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88 PRETREATMENT LIMITS FOR FATS, OIL AND GREASE

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INTRODUCTION

A discrepancy exists between the information available in the literature regarding oil and grease and the information used to establish discharge limits for this material. The goal of this chapter is to present information and recommendations that will be useful in the establishment of pretreatment limits for the discharge of oil and grease material to publicly owned treatment works (POTW's). The recommendations are intended to facilitate the development of regulations that will result in efficient use of POTW treatment capacity while minimizing the cost of pretreatment for industry. The chapter is organized as follows:

- Oil and Grease in Domestic Wastewater
- Physical and Chemical Characteristics of Oil and Grease
- Operational Problems
- Pretreatment Regulations
- Regulatory Approaches
- Pretreatment Technology
- Summary
- Recommendations for Oil and Grease Limits

The first sections address the amount and the character of oil and grease that is present in waste water, the nature of the pollutant, and the reasons for implementing discharge limitations for oil and grease. The next sections describe the approaches used to establish pretreatment limits, the recommendations of the federal government and professional guidance manuals and the results of a survey of local discharge limitations. The last sections address the treatability of oil and grease followed by a summary and the recommendations.

OIL AND GREASE IN DOMESTIC WASTEWATER

Environmental engineers and wastewater treatment plant operators are primarily aware of oil and grease in wastewater by the presence of grease balls and blockages in the collection system and by the presence of floating scum on sedimentation tanks. The oil and grease concentration for weak, medium and strong wastewaters is 50, 100, and 150 mg/L, respectively.[1] Rudolfs[2] conducted oil and grease analysis on a number of raw wastewater samples and found that the concentration ranged from 8.4 to 220.8 mg/L. Skimming volumes from primary treatment have been reported to range between 0.1 and 6.0 cf/MG.[3] A value of 2 cf/MG would correspond to an oil and grease concentration of 14 mg/L, for an assumed specific gravity of 0.95. An analysis of a raw wastewater containing 45 mg/L oil and grease[4] indicated that over half the oil and grease was colloidal, and that most of the oil and grease was in the form of glycerides of fatty acids (i.e. food fats and oils). The colloidal designation was established by the process used to separate the solids.

A number of researchers have demonstrated that the concentration of oil and grease in industrial and untreated municipal wastewaters and the effluent from biological treatment follows a log-normal frequency distribution.[5,6] The range of maximum to minimum values commonly varies from 5 to 1. This type of variability is not commonly addressed in pretreatment regulations. Municipal ordinances commonly require that industrial discharges not exceed a specified limit, and use grab samples taken at infrequent intervals to monitor compliance. The degree of confidence required to meet such a limit may exceed 99%. The corresponding average operating level required to meet this condition may be 20% of the regulated limit.

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Table I. Fatty Acid Content of Soybean Oil

Fatty Acid		Austin [11]	Sawyer & McCarty [10]	Solomons [12]	CRC Handbook [13]
Butyric	C_3H_7COOH	–	–	–	–
Caproic	$C_5H_{11}COOH$	–	–	–	–
Caprylic	$C_7H_{15}COOH$	–	–	–	–
Caprice	$C_9H_{19}COOH$	–	–	–	–
Lauric	$C_{11}H_{23}COOH$	–	–	–	0.2
Myristic	$C_{13}H_{27}COOH$	–	–	1–2	0.1
Myristoleic	$C_{13}H_{25}COOH$	–	–	–	–
Palmitic	$C_{15}H_{31}COOH$	8.3	6.5	6–10	9.8
Palmitoleic	$C_{15}H_{29}COOH$	–	–	–	0.4
Stearic	$C_{17}H_{35}COOH$	5.4	4.2	2–4	2.4
Oleic	$C_{17}H_{33}COOH$	24.9	32.0	20–30	28.9
Linoleic	$C_{17}H_{31}COOH$	52.7	49.3	50–58	50.7
Linolenic	$C_{17}H_{29}COOH$	7.9	2.2	5–10	6.5
Arachidic	$C_{19}H_{39}COOH$	0.9	0.7	–	0.9
Arachidonic	$C_{19}H_{35}COOH$	–	–	–	–
Clupanadonic	$C_{21}H_{35}COOH$	–	–	–	–
Lignoceric	$C_{23}H_{37}COOH$	–	0.1	–	–

PHYSICAL AND CHEMICAL CHARACTERISTICS OF OIL AND GREASE

The elements and compounds that are measured in the oil and grease test are present in a number of forms and originate from many sources. In the case of oil and grease, development of appropriate discharge limits warrants that consideration be given to the form and origin of oil and grease components. Oil and grease may be derived from either mineral or food sources. Mineral oils may be derived from both petroleum and coal sources. Mineral oils tend to be less miscible in water as a result of their nonpolar structure. Mineral oil in wastewater may originate from a variety of sources including service stations, car washes, laundries, oil refineries, machine shops, leaking underground storage tanks, steel mills, tanneries, drop forge plants, and stormwater runoff.

