Bench-Scale Digestion Studies

Richard O. Mines, Jr.
Laura W. Lackey
Andre' J. Butler
Mercer University School of Engineering
Macon, Georgia

Presentation Outline

- Background
- Objectives of Study
- Materials & Methods
- Results & Discussion
- Summary & Conclusions
- Future Work

Background

- Sludge treatment and disposal costs represent 35-40% of the total cost of treating wastewater
- Promulgation of Standards for Use or Disposal of Sewage Sludge,Title 40 CFR Part 503 established:
  - Requires Compliance Monitoring
  - Meeting Pathogen Reduction Criteria
  - Meeting Vector Attraction Reduction Criteria

Pathogen Reduction: Class A

- Monitor fecal coliform or *Salmonella* sp. Bacteria
  - Fecal coliform < 1000 MPN per gm of total solids
  - *Salmonella* sp. < 3 MPN per 4 gm of total solids
- Alternative 1: Thermally Treated Sludge, Time-Temperature Requirement.
  - 4-Time-Temperature Regimes with equations
- Alternative 2: High pH-High Temperature Process.
  - Elevated pH > 12, maintain for 72 hr, max. temperature > 52 ° C for 12 hours, air dry 50% solids

Pathogen Reduction: Class A Cont'd

- Alternative 3: Prior Testing for Enteric Viruses and Viable Helminth Ova in Raw Sludge.
  - If enteric viruses > 1 PFU per 4 gm TS and Viable helminth ova > 1 per 4 gm TS must analyze after sludge treatment.
- Alternative 4: Sludge Treated in Unknown Process.
  - Enteric viruses < 1 PFU per 4 gm TS
  - Viable helminth ova < 1 per 4 gm TS
  - Document operating parameters that achieve pathogen reduction criteria.

Pathogen Reduction: Class A Cont'd

- Alternative 5: Use One of 7 PFRP Processes.
  - Composting
  - Heat Drying
  - Heat Treatment
  - Thermophilic Aerobic Digestion
  - Beta Ray Irradiation
  - Gamma Ray Irradiation
  - Pasteurization
- Alternative 6: Use PFRP Equivalent Process.

Pathogen Reduction: Class B

- Alternative 1: geometric mean fecal coliform density of 7 samples < 2 million CFU or MPN per gm of TS.
- Alternative 2: Use of one of 5 PSRP Processes.
  - Aerobic Digestion
  - Air Drying
  - Anaerobic Digestion
  - Composting
  - Lime Stabilization
- Alternative 3:Use of Process Equivalent to PSRP Process.

Vector Attraction Reduction 1

- Option 1: 38% reduction in VS content by aerobic or anaerobic digestion.
- Option 2: 40 days additional anaerobic digestion with < 17% additional VS destruction.
- Option 3: 30 days additional aerobic digestion with < 15% additional VS destruction.
- Option 4: SOUR for aerobically digested sludge $\leq$ 1.5 mg oxygen per hour per gm of total solids.

Vector Attraction Reduction 2

- Option 5: Aerobic processes > 40° C for 14 days or longer and average temp. @ 45 ° C or higher.
- Option 6: Addition of alkali to pH of 12 at 25 ° C and maintain for 2 hours, and then maintain at pH of 11.5 for an additional 22 hours.
- Option 7: Moisture reduction by achieving ≥ 75% solids content prior to mixing with other materials.
  - Contains no unstabilized solids.

Vector Attraction Reduction 3

- Option 8: Moisture reduction by achieving ≥ 90% solids content prior to mixing with other materials.
  - Contains some unstabilized solids.
- Option 9: Inject sewage sludge or septage below ground surface.
- Option 10: Incorporate sludge or septage into soil within 6 hours after application.
- Option 11: Sludge or septage applied must be covered daily with soil or other material.

Aerobic Digestion 1

- Continuation of the activated sludge process.
- Digesters are operated in the endogenous phase.
- Microorganisms oxidize their own protoplasm into carbon dioxide, water, and ammonia.
- Subsequently, ammonia is removed through nitrification.

