



The University of Georgia

College of Agricultural & Environmental Sciences

**Department of Biological & Agricultural Engineering
Engineering Outreach Program**

**Characterization of the Generation, Handling
and Treatment of Spent Fat, Oil, and Grease (FOG)
from Georgia's Food Service Industry**

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1.0 INTRODUCTION

Proper utilization of food service by-products is an ever-increasing problem for the industry and for Georgia. To address this issue, the Georgia Environmental Partnership (GEP) members have recognized the need to identify companies in Georgia that collect and treat previously used or “spent” fat, oil and grease (henceforth identified as ‘FOG’) produced within the state’s food service industry. The generation, handling, treatment and further use or ultimate disposal of spent FOG from small generators in Georgia (i.e., restaurants, motels/hotels, schools, cafeterias, hospitals) has been and continues to be of economic and environmental concern throughout the state.

The state of Georgia lacks a systematic, regulated statewide program to deal with the spent FOG issue. To provide assistance to Georgia’s food service industry in the area of the handling, treatment and final use of spent FOG, the University of Georgia, Engineering Outreach Program, in conjunction with the Pollution Prevention Assistance Division (P2AD) of the Georgia Department of Natural Resources’ FOG Initiative, is producing this report outlining the current FOG activities taking place in our state. This report seeks to identify and provide pertinent information on the network of spent FOG transportation and treatment operations currently servicing Georgia’s food service industry.

1.1 Report Objectives

The objectives of the report are:

- To identify and define the sources of spent FOG generated by Georgia’s food service industry.
- To identify, gather and present pertinent information on companies in Georgia that collect and transport spent FOG (henceforth identified as “haulers”) for by-product recovery or disposal.
- To identify, gather and present pertinent information on companies in Georgia that render spent FOG to produce value-added products or treat spent FOG for either disposal or beneficial use.
- To identify and explore the traditional and innovative value-added products produced from spent FOG.

1.2 Food Service Industry

The food service industry in the United States has grown by staggering amounts over the past three decades. The National Restaurant Association (NRA) recently reported in their Restaurant Industry Forecast that U.S. restaurant sales are forecast to reach \$399 billion in 2001, an increase of 5.2% over 2000 (NRA, 2001). The association reports that during a typical day in 2001, the restaurant industry will post average sales of \$1.1 billion and that the states in the southeast portion of the country are leading the food service boon. The NRA predicts that eating-place sales in the South Atlantic region of the U.S. should total nearly \$58.9 billion in 2001 – the largest volume of any region in the country. Georgia is predicted to set the pace with a 7.1% increase in eating-place sales in 2001.

In 1998, a study conducted by Appel Consultants reported that there are approximately 1.4 restaurants per 1,000 population in the United States. The study also reported that this statistic did not vary appreciably by geographic region (NRA, 2001). In a separate study conducted by SRI International in 1989 on U.S. production and uses of yellow grease, it was reported that there were over 440,000 commercial food service establishments (Pearl, 2000).

The Georgia Department of Human Resources, Division of Public Health reports that Georgia has approximately 17,200 restaurants, cafeterias and school lunch programs. Combined with an additional 1,300 hotels, motels and various hospitality venues (Georgia Public Health, 2000) Georgia food service establishments number an estimated 18,500. Based on an estimated state population of 7.65 million people (Boatright, 1999), Georgia currently has one food service establishment for every 400 residents. Since most food service establishments are located in more densely populated areas of Georgia, their economic and environmental impact is most significant in the state's urban areas (see Table 1).

1.2 Spent FOG Production

Spent FOG generated in food service establishments during the process of food preparation comes from both FOG used to assist in the cooking of the food (i.e., frying oil) and from the food itself (i.e., hamburger meat). The amount of spent FOG generated at a food service establishment varies from site to site based on the type of food being prepared, the cleaning and maintenance practices employed, and seating capacity.

Table 1.

Georgia Counties with Populations Exceeding 100,000

<i>Rank</i>	<i>County</i>	<i>Associated City</i>	<i>Current Population*</i>	<i>% of State Population</i>
1	Fulton	Atlanta	739,367	9.7
2	Dekalb	Decatur	593,850	7.8
3	Cobb	Marietta	566,203	7.4
4	Gwinnett	Lawrenceville	522,095	6.8
5	Chatham	Savannah	225,543	3.0
6	Clayton	Jonesboro	208,999	2.7
7	Richmond	Augusta	191,329	2.5
8	Muscogee	Columbus	182,752	2.4
9	Bibb	Macon	156,086	2.0
10	Cherokee	Canton	134,498	1.8
11	Hall	Gainesville	119,210	1.6
12	Houston	Warner Robins	105,808	1.4
13	Henry	McDonough	104,687	1.4
		Total	3,850,427	50.5

* Boatright S.R., Bachtel, D.C. (1999) The Georgia County Guide: Eighteenth Edition 1999. University of Georgia, College of Agriculture and Environmental Services, Athens, Georgia

Spent FOG comes in two basic forms with each being handled and processed in a different manner. The first form of spent FOG is known in the industry as ‘Yellow Grease’. In general, yellow grease can be defined as the inedible and unadulterated FOG that is removed from food service kitchen operations. In most cases, yellow grease is placed in an enclosed container marked ‘inedible’ located outside of the food service establishment where it remains until the material is collected by a hauler and transported for processing by a renderer (a company that processes animal by-products into value-added commodities). The major sources of yellow grease generated in food service kitchens are from bulk deep-frying operations and water/oil separator units usually associated with specific food preparation areas. The collection and further use of yellow grease by the rendering industry for use in animal feed and other commodities is well established, and discussed in detail in Section 2.0 of this report.

The second form of spent FOG generated in the food service industry is the material recovered from grease traps, and is often designated in the FOG treatment industry as ‘Brown Grease’. Brown grease is the general term used to describe the floatable FOG, settled solids and associated wastewater retained by grease traps. Unlike yellow grease, the majority of brown grease removed from grease traps had been adulterated by coming in contact with such agents as detergents and cleaning solutions used in food service kitchens. The major source of brown grease generated in food service kitchens is from the cleaning of equipment and utensils used in the preparation and serving of food. In contrast to yellow grease, the history of the collection, handling, disposal and beneficial use of brown grease is not well documented. Typical flow trains for spent FOG generated in food service establishments are shown in Figure 1.

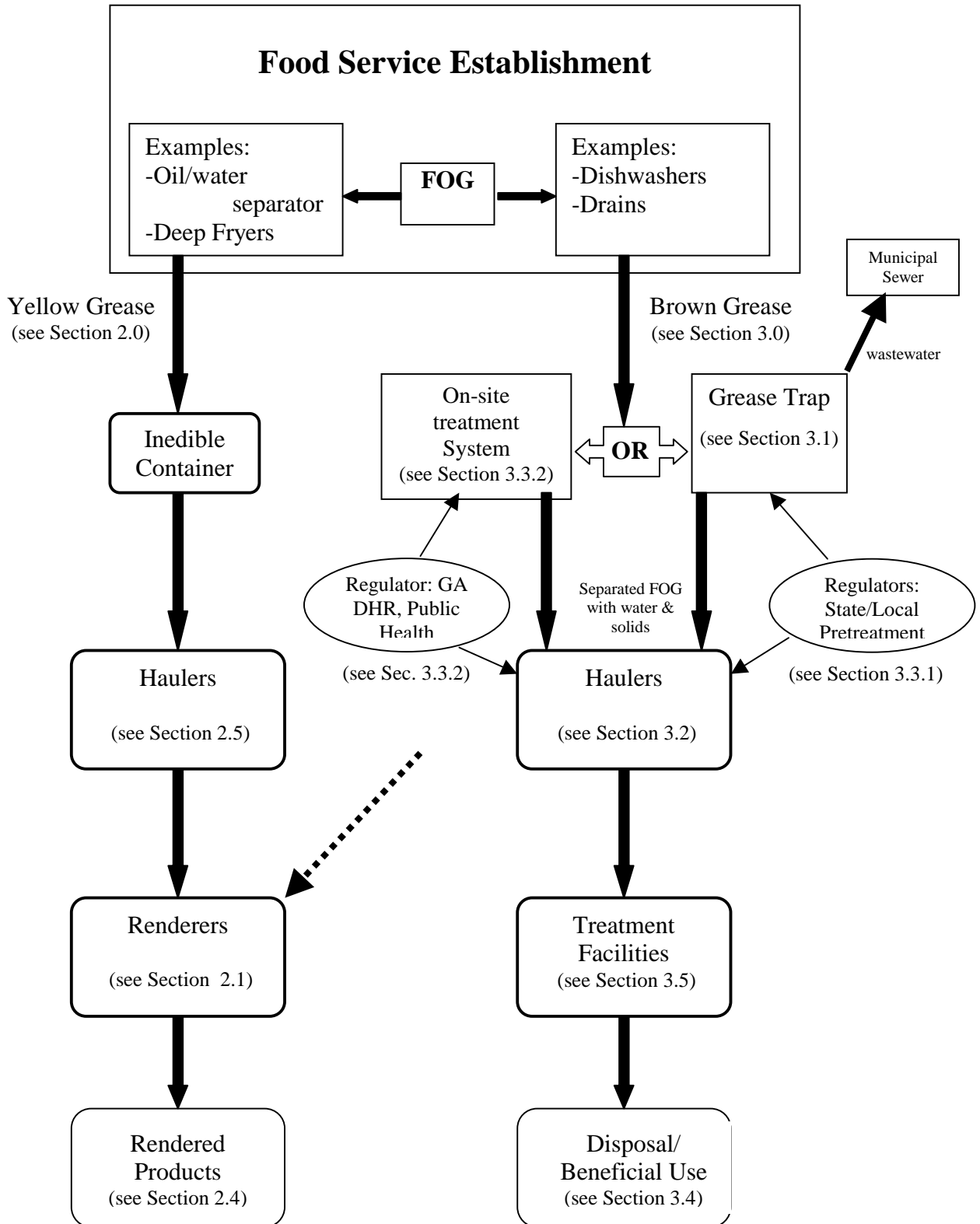
1.4 Report Layout

This report is separated into two major parts: yellow grease and brown grease. The first part of the report, following the introduction, is dedicated to yellow grease (Section 2.0). The characterization and generation of yellow grease are discussed first. Then the rendering process is described, and a history of the values and markets for yellow grease are presented. Next, the traditional and new innovative products developed from yellow grease are outlined. Finally, the Georgia rendering companies that accept and process yellow grease from the state’s food service industry are profiled.

The second major part of the report is dedicated to the brown grease collected from food service facility grease traps. Basic information is provided on the purpose and types of grease traps available in the food service industry.

Figure 1.

Typical Spent FOG Flow Options



Additional information on grease traps and pollution prevention techniques to reduce the amount of spent FOG lost to drains is available from the P2AD, both in print and on the Internet (<http://www.ganet.org/dnr/p2ad/>). The bulk of the Brown Grease information is centered on the cleaning and maintenance of grease traps. The common misconceptions and problems associated with grease traps are discussed. Details are given to food service operators on the criteria and steps to be taken in selecting a company to clean and transport their brown grease, and a database of Georgia companies that currently provide grease trap collection and hauling services is provided. A description and contact information is provided to the state's major environmental regulators of food grease traps. Finally, profiles and contact information are given for the companies that accept and treat brown grease.

NOTE: The authors of this report recognize that despite effort to the contrary, there is the possibility that Georgia companies that are involved in the collection, transportation and treatment of spent FOG might not be included in the report databases. We welcome anyone viewing this report to contact the author with additional information on companies serving Georgia food service customers. Additional information will be verified and added to the database for periodic future release. Please send additional information to:

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2.0 YELLOW GREASE

Yellow grease can be defined as the inedible and unadulterated spent FOG removed from food service operations. Typically, yellow grease is placed in an enclosed container marked “inedible” and located outside of the food service establishment where it remains until the material is collected by a hauler and transported for processing by a renderer. (Renderers are companies that collect animal by-products from livestock producers, meat packers and food service establishments; and then process the materials to produce products that are used in the manufacture of chemicals, soap, cosmetics, plastics, lubricants, livestock and poultry feeds, pet foods, and leather goods.) The major sources of yellow grease generated in food service kitchens are from bulk deep-frying operations and water/oil separator units usually associated with specific food preparation areas.

Traditionally, yellow grease acquired by renderers from food service establishments was of animal origin and was in the form of tallow and lard. However, in recent years a major movement over the health concerns surrounding saturated and unsaturated fats used in cooking has led to the use of vegetable oils in place of traditional animal-based frying oils. This shift in the types of fat used to prepare foods has had a dramatic effect on the role yellow grease plays in the tallow and lard markets, and has led to the creation of a new category of fats: ‘feed grade animal fat’ or ‘yellow grease’ (Pearl, 2000).

Yellow grease is best defined as a fat product that does not meet the definition for animal fat, vegetable fat or oil, hydrolyzed fat, or fat ester. It is processed and sold using the same specifications as any other grade of FOG: minimum percentage of total fatty acids, maximum percentage of unsaponifiable matter (or amount of matter that can not be converted to soap, specifically the inability of the fat to be decomposed by alkalies) (Webster’s, 1998), maximum percentage of insoluble impurities, maximum percentage of free fatty acids (FFA), and percent moisture (see Table 2). Also, yellow grease must meet the Food and Drug Administration’s established criteria for pesticides or other toxic chemicals (Pearl, 2000).

Table 2. Basic Specifications for Yellow Grease

<i>Parameter</i>	<i>Type</i>	<i>Percentage</i>
Total Fatty Acids (TFA)	Minimum	90%
Free Fatty Acids (FFA)	Maximum	15%*
Moisture (M)	Maximum	1%
Impurities (I)	Maximum	0.5%
Unsaponifiable (U)	Maximum	1%
Total MIU	Maximum	2%

* Amount of FFA in fats or animal by-products is often considered an indication of rancidity. Note: Although these are basic specifications, they are subject to be negotiated between the buyer and sellers on a specific contract basis.

There are no published statistics on the total production and consumption of yellow grease by food service establishments. Although amounts can be estimated based on the number of food service establishments and the average yellow grease generation from a typical site, the true volume of used cooking oils and other restaurant grease generated by the food service industry has not been well documented. Because of this lack of documentation of the total amount of yellow grease generated, it is impossible to determine what percentage of yellow grease produced is recovered by the rendering industry, despite the fact that the rendering industry has published statistics on their industry’s consumption of yellow grease. Some of the difficulties in establishing accurate volumes of spent FOG generated include the fact that the collected yellow grease is typically diluted with an unknown amount of water and contains solid material such as french fry and breading particles. These foreign materials must be removed by processing. A commonly cited yield by the rendering industry for yellow grease is 65 percent. However, yellow grease is highly variable and processing procedures and yields are considered to be proprietary by most renderers. Another difficulty is that yellow grease collected by non-renderers for resale or disposal often is not recorded.

With the trend towards consolidation in the rendering industry (NRA, 2000) and a continuing increase in demand both in the United States and abroad for rendered products, most experts predict that the industry will continue to expand to capture more of the food service yellow grease market. In most areas of the country, renderers have a very diversified infrastructure geographically positioned to serve the majority of the food service industry.

Despite the lack of true yellow grease generation statistics, some data has been established. There is over 2.75 billion pounds of yellow grease recycled in the United States annually. At this volume, it now represents over 20 percent of the feeding fats market. Total animal fats/oils, including those derived from used spent FOG in the United States, is estimated at 11.25 billion pounds (Grummer, 1992).

Yellow grease has been labeled, very inappropriately, as derived from ‘waste’ grease by many people. Whether rendered as an animal feed ingredient or processed into a biofuel, yellow grease is a valuable contributor to the food and energy cycle. Its energy contribution to livestock, poultry and pet food is empirically well established. As a general rule the energy contributions to animal diets represents from 2.5 - 3.5 times the energy value derived from an equal measure of corn (Grummer, 1992). Most recently, yellow grease’s value as a raw ingredient in the production of methyl esters (biodiesel) has received significant recognition. With the dramatic increases in the cost of petroleum-based fuels, it becomes a very viable alternative source of energy (Pearl, 2000).

2.1 Rendering Process

The modernization of animal processing for human consumption has fueled research and technical advances that have led to a highly efficient food processing industry. However, despite these advances, approximately 50 percent of every animal slaughtered is still inedible and these by-products must be handled in a profitable manner for the food cycle to continue. With an average of 220 lbs. of meat consumed per capita per year in the United States, total volumes of inedible raw materials from animal production and processing are enormous. In 1987, yellow grease made up 6 percent of the rendering industry’s raw material (see Table 3) (John, 1991).

Table 3. Raw Material Sources for the Rendering Industry - 1987

<i>Category</i>	<i>Weight</i>	<i>Percentage of Total</i>
Beef	16,100,000,000 lbs.	45%
Poultry	7,000,000,000 lbs.	19.5 %
Swine	5,750,000,000 lbs.	16%
Dead Stock	3,600,000,000 lbs.	10%
Yellow Grease	2,250,000,000 lbs.	6%
Miscellaneous	700,000,000 lbs.	2%
Sheep & Veal	600,000,000 lbs.	1.5%
Total	36,000,000,000 lbs.	

