Factors that influence the Formation of FOG Deposits in Sewer Collection Systems

Joel Ducoste, PhD

North Carolina State University

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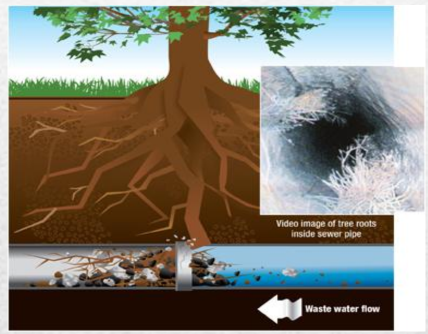
Outline

- Issues related to FOG
- Background on FOG and GI Research
- Factors that influenced FOG Deposit Formation
  - Chemical
  - Physical
- Summary
- Issues for the Future
- Questions

Sewer Collection System Infrastructure

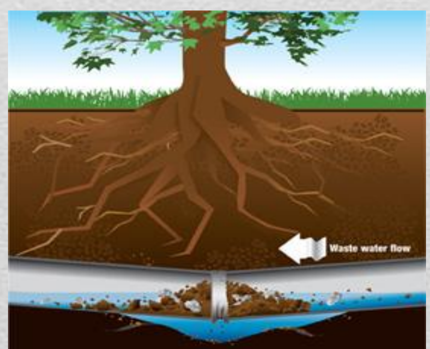
- Grease accumulation and roots intrusion are affecting sewer conveyance performance nationwide
  - Projected that more than 75% of sewer systems work at half capacity due to either grease related clogs or roots intrusion
  - Projected cost to keeping the sewers clear is well over $25 billion



Root Intrusions

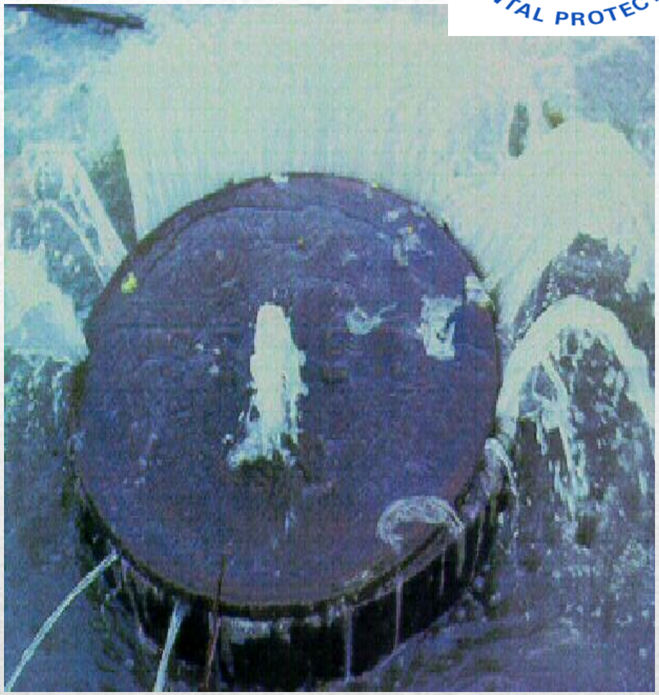
Poorly maintained grease interceptor

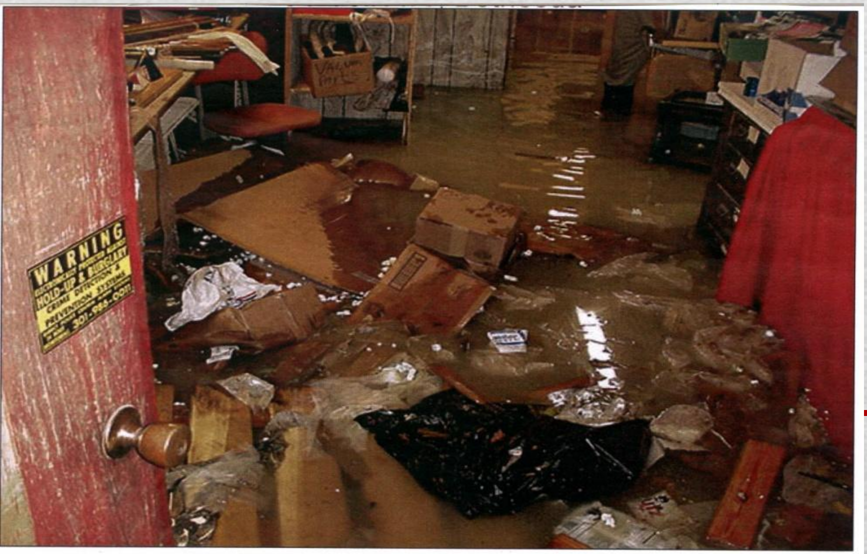
Sewer pipe blocked with FOG



Pipe Sag

SSO or SOS





Grease Deposits is the Word

Brief Review of Prior Research

Ducoste et al. Research

- Deposits
  - Moisture content: 6 to 86%,
  - Contained >50% lipid content, (palmitic acid).
  - Contained calcium
  - The adhesion of oil on Willow tree roots occurs instantaneously, and is independent on amount of time
- Field Interceptors
  - Peak flows 3-7 times the average flow
  - Long average residence times, exceeding 2 hrs
  - Low pH's and DO suggest microbial activity
  - Simple modifications to GI configuration can enhance performance
- Controlled Lab Experiments with Lab Interceptors
  - 3x Residence Time Yielded ~ 10% increase in performance
  - GI piping must be designed to distribute the influent/ effluent flow
  - Baffle wall designs with inlet/outlet configurations

