NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

ANAEROBIC DIGESTER

(No.)

CODE 366

DEFINITION

A component of a waste management system that provides biological treatment in the absence of oxygen.

PURPOSE

For the treatment of manure and other byproducts of animal agricultural operations for one or more of the following reasons to

- capture biogas for energy production
- manage odors
- reduce the net effect of greenhouse gas emissions
- reduce pathogens

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where:

- Biogas production and capture are components of a planned animal waste and byproduct(s) management system.
- Sufficient and suitable organic feedstocks are readily available.
- Existing facilities can be modified to the requirements of this standard or for new construction.
- The operator has the interest and skills to monitor and maintain processes or contracts with a consultant to provide these services.

CRITERIA

General Criteria Applicable to All Purposes

Feedstock Characteristics. The design of the digester needs to take feedstock properties into account. Extraneous material such as soil, sand, stones or fibrous bedding material (including clumps of straw), must be ground, removed, reduced, or otherwise handled. The total solids of feedstock influent to the digester shall be as required by the digester type and process design. Exclude excess water and 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. The treatment of feedstock will comply with all state and local regulations.

Safety. If the digester will create a safety hazard, it shall be fenced and warning signs posted to prevent using it for purposes other than intended.

Biogas is flammable, highly toxic, and potentially explosive. The design of the digester and gas components, including the gas collection, control, and utilization system, must consider the hazards associated with normal operation and maintenance, provide adequate safety measures including appropriate earthquake loads, and shall be in accordance with standard engineering practice for handling a flammable gas and to prevent undue safety hazards. As a minimum:

- "Warning Flammable Gas" and "No Smoking" signs shall be posted.
- Appropriate fire protection equipment and

biogas leak detection sensors, especially in confined areas shall be provided.

- Flares shall be located an appropriate distance from biogas sources. Enclosed flares shall be located as recommended by the manufacturer. Open flares shall be located a minimum distance of 95 feet (30 m) from the biogas source. The flares shall have a minimum height of 10 ft and shall be grounded or otherwise protected to minimize the chance of lightening strikes.
- A flame trap device shall be provided in the biogas line between the digester and sources of ignition or as recommended by the flame arrester manufacturer.
- The location of underground gas lines shall be marked with signs to prevent accidental disturbance or rupture. Mark exposed pipe to indicate whether gas line or other.

Digester Types

Plug Flow Digester

1. The total solids concentration of influent shall be 11 to 14 percent.
2. Digester retention time shall be a minimum of 20 days.
3. Operational temperature shall be mesophilic (ranging from 35 – 40 ºC or 95 – 104 ºF).
4. The length to width ratio of digester flow path shall be a minimum of 3.5:1
5. The ratio of flow path width to fluid depth shall be less than 2.5:1.
6. The shape of the floor and walls shall facilitate the movement of all material through the digester to minimize short-circuiting flow.

Complete Mix Digester

1. Total solids concentration of manure influent shall be less than 11 percent.
2. Digester retention time shall be a minimum of 17 days.
3. Operational temperature shall be mesophilic (ranging from 35 – 40 ºC or 95 – 104 ºF).
4. Appropriate devices shall be provided, as necessary, to assure a continuous flowing and mixing process.

Covered Lagoon

The digester shall meet the General Criteria for All Lagoons given in Practice Standard 359, Waste Treatment Lagoon, as appropriate, and the following additional requirements:

1. Minimum Design Operating Volume. The design operating volume shall be based 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 is greater. The maximum daily VS loading rate shall be selected from the values listed on the map in Figure 1. The minimum HRT shall be selected from values indicated on the map in Figure 2.
2. Required Total Volume. The required total volume of the digester shall be equal to the minimum design operating volume except where waste storage is included in the design, in which case the volume shall meet the additional criteria for Design Storage Volume in Practice Standard 313, Waste Storage Facility, as appropriate.
3. The digester storage volume does not need to account for rainfall in completely covered digesters.
4. 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.
5. Operating Depth. The operating depth of the digester shall be at least 8 feet over 50 percent or more of the bottom area.
6. Inlet and Outlet. Locate the inlet and outlet devices as far apart as

practical to minimize "short circuiting." The inlet shall 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.

7. 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 materials shall meet the requirements of Practice Standard 367, Waste Facility Cover.

Alternative Type Digester

Types of digesters not meeting the above criteria or for a type other than listed in this standard (such as fixed film, induced blanket, or thermophilic reactors) shall be based on the documented design and performance of such existing animal waste digester and certified as such by a registered professional engineer licensed in the state of the proposed installation.

Digester Containment Characteristics.

