United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

ANAEROBIC DIGESTER

Code 366

(Number)

DEFINITION

A component of a waste management system in which biological treatment breaks down animal manure and other organic materials in the absence of oxygen.

PURPOSE

This practice is applicable for one or more of the following purposes:

- Manage odors
- Reduce the net effect of greenhouse gas emissions
- Reduce pathogens
- Captures biogas to facilitate energy production

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where—

- Biogas production and capture are components of a waste management system plan and comprehensive nutrient management plan (CNMP)
- Sufficient and suitable organic feedstocks are readily available.

CRITERIA

General Criteria Applicable to All Purposes

Laws and Regulations. Plan, design, and construct the anaerobic digester to meet all Federal, State, Tribal, and local laws and regulations.

Location. Locate the anaerobic digester outside the 100-year floodplain unless site restrictions require locating it within the floodplain. If located in the floodplain, protect the facility from inundation or damage from a 25-year flood event. Additionally, follow the policy found in the NRCS General Manual (GM) 190, Part 410, Subpart B, Section 410.25, “Floodplain Management,” which may require providing additional protection for structures located within the floodplain.

Feedstock Characteristics. Digester design must consider the varying feedstock properties. Depending on the system design, extraneous material such as soil, sand, stones or fibrous bedding material (including clumps of straw), may need to be ground, removed, reduced, or otherwise handled. Ensure that the total solids of feedstock influent match the digester type and process design. Exclude excess water and foreign material from the digester. Food waste, wastewater from food processing operations, and other allowable organic substrates may be added as supplemental feedstock to a digester when the digester is designed to treat such wastes, as described in the operation and maintenance plan.

Connections. Ensure that all connections and fittings are properly sized and installed for design flows and vibrations.

Agricultural Waste Management System. Do not consider the volume of the digester in determining the storage requirement of the waste storage facility.

Safety. If the digester has the potential to create a safety hazard, install fence and post warning signs to prevent using it for purposes other than intended. Include appropriate safety features to minimize the hazards of the facility (refer to American Society of Agricultural and Biological Engineers (ASABE) Standard EP470, Manure Storage Safety for guidance, as needed).

Biogas is flammable, highly toxic, and potentially explosive. Design of the digester and gas collection, control, and utilization system with adequate safety measures including appropriate earthquake loads (as required)**,** and install components in accordance with standard engineering practice for handling a flammable gas and to prevent undue safety hazards. As a minimum—

- Post “Warning Flammable Gas” and “No Smoking” signs.
- Provide appropriate fire protection equipment and biogas leak detection sensors, especially in confined areas.
- Install a flare for the anaerobic digestion system unless another option is provided by the manufacturer which adequately addresses conditions to prevent biogas release into the atmosphere.
- Locate flares the appropriate distance from the digester and other buildings according to manufacturer’s specifications, and electrical code. Install flares a minimum of 10 feet above the ground. Locate open flares a minimum distance of 50 feet from the biogas source. Properly ground flares or protect to minimize potential damage caused by lightning strikes.
- Provide a flame trap device in the biogas line between the digester and sources of ignition to prevent flame migration from the flare to the gas source or as otherwise recommended by the flame arrester manufacturer.
- Use explosion-proof motors, switches and other spark producing devices on all biogas blowers or other equipment installed where biogas is present.
- Provide and maintain above-ground permanent markers to indicate the location of underground gas lines to prevent accidental disturbance or rupture. Mark exposed pipe to indicate type of pipe whether gas or other.

Criteria for Plug Flow Digester

- Recommended total solids content of influent is 11 to 14 percent.
- Minimum digester retention time is 20 days.
- Operational temperature is mesophilic (ranging from 95 to 104 ºF).
- Minimum length to width ratio of digester flow path is 3.5:1.
- Maximum ratio of flow path width to fluid depth is 2.5:1.
- Design the floor and wall shapes to facilitate the movement of all material through the digester to minimize short-circuiting flow.

Criteria for Complete Mix Digester

- Recommended total solids content of manure influent is less than 11 percent.
- Minimum digester retention time is 17 days.
- Operational temperature is mesophilic (ranging from 95 to 104 ºF).
- Provide appropriate devices, as necessary, to assure a continuous flowing and mixing process.

