TECHNICAL SUPPORT DOCUMENT FOR INDUSTRIAL WASTEWATER TREATMENT: FINAL RULE FOR MANDATORY REPORTING OF GREENHOUSE GASES

Climate Change Division
Office of Atmospheric Programs
U.S. Environmental Protection Agency
June 2010

CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

1. INTRODUCTION AND BACKGROUND

This document supports the Mandatory Reporting of Greenhouse Gases Final Rule (Reporting Rule) for the industrial wastewater treatment source category. The rule is divided into industry-specific categories and other categories that span industries. Categories that span industries include stationary fuel combustion sources, industrial landfills, and industrial wastewater treatment. EPA proposed reporting requirements for the wastewater treatment source category in the *Federal Register* on April 10, 2009, under Subpart II. EPA received comments on this subpart and revised the proposed regulation. The major changes from the proposed rule include:

- Renaming the source category Industrial Wastewater Treatment;
- Clarifying the subpart's applicability;
- Removing reporting requirements for petroleum refining oil/water separators and petrochemical facilities; and
- Revising monitoring requirements.

This document provides technical support for the final rule.

2. INDUSTRY DESCRIPTION

The industrial wastewater treatment source category of the Reporting Rule specifically applies to anaerobic processes used to treat industrial wastewater and industrial wastewater treatment sludge at facilities that perform pulp and paper manufacturing, food processing, ethanol production, and petroleum refining. This section describes industrial wastewater treatment, including the anaerobic treatment operations covered under the Reporting Rule, and explains how the Reporting Rule applies to this source category.

2.1 Industrial Wastewater Treatment

Wastewater treatment refers to processes that treat or remove pollutants and contaminants, such as soluble organic matter, suspended solids, pathogenic organisms, and chemical contaminants, from wastewater prior to its reuse or discharge from the facility. These pollutants and contaminants are removed from wastewater using physical and chemical processes (such as sedimentation and chlorine disinfection) and biological processes. Biological wastewater treatment processes can produce CO_2 and anthropogenic CH_4 and N_2O emissions.

Industrial wastewater may be treated either on site at an industrial facility (industrial wastewater treatment) or in combination with municipal wastewater at a centralized publicly owned treatment plant (POTW) or privately owned treatment plant. Industrial wastewater is defined as water that comes into direct contact with or results from the storage, production, or use of any raw material, intermediate product, finished product, by-product, or waste product. Examples of industrial wastewater include, but are not limited to, paper mill white water, wastewater from equipment cleaning, wastewater from air pollution control devices, rinse water, contaminated stormwater, and contaminated cooling water. Municipal wastewater treatment refers to a series of treatment processes used to remove contaminants and pollutants from domestic, business, and industrial wastewater collected in city sewers and transported to a centralized wastewater treatment system such as a POTW.

Soluble organic matter is generally removed from wastewater using biological processes in which microorganisms consume the organic matter for maintenance and growth. The resulting biomass and other suspended solids, together known as sludge, are removed from the treated wastewater before it is discharged to a receiving stream. Microorganisms can biodegrade soluble organic material in wastewater under aerobic or anaerobic conditions. Anaerobic wastewater treatment refers to the procedure in which organic matter in wastewater or other material is degraded by microorganisms in the absence of oxygen, resulting in the generation of CO_2 and CH_4.

Figure 2-1 shows a simplified diagram outlining the inputs and outputs from wastewater treatment operations. Typically, treatment of wastewater begins with primary treatment using processes such as screening or settling. Subsequently, wastewater may be biologically treated either under aerobic or anaerobic conditions. Most biological treatment processes are designed to separate solids from wastewater; often, these solids are treated further in sludge digesters, which may be either aerobic or anaerobic.

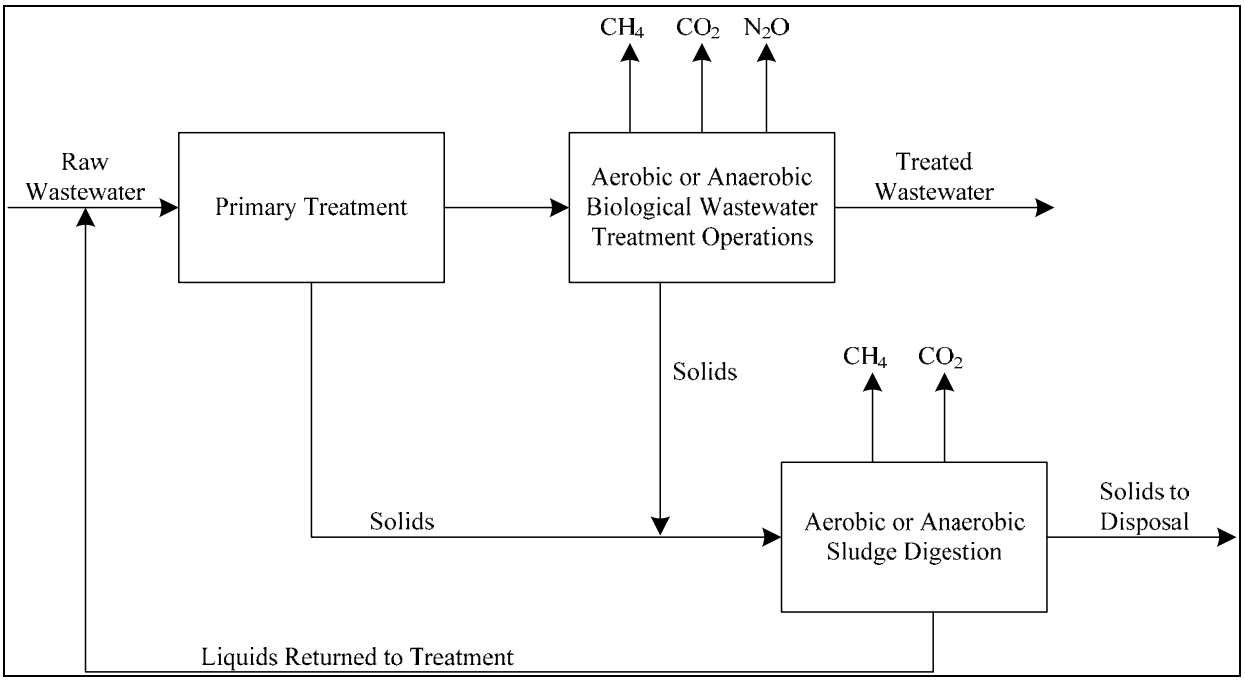

Figure 2-1. Diagram of Wastewater Treatment Inputs and Outputs

As shown in Figure 2-1, both biological wastewater treatment and sludge digestion generate greenhouse gases (GHGs). Aerobic processes emit CO_2; however, these are not considered anthropogenic emissions and therefore are neither included in *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (EPA, 2007) (hereafter referred to as the *Inventory*) nor in the Reporting Rule. Because CO_2 released from wastewater treatment is biogenic in origin (i.e., produced by biological processes), the Intergovernmental Panel on Climate Change (IPCC) considers these CO_2 emissions to be part of the natural carbon cycle.

Domestic and some industrial wastewaters contain nitrogen, usually in the form of urea, ammonia, and proteins. These compounds are converted to nitrate (NO_3) through the aerobic process of nitrification. Denitrification occurs under anoxic conditions (without free oxygen), and involves the biological conversion of nitrate into di-nitrogen gas (N_2). N_2O can be an intermediate product of both processes, but is more often associated with denitrification. Industrial wastewater is generally low in nitrogen and, as a result, its treatment generates little N_2O. Emissions of N_2O from industrial wastewater treatment are not included in either the *Inventory* or the Reporting Rule. The IPCC has stated that the N_2O emissions from industrial sources are insignificant compared to emissions from domestic wastewater.

The only GHG accounted for in Subpart II of the Reporting Rule is CH_4. The principal factor in determining the CH_4 generation potential of wastewater is the amount of degradable organic material in the wastewater. Common parameters used to measure the organic component of the wastewater are Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD). BOD_5 represents the amount of oxygen used by microorganisms to consume the organic matter contained in the wastewater through aerobic decomposition processes in a 5-day period. COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable).

2.2 Reporting Rule Applicability

The requirements of Subpart II apply to anaerobic processes used to treat industrial wastewater and wastewater treatment sludges at pulp and paper mills, food processing facilities, ethanol production facilities, and petroleum refineries. These are the only industries covered by Subpart II. Further, Subpart II does not include emissions from:

- Municipal wastewater treatment plants;
- Separate treatment of sanitary wastewater at industrial facilities;
- Oil/water separators; or
- Aerobic and anoxic treatment of industrial wastewater.

2.2.1 Processes Included in the Reporting Rule

The anaerobic treatment processes covered by Subpart II are those processes in which organic matter in wastewater or wastewater treatment sludge is degraded by microorganisms in the absence of oxygen, resulting in biogas generation. "Biogas" refers to the combination of CO_2, CH_4, and other gases produced by the biological breakdown of organic matter in the absence of oxygen (Metcalf & Eddy, 1979).

Requirements for this source category require facilities to report CH_4 emissions only from anaerobic processes and related biogas destruction devices. Anaerobic processes are biological processes that occur in the absence of oxygen (Metcalf & Eddy, 1979). Facilities are required to report CH_4 emissions from anaerobic reactors and anaerobic lagoons used to treat industrial wastewater and from anaerobic sludge digesters used to treat industrial wastewater treatment sludges. The sludges may be produced by either aerobic or anaerobic wastewater treatment processes. Facilities are also required to report methane emissions from devices used to destroy the biogas recovered from the anaerobic processes.

Anaerobic reactors. Anaerobic reactors are enclosed vessels used for anaerobic wastewater treatment processes (Grady, Daigger, and Lim, 1999; Metcalf & Eddy, 1979). The IPCC methodology for estimating CH_4 emissions from industrial wastewater treatment identifies two types of anaerobic reactors, anaerobic sludge blanket and fixed film (IPCC, 2006; Table 6-8).