Control agencies should note that the oils used in metal working are not all of mineral origin. Taras[7] and Lawrence[8] have described lubricating oils that are formulated with limited or no mineral oil. High water content fluids (HWCF) contain a maximum of 3 to 15% petroleum oil emulsified in water. Synthetic HWCF oils contain no petroleum oil and provide the lubricating affect by other water soluble organics. Taras[7] explained that some engine lubricants contain fatty oils in addition to mineral oils and that cutting oils are a blend of fatty oils, mineral oils and water.

Food fats and oils are one of the three major components of food, along with proteins and carbohydrates. Thirty eight percent of human caloric intake is via food fats and oils.[9] Data published by the Edible Oil Institute[9] shows a long term increase in per capita consumption, from 120 pounds per person in 1965 to 138 pounds in 1985. Food fats and oils that are present in household wastewater originate from sources such as meat, margarine, shortening, vegetable oils, mayonnaise, salad dressing, and dairy products. Food fats and oils are also present in wastewaters discharged from commercial establishments and industries including; meatpacking plants, slaughterhouses, bakeries, rendering plants, food manufacturers, and restaurants.

Food fats and oils are esters of the alcohol glycerol with fatty acids and are termed triglycerides. Food fats tend to be miscible in water, due to the polar nature of the molecule. Food oils differ in the relative amounts of the various fatty acids that they contain. Tables have been presented in several texts and references[10-13] that show the relative composition of fatty acids for each type of vegetable oil. Table I presents a sample compilation of information for soybean oil. Note that food oils are composed of a variety of fatty acids. The combination of fatty acids can be used as a finger print to identify the presence of a particular oil. There may be some variability in the fatty acid composition of each oil as noted by the information presented in Table I.

Triglycerides that are liquid at room temperature are called oils, and those that are solid are called fats. The melting point is affected by the degree of saturation, length of the carbon chain, isomeric forms of the fatty acid, molecular configuration, and method of processing.[9] The melting point of an oil can be raised by the process of hydrogenation in which hydrogen atoms are added to the fat molecule.

When alkali is mixed with food oil and fats the glycerol is liberated. The fatty acids and alkali react to form salts of fatty acids termed soaps, by a process known as saponification. Common soaps are formed by the saponification of fats with sodium hydroxide, and are soluble in water. In the presence of hardness, the sodium salts are converted to calcium and magnesium salts, which are insoluble and precipitate. The implication is significant for industries that use caustic cleaners for cleaning process equipment. As the rinse waters mix with fats and oils the free floating material will become emulsified. The subsequent saponification and precipitation could account for high effluent solids concentrations even after pretreatment. This is justification for pH neutralization as soon in the treatment process as is practical.

Important to the discussion of regulatory techniques is the method of analyzing for oil and grease. The oil and grease determination does not measure a specific substance, but rather groups of substances with similar physical characteristics based on common solubility in Freon®. Control agencies should consider that the source of the oil and grease material may be more important than the absolute concentration of the material that is present in the wastewater, as the composition of the material that is monitored may vary while the overall concentration remains the same.

The U.S. Environmental Protection Agency[14] specified that oil and grease be measured using Method No. 503 A of the 16th Edition of *Standard Methods*.[15] This is the gravimetric extraction technique and trichlorotrifluoroethane, Freon®, is the solvent used for extraction. Method No. 503 E describes the method used to determine the polar and nonpolar fractions of the oil and grease samples. Section 206 of *Standard Methods*[15] presents two tentative methods for measuring the amount of floatable material present in a wastewater sample. Section 206 is significant since sewer use ordinances should restrict the amount of floatable material discharged to the wastewater collection system, and there should be a method to reliably check compliance with this requirement.

OPERATIONAL PROBLEMS

The need to create regulations for the discharge of oil and grease to sewerage systems is the result of operational and maintenance problems that have arisen. Problems resulting from oil and grease components in wastewater have been well documented.[16] Explosions in sewers and pump stations from the discharge of petroleum products were a major problem reported in the literature during the 1930's. The result was loss of life to sewer workers and cost to the local community for system repair.

Accumulations of free floating oil and grease in sewers and pump station wetwells have resulted in maintenance and odor problems. The floating material may create a blanket on top of the liquid in wetwells and require manual removal. Free floating fat and grease may cause pipe blockages that can be difficult to remove. POTW control authorities recognize the problems related to explosions and blockages and have responded by prohibiting the discharge of flammable, explosive or viscous oil and grease material to wastewater collection systems.

Mahlie[14] reported that a number of researchers encountered problems with toxicity in activated sludge treatment due to the presence of oil and grease. The toxicity was commonly related to the presence of mineral oils. Oil and grease has also been blamed as a cause of bulking, or for decreasing the specific gravity of sludge by sorption onto the biomass resulting in poor settling characteristics. Only one well documented case of this was identified in the available literature.[5] The case referred to involved an industrial wastewater treatment plant receiving wastewaters with high concentrations of oil and grease (745 mg/L average). Problems with settling were experienced primarily during peak loading conditions.

The problems cited above generally relate to the presence of free floating fats and grease, to mineral oils that are not generally biodegradable in the biological treatment systems used by the POTW's, or to the presence of large quantities of oil and grease that have overloaded the biological treatment system. The literature has not addressed specific problems resulting from the presence of emulsified food oil at concentrations normally experienced at POTW's.

