“Review of Research into Fat, Oil and Grease (FOG) Deposits in Collection Systems”

Casey R. Furlong, P.E.

Environmental Specialist

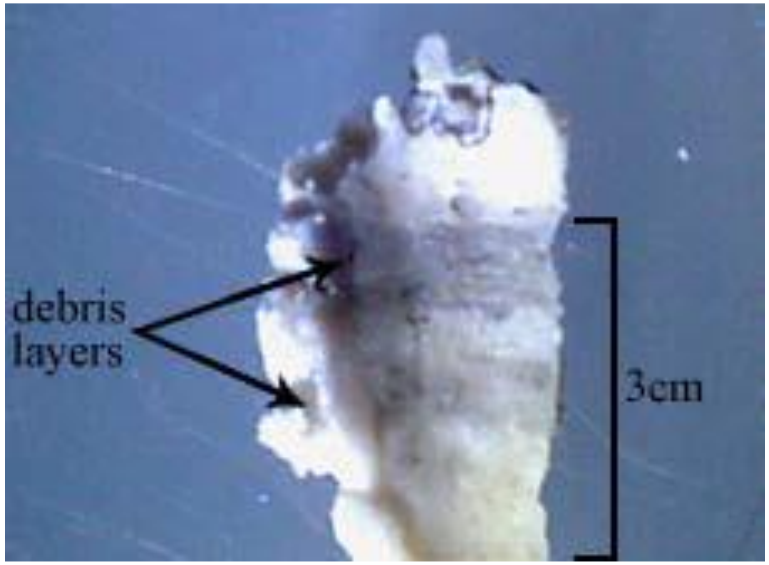
InSinkErator

Background

- Large Contributor to Sanitary Sewer Overflows per EPA
- Issue Occurs Globally
- Viewed as “Cost of Doing Business”
- Presentation to Review Previous Research of:
  - Deposit Component Sources and Chemistry
  - Conditions and Mechanisms of Formation
  - FOG Control Challenges

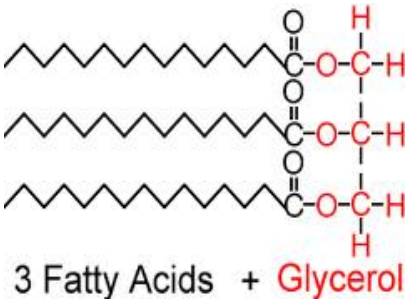
"Properties Influencing Fat, Oil, and Grease Deposit Formation." *Keener*, 2008.

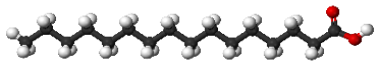
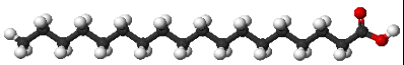
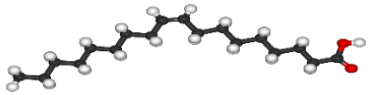
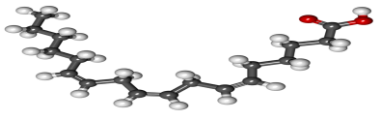
- Characterized Chemical and Physical Makeup of 27 FOG Deposit Samples from Different U.S. Collection Systems.
- Deposits Contain High Amounts of Saturated Fats and Calcium
  - Higher Than Background Levels.
  - Average Ca at 4,300 ppm, Wastewater Ca Level < 200 ppm
  - Dry Content 85% Total Fat
- Determined that FOG Deposits are Formed Primarily by Saponification and are Metal Soaps.
- Evidence of Layering During Formation Process