Anaerobic lagoons. Anaerobic lagoons are lined or unlined earthen basins used for wastewater treatment, in which oxygen is absent throughout the depth of the basin, except for a shallow surface zone (Metcalf & Eddy, 1979). Anaerobic lagoons are not equipped with surface aerators. The IPCC methodology for estimating CH_4 emissions from industrial wastewater treatment classifies anaerobic lagoons into two depths: deep (depth more than 2 meters) or shallow (depth less than 2 meters) (IPCC, 2006; Table 6-8).

Anaerobic sludge digesters. Anaerobic sludge digesters are enclosed vessels in which wastewater treatment sludges are degraded by microorganisms in the absence of oxygen, resulting in the generation of CO_2 and CH_4 (Metcalf & Eddy, 1979). The digested wastewater treatment sludges may have been generated by aerobic treatment processes (e.g., the activated sludge process). If the sludge digester is operated in the absence of oxygen, it is considered an anaerobic process. Anaerobic sludge digesters are designed for CH_4 recovery and are not expected to emit methane directly from the digester. The IPCC methodology for estimating CH_4

emissions from industrial wastewater treatment includes a methodology for estimating emissions from "anaerobic digester for sludge" (IPCC, 2006; Table 6-8).

Biogas destruction devices. Biogas destruction devices include flares, thermal oxidizers, boilers, turbines, internal combustion engines, or any other combustion units used to destroy or oxidize CH_4 contained in biogas.

2.2.2 Industries Included in the Reporting Rule

Subpart II includes industries that both have high levels of BOD_5 or COD in their wastewater and frequently use anaerobic treatment. For these reasons, these industries are also represented in the wastewater treatment sector of the U.S. GHG *Inventory*. These industries (pulp and paper mills, food processing facilities, ethanol production facilities and petroleum refineries) are described in more detail below.

Pulp and Paper Mills. Pulp and paper mills are facilities that produce market pulp (i.e., stand-alone pulp facilities), manufacture pulp and paper (i.e., integrated facilities), produce paper products from purchased pulp, produce secondary fiber from recycled paper, convert paper into paperboard products (e.g., containers), or operate coating and laminating processes (40 CFR §98.270).

Wastewater treatment for the pulp and paper industry typically includes primary treatment (such as screening, sedimentation, and flotation/hydrocycloning) to remove solids (World Bank, 1999; Nemerow and Dasgupta, 1991), followed by secondary biological treatment (such as activated sludge or anaerobic or aerobic lagoons). In the United States, primary treatment is focused on solids removal, equalization, neutralization, and color reduction (EPA, 1993). The vast majority of pulp and paper mills with on-site treatment systems use mechanical clarifiers to remove suspended solids from the wastewater. About 10 percent of pulp and paper mills with treatment systems use settling ponds for primary treatment and most of these likely do not perform secondary treatment (EPA, 1993). Negligible GHG emissions are assumed to occur during primary treatment.

Approximately 42 percent of the BOD_5 in pulp and paper wastewater passes on to secondary treatment, which consists of activated sludge, aerated stabilization basins, or non-aerated stabilization basins (EPA, 1997b). No anaerobic activity is assumed to occur in activated sludge systems or aerated stabilization basins. However, for the *Inventory*, EPA assumes about 25 percent of the wastewater treatment systems used in the United States are nonaerated stabilization basins. These basins are typically 10 to 25 feet deep and are classified as anaerobic deep lagoons.

Food Processing Facilities. For the purpose of the Reporting Rule, food processing facilities are defined as those that manufacture or process meat, poultry, fruits, and/or vegetables. The North American Industry Classification System (NAICS) is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. It was developed in 1997 to replace the Standard Industrial Classification (SIC) system (NAICS, 2007).

Meat or poultry processing or rendering facilities are those covered under NAICS code 3116 (which was SIC code 201, Meat Product Manufacturing). NAICS code 3116 (Animal Slaughtering and Processing) is made up of the following subsectors:

- 31161 Animal Slaughtering and Processing
  This industry comprises establishments primarily engaged in one or more of the following: (1) slaughtering animals; (2) preparing processed meats and meat by-products; and (3) rendering and/or refining animal fat, bones, and meat scraps. This industry includes establishments primarily engaged in assembly cutting and packing of meats (i.e., boxed meats) from purchased carcasses.

- 311611 Animal (except Poultry) Slaughtering
  This U.S. industry comprises establishments primarily engaged in slaughtering animals (except poultry and small game). Establishments that slaughter and prepare meats are included in this industry.

- 311612 Meat Processed from Carcasses
  This U.S. industry comprises establishments primarily engaged in processing or preserving meat and meat by-products (except poultry and small game) from purchased meats. This industry includes establishments primarily engaged in assembly cutting and packing of meats (i.e., boxed meats) from purchased meats.

- 311613 Rendering and Meat By-product Processing
  This U.S. industry comprises establishments primarily engaged in rendering animal fat, bones, and meat scraps.

- (311614 is not a valid 2007 NAICS code)

- 311615 Poultry Processing
  This U.S. industry comprises establishments primarily engaged in (1) slaughtering poultry and small game and/or (2) preparing processed poultry and small game meat and meat by-products.

Fruit or vegetable processing facilities are facilities covered under NAICS code 3114 (which was SIC code 203, Fruit and Vegetable Preserving and Specialty Food Manufacturing). NAICS code 3114 (Fruit and Vegetable Preserving and Specialty Food Manufacturing) includes the following: (1) establishments that freeze food and (2) those that use preservation processes, such as pickling, canning, and dehydrating. Both types begin their production process with inputs of vegetable or animal origin.

NAICS 3114 (Fruit and Vegetable Preserving and Specialty Food Manufacturing) is made up of the following subsectors:

- 31141 Frozen Food Manufacturing
  This industry comprises establishments primarily engaged in manufacturing frozen fruit, frozen juices, frozen vegetables, and frozen specialty foods (except seafood), such as frozen dinners, entrees, and side dishes; frozen pizza; frozen whipped toppings; and frozen waffles, pancakes, and french toast.

- 311411 Frozen Fruit, Juice, and Vegetable Manufacturing
  This U.S. industry comprises establishments primarily engaged in manufacturing frozen fruits; frozen vegetables; and frozen fruit juices, ades, drinks, cocktail mixes and concentrates.

- 311412 Frozen Specialty Food Manufacturing
  This U.S. industry comprises establishments primarily engaged in manufacturing frozen specialty foods (except seafood), such as frozen dinners, entrees, and side dishes; frozen pizza; frozen whipped topping; and frozen waffles, pancakes, and french toast.

- 31142 Fruit and Vegetable Canning, Pickling, and Drying
  This industry comprises establishments primarily engaged in manufacturing canned, pickled, and dried fruits, vegetables, and specialty foods. Establishments in this industry may package the dried or dehydrated ingredients they make with other purchased ingredients. Examples of products made by these establishments are canned juices; canned baby foods; canned soups (except seafood); canned dry beans; canned tomato-based sauces, such as catsup, salsa, chili, spaghetti, barbeque, and tomato paste, pickles, relishes, jams and jellies, dried soup mixes and bullions, and sauerkraut.

- 311421 Fruit and Vegetable Canning
  This U.S. industry comprises establishments primarily engaged in manufacturing canned, pickled, and brined fruits and vegetables. Examples of products made in these establishments are canned juices; canned jams and jellies; canned tomato-based sauces, such as catsup, salsa, chili, spaghetti, barbeque, and tomato paste; pickles, relishes, and sauerkraut.

- 311422 Specialty Canning
  This U.S. industry comprises establishments primarily engaged in manufacturing canned specialty foods. Examples of products made in these establishments are canned baby food, canned baked beans, canned soups (except seafood), canned spaghetti, and other canned nationality foods.

- 311423 Dried and Dehydrated Food Manufacturing
  This U.S. industry comprises establishments primarily engaged in (1) drying (including freeze-dried) and/or dehydrating fruits, vegetables, and soup mixes and bouillon and/or (2) drying and/or dehydrating ingredients and packaging them with other purchased ingredients, such as rice and dry pasta.

The meat and poultry processing industry makes extensive use of anaerobic lagoons in sequence with screening, fat traps, and dissolved air flotation when treating wastewater on site. About one third of meat processing operations (EPA, 2002) and one fourth of poultry processing operations (U.S. Poultry, 2006) perform on-site treatment in anaerobic lagoons.

Treatment of wastewater from fruits and vegetable processing includes screening, coagulation/settling, and biological treatment (lagooning). The flows are frequently seasonal, and robust treatment systems are preferred for on-site treatment. Effluent is suitable for discharge to

the sewer. Like meat and poultry processing, this industry may also use anaerobic lagoons (Nemerow and Dasgupta, 1991).

The food processing facilities covered by Subpart II are the same as those in the industrial wastewater treatment sector of the *Inventory*. The Reporting Rule does not include the manufacturing of food products, such as the manufacture of sugar from beets or sugar cane, because these operations are not included in the definition of food processing.

Ethanol Production Facilities. The *Inventory* describes ethanol production facilities as those that produce ethanol from the fermentation of sugar, starch, grain, or cellulosic biomass feedstocks, or produce ethanol synthetically from petrochemical feedstocks, such as ethylene or other chemicals. However, synthetic ethanol comprises only about 2 percent of ethanol production (EPA, 2007).

