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GREENHOUSE GAS SOURCES AND SINKS FOR WATER RESOURCE RECOVERY FACILITIES

Introduction

The effects of climate change are becoming more apparent every year, including on the operations of water resource recovery facilities (WRRFs). Longer and warmer summers, water scarcity, more intense storms, increased stormwater flows, increased combined and sanitary sewer overflow events, facility flooding, and electrical grid instability are increasingly significant issues for utilities across the country.

Typical greenhouse gas (GHG) emissions from a WRRF are equivalent to household emissions for an entire small town. In fact, centralized wastewater treatment is estimated to produce 0.3% of all U.S. GHG emissions. That may not sound like a lot, but when you think of this as our industry's portion of the emissions from every car, factory, building, farm, and cleared forest in the country, it is clear we have a lot to do. An average-sized facility produces as much GHG as tens of thousands of cars. As a result, wastewater utilities have an opportunity to help reduce future effects from GHG emissions.

This operator fact sheet provides an overview of process and nonprocess GHG emissions from wastewater utilities, specifically from WRRFs and wastewater collection systems. This document also provides information regarding GHG "sinks" that can be used to offset emissions. By understanding how system operations affect climate change, wastewater operators can make efforts to minimize negative effects and maximize offsets.

Types of Emissions and Sinks

The following GHGs are commonly emitted from wastewater operations:

- Carbon dioxide (CO_2)—typically associated with organic matter breaking down in aerobic conditions (with oxygen) or combustion (see insert on biogenic sources)
- Methane (CH_4)—typically associated with organic matter breaking down in anaerobic conditions (without oxygen); when fully oxidized during combustion, CH_4 becomes CO_2
- Nitrous oxide (N_2O)—in nitrification/denitrification processes, a small fraction of the nitrogen treated is emitted as N_2O; it is different from "NOx" (oxides of nitrogen) that are regulated in many air permits
- Refrigerants—coolants used in many air conditioning systems are highly potent GHGs if released to the atmosphere via leaks or spills

Different GHGs have different effects on climate change. The relative effect of a given gas is referred to as its global warming potential (GWP). As shown in Figure 1, the GWP varies widely among the types of gases. GWP for different gases is measured relative to the effect of carbon dioxide, which has a GWP of one. Common refrigerants can have GWPs in the thousands. As illustrated in Figure 1, while the amount of nitrous oxide emitted from a WRRF may be small, the effect of those emissions to the atmosphere can still be significant.