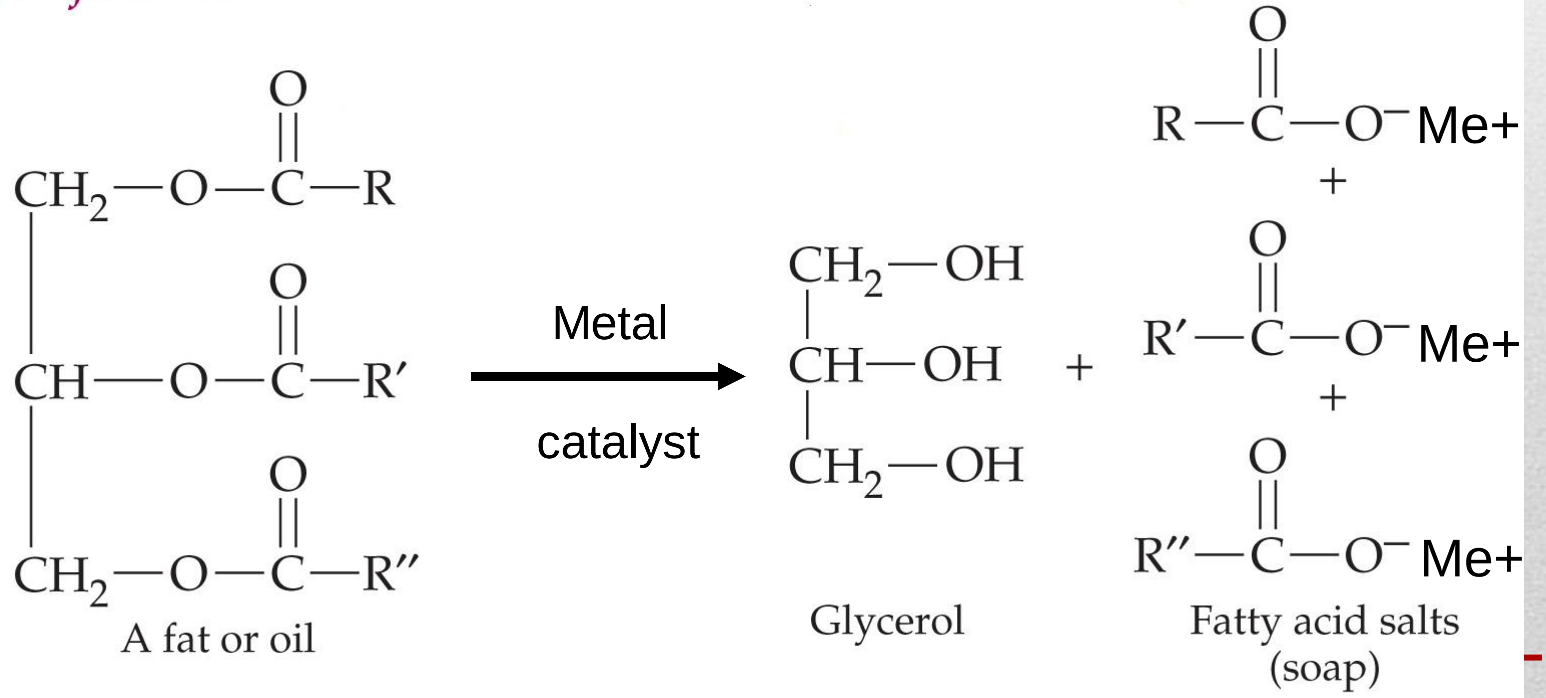
Ducoste et al. Research

- Analysis of Internal Grease Abatement Devices
  - Challenged with a range of Emulsion strengths, Flow Rates, and Temperature
- Results
  - Emulsion strength and flow increase, the performance of the GAS decreased
    - Results, in general, below 50%
    - Air induction did not improve performance
  - The heightened temperature caused a narrowing of the oil globule distribution, with the count of relatively smaller globules and relatively larger globules decreasing.
    - Increasing temp reduced performance for weak emulsions and improved performance for strong emulsions
  - External GIs were able to remove 75- 80%

Ducoste et al. Research

- What is really going on in GIs and subsequently in the sewer collection system?
- Initial Hypothesis: Saponification
  - (insoluble calcium based fatty acid salts)

Saponification



EPA Research Project Objectives

- **<u>Project Title:</u> An Integrated Approach to Understanding and Reducing FOG Deposit Formation for Sustainable Sewer Collection**

- Perform bench scale experiments that attempts to recreate FOG deposits and determine parameters that significantly influence their formation rate,

- Develop a numerical model that describes FOG deposit formation kinetics,

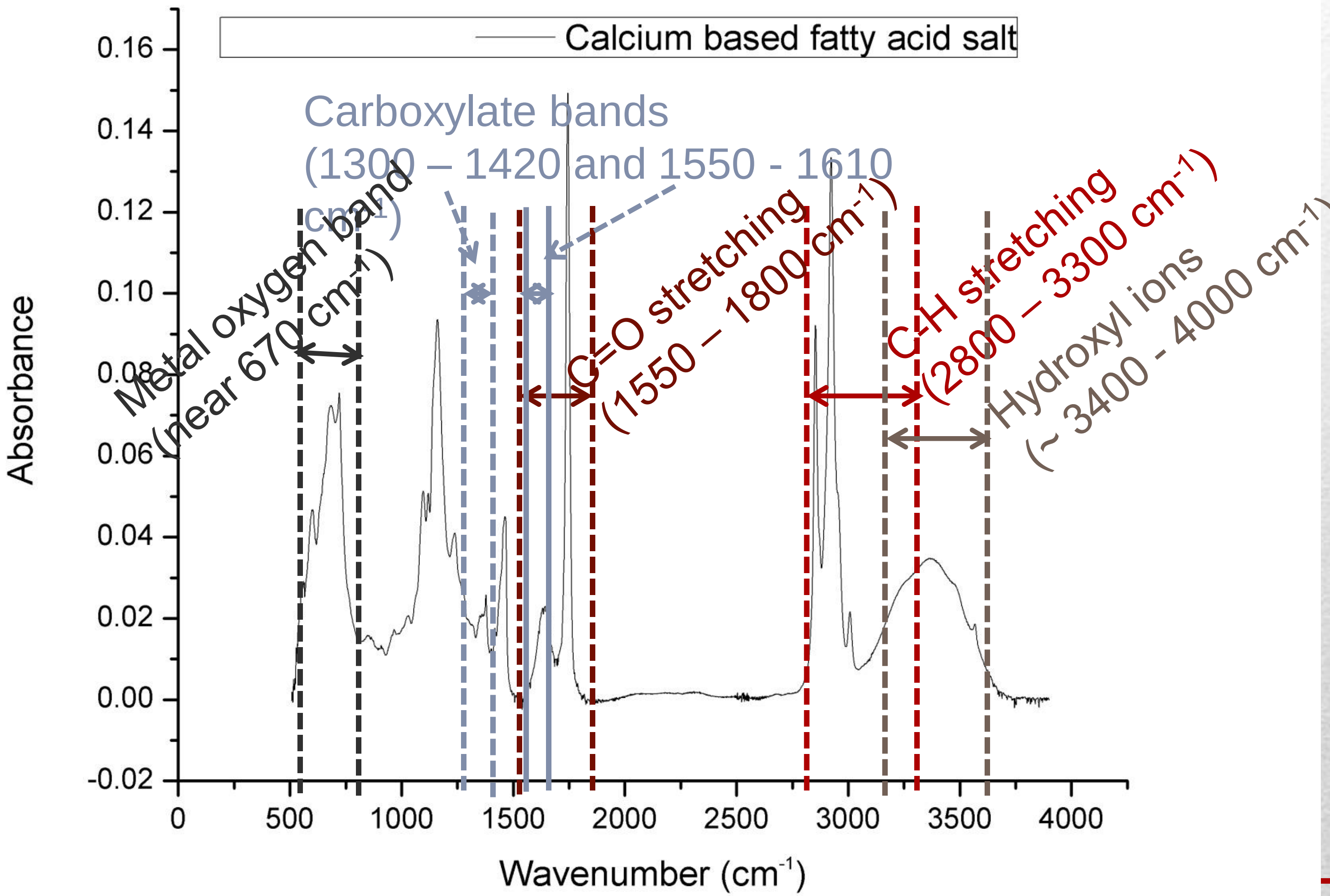
- Perform bench scale tests to explore enhanced treatment methods to improve the removal of FOG deposit chemical precursors with grease interceptors,

- Perform pilot scale experiments on a continuous flow sewer collection system to explore spatial variations in FOG deposit formation, and

- Develop a sewer pipe network transport model to predict FOG deposit formation in sewer collection systems.

