OIL / WATER SEPARATION
TECHNICAL INFORMATION

Introduction

Fats, Oil and Greases (FOG) are one of the most common forms of contamination found in industrial wastewater. It ranks right up there with Biological Oxygen Demand (BOD) and Suspended Solids (SS). As one of the “Big Three”, the sanitary districts, state, or Local EPA always checks for it.

The federal limits on FOG are broken down by industry and are posted in the Development Document for each individual industry. Each State generally develops encompassing guidelines without regard to the industry and they are commonly in the range of 15 MG/L average, 30 MG/L maximum. This is what Ohio has adopted for example. Each local sanitary district can then establish their own limits, either tighter or looser from the state limits and they are generally looser.

If a local sanitary district finds itself with a treatment plant that is operating a maximum capacity, it would set FOG limits low, maybe 25 or 50 MG/L in order to reduce the load on the treatment plant. Before the sanitary district is allowed to discharge to its river or stream, however, it has to reduce the FOG to at or below the State Limits of 15/30. On the other hand, if the district's plant is very efficient, they allow higher levels, as much as 100 or possibly 200 MG/L to be discharged in the sewer.

Industries discharging directly into a river or stream would certainly be expected to be within the General State Limits and they could be governed by the Development Document for their particular industry. Industries discharging directly to a river or stream that is already heavily contaminated will have much tighter restrictions placed on them. These limits may be as low as 5 MG/L or less.

FOG classification is broad and includes all types of fats, oils and greases such as hydrocarbons, animal fats and vegetable oils. Certainly if you were to ingest 300 MG/L of hydrocarbon type oil it would be a lot more harmful to you than if you were to do the same with an animal fat or vegetable oil. There is more than 300 MG/L of oil in most vinegar and oil salads but regardless of their origin, all oils are treated the same - as bad. However, recently there have been attempts at various levels to actually specify separate limits for hydrocarbon type oils versus animal or vegetable oils.

Some hydrocarbon compounds have been classified as hazardous and toxic and well they should be. Generally, any hydrocarbon that has been chlorinated or includes a benzene ring in its chemical diagram falls into this category. Cross-linking the chlorine with hydrocarbon makes the hydrocarbon very stable and therefore it does not break down biologically. Most solvents, as well as the infamous transformer oil – PCB, are in this category.

TESTING

Testing for FOG is most often done with the Freon extraction method. Here Freon is added to a measured water and oil sample and it is mixed to allow the fats, oils and grease present to become soluble in the Freon. The water is drawn off the sample and the Freon is boiled off leaving the FOG residue behind on a gauze wafer. The wafer is weighed at the beginning of the test and after. The difference in weight is the amount of oil that was present in the sample. The results are given in milligrams of FOG per liter of water. (MG/L is equal to PPM or parts per million, while MG/L is weight/volume, PPM is volume/volume or weight/weight.) This type of testing does have some drawbacks. It will boil off light end oils and if there are surfactants present they will report to the Freon and show up as part of the FOG when they are really not. If a wastewater stream was contaminated with only Freon and we used a Freon extraction method to test, our results would show zero FOG, which is not true. This is a good example of the light end oils, especially hydrocarbons being removed with the Freon. But generally this test method satisfies 95 percent of the application.

INDUSTRY APPLICATIONS

With millions of barrels of crude oil being processed in this country every day and probably half that amount of animal and vegetable oil being processed, handled or shipped, it is easy to understand why FOG is such a prevalent problem. It is virtually everywhere; from parking lots to all types of industry; from transportation to national security, with the list going on and on. The legislative bodies have become more stringent and the demand for added controls has become more acute.

In the last twenty years we have seen the spotlight go from one industry to another as the primary consumer of separation equipment. During this time you might expect the market to become satisfied and the demand to decrease. This is not what has happened, however. There are a number of reasons for this but one of the major ones is the concerted legislative and enforcement effort that has been put forth. The result is that not only the large polluter, that was easily identified, is forced to comply but the medium and small dischargers are being pressured as well. Further, the demand for larger separators also exists in certain industries especially in the chemical industry. Many parts of this industry have grown because of the relatively low oil prices.