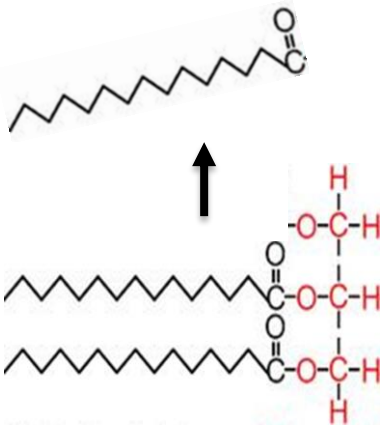


FOG, Triglyceride and Free Fatty Acid Refresher

Fats	Oils	Grease
Animal Based (Lard, Shortening)	Vegetable Based (Corn, Soybean)	Residue Left Over After Cooking
Liquid With Some Heat Added	Able to Withstand High Temperatures	Liquid To Semi-Solid at Room Temperature
Solid at Room Temperature	Liquid at Room Temperature	



Fatty Acid	Model	Carbon Atoms	Molecular Formula	Solubility In Water	Density
Palmitic Acid		C16:0	$C_{16}H_{32}O_2$	Insoluble	0.82 g/cm^3
Stearic Acid		C18:0	$C_{18}H_{36}O2$	3 mg/L	0.94 g/cm^3
Oleic Acid		C18:1	$C_{18}H_{32}O2$	Insoluble	0.89 g/cm^3
Linoleic Acid		C18:2	$C_{18}H_{32}O2$	0.14 mg/L	0.90 g/cm^3



Fatty Acid Profiles of Common Animal Fats, Vegetable Oils and FOG Dposits

Lipid Type	Saturated Fat (%)	Primary Saturated Fat	Mono-Unsaturated Fat (%)	Primary Unsaturated Fat	Polyunsaturated Fat (%)	Primary Polyunsaturated Fat
Animal Fats						
Chicken Fat	33.0	Palmitic (C16:0)	45.2	Oleic (C18:1)	21.4	Linoleic (C18:2)
Lard (pig)	41.8	Palmitic (C16:0)	47.9	Oleic (C18:1)	9.9	Linoleic (C18:2)
Tallow (beef)	47.9	Palmitic (C16:0)	47.4	Oleic (C18:1)	3.3	Linoleic (C18:2)
Vegetable Oils						
Canola	7.3	Palmitic (C16:0)	62.9	Oleic (C18:1)	30.5	Linoleic (C18:2)
Corn	13.6	Palmitic (C16:0)	25.6	Oleic (C18:1)	60.8	Linoleic (C18:2)
Olive	12.1	Palmitic (C16:0)	80.9	Oleic (C18:1)	7.0	Linoleic (C18:2)
Palm	49.4	Palmitic (C16:0)	39.5	Oleic (C18:1)	11.1	Linoleic (C18:2)
Peanut	19.4	Palmitic (C16:0)	48.5	Oleic (C18:1)	32.0	Linoleic (C18:2)
Soybean	15.4	Palmitic (C16:0)	23.3	Oleic (C18:1)	61.3	Linoleic (C18:2)
Average FOG Profile (Keener et al, 2008)						
FOG	61.3	Palmitic (C16:0)	22.3	Oleic (C18:1)	4.4	Linoleic (C18:2)

"Evidence for FOG Deposit Formation Mechanisms in Sewer Lines." *He, 2011*.

