New Business Opportunities for Recycling Biomass, Phosphorus and Water

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Global Business Club of Mid-Michigan
Environmental Sustainability and Business Profitability:
An International Perspective

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MSU Henry Center for Executive Development

MICHIGAN STATE UNIVERSITY
BAE Department of Biosystems and Agricultural Engineering
MICHIGAN STATE UNIVERSITY Extension
Michigan State University AgBioResearch
Turning Resources Into Waste — Michigan State University ADREC Anaerobic Digestion Research and Education Center

Contents

Challenges in the Global Environment

- World population in 2012: 6.9 billion; projected in 2030: 8.3 billion[1]
- Water projected needs in 2030: 30% increase[2]
- Energy projected needs in 2030: 40% increase[2]
- Food projected needs in 2030: 50% increase[2]

- Water quality resulting in premature deaths: 1,700,000/year[3]
- World population suffering from waterborne diseases or shortages: 50%[4]
- Air quality resulting in premature deaths: 800,000/year[3]

[1]United Nations World Water Assessment Program. http://unesco.org/images/021/002154/215492a.pdf

[2]The Water-Food-Energy Live Debates, The Guardian, www.guardian.co.uk/sustainable-business/nexusthinking-global-water-food-energy

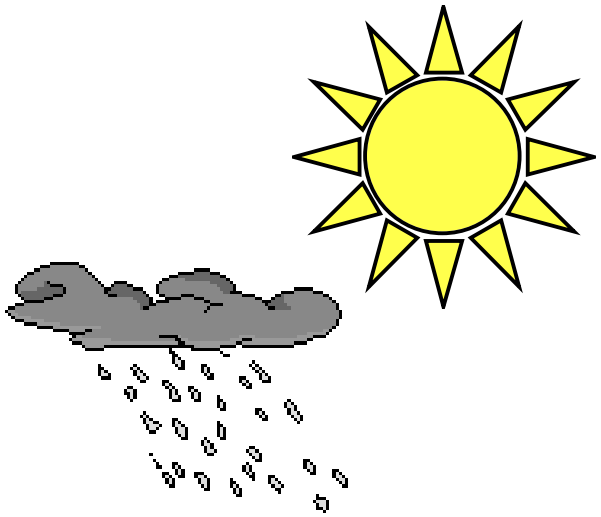
[3]Organization of Economic Co-Operation and Development http://www.oecd.org/els/health-systems/40396531.pdf

[4]Our Planet, Our Health, Report by WHO Commission on Health and Environment http://www.ciesin.or/docs1001-012/001-012.htm

Evolution of Waste Management

From: Pollution Prevention: Fundamentals and Practice, Bishop,2000

Evolution of Waste Management



Environment → Raw Material

Waste as a Resource

Waste Material ← Product

Challenges = Opportunities
Wastes = Resources

Wastes

Resources

Food production wastewater to grow commodities

Energy production from organic wastes

Nutrients from wastewater

http://www.norganics.com/products/fertilizers/phosphate-rock.html

Why Agriculture

- Amount of fresh water required by agriculture: 70%[1]
- Required water for a pound of rice: 3,500 L; for beef: 15,000 L[1]
- Increase in phosphorus use since1960: doubled[2]
- Global estimated phosphorus reserves: 35 years[3]
- Phosphorus reserves: 90% in Morocco, Jordan, S. Africa, US, China[3]

[1]United Nations World Water Assessment Program. http://unesco.org/images/021/002154/215492a.pdf

[2]USDA Soil Quality Institute Technical Pamphlet 2, Phosphorous in Agriculture. http://soils.usda.gov/sgi/publications/files/prole.pdf