PRETREATMENT REGULATIONS

mplementation of Public Law 92-500, the Clean Water Act, as amended, has resulted in the ction of well operated wastewater treatment plants capable of discharging high quality effluents. The discharge of highly treated effluents that generally improve the local water quality is now the rule rather than the exception. The reliability of the plants has been enhanced by the implementation of pretreatment programs that give municipalities the authority and legal responsibility to limit and control the discharge of incompatible wastewaters to the plant. A key component of a successful pretreatment program is the establishment of consistent and appropriate discharge limits for users of the collection and treatment system. There are three principal objectives for the establishment of pretreatment discharge limits.

- Protection of the wastewater collection system
- Protection of the wastewater treatment plant
- Protection of the environment

Discharge limitations should be established on the basis of good data and should be fair, flexible, and economical for both the POTW and the people and industries served by the plant. Heukelekian[17] spoke definitively about the establishment of arbitrary standards, indicating that the standards are convenient to apply but that the resulting regulations are based on insufficient information and are often repeated and accepted by others until they are considered to be based on authority.

When the process of establishing discharge limitations is undertaken, the control authority should consider that industries will impact the POTW according to the relative significance of the flow or pollutant load discharged to the collection system. The significance is affected by factors such as the size, type and number of related industries and the size and age of the community. A well documented and accepted principal of wastewater treatment is that POTW's should accept and treat conventional wastes.[17,18] Successful examples of treating combined municipal and industrial wastewaters have been presented by Balden[19] and Rooney.[20] Odette[21] suggested that the criteria for establishing numeric limits be based on a determination that a pollutant is detrimental to the municipal wastewater treatment plant. Numeric limits should be determined on a mass based system wide allocation, with a permit issued to the industrial users stipulating a concentration based on daily average flow. Industries should not be prevented from implementing water conservation measures that may increase the pollutant concentration.

The most extensive and thorough description of a rationale approach to use in determining a specific discharge limit was presented in the EPA Guidance Manual for POTW Pretreatment Program Development published in 1983.[22]

Federal regulations and guidelines help to form the basis for development of pretreatment programs. The EPA has defined oil and grease to be a "compatible" pollutant.[23] This definition referred only to fats, oils and greases of animal or vegetable (A/V) origin. Compatible pollutants were defined as those entities for which a POTW had been designed to provide treatment. On April 22, 1975 the EPA proposed the following standards for oil and grease:[24]

Source of Oil and Grease	Proposed Limitation
Animal/Vegetable	No Limit
Petroleum	100 mg/L

The proposed standards were issued for comment but were never promulgated. The proposed limits were based on a report entitled "Treatability of Oil and Grease Discharged to Publicly Owned Treatment Works",[25] which described the EPA's position that, pretreatment limits should be based on the ability of a POTW to remove specific pollutants that are present in wastewater. The report concluded that oil and grease of A/V origin were subject to biochemical degradation in POTW's employing secondary treatment and that the concentration would be reduced along with other organics.

Pursuant to the Clean Water Act, and the development of the General Pretreatment Regulations, the EPA issued notice designating oil and grease as a conventional pollutant.[26] Conventional pollutants were defined as those entities which were naturally occurring, biodegradable substances and those which have been the primary focus of wastewater treatment.

The EPA has issued specific effluent guidelines and standards for 24 industrial categories. With the exception of the Metal Finishing Category and the Plastics Molding and Forming Category, the guidelines and standards developed for oil and grease are mass-based standards, that is, the discharge limits for oil and grease are based on the production rates for particular manufacturing processes. It is beyond the scope of this chapter to list the guidelines and standards for each of the industrial subcategories. However, the fact that pretreatment standards for existing sources (PSES) have not been developed for any of the industrial categories should be noted. The EPA has established guidelines and standards for oil and grease discharge limits only for new industrial sources (PSNS and NSPS).

Many municipal regulations limit the discharge of oil and grease to 100 mg/L.[27,28] Anderson[29] described the industrial wastewater pretreatment regulations established in the Los Angeles area in the early 1950's. Pretreatment requirements for industries with large flows were:

- Floating Oil
  - Hydrocarbons limited to 10 mg/L
  - Food oils limited to 25 mg/L
- Stable emulsions
  - 600 mg/L

The current version of the Pretreatment Ordinance for the Combined Sanitary Districts of Los Angeles County require only that excessive discharges of oil and grease, that would tend to cause adverse affects on the sewerage system, shall not be discharged.

Lordi[30] reported in 1976 that the State of Illinois rules and regulations for discharge to water ways limited the oil and grease in treated wastewaters to 15 mg/L. If the oil and grease sample was analytically separated into polar and non-polar components the limit was changed to allow 15 mg/L polar materials and 15 mg/L non-polar materials. Compliance with the numerical standard was determined on the basis of 24 hour composite samples, averaged over any monthly period. No single 24 hour composite was allowed to be greater than 2 times the numerical standard and no grab sample was allowed to be greater than 5 times the numerical standard.

The Water Pollution Control Federation (WPCF) Manual of Practice (MOP) No. 3 Regulation of Sewer Use, offered the guidance that if oils and greases are biodegradable and in a physical state that does not cause clogging or undue maintenance problems in the sewerage facilities, the discharge of these substances may be accepted in a wastewater treatment system.[31] MOP No. 3 also stated that POTW's have a responsibility to accept any wastes that can be successfully treated and in such volumes as the treatment plant can handle without overloading.

