Biogas start up

From Appropedia

Contents

STARTING UP AN ANAEROBIC BIODIGESTER: A HOW TO GUIDE

AIDG Biogas- www.aidg.org

You Have A Biodigester

Congratulations! Conditions are good that biogas will save the world, and you, a new biodigester owner, are on the forefront. But before producing biogas, a community of microbes needs to be established in the tank/ bag/ bamboo dome biodigester you have just built, bought or inherited. Luckily establishing the microbes to carry out this process is simple if you know what you are doing. But before focusing on startup a few questions need answering:

- Does you biodigester hold water where it needs to hold water?
- Does your biodigester hold gas under the designed gas pressure?

When these two important structural considerations have been established the next few steps are easy. There are some important materials to have on hand once everything is sealed up and structurally functional; a lighter and a pH test. A lighter will give the sign when you begin to produce a combustible gas. The pH signifies the health of the biodigester.

- Optimal pH range: 6.8- 7.5. An anaerobic biodigester for the most part operates under a specific pH range (6.8- 7.5). At this pH methane producing activity eliminates inhibitory byproducts will inhibit the process.

- pH too low: under 6.0. During start up the acid producing and hydrolyzing microbes might out grow the methanogens causing a drop in pH. If the pH ever drops below 6.8 methanogen growth will be inhibited and if the pH ever drops below 6.0 you may want to consider cleaning out and restarting the biodigester.

- pH too high: Above 7.5 When the pH is too high then there is a problem with what you are feeding the biodigester, this problem might arise from using “hard water” to biodigesting organic material too rich in proteins or ammonia.

Anaerobic digestion is carried out by a community of hydrolyzing (turning solids into solubles), acid producing, acetate producing, and methane producing microbes (methanogens). Numerous other byproducts make up an important part of the process. Understanding a little of the science can better the start up process and help with troubleshooting. If you are new to some of the biodigester lingo or want a quick update, take a look over the glossary to familiarize yourself with a few terms.

NOTE

> Numerous pH meters and litmus paper are available on the web or at your local pool supply or local aquarium store; also natural indicators such as red cabbage can be used in lieu of the availability of pH meters. When selecting an instrument be sure to select at the minimum a meter with ranges from pH 6-8.

What Are You Doing In What Kind Of Biodigester?

This is a two-component question. There is considerable biodigester design diversity and biodigesters can have different ways to start up. However, for the most part we will be dealing with tank and plug flow reactors so we will focus on them until the end, where more advanced designs will be discussed. An example of a plug flow digester would be the Salchicha or polybag digester, while most floating domes and Indian style biodigesters would be tank reactors. If you have a fixed film or up flow anaerobic sludge blanket biodigester, you likely know that those bioreactors will likely need a different start up than the plug flow or tank reactors. The start up for these different systems can be similar though installation, loading rate, and digester management might differ. What you are feeding the digester will effect which startup procedure is used. The feed consideration becomes especially important when you deviate from the common pig/cow manure feedstock. Manure feedstock, for example, tends to have larger populations of methane-producing organisms called methanogens (especially that of “ruminate” mammals, i.e. cow, goat, sheep, etc.). Your feeding substrate might not be high on the methanogen’s favorite places to live if it is fresh food waste, a process byproduct, or a number of other wastes, but don’t worry! You may just need to establish a biodigester community (using one of various methods) before loading the way you would normally feed your biodigester. Knowing the type of biodigester and what you are feeding will aid in putting into practice the following start up methods.

Starting with Biodigester Slurry and “Idling” Biodigesters

The easiest and surest way to start up a plugflow or tank biodigester is to simply fill her up with the contents and/or sludge of another biodigester. Proximity and availability are the biggest issues with this process, but assuming availability the biodigester should be fed at a lowered amount of substrate and the pH should be monitored, daily if possible, until you quickly reach the designed loading rate. This is especially true if the biodigester being started up ran on a different substrate than the biodigester in operation. Many biodigester construction manuals are such fans of this method that they recommend starting up an "inoculum" or "seed" before even building the biodigester! This can be done in numerous ways. One way is to fill a 55 gallon drum with one part manure and one part water and allowing it to develop an anaerobic digestion community of microorganisms. It is a good idea to monitor the pH of the drum every now and then to make sure the slurry developed correctly; certainly you want to check the pH before adding the slurry to a biodigester.

A biodigester may be “idled” (i.e. left alone for say a growing season) and then restarted in the same manner (lowered amount of substrate and pH monitoring). Gas combustibility is important to monitor in start up; however when using anaerobic sludge combustibility is rarely an issue. In the first phases of the anaerobic process Carbon Dioxide is produced and it is important to know when methane begins to be produced as that is the likely point of biodigester stability (i.e. the acids are being removed as fast as they are produced).