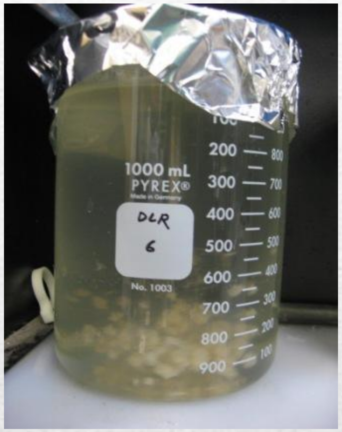
EPA Research: Results to date

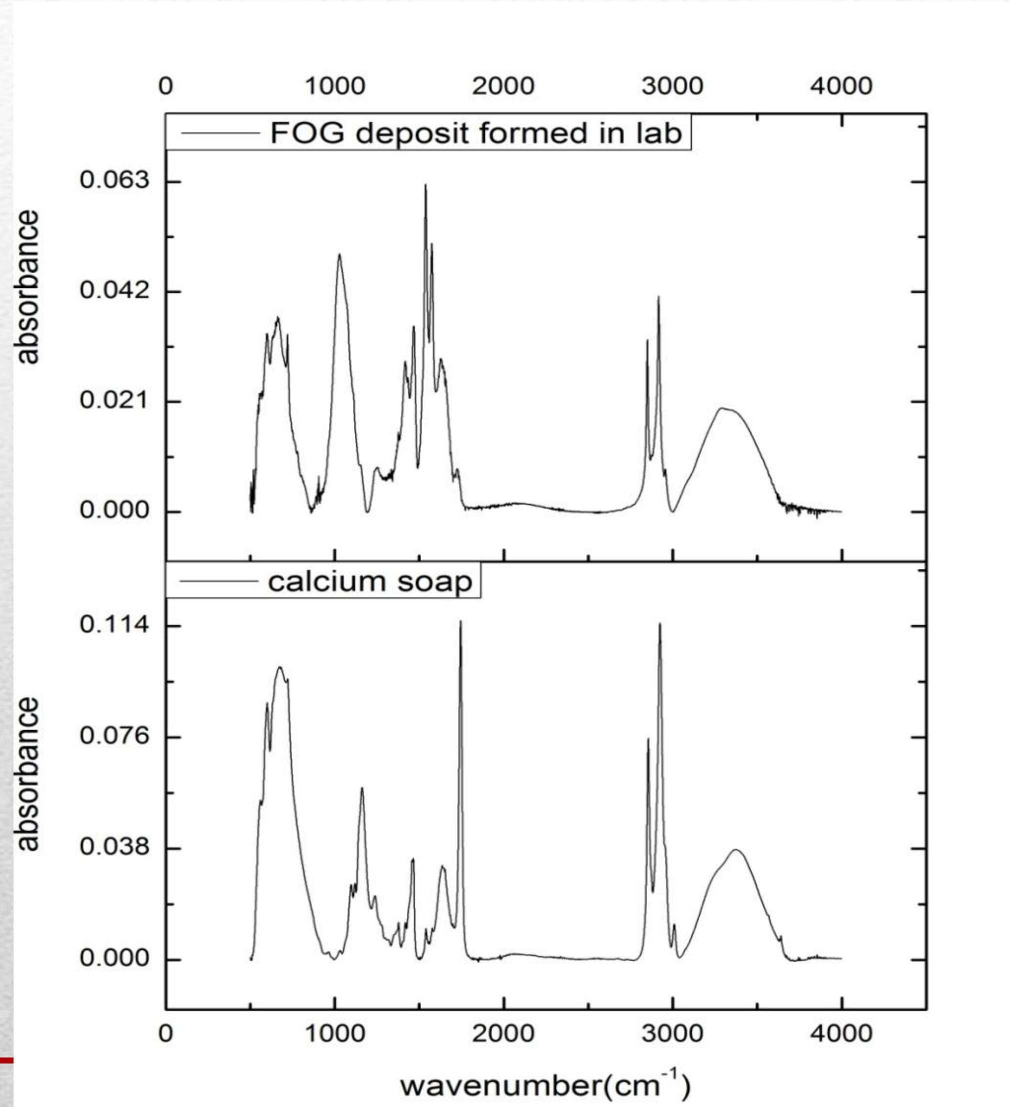
FTIR-ATR sections in calcium based fatty acid salts



