Fats, Oils, and Grease (FOG) Science

FOG-Clogged Pipe

FOG-Clogged Sewer Main

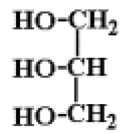
Fats, Oils, and Grease (FOG) – Fats, Oils, and Grease (FOG) are a byproduct of food preparation, cooking, and cleanup of dishes, pots and pans, utensils, moping of grease laden floors, etc. FOG is derived from many organic non-polar compound food sources: meats, lard, fats, fish oils, nuts, certain nut oils, plant/vegetable oils, dairy products, soups, gravies, certain grease laden condiments, mayonnaise, salad dressings, sauces, pastas, poultry, waxes, butter, margarine, the germinal areas of cereals, seeds, certain fruits, etc.

Fats, oils, and grease (FOG) compounds consist of fatty acids and glycerol. An example of a FOG compound is triglyceride. Triglycerides are the main constituents of vegetable oils and animal fats. Triglycerides have lower densities than water (they float on water), and at normal room temperatures may be solid or liquid. When solid, they are called "fats" or "butters" and when liquid they are called "oils". A **triglyceride**, also called triacylglycerol (TAG), is a chemical compound formed from one molecule of glycerol and three fatty acids.

$$\begin{array}{r} CH_3(CH_2)_7CH{=}CH(CH_2)_7C(O)O\text{-}CH_2 \\ CH_3(CH_2)_7CH{=}CH(CH_2)_7C(O)O\text{-}CH \\ CH_3(CH_2)_{14}C(O)O\text{-}CH_2 \end{array}$$

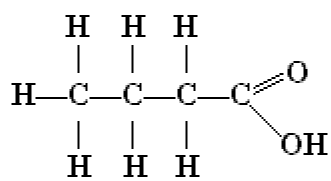
Triglyceride

Glycerol – Glycerol is a trihydric alcohol (containing three **-OH** hydroxyl groups) that can combine with up to three fatty acids to form monoglycerides, diglycerides, and triglycerides. Fatty acids may combine with any of the three hydroxyl groups to create a wide diversity of compounds. Monoglycerides, diglycerides, and triglycerides are classified as *esters* which are compounds created by the reaction between acids and alcohols that release water (**H_2O**) as a by-product.



Glycerol or Glycerin

Fatty Acids – Fatty acids (a component of FOG) are composed of the elements carbon (C), hydrogen (H), and oxygen (O) arranged as a carbon chain with a carboxyl group (-COOH) at the end. As illustrated in table 3, there are many types of fatty acids contained in FOG and varying numbers of carbon atoms and associated bonds. **Saturated fatty acids** (SFAs) have all the hydrogen that the carbon atoms can hold, and therefore, have no double bonds between the carbon and hydrogen. **Monounsaturated fatty acids** (MUFAs) have only one double bond. **Polyunsaturated fatty acids** (PUFAs) have more than one double bond.



Butyric Acid

An example of a fatty acid is butyric acid (butanoic acid) and is one of the saturated short-chain fatty acids contained in butter responsible for the characteristic butter flavor. The image above is a detailed structural formula explicitly showing four bonds for every carbon atom with no double bonds between a carbon atom and a hydrogen atom. The image can also be represented as the equivalent line formulas:

$$\mathbf{CH_3CH_2CH_2COOH} \quad \text{or} \quad \mathbf{CH_3(CH_2)_2COOH}$$

Butyric Acid

Food Service Establishment (FSE) – FSE's are those establishments primarily engaged in activities of preparing, serving, or otherwise making available for consumption foodstuffs and that use one or more of the following preparation activities; cooking by frying (all methods), baking (all methods), grilling, sautéing, rotisserie cooking, broiling (all methods), boiling, blanching, roasting, toasting, dehydrating, microwaving, or poaching. Also included are infrared heating, searing, barbecuing, and any other food preparation or serving activity that produces a grease laden food product in or on a receptacle, utensil, etc. that requires washing. These facilities include restaurants, hospitals, cafeterias, daycares, hotels, motels, nursing homes, schools, grocery stores, prisons, jails, concession stands, mobile food cart commissaries, delicatessens, bakeries, churches, summer/seasonal feeding programs, certain convenience stores and department stores with food preparation, meat/seafood markets, ice cream/dairy type businesses, certain health food stores engaged in food preparation/serving, camps, caterers, senior and community centers, coffee/donut/pastry/cookie businesses, manufacturing plants, break/lunch rooms in large businesses, or any other sewer users as determined by the City of Dothan, who discharge applicable wastewater. Collectively, FSEs are a major contributor of FOG to the wastewater collection system.