1. Earthen structures shall meet the General Criteria for All Lagoons given in Practice Standard 359, Waste Treatment Lagoon, as appropriate.
2. Design tanks and internal components (including heat pipes) to facilitate periodic removal of accumulated solids and for corrosion protection.
3. Tanks shall meet the structural criteria for "Fabricated Structures" in Practice Standard 313, Waste Storage Facility, and the requirements of state and local seismic codes as applicable.
4. The following additional criteria apply:
   - Design Operating Volume. Size the digester to retain the design hydraulic and solids retention times (days).
   - Inlet and Outlet. Locate the inlet and outlet devices to facilitate process flow. Inlets shall be of any permanent type designed to resist corrosion, plugging, freeze damage, and prevent gas loss. Equip the digester with an outflow device, such as an underflow weir, that will 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.
   - Cover. Covers shall meet the requirements of Practice Standard 367, Waste Facility Cover. Equip tanks with suitable covers designed for accumulation and collection of biogas.
   - Heating System (if required). Heating system should be designed and installed with consideration for minimizing 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.).

1. Gas collection and transfer - Pipe and/or appurtenances shall meet the following:
   - Design the gas collection system within the digester to minimize plugging.
   - Securely anchor pipe and components within the digester to prevent displacement from normal forces including loads from accumulated scum.
   - Design the collection and transfer pipe for wet biogas. In colder climates, protect the pipe as necessary to prevent frost buildup. The pipe size shall be no less than 3-inch diameter, unless a detailed design is performed to account for frost buildup and pressure drop in a low-pressure system. Pressurized systems shall be designed as an Alternative Type Digester.

- Pipe used for transfer of gas must include provisions for drainage of condensate, pressure and vacuum relief, and flame traps.
- Steel pipe shall meet the requirements of AWWA Specification C-200 or ASTM A53/A211 for stainless steel.
- Plastic pipe shall meet the requirements of AWWA Specification C-906 or ASTM D-3350 for HDPE.
- Pipes shall be installed to enable all sections to be safely isolated and cleaned as part of routine maintenance.

2. Gas Control

- Equipment and components shall be conveniently located and sheltered from the elements.
- Equipment and components shall have a service life of not less than 2 years and shall be readily accessible for replacement or repair.
- The size of equipment and connecting pipe shall be based on head loss, cost of energy, cost of components, and manufacturers' recommendations.
- Where electrical service is required at the control facility, the installation and all electrical wire, fixtures, and equipment shall meet the National Electrical Code and local and state requirements.

Gas Utilization. Design and install gas utilization equipment in accordance with standard engineering practice and the manufacturer's recommendations. Include a flare to burn off collected gas.

- Equip the flare with automatic ignition and powered by battery/solar or direct connection to electrical service. The flare shall have a capacity equal to or greater than the anticipated maximum biogas production. Install a windshield to protect an open flare against wind.
- Gas-fired boilers, fuel cells, turbines, and internal combustion engines, when a component of the system, shall be designed for burning biogas directly, in a mix with other fuel, or shall include equipment for removing H_2S 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

Waste Storage Facility. When a waste storage facility is a component of the waste system, it shall meet the requirements of Practice Standard 313, Waste Storage Facility. The volume of the digester shall not be considered in determining the storage requirement of the waste storage facility except that the volume can be reduced by the anticipated percent destruction of total solids.

CONSIDERATIONS

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

Manure Characteristics. Fresh manure has the most energy content; however, aged manure can be fed to the digester if properly reconstituted to the digester design total solids 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. If frozen, little biodegradation will have occurred; whereas, manure in a warm, moist state could be significantly degraded and biogas production will be substantially reduced. Also, consider potential inhibitory effects of any antimicrobial agents in the manure or waste stream.

Collection/Mix Tank. A collection/mix tank may be included to accumulate manure, settle foreign material, pre-heat, and/or pre-treat 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. Consider designing the transfer system with the capability to bypass the digester, going directly to storage or land application equipment in case of equipment failure.

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. Interior slopes should be 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: The design should include a means of maintaining the digester within acceptable operating temperature limits, where appropriate.

Gas Transfer Pipe. Exposed pipe conveying flammable gas is generally painted yellow, per IAW ASME A13.1-1996.

Gas Collection Cover. In areas of extreme wind or excessive snow, appropriate structures may be necessary 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.

Gas Utilization. The most beneficial use of the biogas energy should be investigated and selected. 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. An effluent tank to hold digester effluent for subsequent mechanical solid-liquid separation may be considered due to the potential use of digested separated solids for bedding or soil amendment.