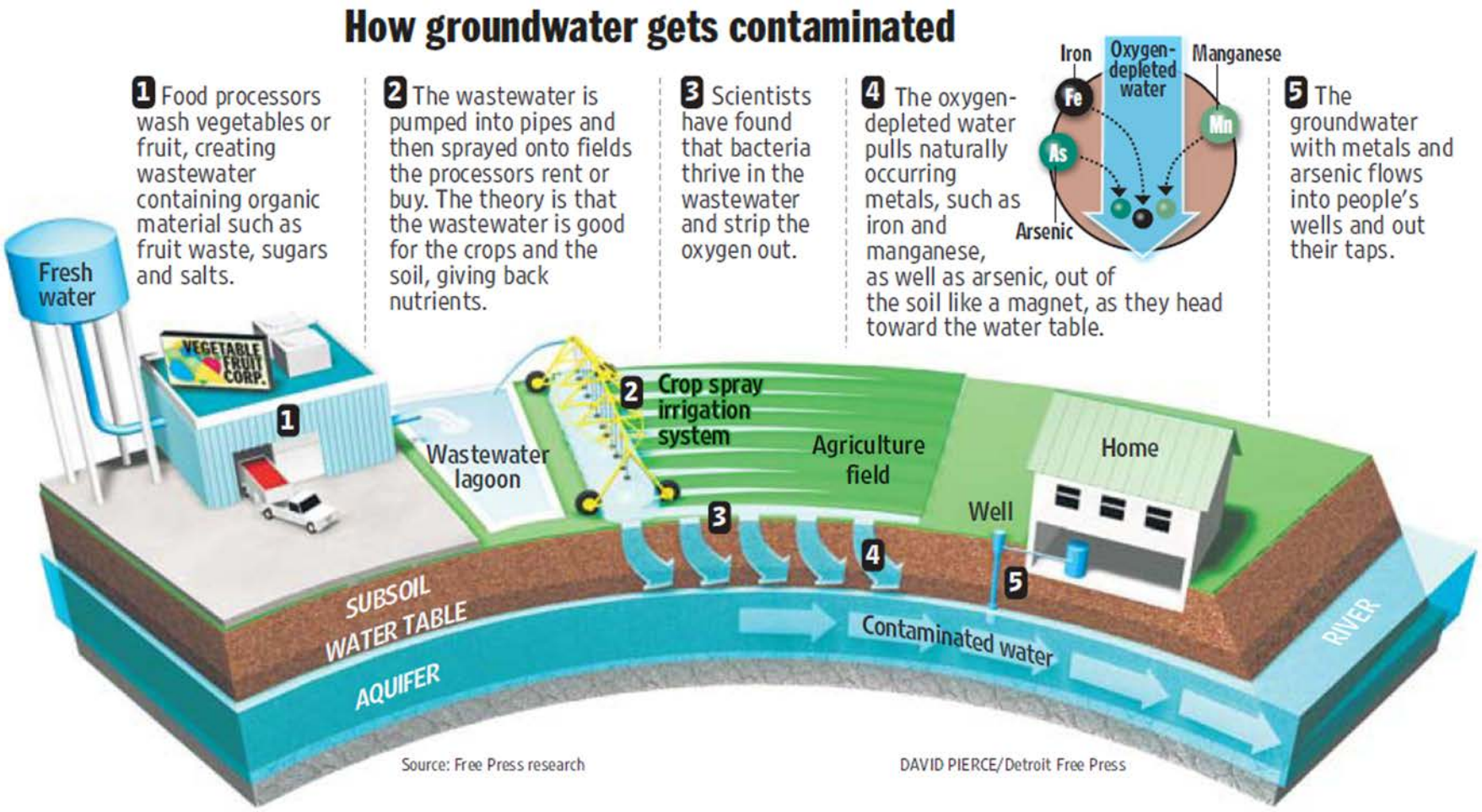
[3]Does Peak Phosphorous Loom? American Scientist, 2010, 98(4):291

Wastewater Irrigation

Food Processing Wastewater

- Efficient treatment
- Commodity production
  - Water
  - Nutrients
- Aquifer recharge
- Effective treatment?

Improper Wastewater Disposal



Detroit Free Press, 8/10/2009
(http://www.freep.com/uploads/pdfs/2009/08/0809%20GROUNDWATER%20dp.pdf)

Improper Wastewater Disposal

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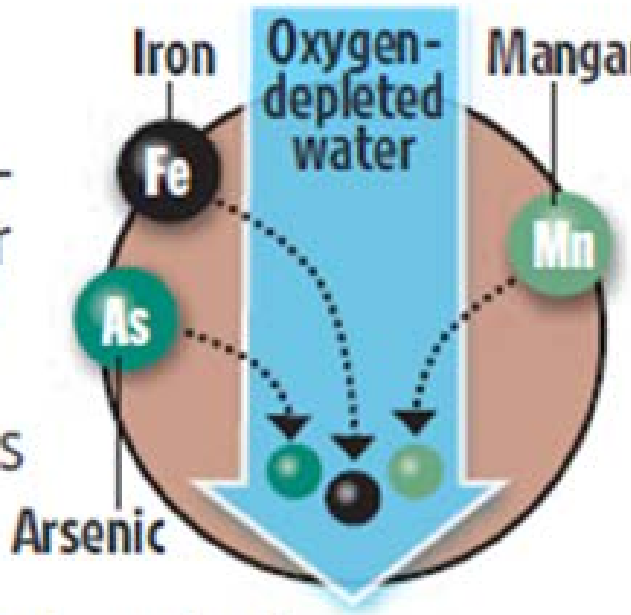
4 The oxygen-depleted water pulls naturally occurring metals, such as iron and manganese, as well as arsenic, out of the soil like a magnet, as they head toward the water table.