EPA Research: Results to date

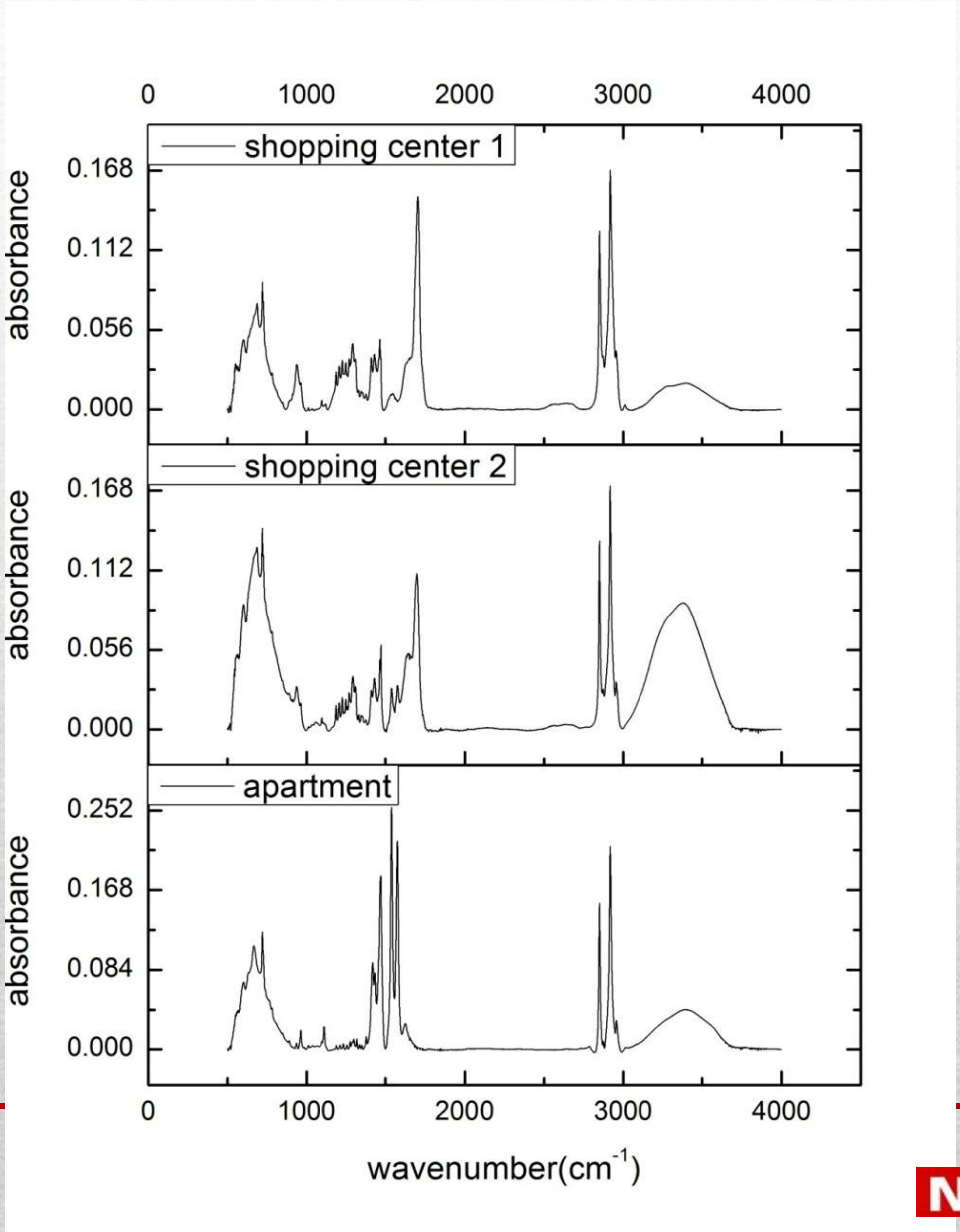
Grease interceptor (GI) effluent + calcium salt





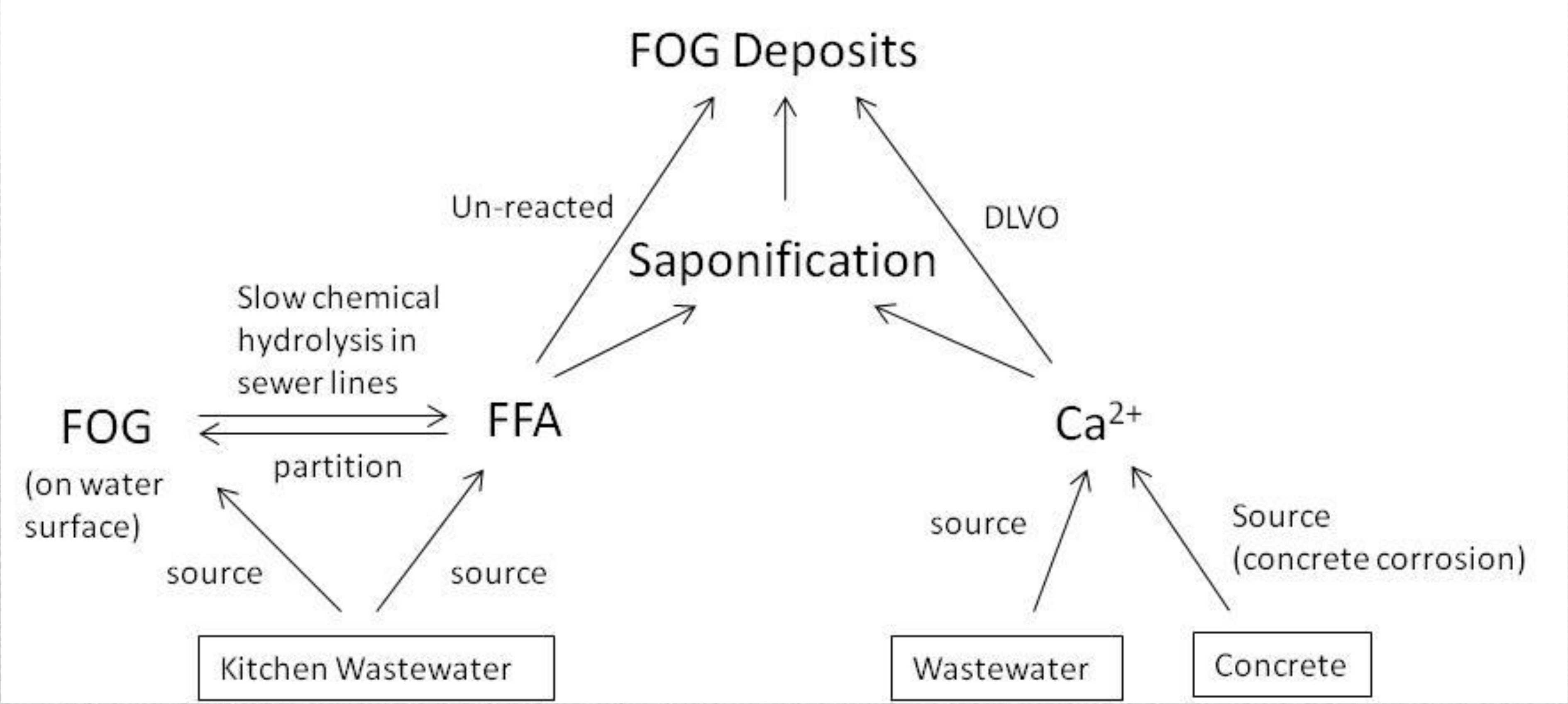
EPA Research: Results to date

Saponification→YES



EPA Research: Results to date

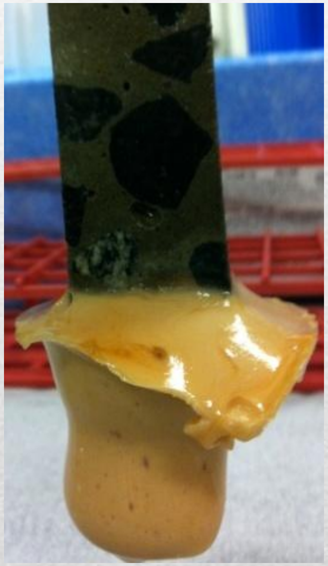
Proposed Overall Mechanism for FOG Deposit Formation