The WPCF MOP No. FD-3, *Pretreatment of Industrial Wastes*, provided limited design and operational information regarding pretreatment of oil and grease.[32] However, the manual stated that if oil and grease globules are large enough to float, they should be removed at the industrial facility prior to discharge to the municipal sewerage system. The manual also stated that A/V oil, in a dispersed state, may be degraded at the municipal wastewater treatment plant.

The WPCF publication, *Joint Treatment of Industrial and Municipal Wastewaters*, addressed the formulation and content of sewer use ordinances.[33] Fats, oils and grease were classified as restricted substances. These were defined as wastes that had the potential to be troublesome, which should be monitored, but which would not usually be harmful to the sewerage system. Oil and grease materials of a mineral origin were described as "doubtful" substances meaning that consideration should be given to banning or limiting the discharge of these wastes to the collection sewer. Oil and grease materials of food origin were described as being generally acceptable for discharge to the sewerage system. No recommendations were made regarding specific numerical discharge limits.

The WPCF MOP OM-4, *Industrial Wastewater Control Program for Municipal Agencies*, provided guidelines regarding the establishment or upgrading of an industrial wastewater control program.[34] Oil and grease materials of food origin were described as being ordinarily biodegradable and treatable at the wastewater treatment plant. Oil and grease materials of a mineral origin were described as being resistant to biodegradation requiring removal by methods other than biological treatment. The recommendation was made to include fats, oils and grease as pollutants that require control by the municipality.

In summary, the guidance materials available which address the control of oil and grease discharged to sewerage systems have the following common theme:

- Oil and grease materials of food origin are generally biodegradable.
- Discharge of significant quantities of oil and grease materials may impact the capacity of the sewerage system.
- Oil and grease materials of mineral origin are not readily biodegradable and consideration should be given to requiring removal or control prior to discharge to the wastewater treatment plant.
- No guidelines or recommendations were made regarding specific numeric limits for discharge of oil and grease materials to the sewerage system.

REGULATORY APPROACHES

An informal survey was conducted of municipal (control authority) regulations governing the discharge of wastewaters to sewerage systems. Published sewer use ordinances or equivalent regula-

Table II. Summary of Pretreatment Limits for Oil and Grease

Municipality or Control Authority	Local Limit for FOG
Hammond, IN	No numerical limit
Brookfield, WI	No numerical limit
Atlanta, GA	100 mg/L—Mineral origin
Fond du Lac, WI	100 mg/L—Mineral origin
Green Bay, WI	100 mg/L—Total
Appleton, WI	25 mg/L—Mineral origin
	100 mg/L—Total
Oshkosh, WI	100 mg/L—Mineral origin
	100 mg/L—A/V origin
Dallas, TX	100 mg/L—Mineral origin
Los Angles County Sanitation Districts	No numerical limit
Baltimore, MD	100 mg/L
Detroit, MI	2000 mg/L
Kenosha, WI	100 mg/L—Mineral origin
Milwaukee, WI	100 mg/L

tions were used as the primary source of information for the survey. Enforcement of these regulations are usually achieved by issuance of a discharge permit to the industrial user, in conjunction with a monitoring program implemented by the control authority.

A summary of specific discharge limitations for oil and grease as mandated by the sampling of control authorities is presented in Table II. A majority of the ordinances contain language that prohibits the discharge of free floating fats, oils, and grease of any origin (food or mineral). Additionally, most of the ordinances contain language that prohibits the discharge of fats, oils and grease in such quantities as to interfere with the normal operation of the POTW and collection system. This type of general prohibition is often used by those control authorities which do not have specific numerical limits for oil and grease or who have numerical limits for oil and grease of mineral origin only.

Examination of the ordinances and conversations with representatives of the control authorities revealed that the limits were typically subject to variance request and approval procedures. For the most part, strict enforcement of the published local discharge limit was not practiced. Rather, the control authority had in many cases entertained requests for variances and granted such requests so long as the operation of the wastewater treatment plant or its ability to meet the National Pollution Discharge Elimination System (NPDES) permit limits was not adversely impacted. Due to the fact that control authorities have granted variances to their local limits, it is difficult to make any definitive statement regarding the relationship of the oil and grease limits to the size of the plant or to its geographic location.

In the survey, the value of 100 mg/L appeared often. However, the value applied to oil and grease of a mineral origin as often as it applied to total oil and grease. While 100 mg/L was a common value for the discharge limit for industrial users, the manner in which it was applied was not consistent. The rationale used to establish the local discharge limit for oil and grease were not well documented by the control authorities contacted.

PRETREATMENT TECHNOLOGY

A review of the literature revealed that almost every biological or physical/chemical treatment process available has been evaluated for its ability to remove oil and grease. The systems that have had the broadest applicability to oil and grease treatment are gravity separation, dissolved air flotation, chemically assisted dissolved air flotation, and aerobic biological treatment.