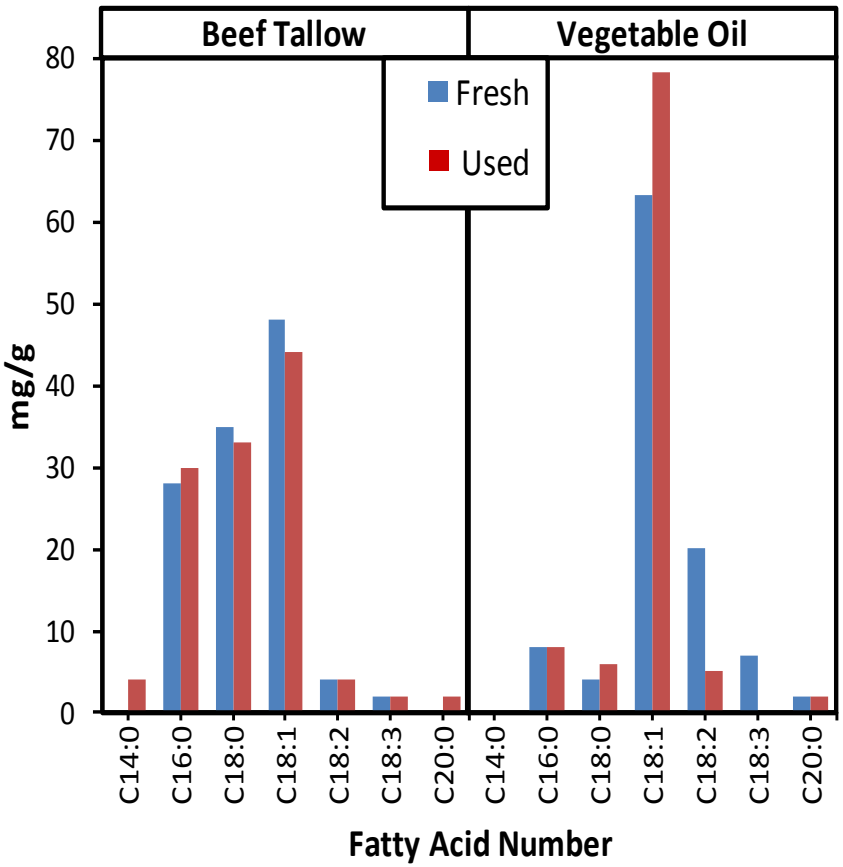
- Formed FOG Deposits in Lab Using $CaCl_2$ and GI Effluent.
- Without Free Fatty Acids (FFAs), Calcium Salts Do Not Form.
- Analysis Results Showed Both Lab and Field Deposits Similar to Calcium Soap.

- Field Deposits Contain Un-reacted FFAs / Calcium Limited

FOG Study	Saturated Fat %	Primary Saturated Fat	Mono-Unsaturated Fat %	Primary Mono-Unsaturated Fat	Poly-Unsaturated Fat %	Primary Poly-Unsaturated
Keener (2008)	61.3	Palmitic (C16:0)	22.3	Oleic (C18:1)	4.4	Linoleic (C18:2)
He (2011)	61.1	Palmitic (C16:0)	23.3	Oleic (C18:1)	3.2	Linoleic (C18:2)

"Fat, Oil and Grease Deposits in Sewers: Characterisation of Deposits and Formation Mechanisms." *Williams*, 2012.

- Study Notes Mechanisms That May Affect FOG Deposits Physical Properties.
- Calcium Accumulation Occurred Where Higher Water Hardness Levels Lead to Harder Deposits.
- Bacteria Transform Fatty Acids from Unsaturated to Saturated Forms.
  - Similar to *Brooksbank*, 2006, Where Wastewater Bacteria Degraded Unsaturated FFAs to Saturated FFAs.



