Methane Mitigation from Municipal Wastewater Treatment Plants

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BIOGAS SECTOR
Wastewater Treatment

The Global Methane Initiative (GMI) is a voluntary, international, multilateral partnership that aims to reduce methane emissions and advance the abatement, recovery, and use of methane as a valuable energy source. Methane (CH_4) is a potent greenhouse gas (GHG); it is the second most abundant, human-caused GHG and accounts for about 20 percent of global emissions. The Intergovernmental Panel on Climate Change (IPCC) has identified methane reduction strategies as critical opportunities to address climate change (IPCC, 2021). Reducing methane emissions associated with wastewater treatment can play a significant role in reaching global climate mitigation goals (Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions, United Nations Environment Programme and Climate and Clean Air Coalition [2021]).

Wastewater treatment plants (WWTP) have the potential to release methane, which is generated through anaerobic decomposition of organic material and emitted during collection, treatment, and management of wastewater liquids and solids. Most developed countries rely on wastewater treatment systems that are aerobic and emit small amounts of methane from the liquids treatment stream. However, in some developing countries, liquids treatment systems tend to be decentralized, less technologically advanced, and anaerobic (for example, latrines, septic tanks, Imhoff tanks, and settling ponds); this results in greater rates of methane emission. Regardless of the liquids treatment process (aerobic or anaerobic), the management of biosolids can generate significant methane emissions. This fact sheet reviews the points and processes at which methane generation and release are most likely for three types of WWTP systems, examines biosolids management and its potential for methane generation and emission, and provides suggestions for methane abatement, capture, and use.

Methane Generation and Emission in Wastewater Collection and Treatment Systems

Methane can be generated in both wastewater collection systems and at wastewater treatment plants (WWTP). The following sections provide an overview of these emission sources.

Wastewater Collection System

Wastewater is generated and transported to the WWTP through a network of pipes which leads to anoxic (i.e., oxygen deficient) and anaerobic conditions in the collection system that can potentially generate methane in the wastewater before it enters the WWTP. When the raw wastewater is agitated through pumping, changes in hydraulic profile, or entry to the WWTP, the dissolved methane can be emitted. Therefore, the headworks, where the sewer lines daylight into the WWTP facility, is an area of concern for emissions of sewer gases including methane. Recently, predictive models have been developed to assess methane emissions from sewers (Conveyance Asset Prediction System [CAPS], 2020); these models can help develop and evaluate methane mitigation strategies for pre-treatment activities. However, each wastewater system must be evaluated holistically for methane mitigation opportunities.

Layout of a WWTP with a CAS treatment system and primary and secondary sludge anaerobic digestion.

Conventional Activated Sludge (CAS) Treatment System

Liquids Stream Treatment. For most conventional activated sludge treatment systems, treatment is primarily aerobic, with few emissions associated with treatment of the liquids stream. In addition to the headworks, primary clarifiers can be a potential minor source of methane emissions. Subsequent liquids treatment processes such as in aeration basins, secondary clarifiers, and disinfection units, generate minimal methane emissions. Figure 1 shows the process flow diagram for liquids stream treatment in a conventional, activated sludge treatment system.

Solids Stream Treatment. Solids stream treatment is more often the largest source of methane emissions, but the quantity of emissions varies depending on how the solids are managed. Storage of sludge can promote anaerobic conditions and generate methane if the holding time is not managed properly. Methane generated in the waste storage tanks can then be released by downstream processes (for example, thickening/dewatering) that mix or agitate the sludge. The amount of methane emitted by these processes is also variable; gravity belt thickeners or plate and frame presses are open to the atmosphere, resulting in a higher potential for emissions. Screw presses or centrifuges contain the sludge in a closed piece of equipment, which holds the methane gas more effectively. The open conveyance of sludge between these processes can also be a source of emissions if the sludge is anaerobic. Figure 2 shows the elements associated with solids stream treatment and their associated potential for methane emissions.

Figure 1. Process Flow Diagram for Typical Activated Sludge Liquids Stream Treatment

The potential for methane generation and emission is indicated by the color bars above each process step (darker green colors indicate higher potential). This qualitative emissions scale is used across this fact sheet's subsequent figures.