The "Water Start"

Assuming the unavailability of biodigester sludge and contents, the next easiest method of starting a biodigester would be the Water Start. The instructions are simple: fill the biodigester with water and load at a regular loading rate of manure. The idea is the water will dilute the inhibitory intermediates (acids) and byproducts until the methane-producing population has had time to catch up. Often times this can be done without too much monitoring or trouble. The disadvantages are that the process can take time and is limited really to substrates with a large population of methane producing organisms like fresh manures. Some manure that might not be as applicable can include poultry and possibly human manures. This method should especially be considered for plugflow biodigesters.

Manure is the popular use for anaerobic digestion, but as alluded to before it certainly isn’t the only use. Any biodegradable organic material can be converted into biogas. Some materials are better than others. To start a biodigester that will degrade food waste, it is a good idea to feed the biodigester with manure as previously described with the water start. Once the biodigester begins producing methane (test this by igniting the gas) begin to feed with food waste at a lower rate slowly building up to the designed feeding rate.

Culture Enrichment And Starting With A Rumen

In a very general sense starting an anaerobic biodigester consists of providing a population of methanogens to remove inhibitory byproducts of the faster growing hydrolyzing and acid producing processes. Remember anaerobic digestion is carried out by a community of hydrolyzing, acid producing, acetate producing and methane producing microbes. There are numerous ways to start a biodigester and here we will discuss some of the less used methods. Essentially you can load the biodigester with a population of methanogens from an environment where they already exist. Methanogens can be found in hydric soils (wetland soils), aquatic sediments, animal rumens, thermal vents, anoxic zones in the ocean, various parts of many organism's bodies, landfills, and other anaerobic environments. Out of these, two have commonly been used to start up an anaerobic biodigester, and typically in the laboratory. Landfill leachate and rumens are some common methods to start a biodigester in the lab. Due to toxicity issues with landfill leachate, the rumen is a preferable source of a methanogenic population. Ruminant animals are defined as animals that soften food with its first stomach; examples would be cows, goats, sheep, buffalos, and llamas. You can get a rumen from a slaughter house or if a dairy sciences unit is available from a fistulated cow. The contents of the cow rumen can contain half to a quarter of the methanogen population of anaerobic sludge in a tank or plug flow manure digester. To start a tank or plug flow biodigester with a rumen, one would remove the contents of a rumen to fill 10% of the volume of the biodigester and the other 90% with tap water (any water except distilled or deionized). Feed the biodigester at the calculated rate and within a few days one would expect biogas to be produced.

Another option is to artificially culture methanogens and add the sludge from the culture enrichment to your biodigester. This is what you are buying when you buy a already packaged culture, from say Europe. However given time, diligence and skill you can do this too! The easiest way is to grow a sample of an anaerobic environment and feed the culture in a closed environment Hydrogen, Carbon Dioxide, Acetate, and Formic acid. Or soluble organics that readily break down into those products. All the while you will need to monitor pH, temperature, and gas combustibility/content. Then you need to calculate the doubling time of the methanogens, estimate initial concentration and grow your sludge to a sufficient capacity. You will want to add 10% of methanogenic sludge to the 10% start up sludge volume of the biodigester. You may also want to enrich a culture to degrade a particular compound of interest such as cellulose (woody material). A similar rule of thumb of 10-20% volume inoculum (depending how fast you want the process to go) works well with starting up batch anaerobic processes (as opposed to continuous feeding), however that is more of an operational consideration and outside the scope of this guide.

Starting With Slurry (Batch Process)

Another possible way to start an anaerobic biodigester is to fill up with 5-20% manure and water and then let the slurry sit in a sort of “batch” process. When biogas begins to evolve from the slurry, then you may begin to feed the biodigester at the recommended rate. Care and monitoring of the pH needs to be taken into account because using the “batch” start up method can easily overload and imbalance the biodigester causing a drop in pH. In a variation of starting with slurry you may begin using an empty biodigester and add the slurry little by little. Considerations need to be made for a floating dome (i.e. will a water seal be produced on your first addition?). This start up option might be especially desirable if your biodigester is prone to leaks. A similar process is used when creating an inoculum for you biodigester prior to construction as mentioned in the filling up and idling section.

Effects Of Temperature

You know (hopefully!) that temperature impacts the amount of organic material that can be loaded into a biodigester, but did you know temperature impacts start up as well? In a general sense, methanogens can out grow (given available substrate) acid producing organisms at higher temperatures, while at lower temperatures the acid producers can outgrow the methanogens. What this means is that starting a biodigester at a lower temperature like up in the mountains may be more difficult and more prone to collapse than starting a biodigester in a low altitude tropical environment. One solution might be to increase the dilution, moving to a more safe technique like the water start, or reducing the start up loading rate.