Gravity separation offers the most basic form of pretreatment for oily wastes. Gravity separators are generally considered to have a nominal removal efficiency of 60%. In practice removal efficiency is affected by the form of the oil in the wastewater, presence of surfactants, wastewater temperature, surface area of the gravity separator, and the flow rate. Gravity separation will not remove emulsified oils and greases, unless chemical treatment is used to break the emulsion. This usually requires pH neutralization, chemical feed equipment, increased gravity separator capacity for solids handling, and sludge and scum removal and disposal facilities. Gravity separators should be designed in accordance with API guidelines and be provided with equipment capable of continuously removing collected oil and grease.

Table III. Summary of Analytical Data for Various Food and Petroleum Oils[a]

Oil	CTOD g O_2 / g oil	g BOD_5 / g oil	g COD / g oil	g BOD_5 / g COD	g BOD_u / g oil	BOD Rate Constant (k)
Edible Oils						
Beef lard	2.89	1.79	2.38	0.72	1.83	0.29
Butterfat	2.77	1.79	2.65	0.67	2.28	0.31
Coconut oil	2.73	1.77	2.48	0.71	2.17	0.28
Corn oil	2.86	1.88	2.74	0.69	2.44	0.26
Herring oil	2.92	1.71	2.65	0.64	1.92	0.40
Hydrogenated herring oil	2.91	1.79	2.88	0.62	2.06	0.35
Palm oil	2.88	2.00	2.81	0.71	2.14	0.56
Soybean oil	2.89	1.82	2.51	0.73	2.18	0.35
Petroleum-based Oils						
Kerosene	3.5–3.6	0.87	1.58	0.55	1.32	0.133
#2 Fuel oil	3.4–3.5	0.98	1.35	0.73	1.24	0.165
Machine oil	3.4–3.5	0.29	1.78	0.16	1.02	0.065
Mineral oil	3.4–3.5	0.31	2.22	0.14	0.91	0.076

[a] Reference: Groenwold, *JWPCF*, 54, 398 (1982).

Dissolved Air Flotation (DAF) is a another process commonly applied for the pretreatment of wastewaters containing oil and grease. As with gravity separation, a DAF system cannot by itself remove emulsified material unless the emulsion has first been chemically broken and the oil and grease has become free floating. Chemically assisted DAF systems have been used for a variety of industries, with varying degrees of success.

Biological treatment is normally used when direct discharge to a surface water is required. Aerobic biological systems have been used for treating wastes from edible oil refineries, slaughter houses, meatpacking plants, and petroleum refineries.

Biological Oxidation of Oil and Grease

The biodegradability of food oils and greases has been demonstrated at bench and full scale operational levels. Groenewold et al.[35] conducted laboratory tests to determine the biodegradability of a variety of oils. Food oils were selected to include both long and short chain fatty acids, and saturated and unsaturated fatty acids. Mineral oils were also tested and were selected to represent a range of carbon chain lengths. Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and computed theoretical oxygen demand (CTOD) were determined for each of the oils. A summary of the data has been duplicated in Table III. The CTOD of petroleum oils was higher than for food oils but the corresponding measures of BOD and COD were lower indicating that the petroleum based oils were not as biodegradable. The observed BOD:O&G ratios for food oils averaged 1.82, which was higher than the value of 0.89 previously reported in other literature. The BOD:COD ratios for food oils averaged 0.69. This was greater than the value of 0.5 that is commonly used to indicate a readily biodegradable waste. The BOD rate constant of the food oils averaged 0.35 in comparison to the value of 0.17 commonly accepted for municipal wastewater. Figure 1 illustrates the BOD curves presented by Groenewold et al.[35] The initial slopes of the curves reflect the high BOD rate constant for the food oils. The difference in the total oxygen demand exerted between food and petroleum oils reflected the relative differences in biodegradability.

Loehr et al.[36] indicated that long chain fatty acid salts are one of the major components of oil and grease in domestic wastewater and conducted laboratory investigations to study the aerobic degradation of these compounds. Factors investigated included chain length, degree of saturation, acclimation, type of salt, and concentration. The laboratory investigations demonstrated that the ease and rate of metabolism increased for compounds with shorter chain length and that the salts of unsaturated fatty acids were metabolized faster than were the corresponding salts of saturated fatty acids. Tests were conducted to evaluate the affect of concentration on oxygen uptake rate and the results are duplicated in Figure 2. The values on each curve reflect the initial COD concentrations. All the curves indicated a lag period followed by a period of rapid increase in the oxygen uptake rate. Subsequent tests with refeeding demonstrated that acclimation of the seed microorganisms to long-chain fatty acid salts increased the ease with which the acids were metabolized.