Criteria for Covered Lagoon

Meet the “General Criteria for All Lagoons” given in Conservation Practice Standard Waste Treatment Lagoon (Code 359) as appropriate. Additional requirements include—

- Minimum Design Operating Volume.—Base the design operating volume either on the daily volatile solids (VS) loading rate per 1,000 ft^3 or the minimum hydraulic retention time (HRT) adequate for methane production, whichever volume is greater. Select and apply the maximum daily VS loading rate from the values listed on the map in figure 1. Select and apply the minimum HRT from values indicated on the map in figure 2.
- Required Total Volume.—The required total volume of the digester is equal to the minimum design operating volume except where waste storage is also included in the design. For this exception, meet the additional criteria pertinent to volume requirements found in Design Storage Volume in CPS Waste Treatment Lagoon (Code 359), as appropriate.
- Provide a minimum of 2 feet of freeboard above the digester design water surface; if rainfall is included in determining the operating volume, only 1 foot of freeboard is required. The digester storage volume does not need to account for rainfall for completely covered digesters.
- Operating Depth.—The minimum operating depth of the digester is 8 feet.
- Inlet and Outlet.—Locate the inlet and outlet devices as far apart as practical to minimize “short circuiting.” Locate the inlet discharge a minimum of 12 inches below the digester liquid surface. Equip the digester with an outflow device that maintains the digester liquid surface at its design operating level.
- Digester Cover.—Design the digester cover, materials, anchorage, and all appurtenances, such as weights and floats, to capture and convey biogas to the gas collection system. The digester cover and associated materials must meet the requirements of CPS Roofs and Covers (Code 367).

Criteria for Alternative Type Digester

For digester types not meeting the above criteria or for digester types other than listed in this standard (such as fixed film, induced blanket, high solids (dry digesters) or thermophilic reactors) follow the documented design and performance requirements of the proposed anaerobic digester.

Alternative Type Digester Containment Characteristics. For the various alternative digester types, ensure that the following applicable criteria are applied:

- For earthen structures meet the “General Criteria for All Lagoons” given in CPS Waste Treatment Lagoon (Code 359), as appropriate.
- Design tanks and internal components, including heat pipes to facilitate periodic removal of accumulated solids and for corrosion protection.
- For tanks meet the structural criteria for “Fabricated Structures” in CPS Waste Storage Facility (Code 313), and the requirements of State and local seismic codes as applicable.
- The following additional criteria apply:
    - Design Operating Volume.—Size the digester to retain the design requirements to meet the hydraulic and solids retention times (days).
    - Inlet and Outlet.—Locate the inlet and outlet devices to facilitate process flow. Design inlets and outlets of any permanent material to resist corrosion, plugging, freeze damage, and prevent gas loss. To maintain the operating level, maintain a gas seal under the cover, prevent gas loss, and release effluent directly to separation, storage, or other treatment facility. Equip the digester with an outflow device, such as an underflow weir.
    - Cover.—For covers meet the requirements of CPS Roofs and Covers (Code 367). Equip tanks with suitable covers designed for accumulation and collection of biogas.
    - Heating System (if required).—Design and install the heating system to maintain proper digester temperature and to minimize corrosive attack and scalding build-up on the heated surfaces.

Gas Collection, Transfer, and Control System. Design the biogas collection, transfer, and control system to convey captured gas from within the digester to gas utilization equipment or devices (flare, boiler, engine, etc.).

Gas collection and transfer.— Meet the following for pipe and/or appurtenances:

- Design the gas collection system within the digester to minimize plugging or install cleanout ports as needed.
- Securely anchor pipe and components within the digester to prevent displacement/damage from normal forces including loads associated with scum accumulated.
- Design the collection and transfer pipe for wet biogas. In colder climates, protect the pipe as necessary to prevent frost buildup. Use pipe sizes no smaller than 3-inch diameter, unless a detailed design is performed to account for frost buildup and pressure drop in a low-pressure system. Design pressurized systems as an alternative type digester.
- For pipes used to transfer biogas include provisions for drainage of condensate, pressure and vacuum relief, and flame traps.
- For steel pipe meet the requirements of American Water Works Association (AWWA) Specification C-200, or American Society for Testing and Materials (ASTM) Specification A53/A211 for stainless steel.
- For plastic pipe meet the requirements of AWWA Specification C-906 or ASTM Specification D-3350 for high-density polyethylene (HDPE).
- Install pipes to ensure all sections can be safely isolated and cleaned as part of routine maintenance.