5 The groundwater with metals and arsenic flows into people's wells and out their taps.

Detroit Free Press, 8/10/2009
(http://www.freep.com/uploads/pdfs/2009/08/0809%20GROUNDWATER%20dp.pdf)

Improper Wastewater Disposal

Metal Mobilization

- Food processing wastewater
- Domestic wastewater infiltration basins
- Manure land applied to crops
- Bioremediation of hazardous waste
- Filter strips for agricultural runoff
- Filter beds for milking facility wastewater

Surface Water Impacts

Wastewater Irrigation Design Criteria

For food processing waste,

Organic loading: 40 to 1800 lb BOD/acre/day

Hydraulic loading: 2,700 to 16,000 gal/acre/day

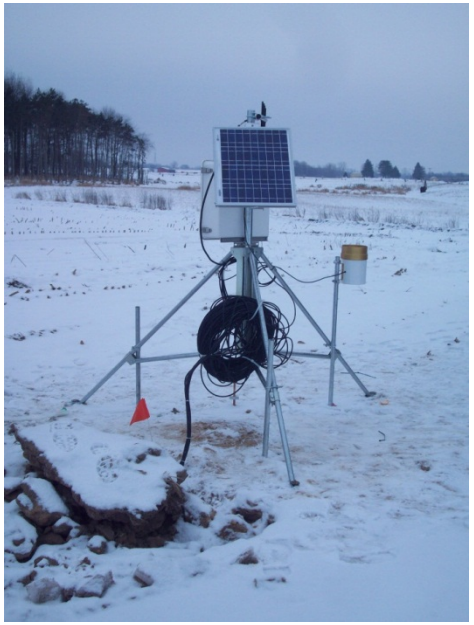
Little justification for these loadings and no coherent irrigation strategies that minimize environmental harm and maximize loadings.

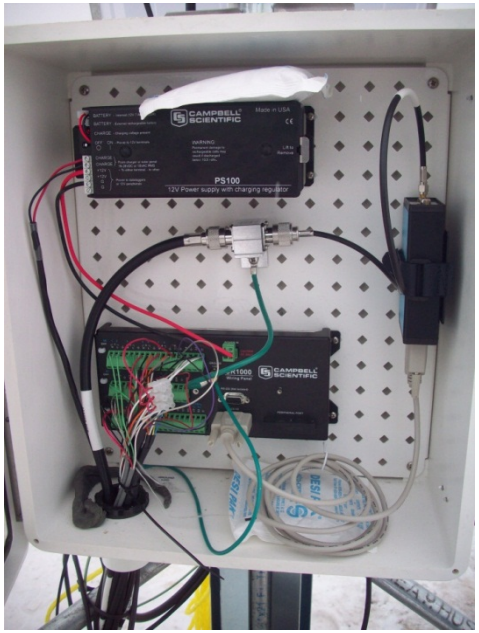
http://www.egr.msu.edu/~safferma/Research/Greeen/Deliverables/Assimilation%20Capacity%2012-8-2007.pdf

MSU Research Program

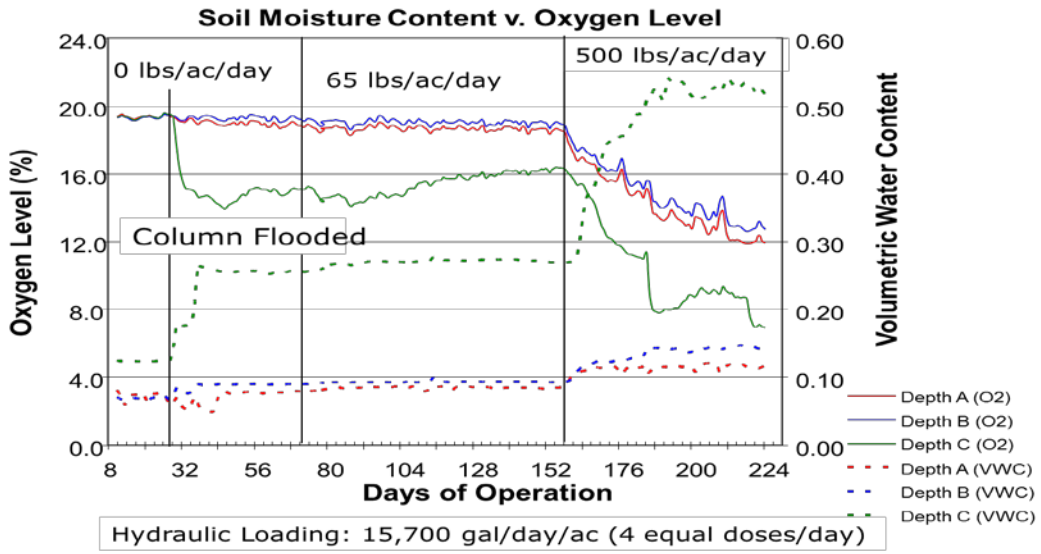
- Laboratory column – prescriptive values
- Field monitoring