EPA Research: Results to date

- Effect of different types of fatty acids on surface saponification reaction



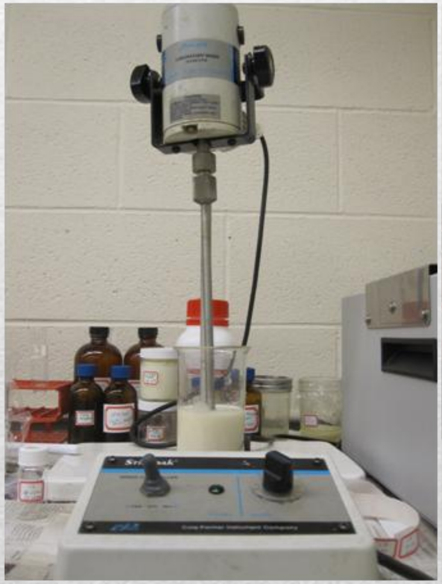
Palmitic acid 0.25 g (Palmitic_1)	Palmitic acid 1 g (Palmitic_2)	Oleic acid 0.25 g (Oleic)	Linoleic acid 0.25 g (Linoleic)

Question that make me wonder

- How do chemical and physical factors influence the properties and formation of FOG deposits?
  - Type of fat
  - Type of calcium source
  - pH
  - Temperature
  - Extent of hydraulics or physical characteristics of the sewer system

EPA Research: Experimental Methods

- Batch scale experiments with variables
  - Two fats (Canola vs. Beef tallow)
  - Three calcium sources
    - Calcium chloride, Calcium sulfate, and Calcium hydroxide
  - Three pH (7±0.5, 10±0.5, and 14)
  - Two temperature (22-25°C and 45°C)
  - Eight hours of mixing



EPA Research: Experimental Methods

- Spatial variation in FOG deposit formation was assessed in a pilot-scale sewer collection system that contains different hydraulic configurations, obstructions and pipe deformations.

Fig 1: Schematic of the pilot-scale sewer system

EPA Research: Experimental Methods

Setup of the pilot-scale sewer system

Section 1

Section 2

Root Intrusion in Section 2

Roots

Section 3

EPA Research: Experimental Methods

Pilot Operational Procedure

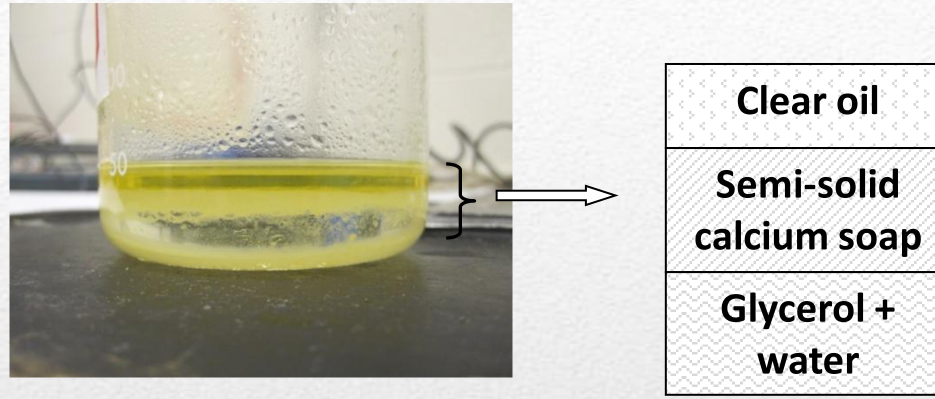
- Operating period for a particular experiment– 1 month.
- Each test consists of different calcium source, different pH conditions or addition of FFA into the system.
  - Vegetable oil and calcium hydroxide (pH=10)
  - Vegetable oil and calcium chloride (pH=7)
- Feed rates of calcium and oil were based on a target influent concentration of 50 mg/L of calcium and 200 mg/L of oil, respectively.

EPA Research: Experimental Methods

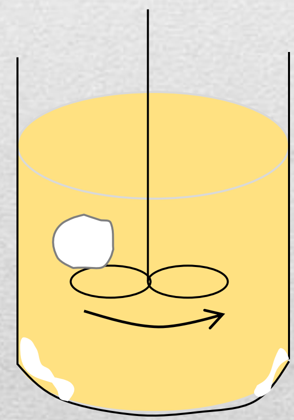
- Fourier Transform Infrared-Attenuated Total Reflection (FTIR-ATR) → percent soap
- Mineral and metal analysis
- Fatty acid composition of the final soap samples

EPA Research: More Results

- Role of calcium sources
  - Calcium chloride
    - Soap dissolved in the liquid while mixing
    - Phase-separated when mixing ceased



- Calcium sulfate
  - significant agglomeration property
    - Under slow vs. high mixing condition
  - Calcium chloride and calcium hydroxide showed no such properties
  - **Calcium sulfate**, having the sticky and agglomeration property **may stick to the sewer wall** with the FOG on the sewer surface due to wave action of water



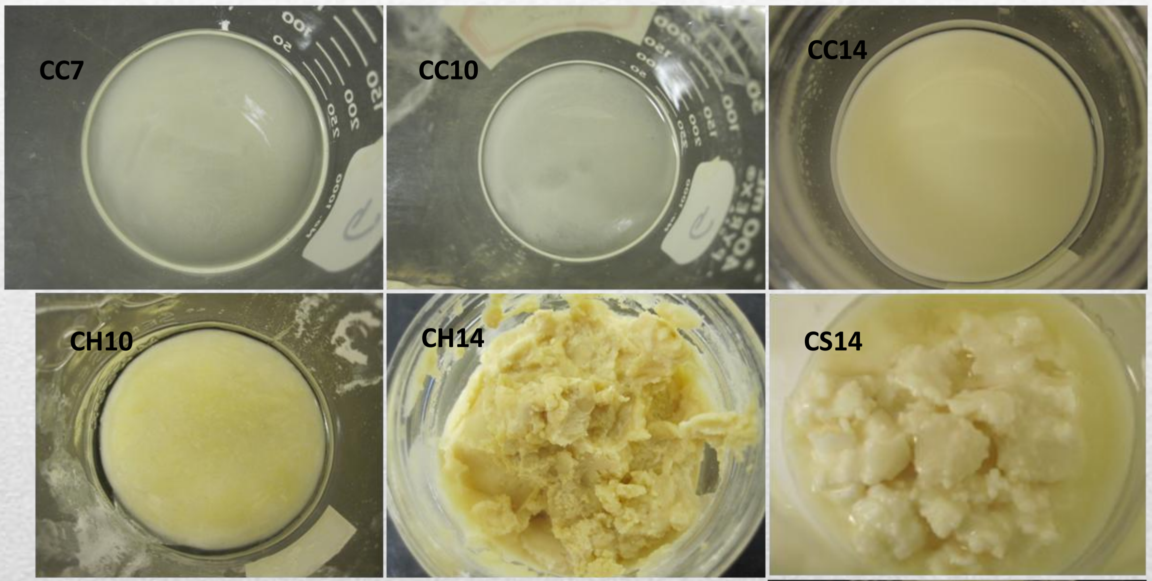
EPA Research: More Results

- Role of pH:
  - Canola (C) and calcium chloride (C): pH↑, % soap ↑
  - Canola (C) and calcium sulfate (S):
    - percent soap $_{pH=7}$ > percent soap $_{pH=10}$ > percent soap $_{pH=14}$
    - However, interference with Ca=O bond is hard to differentiate