Ethanol, or ethyl alcohol, is produced primarily for use as a fuel component, but is also used in industrial applications and in the manufacture of beverage alcohol. Ethanol can be produced from fermenting sugar-based feedstocks (e.g., molasses and beets), starch- or grain-based feedstocks (e.g., corn, sorghum, and beverage waste), and cellulosic biomass feedstocks (e.g., agricultural wastes, wood, and bagasse). Although the Department of Energy predicts cellulosic ethanol production will increase in the coming years, it is currently only in development in the United States. According to the Renewable Fuels Association, 82 percent of ethanol production facilities use corn as the sole feedstock and 7 percent of facilities use a combination of corn and another starch-based feedstock. Corn fermentation is the principal ethanol production process in the United States and is expected to increase through 2012. (RFA, 2009).

Ethanol is produced from corn (or other starch-based feedstocks) primarily by two methods: wet milling and dry milling. Historically, most ethanol was produced by the wet milling process, but now the majority is produced by the dry milling process. The wastewater generated at ethanol production facilities is handled in a variety of ways. Dry milling facilities often combine the resulting evaporator condensate with other process wastewaters, such as equipment wash water, scrubber water, and boiler blowdown, and treat the mixed wastewater in anaerobic digesters. Wet milling facilities often treat their steepwater condensate in anaerobic systems followed by aerobic polishing systems and may treat the stillage (or processed stillage) from the ethanol fermentation/distillation process separately or together with steepwater and/or wash water. CH_4 generated in anaerobic digesters is commonly collected and either flared or used as fuel in the ethanol production process (ERG, 2006). EPA estimates that one-third of wet milling and three quarters of dry milling facilities treat wastewater anaerobically.

Petroleum Refineries. A petroleum refinery is any facility engaged in producing gasoline, gasoline blending stocks, naphtha, kerosene, distillate fuel oils, residual fuel oils, lubricants, or asphalt (bitumen) through distillation of petroleum or through redistillation, cracking, or reforming of unfinished petroleum derivatives (40 CFR §98.250).

Many refineries use oil/water separators as a primary treatment method. These treatment operations use gravity separation to remove oil from refinery wastewater and can emit volatile organic compounds (VOCs). Although these VOCs are not GHGs, they convert to CO_2 in the atmosphere. Emissions from oil/water separators were included in the proposed rule but are not included in the final because the purpose of the Reporting Rule is to collect direct GHG

emissions data from downstream sources[1] including industrial wastewater treatment. Therefore, the rule does not require facilities to report indirect emissions such as VOCs that can convert to CO_2 once in the atmosphere. EPA expects no direct emissions of CO_2 or other GHGs from these oil/water separators. Following primary treatment, most refineries use biological treatment systems that exhibit anaerobic conditions, resulting in CH_4 production.

Other Facilities Not Covered by the Reporting Rule. Although other industrial facilities may use anaerobic wastewater treatment processes that generate CH_4, Subpart II applies only to facilities in the four categories described above. EPA has not characterized anaerobic wastewater treatment operations or estimated CH_4 emissions in other industries. The petrochemical industry was included in the proposed Reporting Rule, but is not included in the final rule because petrochemical facilities are not known to use anaerobic wastewater treatment.

[1] The rule requires fuel suppliers to report indirect emissions; however, downstream sources are not required to report emissions of VOCs or other emissions that convert to CO_2 in the atmosphere.

3. EMISSION ESTIMATES

During the development of the Reporting Rule, EPA estimated the number of facilities in each industry that will be required to report their industrial wastewater GHG emissions. EPA also estimated the mass of emissions expected to be reported by each industry. For these estimates, EPA used assumptions and methodologies developed for the *Inventory*.

Each industry covered by Subpart II of the Reporting Rule (40 CFR Part 98) has different reporting requirements as outlined below:

- Pulp and Paper: Mills are required to report their GHG emissions only if their emissions exceed 25,000 tCO_2e per year in combined emissions from all applicable source categories in the final Reporting Rule including pulp and paper manufacturing, and, if present, stationary fuel combustion sources, industrial solid waste landfills, industrial wastewater treatment, and any others that may apply.

- Food Processing: Facilities are required to report their GHG emissions only if they exceed 25,000 tCO_2e per year in combined emissions from all applicable source categories, including, but not limited to stationary fuel combustion sources, industrial solid waste landfills, and industrial wastewater treatment. Process emissions are not included in determining the threshold, nor are facilities required to report process emissions.

- Ethanol Production: Facilities are required to report their GHG emissions only if they exceed 25,000 tCO_2e per year in combined emissions from all applicable source categories, including, but not limited to stationary fuel combustion sources, industrial solid waste landfills, and industrial wastewater treatment. Process emissions are not included in determining the threshold, nor are facilities required to report process emissions.

- Petroleum Refining: All petroleum refineries are required to report their GHG emissions. Refineries must report emissions from their refinery operations and, if present, from stationary fuel combustion sources, industrial solid waste landfills, industrial wastewater treatment, and any other applicable source categories.

The procedures EPA used to estimate the number of facilities required to report and their industrial wastewater treatment GHG emissions are described in the following subsections.

3.1 Pulp and Paper Mills

EPA estimated that there are 565 pulp and paper mills in the United States (EPA, 1993). Using assumptions presented in the *Inventory*, EPA estimated that 25 percent (141) of these mills have anaerobic secondary treatment and would be required to report their industrial wastewater treatment CH_4 emissions. EPA does not know the production or emissions from these mills, but assumed that all facilities with anaerobic wastewater treatment would have total facility emissions that exceed the 25,000 metric tons of CO_2e per year reporting threshold.

To estimate CH_4 emissions from industrial wastewater treatment at pulp and paper mills, EPA used the methodology presented in the *Inventory*, which is summarized in Equation 3-1:

$$CO_2e = F \times P \times W \times BOD \times cf \times TA \times B_0 \times MCF \times GWP \quad (3\text{-}1)$$

where:

CO_2e	=	CO_2 equivalent of methane emissions for facilities required to report (tCO2e).
F	=	Estimated fraction of facilities required to report (decimal).
P	=	Total industry production (thousand metric ton/year).
W	=	Wastewater outflow (m^3/metric ton).
BOD	=	Organic matter concentration in untreated wastewater, measured as BOD_5 (kg/m^3).
cf	=	Factor for conversion of BOD to COD (unitless)
TA	=	Fraction of wastewater BOD treated anaerobically in secondary treatment (decimal).
B_0	=	Maximum CH_4-producing capacity (kg CH_4/kg COD).
MCF	=	Methane conversion factor for anaerobic treatment.
GWP	=	Global warming potential for CH_4.

EPA estimated that pulp and paper industrial wastewater treatment emissions amount to 4,075,044 tCO_2e, using the values listed in Table 3-1.

Table 3-1. Values Used to Estimate Pulp and Paper CH_4 Emissions

Variable	Parameter	Value	Source
F	Estimated fraction of facilities required to report (decimal)	0.25	ERG, 2008
P	Total industry production (thousand metric tons/year)	135,889	EPA, 2010
W	Wastewater outflow (m^3/ton)	85	World Bank, 1999 Nemerow and Dasgupta, 1991
BOD	Organic matter concentration in untreated pulp and paper mill wastewater, as BOD_5 (kg/m^3)	0.4	EPA, 1997b EPA, 1993 World Bank, 1999
cf	Factor for conversion of BOD to COD, specific to pulp and paper mill wastewater (kg COD/kg BOD)	2	EPA, 1997a
TA	Fraction of pulp and paper industry wastewater BOD treated in secondary treatment	0.42	EPA, 2010
B_0	Maximum CH_4-producing capacity (kg CH_4/kg COD)	0.25	IPCC, 2006
MCF	Methane conversion factor for anaerobic systems	0.8	IPCC, 2006
GWP	Global warming potential	21	EPA, 2010

3.2 Food Processing Facilities

Food processing facilities covered by Subpart II fall into three segments: fruits and vegetables processing, meat processing, and poultry processing. EPA's estimates of the number

of facilities in each segment required to report and their industrial wastewater treatment CH_4 emissions are discussed below.

Fruits and vegetables processing. Based on information from the 2002 U.S. Economic Census for Manufacturing (U.S. Census Bureau, 2002), EPA estimated that there are 1,746 fruits and vegetable processing facilities in the United States. Using assumptions presented in the *Inventory*, EPA estimated that 5 to 6 percent (100) of these facilities have anaerobic secondary treatment resulting in emissions of 123,000 tCO_2e. Thus, for 100 facilities, the average emissions are 1,230 tCO_2e per plant per year. Because this estimate is far below the 25,000 tCO_2e per year threshold for reporting, EPA estimated that no fruits and vegetables processing facility would be required to report its industrial wastewater treatment GHG emissions.

Meat processing. Meat processing facilities are required to report their GHG emissions if they exceed 25,000 tCO_2e per year in combined emissions from stationary fuel combustion sources, industrial solid waste landfills, and industrial wastewater treatment. EPA estimated the number of meat processing facilities that would be required to report GHG emissions based on emissions from industrial wastewater treatment only. EPA ignored the other sources because it had no information about emissions from stationary fuel combustion sources or industrial solid waste landfills at meat processing facilities.

EPA had no data on meat production or GHG emissions per plant. As a result, to estimate the number of meat processing facilities that would emit more than 25,000 tCO_2e per year from industrial wastewater treatment processes, EPA back-calculated the production rate that would result in emissions of 25,000 tCO_2e using Equation 3-2.

$$P = t/(W \times BOD \times cf \times B_0 \times MCF \times GWP) \times 1{,}000 \text{ kg/ton} \qquad (3\text{-}2)$$

where:

P	=	Production resulting in GHG emissions above the reporting threshold (ton/year).
W	=	Wastewater outflow (m^3/ton).
BOD	=	Organic matter concentration in the wastewater, measured as BOD, kg/m^3.
cf	=	Factor for conversion of BOD to COD (unitless)
B_0	=	Maximum CH_4-producing capacity (kg CH_4/kg COD).
MCF	=	Methane conversion factor (decimal).
GWP	=	Global warming potential.
t	=	Reporting threshold (25,000 tCO_2e/yr).