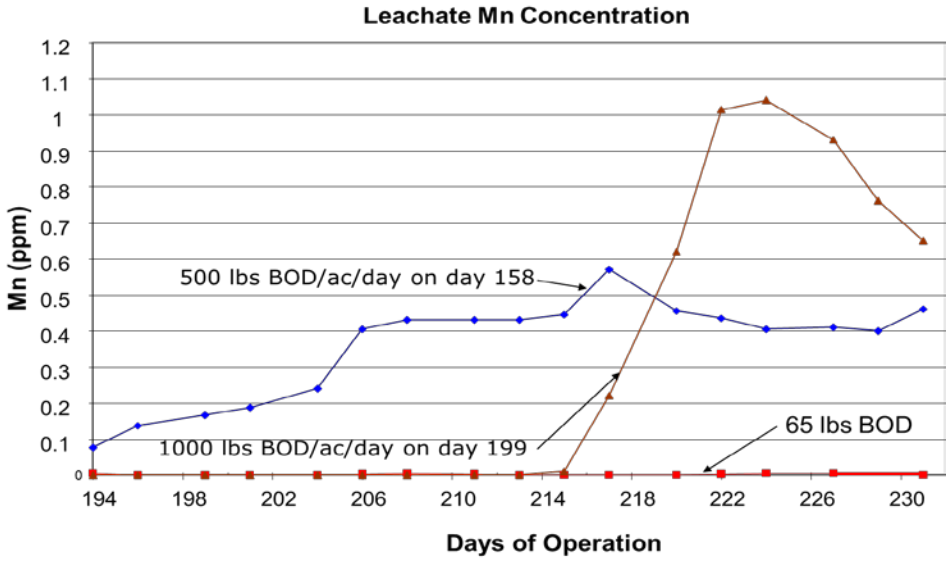
MSU Wastewater Irrigation Research





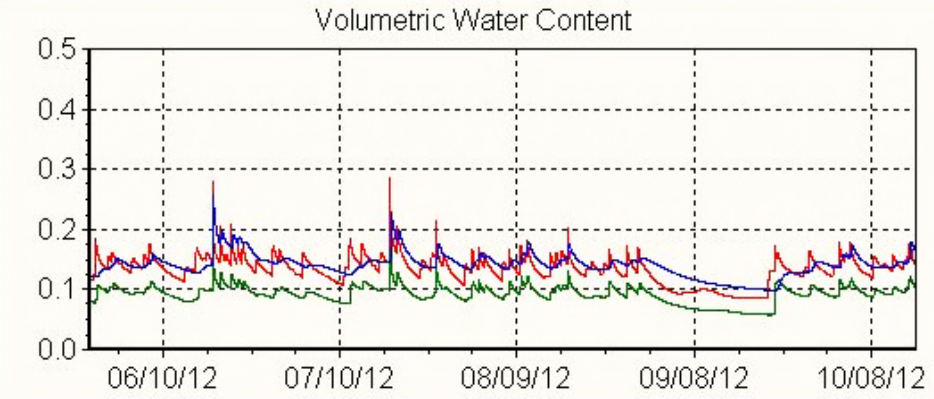
MSU Wastewater Irrigation Research

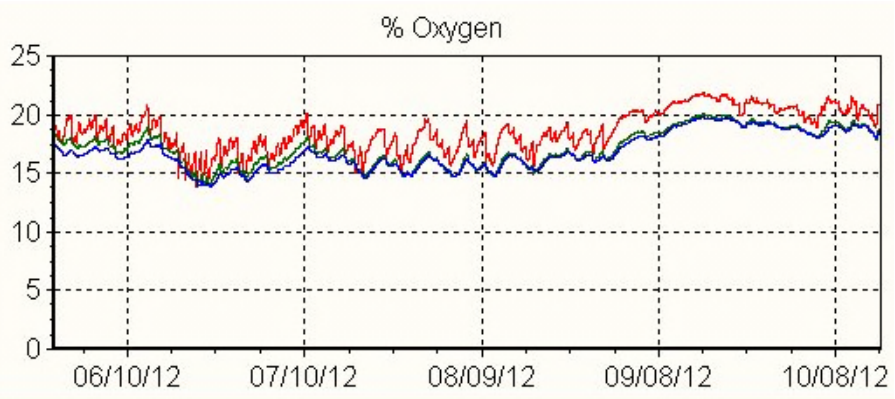




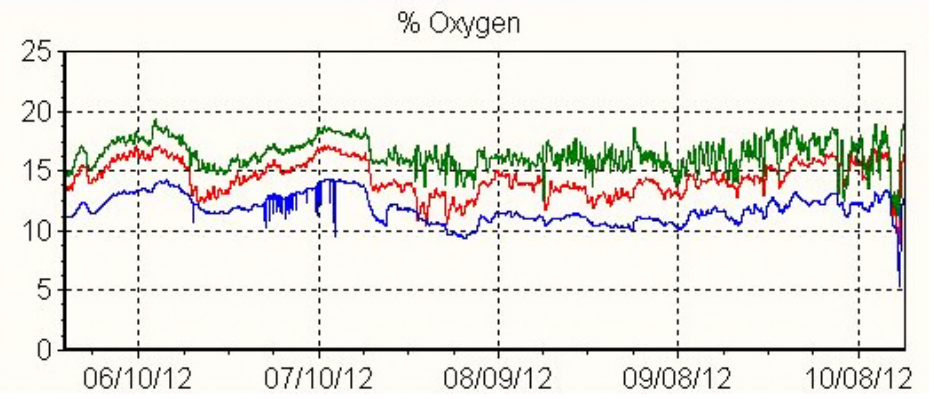
MSU Wastewater Irrigation Research

Cluster 1





Cluster 2



Anaerobic Degradation

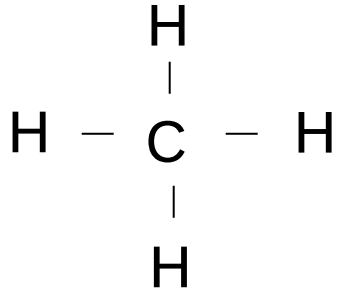
What does carbon look like in manure and food processing waste?