One major concern that has developed over recent years within the rendering industry is the use of substitute or 'fake' fats that provide little or no energy value. These substitute fats, such as Olestra, can significantly reduce the value of recycled feeding fats.

In 1990, the United States rendering industry was made up of about 50 companies that operated an estimated 150 processing plants, of which approximately 120 processed yellow grease. However, only five companies accounted for an estimated 75% of rendered product sales (Fitch-Haumann, 1990).

In U.S. metropolitan areas, renderers generally pay food service establishments for spent FOG according to a formula, most often based on the weight of waste grease collected and the selling price of the finished yellow grease products on the current commodities market. In isolated areas in the United States, food service establishments may give their yellow grease away. Rendering companies sell most of their processed yellow grease to animal feed manufacturers, but some companies also sell directly to large hog, poultry, dairy and beef operations (Fitch-Haumann, 1990). One of the nation's largest rendering companies, Darling International, reports that an estimated 15% of their revenue comes from the reprocessing of yellow grease from the food service industry (Render, 2000).

The process of rendering inedible animal products has changed little over the years and basically consists of cooking raw materials to remove fat and moisture from the protein and bone. Rendering can be categorized into 3 basic types: batch, continuous, or continuous at low-temperature. Batch and continuous rendering are often referred to as 'dry-rendering', while continuous at low temperature is often called 'wet rendering'. During batch rendering, the raw material is first ground and then placed in steam-jacketed vessels for cooking. Cooking both removes moisture and releases fats that are drained from the remaining solid mass. Time and temperature of the cooking process are critical. Sufficient moisture must be removed prior to the next stage of 'pressing'. However, at the same time the protein based solids must not be overcooked. Excessive denaturing of the protein by overcooking will reduce its value of the finished product as an animal feed stock (Grummer, 1992).

Cooking times vary from 20 minutes to three hours at temperatures ranging from 240-290°F. Some large continuous rendering systems can cook between 20,000 - 40,000 pounds of material per hour under highly controlled and monitored conditions. In general, raw materials contain 50% moisture, 25% fat, and 25% protein and bone (John, 1991).

During the pressing operation, the cooked solid mass is compressed to remove additional moisture and fat. The final solid mass is now termed 'dry-rendered tankage' or 'cracklings' and contains approximately 10% fat. The separated fat fraction is then processed to remove moisture and solids. Depending on the final product desired, further refining of the fat occurs to meet quality specifications of the final product.

Continuous rendering differs from batch processing only in that the raw material is continually fed and removed from the cooking vessel. Continuous cooking times are usually in the range of 45 – 80 minutes at temperatures range from 240 - 445°F. Continuous wet rendering involves heating the raw material at low temperatures. The low temperature allows the moisture to remain in the raw material while approximately half the water is removed. Operating at only 158°F, temperatures are much lower than with the dry-rendering process.

The role of heating is to break the tissue cells open so that the fat within the tissues is released. Following draining and pressing to remove fat and moisture, the wet pressed cake is dried at elevated temperatures to obtain adequate heat treatment of the protein (Grummer, 1992).

Rendered fats are classified based on a number of criteria. Titre is one measure used to classify fats. Fats with a titre of 40°C (104°F) or higher are called 'inedible tallows' and those with a titre of less than 40°C are called 'greases'. Titre is a test that measures the temperature at which melted fatty acids, obtained by hydrolysis of a fat source, congeal upon cooling. In the past virtually all cooking fats were animal based; however, today most cooking fats are a combination of hydrogenated vegetable oils and/or animal fats. The term 'hydrogenated' means the vegetable oils used for cooking can withstand high temperatures. Hydrogenation causes the oil to become more saturated or 'harder' (Grummer, 1992).

Rendered tallows and greases are marketed in several grades. One of the major criterion for grading fats is titre, but other factors such as the level of free fatty acid and color are important. Free fatty acid levels are sometimes used to indicate rancidity. However, some fat sources fed to livestock are almost totally free fatty acids, but this is the result of industrial hydrolysis of the triglyceride molecule. Consequently, the level of fatty acids in a fat source alone is not an indicator of rancidity. In addition, high levels of moisture in fats indicate incomplete removal of water during the rendering process. Excess moisture can accelerate oxidation and rancidity of fat during storage.

Rendered fats are also categorized according to how they are marketed to the animal feed industry. The term ‘animal fat’ refers to fat rendered from beef or pork fatty tissues and can be classified as tallow or grease depending on titre. ‘Poultry fat’ includes fats that are derived from 100% poultry offal. ‘Blended feed-grade animal fats’ include mixtures of tallow, grease, and yellow grease. ‘Blended animal and vegetable fats’ are combinations of animal, poultry, vegetable and/or yellow grease.

The wastewater generated during spent FOG processing shows high levels of contamination. Table 4 lists the typical concentrations for common wastewater parameters. In addition to the high concentrations displayed, the difference between the typical values for ‘total solids’ and ‘suspended solids’ should be noted. The table reveals that approximately 35% of the solids present are in a dissolved form. Research has shown that most of the dissolved solids in spent FOG wastewater are of proteinaceous nature. Protein-based solids are particularly difficult to remove from wastewater using traditional physical/chemical treatment techniques because of their inherent emulsifying properties. Treatment technologies capable of handling these waste streams are available, but removing significant amounts of dissolved organic solids using these methods is expensive (Osborne, 1990).

Table 4. Typical Analyses of Wastewater from Spent FOG Processing

Total Solids	76,920 mg/l
Suspended Solids	50,290 mg/l
FOG	20,460 mg/l
COD*	130,250 mg/l
BOD**	25,240 mg/l
pH	4.5 S.U.

Concentrations given in Milligrams per Liter

* Chemical Oxygen Demand

** Biochemical Oxygen Demand

2.2 Markets of Yellow Grease

The idea of recycling FOG dates back to World War II, when households were asked to save their bacon drippings. These drippings were collected and converted to oils for use as machinery lubricants during the war. Then during the 1950s, as the fast-food industry began to explode, the United States was faced with a growing supply of spent FOG. Researchers began working with FOG recovered from restaurants and found that the cooking process did not destroy the FOG - it just got dirty.

Further research showed that if processes were developed to clean the spent FOG material, then reuse was possible. At about this same time, livestock ranchers began reacting to higher demand from the marketplace by feeding their cattle more grain to fatten the cattle faster. In an attempt to find additional feed stuffs for animal rations, rendered FOG was introduced as an additional energy source and was found also to make the feed more palatable (Fitch-Haumann, 1990).

In 1990, approximately 35% of rendered fat was exported and 65% was consumed in U.S. markets. Exports of rendered FOG reached a high of 56% in 1980 (Grummer, 1992). The importance of the export market to the rendering industry dates back to the 1950's. During that decade petroleum-based detergents began capturing a major share of the laundry soap market in the U.S., and the demand for tallow and grease collapsed. At this same time use of animal fats in feed formulation around the world began to increase in popularity and the demand for rendered fats worldwide has continued to grow since.

Usage of inedible tallow and grease is likely to continue growing (see Appendix D-F for recent production and consumption statistics). Prices have been kept low because of increased competition from soybean and palm oil. In addition, increased use of vegetable oils by fast-food restaurants and the introduction of synthetic fats have reduced demand for edible animal-based FOG for cooking.

Today, the rendering of FOG material recovered from the food service industry plays a major role in the current animal by-product market. However, recent research developments in areas such as biodiesel and composting promise new opportunities for spent FOG, indicating that demand will continue to grow.

In many areas of the United States, the value of yellow grease generated at food service establishments has increased to the point that theft of spent FOG from unsecured inedible containers has become a concern. News stories relating to the pilfering of grease containers are becoming commonplace in certain competitive locations and markets:

- *FoodService Director, 1999:*
[California Highway Patrol Sets Crackdown on Grease Thieves](#)

The California Highway Patrol has begun intercepting trucks that haul kitchen grease as part of a new crackdown on thieves who have been raiding the larder at foodservice establishments throughout the state. The surprise inspections were authorized under a new state law enacted in response to an outbreak of kitchen grease thefts at California restaurants.

- *Tulsa World: Final Edition, 1997:*
Two Arrested in Cooking Grease Theft

Congeaed, gooey gobs of used cooking grease would seem to be the last thing on a thief's list of items to steal, but police in Vinita said they caught two men in the act. The two men were arrested Wednesday morning after allegedly being seen by police officers taking 400 pounds of grease from a tank behind the Golden Spike Restaurant.

The men were arrested on a complaint of grand larceny. The suspects told officers they were taking the grease to resell for 50 cents a pound. The men were first seen behind Clanton's Cafe, but the grease barrel there was empty, officers said. The cafe's owner said he couldn't see how the men were getting 50 cents a pound for the used grease when he buys lard for 30 cents a pound. He also said that a rendering company pays about 8 cents a pound to come haul it off, but he's found the unlocked barrel behind his cafe empty several times.

- *Los Angeles Time: Home Edition, 1997:*
The Rancid Riches of Texas' New Range War

Lucrative recycling industry fuels demand for restaurants' used cooking oil. Across this fry cook's nirvana, big entrepreneurs and rogue operators battle over who gets the goo. HOUSTON -- Oil is king in Texas. Only the black gold that's got wildcatters in a lather these days isn't pumped from the ground, it's drained from the kitchen. The market for used restaurant grease is big business here, a multimillion-dollar trade that's often as nasty as the product that feeds it. Not many people spend their time pondering the fate of dirty cooking oil, nor do many care to, especially after downing a super-sized order of fries. But the rendering industry lives off of that waste, recycling it in ways that many people also probably don't care to ponder--as an additive in soap, cosmetics, lubricants and livestock feed, among other uses.

To retrieve the goo, the largest renderers sign contracts with restaurants, installing grease vats in kitchen alleys and paying a few cents per pound every time they come for a load. That arrangement, however, rarely goes unchallenged. In a testament to the boundlessness of the entrepreneurial spirit, rogue haulers often snatch the grease before the big companies can get there--a phenomenon that has led to criminal probes, civil lawsuits and other charges of slippery commerce.

"Anywhere there's grease, there's going to be grease thieves," said Vernon Stewart, director of the Texas Renderers Association, which is lobbying for stricter laws against illegal grease vendors, some of whom pocket hundreds of dollars a night. "It's sort of a crude way of making a living. But any time you have a profit like this, you're going to find dishonest people filling the void."

These skirmishes exist throughout the country, including California, which is home to the official industry magazine, *Render*. Yet for reasons that can't be entirely explained, the Lone Star State is considered the front

line of America's grease wars. "There's some thievin' going on here and there around the country, but nothing like we got in Texas," said Al Cuellar, a security officer for Kentucky-based Griffin Industries, one of the nation's largest renderers with more than 50,000 kitchen-grease accounts in 16 states.

This week in San Antonio, and last week in Houston, Cuellar's gumshoe work led to a series of indictments and arrests that constitutes one of the biggest grease busts in the history of the rendering industry, not that many cases had been competing for that crown. Using an undercover grease policeman and a confidential grease informant, authorities secretly tape-recorded transactions with four suspected grease fences. Seven people were charged with receiving stolen property.

In the shadows of a restaurant alley, an oil barrel looks about as exalted as a garbage can. You'd think people would be happy just to have it taken off their hands. "After all," said Cuellar, summing up the prevailing attitude, "it's just grease." But if one man's trash is another man's treasure, used kitchen oil can be a mother lode. A poacher can earn 7 to 14 cents a pound, depending on the demand for rendered grease, which is bought and sold each day on the commodities market. It wouldn't take much for an industrious thief to loot 10 oil barrels, each weighing 400 pounds, in a single night - and be about \$400 richer by morning. Griffin Industries estimates that it loses at least \$10,000 a week in Houston alone.

Most of the outright theft - in which locked containers are pried, cut or blow-torched open - occurs at night with few witnesses around. Sometimes, if there is no lock, restaurants don't even know that their vats have been tampered with. Only when the rendering company that installed the container arrives for its grease may anybody discover that there's less than a full load.

The Texas Department of Health, which regulates the state's rendering industry, has almost no power to intercede. Although it issues grease-hauling licenses, just about anyone with a leakproof truck and the \$150 annual fee can get one, even if they've been convicted of theft. In fact, some rendering firms complain that the whole process bestows an aura of legitimacy on crooks, who can always flash their Texas Renderer's Licensing Act number if they're ever stopped by police.

California has a somewhat stricter program, launched in 1995 and run under the state Department of Agriculture. The licensing fee is twice that of Texas, and the extra money is used to fund a full-time detective. His work has placed several grease thieves on probation and brought in more than \$18,000 in fines, yet after nearly three years of sleuthing, nobody's been sent to jail and no licenses have been revoked. "What we're after is compliance with the law, not to put people out of business," said Dennis Thompson, chief of the department's meat and poultry inspection unit, which oversees the program. After all, the rendering industry "is really a boon to society," he added. "It's important that this grease be conserved and reprocessed, not dumped down our drains and into our rivers and lakes." (Espinosa, 1997)

- *Tulsa World: Final Home Edition, 1996:*
Restaurant Thieves Banking on Grease

FAYETTEVILLE, Ark. - Grease is the word among restaurant thieves in northwest Arkansas. In fact, there's gold in them thar vats. From chicken feed to cosmetics, the used cooking oil collected by area restaurants can be worth millions to recyclers. And gobs of money like that is sure to attract the criminals.

Authorities say five Missouri men are out of the frying pan and into the fire after they were allegedly caught stealing used restaurant grease from bins behind several northwest Arkansas eating establishments. The five - two from Springfield, Mo., and three from Joplin, Mo., --have been charged with felony theft of property. The owner of a grease recycling company that has contracted with area restaurateurs for their old frying oil said that although his company uses the stuff to make chicken feed, the profits from its sale have netted thieves a bundle. "We estimate that overall, in one year's time, these thieves have cost us a half-million dollars," said Walter Hune, general manager of Griffin Industries of Little Rock, Ark. Hune said that northwest Arkansas, with its large population and many restaurants, is an excellent market for waste oil. That is why the company has contracted with area food preparers to buy the grease.

Restaurants place used oil outside in bins provided by Griffin Industries. Every week a truck comes by and pumps it out, then takes it to the rendering plant where it is cleaned and sold for other purposes. "It can't be used again for human consumption but is usually put in animal feed," Hune said. "We sell most of ours to Tyson Foods, who uses it to make chicken feed for their growers to use." Other uses include dog and cat food. Some companies use waste oils in nonfood products, such as cosmetics, Hune said.

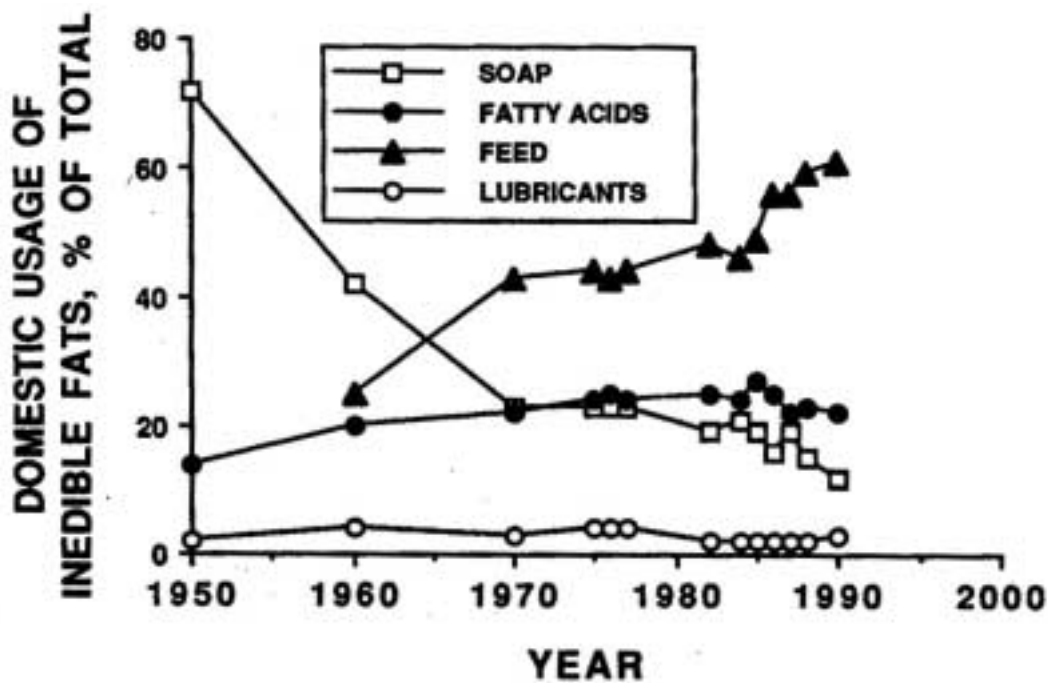
The going rate for recycled waste grease is about 14 cents a pound. Hune said the restaurants get about 30 percent of this for letting Griffin Industries collect it. But lately, Griffin's trucks have come back empty. Fayetteville police and the Washington County Sheriff's office began staking out the restaurants this summer and in August made the first three arrests. "These guys were coming up in the middle of the night and pumping out the grease," said Fourth Judicial Prosecutor Terry Jones. (Kirby, 1996)

2.2 Traditional Rendered Products from Yellow Grease

Approximately 2.5 billion pounds of spent FOG from the food service industry are collected annually in the United States by the rendering industry and independent grease haulers. This spent FOG is then specially processed to yield approximately 1.6 billion pounds of yellow grease for possible incorporation into animal feeds, as a source for fatty acids, as a raw ingredient for soap making and lubricants for industrial use, and as a diluent in higher grade inedible fat products such as bleachable fancy tallow (see Figure 2) (Fitch-Haumann, 1990).