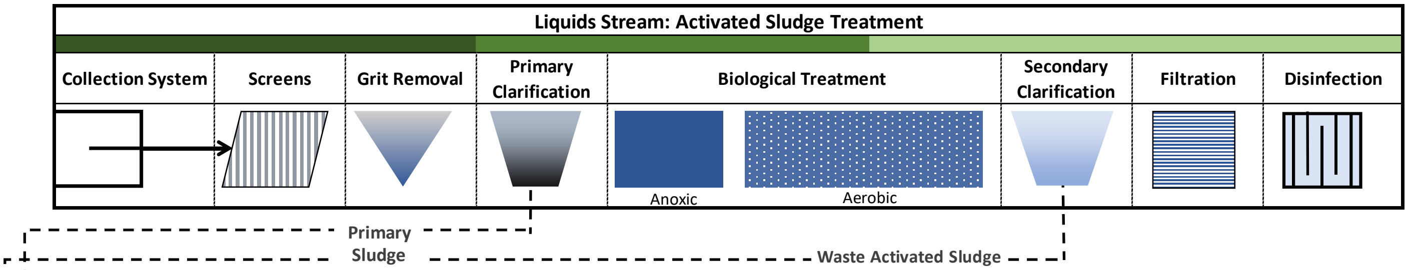
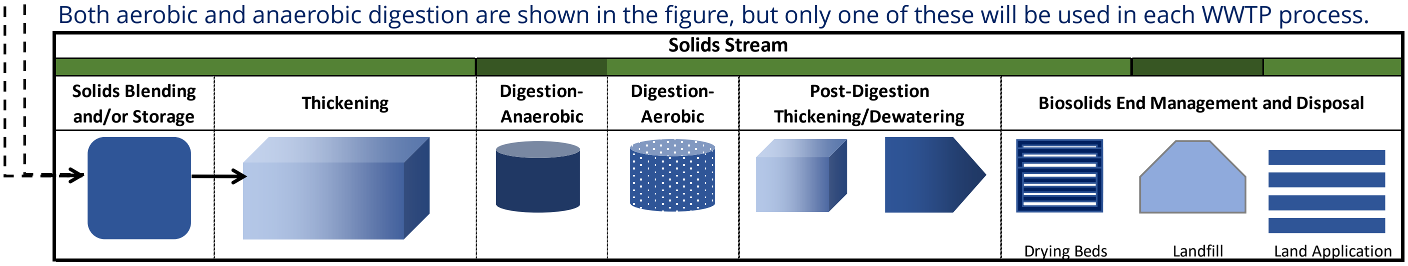


Figure 2. Process Flow Diagram for Typical Solids Stream Treatment

Both aerobic and anaerobic digestion are shown in the figure, but only one of these will be used in each WWTP process.

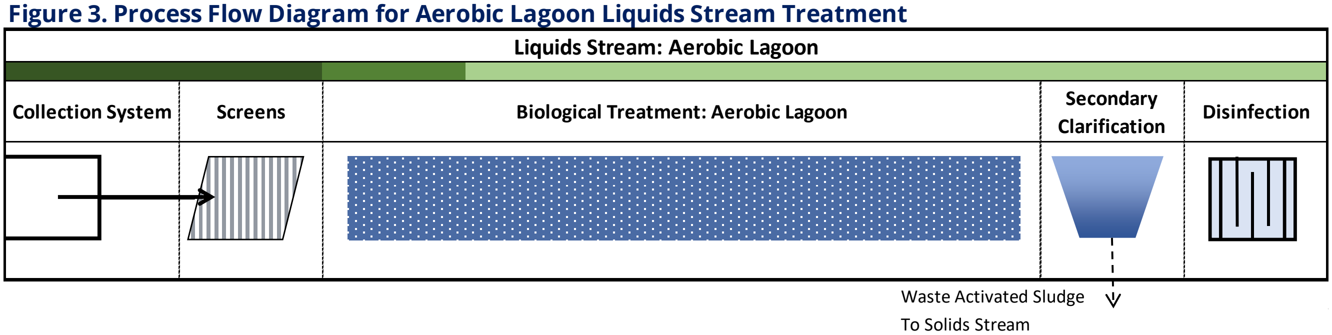


The primary processes for generating and releasing methane during the solids stream treatment process are (1) anaerobic digestion and improper containment (for example, leaky valves, pipes, and other equipment) and (2) incomplete combustion of methane during flaring. Gas flares, a necessary component of a digester system, can also be a significant source of non-combusted methane if the flare is improperly sized, corroded, or poorly maintained. Properly designed digester systems provide a methane mitigation opportunity if the methane generated is efficiently *captured and combusted* for beneficial use (e.g., to generate heat or electricity).