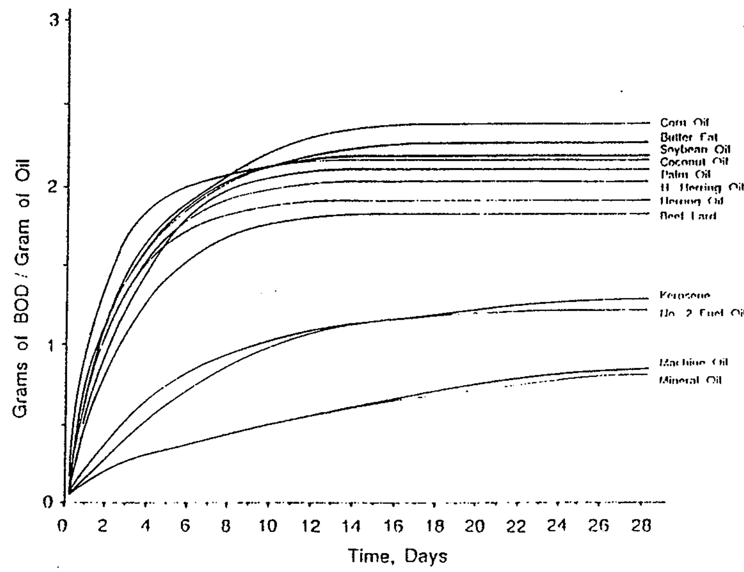

Figure 1. BOD curves for edible and petroleum oils.[35]

McCarty et al.[37] reported on the results of laboratory tests with industrial wastewaters containing oil and grease. The objective of the work was to evaluate the compatibility of the industrial wastewater with the conventional treatment processes at a POTW. The industrial wastewaters originated from soap manufacturing, edible oil refining, and combined manufacturing plants. The oil and grease concentrations in the effluent of samples tested ranged from 1 to 11 mg/L, with corresponding influent concentrations in excess of 50 mg/L. Analysis of the oil and grease content of the activated sludge demonstrated that most of the oil and grease was biologically oxidized and not simply incorporated with the activated sludge solids. Tests conducted with a Warburg Respirometer demonstrated that the oxygen uptake rates of the industrial wastewaters were comparable to those for activated sludge systems.

Mulligan et al.[5] reported on the full scale treatment of an industrial wastewater from an organic chemical plant that used animal fats and food oils as raw materials. The Hexane Extractable Material (HEM) concentration in the raw wastewater followed a log normal probability distribution that varied from 370 to 9,000 lb/day with a median of 1,800 lb/day. The median influent concentration was 745 mg/L. The effluent HEM concentration followed a log normal probability distribution with values ranging between 30 and 300 mg/L and a median value of 72 mg/L. A portion of the effluent HEM concentration was attributed to the lipid (fatty acid) content of waste activated sludge solids that were discharged to the municipal collection system with the treated effluent. The authors demonstrated in laboratory tests that the initial removal of HEM from wastewater was achieved by sorption onto the biological floc. The authors observed that HEM load to the plant can affect the settleability of biological solids and that loading rates should be controlled to maintain proper solids settlement. These results and recommendations were developed for an industry where a biological process was used to treat a high strength oil waste, and represents a situation more severe than the typical wastewater treatment plant would experience.

Loehr et al.[38] reported on the removal of oil and grease at the Topeka, Kansas POTW. Grab samples were collected on an hourly basis to characterize the raw wastewater, primary clarifier, and plant effluents. The results are duplicated in Figure 3. The results demonstrated a daily variation in the concentration of oil and grease entering the plant and an ability of the conventional plant to reduce oil and grease concentration to below 20 mg/L. Thin layer chromatography was used to estimate the forms and magnitude of oil and grease present in the wastewaters. The ranking system was qualitative with "1" representing the most predominant material. Table IV duplicates the results. Fatty acids were the most predominant component of the raw and settled wastewater, but hydrocarbons were the most predominant form in the effluent. Compound lipids present in the effluent were considered to be due to bacterial lipids.

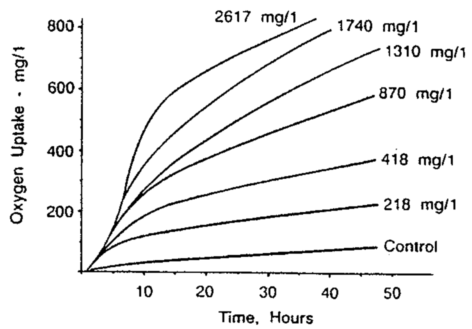

Figure 2. Concentration of sodium oleate (in terms of COD) in the flask affects the oxygen uptake pattern.[36]

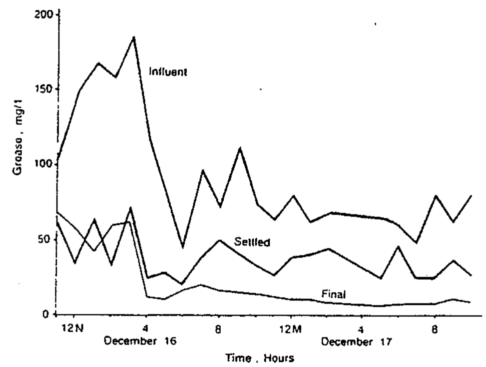

Figure 3. Hourly variation of grease over 24 hours.[38]

Young[6] reported on the results of a survey of 55 wastewater treatment plants. The concentration of oil and grease in the influent ranged from 9.8 to 162.5 mg/L and averaged 80 mg/L. Effluent concentrations ranged from 0.1 to 61.8 mg/L and averaged less than 10 mg/L. A probability plot of influent and effluent oil and grease concentrations for different types of biological processes are duplicated in Figure 4. The curves are considered to be representative of a log normal probability distribution.