Approximately 95% of the yellow grease produced from the food service industry is later incorporated into animal feed and pet foods. An SRI International study, commissioned by The Procter & Gamble Company in 1988, estimated that approximately one billion pounds of yellow grease were used in domestic animal feed and pet food, and 300 million pounds are exported for such use (SRI, 1988). An additional 200 million pounds are blended into inedible tallow. The study shows that over 440,000 commercial food service operations in the U.S - the predominant sources of spent FOG - purchase an estimated 1.75 billion to 2 billion pounds of frying fats and oils each year.

Figure 2. Trends in U.S. Domestic Usage of Inedible Tallow and Grease



source: Grummer, 1992

Of the approximately 36 billion pounds of raw material utilized by the rendering industry each year, between 3 and 3.5 billion pounds are in the form of inedible fats (see Table 5).

Table 5. Utilization of Inedible Fats in the United States – Calendar Year 1990

<i>Use</i>	<i>Pounds</i>	<i>Percent of Total (%)</i>	<i>Change from previous year (%)</i>
Animal feed	2,013,000,000	61.1	+ 5
Fatty Acids	722,000,000	22.0	+ 8
Soap	397,000,000	12.1	+ 8
Lubricants	110,000,000	3.5	+ 55
Others	43,000,000	1.3	+ 6

2.3.1 Animal Feed

The use of spent FOG in the formulation of animal diets has been relatively slow to evolve over the years. The slow growth in fat feeding, particularly to ruminant livestock (i.e., cattle), was in large part due to slow recognition that all fat supplements are not equal in composition and performance. Additionally, there is considerable variation among animal species in the types and amounts of fat that can be efficiently utilized. In 1990, for the first time, use of inedible tallow and grease in feeds for livestock and pets exceeded 2 billion pounds (Grummer, 1992). Just five years prior, only 1.3 billion pounds were used. Based on recent trends, significant growth in the use of fat in animal diets should continue (see Table 6).

The production of animal feed consumes over 60% of the rendered FOG produced in the United States. Utilizing over two billion pounds of rendered FOG each year; the manufacturing of animal feed is far and away the most popular use of this by-product material. According to the U.S. Census Bureau, in 1997 there were over 3,400 facilities involved in some form of animal feed manufacturing. The animal feed manufacturing industry employs almost 100,000 people and produces a staggering \$76 billion in shippable products each year (U.S. Census Bureau, 1998).

Table 6. Estimated Usage of Fats in Animal Feeds (millions of pounds)

<i>Type of Feed</i>	<i>1986</i>	<i>1991</i>	<i>% Increase</i>
Poultry - Broilers	650	1,100	+69
Poultry - Turkeys	500	900	+80
Pet Food	400	500	+25
Swine	100	250	+150
Cattle -Beef	200	200	0
Cattle – Dairy	90	200	+155
Cattle – Veal	100	100	0
Poultry – Layers	30	60	+100
Fish	30	50	+67

Rendered FOG has been a common ingredient in the production of poultry feed for a longer period than with any other animal species. Since the 1940's, fat has been used in poultry feed formulations to increase energy density and feed efficiency. Virtually all of the information available today concerning the effect of rendered FOG on the digestibility of animal feeds on non-ruminant animals was learned through research with poultry (Grummer, 1992). Research done in the 1960's showed that poultry species that were fed fat in their diets performed better than scientists expected as metabolizable energy intake increased dramatically (Reid, 1985).

Fat supplementation of dairy diets was not commonplace until the 1980's. However, the use of fat in dairy diets continues to increase. Only a relatively small amount of research has been completed on the effects of FOG supplementation in beef cattle, however the available research shows very positive results (see Table 7).

Table 7. Effects of 4% Supplemental Fat on Performance of Finishing Yearling Steers

	<i>Control Group</i>	<i>Soybean Oil</i>	<i>Tallow</i>	<i>Yellow Grease</i>
Initial Weight (lb)	811	799	799	815
Final Weight (lb)	1191	1207	1199	1235
Daily Gain (lb)	3.13	3.39	3.30	3.50
Daily Feed (lb)	19.6	19.6	19.1	20.1
Gain/feed	0.160	0.173	0.174	0.175

In addition to enhancing the energy density of animal food diets, rendered FOG also serves some other important functions within the feed industry. Adding rendered FOG to animal diets acts as a dust control agent. By reducing the amount of dust produced during the feed manufacturing process, it improves the working condition within the processing mills. Also, less dust increases both the appearance and palatability of the feed.

Fat supplementation in animal feeds can also increase the stability of fat-soluble vitamins and improve their absorption from the gastrointestinal tract. Fat also has an inherent lubricating effect that aids in extending the life of feed mill equipment. Since most commercial / industrial lubricants can not be used where they may come in contact with food, rendered FOG can act as a replacement lubricant to increase pelleting ease, reducing power requirements and extending equipment life (Grummer, 1992).

2.3.2 Fatty Acids / Glycerol

The commercial production of fatty acids accounts for about 22% of the United States' rendered inedible FOG, which makes this by-product recycling method a distant second compared to utilization for animal feeds (Grummer, 1992). Traditionally, fatty acids are formed by the hydrolysis or 'splitting' of triglycerides to form fatty acids and glycerol. The goal of this 'splitting' is to have both a high rate of hydrolysis and a high percentage of final product formation. To accomplish this goal, an excess of water, selection of an appropriate combination of temperature and pressure, removal of glycerol, and often the use of an acid catalyst are required (Sonntag, 1979). The glycerol formed by the process is separated and sold as a value-added by-product.

The melted fatty acids are then fractionated by lowering their temperature and allowing them to crystallize at 1-3°C (34-37°F). The crystallized mass is then pressed to form a liquid and/or a solid fraction. The liquid fraction is referred to as 'oleic acid oil' or 'red oil'. The solid fraction is known as 'single pressed stearic acid'. However, this process has limited efficiency, as the red oil product typically contained less than 70% oleic acid and the stearic acid products contained slightly more palmitic than the desired stearic acid. Because of limited yield offered by pressing, it has been largely replaced by other methods (Grummer, 1992).

One alternative method, known as the Emersol process, relies on a continuous solvent preparation technique. Fatty acids are dissolved in methanol-based solvents and crystallized at -15°C (5°F). The solid or stearic acid fraction is removed by filter and the filtrate containing the liquid or oleic acid fraction is stripped of solvent in a laboratory recovery still. Another alternative method, known as the Henkel Process uses water emulsion separation of fatty acids in the presence of a surfactant to produce purified fatty acids. The resulting saturated / unsaturated fatty acid mixture is allowed to cool and is combined with a surface-active agent. Centrifugation is used to remove the oily phase, the saturated fatty acids are heated to separate the aqueous layer.

Distillation is used to yield high quality, pure fatty acids that are in demand for a variety of specific industrial applications. Through this method, it is now common to obtain fatty acid fractions that contain up to 99% of a single desired fatty acid. It is likely that the demand for single fatty acid sources with minimal color, taste and odor defects will continue to expand in the future (Grummer, 1992).

The uses for fatty acids in manufacturing products are numerous. Common products derived from the inclusion of fatty acids, include surfactants, soaps, plastics, resins, rubber, plants, lubricants, textiles and cosmetics. Also, isolated fatty acid nitrogen derivatives, which include amides, are used in the manufacture of water repellents, synthetic detergents, non-ionic surface-active agents, printing inks and plastics (see Table 8).

Fatty acid amines are extremely water-soluble and are used in the rubber and textile industry and as corrosion inhibitors, liquid detergents and surface-active agents. Fatty acid esters are characterized by high boiling points and are used in the manufacture of emulsifiers, coating agents, textile sizers and lubricants, plasticizers, and defoaming agents. Long-chain fatty alcohols are formed by reduction of fatty acids. Their greatest use is in the production of sodium alkyl sulfates that are used in the production of detergents. Some alcohols find use in the production of nonionic detergents and waterproofing agents. Dibasic acids formed from fatty acids are used in the manufacture of plasticizers, synthetic lubricants, and high molecular weight polymers (Grummer, 1992).

Table 8. Fatty Acid Profile of Various Commodity and Specialty Fat Sources (Weight %)

Fat Source	Myristic C14:0	Palmitic C16:0	Palmitoleic C16:0	Stearic C18:0	Oleic C18:1	Linoleic C18:2	Linolenic C18:3	Saturated %	Unsaturated %
Whole Cottenseed	1	25	--	3	17	54	--	29	71
Whole Soybeans	--	11	--	4	24	54	7	15	85
Tallow	3	26	6	19	40	5	1	48	52
Yellow Grease	3	18	4	12	47	13	3	33	67
Animal – Vegetable Blend	1	22	5	5	36	29	2	28	72

Saturated fatty acids (C14:0, C16:0, C18:0)

(Dale, 1991)

Unsaturated fatty acids (C16:1, C18:1, C18:2, C18:3)

For more detailed information on the production of fatty acids from rendered yellow grease, see: Formo, M.W. (1982). Miscellaneous oil and fat products. In Bailey's Industrial Oil and Fat Products, Vol. 2, p. 343. John Wiley and Sons, New York.

2.3.3 Soap Making

Ranking third on the list of traditional products made from rendered FOG, 12.1% of inedible tallow and grease (397,000,000 pounds) was used in soap making in 1990. Documented evidence of soap making dates back to 2800 B.C. and ancient Babylon. Ancient Egyptians combined animal and vegetable oils with alkaline salts to form a soap-like material for washing and treating skin diseases (Myers, 1992).

In past centuries, soap merchants would travel with carts through the streets, collecting spent FOG from homeowners in exchange for portions of soap. As with many industries in America, large-scale soap making began as a result of the centralizing effects of the Industrial Revolution. Large-scale animal slaughterhouses not only produced large amounts of meat products, they also created large volumes of by-products such as FOG.

Ordinary soap is made from a mixture of the sodium salts of various fatty acids of naturally occurring oils and fats. Basically, soap comprises the alkali and ammonium salts of fatty acids. Fatty acids in the range of 8-22 carbon chains are used in most common soaps today. Most household soaps are made to be soluble in water, however some soaps, such as magnesium, are insoluble in water and thus have unique industrial applications (Myers, 1992).

2.3.4 Lubricants

Approximately 110,000,000 pounds of fats and greases were used for the production of lubricants in 1990. Although there is some use of fats and greases directly as lubricants, the majority of lubricants today contain fatty acid soaps and/or chemically modified fatty acids. These improvements have assured production of lubricants with uniform characteristics that will perform at wider ranges of temperatures and have greater stability for extended life spans (Formo, 1982).

Lubricating greases are made by mixing lubricating oil with fatty acid soaps at high temperatures and allowing the mixture to cool. The resulting properties depend upon the ratio of oil to soap and the fatty acids comprising the soap. Tallow and greases account for greater than 60% of the fatty raw material used in manufacturing lubricating greases; however, commercial oleic and stearic acids also account for a large portion of the fatty material used.

Fatty acid esters are the most prevalent materials used for 'synthetic' lubricants. Synthetic esters fall into several categories. Monobasic esters, such as methyl stearate or methyl oleate, are used in lithium-based greases, textile lubricants, and rolling and cutting oils. Dibasic

acid esters are characterized by high viscosity indexes, low pour points, and an improvement in thermal and oxidative stability. Monobasic acid esters of branched polyols are also characterized by excellent thermal and oxidative stability. Although synthetic lubricants only make up a small portion of the market, the demand for high-performance lubricants is increasing.

Other uses for rendered fat include lubricants for tools used for cutting, machining, stamping, and drawing of metal. These lubricants are referred to as cutting oils and may be used alone or in an emulsion with water. Number 1- or 2-grade lard oil is often used as cutting oil. Lard and tallow may also be used as a lubricant in the textile industry to strengthen yarn during weaving and to minimize abrasion (Grummer, 1992).

2.4 Innovative Uses of Yellow Grease

2.4.1 Biodiesel

In recent years the utilization of fats and oils for the manufacture of biodiesel has received considerable interest. Due to increasing costs and foreign reliance on petroleum-based fuels, an enhanced priority for the development of more energy efficient utilizations and alternative energy sources has arisen. Currently the combination of unprecedented high fuel costs and relatively low fat/oil prices has highlighted the benefits of recycling spent FOG in biodiesel (Pearl, 2000).

Using modern processing techniques, spent FOG can be converted into derivatives called 'esters'. These esters are more commonly known as 'biodiesel'. Today, various esters derived from spent FOG are being evaluated worldwide as alternatives to petroleum-derived diesel fuel. Biodiesel offers an environmentally sound replacement or additive/extender for conventional diesel fuel. Improved chemical technology for biodiesel production is needed to make biodiesel cost-competitive with the conventional fuel while preserving the fuel characteristics needed for use, especially in cold weather (Foglia, et. al., 2000).

2.4.1.1 Manufacturing Process

Typically, biodiesel is prepared by esterification of the spent FOG with methyl alcohol under alkaline conditions. The resulting methyl esters are cleaned of their co-product, glycerol, and isolated as biodiesel. Two major issues must be overcome in using spent FOG as biodiesel feedstock. The first is seen when converting animal fat into biodiesel. The methyl ester biodiesel derived from animal fat has relatively poor cold temperature properties; and becomes too viscous

and even solidifies under winter climatic conditions. However, recently completed research by Foglia, Marmer and Haas, demonstrated that substituting typical alcohol feedstock - methyl alcohol - with branched-chain alcohols - such as isopropyl, isobutyl or secondary butyl - allows conversion of animal fats into branched-alkyl esters. The branched-alkyl esters demonstrate cold-temperature properties that were significantly improved over their methyl ester counterpart (Foglia, et. al., 2000).

The second major issue in the production of biodiesel involves the use of spent food service grease. Since spent FOG from food service establishments has undergone some degradation during its use in cooking a considerable buildup of free fatty acids has accumulated. Conventional conversion technology to produce biodiesel does not convert free fatty acids; instead the free fatty acids are converted into soap by the alkali catalyst. To produce an effective biodiesel fuel, the free fatty acids must be converted into the desired esters.

2.4.1.2 Recent Developments

Current developments in the area of biodiesel production and research appearing in recent *Render* publications:

- Did you hear?

Buses and other diesel-burning vehicles will run cleaner if they mix soy-based biodiesel with their regular diesel fuel, or so the U.S. Department of Agriculture's Agriculture Research Service (ARS) hopes to prove. To test the feasibility of switching to this fuel blend, ARS began a year-long demonstration in January at the Beltsville Agriculture Research Center (BARC) in Maryland. BARC has 65 vehicles operating on "B20," a 20 percent biodiesel/80 percent diesel mix.

This test is part of a federal effort to reduce reliance on petroleum and create new markets for U.S. crops. There is interest in permanently switching as many federal government vehicles as possible nationwide to alternative diesel fuels, using biodiesel from soybean and other seed oils or animal fat. One goal is to increase the federal purchases of bio-based fuel and other products by 10 percent each year for the next five years.

The demonstration may help encourage local governments and the private sector to do the same, especially in areas where air quality is an issue. Crop-based diesel burns cleaner and produces less soot, and vehicles don't need modification before being switched to the fuel. Recent changes in the Energy Policy Act of 1992 allow for credits for biodiesel usage in existing vehicles, reducing the number of alternative fuel vehicles that must be purchased. Future changes could also affect large municipal vehicle fleets, such as buses and public works vehicles.

- Renderers Demand Level Playing Field in Biodiesel

The U.S. Department of Agriculture (USDA) is committed to increasing the production of alternative fuels, namely ethanol and biodiesel. The objective is to expand industrial consumption of agricultural commodities by promoting their use in the production of bioenergy (ethanol and biodiesel) which will also advance the goals set forth in the President's Executive Order on Biobased Products and Bioenergy.

The USDA wants to find new uses for crops that are often in an oversupply, a noble endeavor that deserves support. There are a lot of benefits to such programs. In order to advance these goals, the USDA is proposing to spend \$450 million over the next three years in the form of cash incentives to producers of alternative fuels who increase their consumption of various crops such as barley, corn, grain sorghum, oats, rice, wheat, soybeans, sunflower seed, canola, rapeseed, safflower, flaxseed, and mustard seed. There is a hitch here. There is no mention of animal fats or used cooking oils, both very good sources of, feed stocks for the production of biodiesel.

While the USDA wants to help out the soybean, corn growers, and other plant producers, they cannot do so at the expense of other segments of the industry. This means that if the people in the animal fats and used cooking oils business, in other words, renderers, want to produce biodiesel, they will start out at an unfair competitive disadvantage with the plant producers. The government would, again, be subsidizing the competition (Cook, 2000).

2.4.1.3 Case Studies

During the 1980's, some innovative companies and environmentally minded individuals worked on various methods designed at using spent FOG directly in engines for fuel. Unlike biodiesels produced today, the spent FOG was used without first transesterifying the raw material. The major problem with this approach was that the spent FOG was never characterized. Often spent FOG of vegetable, animal or blends of both fats were used. Because of this lack of specific data on raw materials, manufacturers of the time were not interested in research that they saw as lacking quality control.