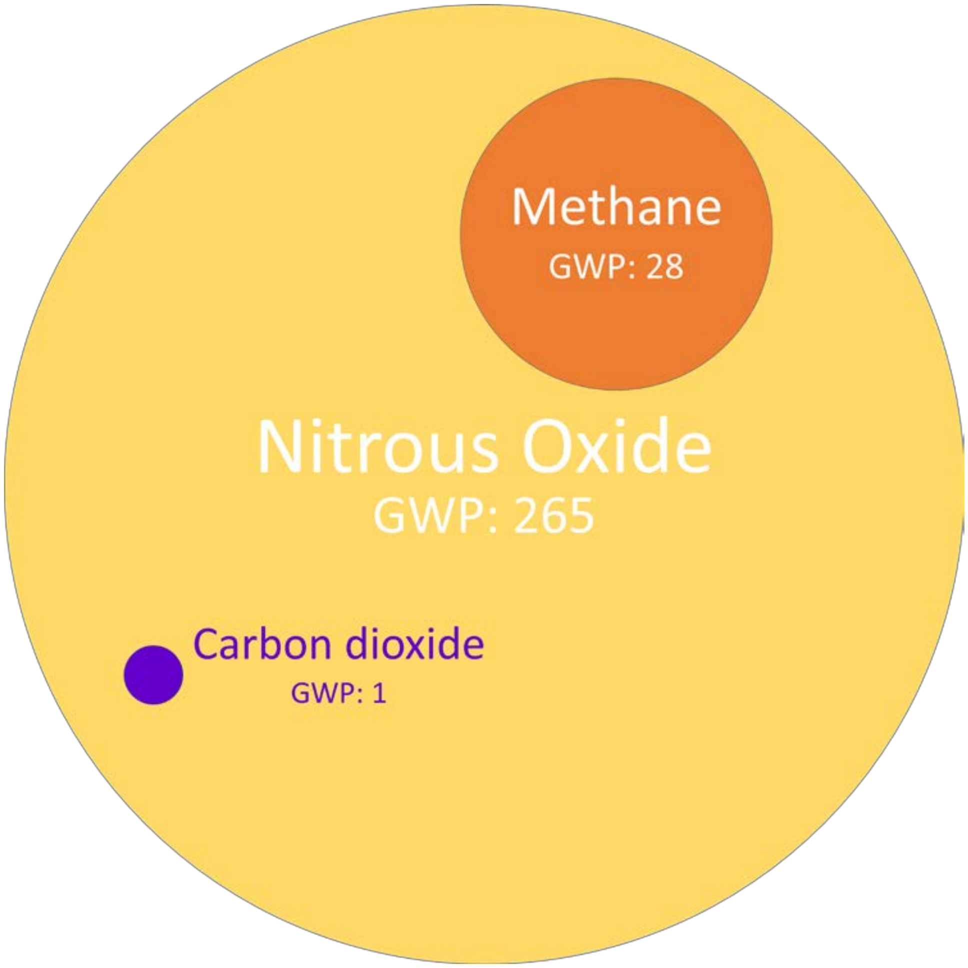

Figure 1. Global warming potential of three common GHGs, area scaled by relative effect.

Biogenic Sources

Carbon dioxide that is emitted from the breakdown of organic matter with a biological/non-fossil-fuel-based source is considered to have a net-zero effect on the amount of GHG in the atmosphere. One example of a biogenic source is the food we eat, digest, and excrete that is converted to carbon dioxide as part of the activated sludge treatment process. This includes plants we directly or indirectly consume (i.e., by eating animals that eat plants). As plants grow, they remove carbon dioxide from the air during photosynthesis and create more complex organic molecules like sugars. The carbon dioxide released when these molecules break down is equivalent to the amount taken up by the plant when it was growing. The net effect to the atmosphere over a short time span is zero; accordingly, this source can be referred to as "net zero," or having no carbon-footprint effect. The use of fossil fuels, on the other hand, puts "new" carbon into the atmosphere that had been sequestered below ground for millions of years.

Greenhouse Gas Sources (Emissions)

GHGs emitted directly from WRRFs and wastewater collection systems can come from the process itself or from associated, nonprocess sources. The figure below shows typical process emissions.