Aerobic Digestion 2

- To meet pathogen reduction criteria, aerobic digesters must be operated at:
  - a detention time of 40 days @ 20°C to 60 days @ 15°C to meet Class B requirements.
  - a detention time of 10 days @ 55°C to 60 °C to meet Class A requirements.

Ozonation Destruction Mechanism

- Ozone is a very reactive oxidizing agent.
- Cesbron et al. reports that ozone is used for solubilizing and converting slowly biodegradable particulate organics into low molecular weight, readily biodegradable compounds
- According to Scheminski et al. ozone attacks and destroys the cell wall releasing intracellular components

Ozonation 1

- Scheminski et al. demonstrated that 60% of the solid organic components of digested sludge can be transformed into soluble substances at a specific ozone consumption rate of 0.5 g O_3 per gram of organic dry matter (ODM).
- Park et al. achieved 65% removal of Suspended Solids at an ozone dose of 0.5 g O_3 consumed per g of dried solids.
- Sakai et al. eliminated excess sludge production by ozonating RAS at an ozone dosage of 34 mg O_3 per gram of SS (0.034 kg/kg SS).

Ozonation 2

- Yasui et al. demonstrated sludge reduction or elimination efficiencies ranging from 62.5 % to 100 % for nine different types of wastewaters.
- Ozone dosage of 0.05 g of O_3 consumed per gram of SS applied was used in the bench-scale, pilot-scale, and full-scale studies.
- Nitrogen and phosphorus concentrations in the effluent eventually increased and equaled those of the influent.
- Soluble effluent TOC concentrations were higher resulting in overall TOC removal efficiencies that were 1 to 7% lower than the control activated sludge process.

Objectives of Study

- Determine and compare the total solids reduction in aerobic digesters versus ozonated digesters.
- Determine and compare the kinetics of volatile suspended solids reduction in the aerobic versus ozonated digesters.
- Estimate the quantity of oxygen required or utilized per mg of total volatile solids destroyed.
- Determine the quantity of ozone required per mg of total solids destroyed.

Bench-Scale Digestion Systems

Ozonated Digesters

Aerobic Digesters

Materials and Methods

- Four, 1-L .bench-scale digesters were operated in parallel for 25 days.
- Aerobic digesters #1 and #2 were supplied with air at 1.44 L/min and 1.47 L/min, respectively.
- The applied oxygen loading rate was 432 mg O_2/min and 442 mg O_2/min for aerobic digesters #1 and #2, respectively.
- Ozonated digesters #1 and #2 were supplied air ladened with ozone at a rate of 2.78L/min and 2.87L/min, respectively.