Why Oil Floats on Water – Polar molecules have a positive charge on one end and a negative charge on the other end. Non-polar molecules do not have two electrical poles and the electrons are distributed symmetrically on both sides. As previously mentioned, FOG is composed of organic non-polar compounds. Water is a polar solvent. Only polar compounds or other polar solvents will mix with water. Therefore, non-polar FOG will not readily mix with water. Depending on the source, FOG has a density of approximately 0.863 – 0.926 g/cm^3. Water has a density of approximately 1.000 g/cm^3. The lesser density will float on top of the greater density substance if it does not mix, thus non-polar FOG floats on water because it does not mix and gravity exerts more pull on the greater density. Molecules of water are relatively small because they are only composed of one oxygen and two hydrogen molecules (H_2O). They therefore pack closely together in a space. Molecules of oil are large and have complicated shapes, thus can't pack many molecules together in a space. This is why oil is less dense than water.

A few oils having densities less than water are known to be polar compounds and can mix with water and therefore not float on the water's surface.

Thus, polarity and density both contribute to oil floating on water.

Polarity is a relative term. On a sliding scale, some oils are more or less polar than others are and have both polar and non-polar attributions (see tables1and 2). Also, the heating of oils and interaction with other organic compounds it is exposed to during heating, can change the oil's chemical composition, and thus change the relative polarity.

Emulsions – Non-polar oils and water may not mix, but with a little help, the two can join in an emulsion. We can have an emulsion of fats in water, like milk, cream, or most salad dressings, or we can have an emulsion of water in fat, as we do in butter, margarine, and peanut butter. Other examples are mayonnaise, various sauces, and vinaigrettes.

Emulsions require an emulsifier (also known as a surfactant) to stabilize the emulsion, thus allowing the non-polar oil and water to mix. Examples of emulsifiers are egg yolk, soy lecithin, mustard, sodium stearoyl lactylate, garlic, vegetable gum, xanthan gum, polysorbates, monoglycerides, diglycerides, glyceryl stearate, and emulsifing waxes such as ceteareth alcohol, cetyl alcohol, or stearyl alcohol. Note that detergents are also a class of surfactants.

To summarize, the addition of emulsifiers or surfactants allow the mixture of two or more liquids that are normally immiscible, such as non-polar oil and water. Emulsions are inherently unstable (weak bonds) and over time will separate. Emulsions and surfactant mixtures (such as grease-laden dish detergent water) tend to quickly separate upon entering the sewer, thus allowing the oil to become a FOG component. In addition, the emulsions have a lesser density than water and will float on the water's surface.

Gravity Grease Interceptor – A gravity grease interceptor is identified as a large, in-ground tank, usually 1000 gallons or larger in capacity, which provides FOG remediation for a FSE. The grease-laden wastewater travels through the Food Service Establishment's (FSE) plumbing and enters the interceptor. A typical gravity grease interceptor is composed of two chambers, with the first chamber being the inlet chamber and comprising about two thirds of the interceptor's volume, followed by a baffle and the outlet chamber which comprises about one third of the total water volume. The water passes through the baffle from the inlet chamber into the outlet chamber via a sweep or slots. The baffle is a <u>required and integral component</u> and serves to slow the passage of water, allowing sufficient detention time for the separation of the non-polar FOG and settling of the solids, and to retain the majority of the FOG and solids in the inlet chamber. Therefore, the majority of the non-polar FOG rises to the water's surface (see FOG Chemistry) on the inlet side and the solids gravity settle to the bottom. The partially treated water from the inlet chamber then passes through the baffle to the outlet chamber where the process is repeated. Finally, the treated water exits the outlet chamber of the interceptor, travels to the City's wastewater collection system, and is routed to a wastewater treatment plant.

Hydo-Mechanical Grease Interceptor – Hydro-mechanical grease interceptors (HGIs) are small grease interceptors often referred to as "grease traps", which are usually located above the floor in the kitchen and typically provide FOG remediation for the two or 3-compartment culinary washing sink. Some hydro-mechanical grease interceptors may be located in the floor inside the kitchen or located above or below ground adjacent to kitchen and outside the building.

The interceptor functions by entraining air in the wastewater stream from the sink it remediates (thus the name hydro-mechanical) via a properly vented flow control device located on the inlet side of the interceptor. The flow control device contains an orifice that restricts the flow to the interceptor to no more than its rated gpm flow rate. This device controls the flow of water through the interceptor which allows sufficient time for the FOG to separate and solids to settle. The properly installed flow control device should have the vent side of the device located between the orifice and the inlet of the interceptor. This configuration will allow the vent to pull air into the flow control device which will entrain air bubbles with the wastewater stream. The vent also serves to facilitate draining of the sink, to prevent "air-locking" inside the interceptor and to vent odors. The entrained air bubbles facilitates the rapid rising (separation) of FOG to the water's surface while inside the interceptor. The interceptor typically has a baffle plate located just inside the interceptor which will drastically reduce the water velocity allowing for separation of FOG and the settling of solids. The interceptor contains addition baffles that will further separate FOG and solids from the waste stream. Finally, the treated water exits the outlet chamber of the interceptor, travels to the City's wastewater collection system, and is routed to a wastewater treatment plant. Optionally, a hydro-mechanical interceptor will have a vent installed on the outlet side of the interceptor to further assist movement of the wastewater stream through the grease trap and to vent odors.