Siting and Vegetation. Analyze the visual impact of the digester within the overall landscape context and effects on aesthetics. Screening with vegetative plantings, landscaping, or other measures may be implemented to alleviate a negative impact or enhance the view. In addition, disturbed areas should be vegetated as soon as possible.

Soil Properties. Soil properties such as texture, Ksat, flooding, slope, water table and depth, as well as limitations related to seepage, corrosivity, or packing of soil material should be considered when designing storage structures. 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

Plans and specifications shall be prepared in accordance with the criteria of this standard and sound engineering practice, and shall describe the requirements for applying this practice to achieve its intended use.

As a minimum, the plans and specifications shall provide the following:

1. Layout and location of livestock facilities, waste collection points, waste transfer pipe, digester, biogas utilization facilities, and digester effluent storage.
2. Grading plan showing excavation, fill, and drainage, as appropriate.
3. Materials and structural details of the digester, including all premixing tanks, inlets, outlets, pipes, pumps, valves, and appurtenances as appropriate to the complete system.
4. 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.
5. Specify insulation, heat exchanger capacity, and energy requirements as appropriate for maintaining the digester operating temperature within acceptable limits.
6. A process flow diagram with the following:
    a. Flow rates of influent, effluent, and biogas.
    b. Design total and volatile solids content of influent and effluent.
    c. Digester volume.
    d. Hydraulic and solids retention times.
    e. When applicable, heating system type and capacity, control, and monitoring.
    f. Biogas production, including methane yield.
    g. 12-month energy budget when applicable.

OPERATION AND MAINTENANCE

An operation and maintenance (O&M) plan shall be developed and reviewed with the owner prior to construction. The operation and maintenance plan shall be consistent with the purposes of the practice, its intended life, safety requirements, and the criteria for its design. The plan shall contain operation and maintenance requirements including but not limited to:

- Proper loading rate 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.
- Controlled temperature digesters shall be maintained at internal temperatures appropriate to the digester type and design. Mesophilic digesters shall be maintained between 35 ºC and 40 ºC (95 ºF-104 ºF) with an optimum of 37.5 ºC (100 ºF) and daily fluctuation of digester temperature limited to less than 0.55 ºC (1 ºF).
- The operating level of digesters shall be designed with appropriate freeboard and overflow or automatic shutdown devices to prevent accidental spillage of effluent or discharge into the gas collection system.

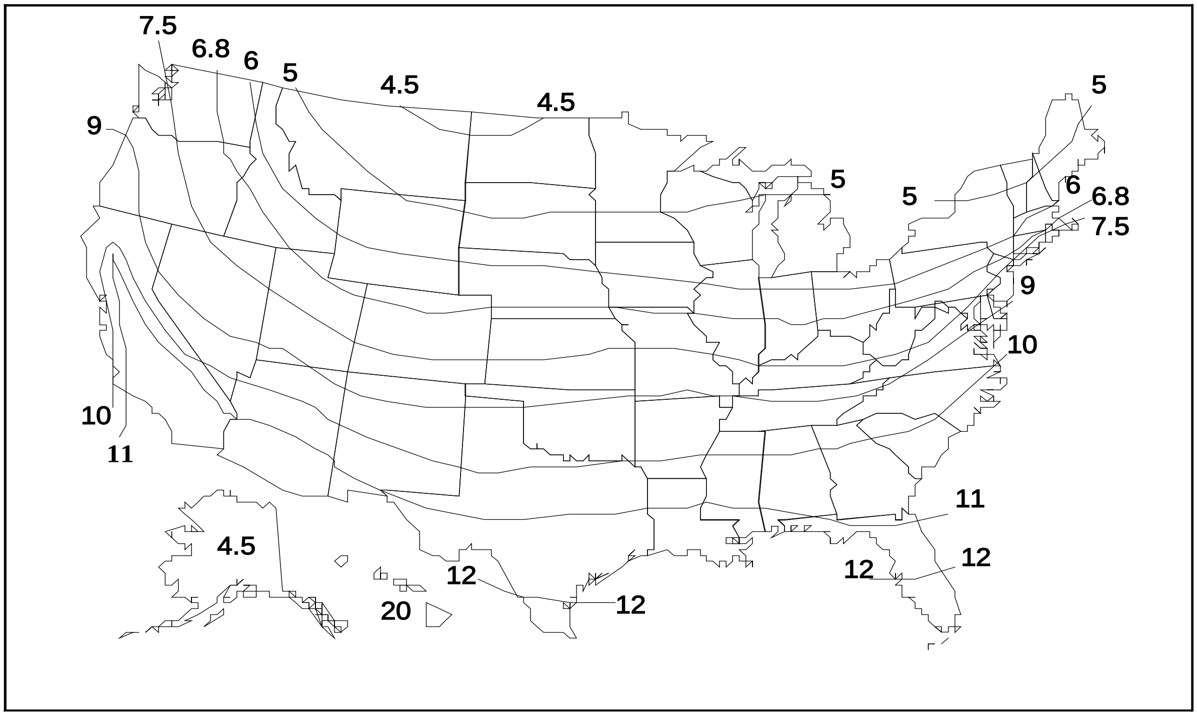

Figure 1. Covered lagoons - maximum loading rate (lb VS/1,000 ft^3/day).