Gas Control

- Locate and shelter all equipment and components from the elements.
- The minimum service life for all equipment and components is 2 years or more. Provide easy access for replacement or repair of components.
- Base the size of equipment and connecting pipe on head loss, cost of energy, cost of components, and manufacturers' recommendations.
- Where electrical service is required at the control facility, follow the National Electrical Code and local and State requirements for the installation and all electrical wire, fixtures, and equipment.

Gas Utilization. Design and install gas utilization equipment in accordance with standard engineering practice and the manufacturer's specifications.

- Equip flares with automatic ignition and powered by battery/solar or direct connection to electrical service. Ensure that the flare capacity is equal to or greater than the anticipated maximum biogas production. Install a windshield or other device to protect an open flare against wind.
- As needed, design appropriate facilities to store excess gas.
- Design gas-fired boilers, fuel cells, turbines, and internal combustion engines to burn biogas directly, in a mix with other fuel, or include equipment for removing hydrogen sulfide and other contaminants from the biogas.
- Install and maintain a gas meter, suitable for measuring biogas.

Monitoring for Mesophilic and Thermophilic Digesters. Install equipment needed to properly monitor the digester and gas production as part of the system. As a minimum, the following equipment is required:

- Temperature sensors and readout device to measure internal temperature of digester
- Temperature sensors and readout device to measure inflow and outflow temperature of digester heat exchanger

CONSIDERATIONS

Location

Locate the digester as near the source of manure and as far from neighboring dwellings or public areas as practicable. Consider slope, distance of manure transmission, vehicle access, prevailing wind direction, proximity to hydrologically sensitive areas, and visibility for proper location. Locate the digester near a suitable site for energy utilization equipment. Minimize distances for the transmission of biogas through buried pipe. Locate the waste storage facility, considering elevation and distance from the digester, to take advantage of gravity flow.

Manure Characteristics

Consider using only fresh manure which has the highest energy content. The biogas yield from aged manure (generally less than 6 months old) is dependent on the biodegradation that has taken place during the storage period. Little biodegradation occurs when frozen. Manure stored in a warm, moist state could be significantly degraded resulting in reduced biogas production.

Chemicals and Amendments

Consider potential inhibitory effects on gas production of any antimicrobial agents in the manure or waste stream.

Waste Separation. Consider waste separation to prepare the waste stream for introduction to the anaerobic digester or for post-digestion treatment.

Collection/Mix Tank

Consider using a collection/mix tank to accumulate manure, settle and separate foreign material, pre-heat, and/or pretreat influent waste to the appropriate total solids concentration. A volume of 1 to 3 days of manure collection, depending on the planned system management, is often used.

Overflow Protection

In case of digester equipment failure, consider designing the transfer system with the capability to bypass the digester, going directly to storage or land application equipment.

Digester Type

The type of digester selected may be affected by geographical location (figure 3), energy considerations, wastewater properties, and other design considerations (figure 4).

Digester Design

A digester operating fluid depth of 8 feet or greater is usually more economical for tank design. Tank dividers or flow separators may be utilized to increase efficiency and prevent short-circuiting. Install interior slopes as steep as permitted by soil properties and construction techniques.

Grounding and Cathodic Protection

Stray voltage, electrolysis and galvanic corrosion can damage pipes inside digesters. Consider the design requirements for electrodes and anodes.

Electrical Component Protection

Very small concentrations of biogas can corrode electrical hardware. Consider locating electrical controls in a separate room or building away from the digester and generator.

Temperature Maintenance

For the design include a means of maintaining the digester within acceptable operating temperature limits, use insulation where appropriate.

Gas Transfer Pipe

Exposed pipe conveying flammable gas is generally painted yellow, per ASME A13.1-2015.