National Security represents a large and consistent consumer of separator equipment. Throughout its vast network of Army, Navy, Air Force, and Marine Corps bases, there is a tremendous amount of refueling and garage, maintenance and shop areas that need control. All of these jobs are controlled through engineering companies that are in some cases governed by the agency.

General manufacturing, which includes all types of industries such as metal finishing, metal plating, machine tool and the various SIC groups - those industries that produce something from metal, plastic or glass, represent a vast portion of the market, probably over 50 percent. Because machine coolants are used in these industries, tramp oil removal has developed into a major business. Disposal of machine coolants has become expensive and removing the tramp oil that accumulates on the surface extends the coolants life thereby reducing the frequency of disposal.

The petroleum industry is comprised of a number of segments that operate autonomously from one another. They include refineries, pipelines, bulk plants, terminals and gas stations. The demand in this industry remains constant across the board with some large unit needs existing in refineries. Currently a number of majors are evaluating small separators for gas station use. Almost all of this business is controlled either at the home office or mostly at the regional office. The exception is the engineering company working for the Oil Company.

Chemicals and its allied products are a gigantic industry with over 15,000 plant locations. Many parts of the industry are and have been expanding because of relative low oil prices, as we have said. Some of the largest separators built have been going to the chemical industry. Their needs rarely end with FOG removal. Therefore they could be a source of need for large wastewater treatment systems.

The transportation Industry as a whole includes railroads, airports, bus and cab terminals as well as trucking operations and their entire garage, maintenance and wash operations. This has been another constant market because of the changes within the industry, such as deregulation. Stricter enforcement has also been a positive contributing factor.

Utilities at one time were one of the largest users of separation equipment for controlling coal pile run off and floor drains from generating stations. Much of this industry has been satisfied and with the trend going to nuclear instead of coal, new installations have fewer needs. From time to time, however, there are sizable jobs that occur and because it was one of the first industries hit, it is the prime target for upgrades and replacement.

The food industry has remained steady and has some very specific needs that generally require types of separation equipment. Because of the diverse nature of the waste FOG a great deal of customization exists in the separation equipment that serves the food industry. There are approximately 10,000 to 13,000 plants across the country that deal with vegetable or animal fats and oils. The poultry industry has been growing for the past number of years and the growth is projected to remain at the same rate in the future.

Engineering companies that do work for any of the industries mentioned above are some of the best candidates for separators for their customers. Engineering companies that have traditionally done municipal work are switching or also doing industrial work.

OIL IN WATER CONDITIONS

While we have discussed some of the major industries where we can expect to find oily water applications, it is important to be able to recognize the various oil-in-water conditions that these industries can generate. A chart has been developed entitled "OIL IN WATER CONDITIONS" that defines each class, provides simple guidelines for identifying the simple ones and indicates the types of equipment that will separate that particular class of oil in water. This chart applies mainly to hydrocarbons in water and some of the information is applicable to vegetable oils. Food industry application vary so widely because of the different processing techniques required create the wide range of end products; it is not wise to generalize here. Each application should be dealt with on an individual basis. In reviewing the chart it is easy to see that the larger the reviewing the droplet of oil, the easier it is to remove and it is the least expensive. As the droplet gets smaller and as surfactants and emulsifiers are added, it becomes increasingly difficult and more expensive to remove it.

<u>FREE OIL</u>

- Droplet size - 150 microns and larger
- Will separate in a 6" high beaker in 90 seconds
- Requires gravity separation such as API type

<u>DISPERSED OIL</u>

- Droplet size - 149 microns down to 20 microns
- Will separate in a 6" high beaker in 80 minutes
- Requires gravity coalescing to separate such as the PCS OCS separator

<u>MECHANICALLY EMULSIFIED OIL</u>

- Droplets less than 20 microns in size
- Will <u>not separate</u> in a 6" high beaker in 80 minutes
- Requires chemical treatment and pressure coalescing or DAF or UF

<u>CHEMICAL EMULSIFIED OIL</u>

- Droplets less than 20 microns in size with surfactants or emulsifiers present in the water
- Will <u>not</u> separate in a 6" high beaker in 80 minutes
- Requires chemical treatment and coalescing or chemical treatment and DAF or UF. In the case of the UF, the surfactants will pass thru with the permeate

<u>SOLUBLE OIL</u>

- No discernible droplet size and the ion are cross-linked in the water
- Will <u>not</u> separate in a 6" high beaker in 80 minutes
- Requires chemical treatment and coalescing or chemical treatment and DAF or UF (with solublizers staying with permeate)

NOTE: Some soluble oil solutions are non-breakable regardless of the treatment. This is true of most synthetic oils.

