Bldg. Boilers</td>
<td>160,000</td>
<td>153,000</td>
<td>123,000</td>
<td>88,000</td>
<td>36,000</td>
<td>21,000</td>
<td>10,000</td>
<td>9,000</td>
<td>11,000</td>
<td>44,000</td>
<td>90,000</td>
<td>119,000</td>
</tr>
<tr>
<td>Biogas Usage in Engines</td>
<td>536,000</td>
<td>536,000</td>
<td>536,000</td>
<td>536,000</td>
<td>268,000</td>
<td>268,000</td>
<td>268,000</td>
<td>268,000</td>
<td>268,000</td>
<td>536,000</td>
<td>536,000</td>
<td>536,000</td>
</tr>
<tr>
<td>Biogas Usage in Boilers</td>
<td>218,000</td>
<td>216,000</td>
<td>209,000</td>
<td>203,000</td>
<td>94,000</td>
<td>87,000</td>
<td>81,000</td>
<td>80,000</td>
<td>87,000</td>
<td>104,000</td>
<td>203,000</td>
<td>212,000</td>
</tr>
</tbody>
</table>
Digestion / Biogas System Improvements will Enhance WRA’s Overall Sustainability

• Reliable systems to provide valuable public services

• Increased revenue potential

• Flexibility for multiple uses of biogas will be critical
Questions?

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