Role Of Nutrients

Nutrients play an important role in the creation of anaerobic sludge and having an availability of them can ease the anaerobic digestion process in general. Nitrogen, Phosphorous, Sulfur, Calcium, Magnesium, Iron, Nickel, Cobalt, and Zinc are recommended supplements to an anaerobic biodigester. Many fertilizers will contain these compounds and if the biodigester you are starting up is a tank or plugflow system (one that doesn’t have long anaerobic sludge retention times), a nutrient supplementation may speed along the startup process. Nutrient supplementations may also aide in starting up some biodigesters where precipitation of nutrients occurs. Anaerobic digesters can be stimulated with the following trace metals iron, cobalt, nickel, copper, manganese, selenium, boron, tungsten, molybdenum, and zinc. Please see the reference section for more information on nutrient and trace metal supplementation (especially Speece and Wilkie). Another factor that plays a role in getting your biodigester community going is the carbon source. Some organics have a greater ability to produce cellular biomass in anaerobic conditions than others; an important example is carbohydrates, which have much energy available for biomass production. This is similar to the role athletes will consume many pastas and other carbs for "carboloading" before a race or event. Addition of starches may be one reason why a biodigester regimen, such as the one by Appropriate Rural Technology Institute, has achieved such low hydraulic retention times. The role of nutrients and trace metals in anaerobic biodigester dependent on biofilm and granulation will be discussed in the next section.

Another issue with nutrients may be too much of a nutrient such as ammonia toxicity, or too little of a nutrient and the need for a nutrient supplement. There are methods for testing both the lack of nutrients (nutrient deficiency assays) and toxicity issues (anaerobic toxicity assays). There are also methods of alleviating such problems. A few simple ones might be that if you are dealing with toxicity issues (i.e. digesting nitrogen rich wastes such as poultry manure) to dilute the toxin out of the system. Supplementing your influent with a substrate rich in nutrients such as food waste. Kinds of systems that might be prone to nutrient deficiency might be substrates rich in one kind of organic material, the presence of metals that might be corroding and "precipitating" nutrients, using water rich in ions that can bind up some nutrients, or a combination of these factors. However before blaming a failed start up on toxicity or nutrient deficiency issues I must point out that they should be a last resort because they are likely not the problem.

How Long Is This Going To Take?

Well the answer to this question, for the more simple designs previously mentioned, is complicated. Start up time depends on temperature, initial concentration of microbes, concentration of microbes in feedstock, and availability of nutrients. That said in a warm climate, using manure from a ruminate mammal, using any of the methods previously mentioned, a biodigester may be started anywhere from a few days to at most a few weeks. In any case there is something wrong with your start up method if you are starting a simple biodigester and it is taking more than a month (the only exception might be an exceptionally cold climate where you would probably want to provide some form of active or passive heating or anaerobic digestion wouldn't be appropriate anyways). You may also get fancy and add nutrients, maybe some carbohydrates or attempt to speed up the start up procedure with some other methods (DO NOT try increasing the temperature just for start up, you will collapse the biodigester when it goes under normal operations). The only drawback is that your "speed up" solution that you haven't tried before may collapse or inhibit the biodigester. Start up time for more advanced designs will be discussed in the next section.

Biofilm And Granulation Start Up

This section for the majority of readers can be skipped or read for interest. This isn’t an instruction guide, but more of a starting point for the start up of a “sludge retaining” anaerobic biodigester. Some anaerobic bioreactors will retain sludge to gain numerous benefits such as extremely low hydraulic retention time (< 6 hours have been reported), increased methane content, low biodigester volume, resistance to stress factors, ease of idling, increased speed of "digestion," lower maintenance, and low to no sludge in the effluent. However while a simpler biodigester might require 2 weeks at most to start up a biofilm or granulated sludge biodigester might take 4 months or more. More simple designs and processes also do without certain expensive materials such as pumps and media support. That said mechanisms of microbial attachment and granulation aren't entirely elucidated but much work and research has gone into studying these processes. Microbes attach to themselves or to support media often times as a response mechanism to environmental stress or through physical filtration. Biofilm formation can occur in stressed environments such as when nutrients are limiting or some stress such as high movement (not enough to "sheer") that can be alleviated through attachment. Increased surface area such as etching or growing biofilms on activated carbon facilitates formation. Some researchers have found that applications of calcium may facilitate biofilm formation, it is theorized that calcium deposits may increase surface area. That said calcium deposits in the long run might clog up your growth media. Biofilm formation usually requires the growth of a "colonizing" population or organism while other microbes will attach to the living surface. Granulation occurs under numerous conditions and takes quite a long time like biofilm formation. There are different process and while calcium won't have the same role in granulation other nutrient supplementation such as K+, N, P and Mg 2+. Another important consideration for granulation is gradual increase of flow to ensure granules aren't knocked out when developing. One way to simply and probably the only quick way to start the most popular granulation reactor, an upflow anaerobic sludge blanket (UASB), is to remove granules from one reactor and put into another. Making clear these microbial processes of attachment is a holy grail not only for biotechnologists, but also for microbial or applied ecology. Many more details can be found in the excellent resources noted in the reference section.