<u>SEPARATION PROBLEMS</u>

Some of the operating conditions that create the more difficult to separate conditions of oil in water could be prevented in certain circumstances. This would keep the condition to a lower order of magnitude if the operator were made aware. Any type of pumping or high shear situation caused by hose down, stream or high pressure cleaning will more finely divide the droplet and make the removal more difficult. The addition of surfactants such as detergents or cleaning agents that reduce the surface tension of the water also make droplet removal more difficult. Emulsifiers or solublizers are chemicals that change the molecular structure of the oil and mix the ions into the water phase. This condition is absolutely the most difficult of all to separate.

SEPARATOR SELECTION GUIDE

For each oil-in-water condition at least one type of equipment is available that will effectively separate the oil. The attached chart entitled "Oil/Water Separator Selection Guide" indicates the relationship between the equipment required and the oil in water condition.

CLASSIFICATION	EQUIPMENT
Free Oils	OCS
Dispersed Oils	OCS
Mechanically Emulsified Oils	Chem-Treat/Coalesce Chem-Treat/DAF Ultra Filtration Filter Coalescer
Chemical Emulsified Oils	Chem-Treat/Coalesce Chem-Treat/DAF Ultra Filtration
Soluble Oils	Chem-Treat/Coalesce Chem-Treat/DAF Ultra Filtration Reverse Osmosis

PRINCIPAL FACTORS

The principal parameter or factors that need to be considered when solving an oily wastewater problem are:

1. Flow rates: maximum and normal.
2. Operating temperatures: normal and seasonal low.
3. Condition of oil "Classification": Free Oil, Dispersed Oil, Mechanically/Chemically Emulsified or Soluble.
4. Specific gravity of the oil.
5. Specific gravity of the water.
6. pH of the waste stream: high, low or normal.
7. Identification of the other contaminants presents in the waste stream. Suspended solids (SS), Dissolved Solids (TDS).

The values that we assign to these factors will determine the type and size of the separation equipment necessary to efficiently treat the wastewater.

STOKES LAW AND API

Straight gravity separation is the simplest form of separation as it provides sufficient retention time for the droplet to rise to the surface before the water reaches the outlet end of the separator. There are no nationally approved design formulas for gravity separation but the American Petroleum Institute (API) established various minimum horizontal and vertical cross-sectional areas and depth-to-width ratios. These minimum were based on testing and a formula derived from Stokes' Law:

$$VR = g/(C*(PW-PO)*D^2)$$

Where:

VR	=	Velocity of the rate of rise of the oil droplets
g	=	Acceleration caused by the force of gravity 981 cm per second
PW	=	Specific gravity of water
PO	=	Specific gravity of oil
D	=	Diameter of oil droplet
C	=	Viscosity of the water at operating temperature

DROPLET SIZE

From the formula we can see the rate of rise of the oil droplet increases as the square of the diameter. Consider two applications in which all factors are the same except for the oil droplet size:

Example:

$$\frac{\text{150 micron oil droplet}}{\text{50 micron oil droplet}} = 3 \text{ times larger and } 3^2 = 9$$

The 150-micron droplet will rise 9 times faster than the 50-micron droplet. There is no other factor in the formula that affects rate of rise of the oil droplet greater than its diameter.

SPECIFIC GRAVITY DIFFERENTIAL

Specific gravity differential between the oil and water has the second greatest affect on the droplet rate of rise. The greater the differential, the faster the rate of rise. Compare the specific gravity of a No. 2 fuel oil at 0.85 versus a No. 6 at 0.95. The differentials from fresh water, which is 1.00, are 0.15 versus 0.05 respectively. As a result, the rate of rise of the No. 2 fuel oil in this example will be three times that of the No. 6 with both being in free oil conditions.