Gas Collection Cover

In areas of extreme wind or excessive snow, consider installing structures to protect inflatable and floating digester covers from damage.

Air Quality

Recovering energy from the biogas may be a preferable alternative to flaring. This could reduce fossil fuel combustion and associated emissions, thereby reducing the net effect of greenhouse gases and improving air quality. Some energy recovery options, such as the use of internal combustion engines to convert biogas to energy, may also result in additional emissions of some air pollutants.

Gas Utilization

Investigate and select the most beneficial and economical use of the biogas energy. Sales of carbon credits may affect the manner of utilization. Depending on the design and climate, digesters may require more than 50 percent of the biogas heat value to maintain the design temperature in the winter. Digesters can be heated by hot water from boilers burning biogas or by heat recovery from internal combustion engines and micro turbines burning biogas for power generation.

Effluent Tank

Due to the potential use of digested separated solids for bedding or soil amendment consider utilizing an effluent tank to hold digester effluent for subsequent mechanical solid-liquid separation.

Siting and Vegetation

Analyze the visual impact of the digester within the overall landscape context and effects on aesthetics. Consider screening with vegetative plantings, landscaping, or other measures to alleviate a negative impact or enhance the view. In addition, vegetate disturbed areas as soon as possible.

Soil Properties

Consider soil properties such as texture, saturated hydraulic conductivity, flooding, slope, water table and depth, as well as limitations related to seepage, corrosivity, or compactibility of soil material when designing and installing an anaerobic digester. Refer to local soil survey information and on-site soil investigations during planning.

Nutrient Availability

Consider the effects of digestion upon nutrient availability. Land application of digester effluent, compared with fresh manure, may have a higher risk for both ground and surface water quality problems. Compounds such as nitrogen, phosphorus, and other elements become more soluble due to anaerobic digestion and therefore have higher potential to move with water.

PLANS AND SPECIFICATIONS

Prepare plans and specifications that describe the requirements for applying the practice according to this standard. As a minimum, include—

- Plan view of the system layout and location of livestock facilities, waste collection points, waste transfer pipe, digester, biogas utilization facilities, and digester effluent storage. Include utilities and structures on the site.
- Grading plan showing excavation, fill, and drainage, as appropriate.
- Materials and structural details of the digester, including all premixing tanks, inlets, outlets, pipes, concrete, pumps, valves, and appurtenances as appropriate for the complete system.
- Foundational requirements including preparation and treatment.
- Details of biogas collection, control, and utilization system including type of materials for pipe, valves, regulators, pressure gages, electrical power and interface as appropriate, flow meters, flare, utilization equipment, and associated appurtenances.
- Specify insulation, heat exchanger capacity, and energy requirements as appropriate for maintaining the digester operating temperature within acceptable limits.
- Provide a process flow diagram with the following design information:
    - Flow rates of influent, effluent, and biogas.
    - Design total and volatile solids content of influent and effluent.
    - Digester volume.
    - Hydraulic and solids retention times.
    - When applicable, heating system type and capacity, control, and monitoring.
    - Biogas production, including methane yield.
    - 12-month energy budget when applicable.
    - Safety features

OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan for the operator.

As a minimum, include the following items in the operation and maintenance plan:

- Proper loading rates of the digester and total solids content of the influent.
- Accounting for the nutrient impact of all feedstock in the farm's nutrient management plan.
- Proper operating procedures for the digester.
- Estimates of biogas production, methane content, and potential energy recovery.
- Description of the planned startup procedures, normal operation, safety issues, and normal maintenance items.
- Alternative operation procedures in the event of equipment failure.
- Instructions for safe use and flaring of biogas.
- Digester and other component maintenance.
- Troubleshooting guide.
- Monitoring plan with frequency of measuring and recording digester inflow, operating temperatures, biogas yield, and/or other information as appropriate.
- Maintain the internal temperatures for controlled temperature digesters as appropriate to the digester type and design. For mesophilic digesters maintain the temperature between 95 ºF and 104 ºF with an optimum of 100 ºF and daily fluctuation of digester temperature limited to less than 1 ºF.
- Design the digester with appropriate freeboard and overflow or automatic shutdown devices to prevent accidental spillage of effluent or discharge into the gas collection system.
- Establish and maintain emergency contact information for consultation with qualified experts.