Laboratory tests were conducted to determine the extent to which BOD measurements include the demand of biodegradable oil and grease.[6] Parallel BOD tests were conducted in Electrolytic Respirometers. Figure 5 presents the BOD curve for wastewater MLSS from which 9.2 mg/L of oil and grease was extracted. The difference in BOD values was 8 mg/L resulting in a BOD:O&G ratio of 0.87. Both samples showed comparable oxidation rates of 0.164 for MLSS and 0.160 for extracted MLSS. Figure 6 presents the results of tests for which food oil was added to the MLSS.[6] The BOD rate constant for the MLSS control was 0.159. The rate constants were 0.179, 0.158 and 0.144 for the addition of 12.5, 25 and 80 mg/L of oil, respectively. As a result of the survey and laboratory tests, Young observed that "there is no basis for concluding that municipal biological treatment plants should not be able to accept and treat satisfactorily much higher concentrations of biodegradable grease and oil than normally are received".[6]

Lordi et al.[30] reported on the efforts made by the Metropolitan Sanitary District of Greater Chicago (MSDGC) to evaluate MSDGC treatment plants for compliance with oil and grease effluent standards. The Illinois Pollution Control Board (IPCB) limited the concentration of HEM in the effluent of the MSDGC plants to 15 mg/L. The authors reported that for a twelve month period in 1973 and 1974, the monthly average HEM levels from the six MSDGC wastewater treatment plants ranged between 5 and 22 mg/L. Frequency distribution curves were presented for the effluent values observed in 1973. All six plants had daily concentrations that exceeded 15 mg/L some percent of the time. The experience observed at the MSDGC plants was that HEM removal was primarily a function

Table IV. Predominant Lipid Classes in Wastewater Samples[a]

Sample	Hydrocarbons	Sterol Esters	Triglycerides	Fatty Acids	Sterols	Compound Lipids
Influent wastewater	3	5	2	1	6	4
Settled wastewater	3	6	2	1	5	4
Plant effluent	1	5	4	3	6	2
Contact tank						
Influent	3	4	5	2	6	1
Effluent	3	4	5	2	6	1
Reaeration Tank						
Influent	3	4	5	2	6	1
Effluent	3	4	6	2	6	1

[a] Determined by TLC; 1 indicates most predominant class.
Reference: Loehr, *JWPCF*, 41, R142 (1969).

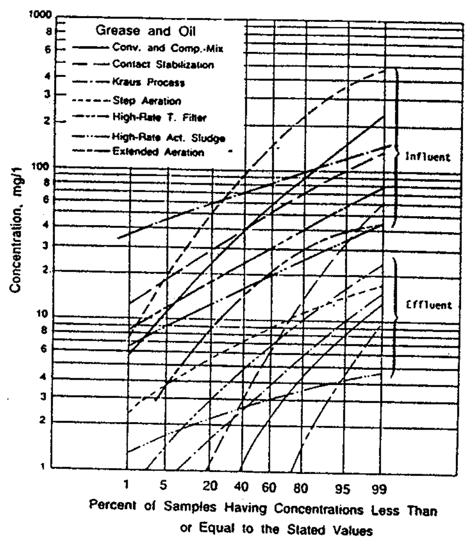

Figure 4. Probability plot of influent and effluent grease and oil concentrations for various types of biological treatment processes.[6]

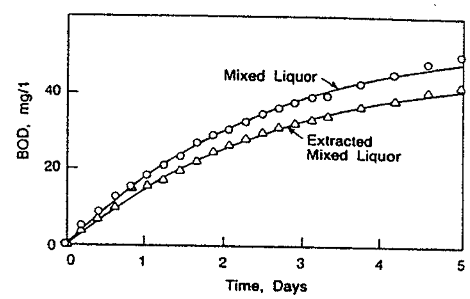

Figure 5. BOD curves for wastewater samples, one of which had grease and oil extracted.[6]

of the concentration of HEM in the raw wastewater. An analysis was made of polar and nonpolar constituents in the wastewaters, the results are duplicated in Table V.[30] The data indicated that the polar fraction was generally reduced through treatment, but that the degree of reduction could vary from plant to plant. The Hanover Park Plant received only domestic and commercial wastewater and had the highest relative proportion of polar HEM in the raw wastewater and the greatest degree of reduction of both polar material and total grease and oil through treatment.

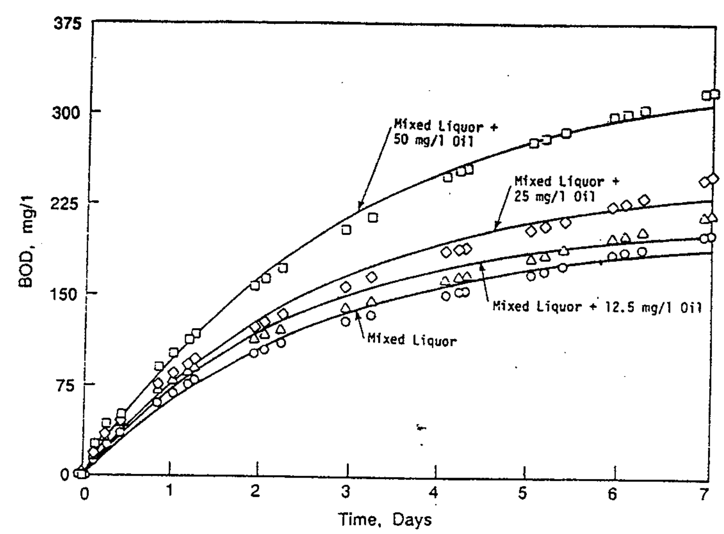

Figure 6. BOD of diluted mixed liquor and diluted mixed liquor to which various concentrations of oil were added.[6]