$C_aH_bO_c?_d?_e?_f?_g?_h$

Photo Credit: Andrew Wedel, McLanahan Corp.

What does carbon look like in energy?

CH_4



Landfills v. Anaerobic Digestion

Anaerobic Digestion

Environmental Benefits

- **Pathogen reduction**
- **Nuisance avoidance**
- **Greenhouse gas reduction**

Biogas

- CH_4 (50 – 60%)
  - **Heat**
  - **Electricity**
  - **Natural gas**
  - **Flare**
- CO_2 (40 – 50%)
- Other? (Trace)

Bioproducts

- **Fiber**
- **Water**
- **Nutrients**

Anaerobic Digestion Costs/Revenues

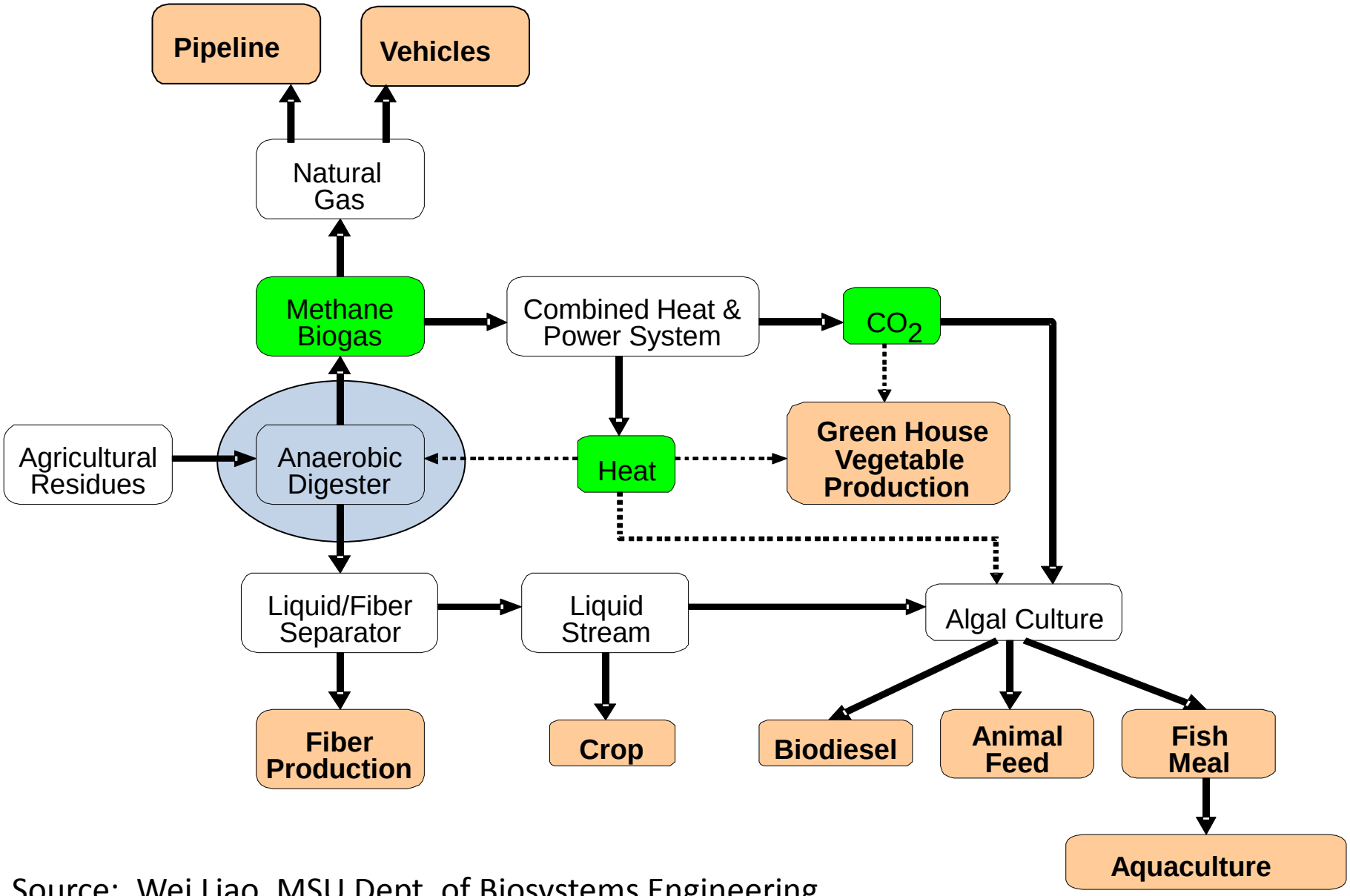
Costs

- Management
- Capital
  - Materials Handling
  - Digesters
  - Interconnections
  - Generator
- Operations