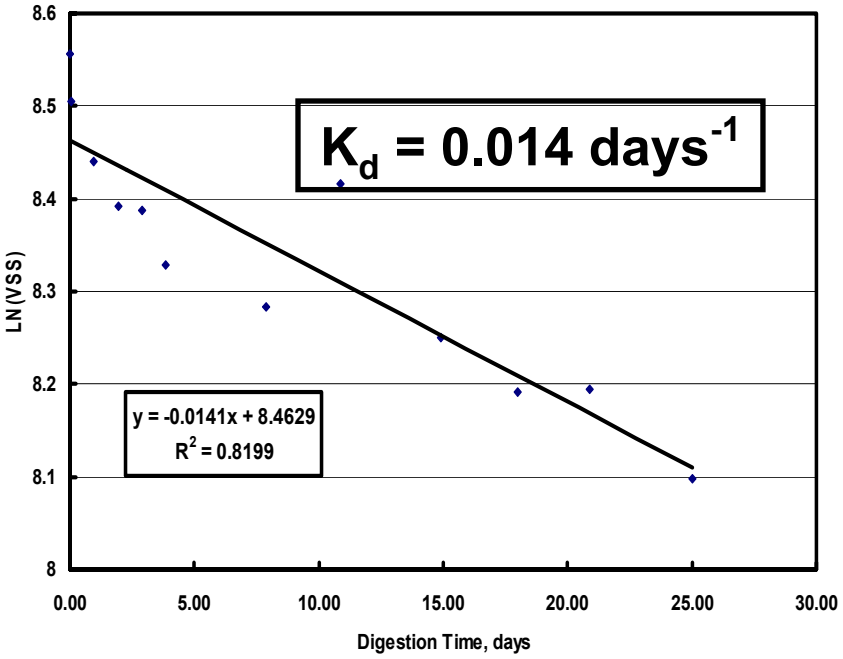
Materials and Methods cont'd

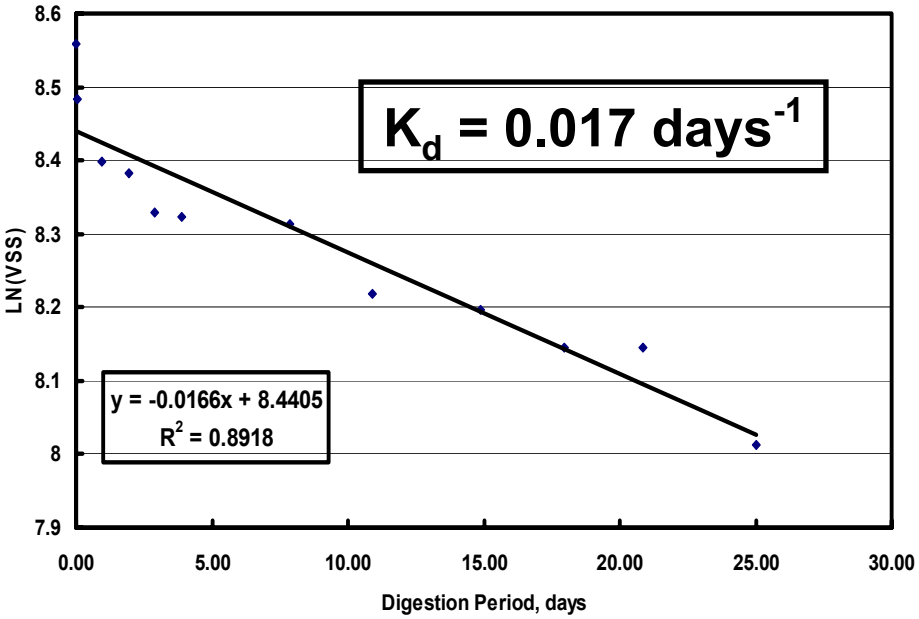
- Applied ozone loading rate was 0.36 mg O_3/min and 0.39 mg O_3/min for ozonated digester #1 and #2, respectively.
- Operating temperature was 19° C.
- Ozone transfer rate measured by sparging O_3 into potassium iodide solution.
- Ozone was measured by titration with 0.005N sodium thiosulfate *(Standard Methods).*
- COD was measured colorimetrically by HACH method 8000.
- Solids analyses were conducted in accordance with *Standard Methods*.

Results and Discussion

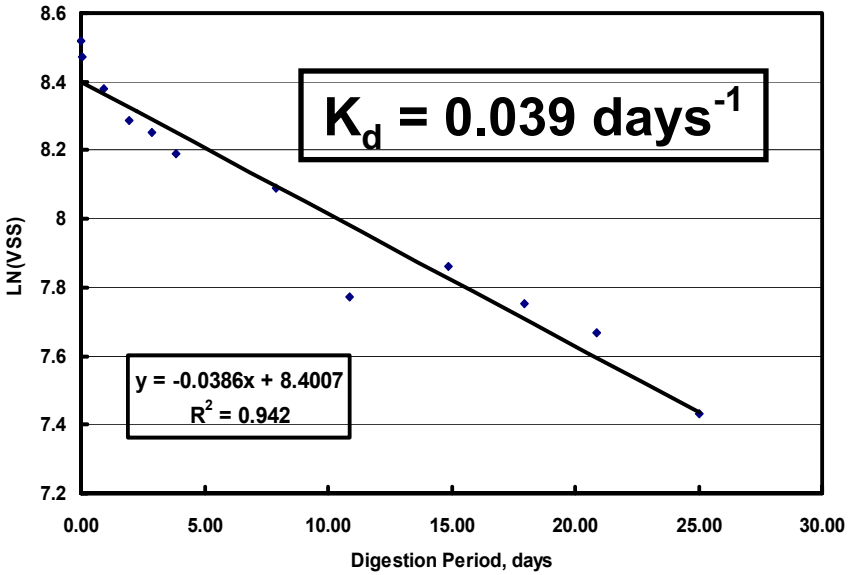
	Aerobic Digesters	Ozonated Digesters
Average TSS Removals	**37%**	**64%**
Average VSS Removals	**39%**	**70%**