Aerobic/Aerated Lagoon Treatment System: Liquids and Solids Streams

Aerobic lagoons for liquids stream treatment are much simpler than anaerobic systems and rely on processes that have a low potential for methane generation and release. The highest potential areas for methane emissions in an aerobic lagoon system are at the headworks (see collection system/screens in Figure 3) and at the front end of the treatment lagoon where agitation of the wastewater may release methane dissolved in the liquid. Also, an aerobic lagoon generates a lower volume of biosolids than typical aerobic systems; therefore, treatment of the solids stream is required less frequently. Solids handling at these WWTPs generally involves thickening, dewatering, and disposal. The potential for methane generation from the solids stream of aerobic lagoons is similar to, or slightly less than that for conventional activated sludge treatment systems (see Figure 2) as the sludge is highly aerated.

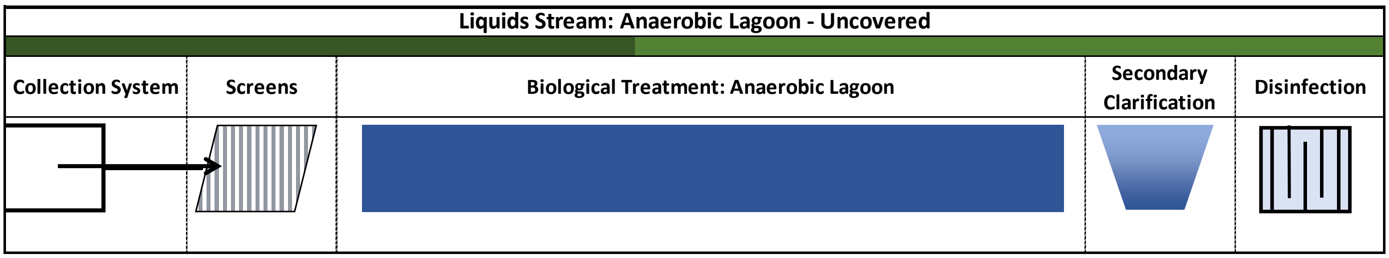
Figure 3. Process Flow Diagram for Aerobic Lagoon Liquids Stream Treatment



Anaerobic Lagoon Treatment System: Liquids and Solids Streams

In anaerobic lagoons, wastewater is generally screened to remove inerts (e.g., trash, rocks, etc.) before entering the lagoon. Communities and countries with less access to capital often use lagoon systems which break down organic material using processes that require little or no energy input and are low-cost, simple, and effective. Most anaerobic lagoons, however, are not equipped with a cover that can collect and store any methane generated. Consequently the lagoons can be a source of methane emissions. Similar to the previously discussed treatment systems, this collection system discharges some dissolved methane to the lagoon, while anaerobic decomposition within the lagoon generates additional dissolved methane that is released to the atmosphere. Turbulence at the point of effluent discharge can also release dissolved methane, resulting in methane emissions at the end of the process. Figure 4 shows the process flow for wastewater through an anaerobic treatment lagoon system; it does not show a means for sludge removal because these systems produce dramatically less solids than other treatment systems. An operational advantage of an anaerobic lagoon is that the sludge is removed, on average, every 5 years. However, the periodic sludge removal and management can be a source of methane emissions (as shown in the process flow diagram for treating the solids stream, Figure 2).

Figure 4. Process Flow Diagram for Anaerobic Liquids Stream Treatment



Biosolids Management

Biosolids generated by a WWTP are generally managed and disposed outside the WWTP and their handling also provides an opportunity to reduce methane emissions. Disposal of biosolids in landfills is common, but landfilling any type of organic material can contribute considerably to methane emissions. Global efforts to divert organic material from landfills are largely driven by the desire to reduce methane emissions associated with this waste management approach. Land application of biosolids is very common and highly regulated in developed countries. Biosolids are typically tilled into the upper layers of soil so that bacteria can decompose the organic material aerobically. While this practice beneficially returns nutrients to soil and agricultural land, local weather conditions (for example, rainy conditions that saturate soils) may contribute to anaerobic conditions that generate and release methane.

Opportunities and Challenges for Methane Mitigation and Use

The potential for generating methane emissions and the degree to which emissions can be abated, captured, and used, are WWTP-specific, depending on the collection system, treatment processes, population served, waste characteristics, and management of biosolids. Table 1 identifies some of the opportunities and challenges for methane mitigation for each type of treatment system.