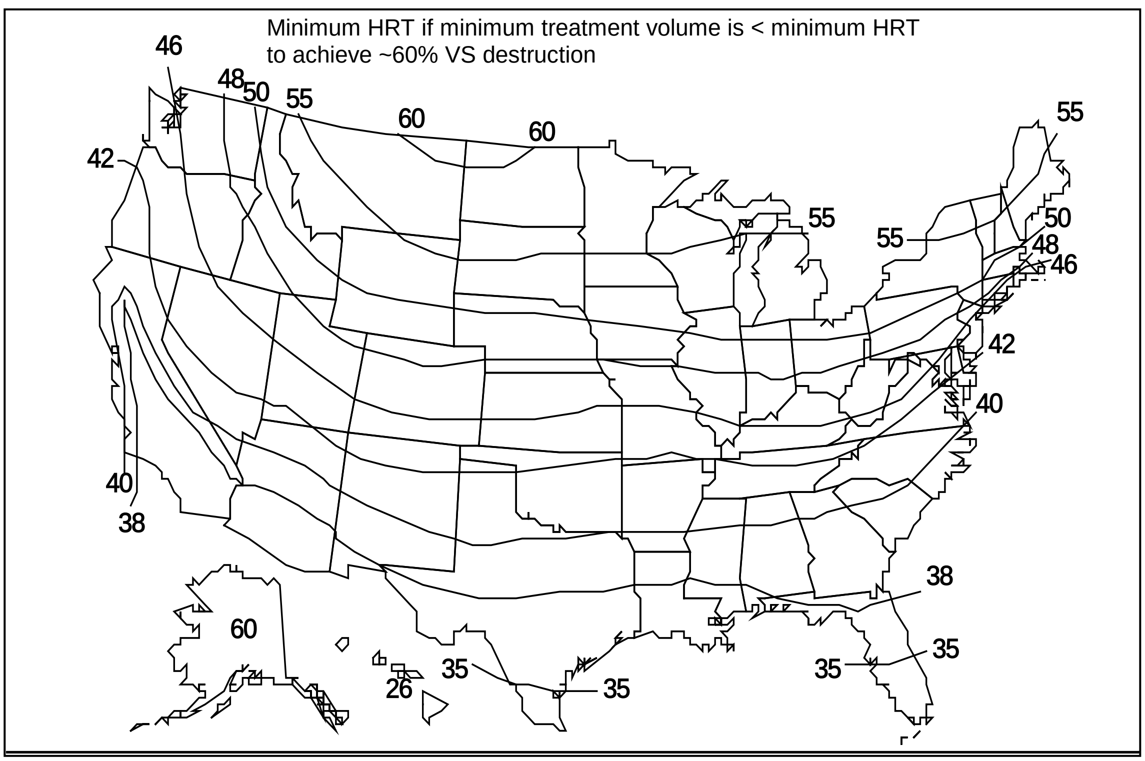

Figure 2. Covered lagoons - minimum hydraulic retention times (MINHRT) in days.