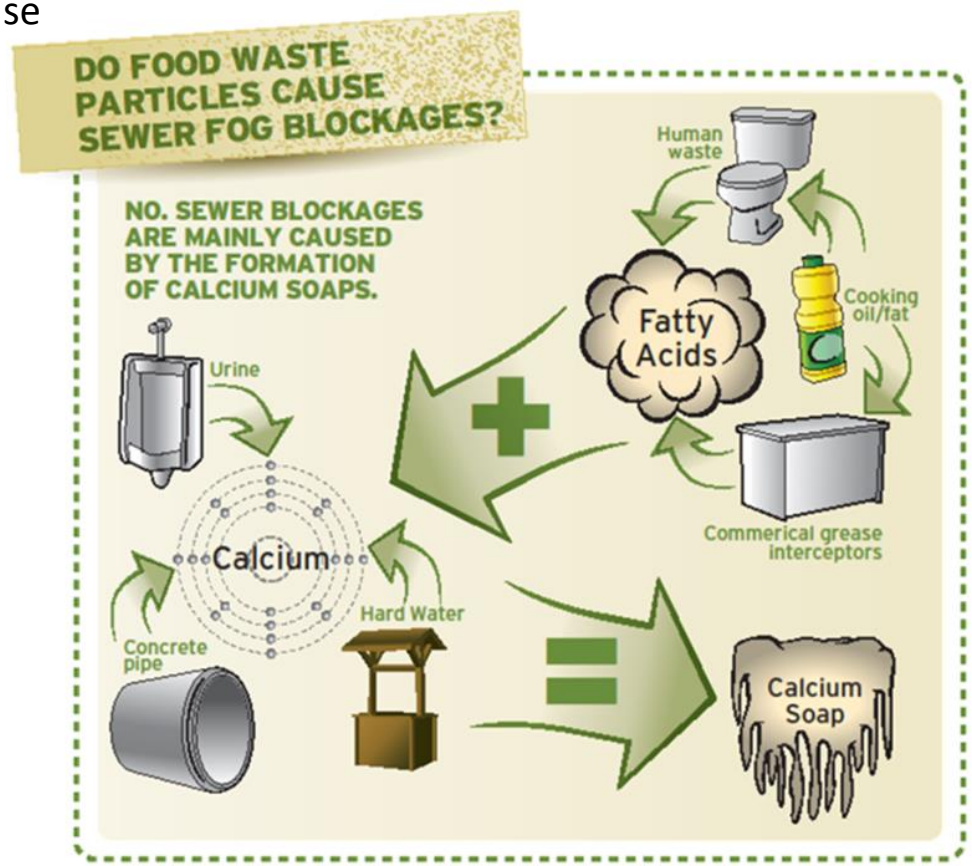
In 2012, *Reyes* and *Dominic* Each Studied Factors Affecting FOG Formation in Collection Systems.

- FFAs Produced from Cooking Processes & Discharged with Kitchen Wastewater to Sewer.
- Formations More Likely to Occur at Pipe Fitting Ridges, Roots and Sags, Rather Than in Straight Pipe Sections.
  - Indicates Nucleation Site May Be Necessary
- Sticky Solid Formed after Saponification Adsorbing FFAs, Calcium and Debris
- Surfactants Appear to Inhibit FOG Deposit Formation.
- FFAs Partition in FOG and Float on Wastewater Surface.
  - Alkali Conditions at the Air-Water Surface May Lead to Hydrolysis of FOG.