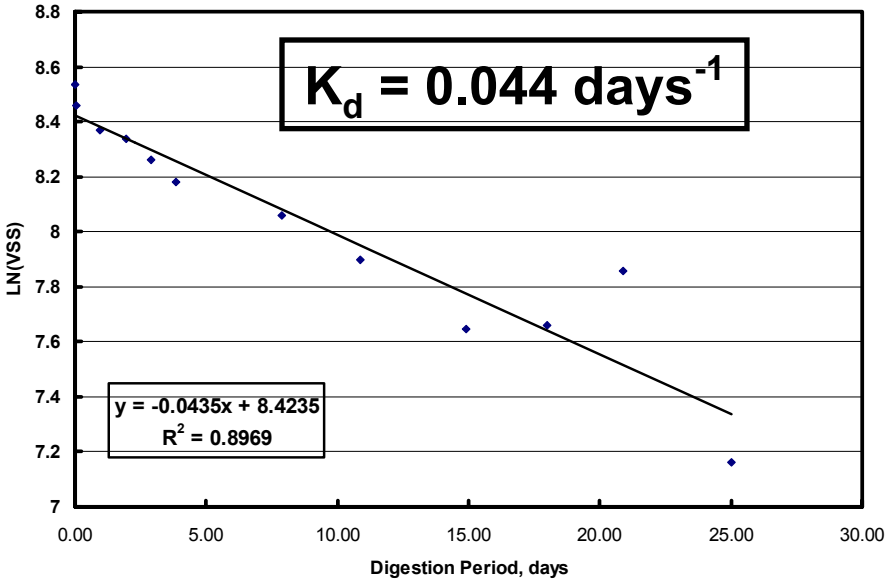
Solids Degradation Rate AD





Solids Degradation Rate OD





Oxygen Utilized per TVS Destroyed

$$\frac{O_2\ Utilized}{TVS_{Destroyed}} = \frac{(TCOD_0 - TCOD_t)V}{(TVS_0 - TVS_t)V}$$

$TCOD_0$ & $TCOD_t = Total\ COD\ @\ start\ and\ end\ of\ digestion, mg/L$

TVS_0 & $TVS_t = Total\ Volatiel\ Solids\ @\ start\ and\ end\ of\ digestion, mg/L$

$V = Volume\ of\ digester, L$

Oxygen Utilized per TVS Destroyed

Digester	Oxygen Utilized per Total Volatile Solids Destroyed
Aerobic	1.85
Ozonated	1.82