Using the values listed in Table 3-2. EPA estimated that 133,000 metric tons/year of meat production would result in industrial wastewater treatment CH_4 emissions that would reach the 25,000 t CO_2e reporting threshold.

EPA had collected limited production information when it established national effluent limitation guidelines and standards for this industry in 2004 (EPA, 2004a). At that time, EPA estimated that there were 139 meat processors that processed more than 50 million pounds (22,700 metric tons) per year. For the purpose of this estimate, EPA assumed that 40 facilities processed more than 133,000 tons/year, the tonnage that reaches the reporting threshold. EPA estimates that 33 percent of meat processing facilities have on-site anaerobic treatment. Thus,

EPA estimated that 13 meat processing facilities would be required to report their industrial wastewater treatment CH_4 emissions and that none of these facilities recover biogas.

Table 3-2. Values Used to Estimate Meat and Poultry Processing CH_4 Emissions

Variable	Parameter	Meat Processing	Poultry Processing	Source
W	Wastewater outflow (m^3/ton)	5.3	12.5	ARCADIS, 2004 EPA, 2004a
BOD	Organic matter concentration in the wastewater, measured as BOD (kg/m^3)	2.822	1.508	EPA, 2002 ARCADIS, 2004
cf	Factor for conversion of BOD to COD, specific to meat and poultry processing wastewater (kg COD/kg BOD)	3	3	EPA, 1997a
B_0	Maximum CH_4-producing capacity (kg CH_4/kg COD)	0.25	0.25	IPCC, 2006
MCF	Methane conversion factor	0.8	0.8	IPCC, 2006
GWP	Global warming potential	21	21	EPA, 2010

EPA estimated these 13 meat processing facilities each emit 25,000 tCO_2e per year, for a total of 325,000 tCO_2e.

Poultry processing. Like meat processing facilities, poultry processing facilities are required to report if their combined emissions from stationary fuel combustion sources, industrial solid waste landfills, and industrial wastewater treatment exceed the threshold. As with meat processing, EPA had no data on per plant poultry production or per plant GHG emissions. Again, EPA back-calculated the production rate that would result in emissions of 25,000 tCO_2e using Equation 3-2.

Using the values listed in Table 3-2, EPA estimated that 105,000 metric tons/year) of poultry production would result in industrial wastewater treatment CH_4 emissions that would reach the 25,000 tCO_2e reporting threshold.

EPA had limited production information collected when it established national effluent limitation guidelines and standards for this industry in 2004 (EPA, 2004a). At that time, EPA estimated that there were 206 poultry processors that processed more than 100 million pounds (45,400 metric tons) per year. For the purpose of this estimate, EPA assumed that any of these 206 facilities that used anaerobic wastewater treatment processes would be required to report their GHG emissions. EPA estimates that 25 percent of the 206 poultry processing facilities that process more than 100 million pounds per year have on-site anaerobic treatment. Thus, EPA estimated that 50 poultry processing facilities would be required to report their industrial wastewater treatment GHG emissions.

EPA estimated these 50 poultry processing facilities each emit 25,000 tCO_2e per year, for a total of 1,250,000 tCO_2e.

3.3 Ethanol Production Facilities

Ethanol production facilities are required to report their GHG emissions if they exceed 25,000 tCO_2e per year in combined emissions from all applicable source categories, including, but not limited to stationary fuel combustion sources, industrial solid waste landfills, and industrial wastewater treatment. EPA estimated the number of ethanol production facilities that would be required to report GHG emissions based on emissions from industrial wastewater treatment only. For estimates of coverage based on combined emissions, see the TSD for Ethanol Production.

Based on information from the Renewable Fuels Association (RFA, 2009), EPA estimated that there are 170 ethanol production facilities in the United States. Of these, EPA estimated that 85 percent use dry milling and 15 percent use wet milling (EPA, 2007). Using production information provided in the RFA data and parameter values listed in Table 3-3, EPA estimated CH_4 emissions from industrial wastewater treatment at each ethanol production facility using methodology presented in the *Inventory* and summarized in Equation 3-1.

Table 3-3. Values Used to Estimate Ethanol Production CH_4 Emissions

Variable	Parameter	Wet Milling Value	Dry Milling Value	Source
F	Facilities with anaerobic treatment (decimal)	1	0.33	ERG, 2008
P	Total industry production (million gallons/year)	1,494	5,006	EPA, 2010
W	Wastewater outflow (gal/gal ethanol)	10	1.25	Donovan, 1996 NRBP, 2001 Ruocco, 2006a Ruocco, 2006b Merrick, 1998
BOD	COD or BOD (kg/m^3)	BOD = 1.5	COD = 3	Ruocco, 2006a Ruocco, 2006a Merrick, 1998 White and Johnson, 2003
cf	Factor for conversion of BOD to COD, specific to ethanol production wastewater (kg COD/kg BOD)	2	2	EPA, 1997a
B_0	Maximum CH_4-producing capacity (kg CH_4/kg COD)	0.25	0.25	IPCC, 2006
MCF	Methane conversion factor	0.8	0.8	IPCC, 2006
GWP	Global warming potential	21	21	EPA, 2010
TA	Fraction of industry wastewater BOD treated in secondary treatment	0.75	0.333	EPA, 2010

EPA determined that 12 facilities that use wet milling operations had sufficient production to exceed the 25,000 tCO2e reporting threshold. However, only one-third of facilities that use wet milling are expected to use anaerobic treatment (ERG, 2008). Therefore, EPA

estimated that four facilities with wet milling operations will be required to report GHG emissions (based on emissions from industrial wastewater treatment only).

EPA assumed that all facilities that use dry milling operations had anaerobic treatment in place and none operated a biomethanator[2]. In keeping with the *Inventory* estimation methodology, EPA assumed that 75 percent of the facilities recovered biogas from their anaerobic treatment processes. EPA estimated that no ethanol production facilities that use dry milling operations would meet the reporting threshold based on emissions from industrial wastewater treatment only.

3.4 Petroleum Refineries

All petroleum refineries are required to report their GHG emissions. Refineries must report emissions from their refining operations and, if present, from stationary fuel combustion sources, industrial solid waste landfills, and industrial wastewater treatment.

Based on information from the Energy Information Administration (EIA, 2009), EPA determined that there are 150 petroleum refineries in the United States. Using assumptions presented in *2007 Inventory*, EPA estimated that 100 percent of the refineries use wastewater treatment that exhibits anaerobic conditions, and thus they would be required to report their industrial wastewater treatment CH_4 emissions. Using production information from EIA (EIA, 2009) and parameter values listed in Table 3-4, EPA estimated CH_4 emissions from industrial wastewater treatment for petroleum refineries using methodology presented in the *Inventory*, as summarized in Equation 3-1.

Table 3-4. Values Used to Estimate Petroleum Refinery CH_4 Emissions

Variable	Parameter	Value	Source
F	Facilities with anaerobic treatment (decimal)	1	ERG, 2008
P	Total industry production (thousand barrels/year)	6,567,929	EPA, 2010
W	Wastewater outflow (gal/barrel produced)	35	CARB, 2007 Timm, 1985
COD	COD (kg/m^3)	0.45	Benyahia *et al* (2006)
B_0	Maximum CH_4-producing capacity (kg CH_4/kg COD)	0.25	IPCC, 2006
MCF	Methane conversion factor	0.3 [a]	IPCC, 2006
GWP	Global warming potential	21	EPA, 2010
TA	Fraction of industry wastewater BOD treated in secondary treatment	1	EPA, 2010

a – EPA assumes refineries operate trickling filters, rotating biological contactors, or other systems that exhibit anaerobic conditions. Therefore, EPA selected a CH_4 conversion factor of 0.3 for these treatment systems.

EPA assumed that no petroleum refineries recover biogas and estimated that petroleum refinery industrial wastewater treatment emissions amount to 616,674 (tCO_2e) per year (EPA, 2007).

[2] A biomethanator is a specific type of anaerobic reactor, treating a higher fraction of industry wastewater BOD than is typically treated in secondary treatment.

3.5 Summary

Table 3-5 summarizes the number of plants EPA estimates will be required to report under the Reporting Rule and their estimated emissions. These estimates were used to calculate estimated cost of compliance, which can be found in *Greenhouse Gas Reporting Rule, Industrial Wastewater Treatments Source Category, Costs for Final Rule Monitoring Requirements – Revised* (ERG, 2010).

Table 3-5. Estimated Number of Plants Required to Report and Estimated Emissions

Category	No. of Plants in the U.S.	Estimated Plants with Anaerobic Treatment	Estimated No. of Plants Required to Report	Estimated No. of Reporting Plants with CH_4 Recovery	Estimated Emissions Plants are Required to Report (tCO_2e)
Pulp and Paper	565	25%	141	0	4,075,044
Fruits and Vegetables Processing	1,746	100% have anaerobic treatment, but none (0) exceed reporting threshold	0	0	123,000
Meat Processing	3,337	33% have anaerobic treatment, but EPA estimates only 13 exceed the reporting threshold	13	0	0
Poultry Processing	536	25% have anaerobic treatment, but EPA estimates not more than 50 exceed the reporting threshold	50	0	1,250,000
Ethanol Production - wet mill 15% of 170 mills	25	33% have anaerobic treatment; of those plants, half have enough production to exceed the reporting threshold	4	4	21,681
Ethanol Production - dry mill 85% of 170 mills	145	100% but none exceed reporting threshold based solely on wastewater treatment	0	0	0
Petroleum Refineries	150	100%	150	0	616,674

4. ESTIMATING METHANE GENERATION FROM WASTEWATER TREATMENT

CH_4 emissions from industrial wastewater treatment are a function of the concentration of soluble organic material in anaerobically treated wastewater and an emission factor that characterizes the extent to which waste becomes CH_4 (IPCC, 2006). The emission factor is the product of the maximum CH_4 producing capacity of the wastewater (B_0) and the methane conversion factor (MCF) that accounts for the ability of the particular system to achieve that maximum CH_4 production. The 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 6, p.6.2.1, provide values of B_0 for organic material measured as COD and as BOD (see Table 4-1).