In the early 1990's Colorado School of Mines (CSM) fuels chemist Tom Reed believed that spent FOG from food service establishments could be used in blends to fuel vehicles and set out to show that it could be accomplished. Reed developed a recipe that recycled spent FOG into a viable alternative diesel fuel. Using transesterification to combine methanol and spent FOG over a catalyst under controlled heat conditions, he has produced "M-Diesel," a 10% oxygenated

fuel that contained 95% of petroleum-based diesel energy. Research tests showed that the biodiesel burned significantly cleaner and more efficiently than regular diesel (Fitch-Haumann, 1990).

To test the actual effectiveness of the biodiesel fuel, the Regional Transportation District (RTD) in Denver, Colorado, used the fuel - which originated from a vat of corn dog frying oil - to run an unmodified bus for a 120-mile test ride. RTD officials reported that there were no noticeable differences in power, thus verifying previous research data completed in laboratory testing. Also, the RTD's manager of technical support reported that the fuel had a reduced opacity, the amount of light filtered by the particles in the exhaust. Additionally, he noted that M-Diesel could be used pure, in place of diesel, and resulted in a fourfold reduction in smoke.

At the time of the testing, Denver officials said that in the metropolitan area alone, commercial food service establishments each week were discarding over 80,000 gallons of used cooking oil. Although the cost for the initial 100-gallon batch of M-diesel was approximately \$30 per gallon, it was projected that mass production of the fuel will make it economically competitive with diesel, especially where low air emissions were required. In 1990, CSM estimated that national production of waste cooking oil amounted to approximately 2% of U.S. diesel consumption (Fitch-Haumann, 1990).

In a recent 2000 issue of *Render*, a project involving the Cincinnati, Ohio Metro bus fleet was highlighted. Spent FOG from Cincinnati restaurants was collected and rendered by a local Griffin Industries facility. The rendered FOG was then converted to biodiesel and was used to fuel 288 of the city's public transit buses. The buses were supplied with 500,000 gallons of "B20", a blend of 20 percent biodiesel mixed with 80 percent petroleum diesel for use over a two-month period. The buses were expected to run 2.5 million miles using the alternative fuel. The program created a great deal of local and national interest; including National Public Radio and the cable television news station MSNBC.

According to the National Biodiesel Development Board, the program was believed to be the first demonstration project in the country using biodiesel made from recycled spent FOG to fuel public transit fleets. Based on preliminary tests, the transit systems expected significant reductions in air emissions from the test buses. The cost of the biodiesel was funded by a grant from the Department of Transportation's Congestion Mitigation / Air Quality program, which

encourages innovative clean air solutions. The funds are made available through OKI Regional Council of Governments. Although this is believed to be the first tests done using spent FOG specifically from food service establishments, this was not the first test of alternative fuels for Cincinnati. In 1993 and 1994, Metro participated in two successful national tests for soybean-based biodiesel. However, the cost of SoyDiesel was significantly higher than regular diesel fuel, which prohibited Metro from continuing its use after the tests ended. The B20, spent FOG biodiesel is less expensive than SoyDiesel.

2.4.2 Other Innovative Uses

As pointed out earlier in this report, spent FOG from food service establishments is classified as inedible animal fats even though they often contain vegetable oils. Industry groups, like the Fats and Proteins Research Foundation, continue to seek new applications for inedible animal fats and proteins. Currently, some of the better-grade FOG is used as a lime soap-dispersing agent in biodegradable detergents. Industry driven research also is examining the possible use of inedible animal fats in biodegradable plastics.

Other research areas include studies concerning the metabolized energy value of spent food service grease. One example involved a poultry study with baby chicks. Research at the University of Georgia investigated whether there was a difference in feed value of oils that have been used in deep-fat frying versus unused oils. The work focused on whether polymers were created that might interfere with feeding by the baby chicks. Results indicated that there is no difference in the nutritional value or metabolizable energy between the unused frying oil and the product after use. Although some polymers were formed, there are not enough to cause a problem even for baby chicks.

In addition, the Fats and Proteins Research Foundation has experimented with spent FOG by mixing it with concrete in an effort to help prevent cracks; spraying plants with a FOG mixture to decrease the amount of water lost through evaporation and cut down on the amount of irrigation needed; and testing its value as a soil additive. Some tests, for instance, have shown it helps seedlings sprout by breaking up the tension of soils (Fitch-Haumann, 1990).

2.5 Rendering Company Profiles

A recent article in *Render* highlighted the current trend in the rendering industry towards consolidation. A recent report in the *Chemical Market Reporter* stated that as national restaurant chains focus on developing efficient and ecologically sound ways to dispose of spent FOG, industry analysts expect that the number of independent recyclers will continue consolidate (NRA, 2000). (Note: See Appendix B for location and contact information on Georgia's yellow grease renderers.)

2.5.1 American Proteins

Georgia-based American Proteins is best known in the state for the rendering of poultry processing offal. In addition to these better known services, American Proteins also renders spent FOG from food service establishments at three locations in Georgia.

American Proteins operates yellow grease processing facilities in Kennesaw, Dalton and Macon – where the facility operates under the name Mercer, Inc. Serving food service customers all over Georgia, American Proteins services include both the pumping and hauling of yellow grease. American Proteins renders yellow grease (no brown grease is accepted) from its own hauling operation, as well as from a select group of independent haulers.

American Proteins renders the collected yellow grease after it has been processed to remove impurities and water contained in the spent FOG. The rendered product is then blended with other ingredients to form animal feed. American Proteins reported that the price for yellow grease fluctuates based on the amount collected. The company also reports that they have ample room for future expansion for spent FOG processing.

2.5.2 Griffin Industries

Griffin Industries, the second largest rendering company in the nation, has five Georgia facilities throughout the state with the largest one located in Ellenwood, near Atlanta. Griffin Industries serves the entire state and surrounding regions by offering a wide range of spent FOG services. Available services in the area of yellow and brown grease include providing bulk storage containers with scheduled maintenance, waste cooking oil collection, and grease trap cleaning. All services offered are available with nighttime operations, eliminating customer exposure to offensive odors and excess traffic.

Griffin Industries only accepts waste that they themselves collect and does not accept spent FOG or other wastes from independent haulers to ensure complete separation of yellow and brown grease waste streams. Griffin Industries collects both inedible yellow grease (waste cooking oil) from food service establishments that is rendered and sold as an ingredient in animal feeds and brown grease (from grease traps) that is rendered and sold as a non-animal feed product for use in such items as industrial lubricants. In an effort to obtain the higher quality and valued yellow grease, Griffin Industries offers the service of grease trap cleaning in exchange for the contractual collection of the customers yellow grease.

Griffin Industries began in 1942 as a one-man/truck dead animal collection operation and since has grown into a nationwide company. The Ellenwood facility, primarily serving all of North Georgia, has 3-4 trucks devoted to collection of yellow grease and renders approximately 100,000 lbs of yellow and brown grease each day. Brown grease accounts for 20% of the total material processed. South Georgia customers are served from the Dublin plant that operates 1 truck and transports approximately 75,000 lbs per week of brown grease to the Ellenwood plant for processing.

Griffin Industries utilizes traditional large scale rendering techniques that consist of a primary grinding process followed by cooking in a high pressure steam vessel that separates the hot liquid fat from the solid protein material. Both streams are pumped into separate holding tanks for further processing. Water recovered from the processing of the brown grease is pretreated in a 900,000-gallon pond prior to discharge to the local POTW. The costs of services vary greatly based on distance and individual contracts with clients. Clients are charged on a per pick up basis with an average load of 1,500 gallons. Griffin Industries is presently operating at the plant capacity and has no future plans for expansion.

3.0 BROWN GREASE (GREASE TRAPS)

Brown grease is an industry term used to describe the floatable spent FOG, settled solids and associated wastewater retained by food service grease traps. Unlike yellow grease, the majority of brown grease removed from grease traps has been adulterated by coming in contact with detergents and other cleaning solutions used in food service kitchens. The major source of brown grease generated in food service kitchens comes from the cleaning of equipment and utensils used in the preparation and serving of food. In contrast to yellow grease, the history of the collection, handling, disposal and beneficial use of brown grease is not well documented.

Due to the unlimited sources of materials that pass through foodservice grease traps, characterizing brown grease is difficult. However, some basic classification standards have been established within the industry (see Table 9).

Table 9. Fat Classification and Standards

<i>Type of Fat</i>	<i>Titer*</i> (°C)	<i>F.A.C. Color Limit**</i>	<i>% F.F.A[^]</i>
Tallow (Edible)	41	1	0.5
Fancy Tallow	42-43	3-5	1.5-3
Prime Tallow	42-43	7-11	3-5
Special Tallow	42	19	10
Yellow Grease	None	31-41	10-25
Brown Grease	None	41-45	25-30

* Titer – the solidification point of fatty acids. Titer < 40 = grease, Titer > 40 = tallow. Titer is dependent on the relative amounts of saturated and unsaturated fatty acids.

** F.A.C. Color Limit – ‘FAC’ is the abbreviation for the Fat Analysis Committee. FAC color standards run from 1-45 using odd numbers only. A sample is filtered and compared to standardized color slides. In basic terms, the lower the number - the less color the fat contains – the higher value the fat has on the market.

[^] % F.F.A. – Percent of Free Fatty Acids – Used as a determinant of rancidity by many in the industry.

Source: Dupps, 2001

3.1 Grease Traps

A grease trap is an engineered device designed to remove spent FOG and associated solids and debris from food service establishment waste streams, thus preventing entry into either municipal sewer collection systems or privately owned on-site wastewater treatment facilities. The basic design and principles of operation of grease traps have changed little since the first United States patent was issued for a passive grease removal system in 1885 (Kaley, 2000) (see Figure 3). Spent FOG is 10 to 15 percent lighter than water (Kaley, 2000) and will float to the surface of a container if not emulsified. Emulsification is the term given to the condition when spent FOG does not separate from water. This is a concern because emulsification allows spent FOG to pass readily through grease traps to enter other systems. Heat is the most common cause of emulsification in food service generated brown grease. Thus, one of the primary purposes of a properly sized grease trap is to retain high temperature spent FOG until cooling and separation of the spent FOG and water can take place. In addition to heat, certain advertised grease trap cleaning agents and biodegrading bacteria act simply as emulsifying agents to cause grease trap pass-through.

The retention of food service solids lost to the waste stream is also an important function of a grease trap. Large particle solids, with masses greater than that of water, settle to the bottom of the grease trap and are intended for removal along with the floatable spent FOG during periodic cleaning.

3.1.1 Types of Grease Traps

Three basic types of grease traps are used in typical food service operations:

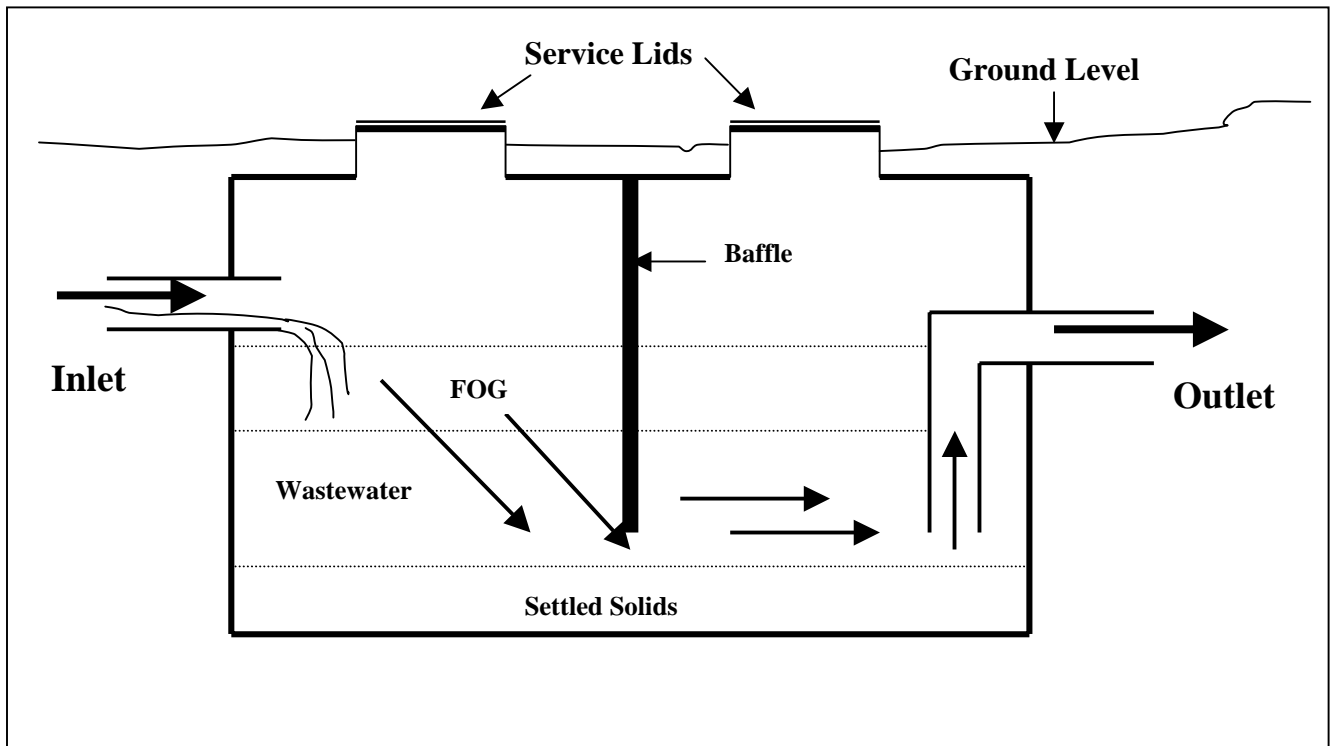
1. In-Kitchen Passive Interceptors -

These units collect grease as it rises to the top of a small baffled tank when wastewater generated in the facility flows through the unit. The collected grease from these types of traps must be removed manually. Because of their relative small size (typically 20-25 gallons) these traps must be cleaned on a short periodic interval (usually ranging from daily to once a week), depending on the load at each particular food service establishment. If these small units are not cleaned accordingly, they quickly become full of grease and simply begin to operate in a pass-through mode, allowing spent FOG to enter directly into the waste stream. However, if maintained properly, In-Kitchen Passive Interceptors can remove spent FOG and associated solids at a rate of 95%. New installations of typical In-Kitchen Passive Interceptors range in cost from \$1,000 - \$1,500 (Kaley, 2000).

2. Pre-Cast Concrete In-Ground Grease Traps -

A pre-cast concrete grease trap operates on the same principle as the in-kitchen type, only on a larger scale. The most common sizes of in-ground grease traps are in the range of 750 to 2,000 gallons (2.8 – 7.6 m³). These larger traps are capable of handling much larger volumes of spent FOG and related material than in-kitchen types; however, they are also more expensive to install and maintain. Food service establishments using these larger grease traps must pay grease-pumping companies to clean the traps periodically. Installing a grease trap of this type while a new food service establishment is under construction will have an average cost of \$2,500 - \$4,000. However, the cost of installing a grease trap in-ground at an existing facility can exceed \$25,000 (Kaley, 2000).

Figure 3. Basic In-Ground Grease Trap Design



3. Automatic Grease Traps -

Similar to other types of grease traps, automatic units first collect spent FOG and solids in a baffled chamber as wastewater flows through the unit. The difference is that automatic grease traps are designed to remove spent FOG automatically on a predetermined schedule. Due to the automatic cleaning function, these traps will remove up to 98% of spent FOG (Kaley, 2000) from the waste stream. Typical automatic grease trap units are relatively small and are used as in-kitchen applications. Most units operate by ‘skimming’ the spent FOG from the surface of the wastewater and depositing the product in containers. Automatic units must be cleaned and maintained periodically to remove settled solids build-up and keep equipment clean; however, this is required only occasionally compared to other manual units.

For more detailed information on the engineering principles utilized in the design and operation of grease traps see:

Horvath, I.C. (1994) *Hydraulics in Water and Waste-Water Treatment Technology*, Chapter 6: Grease, oil and petrol traps (flotation facilities). John Wiley & Sons, New York, NY.

3.1.2 Common Misconceptions of Grease Traps

Food service operators are in the business of supplying the public with wholesome, safe food under profitable conditions. On the other hand, food service operators are not in the business of wastewater treatment. This lack of knowledge in the area of managing spent FOG generated from food service operations has led to some basic misconceptions.

First and by far the most glaring misconception observed from interviews of food service establishment operators throughout the state of Georgia is the perception that a grease trap, especially those located in-ground, are wastewater treatment devices. Food service establishments unknowingly think of grease traps in the same light as wastewater septic tanks, viewing them as treatment systems that only have to be maintained and serviced when a problem occurs. “I’ve been at here (a metro Atlanta area restaurant) for eleven years now,” said one restaurant owner, in a phone interview, “I’ve never even looked in the thing (grease trap), never had a problem with it, it’s always worked great.” This misconception not only leads to the discharge of brown grease into waste streams, but in some cases food service operations with no outlet for yellow grease, simply pour it down kitchen drains with hot water thinking the grease trap will simply ‘treat’ the spent FOG.