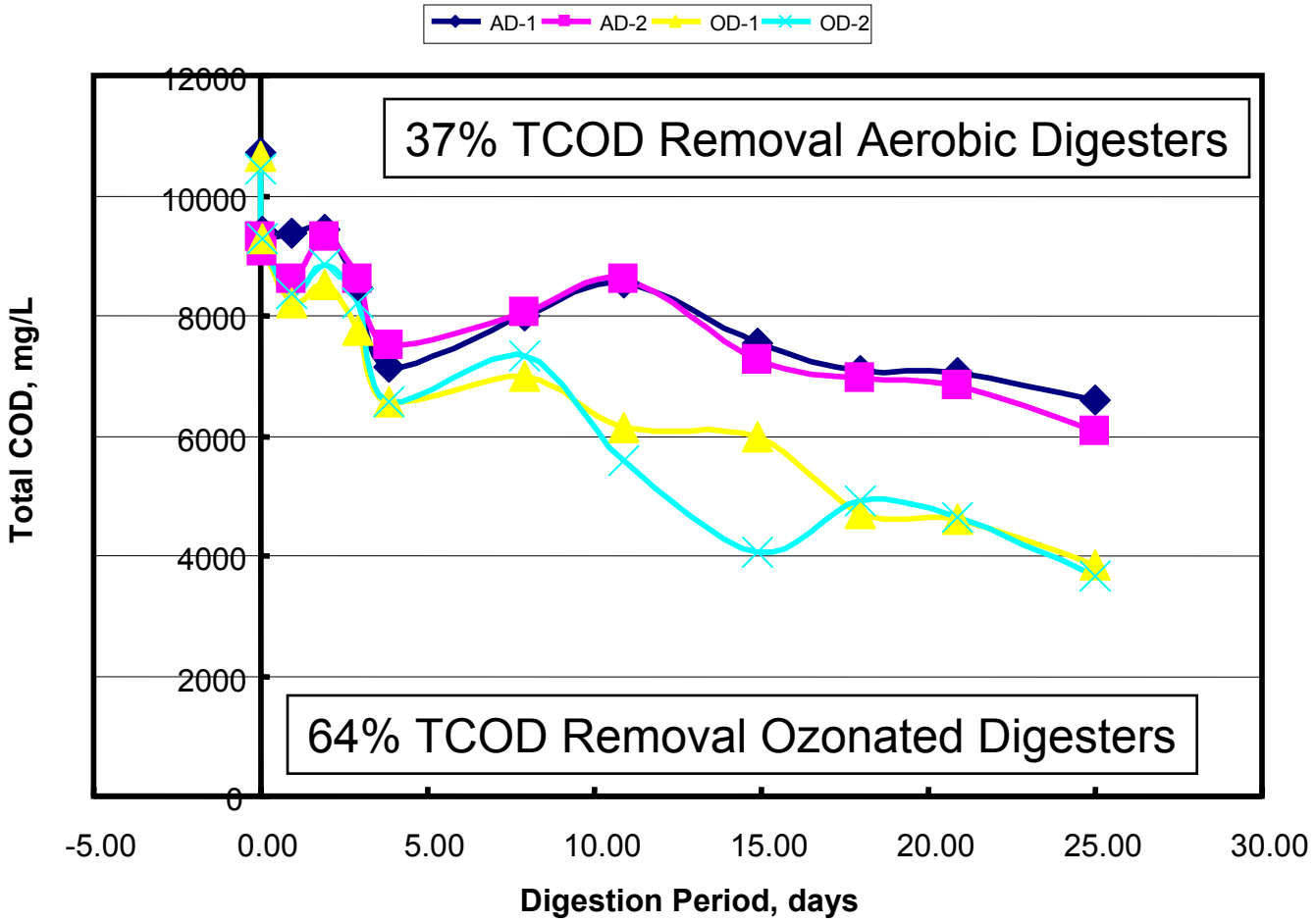
EPA Manual 1.74 – 2.07 lb oxygen per lb of cell mass oxidized.