Most wastewater treatment systems will not produce the maximum amount of CH_4 possible because the conditions in the systems are not ideal for CH_4 production. The CH_4 producing potential of a specific system is represented by a parameter known as the CH_4 conversion factor (MCF). This value ranges from 0 to 100 percent and reflects the capability of a system to produce the maximum achievable CH_4 based on the organic matter present in the wastewater. A higher MCF equates to a higher CH_4 production. MCF values for various types of treatment systems are presented in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 6, Table 6.8. The MCFs used in the Reporting Rule are listed in Table 4-1.

Using the emission factors in Table 4-1 and measured concentrations of organic matter and flow rates, facilities covered under the Reporting Rule are required to estimate the annual mass of CH_4 they generate from their anaerobic wastewater treatment processes[3]. Facilities must measure both the wastewater flow and the concentration of organic material entering anaerobic wastewater treatment processes (specifically anaerobic reactors and anaerobic lagoons) for this calculation, as shown in Figure 4-1.

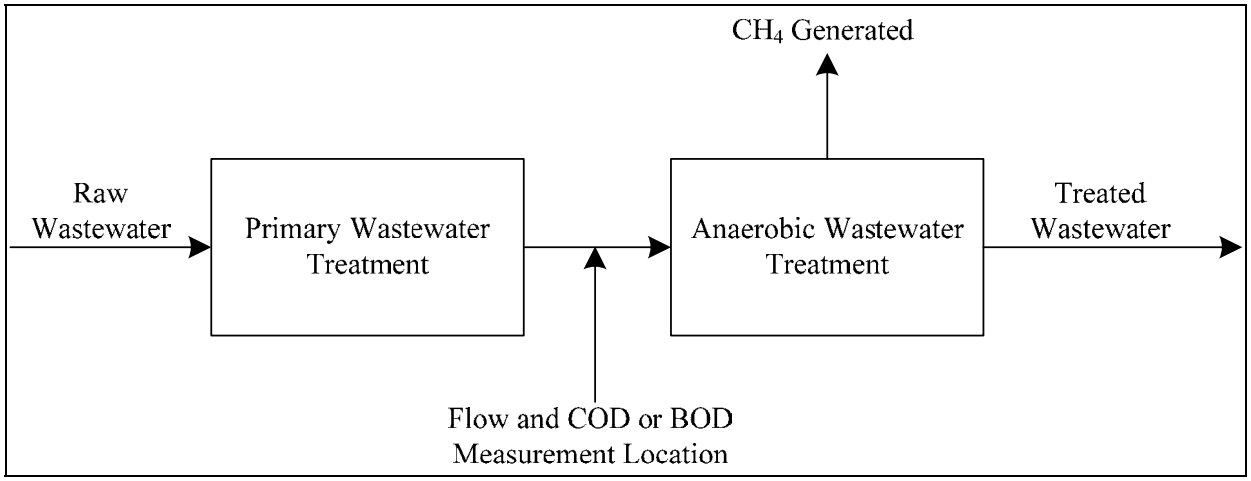

Figure 4-1. Methane Generation

[3] Operators of anaerobic sludge digesters are not required to report CH_4 generated. Anaerobic sludge digesters are designed to recover CH_4 and not emit CH_4 directly from the digester apparatus. Operators of anaerobic sludge digesters are required to report the amount of CH_4 recovered and emitted from the recovery system. See Sections 5 and 6 of this document for these requirements.

To reduce the reporting burden, the Reporting Rule allows facilities to use COD in conjunction with Equation 4-1 or 5-day biochemical oxygen demand (BOD_5) with Equation 4-2 to calculate CH_4 generation. If facilities measure COD, they should estimate the annual mass of CH_4 generated by each anaerobic wastewater treatment process they operate, using Equation 4-1:

$$CH_4G = \sum_{w=1}^{52} \left[Flow_w \times COD_w \times B_o \times MCF \times 0.001 \right] \quad (4\text{-}1)$$

where:

CH_4G	=	Annual mass CH_4 generated from the anaerobic wastewater treatment process (metric tons).
$Flow_n$	=	Volume of wastewater sent to an anaerobic wastewater treatment process in week n (m^3/week).
COD_n	=	Average weekly concentration of COD of wastewater entering an anaerobic wastewater treatment process (for month n)(kg/m^3).
B_0	=	Maximum CH_4 producing potential of wastewater (kg CH_4/kg COD), use the value 0.25.
MCF	=	CH_4 conversion factor, based on relevant values in Table 3-2.
0.001	=	Conversion factor from kg to metric tons.
w	=	Index for weekly measurement period.

If facilities measure BOD_5, they should estimate the annual mass of CH_4 generated by each anaerobic wastewater treatment process they operate, using Equation 4-2:

$$CH_4G = \sum_{w=1}^{52} \left[Flow_w \times BOD_{5,w} \times B_o \times MCF \times 0.001 \right] \quad (4\text{-}2)$$

where:

CH_4G	=	Annual mass of CH_4 generated from the anaerobic wastewater treatment process (metric tons).
$Flow_n$	=	Volume of wastewater sent to an anaerobic wastewater treatment process in week n (m^3/week).
$BOD_{5,n}$	=	Average weekly concentration of 5-day BOD of wastewater entering an anaerobic wastewater treatment process for month n (kg/m^3).
B_0	=	Maximum CH_4 producing potential of wastewater (kg CH_4 /kg BOD_5), use the value 0.6.
MCF	=	CH_4 conversion factor, based on relevant values in Table 3-2.
0.001	=	Conversion factor from kg to metric tons.
w	=	Index for weekly measurement period.

Table 4-1. Emission Factors

Factors	Default Value	Units
B_0 – for facilities monitoring COD	0.25	kg CH_4/kg COD
B_0 – for facilities monitoring BOD_5	0.60	kg CH_4/kg BOD_5
MCF – anaerobic reactor (e.g., upflow anaerobic sludge blanket, fixed film)	0.8	Fraction
MCF – anaerobic deep lagoon (depth more than 2 m)	0.8	Fraction
MCF – anaerobic shallow lagoon (depth less than 2 m)	0.2	Fraction

To determine CH_4 generation using Equations 4-1 or 4-2, facilities are required to measure both flow and either the COD or BOD_5 concentration of wastewater entering the anaerobic wastewater treatment process once each calendar week that the process is operating, with at least three days between measurements. Facilities must collect samples representing wastewater influent to the anaerobic wastewater treatment process, following all preliminary and primary treatment steps, as shown in Figure 4-1.

4.1 Flow Measurement

Flow can be measured with hydraulic structures such as flumes and weirs that are inserted in open channel flow (flow in conduits that are not full). Flow can also be measured with meters (e.g., electromagnetic, Venturi, ultrasonic) that are appropriate for closed channel flow (flow in a liquid-full conduit). Facilities must measure the flow rate for the 24-hour period for which they collect samples analyzed for COD or BOD_5 concentration. Also, the flow measurement location must correspond to the location used to collect samples analyzed for the COD or BOD_5 concentration.

Facilities may measure flow rate using one of the methods specified below:

- ASME MFC–3M–2004 Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi;
- ASME MFC–5M–1985 (Reaffirmed 1994) Measurement of Liquid Flow in Closed Conduits Using Transit-Time Ultrasonic Flowmeters;
- ASME MFC–16–2007 Measurement of Liquid Flow in Closed Conduits with Electromagnetic Flowmeters;
- ASTM D1941 - 91(2007) Standard Test Method for Open Channel Flow Measurement of Water with the Parshall Flume; or
- ASTM D5614 - 94(2008) Standard Test Method for Open Channel Flow Measurement of Water with Broad-Crested Weirs.

A facility may choose another method of measurement other than those listed above; however, they must follow the manufacturer's instructions for the wastewater flow measurement device.

Any chosen flow measurement system must measure the entire discharge flow; it must be accurate and in working order, calibrated, and maintained. Facilities are required to calibrate all wastewater flow measurement devices prior to the first year of reporting and recalibrate them either biennially (every 2 years) or at the minimum frequency specified by the manufacturer. Wastewater flow measurement devices must be calibrated using the procedures specified by the

device manufacturer. For more information on flow measurement see the *NPDES Compliance Inspection Manual*, Appendix O (U.S. EPA, 2004a).

4.2 Organic Matter Concentration Measurement and Analysis

To calculate CH_4 generation, in addition to wastewater flow, facilities are also required to measure organic matter concentration in the form of either BOD_5 or COD. Facilities must collect samples representative of the wastewater entering their anaerobic treatment systems. Wastewater typically flows through a pipe or a conduit and both the flow rate and the concentration of organic material in the wastewater varies over time. For example, wastewater may be discharged intermittently after batch food processing operations, resulting in spikes of flow and pollutant load into the anaerobic wastewater treatment system.

Wastewater samples are collected in three ways:

- Grab sample: single samples collected at one time and place. Grab samples are representative when the sampled stream does not vary in concentration over time.

- Time-weighted composite sample: equal volume discrete sample aliquots collected at constant time intervals into one container. A time-weighted composite sample can be collected either manually or with an automatic sampler. Time-weighted composites are representative of the sampled stream when the flow rate does not vary over time.

- Flow- proportional sample: equal volume discrete sample aliquots collected after a fixed stream flow intervals into one container. This can be achieved by:
  - — Collecting a constant sample volume at varying time intervals proportional to the wastewater flow; or
  - — Collecting a volume of each individual aliquot proportional to the flow, while maintaining a constant time interval between the aliquots.