Revenues

- Electricity
- Heat
- Carbon credit
- Renewable energy credits
- Tipping fees
- Fiber
- Difficult to quantify
  - Pathogen reduction
  - Nuisance avoidance
  - Nutrient management

Anaerobic Digestion



Source: Wei Liao, MSU Dept. of Biosystems Engineering

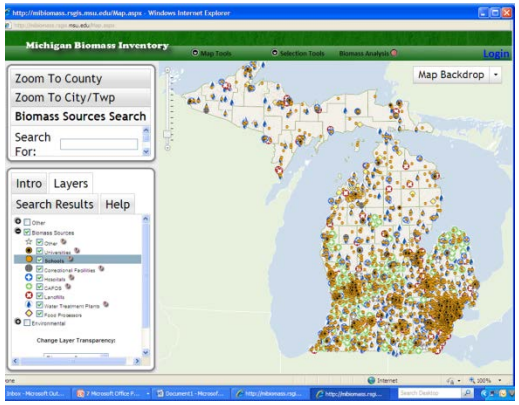
MSU Anaerobic Digestion Research

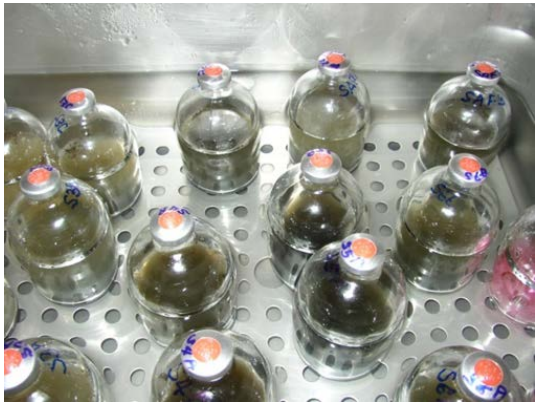
Anaerobic Digestion Research and Education Center

MSU Anaerobic Digestion Research

Continuum of Anaerobic Digestion Research

- Locating Feedstocks
- Modeling
- Biogas Methane Potential
- Design and Cost Testing
- Logistics
- Basic and Applied Research





Phosphorus - Impact

Grand Lake St. Marys

http://www.ohiotraveler.com/popular_ohio_parks.htm

Drakejournal.com
http://www.darkejournal.com/2010/06/yuk-some-photos-of-grand-lake-st-marys.html

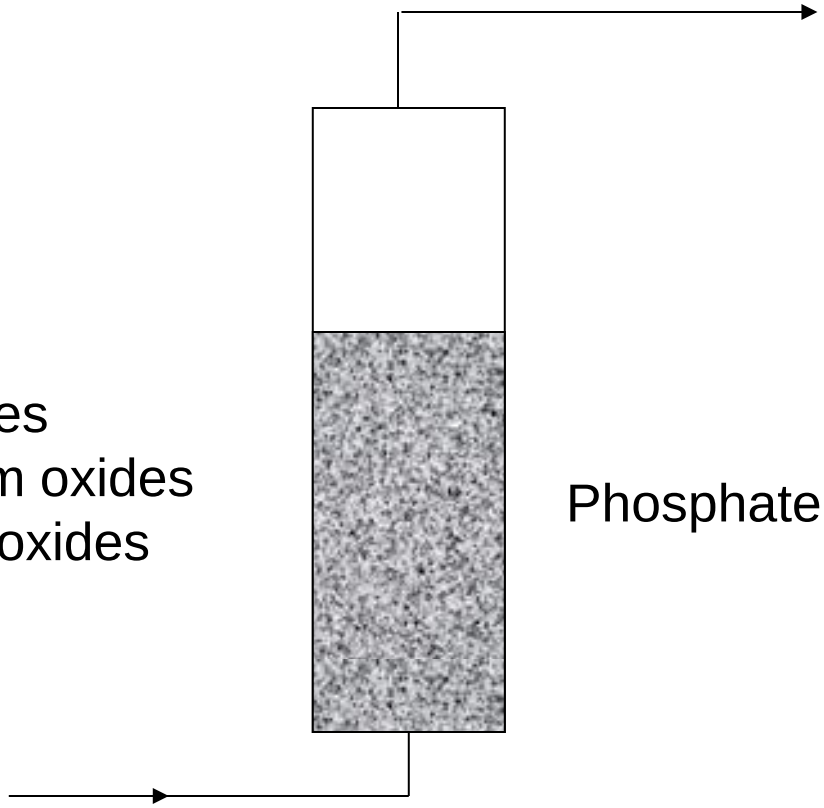
http://www.lakescientist.com/2010/toxic-algae-continues-to-defile-water-quality-in-the-buckeye-state

http://www.daytondailynews.com/news/news/local/algae-chokes-off-lakes-life-regions-livelihood/nNFBH/