FOG FFA Densities Range From 0.82 to 0.94 g/cm^3

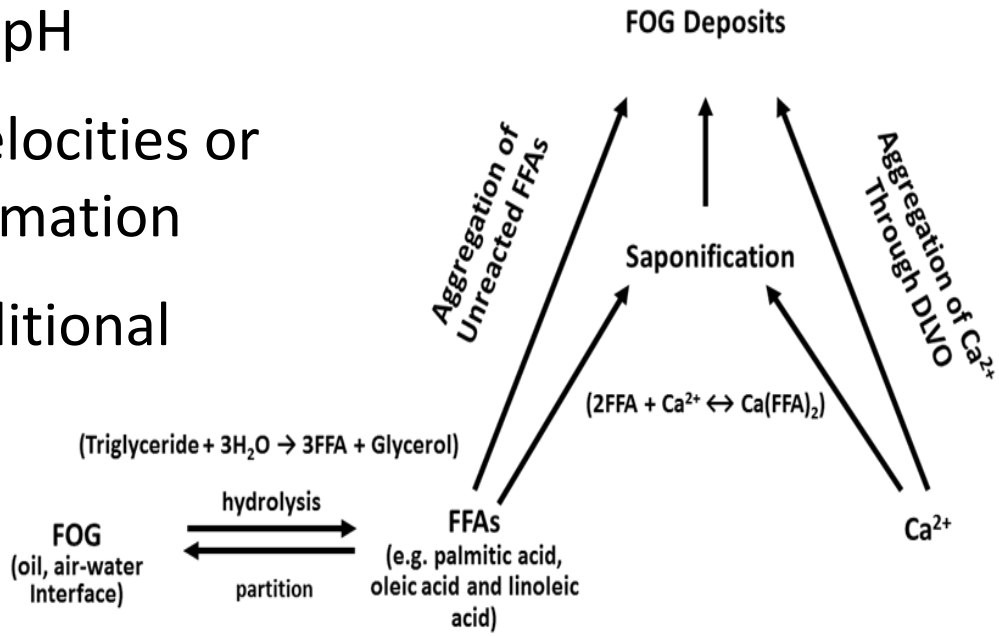
Sources of FOG Components

- Sewer FOG Deposits are Insoluble Calcium Soaps
- FOG Hydrolysis
  - Physically From Heating
  - Chemically Under Basic pH Conditions
  - Microbially Through Enzymatic Lipase
- Free Fatty Acid Sources
  - Hydrolyzed FOG
    - Vegetable Oils
    - Animal Fats
  - Bacteria
  - Personal Care Products
  - Human Waste
    - Total Fecal Fat is 5-6% FFAs
- Calcium Sources
  - Water Hardness
  - Concrete
  - Diet
  - Human Waste
    - Urine Has ~300 mg/L of Calcium



"Mechanisms of Fat, Oil and Grease (FOG) Deposit Formation in Sewer Lines." *He*, 2013.

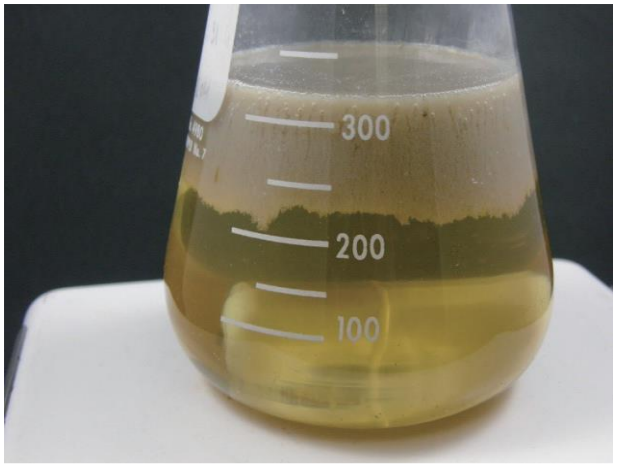
- Low pH from Fatty Acid Creation Release of Calcium From Concrete
- Deposits Formed at Higher pH
- Locations with Low Flow Velocities or Turbulence More Likely Formation
- Unreacted FFAs Attract Additional Fatty Acids and Calcium
- Deposit Formation Model
  - DLVO (Derjaguin, Landau, Verwey, Overbeek) theory



Consider Concrete Coatings or Alternative Materials

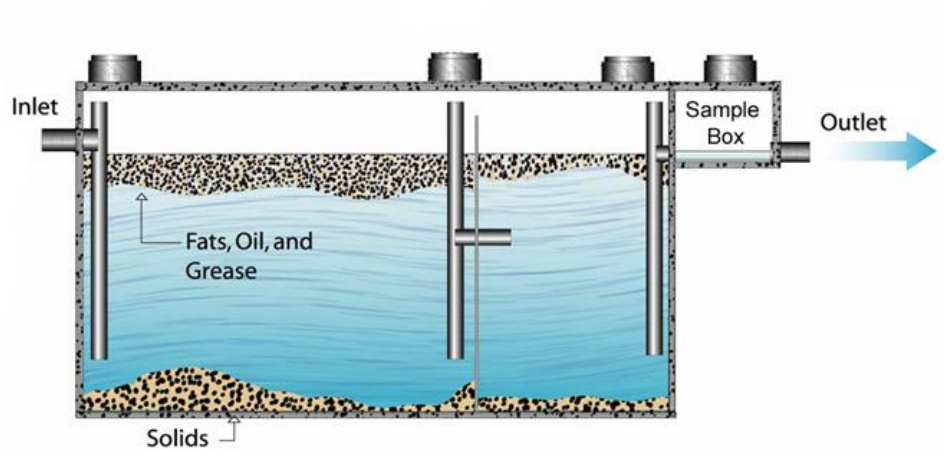
"Efficient Fractionation and Analysis of Fatty Acids and Their Salts in FOG Deposits." *Benecke*, 2017.