Flow proportional samples can be collected with an automatic sampler and a compatible flow measuring device, with a flow chart and an automatic sampler capable of collecting discrete samples, or manually by compositing individual grab samples by volume versus flow chart readings.

EPA considered allowing facilities to collect grab samples if the wastewater influent to the anaerobic wastewater treatment process represents the discharge from a well-mixed wastewater storage unit (tank or pond), such that the COD or BOD_5 concentration of the waste stream does not vary in a 24-hour period. EPA also considered allowing facilities to collect time-weighted composite samples if the flow rate of the wastewater influent to the anaerobic wastewater treatment process does not vary more than ±50 percent of the mean flow rate for a 24-hour sampling period.

However, establishing that the sampled stream meets the conditions necessary for these types of sampling would require the facility to collect additional samples. For this reason, the final Reporting Rule requires facilities to collect a flow-proportional composite sample. The Reporting Rule requires either a constant time interval between samples, keeping sample volume proportional to stream flow, or a constant sample volume with the time interval between samples

proportional to stream flow. The sample must represent the average COD or BOD_5 concentration of the waste stream over a 24-hour sampling period at a location similar to that specified in Figure 4-1.

Facilities are required to collect a minimum of four samples per 24-hour period, which should be combined for analysis. The requirement of the final Reporting Rule ensures that the collected sample represents the wastewater influent to the anaerobic wastewater treatment process, without imposing an unnecessary burden on reporters. For more information on sampling, see the *NPDES Permit Writer's Manual* (U.S. EPA, 1996) and the *NPDES Compliance Inspection Manual* (U.S. EPA, 2004b).

Facilities must determine the organic matter concentration in wastewater treated anaerobically using analytical methods for COD or BOD_5 specified in 40 CFR part 136.3 Table 1B. When determining concentrations of wastewater influent to the anaerobic wastewater treatment process to calculate CH_4 generated, samples may be diluted to the concentration range of the approved method. The concentration of the diluted sample must be multiplied by the dilution factor to determine the concentration of the undiluted sample. The undiluted sample concentration is used to calculate CH_4 generation.

5. ESTIMATES OF METHANE RECOVERY

"Biogas" refers to the combination of CO_2, CH_4, and other gases produced by the biological breakdown of organic matter in the absence of oxygen. Some facilities recover some or all of the biogas generated by anaerobic wastewater treatment and anaerobic sludge digestion and route the recovered biogas to a destruction device. These devices include flares, thermal oxidizers, boilers, turbines, internal combustion engines, or any other combustion units used to destroy or oxidize CH_4 contained in the biogas. Figure 5-1 depicts biogas recovery from anaerobic wastewater treatment.

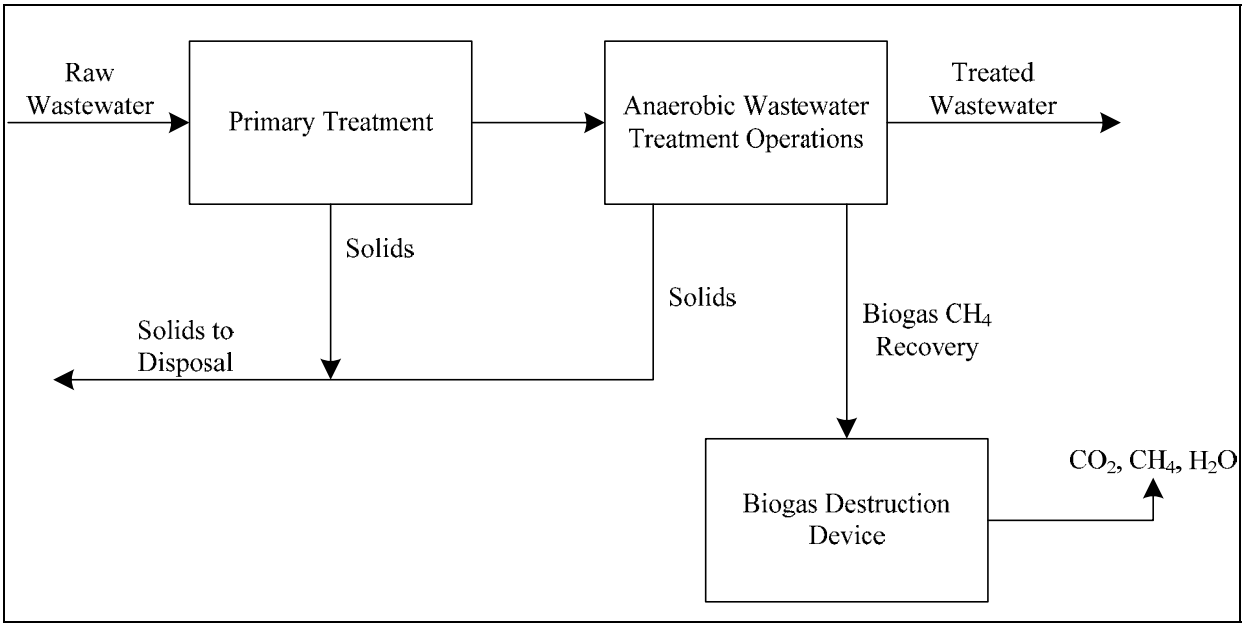

Figure 5-1. Diagram of Biogas Recovery from Anaerobic Wastewater Treatment

Facilities that use aerobic processes to treat wastewater generate larger quantities of waste sludge and may use anaerobic digestion to reduce the volume of sludge and recover the biogas. Figure 5-2 depicts biogas recovery from anaerobic sludge digestion.

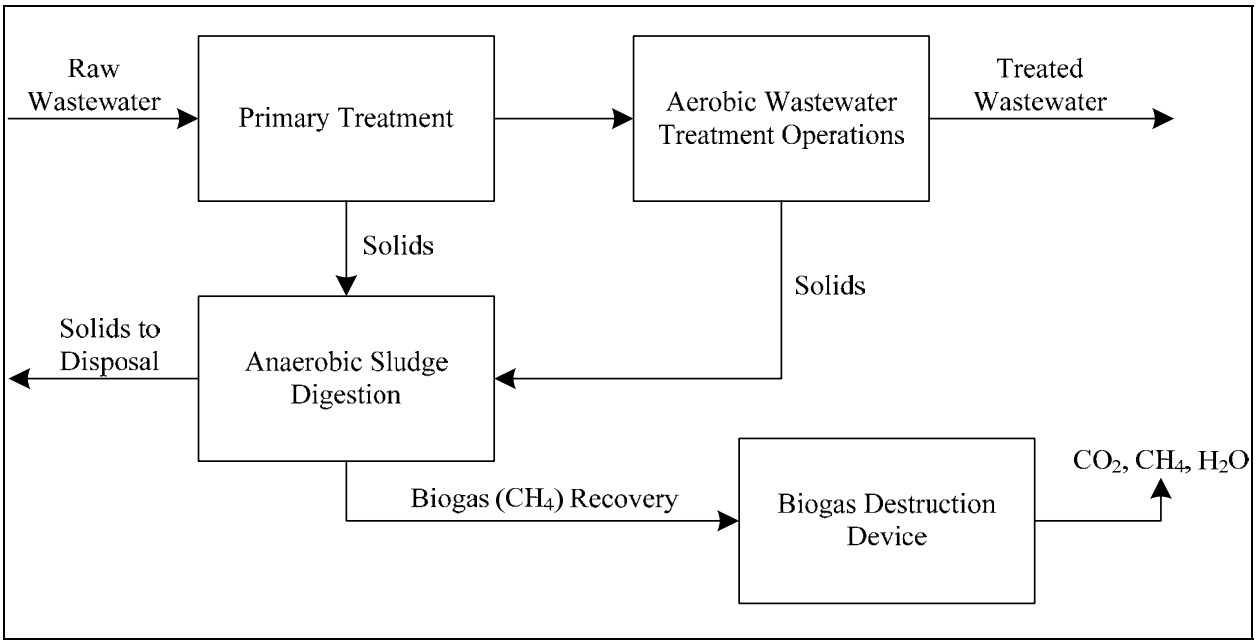

Figure 5-2. Diagram of Biogas Recovery from Anaerobic Sludge Digestion

Subpart II of the Reporting Rule requires facilities to calculate and report the amount of CH_4 they recover. They must calculate CH_4 recovery using Equation 5-1.

$$R = \sum_{m=1}^{M} \left[(V)_m \times (C_{CH4})_m \times CF \right] \qquad (5\text{-}1)$$

where:

R	=	Annual quantity of CH_4 recovered from anaerobic reactor, digester, or lagoon (metric tons CH_4/yr).
M	=	Total number of measurement periods in a year. Use M=365 (M=366 for leap years) for daily averaging of continuous monitoring. Use M=52 for weekly sampling.
m	=	Index for measurement period.
V_m	=	Cumulative volumetric flow for the measurement period in actual cubic feet (acf). If no biogas was recovered during a monitoring period, use zero.
$(CCH4)_m$	=	Average CH4 concentration of biogas during the measurement period, (volume %).
CF	=	Correction factors for temperature, pressure, and/or moisture, if necessary.

For Equation 5-1, facilities must determine the volume of gas recovered during a monitoring period and the CH_4 concentration of the gas. These measured values may be multiplied by a number of correction factors:

- Volumetric moisture correction term for the measurement period, based on the average moisture content of biogas during the measurement period;
- Temperature at which flow is measured for the measurement period; and
- Pressure at which flow is measured for the measurement period.

If a facility continuously monitors the CH_4 concentration and these correction factors using a meter specifically for CH_4 gas, they must use this system to calculate CH_4 recovery. A fully integrated system that directly reports CH_4 content only requires the facility to sum the results of all monitoring periods for a given year.