REFERENCES

American Society of Agricultural and Biological Engineers (ASABE), Standard EP470, Manure Storage Safety. 2011.

American Water Works Association (AWWA). C-200, Standard for Steel Water Pipe 6 in. (150 mm) and Larger. 2012. Denver, CO.

AWWA. C-906, Polyethylene Pressure Pipe and Fittings, 4 In. through 65 In. (100 mm through 1650 mm), for Waterworks. 2015. Denver, CO.

American Society for Testing and Materials. Annual Book of ASTM Standards. Standards D-3350, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials; A-53, Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless; and A211, Standard Specification for Spiral-Welded Steel or Iron Pipe. Philadelphia, PA.

USDA NRCS. National Engineering Handbook-210, Part 651, Agricultural Waste Management Field Handbook. 2012. Washington, D.C.

USDA NRCS, General Manual-190, Part 410, Subpart B, Section 410.25, “Floodplain Management.” 2012. Washington, D.C.

U.S. Environmental Protection Agency (EPA), AgStar Handbook – A Manual for Developing Biogas Systems at Commercial Farms in the United States. 2004.

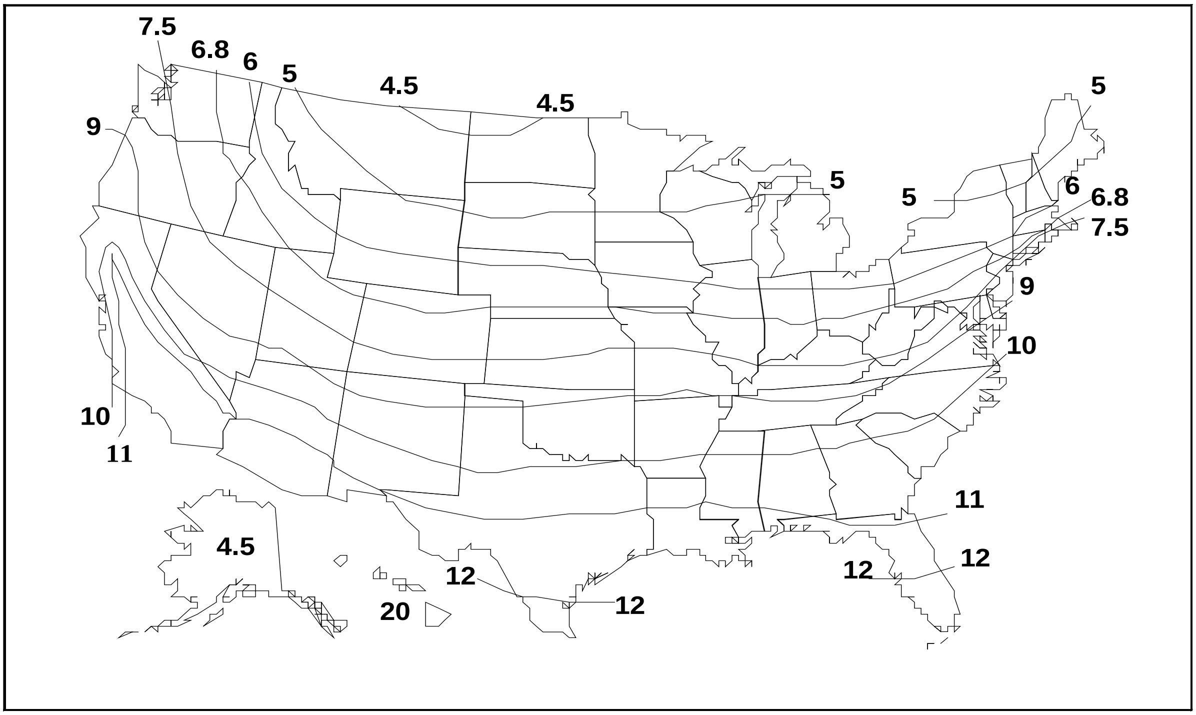

Figure 1. Covered lagoons—maximum loading rate (lb VS/1,000 ft^3/day).