Ozone Utilized per TS Destroyed

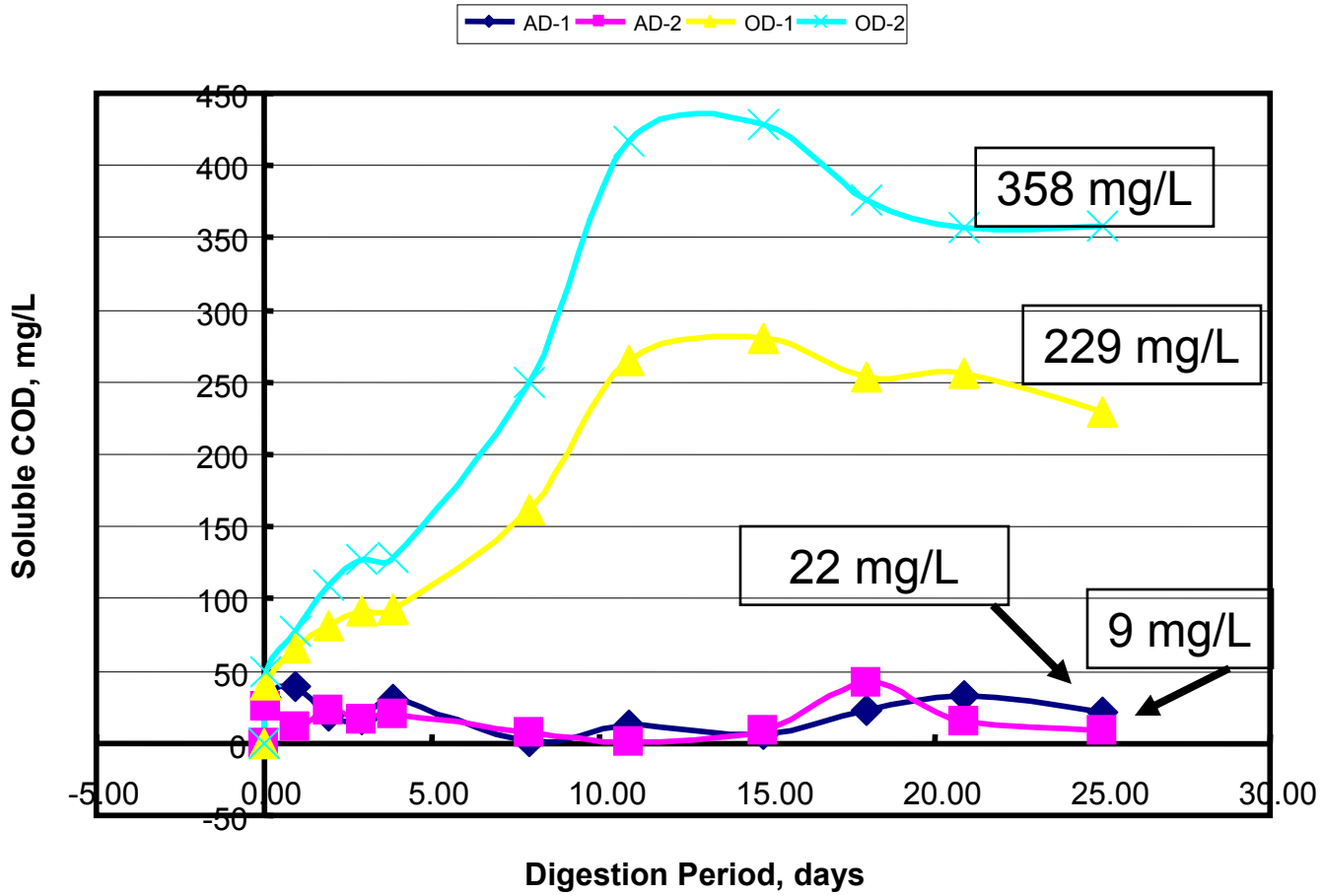
Digester	Ozone Applied per Total Solids Destroyed	Ozone Utilized[1] per Total Solids Destroyed
Ozonated Digester -1	2.6 mg/mg	0.71 mg/mg
Ozonated Digester -2	2.8 mg/mg	0.77 mg/mg

27.4% Ozone Utilization[1]

COD Concentration



Soluble COD Concentration



Summary

- Four, 1-L bench-scale digesters were operated in parallel for 25 days.
- Two, sparged with air and two with ozone.
- Higher solids and total COD removals were achieved in the ozonated digesters and occurred at a faster rate.
- Soluble COD concentrations increased during the digestion period for both the aerobic and ozonated digesters.

Conclusions: 1

- Average overall TSS removals were 37% and 64%, respectively for the aerated and ozonated digesters.
- Average overall VSS removals were 39% and 70%, respectively for the aerated and ozonated digesters.
- Average oxygen required per mg of TVS destroyed was 1.82 for all four digesters.
- Average ozone dosages were 0.71 and 0.77 mg ozone consumed per mg of TS destroyed in OD-1 and OD-2, respectively.