Georgia food service operators must be educated to the fact that grease traps are simple primary separation devices that are designed to retain spent FOG and solids long enough for them to be manually or automatically removed, and not systems that treat wastewater.

A second misconception that many food service operators maintain is that the generation of spent FOG, either as yellow or brown grease, is simply a cost of doing business and unworthy of monitoring closely. However, as cited previously in this report (see Section 2.0), although prices fluctuate depending on market activity, yellow grease is a valuable commodity within the rendering industry. In most urban areas, services are available where companies will supply a container, then periodically collect and pay food service establishment for their yellow grease. On the other hand, food service operators must deal with the economic and time investment of maintaining in-kitchen grease traps or paying others to maintain in-ground grease traps.

Although actual savings will vary depending on specific locations, Georgia food service operators must be educated to understand that significant economic savings that can be realized by minimizing the generation of spent FOG. Also, food service operators must understand that the control over whether spent FOG is recovered and retained as high-value yellow grease, or lost to the waste stream as brown grease, can have a significant economic impact.

Still another common misconception among food service operators is which areas and procedures within food service create the largest amount of brown grease. Contrary to popular perception, food service kitchen floor drains receive relatively little waste. Waste streams generated from floor drains are usually limited to periodic cleaning and wash down and have minimal impact on grease intercepting equipment. Most spent FOG released to the waste stream in food service kitchens is generated from equipment associated with dishwashing. Multi-compartment pot washing sinks, pre-rinse stations and automatic commercial dishwashers generate more spent FOG destined for brown grease than any other source. On-site testing in food service kitchens has shown that nearly 90% of spent FOG is lost in these dishwashing areas (Kaley, 2000).

3.1.3 Cleaning & Maintenance of Grease Traps

By far the greatest factors affecting the amount of spent FOG released to the waste stream in any food service establishment are the cleaning and maintenance techniques of the kitchen staff. The care taken by staff to dry scrape leftover food and spent FOG from cooking utensils, food preparation equipment and dishes prior to using water to continue the cleaning process is key to reducing the loading of grease traps. Also the disposing of high BOD wastes, such as leftover milk and other beverages can have a major effect on the waste stream.

Many people assume that the amount of spent FOG generated at a particular site is directly related to the type of food being prepared, but this is often not the case. The importance of maintaining a clean and properly operating grease trap is often unknown or overlooked by food service operators. Because spent FOG fills a grease trap from the top down, it is hard to measure the depth or 'fullness' of a grease trap on visual inspection. The most important aspect to remember is that as more spent FOG is retained in a grease trap, the more the separation efficiency diminishes.

The negative impacts of grease on wastewater treatment systems have been documented as early as 1974 when Banerji, Robson and Hyatt published a Purdue University engineering extension publication outlining the problems spent FOG had on collection systems and treatment facilities. In most cases, the same problems that existed in the 1970's continue to persist today. Although spent FOG impacts wastewater treatment plants in many ways, the more immediate negative effect is on sewer collection systems. Simply explained, spent FOG that is allowed to pass through grease traps clogs pipes.

An Atlanta Journal & Constitution article in April 2000 highlighted the impact of grease clogs in Gwinnett County:

- *The Atlanta Journal & Constitution, April 21, 2000:*
Slowing flow of county's sewage

Clogging up the works: Congealed grease from restaurant drains plays major role in costly spills.

In the back of your favorite restaurant there's a foul-smelling pit that had better be doing its job. It's a grease trap, collecting the grease, oil and food particles the dishwasher sends down the drain. If not pumped out periodically, the gooey grime will seep into the sewer pipes and slowly congeal. Over time, the buildup will block the pipes, like cholesterol in an artery.

What happens next, nobody wants to see. An overflow of raw sewage, pouring into streets, culverts and ditches, right into the closest stream. It's happened more than 100 times in Gwinnett since 1997, sending hundreds of thousands of gallons of raw sewage into the county's waterways. Roots that grow into cracks, gravel, leaves and other debris also block pipes, but grease is the culprit 70 percent of the time, Public Utilities Director Tommy Furlow said. "Grease is absolutely our worst problem for overflow," Furlow said. "It sticks to whatever comes along." Under the state's fairly new zero-tolerance policy for sewage spills, Gwinnett's punishment has been fines totaling \$75,850. The latest came just last week, when the Environmental Protection Division finalized a fine of \$10,300 for 14 spills, eight of which dumped more than 10,000 gallons of raw sewage into waterways.

But that's only the beginning of the mounting costs to taxpayers. Once a spill has occurred, the county has to monitor the affected stream for a year, according to state law. The cost for those 100-plus spills was about \$400,000. Before the spills occur, though, Gwinnett is spending money on grease. This year, the county will spend more than \$1 million to clean blocked sewer lines. And that's not just routine maintenance.

With 1,650 miles of sewer lines running through the county, the crews are always in crisis-response mode. They can only get to the pipes with blockages, rather than preventing the blockages. They use a high-pressure hot water stream to dislodge the offending materials. For the grease that makes it through the pipes and into a sewage treatment plant; the costs keep piling up. Furlow said he can't put a dollar figure on it, but treating animal fat is a lot tougher than treating human waste. Microorganisms, or bugs, that slowly eat the solid materials take much longer to break down grease. As a result, the plant handles less waste than it otherwise could. "The best thing we can do is keep the grease from ever getting in the sewer," Furlow said.

Responding to a state order after paying the first \$40,000 fine for spills, Gwinnett last year started a program to inspect grease traps, the dual underground pits usually located just outside a restaurant's back door. But it's much harder than it sounds. Two inspectors were hired to go from restaurant to restaurant, opening up manholes and plunging a clear cylinder "sludge judge" into pits full of the slimy white substance with a knock-you-down odor. They both quit not long after training, then a replacement quit.

With an annual salary of about \$23,000 a year, grease-trap inspecting is not the easiest job to fill. At one restaurant, senior monitoring technician Samuel Jinkins said the grease in the trap was "solid all the way to the bottom." Water had cut a channel through the muck to get to the sewer line. "I've never been knocked down" by the smell of decaying animal fat and food particles, he said. "There have been occasions where I had to walk away."

The restaurants themselves have almost as high a turnover rate. Inspectors will educate one manager on the need to regularly pump out the grease trap, and by the next visit, they have to start over with a new guy.

Often it's last on the to-do list. It can cost from \$250 to more than \$1,000 to pump out grease traps. Then there's just the daunting task of inspecting Gwinnett's 1,420 food establishments. Right now there's only one grease-trap inspector in place, with three more jobs to fill. While Gwinnett has a long way to go, last year the county was, for the first time, inspecting grease pits *before* a sewer backed up.

Inspectors looked at 282 restaurants last fall in the fast-food havens on Jimmy Carter Boulevard, Beaver Ruin Road, Indian Trail and Pleasant Hill Road. They didn't mete out any fines. Instead, they instructed the managers on what's required and issued warnings when the pits weren't pumped out as asked. Jinkins said most restaurants are responsive. The only fine recently handed down for dumping grease into the sewer line was given to Rudolph Foods Co. Inc. in Gwinnett Progress Center near Lawrenceville.

The company, which makes pork rinds, last year paid almost \$1,000 - the cost to the county to fix a blocked sewer line. The company has since added at least one grease trap and tried other fixes. Now the county is forcing the company to build a pretreatment system to get rid of the grease before it can get to the trap. "We don't want (to take) the money out of an industry," public utilities director Furlow said. "We want to change the behavior of the industry...Our goal as an environmental organization is to protect the water quality" (Shelton, 2000).

Newspaper headlines from around the country also relate the negative environmental and economic effects of sewer collection system clogs caused by spent FOG:

- *Los Angeles Times: Home Edition, January 10, 2001:*
Restaurants stuck with a problem sanitation

A recently completed EPA audit blames grease blockages for 41% of Los Angeles' sewer spills between 1997 and 1999. The audit stated that improperly disposed grease accounted for 200 to 250 raw sewage spills each of the two years the report covered, and most grease caused spills were isolated near restaurants.

In an attempt to deal with the growing problem, Los Angeles' officials are working to strengthen local laws regulating restaurant grease disposal. The city's Bureau of Sanitation reports that there are currently an estimated 10,000 restaurants, school cafeterias and other food service operations, however fewer than 400 of the largest facilities are currently subject to city inspection (Gold, 2001).

- *The Orange County Register, August 12, 2000:*
Eateries clog sewers' arteries

Grease from restaurants and densely populated apartment buildings clogs sewer lines and causes an avalanche of small sewage spills around Orange County - a problem that can pollute beaches and that most cities are doing little to stop. Virtually all new restaurants in the county are required to install grease interceptors that catch and separate grease and are emptied periodically. However, cities don't inspect them, according to a sewer district report, and many are reluctant to place new laws on existing establishments. When Newport Beach tried to force older restaurants to install the traps seven years ago, restaurateurs revolted and the City Council backed down. Cities are reluctant to make any laws that would deter restaurants from coming into town, say some city officials. Several communities - including Anaheim, Costa Mesa, La Habra, Orange, Santa Ana, Seal Beach, Tustin and Laguna Beach - don't have grease discharge ordinances.

Even when grease traps are used they aren't always properly maintained, said Allen Stroh, a program manager for the Orange County Health Care Agency, which deals with restaurant grease. "A lot of the time people aren't aware of them," he said of the interceptors. "You have such tremendous turnover in the restaurant industry. People don't know about maintaining them or don't have them cleaned out regularly. When they clog up, of course, we have sewage spills."

A survey released in June by the Orange County Sanitation District of 29 cities and sanitation districts in north, central and part of south Orange County during 1998-99 concluded that greases "are the major cause of sewer blockages and resultant sanitary-sewer overflows." "If you want to stop sewage spills, you have to stop the grease," said Rob Hamers, manager and district engineer for Costa Mesa. "You can televise the sewer lines, you can cut roots, but you have to do something about the guy who is pouring grease down the drain by the gobs."

Orange County has 12,000 miles of sewer lines. Most of them are smaller pipes, in greater danger of getting clogged by grease. In the past 4.5 years, clogged pipes caused 670 sewer spills, more than half of all Orange County spills, an analysis of county records shows. Such grease-caused clogs used to be rare - at least, up until 1979, when Proposition 13 ended many sources of funding for public agencies in California. After that, sewer agencies and cities that previously cleaned sewer lines routinely for free began stopping those programs, Stroh said.

Some restaurant owners who have experienced sewage spills on their properties think they were treated unfairly or improperly blamed for clogs that may not have been their fault. Some smaller establishments, like those in crowded Laguna Beach, haven't the space for them. Just 25 percent of the approximately 50 restaurants in that city have grease traps (Kingsley, et. al., 2000)

- *Nations' Restaurant News, June 8, 1998:*
Tapping plumbing services to thwart grease, avoid backups
(plumbing problems in food service industry)

In day-to-day operations, the kitchens at quick and table-service restaurants can generate inordinate amounts of grease, which can accumulate and solidify in the wastewater drains. And if an operator's plumbing system backs up, it can leave the establishment wallowing in sludge and result in a temporary shutdown. In an effort to address such problems before they occur, some foodservice operators have contracted with service companies to establish annual maintenance agreements to clean their drains and grease traps. The most subterranean part of a restaurant's plumbing system, grease traps capture grease and oil from their drains.

Some operators may not give grease traps too much thought, but that can change quickly when wastewater lines clog. That is what occurred several years ago at the Franklin Mills shopping center in Philadelphia, which houses 49 foodservice outlets. "We had a serious backup at one food court that lasted a good three hours," recalled Ernie Bouboulas, an operations manager at the mall's 900-seat food court. "But we came to the immediate realization that we needed to do more than wait for an emergency" and retained the services of a sewer maintenance company.

On a quarterly basis, the company uses a high-velocity pressure system, called a hydrojet, to flush the food court's plumbing line, and a suction hose pumps the mall's 6,000-gallon grease trap. The grease trap at an average freestanding quick-service restaurant has a capacity of several hundred gallons. To treat the mall's two food courts four times per year, the operator pays the service company about \$2,500. "We haven't had any backups since," Bouboulas said.

Seravalli Restaurants Inc. experienced a similar sewer mishap a few years ago at one of its Philadelphia-area units. "We had a backup at one store and had to [temporarily] close the unit on a Saturday afternoon, our busiest period of the week," Seravalli controller Wayne Metzinger said. "During one monthly stretch the sewer backed up four or five times."

If sewers are not correctly drained or are left untreated over time, backups could be a recurring problem, especially for those restaurants in mature sites, like malls and strip centers, where all six of Seravalli Restaurants Inc.'s units are located. Metzinger said that at one unit that experienced recurring backups, the quarterly costs of \$400 (for grease trap and sewer line maintenance) are quite negligible. "Considering the alternative of closing the store, the price is next to nothing," he said (Rubinstein, 1998).

3.1.4 Bioaugmentation

The use of specifically selected bacteria designed to increase the degradability of target compounds is called bioaugmentation. Scientific research over the past decade has shown that bioaugmentation is effective in degrading spent FOG wastes:

Use of respirometry to evaluate the efficacy of biological products for the biodegradation of wastewater grease and oil

by J.L. Tisinger and D.J. Drahos.

Presented at the *Industrial Waste Conference*, West LaFayette, IN, May 6-8, 1996.

Abstract: A laboratory screening protocol was developed to test the efficacy of commercial bacterial products for enhancing the biodegradation of wastewater grease and oil. Biological products formulated with several species of commercially grown bacteria were used to evaluate the biodegradability of waste grease and oil obtained from industrial wastewater treatment systems, municipal lift stations and restaurant grease traps. A biological product is a combination of several natural, environmental bacterial isolates commercially grown and formulated with chemical components to enhance the biodegradation of recalcitrant compounds. The process of adding commercial bacteria to increase the degradability of target compounds is called bioaugmentation. The commercial cultures consist of bacteria selectively enhanced and enriched to provide a superior rate of degradation of grease. The chemical components consist of macro and micronutrients, pH buffers, enzymes, growth inducers, stabilizers and low concentrations of biodegradable surfactants. The two biological products used in this study contained both vegetative and sporulated species. Both gram-negative and gram-positive species were tested. In order to test many samples economically, respirometry was chosen to provide a quick, inexpensive, and reproducible method for measuring grease biodegradability. Our overall project goal was to determine the potential of our biological products compared to the indigenous bacteria for the biodegradation of the field-collected grease samples. The findings of this study showed that the biological products significantly improved the biodegradability of the waste grease compared to the indigenous micro flora.

Investigation into microbial removal of fats, oils and greases

by N.G. Wakelin and C.F. Forster

Bioresource Technology, vol. 59, no.1, pp. 37-43, 1997

Abstract: Fast-food restaurants generate grease-containing wastewaters for which there is, currently, no acceptable treatment technology. The development of microbial cultures for use in a bioreactor could, therefore, provide effective treatment of these wastewaters. Thus, the growth of a range of pure and mixed cultures was examined using vegetable oils, lard and 'grease' from a fast-food restaurant grease-trap. The pure cultures were *Acinetobacter* sp., *Rhodococcus rubra*, *Nocardia amarae* and *Microthrix parvicella* and these were compared with

a mixed culture isolated from a grease-trap, MC1, and with activated sludge. The effectiveness of these cultures was assessed in terms of their grease-removal efficiency, the biomass production and yield coefficients. *Acinetobacter* was the most effective of the pure cultures, typically removing 60-65% of the fatty material whose initial concentration had been 8 g/l. The effectiveness of the mixed culture, MC1, was variable, with the removal efficiency ranging from 29% for rapeseed oil to 73% for the restaurant grease. The activated sludge gave a more consistent removal, which was generally better than 90%. However, there was a lag phase of about 1 day in every case. Acclimatized activated-sludge did not exhibit a lag phase and also achieved a high (> 90%) removal efficiency. The absence of a lag phase resulted in faster growth and fat removal.

At issue is not the fact that controlled laboratory research has showed bioaugmentation can be effective, but because of the proven ability of bacteria to 'eat' spent FOG, many private companies have begun aggressive marketing campaigns designed to sell food service operators on the belief that they can self-maintain their grease traps using specially designed 'bugs'. A recent check of a popular search-engine on the Internet retrieved over 15 companies marketing designer bacteria and enzymes to the food service industry. While some companies state that their products are designed to aid a well managed grease trap maintenance plan, the marketing material of other firms make claims that the use of their product will completely eliminate the need for grease trap cleaning.

While research shows that there are effective bioaugmentation agents in existence, there is also no way to verify the effectiveness of a particular proprietary formula marketed to the food service industry. The simple appearance of effectiveness is not enough. Products exist that are often sold as bioaugmentation agent that simply act as emulsifiers, allowing the spent FOG to remain suspended in the wastewater stream until it leaves the grease traps and enters the collection lines. Also, many effective bioaugmentation formulas take many days to degrade spent FOG, which is much longer than the retention time of most grease traps. In addition, there is the possibility that chemical or biological agents poured into grease traps can harm both the collection system infrastructure and ultimately the microorganisms in the receiving wastewater treatment plant. Due to these concerns, the decision to use bioaugmentation in a food service grease traps should be made cautiously, and regulatory officials alerted to their use (see Section 3.3).