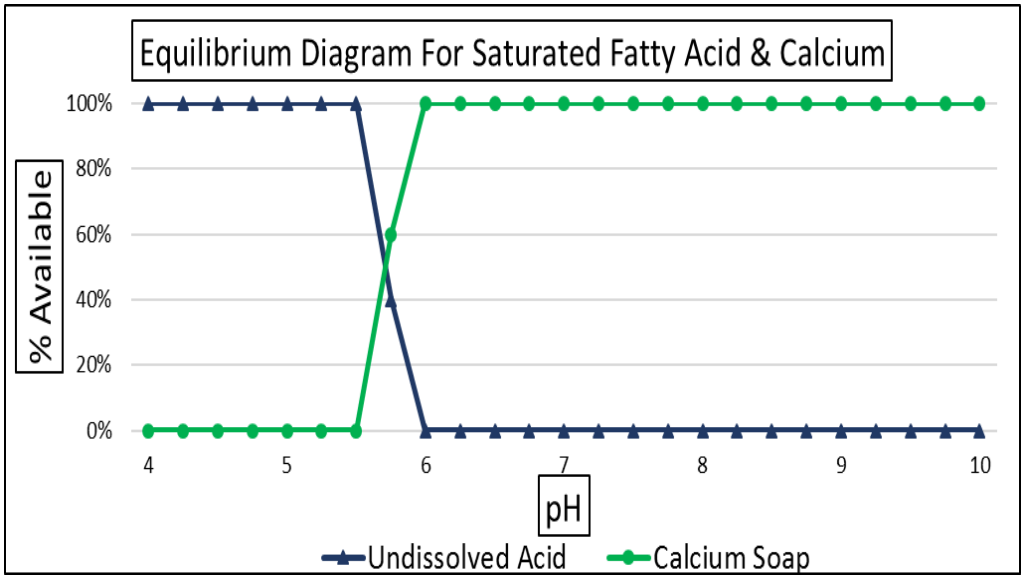
- Separated into Component Parts
- Dry Content 85% Fatty Acids (Similar to Keener and He Research)
- 27% FFAs Were Saponified; 73% Free and Unreacted
  - Supports Calcium May Be a Limiting Factor
- FOG Triglyceride Levels at 0% to 1%
  - New Cooking Oil and Yellow Grease at 100% & 90% Triglycerides



Grease Interceptor Chemistry

- GI Influent Neutral to pH > 8 Due to Alkali Detergents
- FOG Hydrolysis Releases FFAs
- Acidic Conditions Develop
  - Leaching Calcium Ions
  - GI Effluent < 5
- FFA Ladened Discharge Combines with Calcium in Neutral pH Wastewater in Main Downstream of Sewer Lateral





What Can Be Done?

- Continued Messaging on Proper FOG Management
- Debris Free, Well Flowing Sewers
- Less Abrupt Transition Pipe Joints (Y's Instead of T's)
- Minimize Use of Concrete in Sewer Construction
- Shorter GI Pump Out Frequencies
- Control FFAs and Calcium
- Consider FOG Remediation Additives That Degrade FFAs to < C14

	Free Fatty Acid Profile of FOG Deposits				
	Myristic - C14	Palmitic - C16	Stearic - C18	Oleic - C18:1	Linoleic - C18:2
Benecke - 2017	4%	68%	16%	6%	1%
Nieuwenhuis - 2018	5%	31%	5%	14%	9%

QUESTIONS?

Casey R. Furlong, P.E.
casey.furlong@emerson.com
(262) 598-5231