- Role of temperature:
  - Canola (C) and calcium chloride (C): T↑, % soap↓
  - Canola (C) and calcium sulfate (S): T↑, % soap ↑
  - Beef tallow (BC and BS):
    - % $soap_{sulfate}$ > % $soap_{chloride}$

EPA Research: More Results

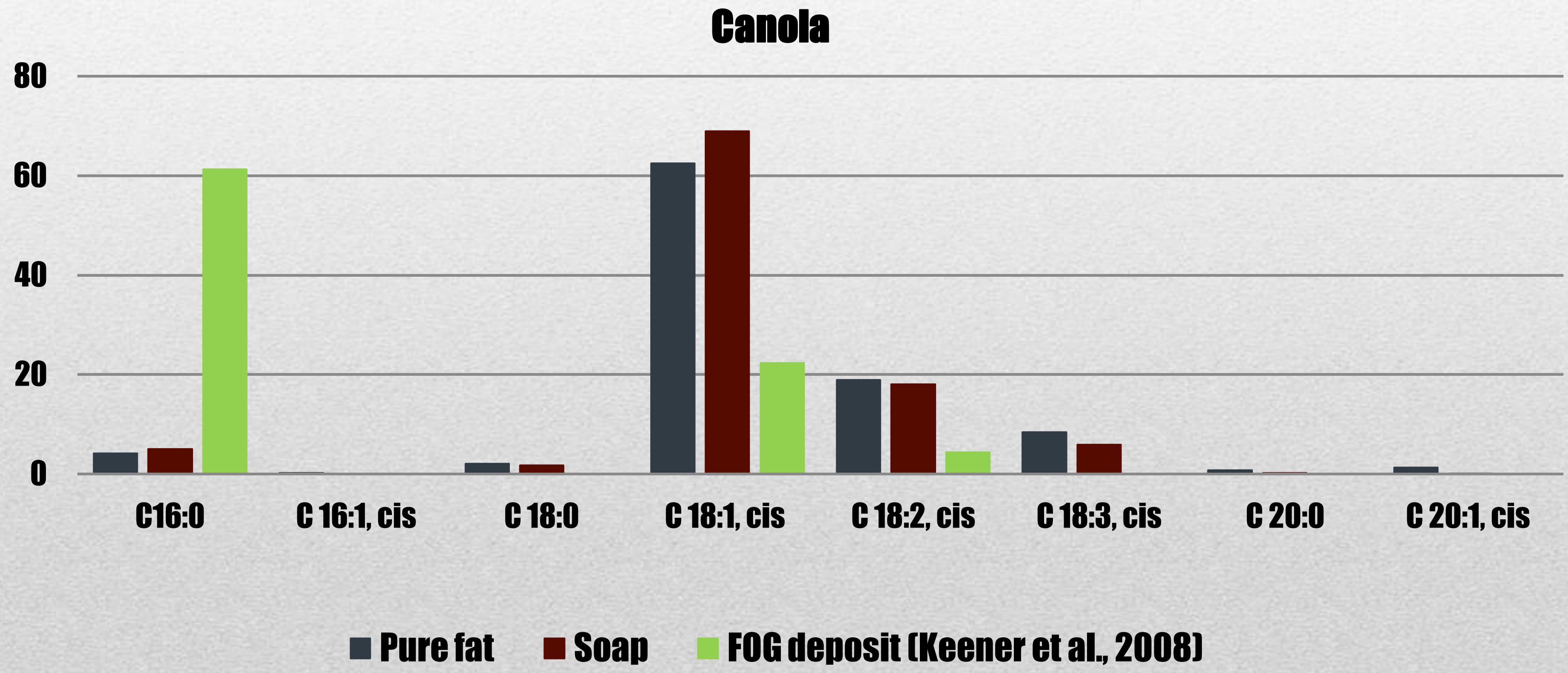
- Role of pH and temperature (continued)
  - Changes solubility of calcium source
  - Changes color



Physical appearances of calcium-based fatty acid salts (*CC = Canola and calcium Chloride; BC = Beef tallow and calcium Chloride; similarly in the second letters, S = calcium Sulfate, and H = calcium Hydroxide; the numbers indicate pH values.*)