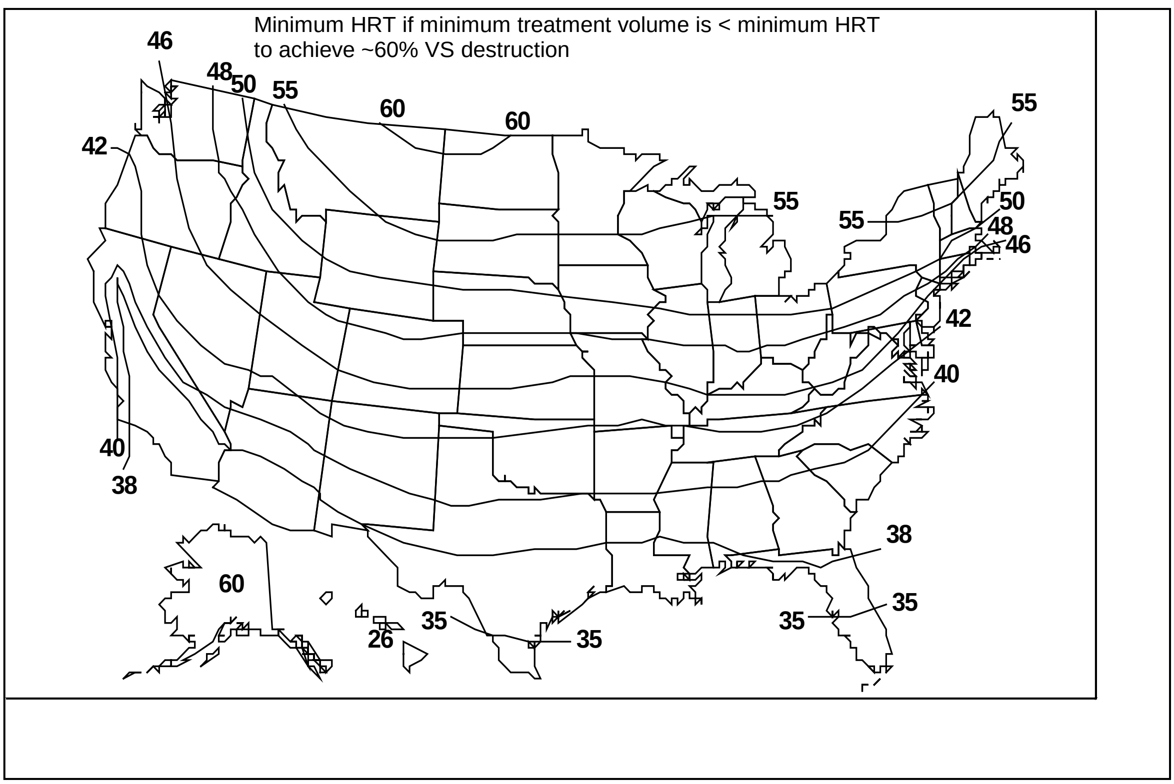

Figure 2. Covered lagoons—minimum hydraulic retention times (MINHRT) in days.