5.1 Biogas Flow Measurement

To estimate the annual mass of CH_4 recovered, facilities are required to continuously monitor the recovered biogas flow rate. Every facility with biogas recovery from anaerobic wastewater treatment operations must use a gas flow meter capable of continuously measuring the volumetric flow rate of the recovered biogas. Facilities may measure flow rate using one of the methods specified below:

- ASME MFC-3M-2004, Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi;
- ASME MFC-4M-1986 (Reaffirmed 1997), Measurement of Gas Flow by Turbine Meters;
- ASME MFC-6M-1998, Measurement of Fluid Flow in Pipes Using Vortex Flowmeters;
- ASME MFC-7M-1987 (Reaffirmed 1992), Measurement of Gas Flow by Means of Critical Flow Venturi Nozzles;
- ASME MFC-11M-2006 Measurement of Fluid Flow by Means of Coriolis Mass Flowmeters;
- ASME MFC-14M-2003 Measurement of Fluid Flow Using Small Bore Precision Orifice Meters; or
- ASME MFC-18M-2001 Measurement of Fluid Flow using Variable Area Meters; or
- Method 2A or 2D at 40 CFR part 60, appendix A-1.

A facility may measure biogas flow using a method other than those listed above; however, they must follow the manufacturer's instructions for the gas flow measurement device. Each gas flow meter must be calibrated every two years or at the minimum frequency specified by the manufacturer.

A facility is required to determine temperature and pressure of the biogas weekly only if its gas flow meter is not equipped with automatic correction for temperature, pressure, or, if necessary, moisture content. A facility must measure moisture content weekly if the CH_4 concentration is determined on a dry basis and biogas flow is determined on a wet basis, or vice-versa, and the flow meter does not automatically correct for moisture content. All temperature, pressure, and moisture content monitors must be calibrated using the procedures and frequencies specified by the device manufacturer. If the device manufacture does not provide calibration specifications, facilities may use an industry accepted or industry standard practice. All equipment must be maintained to the manufacturer's specifications.

5.2 Biogas Composition Monitoring

The Reporting Rule allows either continuous or weekly monitoring of the biogas CH_4 concentration. If a facility has equipment that continuously monitors the CH_4 concentration, the facility must use it. If a facility is not currently monitoring the biogas CH_4 concentration, they

must use either installed or portable equipment to monitor it weekly. Weekly monitoring provides an adequate number of samples to evaluate the variability and uncertainly associated with CH_4 generation.

Facilities with biogas recovery from anaerobic processes must measure gas composition with a monitor capable of measuring the concentration of CH_4 in the recovered biogas using either one of the methods specified below or as specified by the device manufacturer if they use another device. The gas composition monitors must be calibrated prior to the first reporting year and recalibrated either annually or at the minimum frequency specified by the manufacturer, whichever is more frequent.

- Method 18 at 40 CFR part 60, Appendix A-6;
- ASTM D1945-03, Standard Test Method for Analysis of Natural Gas by Gas Chromatography;
- ASTM D1946-90 (Reapproved 2006), Standard Practice for Analysis of Reformed Gas by Gas Chromatography;
- GPA Standard 2261-00, Analysis for Natural Gas and Similar Gaseous Mixtures by Gas Chromatography;
- UOP539-97 Refinery Gas Analysis by Gas Chromatography; or
- As an alternative to the gas chromatography methods, a facility may use total gaseous organic concentration analyzers and calculate the CH_4 concentration.

6. METHANE EMISSIONS CALCULATION

In addition to reporting CH_4 generation, facilities must report the amount of CH_4 emitted to the atmosphere. For facilities that do not recover biogas, total emissions equal the CH_4 generation of each anaerobic reactor or lagoon and can be estimated using Equation 6-1.

$$CH_4E = CH_4G \quad (6\text{-}1)$$

where:

CH_4E = Annual mass of CH_4 emissions from the wastewater treatment process (metric tons).

CH_4G = Annual mass of CH_4 generated from the wastewater treatment process, as calculated in Equations 3-1 or 3-2 (metric tons).

Leakage. Facilities that recover biogas from either anaerobic wastewater treatment operations or sludge digesters must take into account the inefficiency of the recovery process as depicted in Figure 6-1. Leakage refers to the annual mass of CH_4 that is generated but not recovered.

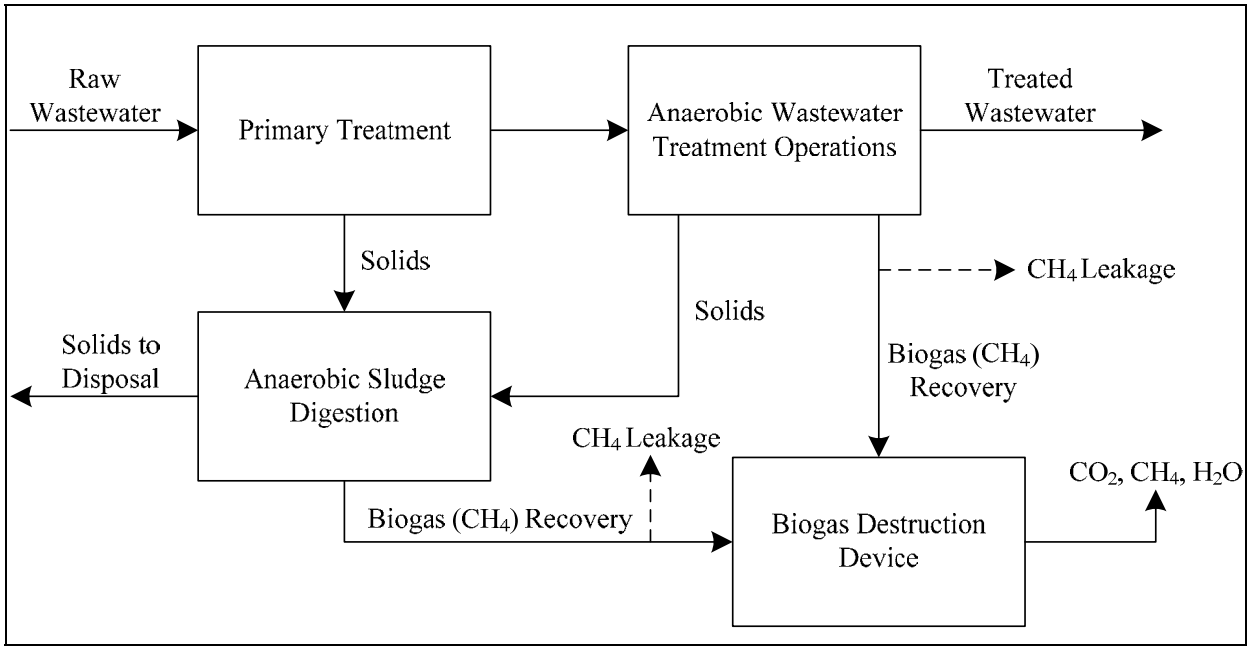

Figure 6-1. Diagram of Leakage From Anaerobic Sludge Digestion Biogas Recovery

For anaerobic processes with biogas recovery, facilities must calculate leakage using Equation 6-2 by multiplying recovery (calculated using Equation 5-1) by a collection efficiency factor in Table 6-1. This allows facilities to quantify the amount of CH_4 that is not captured by their destruction device.

$$CH_4L = R \times \left(\frac{1}{CE} - 1 \right) \quad (6\text{-}2)$$

where:

CH_4L = Leakage at the anaerobic process (metric tons CH_4).
R = Annual quantity of CH_4 recovered from anaerobic reactor, anaerobic lagoon, or anaerobic digester, as calculated in Equation 5-1 (metric tons CH_4).
CE = CH_4 collection efficiency of anaerobic process, as specified in Table 6-1 (decimal).

Table 6-1. Collection Efficiencies of Anaerobic Processes

Anaerobic Process Type	Cover Type	Methane Collection Efficiency
Covered anaerobic lagoon (biogas capture)	Bank to bank, impermeable	0.975
	Modular, impermeable	0.70
Anaerobic sludge digester; anaerobic reactor	Enclosed vessel	0.99

Destruction Efficiency. Biogas destruction devices, such as flares, thermal oxidizers, boilers, turbines, internal combustion engines, and other combustion units destroy or oxidize CH_4 contained in the biogas, producing CO_2 and water. However, biogas destruction devices operate with less than 100 percent efficiency. This means the device exhaust gases will contain some CH_4. At facilities with biogas recovery, reported total emissions must take into account the destruction of CH_4 by these recovery devices. These facilities' total annual mass of CH_4 emissions are equal to their leakage rate plus their total recovery multiplied by the recovery device CH_4 destruction efficiency (DE). Total emissions equal the quantity that leaks from the anaerobic process plus the quantity not destroyed in the destruction device, as shown in Equation 6-3.

$$CH_4E = CH_4L + R\ (1 - DE) \quad (6\text{-}3)$$

where:

CH_4E = Annual quantity of CH_4 emitted (metric tons/yr).
CH_4L = Leakage at the anaerobic process, as calculated in Equation 6-2 (metric tons CH_4).
R = Annual quantity of CH_4 recovered from the anaerobic reactor digester, or lagoon, as calculated in Equation 5-1 (metric tons CH_4).
DE = Destruction efficiency (i.e., the fraction of CH_4 destroyed in the destruction device (decimal)).

Destruction devices may be operated less than continuously. Also, a facility may operate more than one destruction device (e.g., they may operate a primary destruction device and a backup). Total emissions for facilities with biogas destruction devices must be estimated using Equation 6-4.

$$CH_4E = CH_4L + R\ (1 - (DE_1 \times f_{Dest\_1})) + R\ (1 - (DE_2 \times F_{Dest\_2})) \quad (6\text{-}4)$$

where:

CH_4E = Annual quantity of CH_4 emitted (metric tons/yr).
CH_4L = Leakage at the anaerobic process, as calculated in Equation 6-2 (metric tons CH_4).