Conclusions: 2

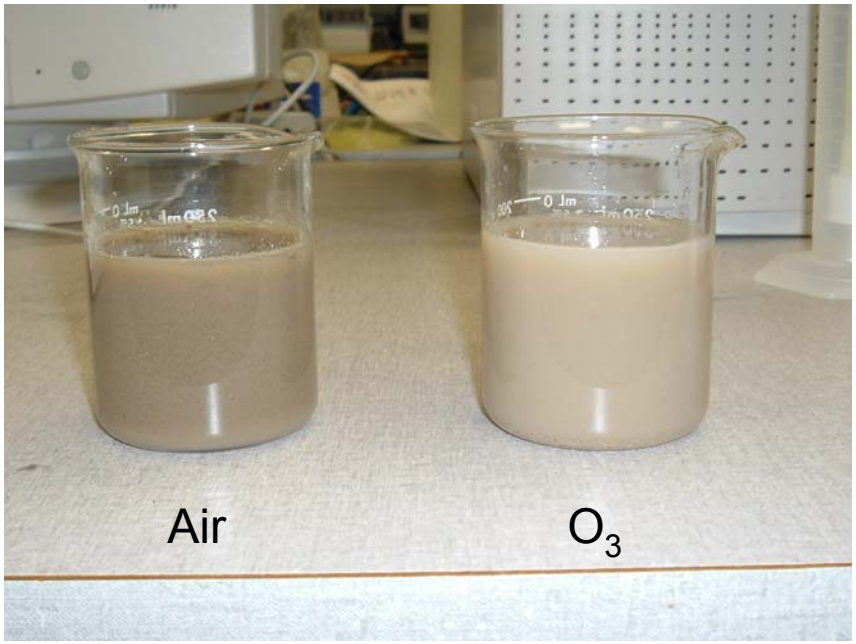
- Average overall TCOD removals were 37% and 64 % for the aerated versus ozonated digesters.
- Average SCOD concentrations increased from 0 to 15 mg/L in the aerobic versus 0 to 294 mg/L in the ozonated digesters.
- Solids degradation constants (K_D) of 0.015 d^{-1} and 0.041 d^{-1} were determined for the aerobic and ozonated digesters, respectively.

Future Work

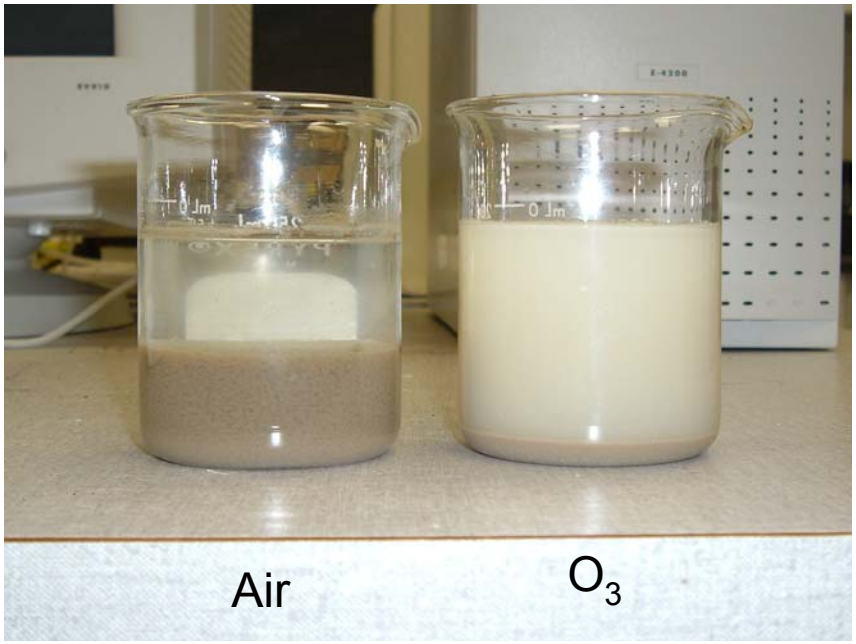
- Biodegradability of supernatant, BOD analyses
- Fecal coliform reduction
- Change air flow rate to aerobic digesters
- Change ozone concentration
- Investigate different initial solids concentrations

Questions?

Settling Characteristics



Sludge After 25 days of Digestion



Sludge After Settling 30 minutes