3.2 Selecting a Hauler

In many areas of Georgia, food service operators are faced with thumbing through the local Yellow Pages directory as the only resource for locating a company that will service small generator grease traps. Although in some cases the phone directory can be a starting point, there are more effective and efficient ways of selecting a spent FOG hauler:

1. Check Appendix A of this report for haulers servicing Georgia. In addition to your local phone directory, Appendix A of this report contains a reference map and database of companies that offer grease trap cleaning and hauling as a service. The information contained in this database was obtained from phone interviews with representatives of each company.
2. Check with other food service operators in the same area. As it is with many business services, word of mouth is often the most effective tool for finding reliable assistance. Although many areas are densely populated with food service establishments, individual operators rarely communicate with other businesses. Food service operators should take the time to ask business neighbors for their recommendation and experiences with grease traps services. Also, if businesses are currently receiving reliable, affordable service, they should take every opportunity to make recommendations to their food service neighbors.
3. Call spent FOG treatment facilities to ask for hauler references. Although some treatment facilities only accepted spent FOG collected by their own service vehicles, many companies also accept waste from independent haulers. Appendix B of this report provides a reference map and database of the treatment facilities profiled. Food service operators can contact these facilities to inquire of their services and ask for recommendations for the independent haulers from which they accept spent FOG.
4. Check with the local pretreatment program staff if food service wastewater is discharged to a local publicly owned sewer system (see Section 3.2.1 for more information). There are currently about 50 Georgia cities that operate state approved industrial pretreatment programs. Many regulate the operation and maintenance of grease traps whose effluent flows to publicly owned sewer systems. Many also maintain a list of haulers that service grease traps in their jurisdictions.
5. Check with the local county health department if food service wastewater is discharged to a privately owned on-site treatment system (see Section 3.2.2 for more information). The state's system of public health districts and counties maintain lists of approved haulers that can pump waste from grease traps and privately owned on-site wastewater treatment systems.

As with any business, although there are many grease haulers that offer reliable, affordable and environmentally-minded service, there are also haulers who are unscrupulous. Food service operators must be educated to the unethical practices certain haulers employ in an attempt to circumvent proper spent FOG handling procedures.

The term 'Pump-and-Dump' is used to describe the practice where unethical haulers come to a food service establishment with a full load of spent FOG obtained from an earlier visit to another site. First, although the hauler appears to put in a hose and pump OUT of the food service grease trap, they are actually first pumping IN to the grease trap causing the trap to overflow into the effluent collection system. When the truck tank is empty, the hauler simply reverses the process and removes the remaining material in the grease trap. If the food service operator inspects the grease trap after the operation is complete, all appears normal. The hauler simply takes his tanker to the next site and repeats the illegal procedure again and again.

Another major environmental concern involving unscrupulous haulers is illegal dumping. Unlike the theft of yellow grease discussed earlier in section 2.0 of this report, illegal dumping has been a major problem for decades. Recent incidences of illegal dumping have made headlines throughout the county:

- *EPA Region 3 Press Release, Nov. 7, 2000 - Philadelphia, PA:*
Waste Hauler Sentenced on Restaurant Grease and Auto Sludge Charges

A waste hauler in Harleysville, PA was sentenced to 6 months house arrest, 5 years probation, a \$15,000 fine and \$56,856 restitution for illegal disposal of liquid waste from restaurant grease traps and petroleum sludge.

This case is part of an on-going initiative by EPA to crackdown on waste haulers who violate the Clean Water Act by dumping grease and sludge at municipal sewer treatment plants. This type of waste must be disposed of at specifically designated treatment centers.

- *The Idaho Statesman, January 30, 1999:*
Illegally dumped grease plagues Meridian (Idaho) sewers

Restaurant grease haulers are flushing thousands of gallons of grease into Meridian's sewer system, causing backed-up drains and costing the public thousands of dollars. Officials always have had problems with grease disposal, but the city's growth has made matters worse.

Celeste Vialet, with the Meridian Wastewater Department, suspects many of the dumpers find a manhole in an isolated place and pour the grease in. "There are a lot of subdivisions with streets and sewers, but no homes, and there are a lot of business areas that are vacant at night," Vialet said. "It's a problem with growth."

Meridian requires restaurants to have a thousand-gallon grease trap between their kitchen and the sewer. Grease floats to the top, food particles sink to the bottom, and water passes through. The traps must be cleaned, sometimes as often as once every two months, depending on the restaurant. The city sends inspectors out to make sure they're being cleaned. A special truck sucks the grease and sediment out of the trap and is supposed to take the waste to one of two landfills that are authorized to accept it. The landfills charge 17 cents a gallon to accept grease. That comes out to nearly \$200 for a truckload, said a local hauler, who hauls grease in Meridian. Instead of taking the grease to landfills, some haulers are finding a manhole in a remote location. Some also may be cleaning the trap, then sticking the hose into the city sewer line right at the same location and emptying the tank, which makes it harder to catch.

When dumped into the sewer, the grease coats the inside of the line, clogging it and causing backed-up plumbing in adjoining homes and businesses. It costs the city \$300 to \$500 to unclog the line. The grease also oozes into the city's treatment plant, where it gums up the machinery and adds to operation expense. "You get these big gooey balls of grease and you can't break it down, you can't dissolve it," Vialet said. "When you get a whole shock load of 300 to 400 gallons at once, you know someone's dumped on you."

Boise also has had problems with grease dumpers and has caught a few. Boise regularly inspects its sewer lines with a special video camera, so it can sometimes trace dumpers. "But if somebody's pulling up a manhole in the middle of the night, that would be very difficult to catch," said Richard Dees, operations manager for Boise Public Works. Meridian doesn't regulate grease from homes. Vialet said it's best for residents to save their grease in a can and throw it away, since it will clog household drains. Illegally dumping grease is a misdemeanor. Meridian police are on the lookout for violators, and residents should call if they see something suspicious, such as a truck pulling up to a manhole late at night. Grease trucks are extremely loud and stinky. Vialet said most grease haulers obey the rules, but the ones who illegally dump grease are able to under-bid the honest ones. The solution, Vialet and Burnette said, is to have an Ada County grease dump instead of hauling it to a neighboring county. Restaurant operators also need to stick with reputable haulers (Johncox, 1999).

When contacting prospective haulers, food service operators can benefit from some basic knowledge of industry terms. Along with discussing the cost of services, availability, and scheduling; food service operators should inquire if the haulers ‘full-pump’. Full-pump is the term used to describe the practice of pumping out a grease trap completely, removing not only the floating spent FOG but also the settled solids at the bottom of the tank and any associated wastewater. There is dispute within the industry whether proper maintenance of grease traps can only be accomplished by full-pumping the trap during each cleanout. Or if simply ‘skimming’ the spent FOG from the surface of the wastewater is adequate during regular maintenance, thus avoiding the need to handle and dispose of the bottom solids following each servicing, and full-pump is only required periodically when solids build up in the bottom of the grease trap.

Other questions of prospective haulers might include what contractual service options are available. Most haulers offer contracts for regularly scheduled service, while others simply respond to customers phone calls. Is the load of spent FOG collected by the hauler manifested? A manifest is a form used to accurately track loads to ensure proper handling. Will the hauler notify customer of upcoming service? Food service operators must be prepared to become familiar with and periodically inspect the work done by a hauler. This will involve understanding and observing the whole collection process, not just completing a visual inspection once the service is completed. More detailed information on the grease trap and septic pumping industry is available on the Internet at <http://www.pumper.com>.

3.2 Environmental Regulators of Grease Traps

Depending on whether the discharge of wastewater effluent from a food service establishment flows to a municipal sewer system or to a privately owned on-site wastewater treatment system will determine which environmental regulatory authority will oversee grease trap operation and maintenance at a particular facility.

Local industrial pretreatment programs usually regulate grease trap wastewater effluent that is discharged to publicly owned sewer systems. However, if a facility’s wastewater is treated on-site, then regulatory power falls under the Georgia Division of Public Health and its network of county health departments.

3.2.1 Industrial Pretreatment Programs

Long-term environmental regulatory trends, beginning with the Clean Water Act of 1972, have resulted in ever restricting regulations on the control of wastewater streams.

However, along with an increase in restrictions, the trend during the 1990's was the diminishment of federal grant funding for replacing and maintaining municipal sewer systems. This lack of funding has put a financial strain on publicly owned sewer system infrastructures. In response, municipalities have increased the scope of wastewater pretreatment programs to oversee restaurants, hospitals, prisons, schools, cafeterias and other spent FOG discharging sites to prevent grease from entering sewer systems and to recover service costs associated with the repair and clean-up caused by sewer clogs.

Currently, about 50 cities in Georgia operate state approved industrial pretreatment programs. The Georgia Department of Natural Resources, Environmental Protection Division, oversees the local programs, as well as acting as a statewide pretreatment program for Georgia's rural areas. The goal of pretreatment programs is quite simple – to protect municipal wastewater treatment systems from the negative impacts of non-sanitary wastewater discharges. In other words, it is the job of pretreatment programs to watchdog commercial businesses and industries that discharge wastewater from their manufacturing facilities.

First and foremost, pretreatment programs closely monitor industries and businesses whose wastewater discharge could have dire effects on sewage treatment plants if left unchecked. In addition, due to the potential spent FOG has for clogging sewer lines, many cities have programs that monitor grease trap cleaning and maintenance at food service establishments. However, as the case is with many government agencies, many pretreatment programs do not have the resources to oversee what in many cases in urban areas amounts to hundreds and thousands of food service establishments.

Appendix C of this report has both a reference map and a database for the Georgia's state approved pretreatment programs. If food service operations deposit wastewater into publicly owned sewer systems, it is important that the local pretreatment program be contacted to ensure complete regulatory compliance with existing regulations.

In addition, rules and regulations addressing the various requirements for grease trap installation and maintenance as well as other information on local pretreatment programs can be found in the local Sewer Use Ordinance issued by each municipal or county water system. Food service operators should request, receive, review and understand the specific environmental rules and regulations governing each operation.

3.2.2 State and Local Public Health Departments

Food service establishments, located mostly in more rural areas of the state, which have on-site sewage treatment systems that collect and treat spent FOG with no discharge to a publicly owned sewer system, fall under the jurisdiction of state and local public health programs.

The Georgia Department of Human Resources (DHR), Division of Public Health, Environmental Health and Injury Control Branch, oversees an Environmental Services program whose mission is to “provide surveillance of environmental factors which may adversely affect the health of people and for compliance with state laws” (Georgia Public Health, 2000).

Along with overseeing more familiar areas such as restaurant food safety, the Georgia Division of Public Health and their associated statewide network of district and county offices, also operate a program that regulates Individual On-site Sewage Management Systems. The goal of the program is the minimization of health problems related to untreated sewage through on-site evaluations of septic tanks and other self-contained wastewater treatment systems. Although overseen at the state level, monitoring of systems is the responsibility of district and local environmentalists.

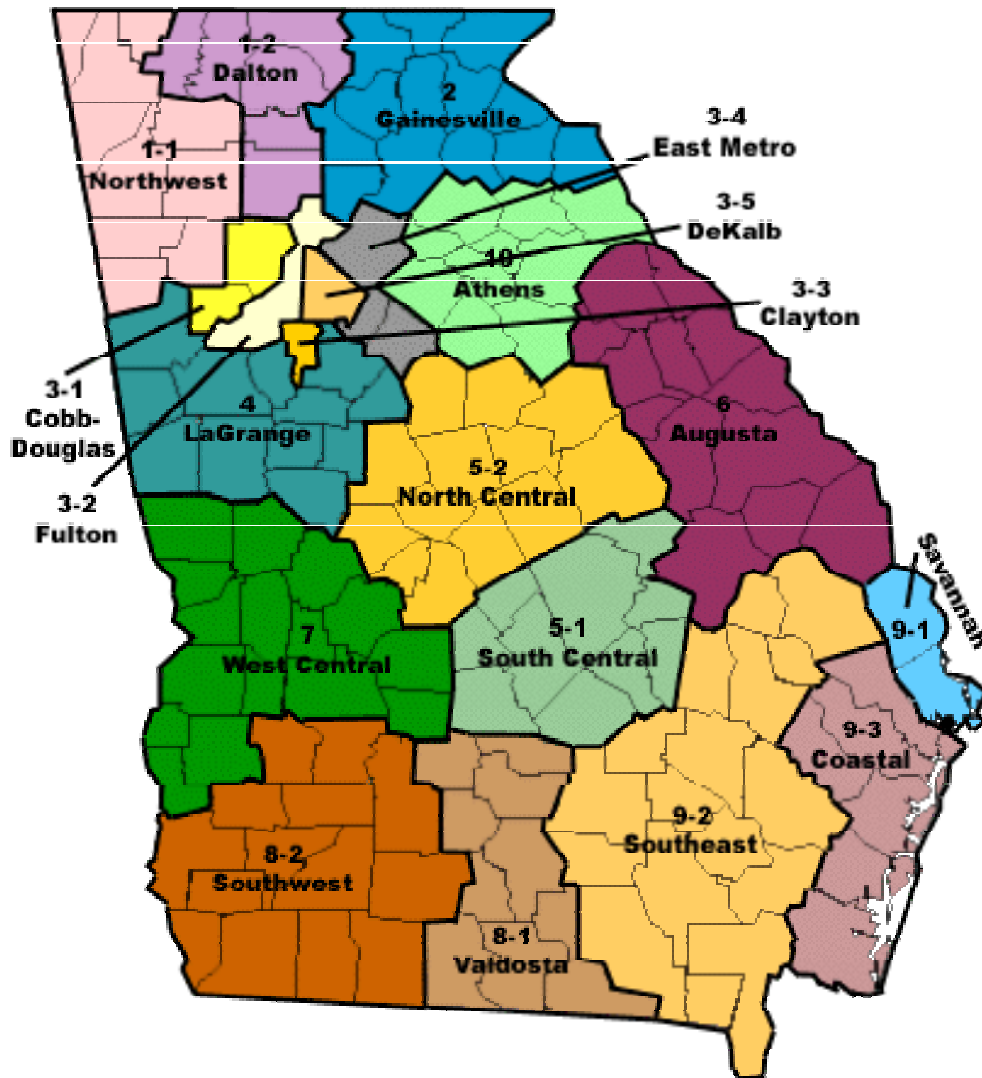
Within the Individual On-site Sewage Management Systems program are the two committees and one board that oversee specific areas. The Technical Review Committee (TRC) makes recommendations to DHR regarding the approval of new systems, aids the Department with the development and revision of standards and guidelines for new technology, assists with the adoption of periodic updates to the *Manual for On-site Sewage Management Systems*, and serves as the final authority in contested interpretation issues.

The Soil Classifier Advisory Committee (SCAC) is responsible for the certification, oversight, performance assessment and recertification of persons who classify soils for on-site sewage management systems.

Finally, the program also has a Certification Review Board (CRB) that is responsible for the certification of persons who install, inspect, pump, service and/or maintain on-site sewage management systems (including grease traps).

The Internet provides detailed information on the Georgia Division of Public Health’s local districts and county offices. By viewing their website at <http://health.state.ga.us/> information is available on individual state public health offices using an interactive map (see Figure 4).

Figure 4. Georgia Division of Public Health Districts and County Clusters



source: Georgia Division of Public Health Internet website, 2001

The Rules and Regulations governing On-site Sewage Management Systems can be found in Chapter 290-5-26 of the Georgia code. Specific rules governing grease traps as part of on-site sewage management systems are found in Chapter 290-5-26-.12:

1. “Grease Traps Required” – Grease traps shall be required for commercial and industrial establishments with on-site sewage management systems where it is determined by the County Board of Health that the amount of grease introduced into the system is in excess of 50 mg/l (milligrams per liter).
2. “Grease Trap Design” – Plans and specifications for grease traps shall be submitted to the County Board of Health for approval. The County Board of Health shall review the grease trap design in accordance with minimum design and construction criteria established by the Department’s current manual for On-Site Sewage Management Systems. Effluent from grease traps shall be disposed of in a septic tank and not directly discharged to the absorption field. Grease traps shall be located, installed and constructed so that the temperature of the sewage will be reduced to permit congealing or separation of grease, and easy access for cleaning is provided.

Note: One additional regulatory agency has jurisdiction over certain environmental rules and regulations governing Georgia’s grocery stores. The Georgia Department of Agriculture, Grocery Stores Section receives consumer inquiries concerning sanitary conditions relative to food and food borne illness. The section also reviews blue prints of retail operations prior to their construction. For more information concerning grease trap requirements, grocery store food service operators should contact the program’s manager, Bob Sherrer, at (404) 656-3622.

3.3 Treatment / Disposal / Beneficial Use of Brown Grease

Once brown grease has been collected from grease traps, transported to a treatment facility and processed, the final step is the beneficial use or disposal of the recovered FOG material and associated solids. In this section, five disposal / beneficial use methods are discussed. Some of the methods listed are currently being utilized by treatment facilities in Georgia and nearby states, while others are in the experimental stage. The methods explored in this report are: landfilling, land application, rendering, composting and incineration.

3.3.1 Landfilling

One disposal option utilized by several brown grease treatment facilities in Georgia and nearby states is landfilling. Although some people view landfill disposal as a loss of a by-product better suited for beneficial reuse, others feel it is currently the only environmentally responsible option for solidified spent FOG and solids recovered from food service grease traps.