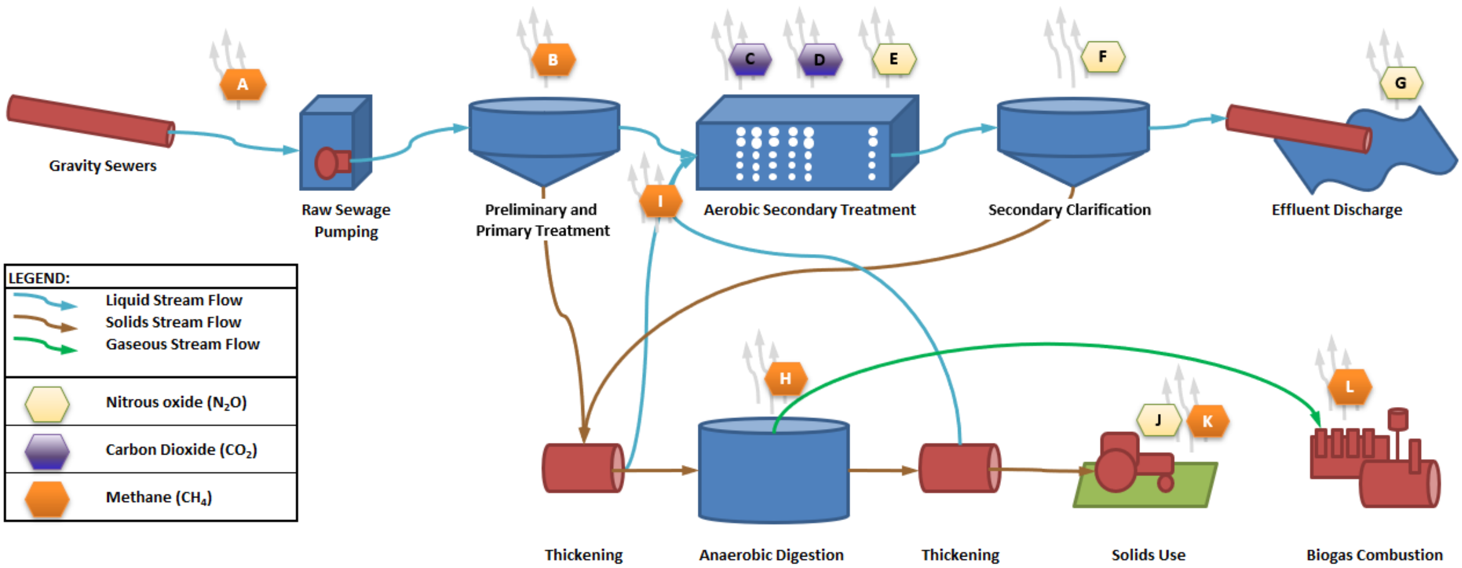

Figure 2. Typical wastewater process GHG emission sources (adapted from Willis et al., 2017).

Following the flow of the figure, typical process emissions at a WRRF include the following:

A. **Methane in the wastewater collection system**—Methane is emitted from wastewater collection systems because of organic matter breaking down in anaerobic conditions that can develop in the collection system.
B. **Methane release and production in preliminary and primary treatment**—Some of the methane that develops in the collection system is released as the flow enters the WRRF because aeration and turbulent flow strip it from the solution and release it to the atmosphere. Anaerobic conditions in these areas can generate additional methane.
C. **Industrial discharge carbon**—Carbon dioxide released in secondary treatment of biogenic carbon is considered net zero; however, flows from industry (and residences) may contain carbon from fossil fuel sources that are not considered net zero.
D. **Carbon source for denitrification**—The most common carbon source for denitrification is methanol, which is typically derived from natural gas (a fossil fuel). When the carbon in the source is emitted as carbon dioxide, it increases net GHG into the atmosphere—unless it is biogenic.
E. **Nitrous oxide from nitrogen removal**—Small amounts of GHGs, including nitrous oxide, are formed in the nitrogen removal process as ammonia is converted to nitrogen gas.
F. **Nitrous oxide from clarifiers**—Additional nitrous oxide will be released from clarifiers following nitrification/denitrification.
G. **Nitrous oxide from effluent**—A portion of the nitrogen discharged to an aquatic environment will be emitted as nitrous oxide as the nitrogen is processed by the biology in the receiving water.

H. **Fugitive emissions from digesters**—Some digesters have leaks in their piping, floating covers with gaps around the edge, or malfunctioning pressure-relief systems that can release biogas, typically at least 50% methane, into the atmosphere.

I. **Dissolved methane**—Some portion of methane is dissolved in the solids stream after anaerobic digestion (and sometimes even in nondigested solids). The methane can be released when solids are dewatered or when filtrate and centrate flows are treated.

J. **Nitrous oxide from solids end-use**—As with all organic fertilizers, when nitrogen in biosolids is applied on land as part of a beneficial use program, a portion of that nitrogen will be converted to nitrous oxide. However, if the biosolids are being applied to offset application of other nitrogen-containing fertilizers, which give off nitrous oxide at rates thought to be similar to those of biosolids, then nitrous oxide from biosolids land application might be considered net zero because it is offsetting the emissions from an equivalent amount of nitrogen applied from a different fertilizer. N_2O can also be generated from the combustion of solids in incineration or other high-temperature processes.