FOG Deposits in Sewer Lines – The general understanding of FOG deposit formation in sewer lines involves a complex chain of events. Upon entering the sewer, the water cools and FOG floats on the water's surface, where it is quickly broken down into constituent parts of fatty acids and glycerols by a process known as **hydrolysis**. Hydrolysis is simply the chemical decomposition (splitting of the chemical bonds) of a compound by reacting with water. These "freed" fatty acids are known as free fatty acids (FFAs). Free fatty acids are also produced from cooking processes and by microbial activities in grease control equipment and sewer. When FFAs are discharged into sewer pipelines, they partition into oil and flow on the wastewater surface. In the presence of calcium and FFAs at the oil/water or oil/concrete interface, a process known as **saponification** occurs at a fast rate. Saponification is a process in which free fatty acids and calcium bond to form a "soap-like" compound. Calcium is either naturally present in the wastewater or released upstream from highly corrosive environments such as in precast concrete grease interceptors and risers, etc. The buildup of FOG deposits in sewer lines is not only caused by saponification, but also due to the aggregation of excess calcium, un-reacted free fatty acids, and debris in wastewater. The saponified solid acts as a core affixed to the sewer pipe walls. The un-reacted FFAs are accumulated around the core. Saponification occurs between un-reacted FFAs and calcium on the solid core matrix to form more saponified solids that result in FOG deposit accumulation on sewer pipe walls. Because of the adhesive character of the "soap-like" compound, debris in wastewater would also accumulate and result in the formation of debris layers interspersed with hardened "soap-like" compounds to cause reduction in flow capacity and if not cleared, eventually cause blockages.

FOG can thus be a leading contributor to blockages in the City's wastewater collection system, leading to sanitary sewer overflows and similarly can lead to blockages in commercial and residential plumbing.

Common Oils

Non-Polar Oils (that will not readily mix with water)

Walnut Oil	Evening primrose oil
Fish oil	Black currant oil
Canola oil	Hempseed oil
Vegetable oil	Safflower oil
Soybean oil	Sesame oil
Peanut oil	Borage oil
Olive oil	Cottonseed oil
Algae oil	Corn oil
Mineral oil	Grape seed oil
Petroleum oil	Primrose oil
Hazelnut oil	Perilla oil
Flaxseed (linseed) oil	Avocado oil
Krill oil	Oil palm fruit
Saw palmetto oil	Citrus fruit oils
Herb oils such as garlic	Caraway Oil (almost completely insoluble in water)
Basil Oil (almost completely insoluble in water)	Apricot oil
Ajwain oil	Black pepper Oil
Cajeput oil	Calendula oil
Caraway oil (almost completely insoluble in water)	Dill Seed oil (almost completely insoluble in water)
Ginger Oil	Cardamom oil
Cinnamon oil	Clove oil
Jojoba oil	Mandarin oil
Juniper berry oil	Marjoram oil
Nutmeg oil	Orange oil
Peppermint oil	Pumpkin seed oil
Ylang Ylang oil	Wintergreen oil
Lemon oil (only slightly soluble in water)	Cashew Nut Oil

Table 1

Polar Oils (will more readily mix with water)

Macadamia nut oil	
Coconut Oil	
Sunflower oil	
Castor oil	
Almond oil	

Table 2

Common Fatty Acids

Common Name	Carbon Atoms	Carbon-Hydrogen Double Bonds	Scientific Name	Sources
Butyric acid	4	0	butanoic acid	butterfat
Caproic Acid	6	0	hexanoic acid	butterfat
Caprylic Acid	8	0	octanoic acid	coconut oil
Capric Acid	10	0	decanoic acid	coconut oil
Lauric Acid	12	0	dodecanoic acid	coconut oil
Myristic Acid	14	0	tetradecanoic acid	palm kernel oil
Palmitic Acid	16	0	hexadecanoic acid	palm oil
Palmitoleic Acid	16	1	9-hexadecenoic acid	animal fats
Stearic Acid	18	0	octadecanoic acid	animal fats
Oleic Acid	18	1	9-octadecenoic acid	olive oil
Vaccenic Acid	18	1	11-octadecenoic acid	butterfat
Linoleic Acid	18	2	9,12-octadecadienoic acid	grape seed oil
Alpha-Linolenic Acid	18	3	9,12,15-octadecatrienoic acid	flaxseed (linseed) oil
Gamma-Linolenic Acid	18	3	6,9,12-octadecatrienoic acid	borage oil
Arachidic Acid	20	0	eicosanoic acid	peanut oil, fish oil
Gadoleic Acid	20	1	9-eicosenoic acid	fish oil
Arachidonic Acid	20	4	5,8,11,14-eicosatetraenoic acid	liver fats
EPA	20	5	5,8,11,14,17-eicosapentaenoic acid	fish oil
Behenic acid	22	0	docosanoic acid	rapeseed oil
Erucic acid	22	1	13-docosenoic acid	rapeseed oil
DHA	22	6	4,7,10,13,16,19-docosahexaenoic acid	fish oil
Lignoceric acid	24	0	tetracosanoic acid	small amounts in most fats

Table 3