Due to the organic nature of treated brown grease, there is only one major issue that must be addressed prior to land filling spent FOG solids. Regardless of the source of the brown grease, it must be dry enough to pass a paint filter test (EPA method SW-846/9095) and be a non-hazardous waste if it is to be disposed in a solid waste landfill subject to federal and state solid waste regulations. Tipping fees at Georgia solid waste landfills average 30 dollars per ton, but fluctuate based on geographic location and negotiated contracts. Calculated the costs of disposing of brown grease solids must not only include landfill tipping fees, but also transportation costs.

3.3.2 Land Application

The land application of spent FOG materials has been well researched and put into practice over the past several years. Recently, Stephen Rohm, an environmental scientist with the Delaware Department of Natural Resources and Environmental Control, was prompted by the National Association of Waste Transporters (NAWT) to complete a study on the possible recycling of brown grease as an agricultural soil amendment. The results of the research were published in the March 2000 issue of *Pumper*, a waste hauler industry magazine. The following is a summary of his research and literature search findings:

Several application methods can be used to land apply brown grease. Spraying of liquids that contain less than 1% TVS (Total Volatile Solids) of spent FOG is an accepted practice that has been verified in studies and yield acceptable results (Neal, et. al., 1977). However, if the brown grease to be land applied is in concentrations greater than 1% TVS, then application involving surface injection or surface application followed by incorporation should be utilized.

Applied over the top of an existing forage crop at greater than a 1% TVS concentration, spent FOG may have an immediate destructive response by suffocating vegetation. When materials containing a high percentage of fats are applied to the soil, the spent FOG and water disperse.

The water fraction percolates readily. However, the FOG fraction in a liquid form coats soil particles and percolates only slightly into the soil, while any solids lay on the soil surface. Initially, the brown grease makes the soil surface water repellent and may cause soil pore blockage. This of course is an undesirable situation as rain or additional liquid waste will pool on the surface, inhibiting oxygen transfer and water percolation to the deeper soil. Biodegradation, when proper conditions exist (warm, moist, aerated soil with ample supply of nutrients, proper pH and a diverse microbe population) proceeds rapidly enough to correct this impact. However, odor emissions and germination inhibition may still occur. The use of mechanical incorporation devices after application corrects this situation. Incorporation serves many purposes. First, it allows the distribution of spent FOG to a larger population of microbes. Second, it aerates the soil and also allows for greater application rates.

In other studies, field application at a loading concentration of 1.5% total fat to the total soil mass, prior to planting, exhibited negative germination effects (Overcash, 1979). An application rate, limited to a concentration of fat at 1% of the soil mass was reported as being the most desirable rate in that no negative effects in germination were observed. The field research portion of a study completed by Reed and Crities in the 1980's examined application rates up to four dry tons per acre prior to crop planting and found no negative effects. This rate corresponded to a 0.41% total acre-foot application rate. It was postulated that this rate could be applied two times per year (in practice) bringing the total applied to seven dry tons per acre. This rate was under the 9.8 ton per acre suggested limit published by Overcash and Pal in 1979.

The land application of some fats occurs incidentally in the spreading of septic tank waste and some food processing wastes. Septage may contain up to 2.3% fats as reported in the USEPA (United States Environmental Protection Agency) Guide to Septage Treatment and Disposal published in 1994. Although the fat component is not usually considered in land application of septage, the fat degradation process does not seem to affect the septage land treatment process. In the land application of poultry processing plant DAF (Dissolved Air Flotation) sludges for their nutrient content, fat content in excess of 6% did not adversely influence study results (Carr, et. al., 1988). In another study on poultry processing DAF sludge with fat at lesser concentrations, no interferences from the fat content was noted (Ritter, 1982).

Other factors affecting the successful land treatment of brown grease require the consideration of normal agricultural parameters. Measurable parameters such as soil texture, soil

moisture content, soil oxygen content, soil pH, availability of nutrients, and soil temperature need to be known. When the above parameters are within accepted ranges, the land application process of brown grease degradation can occur rapidly and completely. Spent FOG, that contains not only fat but other carbonaceous foods as well, provides an excellent feed source for soil microorganisms. If supplied with proper nitrogen and phosphorus nutrient levels, the soil microorganisms reproduce in large numbers in response to the enrichment, although attention must be given to ensure that a proper carbon:nitrogen ratio is maintained to prevent nitrogen savaging by the microbes (Rohm, 2000). The increased populations of microbes in the soil have the ability to consume spent FOG at an ever increasing rate until the FOG supply is depleted and the population decreases. Carbon dioxide gas is emitted during microbial respiration and the remaining residual carbon is distributed as humic substances adding to the organic content of the soil. The added organic content helps to increase soil porosity, water-holding capacity, soil buffering capacity, soil structure retention and other positive benefits derived from the incorporation of humus or compost into a soil. In many ways, proper land application of brown grease resembles the composting process. It produces a similar soil amendment with the advantage that soil incorporation has already occurred.

The following article appeared on the Associated Press Newswires in 1998. Due to the report's close proximity to Georgia, portions of the article are presented here as a case study:

- *Associated Press Newswire, February 2, 1998:*
Mobile County farmer makes use of Deep South grease

MOBILE, Alabama - Cattle farmer Robert "Buddy" Estis is willing to hold his nose when spraying his hay fields with foul-smelling treated liquid waste from restaurant grease. He says that's because the stuff brings eye-opening green grass. Since January 12 (1998), Estis has received at least 13,000 gallons of restaurant wastewater from north Alabama to fertilize pastureland on his Double B Farms south of Wilmer. The water has been coming from Deep South Land Farming in St. Clair County near Pell City, a company that collects and treats waste from restaurant grease traps. The liquid is high in ammonia and contains millions of tiny food particles, Estis said, but it is not greasy to the touch. Double B is the only farm in Alabama known to be using the waste for agricultural purposes, according to state officials.

New green shoots have sprouted from a 50-acre plot of otherwise dormant grass behind Estis' house on his farm. He credits the wastewater for the unseasonal growth, and anticipates a more extensive application of it during summer's growing season.

As with most organic fertilizers, however, the food wastes have some undesirable side effects, including a putrid odor that the St. Clair County district attorney has called a public nuisance. And like most high-nitrogen fertilizers, it can damage aquatic life if enough of it runs off fields into streams. In September, an unauthorized discharge from an open lagoon at Deep South Land Farming killed hundreds of fish in a creek in the Coosa River watershed.

The company is embroiled in a legal dispute with state environmental officials and St. Clair County residents. Preliminary results released Friday from an independent lab test show that the St. Clair County waste, while rank, contains no toxins or heavy metals that could damage the environment by simple field application.

"That's a good sign," said Ted Breaux, who conducted the tests for the independent firm, LRC Global Technologies of Slidell, La. "We don't see significant amounts any material that would be hazardous in nature. There are more tests coming, but we didn't find any obvious indicators of naughty business." For Estis, however, spent restaurant grease shouldn't be so complicated. He wants it simply as a free and viable nutrient source for his 400 brood cows. Estis also receives wastewater from a grease processor in Vancleave in south Mississippi, which he would not identify. "Once this stuff goes under the ground, it's not going to come back up," he said. "But you've got to stay within the absorption range so you don't contaminate anything. I can assure you, nothing counterproductive will go into that soil."

Another case study on the land application of brown grease, taken from the pages of January 2001 issue of *Pumper*, highlights the services provided by the Thrifty Best Service (TBS) company in Fresno, California, which has operated a state permitted land application operation since 1986:

- *Pumper, January 2001: Back to the Earth*

In many areas, land spreading of septage or grease trap materials is not fully accepted. Getting regulatory permits can be a long and difficult process, and winning consent from neighbors can be challenging. But Thrifty Best Service (TBS) of Fresno, Calif., has been fully permitted to land spread food-related grease waste for 14 years. TBS, owned and operated by Russian immigrant Bill Shubin, gives customers a responsible means of managing restaurant grease trap pumpings and food processing residues - at a time when disposal has become more difficult.

Bill prefers not to call the materials 'wastes'. He calls them products, since he recycles their nutrients into the soil to grow crops. TBS land spreads at Shubin Ranch, a 530-acre section of land 30 miles from Fresno, which produces cotton, along with alfalfa and oats, the latter two for animal feed.

As far as Bill knows, Shubin Ranch was the first and is still the only fully permitted operation for the land application of grease in California.

And TBS was fully permitted 14 years ago in 1986 - this in a state noted for tough regulatory policies. Headquartered in modern offices and yard area in the City of Fresno, TBS collects food-related grease from all over California, as well as from around Las Vegas and Phoenix. The equipment includes 3,500-gallon pumpers that are standard in appearance, and a fleet of 2,500-gallon pumpers whose tanks, pumps and hoses are enclosed within large truck vans. "We use our larger pumpers with their exposed tanks mostly for larger trap work," says Bill. "The pumpers with enclosed tanks were developed for marketing reasons. When the van pulls up to service a restaurant customer, it's more welcome there due to its overall appearance."

To provide efficient service to customers distant from Fresno, TBS stations some pumpers in those areas. To enable efficient transport back to Fresno, the company placed 10,000-gallon collection tanks at the remote locations to serve as temporary collection points where pumper servicemen off-load. These tanks are then serviced by the company's highway tanker/pumpers, which make regular pickups and transport the product to Fresno. One of these transporters has an aluminum tank that allows it to haul a legal load of 6,500 gallons. The transport trucks are also equipped with landspreading devices, which allow them to spray product directly onto land on arrival at Shubin Ranch. If the ground is too wet from rains, the tankers off-load into 25,000-gallon tanks, which hold the product for later spreading as the ground firms up. Equipment housed at the ranch is used to disc all material into the soil.

"We have been using the 10,000-gallon temporary collection tanks for our own operations for about 10 years now," Bill said. "But we have received a lot of calls from other pumpers who have been having trouble getting rid of their grease trap material. So recently, we have placed our tanks in the yards of some other pumpers. When they have a load, they will call us, and we'll pick it up."

Besides restaurants and supermarkets, TBS services many food processing companies, including turkey, chicken and meat processors, canners and frozen food companies - anyone who deals with food.

"We service grease traps on a monthly basis," says Bill. "Most of our work is preventive maintenance. By coming in monthly, we can do things like adding bacteria to help keep grease at the top of the trap. It reduces the solids at the bottom, and keeps the grease softer and in suspension. It also makes it easier to pump. "Our drivers have regular routes, and they know the condition of the traps they service. They will sometimes only pick up the top layer of grease, pumping the whole trap only when they see that it needs to be done."

TBS has modified its pumpers, equipping them with a proprietary system that enables removal of the solids and the top layer of suspended grease, while leaving most of the water behind. Bill relates that TBS recently serviced a large casino hotel in Las Vegas that had problems with its combination of large grease traps, totaling 150,000 gallons. The hotel had been relying solely on bacterial additives for trap maintenance instead of ordering regular pumping.

Bill says the idea to land spread grease products came from his early days on the farm. "I remember hearing about the Indians who took fish remains and put them into the ground when they planted corn, so the corn would grow better," he said. "So we are also dealing with nothing but food, and it is good to put it back into the ground. It came from there, so let's put it back again. The material is beneficial to any ground."

The 530-acre Shubin Ranch is map-sectioned into smaller parcels so that TBS staff can conduct a systematic spreading operation. "I worked with John Minney, my consulting engineer, to see that the whole thing was done right," says Bill. "We tested the ground to see just how much nutrient was already there. And we also knew how much nutrient was in the material we were adding. We then established how much we could put there by agronomic standards. The ground is being tested every month using core samples. That includes checking of absorption rates against the loading rate for the land. John knew all the agronomic figures and other requirements of what had to be done."

Bill first grew alfalfa on 40 acres that had been spread with grease products, while planting the same crop on an untreated parcel alongside. The land treated with grease produced a larger crop. A similar test on a cotton crop brought the same kind of result. "During the growing season, we could see the cotton and alfalfa were much greener and richer in appearance," says Bill. "We also found the treated ground was holding moisture longer than the untreated ground." No other fertilizers were used. The tests showed that yields increased from 30 to 40 percent on the treated land. "We are allowed to basically apply one inch of material per year to the land," says Bill. "Every two months, our engineer brings in a drilling rig to take soil samples for analysis. A report is filed to the County Health Department on that and other activities every three months."

"County Health inspectors come to the ranch monthly to check activity and ground condition, randomly taking grease samples from our truck, and filing their own report," adds Bill, "Our engineer also files reports with the State Regional Water Quality Board, and the State Integrated Waste Management Board." In the initial permitting stages, TBS also dealt with other agencies, like the Fish and Game Department, the state Solid Waste Department, and the federal Department of Reclamation (because Shubin Ranch is next to one of the Department's constructed irrigation canals).

Bill notes that TBS has received no negative reports from permitting agencies. Bill also says that all grease trap pickups are manifested. TBS reports to each county where a trap is serviced, so that each county knows that the material is going to a legal disposal site. For years, TBS has used a professionally prepared color video of its operations. The company sends the video to prospective customers and also distributes promotional mailers. In addition, three individuals in the Fresno office conduct a telemarketing program to advise potential customers of TBS' services and maintain contact with existing customers.

3.3.3 Rendering

The rendering of brown grease for use in traditional byproducts is a relatively new area in the spent FOG handling cycle. Although brown grease is collected and rendered by one Georgia company, Griffin Industries, a company spokesman stated that the yellow and brown greases are collected, hauled and processed as separate raw materials streams. While Griffin renders yellow grease with the majority of the resulting product going to the manufacture of animal feed, their brown grease product is not used as an animal feed ingredient, rather it goes to making products like industrial lubricants.

The used of brown grease as an ingredient in animal feeds is controversial. The U.S. Department of Health and Human Services, Public Health Service of the Food and Drug Administration (FDA) has been somewhat ambiguous in their stance on this issue. The following is an excerpt of a 1995 letter from Dr. Daniel G. McChesney, who at the time was the Acting Chief of the Animal Feed Safety Branch of the FDA. The letter was sent to a Georgia company inquiring about the use of brown grease in animal feeds:

“FDA is opposed to the use of sewer grease or any product which has come in contact with or passed through the same drain as sanitary sewer water or solid matter as a component of human or animal food (*author’s note: normal installations of food service grease traps place the device in drain line prior to the entry of sanitary waste*). Furthermore, we are also opposed to the use of grease of unknown origin as a component of human or animal food. We affirmed this position through regulatory action in August 1990 in which a Warning Letter was issued to a Colorado firm and again in 1994 with Warning letters to firms in Georgia and Alabama.”

“The basis for Issuance of the Warning Letters was that sewer grease or grease of unknown origin are ‘unfit for food’ and therefore adulterated, because the potential contaminants could not be known with any certainty. We continue to support this position. This position specifically addresses sewer grease and grease of unknown origin and should not be interpreted as unilaterally applying to all grease trap waste.”

“It is the position of FDA that a product intended for use as a feed or feed ingredient must not be adulterated as defined in Section 402 (a) of the Federal Food, Drug and Cosmetic Act. Section 402 (a) of the Act has numerous provisions for establishing adulteration. The most appropriate subsections of 402 to apply to recycled grease trap grease are (a) (1) and (a) (3). Section 402 (a) (1) states in part that a food (feed) shall be deemed to be adulterated “If it bears or contains any poisonous or deleterious substance which may render it injurious to health” and subsection (a) (3) states in part, “if it is otherwise unfit for food (feed).”

“FDA would oppose the use of grease trap waste from floor drains, pot wash drains, dishwasher drains, sink drains, etc. In animal feed unless the contaminants were known (or not present) and did not result in unsafe tissue residues in milk, meat, and eggs or present a health hazard to animals. We have not opposed the use in animal feed of 'restaurant grease' or 'sludge' when it consists entirely of edible by-products used in, or obtained from, the preparation of human food.”

“Our principle concern over the use of grease trap waste are related to the poorly defined nature of the product; the numerous sources that can range from restaurants, to laundries, to industrial manufacturers; the collection vehicles/receptacles which can vary from dedicated trucks and receptacles to collection by the same trucks used to pump septic systems; the variety of contaminants possible; and the level of control (or lack of control) encompassed by local, and State laws/regulations.”

“In addition to the concerns stated above, the processing of grease trap waste, or other potential recyclable material, can vary from minimal with no testing for contaminants to commercial processing, such as rendering, with pesticide and chemical screens. Clearly, with all these variables, regulating this portion of the recycling industry is challenging. Regulating it on an other than a case-by-case basis at the federal level is currently not feasible.”

“In addition to FDA guidance, the 1994 Official Publication of the Association of American Feed Control Officials (AAFCO) includes a Note in the Fat and Oils section and definitions addressing this issue. In summary it is possible to envision scenarios for the handling and processing of grease trap waste that could result in a final product acceptable for animal feed and others that would not result in an acceptable feed product.”