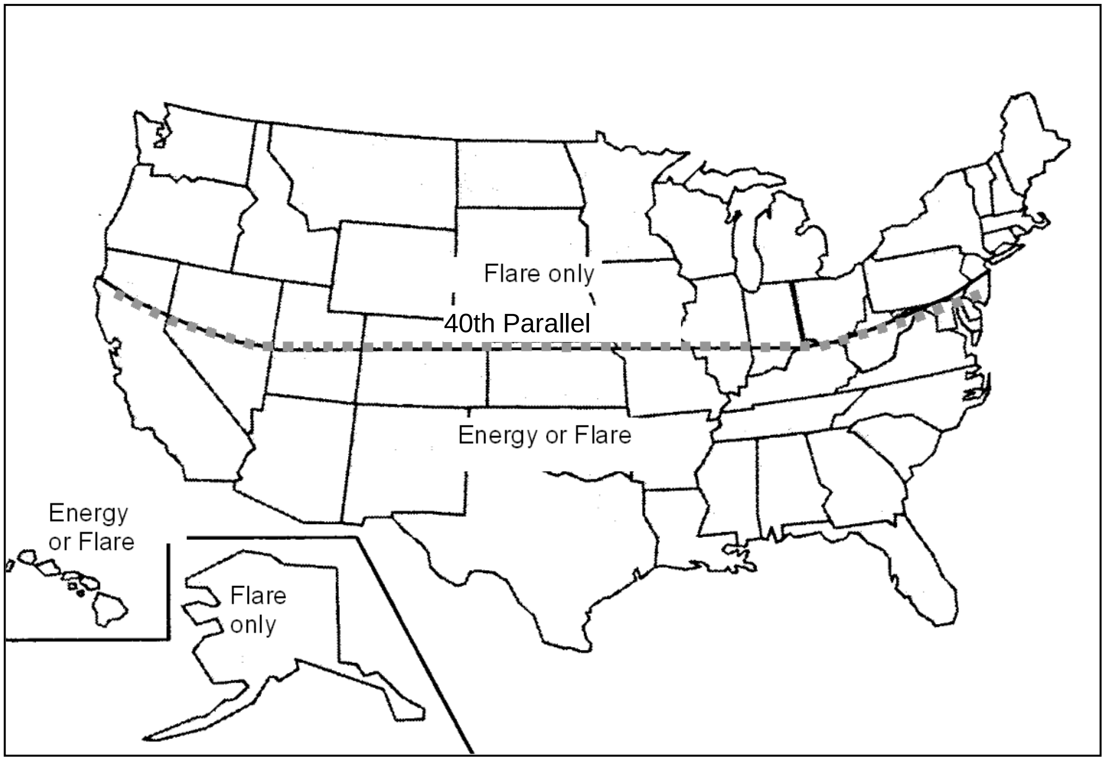

Figure 3. Covered lagoons - locations suitable for biogas to energy conversion generally fall below the 40th parallel.

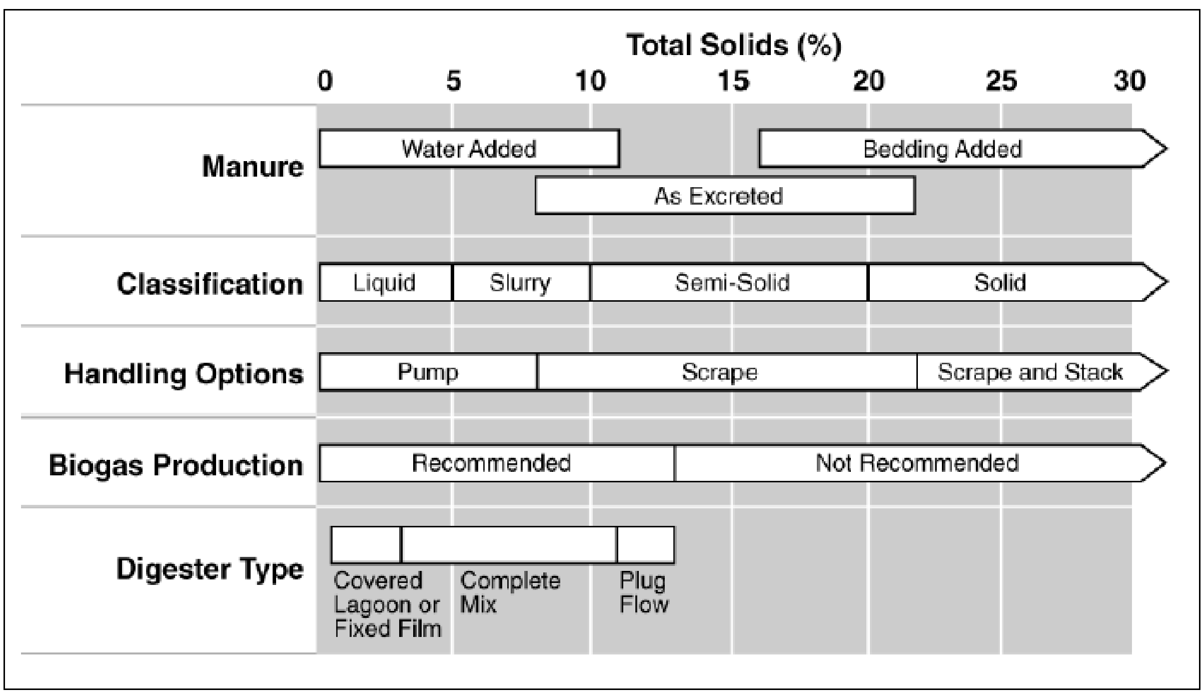

Figure 4. The type of digester selected is affected by multiple parameters and subject to specific design considerations (US EPA – AgStar).