R	=	Annual quantity of CH_4 recovered from the anaerobic reactor, digester, or lagoon, as calculated in Equation 5-1 (metric tons CH_4).
DE_1	=	Primary destruction device CH_4 destruction efficiency (lesser of manufacturer's specified destruction efficiency and 0.99). If the gas is transported off-site for destruction, use DE=1.
f_{Dest_1}	=	Fraction of hours the primary destruction device was operating (device operating hours/8760 hours per year). If the gas is transported off-site for destruction, use f_{Dest}=1.
DE_2	=	Back-up destruction device CH_4 destruction efficiency (lesser of manufacturer's specified destruction efficiency and 0.99).
f_{Dest_2}	=	Fraction of hours the back-up destruction device was operating (device operating hours/8760 hours per year).

7. COSTS FOR GHG REPORTING

The Reporting Rule requires operators to monitor their CH_4-generating processes by measuring the amount of wastewater entering the anaerobic treatment process, the concentration of organic material in the wastewater prior to treatment, the volume of biogas recovered, and the concentration of CH_4 in the recovered biogas. To determine costs of the required monitoring, EPA evaluated whether facilities are currently conducting this monitoring. For monitoring that is not routinely conducted, EPA estimated the costs that a typical facility would incur to meet the requirement.

The estimates include one-time capital costs to purchase and install monitoring devices and recurring annual costs for analytical services, supplies, and labor. Table 7-1 summarizes the total costs EPA estimates will be incurred by facilities in each industry covered by Subpart II. EPA estimated that these monitoring requirements would cost, on average, $4,083 per year per facility (total annualized costs) or $1.4 million for the 358 facilities estimated to incur monitoring costs. For more information on the estimated costs of reporting for this Subpart, please see found in *Greenhouse Gas Reporting Rule, Industrial Wastewater Treatments Source Category, Costs for Final Rule Monitoring Requirements – Revised* (ERG, 2010).

Table 7-1. Industrial Wastewater Treatment Monitoring Costs

Category	No. of Plants Required to Report	%Plants with Anaerobic Treatment	No. of Plants with Anaerobic Treatment	No. of Plants with CH_4 Recovery	National (Scaled-Up) Estimated Costs				National (Scaled-Up) Estimated Costs				National (Scaled-Up) Estimated Costs
					WW Monitoring Costs -Cap	WW Monitoring Costs - Annualized Cap	WW Monitoring Costs - Annual	WW Monitoring Costs -TAC	CH_4 Recovery Monitoring Costs -Cap	CH_4 Recovery Monitoring Costs - Annualized Cap	CH_4 Recovery Monitoring Costs - Annual	CH_4 Recovery Monitoring Costs - TAC	Total (WW +CH_4 recovery) Monitoring TAC
Pulp and Paper	565	25%	141	0	$1,428,843	$134,873	$463,300	$598,173	0	$0	$0	$0.00	$598,173
Food Processing	63	100%	63	0	$455,805	$43,025	$206,640	$249,665	$0	$0	$0	$0.00	$249,665
Ethanol Production - wet mill 15% of 170 mills	4	100%	4	4	$17,064	$1,611	$13,120	$14,731	$23,600	$2,228	$3,600	$5,827.67	$20,558
Ethanol Production - dry mill 85% of 170 mills	0	75%	0	0	$0	$0	$0	$0	$0	$0	$0	$0.00	$0
Petroleum Refineries	150	100%	150	0	$1,085,250	$102,440	$492,000	$594,440	$0	$0	$0	$0.00	$594,440
Total			**358**										**$1,447,417**

Cap – Capital costs.
TAC – Total annualized costs (annualized capital costs plus annual costs).

8. REFERENCES

ARCADIS. 2004. Memorandum from M. Doorn, ARCADIS, to D. Pape, ICF, and E. Scheehle, EPA. Response to ERG Review and New US M&P Estimates. August 16.

Benyahia, F., M. Abdulkarim, A. Embaby, and M. Rao. 2006. Refinery Wastewater Treatment: A True Technological Challenge. Presented at the Seventh Annual U.A.E. University Research Conference, April 2006.

CARB. 2007. Attachments C TO F - Supplemental Materials Document for Staff Report: Initial Statement of Reasons for Rulemaking, Mandatory Reporting of Greenhouse Gas Emissions Pursuant to the California Global Warming Solutions Act of 2006 (Assembly Bill 32), Attachment E: Technical Attachment on Development of Emissions Reporting Requirements for Oil Refineries and Hydrogen Plants. California Environmental Protection Agency Air Resources Board. October 19. Available online at: http://www.arb.ca.gov/regact/2007/ghg2007/suppisor.pdf.

Donovan. 1996. Siting an Ethanol Plant in the Northeast. C.T. Donovan Associates, Inc. Report presented to Northeast Regional Biomass Program (NRBP). (April). Available online at: http://www.nrbp.org/pdfs/pub09.pdf. Accessed October 2006.

Energy Information Administration (EIA). 2009. Number and Capacity of Petroleum Refineries. Available online at: http://www.eia.doe.gov/dnav/pet/pet_pnp_cap1_dcu_nus_a.htm

ERG. 2006. Memorandum from D. Bartram and S. Holman ERG, to Melissa Weitz, EPA. Assessment of Greenhouse Gas Emissions from Wastewater Treatment of U.S. Ethanol Production Wastewaters. October 10.

ERG, 2008. Memorandum from A. Aguiar and D. Bartram ERG to Melissa Weitz, EPA.. Planned Revisions of the Industrial Wastewater Inventory Emission Estimates for the 1990-2007 Inventory. August 10.

ERG 2010. Memorandum from B. Bicknell, A. Aguiar, and D. Bartram ERG, to Rachel Schmeltz, EPA. Greenhouse Gas Reporting Rule, Industrial Wastewater Treatments Source Category, Costs for Final Rule Monitoring Requirements – Revised. March 2010.

Grady, C.P.L., G.T. Daigger, and H.C. Lim. 1999. Biological Wastewater Treatment, Second Edition. Marcel Dekker, New York.

IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Waste, Intergovernmental Panel on Climate Change, National Greenhouse Gas Inventories Programme (Volume 5, Chapter 6).

Merrick. 1998. Wastewater Treatment Options for the Biomass-to-Ethanol Process. Report presented to National Renewable Energy Laboratory (NREL). Merrick & Company. Subcontract No. AXE-8-18020-01. October 22.

Metcalf & Eddy, Inc. 1979. Wastewater Engineering: Treatment, Disposal, Reuse, Second Edition, revised by George Tchobanoglous. McGraw Hill Book Company.

NAICS. 2007. North American Industrial Classification System. Available online at: http://www.census.gov/eos/www/naics/.

Nemerow, N.L. and A. Dasgupta. 1991. Industrial and Hazardous Waste Treatment. Van Nostrand Reinhold. NY. ISBN 0-442-31934-7.

NRBP. 2001. Northeast Regional Biomass Program. An Ethanol Production Guidebook for Northeast States. Washington, D.C. May 3. Available online at: http://www.nrbp.org/pdfs/pub26.pdf. Date Accessed: October 2006.

RFA. 2009. Renewable Fuels Association (RFA). Ethanol Industry Overview. Available online at: http://www.ethanolrfa.org/pages/statistics.

Ruocco. 2006a. Email correspondence from Dr. Joe Ruocco, Phoenix Bio-Systems to Sarah Holman, ERG. Capacity of Bio-Methanators (Dry Milling). October 6.

Ruocco. 2006b. Email correspondence. Dr. Joe Ruocco, Phoenix Bio-Systems to Sarah Holman, ERG. "Capacity of Bio-Methanators (Wet Milling)." October 16, 2006.

Timm, C.M. 1985. Water Use, Conservation and Wastewater Treatment Alternatives for Oil Refineries in New Mexico. NMERDI-2-72-4628.

U.S. Census Bureau. 2002. 2002 Economic Census. Available online at: http://www.census.gov/econ/census02/.

U.S. EPA. 1993. Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Pulp, Paper and Paperboard Point Source Category. EPA-821-R-93-019. Washington, DC. October.

U.S. EPA, 1996. U.S. EPA NPDES Permit Writer's Manual. EPA-833-B-96-003, Washington, D.C., December, 1996.

U.S. EPA. 1997a. Estimates of Global Greenhouse Gas Emissions from Industrial and Domestic Wastewater Treatment. United States Environmental Protection Agency, Office of Policy, Planning, and Evaluation. EPA-600/R-97-091, Washington, DC, September, 1997.

U.S. EPA. 1997b. Supplemental Technical Development Document for Effluent Guidelines and Standards (Subparts B & E). EPA-821-R-97-011. Washington, DC. October.

U.S. EPA. 2002. Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Meat and Poultry Products Industry Point Source Category (40 CFR 432). EPA-821-B-01-007. Washington DC. January 2002.

U.S. EPA. 2004a. Technical Development Document for the Final Effluent Limitations Guidelines and Standards for the Meat and Poultry Products Point Source Category. EPA-821-R-04-011. Washington DC.

U.S. EPA, 2004b. NPDES Compliance Inspection Manual. EPA-305x-04-01. Washington, D.C., July, 2004.

U.S. EPA. 2007. Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005. February.

U.S. EPA. 2010. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008. EPA 430-R-10-006. April 15.US Poultry. 2006. Email correspondence from John Starkey, USPOULTRY, to Deborah Bartram, ERG. August 30.

White and Johnson. 2003. White, P.J. and Johnson, L.A. Editors. Corn: Chemistry and Technology. 2nd ed. AACC Monograph Series. American Association of Cereal Chemists. St. Paul, MN.

World Bank. 1999. Pollution Prevention and Abatement Handbook 1998, Toward Cleaner Production. The International Bank for Reconstruction and Development/The WORLDBANK. ISBN 0-8213-3638-X Washington, DC.