Daniel G. McChesney, Ph.D.
Acting Chief
Animal Feed Safety Branch

3.3.4 Composting

Although spent FOG and their associated settled solids are compostable materials, almost all existing information available discourages the use of FOG related materials in compost recipes. Warnings include problems with odors, the attraction of rodents and the increased time required for material breakdown due to the ‘coating’ action of FOG on compost raw materials. However, under the right conditions, the composting of spent FOG and solids can be a viable option. Two case studies involving unique applications of the composting of spent FOG and solids are presented here:

Case Study 1: (Victoria, Australia 1994) University researchers from La Trobe University in Bundoora developed a specialized composting process to recycle a range of organic residuals from food and agricultural industries, which included grease trap sludges, food-processing biosolids, and abattoir wastes. Using a system called Environmentally Controlled Composting (ECC), separated grease trap sludge material was mixed in a twin auger cattle feed mixer with wheat straw and wood shavings. The mixture was then enclosed in a specially designed air-tight reactor. All materials and raw ingredients were chemically and physically analyzed prior to composting. The operation of the reactor involved adding a small amount of the compost end-product back into raw mix as an inoculum. Upon completion of composting, a fully stabilized product demonstrates little, if any, demand for oxygen and a relatively short curing period (Joshua, et. al., 1994).

Case Study 2: (Payette, Idaho 1999) At the Clay Peak Landfill, operator had begun to chip incoming woody material when the facility first opened in the early 1990's. After six years of stockpiling the chips, several thousand cubic yards of the material had accumulated. Then, county officials voted to ban the dumping of material from restaurant grease traps and garbage disposals at the municipal wastewater treatment plant.

In an attempt to assist the community with handling the newly unwanted waste, landfill operators began putting the chips in excavated holes dug four feet deep, 12 feet wide and 50 feet long. Then the operators began pouring the waste grease and food residuals on top. Another load of wood chips was placed on top of the open piles and allowed to remain static for 1-3 months. The holes were then excavated and placed on top of a wood chip bed for composting in windrows measuring an average of 14 feet wide, seven feet tall and 300 cubic yards in volume.

In addition to the wood chips and waste products, the operators also began incorporating wastewater treatment biosolids into the process. Periodically, brush, wood, hay, straw, grass clippings and leaves are ground and added as necessary. "In the beginning, we kept the windrows separate so if there were any problems, we would know where they were coming from," said Dennis McGehee, who manages the landfill. With a buffer from neighbors measuring more than 2 miles away, odors have not been an issue. The piles initially were high in moisture content, but with only 12 to 14 inches of rain annually, the biggest problem is keeping windrows wet during the summer months. Operators must add water to the piles every day of the

workweek from June through August. Because of the difficulty in maintaining the proper moisture level, maintaining high temperatures in the biosolids windrows can be difficult.

However, this problem seems to have been solved by adding additional spent FOG to the affected piles. Windrows are mixed about once a week, and composting takes 8-9 months. "I couldn't keep up with watering last summer, which slowed down the process," explained McGehee. "But our material was a lot finer when it was done." From October of 1998 through May of 1999, 3,800 tons of compost were sold at \$7.50 per cubic yard (Biocycle, 1999).

3.3.5 Incineration

Although not specifically practiced as a current method of dealing with the residuals of processed brown grease in Georgia, the incineration of spent FOG could be an effective disposal method, or more importantly a valuable beneficial use option. One test completed by the University of Georgia's Feed and Environmental Water Laboratory on a processed brown grease sample showed that the material contained the energy equivalent of 17,100 BTU/lb (Bush, 2000). Currently in Georgia, American Proteins is burning poultry fat in the boilers of their Cuthbert and Cumming plants. The poultry fat is being used to replace #2 fuel oil and natural gas. Testing shows that poultry fat contains the equivalent of 16,000 BTU/lb. #2 fuel oil contains about 18,000 BTU/lb, but current prices range between \$0.17 and \$0.18/lb. On the other hand, poultry fat costs only \$0.06 to \$0.10/lb.

The incineration of poultry fat involves some special concerns, including recirculating flue gas back to the boiler since fat carries its own oxygen, the preheating of the fat about 160 degrees F to burn well and the need to maintain a temperature of 85 to 90 degrees F to allow the fat to flow well through the system. As with any incineration process, air emissions would have to be monitored and controlled. Although simple disposal could be the goal of incineration, utilizing spent FOG as an energy source could be of beneficial use.

3.4 Brown Grease Treatment Company Profiles

A total of eight brown grease treatment facilities were contacted by phone for inclusion in this report. Seven of the interviewed facilities are profiled here (see Section 2.5.2 Griffin Industries to read the profile of the eighth company). Of the eight facilities questioned, seven accept brown grease from small generator food service establishments. Allwaste/PSC currently accepts brown grease only from larger commercial and industrial customers.

3.4.1 Allwaste (PSC)

Allwaste (PSC), located in Fairburn (Fulton County), accepts and treats brown grease from manifested independent haulers. Currently, PSC only accepts commercial and industrial grease trap materials. Fees charged to independent haulers range from 12-14 cents a gallon. PSC has decreased the amount of grease trap FOG they accept as a result of complaints of odor from a nearby residential area. Currently, PSC only accepts FOG from three independent haulers.

For the treatment of the brown grease, PSC has four 11,000-gallon reactor tanks that are used to pre-treat the spent FOG. The pH of the material is first lowered to 2.5-3.0 through the addition of ferric chloride or sulfuric acid and mixed for 30 minutes to break the oil emulsion for coagulation. Next, the pH is brought back up to 7.0- 7.5 with hydrated lime and mixed for 15-20 minutes. A cationic or anionic polymer is then added to the solution and mixed for 30 minutes to one hour. The mixer is then turned off and the resulting floc is allowed to settle. The separated water is drained and placed in an equalization tank where bacteria are added as a bioaugmentation agent to breakdown the remaining grease in the water. Once the bioaugmentation process is complete, the remaining water fraction is then taken to a Fulton County wastewater treatment plant.

The solids recovered during the process are placed in a sludge tank and then pass through a belt filter press. The belt press cake is deposited in dump containers and transported to the Live Oak landfill in Atlanta for disposal.

3.4.2 Boca Industries

Boca Industries, located in Cobb County is a brown grease processor serving the Georgia food service industry. Boca is a self-described “centralized pretreatment facility for small quantity generators”. Services offered include acceptance of spent FOG from manifested independent haulers, emergency support for large quantity generators, water treatment services and contract grease trap cleaning for food service establishments.

In response to many publicly owned wastewater treatment facilities announcement in the mid-1990’s that spent FOG would no longer be accepted, Boca began accepting and processing brown grease. At the start of operation, independent haulers were required to have one manifest for every ten loads of brown grease received. As regulations have changed, Boca now requires that every load have a completed, accurate manifest.

Along with accepting spent FOG from independent haulers, Boca operates its own 4,800-gallon trucks that collect brown grease under contracts with a major restaurant and grocery store chain with locations throughout the state. In an effort to educate and inform their clients, Boca provides each customer with a report detailing the percentage of wastewater, floatable FOG, and settled solids in each grease trap serviced in an effort to assist the client in accessing the need for cleaning frequency.

Spent FOG haulers deliver the brown grease to a central receiving location where the FOG undergoes a basic two-step process, physical separation followed by batch chemical flocculation. After separation and processing, flocculated sludge is dewatered using either a plate filter press or a belt rotary vacuum filter. The dried cake is then landfilled. The treated water is sent to the Cobb County R.L. Sutton wastewater treatment plant, which is located directly across the street from the Boca facility.

The cost for services is dependent upon whether Boca collects and processes FOG or simply processes FOG brought in from independent haulers. Cost of collection and processing for clients is usually in the range of 25-27 cents per gallon. Fees assessed to independent haulers for FOG processing is approximately 15-20 cents per gallon. Boca's main service area is Atlanta but will accept waste from anywhere and will clean out traps if an adequate contract price is established with the client. Boca has plans to expand in the future.

3.4.3 Environmental Waste Recovery

Located in Acworth, Environmental Waste Recovery (EWR), processes brown grease from the food service industry in north Georgia. Services offered include acceptance of FOG from manifested independent haulers and contract grease trap cleaning for businesses. Services are limited to brown grease from traps and do not include yellow grease.

EWR has eight employees and operates two vacuum trucks that collect grease trap material from various restaurants and a major grocery store chain. EWR system is designed to handle 10,000 gallons a day (approximately three million gallons per year) and operates close to capacity. Waste haulers deliver the waste to a central receiving location where the brown grease undergoes simple processing. The process uses physical separation, followed by dewatering by a belt rotary vacuum filter. The dried cake and recovered grease is then landfilled.

The cost for service is dependent upon whether EWR collects and processes FOG or simply processes FOG brought in from independent haulers. Cost of collection and processing for clients is usually in the range of 25-30 cents per gallon. Fees assessed to the three independent haulers that use EWR for FOG processing is approximately 5 cents per gallon. EWR presently does not have any plan for expansion.

3.4.4 G.W. Diggler

G.W. Diggler, located in Ridgeland, South Carolina processes brown grease from South Carolina and the southeast region of Georgia. Services offered include acceptance of FOG from manifested independent haulers and grease trap cleaning of individual businesses. Diggler has nine trucks and four employees to service grease traps. Diggler will accept new grease customers only if they have a proportional amount of septic customers in the same area. A certain proportion of septic waste is required in addition to the grease waste for Diggler's land application system.

Diggler pumps the spent FOG into a holding tank, adds lime, and then lets the brown grease remain static for 2 hours. Afterwards, a pH test is done to ensure a minimum reading of 12.0. The brown grease is then left to sit for another 2 hours and the pH is checked again to ensure it has maintained a reading of 12.0. The waste is then sprayed on land and surge incorporated. Diggler utilizes 12 nine-acre plots of land for their application system. Only one plot is used per month. After each month, a new plot is used. At the end of each year, the cycle begins again.

3.4.5 North Georgia Processing

North Georgia Processing (NGP), located in Martin (Stephens County), is a spent FOG processor serving the Northeast Georgia region. NGP is a pretreatment facility that primarily processes brown grease collected by company-owned trucks. NGP's scope of services include acceptance of FOG from manifested independent haulers, contract grease trap cleaning, and separate collection of commercial yellow grease.

NGP has seven employees and operates three vacuum trucks that collect brown grease from food service establishments. NGP handles approximately 5,000 gallons of brown grease a day and is operating close to design capacity. The spent FOG process at NGP consists of the addition of hydrated lime before dewatering with a belt filter press or a plate-and-frame press.

No polymers are used in the operation. The dried cake, about 30 tons per week, is transported to a landfill in Homer, at a cost of 35 dollars a ton. A South Carolina company collects the recovered yellow grease, at no cost to NGP, and uses it as an ingredient in animal feed. NGP only receives brown grease from one independent hauler and charges 35 cents per gallon to accept the manifested FOG. At this time, NGP does not have any plans for expansion.

3.4.6 Southern Waste Services

Southern Waste Services (SWS), in association with Odum Service Company, is located in Hinesville. SWS is a spent FOG processor that services Georgia's coastal region. Services include pumping and hauling of yellow and brown grease from commercial sites. SWS does not accept waste from independent haulers, citing the risk of septic tank waste contamination. Customers that sign a maintenance agreement to have their grease traps cleaned every 12 weeks pay \$150 to have grease traps pumped. New customers must show receipt from a previous cleaning to get the same price. If no receipt is available, SWS charges the customer 50 cents a gallon.

SWS collects spent FOG in separate streams: yellow grease, brown grease/sludge, and wastewater. The collected yellow grease is sold to companies for animal feed, the brown grease sludge is sent to the Broadhurst Environmental landfill in Wayne County, and the wastewater is placed in a lagoon after it has been treated to decrease its BOD (Biochemical Oxygen Demand) level. SWS is currently expanding its operation and has the facilities in place for future growth.

3.4.7 Weststar Environmental

Weststar Environmental, located in Jacksonville, Florida, offers services that include acceptance of spent FOG from manifested independent haulers and pumping and hauling of brown grease from commercial sites. Weststar's range of operation spans a 300-mile radius and service is provided to southeast Georgia.

They charge 25 cents per gallon per 100 miles for their pumping services. Weststar adds lime to brown grease in a pit until the mixture reaches a pH of 12.5 and maintains this pH for 24 hours. The recovered grease is mixed with municipal wastewater treatment plant biosolids and sold as a soil amendment after curing. Weststar has plans for future expansion.

4.0 RECOMMENDATIONS

Based on the information gathered in preparation of this report, the following recommendations in the areas of education, research and policy are made:

Education:

1. *Development of educational materials for Georgia food service operators on the purpose and function of grease traps.* As pointed out in the text of the report, one of the most pervasive misconceptions of food service establishment operators in the state of Georgia is the perception that a grease trap, especially those located in-ground, are wastewater treatment devices. Food service establishments unknowingly think of grease traps in the same light as wastewater septic tanks, viewing them as treatment systems that only have to be maintained and serviced when a problem occurs. Educational material should be developed emphasizing the fact that grease traps only serve to separate and hold spent FOG and solids from wastewater for periodic removal, and do not function as independent wastewater treatment systems.

2. *Development of educational materials designed to assist food service operators with calculating the true economic impact of spent FOG.* Another misconception that many food service operators maintain is that the generation of spent FOG, either as yellow or brown grease, is simply a cost of doing business and unworthy of monitoring closely. However, as cited previously in this report (see Section 2.0), yellow grease is a valuable commodity within the rendering industry. In most urban areas, services are available where companies will supply a container, then periodically collect and pay food service establishments for their yellow grease. On the other hand, food service operators must deal with the economic and time investment of maintaining in-kitchen grease traps or paying others to maintain in-ground grease traps. Although specific dollars savings will vary depending on specific locations, Georgia food service operators must be educated to understand that significant dollar savings can be realized by minimizing the generation of spent FOG. Also, food service operators must understand that the control over whether spent FOG is recovered and retained as high-value yellow grease, or lost to the waste stream as brown grease, can have a significant economic impact. To aid in this education process, materials should be developed which assist Georgia food service operators with calculating the economic impact of the spent FOG their operation generates. Educational

materials would include instructions and calculations for determining costs associated with current yellow and brown grease handling, potential savings by minimizing spent FOG generation, and the economic impact of diverting the maximum amount of the spent FOG stream to high-value yellow grease versus low-value brown grease.

3. *Education of Georgia food service operators on the role of bioaugmentation in a well-managed grease trap maintenance plan.* Today, Georgia food service operators receive information on a daily basis through phone calls, direct mail, and the Internet on the benefits of bioaugmentation. At issue is not the fact that laboratory research has shown bioaugmentation can be effective, but because bacteria can be effective in ‘eating’ spent FOG, companies have begun aggressive marketing campaigns designed to sell food service operators on the belief that they can self-maintain their grease traps using specially designed ‘bugs’. Without the ability to independently test each product on the market, there is no way to verify the effectiveness of a particular proprietary formula marketed to the food service industry. And the simple appearance of effectiveness is not enough, since many products simply act as emulsifiers, allowing the spent FOG to remain suspended in the wastewater stream until it leaves the grease trap. Educational material needs to be developed that are updated periodically, and provide detailed information concerning current products, recent research, and potential regulatory impact of the use of bioaugmentation in food service grease traps.

Research:

4. *Establishment of an independent testing program of bioaugmentation products marketed to Georgia’s food service industry.* A state-sponsored independent testing program should be established to provide Georgia’s food service industry with an unbiased evaluation of the effectiveness of various bioaugmentation products. A university based laboratory protocol would be established and companies wishing to market their products in Georgia would be allowed or required to submit samples of their formula to be tested and receive a rating of effectiveness.

5. *Use of local and statewide resources in the research and development of biodiesel.* Although extensive research has been completed in the area of biodiesel production and several

case studies have proven its ability as an alternative fuel, the state of Georgia (especially in areas where air quality is now a major concern) should take a keen interest in the development of biodiesel technology in the state. As one of the case studies cited in the text of the report, “the demonstration (project) may help encourage local governments and the private sector...especially in areas where air quality is an issue. Crop-based diesel burns cleaner and produces less soot, and vehicles don't need modification before being switched to the fuel. Recent changes in the Energy Policy Act of 1992 allow for credits for biodiesel usage in existing vehicles, reducing the number of alternative fuel vehicles that must be purchased. Future changes could also affect large municipal vehicle fleets, such as buses and public works vehicles.”

6. *Use of local and statewide resources in the research and development of spent FOG incineration for use as an alternative industrial fuel.* Georgia’s animal rendering industry is already exploring and putting into practice the burning of rendered oils and greases. With the continued rise in cost of petroleum-based fuels, the ability for industries to utilize the BTU value of spent FOG could mean a cost savings in the future. Research in this area should be encouraged, supported and funded in the coming years.

Policy:

7. *Development of a statewide program overseeing regulatory compliance of the collection, transportation, treatment and disposal / beneficial use of brown grease.* Currently, the United States Environmental Protection Agency, the Georgia Department of Human Resources (Division of Public Health), the Georgia Environmental Protection Division (Industrial Pretreatment Program), and the Georgia Department of Agriculture (Grocery Store Program) all play a role in the regulation of food service grease traps and the handling of brown grease generated in the state. Obviously, there is confusion caused by having several different government entities regulating various aspects of the system. All parties involved in the brown grease process: food service generators, spent grease haulers, FOG treatment facilities and renderers, local industrial pretreatment programs, and local health officials would benefit from a systematic statewide regulatory program. A single, state-level authority could not only address and put in place single set of regulations, but also address such issues as manifests, full-pumping, bioaugmentation and future research.

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