K. **Methane from solids end-use**—Methane can be entrained or dissolved in wastewater residuals and released when these are land applied or disposed in a landfill. Additional methane will also be generated when wastewater solids break down in the anaerobic conditions of a landfill.

L. **Uncombusted digester methane**—Inefficient engines, turbines, flares, and gas-cleaning processes can release biogas to the atmosphere. Candlestick-type flares, for instance, typically fail to combust approximately 5% of the methane fed to them. (Boilers, combustion turbines, and low-NOx flares do effectively convert 100% of their methane feed to carbon dioxide.)

Nonprocess emissions can be associated with

- on-site natural gas use (e.g., for boilers),
- vehicle fossil fuel usage, and
- refrigerants.

Often, the largest contribution to a wastewater utility's GHG footprint is from energy produced off site (i.e., electricity, heating and cooling, or steam). For example, the GHGs produced to provide a WRRF with electricity often are emitted at a power plant; however, because the WRRF is responsible for the demand for that power, it is important that the utility takes into account the climate change effect of this off-site fossil-fuel-derived energy use.

Similarly, there are off-site emissions associated with the demand a wastewater facility has for non-energy items, including

- chemical production (e.g., polymer, alkalizing agents, carbon sources),
- chemical hauling,
- residuals hauling (e.g., screenings, grit, biosolids), and
- methane emissions from any organic matter that is landfilled.

Opportunities to Reduce Greenhouse Gas Emissions

Wastewater utilities, through WRRFs and wastewater collection systems, have significant opportunities to reduce their climate effect. Because energy use tends be the largest source of emissions for a wastewater facility, energy efficiency measures (e.g., more efficient blowers or diffusers) are a good place to start. These changes are also likely to have cost savings that are easy to quantify, providing an additional benefit. Other opportunities include

- using the biogas (from anaerobic digesters) on site as a renewable energy source or injecting it to a natural gas pipeline;
- following climate-friendly biosolids management practices, such as nearby beneficial reuse instead of landfilling;
- switching to a biogenic carbon source for nitrogen removal (e.g., ethanol, glycerin, or carbohydrate products), which will result in biogenic emissions from their use, but fossil fuel emissions from their production and transportation should be taken into account;
- switching to low-GWP refrigerants (e.g., R-448A);
- using process optimization (e.g., dissolved oxygen control); and
- optimizing nitrogen removal to reduce nitrogen released to the receiving water body.

Greenhouse Gas Sinks (Offsets)

To address climate change—in addition to reducing emissions—wastewater facilities can reduce the amount of GHGs in the atmosphere by reducing demand for ("offsetting") activities that generate emissions or by helping to sequester ("lock") carbon in a nongaseous form. Some examples are as follows:

- Using waste heat (e.g., from combined heat and power) or heat recovered from sewers instead of heat from a fossil fuel source to heat buildings.
- Applying biosolids to land.
    - When biosolids are land-applied, in addition to improving water-holding capacity, improving drought resistance, and improving soil tilth and health, a portion of the carbon from the biosolids is stored in the soil in stable forms. Biosolids also lead to improved belowground plant growth. The plant pulls carbon dioxide out of the air to grow roots via photosynthesis. When that plant biomass remains in the soil, it leads to a net reduction in carbon dioxide in the air.
    - When biosolids are used in place of inorganic fertilizers, there is a reduction in demand for these fertilizers, the production of which is fossil fuel intensive.
    - The use of biosolids also avoids N_2O emissions from the use of inorganic fertilizers, thereby offsetting the N_2O emissions from biosolids use discussed above.

Conclusion

WRRFs and wastewater collection systems can be significant sources of GHG emissions. It is important that the individuals operating and managing these facilities understand the methods available to minimize the generation and release of these gases and to maximize offsets. It is also important to understand the advantages that biosolids use can have in beneficial use programs when compared to inorganic fertilizers and landfilling.

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