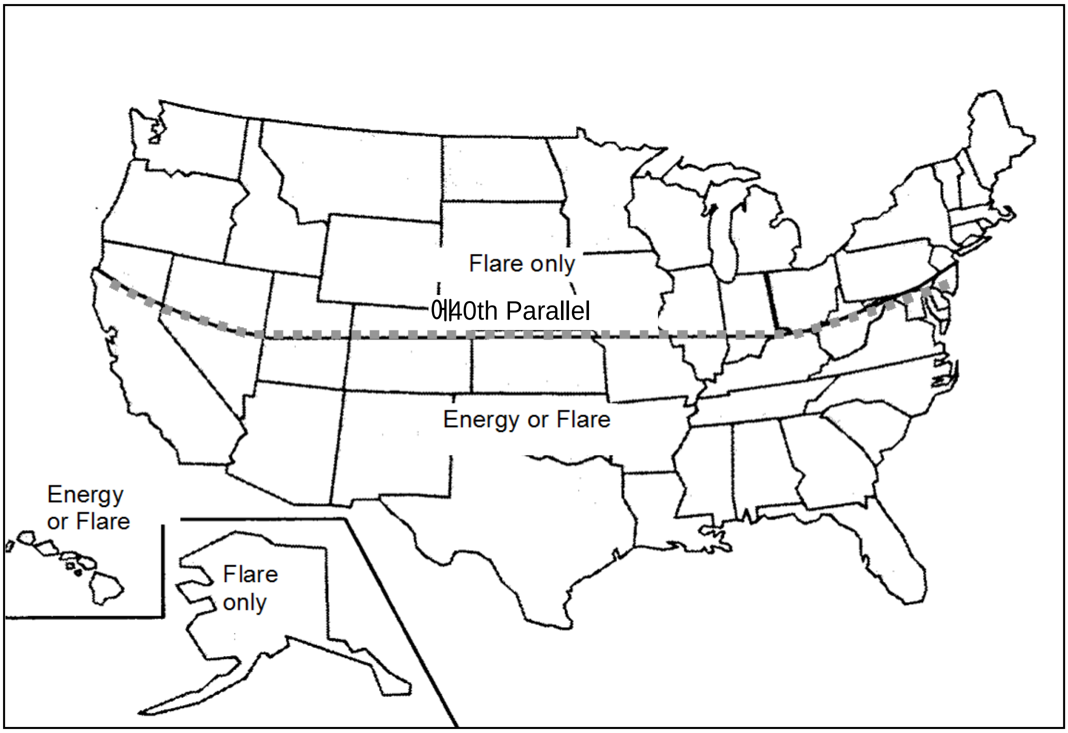

Figure 3. Covered lagoons—locations suitable for biogas to energy conversion generally fall below the 40th parallel.

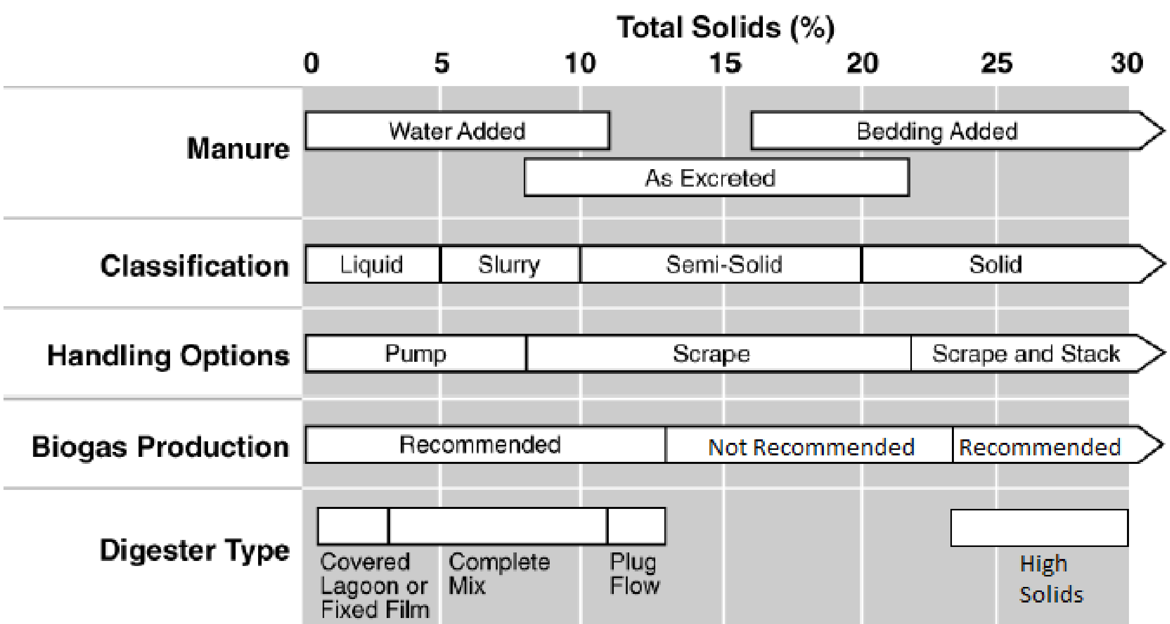

Figure 4. The type of digester selected is affected by multiple parameters and subject to specific design considerations (US EPA – AgStar, modified).