Table V. Distribution of Polar and Nonpolar HEM in Wastewaters[a]

Plant	Total HEM (mg/L)	Polar (mg/L)	Nonpolar (mg/L)	Polar (% of Total)
North Side				
Raw sewage	42.3	32.6	10.6	74.5
Final effluent	7.8	4.4	3.4	53.4
West Southwest				
Raw sewage	—	—	—	—
Final effluent	14.5	11.0	3.4	74.0
Calumet				
Raw sewage	56.0	46.0	9.3	83.5
Final effluent	19.4	15.3	4.1	80.4
Hanover Park				
Raw sewage	70.0	66.6	3.4	94.9
Final effluent	7.1	4.6	2.1	65.5

[a] Reference: Lordi, *Purdue Industrial Waste Conference Proceedings,* 452 (1976).

SUMMARY

Visible forms of oil and grease account for only a portion of the total oil and grease in wastewater, the rest is in the form of colloidal or emulsified material and composed primarily of food oil.

A variety of operational and environmental problems have been directly attributed to the presence of flammable, explosive and viscous oil and grease in wastewater, with the result that discharge of these substances to sewerage facilities has been banned.

The analytical procedure used to measure oil and grease is not specific to a single element or compound, but rather detects a group of substances that are soluble in Freon®.

POTW's should receive and treat compatible wastes. Federal and professional guidelines recognize the ability of POTW's to treat emulsified food oils. The results of bench and full scale tests have demonstrated the ability of biological treatment systems used by POTW's to treat emulsified food oils.

A review of POTW ordinances indicates that 100 mg/L is a common discharge limit for oil and grease. The ordinances are usually not consistent with respect to the substance regulated in that some limits apply to mineral oil while others apply to total oil and grease content.

The BOD rate constant of food oils is greater than for domestic wastewater.

Given the demonstrated biodegradability of food oil and grease materials the BOD test will measure the amount of oxygen required for treatment and removal. Associated costs can be recovered by surcharges to the appropriate user.

RECOMMENDATIONS FOR OIL & GREASE LIMITS

The following recommendations are offered to local control authorities and consulting engineers that may be responsible for developing or revising industrial pretreatment limits for oil and grease. A specific ordinance, or wording for a sample ordinance has not been proposed since no single ordinance could address the varying conditions at all locations and no one limit is universally applicable.

Each industrial wastewater discharge or class of discharger to a municipal system should be given individual review to determine the appropriate pretreatment control of oil and grease. Consideration should be given to the origin, chemical composition, and physical state of the oil and grease before a decision is made on how to regulate. If doubt exists consideration should be given to treatability tests or to accepting the wastes on a trial basis.

Emulsified or dispersed A/V oils should be accepted unless the wastewater treatment plant has limited treatment capacity.

Free floating material should be limited to the amount present in local domestic wastewater. The limit should be applied to viscous materials that are present at normal wastewater temperatures.

If limits must be set then they should be based on good data and arrived at by a rationale approach. The guidelines should consider the concentration that would cause problems in the sewerage system, based on experience at the POTW. The material and the forms to which the limit applies; floating material, total oil and grease, total oil and grease of mineral origin, total oil and grease of food and mineral origin should be specifically stated.

The concentration of oil and grease follows a log normal probability distribution. Consider different limits for average and peak conditions.

Discharge concentrations should be based on mass loading discharge limits and industries should be allowed to reduce flow rate and increase pollutant concentration.

Operating records documenting the amount of waste oil and grease removed from the process wastewater stream could be monitored to establish the effectiveness of pretreatment.

Allow variances so long as an industry can demonstrate that the chance of an environmental hazard being created is acceptable.

POTW's and regulatory agencies should monitor the quantity and forms of oil and grease that enter the wastewater treatment plant, and document the removal efficiency of treatment. Measurement techniques that provide information on the specific components of oil and grease and a procedure to measure free floating oil and grease should be established.

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ABBREVIATIONS

A/V	-	animal/vegetable
BOD	-	Biochemical Oxygen Demand
cf/MG	-	cubic feet per million gallons of wastewater treated
COD	-	Chemical Oxygen Demand
CTOD	-	Computed theoretical oxygen demand
EPA	-	United States Environmental Protection Agency
FEM	-	Freon® Extractable Material
Freon®	-	trichlorotrifluoroethane
HEM	-	Hexane Extractable Material
lb/day	-	pounds per day
MOP	-	Manual of Practice
mg/L	-	milligrams per liter
MSDGC	-	Metropolitan Sanitary District of Greater Chicago
NPDES	-	National Pollution Discharge Elimination System
NSPS	-	New Source Performance Standards
POTW's	-	Publicly Owned Treatment Works
PSES	-	Pretreatment Standards for Existing Sources
PSNS	-	Pretreatment Standards for New Sources
WPCF	-	Water Pollution Control Federation

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