TIME REQUIRED FOR A DROPLET TO RISE A DISTANCE OF .25' AT 68 DEGREES F		
DROPLET SIZE	**OIL SP.G - .85**	**OIL SP.G - .90**
150 M	00:42	01:03
90 M	01:54	02:54
60 M	04:12	06:36
20 M	38:46	58:08
10 M	2:35:02	3:52:33

TEMPERATURE

As you can see from the formula, temperature also affects the droplet rate of rise and it is an important factor in selecting the proper type of separator.

The following is an excerpt from the API Manual, Chapter 5. "The temperature of the influent is important, in-as-much as it influences the viscosity of the waste water and the rate of rise of the oil particles. Thus, a droplet in water at 40 degree F will rise at only half the rate of the same droplet in water at 90 degree F. Seasonal variations should be considered and the separators should be designed for the most adverse conditions, i.e., cold weather."

Temperature control is more of a concern in colder climates where low temperature may not only adversely affect the efficiency of the separator but also bring the system to a complete halt by freezing. To prevent heat loss in the waste stream the system designer may locate the separator immediately following the process that produces the wastewater. If space permits, the separator could be located in a heated facility. Waste heat from machinery might also be used to warm the wastewater. In some instances, the separator may be installed below the frost line. Pumping may be required to lift the effluent to a discharge point. Avoid pumping into the separator. Heaters may be considered for maintaining a desired temperature.

PCS DESIGN CRITERIA

Pollution Control Systems, Inc. has selected the following design criteria for sizing of our OCS type separators:

1. Influent suspended solids less than 200 mg/l.
2. Loading rate never more than 1 gpm / 20 sq. ft. of coalescing media.
3. Hydraulic retention time based on approximately 5-10 minutes.
4. Influent temperature not to exceed 140 degrees F.
5. Designed to remove free oil with a globule size of 20 micron in diameter or larger.

6. Specific gravity of water at 1.0.
7. Specific gravity of oil at 0.85.

If the actual conditions differ from PCS's standard design criteria the separators can be up or down sized to meet the conditions.

OIL COALESCING SEPARATOR

The Pollution Control System, Inc. Oil Coalescing Separator OCS is a combination plate and mixed media coalescer. A coalescer is a multiplier, which is a device to make small droplets into larger droplets that can then rise more rapidly out of the flow to the surface. In a separator, there is very little, if any drop-to-drop coalescing. Virtually all coalescence takes place at the oil/water interfaces created by the multipliers. If sloped plates are installed in the separator, the droplets need only rise a short distance before reaching a plate and thereby be removed from the waste stream. In laminar flow, the maximum stream velocity is twice the average at the center of the stream, which is midway between the plates. The velocity at the edges of the stream, at the surface of the plates is zero.

The plates or media are generally constructed of plastic, which is hydrophobic (water repelling) and oleophilic (oil attracting). When the oil droplet rises to the plate or comes in contact with the plate through a change in direction, it reaches a zone of zero velocity and adheres to the surface. When the media plates become coated with oil, the droplets will coalesce with this secondary interface. Because the media plates are set at a steep angle with respect to the horizontal, the oil migrates upward as a film and accumulates at the top edge of the plate where it detaches as an enormous droplet.

As the oil migrates upward, the solids settle out on the bottom sides of the plates and they migrate downward, being collected in a sludge chamber below the media pack.

The standard media pack material is PVC. We also offer CPVC, polypropylene, stainless steel and carbon steel. The PVC is the most cost effective and can be operated up to 140 degree F continuous and at 160 degree F intermittently.

The Primary advantages of a gravity coalescing type separator such as our OCS, is it is 60 percent smaller than an API type and it will remove oil droplets down to 20 microns in size (dispersed oil). The internal design of the OCS is similar to an API type separator except for a smaller separator chamber, which is packed with the coalescing media.

Some of the major competitors to our type OCS separator use the incline corrugated plate type or the vertical tube coalescer. Our type OCS unit separates smaller droplets (20 microns vs. 60 microns) than the plate type and does an equally good job of separating solids. Comparing the OCS to the vertical tube coalescer, the OCS handles the same droplet size and does a better job of removing solids. A vertical tube coalescer has a tendency to bind where the OCS does not.