Phosphorus - Sources

Phosphorus Treatment and Recovery

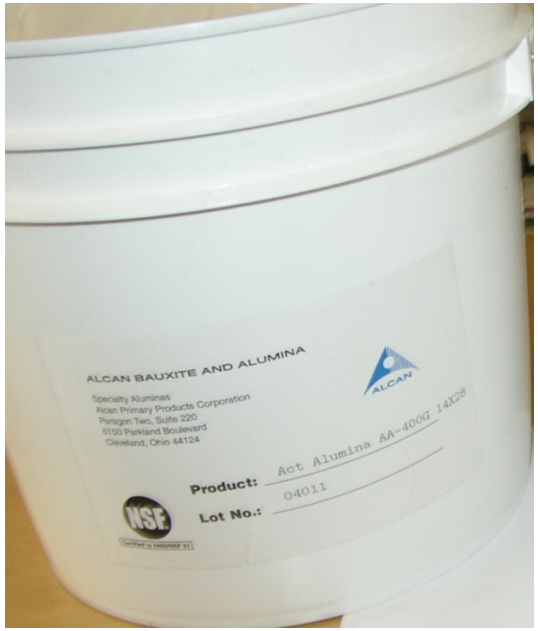
Sorption



- Multiple charged cations to attract phosphates
- Form surface hydroxides that can exchange with phosphates
- Form mineral complexes with orthophosphate

Phosphorus Treatment and Recovery

Media



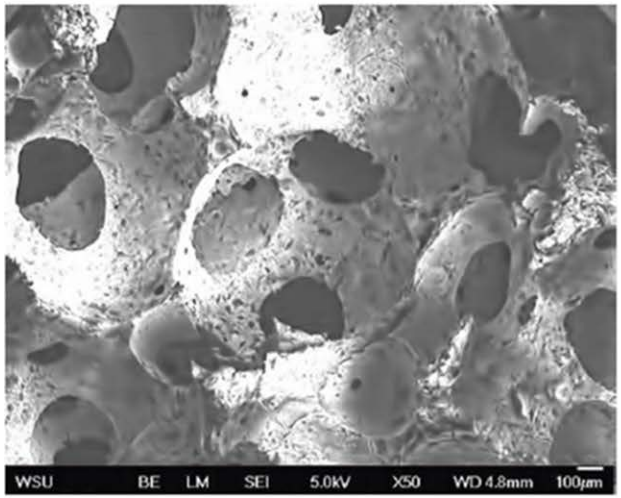
Alcan Activated Alumina (Al_2O_3)
AA400G, Mesh Size 14X28

Nano Enhanced Iron Foam

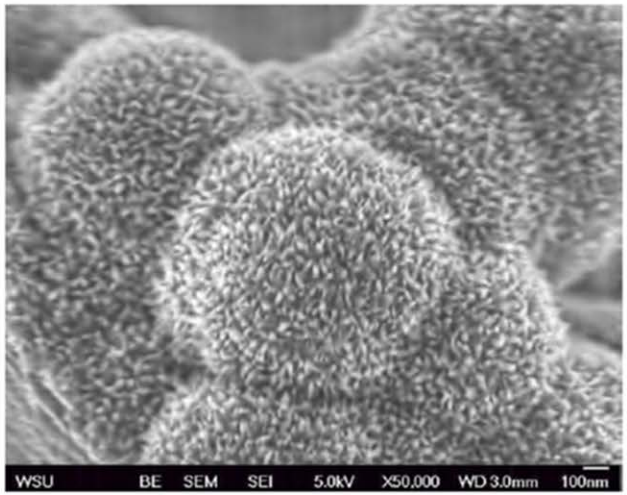
Phosphorus Treatment and Recovery

Nano Enhanced Iron Foam

- Material: iron oxyhydroxide nano fibers grown on zero-valent iron foam
- Porosity: 80%
- Shape: granular or formed
- Pore size: 100-200 micron
- Surface area 60 - 100 m^2/g (non porous media: 1 – 2 m^2/g)



Interconnecting pore structure contains nano to micron pores



Surfaces covered with 20-100 nm crystal fibers

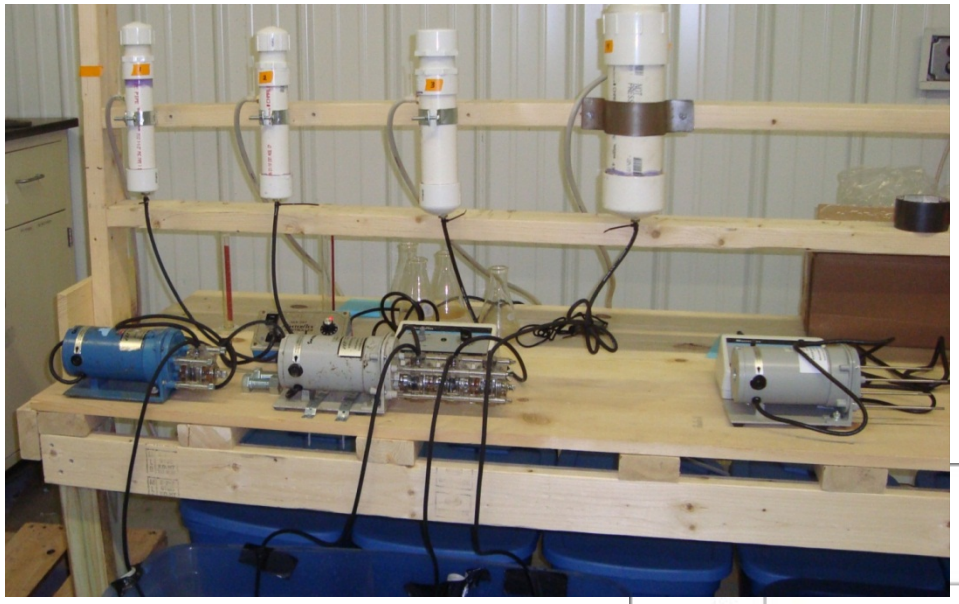
MetaMateria Technologies, LLC, Publicity Materials