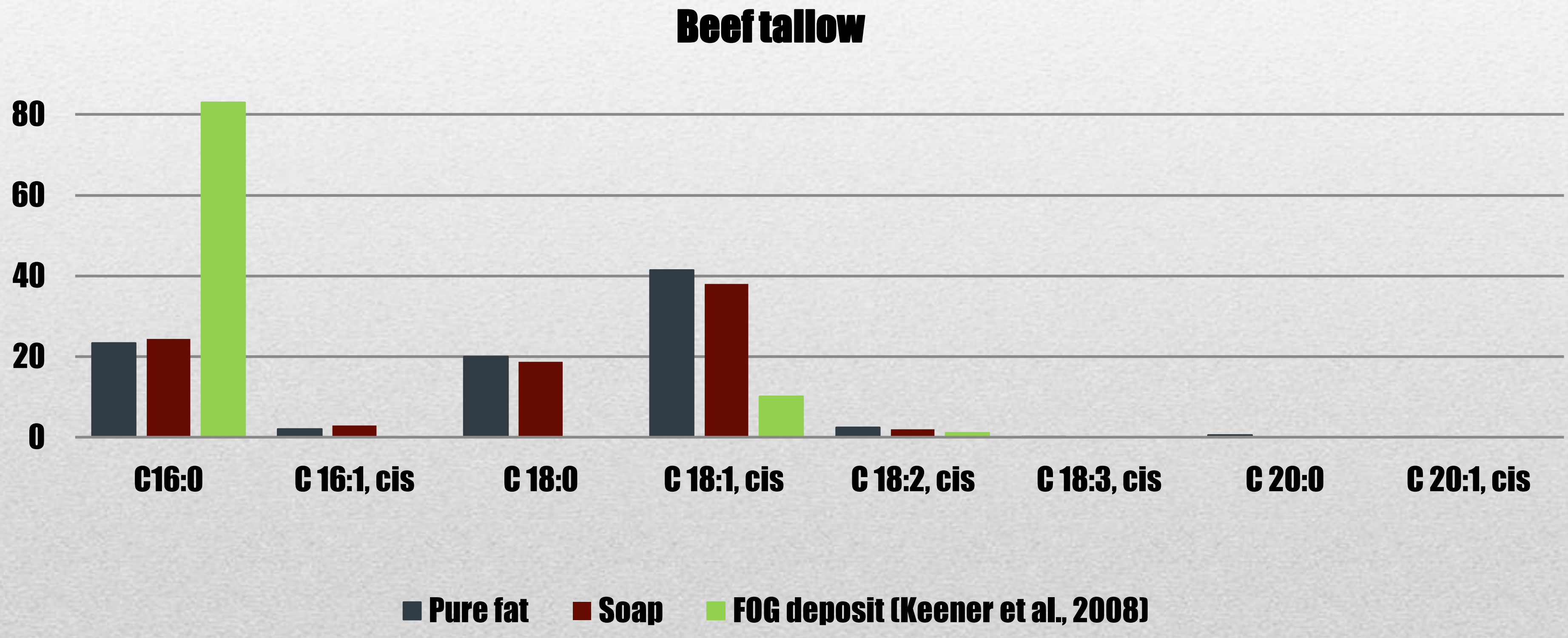
EPA Research: More Results

- Role of Fat type
  - FFA composition of Calcium-based fatty acid salts are similar to the source fats introduced



EPA Research: More Results

- Role of Fat type (continued)
  - Palmitic acid fraction (C16:0) in actual FOG deposits are much higher than its contents in pure fat or soap



EPA Research: More Results

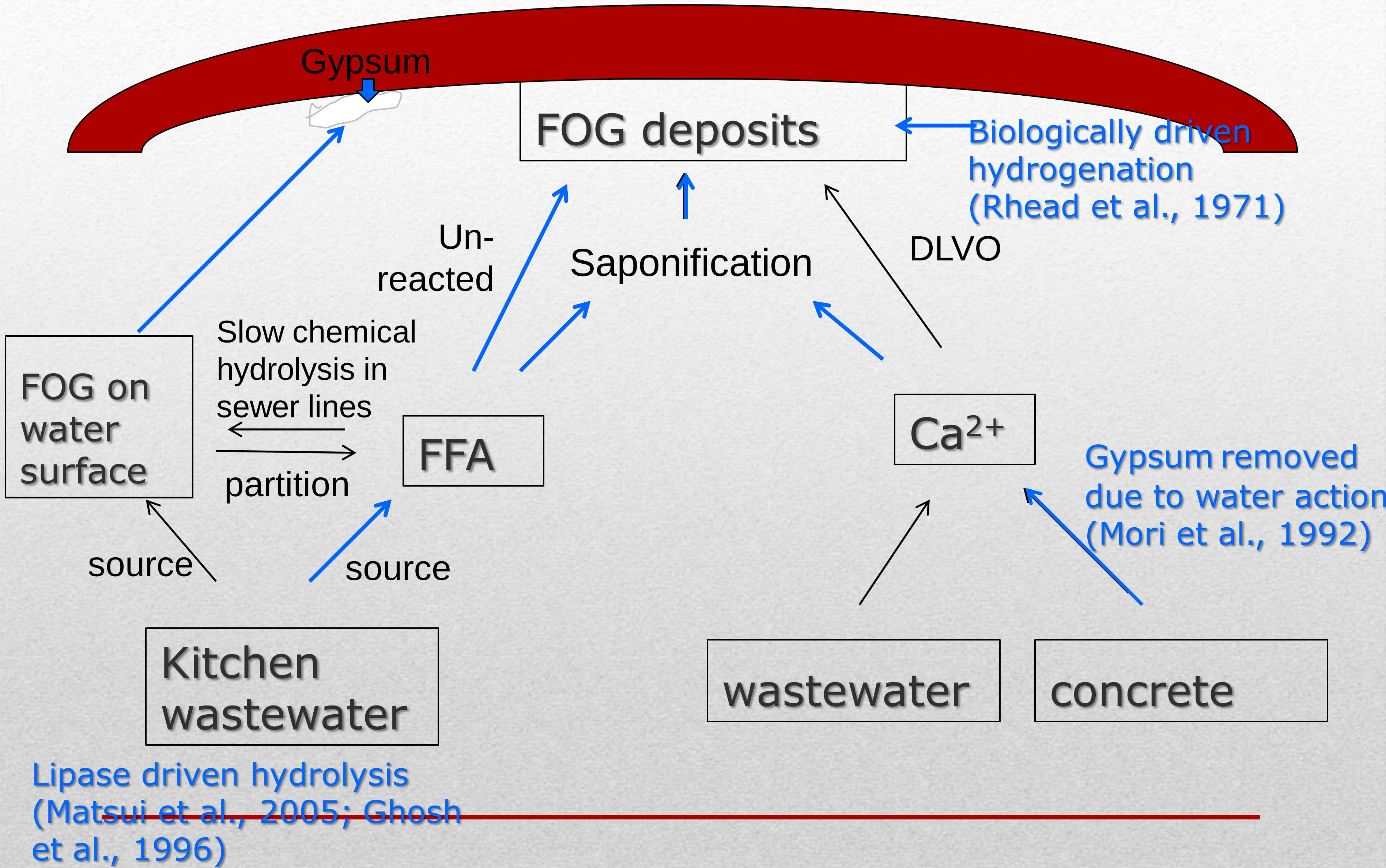
- Role of Fat type (continued)
  - Why is palmitic the primary saturated fatty acid?