Anaerobic treatment processes transform organic matter into biogas (CH_4+CO_2) and generate about 10% by volume of sludge (biomass). Aerobic treatment of biosolids requires significant energy use and does not generate biogas for beneficial use. It is generally recommended to choose anaerobic processes (i.e., Upflow Anaerobic Sludge Blanket [UASB] reactors or Anaerobic Digesters [AD]) over aerobic processes to treat the majority of organic solids.

From an energy and economic standpoint in particular, anaerobic systems are less-capital intensive than aerobic systems, can increase WWTP feasibility and profit, and are able to reduce and replace fossil generated energy consumption (e.g., if biogas is captured for electricity and/or fuel production). A detailed cost-benefit analysis should be conducted to compare the technical and economic feasibility of aerobic versus anaerobic treatment, because financial outcomes are highly dependent on the waste stream's incoming flow rate and organic load.

Table 1: Opportunities and Challenges for Methane Mitigation and Capture at Various Types of Wastewater Treatment Plants (WWTPs)

Liquids Stream		Solids Stream	
Opportunities	**Challenges**	**Opportunities**	**Challenges**
Conventional Activated Sludge (CAS)			
Reducing the potential for methane generation within the collection system will reduce the primary methane emissions source associated with liquids stream treatment. A regular testing plan and protocol can help identify a baseline of emissions and, over time, identify trends in methane emissions (increasing or decreasing) and particular points of higher methane emissions, which can inform mitigation strategies.	The state of the science for estimating methane generation in the collection system is emerging and few data-driven solutions are available. Testing requires staff time and adequate/accurate data collection at open tanks is difficult.	Properly constructed Upflow Anaerobic Sludge Blanket (UASB) reactors and Anaerobic Digesters (AD) contain solids and generate methane in a contained system for capture and use. Captured methane can generate electricity in co-generation engines; alternately, the biogas can be enriched into bio-methane, compressed, and used in natural gas vehicles, cylinders, or natural gas pipelines. Adding co-digestion to existing digesters can increase the controlled production, and use of, methane and increase the WWTP's economic feasibility. New facilities can be designed to include co-digestion. Proper operation and maintenance of pumps, piping, valves, and other equipment associated with the solids treatment system can reduce fugitive methane emissions associated with leaks.	For facilities without digesters (particularly, smaller plants), the construction costs to permit, add, and operate digesters can be a burden. For co-digestion, identifying clean, abundant feedstocks and long-term treatment contracts (that is, with industries and/or municipalities) can be difficult to negotiate. Staff time to conduct thorough evaluations and money to make repairs may be limited and challenging for some facilities.
Aerated Lagoon			
Collection system and testing opportunities are the same as for "CAS."	State of the science and testing challenges are the same as for "CAS."	Opportunity through proper construction of UASB/AD is the same as for "CAS." Proper operation and maintenance opportunities are the same as for "CAS."	Costs challenges are the same as for "CAS." Aerated lagoon sludge lends itself less to anaerobic digestion, making the process less efficient. Staff time and repair cost challenges are the same as for "CAS."
Anaerobic Lagoon			
Collection system and testing opportunities are the same as for "CAS." Covering the anaerobic lagoon can both mitigate emissions and effectively convert the lagoon to a digester. Installing simple degassing devices at the point of effluent discharge can capture methane dissolved in the waste stream; methane can be used beneficially or directed to a flare to reduce methane emissions. The anaerobic lagoon can be converted or replaced by an aerobic lagoon/system.	State of the science and testing challenges are the same as for "CAS." Cost of the cover, methane collection, and use/flare system are the primary challenge for most facilities. Unless other sources of methane are also captured, the amount of methane generated by anaerobic lagoon degassing systems may not justify the cost of equipment required for beneficial use. Aerated systems are energy intensive and require more equipment than anaerobic lagoons, increasing capital/operation costs.	Opportunity through proper construction of the AD is the same as for "CAS." Proper operations and maintenance opportunities are the same as for "CAS."	Costs challenges are the same as those for "CAS." Microbial activity in the lagoon is similar to that in AD and reduces "food" for AD microbial systems; this results in a potentially lower rate of methane generation available for capture and beneficial use. Staff time and repair cost challenges are the same as for "CAS."