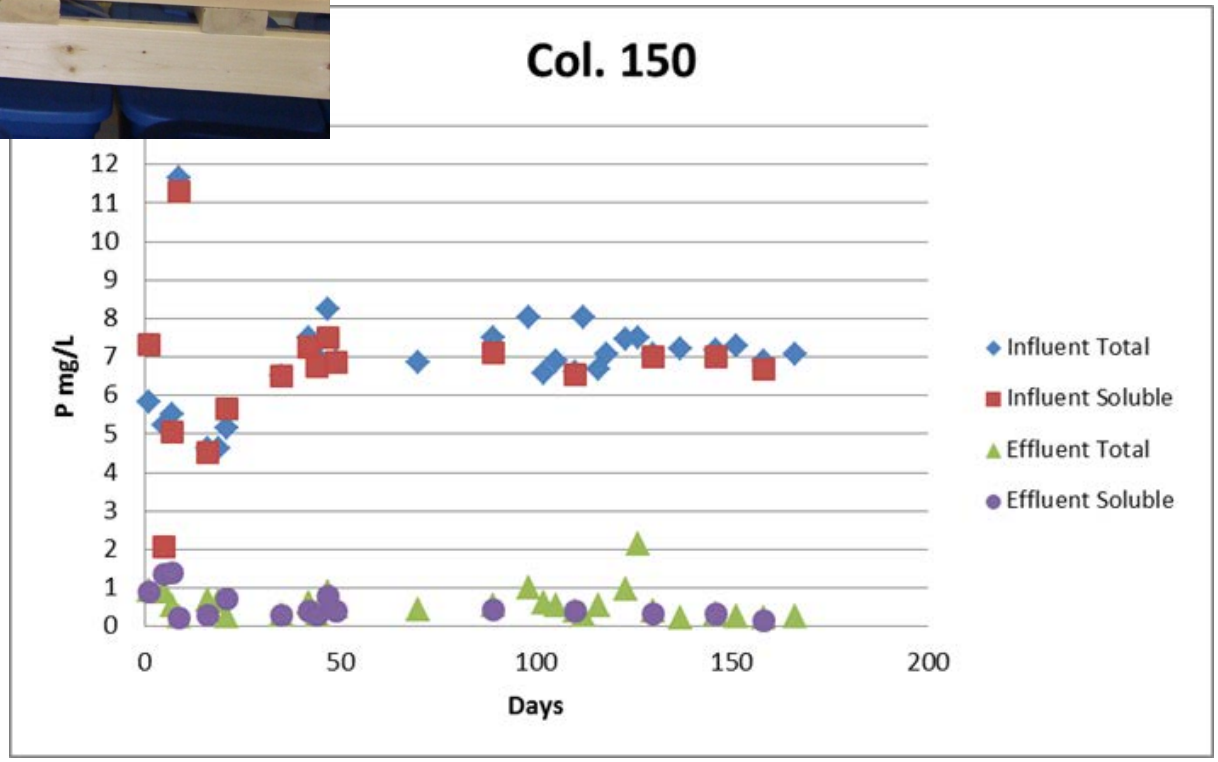
Phosphorus Treatment and Recovery

Nano Enhanced Iron Foam

MetaMateria Technologies, LLC, Publicity Materials

MSU Phosphorus Research





MSU Phosphorus Research

- Nano iron coated iron foam, 2 mg/L breakthrough (450 days): **40–150 mg P/g**
- Activated aluminum A400g: **16.0 mg P/g**
- Activated aluminum A400g, 2mg/L breakthrough (10 days): **10.5 mg P/g**
- Cotton based media coated with iron: **8.9–19.0 mg P/g***
- Natural based media with Fe and Al oxides and kaloinite: **2.1 mg P/g***
- Natural soils and sediments: **0.0063 –0.501 mg P/g****

*Enhanced Adsorption and Regeneration with Lignocelluloses-Based Phosphorus Removal Media Using Molecular Coating Nanotechnology, Kim et al., Journal of Environmental Science, Part A, 41, 2006, pp. 87-100.

**Laboratory Development of Permeable Reactive mixtures for the Removal of Phosphorus from Onsite Wastewater Disposal Systems, Baker et al., Environmental Science Technology, 32, 15, 1998, pp. 2308-2316.

Opportunities?

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