1. Fraction of saturated fats → sewer system
2. Cooking → saturated fractions
3. Lipase driven hydrolysis in GI: Specificity of lipases → palmitic
4. Biologically driven hydrogenation: Oleic → Palmitic

⇒

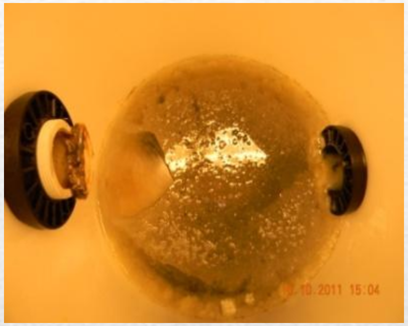
Palmitic acid predominance in FOG deposit

Amendment to FOG deposit formation mechanism

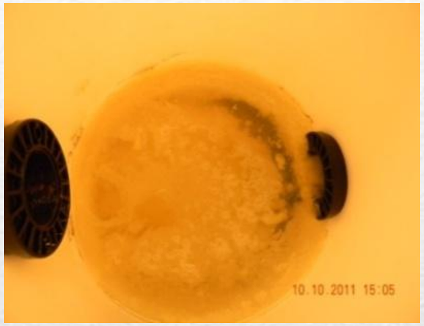


EPA Research: Pilot systems Results

- Experiment – 1
  - Vegetable oil and Calcium Hydroxide
  - pH - 10



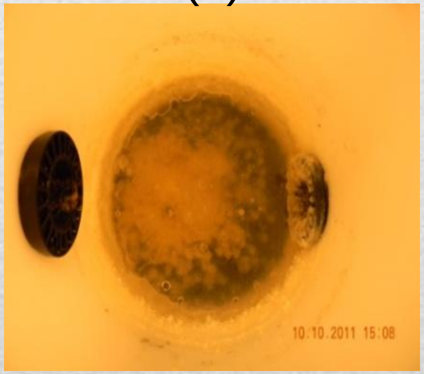
(a)



(b)

(c)

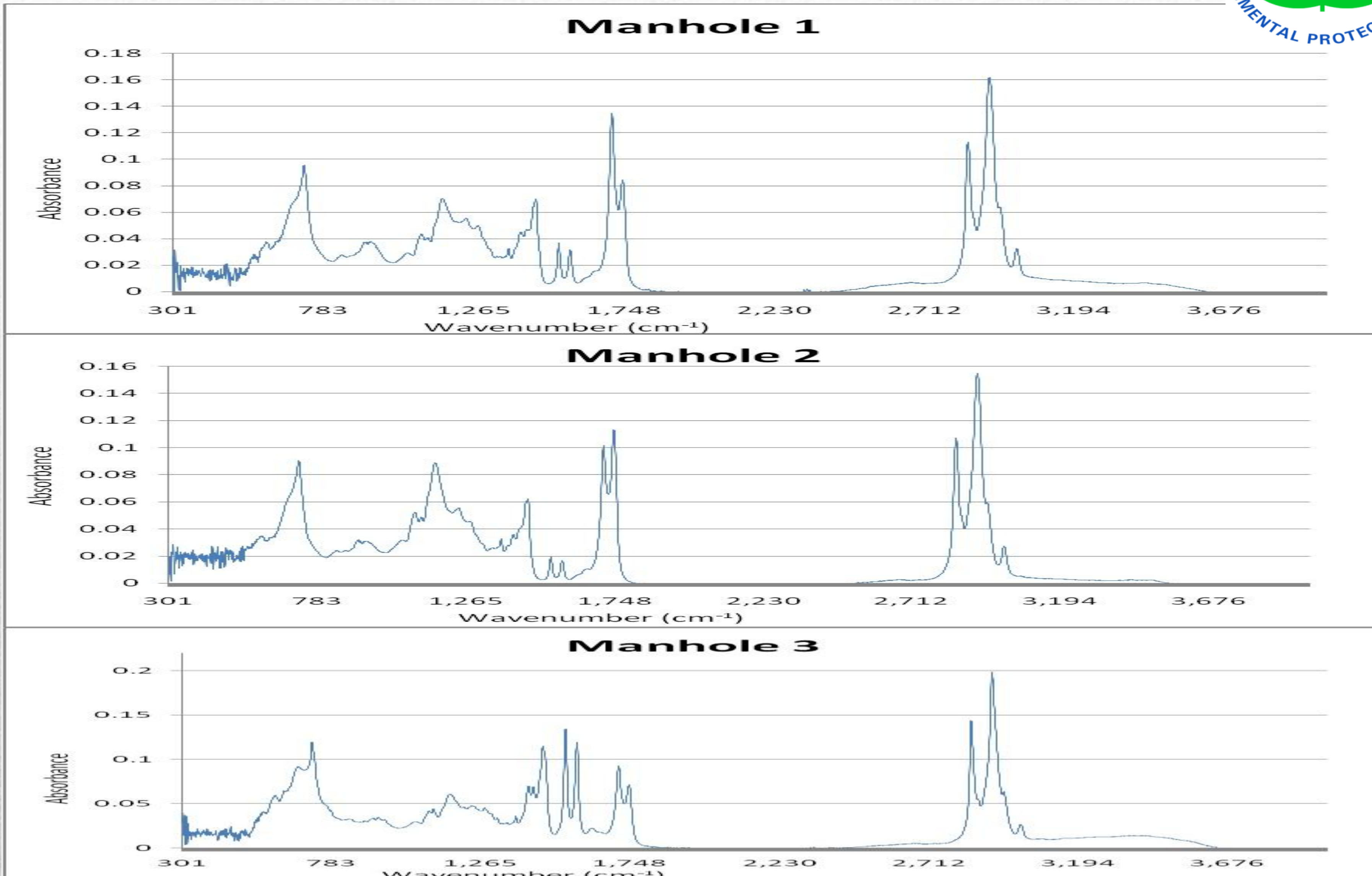
(d)



(e)

Accumulation of solids due to Calcium Hydroxide in various parts of the sewer system. (a) Manhole 1 (Top view); (b) Manhole 2 (Top view); (c) Root intrusion; (d) Pipe Sag; (e) Manhole 3 (Top view)

EPA Research: Pilot systems Results



FTIR Analysis of solids formed due to Calcium Hydroxide in various pars of the pilot system

EPA Research: Summary

- Fatty acid profile of the calcium-based fatty acid salts produced under alkali driven hydrolysis were identical to the profile of the fat source and did not match the profile of field FOG deposits
- Selective microbial metabolism of fats and/or biologically induced hydrogenation may contribute to the FOG deposit makeup in sewer system
- The pilot-scale sewer system showed the potential for spatial variation of FOG deposits when there was hydraulic variations in the configuration of the sewer system
- FTIR results confirmed that the solids formed were calcium based fatty acids.

EPA Research: Summary

- The potential areas where these FOG deposits were found where the pipe sag and root intrusion.
- The reason for the accumulation of solids at the root intrusion is because of additional surface area.
- Pipe sag had low flow conditions which prevented the oil from being washed out leading to accumulation of FOG.

EPA Research: Issues for the Future

- Continued assessment of Factors that influence FOG deposit formation
- Kinetics of FOG Deposit formation
- Alternative strategies for Enhanced FOG separation
- Improvements to measuring FOG in GI effluent
- Numerical model of FOG deposit formation in sewer systems

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Ducoste Contact Info:

- Joel Ducoste, PhD
- Department of Civil, Construction, and Environmental Engineering
- 208 Mann Hall CB 7908
- Raleigh NC 27695
- jducoste@ncsu.edu