Troubleshooting

Many factors can go wrong when starting up an anaerobic biodigester. A large number of these factors are addressed or detailed in this guide. In general troubleshooting needs to be done in a step by step process. Take the pH of your biodigester, test the gas pressure within the biodigester and test the gas in the biodigester for gas combustibility are the three quickest most effective methods for indicating something is wrong. Once you have identified why your biodigester isn't producing gas you need to logically eliminate possibilities of why and address them as they come. If you are stumped on the possible biological issues it is a good idea to take a look at your physical structure. Troubleshooting needs through the process of elimination to ensure that extra work is not being made, many of the things mentioned in this manual can be used as a possible problem with start up (i.e. start up in a colder versus warmer climate, the role nutrients play, possible inhibition from ammonia, etc.).

Conclusion

This guide was meant to target people who know enough about a biodigester to fabricate, size and come up with a feeding regimen. Hopefully enough detail was provided to interest the scientist and not confound the backyard biogaser. The guide should also be used as a troubleshooting document to hopefully identify some of the steps that may have stumped the person replicating their biodigester experience in a different situation. Also this is an open source document and constructive criticism is not only welcome but actively solicited. Please forward any questions or comments to the the.biogas.project@gmail.com. More information, in more detail can be found in the resources located in the references, much information was generated from teachers, experience, and the listed references.

References

- van Haandel, A.C., Lettinga, G. Anaerobic Sewage Treatment: A Practical Guide for Regions with a Hot Climate J Whiley 1994

- House, D. The Complete Biogas Handbook 3rd Ed 2007 www.completebiogas.com

- Speece, R. E. Anaerobic Biotechnology for Industrial Wastewaters Archae Press 1996

- Wilkie, A.C., Colleran E. Start-up of Anaerobic Filters Containing Different Support Materials Using Pig Slurry Supernatant Biotechnology Letters Vol 6 Number 4 Nov 2004

- Wilkie, A. C., Goto M., Bordeaux, R. M., Smith, P. H., Enhancement of Anaerobic Methanogenesis from Napiergrass by Addition of Micronutrients Biomass Vol 11 1986

Glossary

Acetogens

Acetate producing bateria; these organisms take organics and produce CO2, H2, and acetate. All of these products can readily be used by methanogens.

Acidogens

Acid producing bacteria; these organisms take hydrolized products (soluble organics like sugar) and turn them into CO2, H2, and organic acids.

Anaerobic Digestion

A process, carried out by a community of microorganisms, that breaks down organic matter into biogas and mineralized nutrients.

Batch Process

A fermentation that you feed and unload once.

Biodigester

A sealed container that carries out the anaerobic digestion process; a biodigester needs to be able to seperate and remove the liquid and gas phases and have an entrance/exit for the substrate.

Biofilm

An attached community of microbes in this case carrying out the anaerobic digestion process.

Biogas

A gaseous product of Anaerobic Digestion, this combustible gas is primarily made up of CH4 and CO2. The gas also contains trace amounts Hydrogen Sulfide (which is poisonous and corrosive), Ammonia and is saturated with water vapor.

Bioreactor

A container that carries out a biological process.

Continuous Process

A continuously fed fermentation.

Floating Dome

A biodigester where the gas is stored in a dome that rises with production. This is opposed to limited storage capabilities of flexible or fixed domes.

Hydraulic Retention Time

The amount of time liquid resides in the biodigester. Calculated by the volume of the biodigester divided by the volume fed each day. Units are in days. Hydraulic retention time controls your dilution factor.

Hydrolysis

A microbial process carried out by protozoa, fungi, and bacteria to take insoluble organics and convert them into soluble organics

Loading Rate

The amount of organic material you are adding per day. This can be expressed in volume units such as liters, or per the entire biodigester volume. Temperature, volume, type of biodigester, type of feed all control this parameter.

Methanogens

A class of Archaea that have the unique ability to metabolize acetate, CO_2 and H_2, formate, and methyl compounds into Methane.

Plugflow Reactor

A reactor that operates by significantly established flow, as material moves along it is broken down.

Sludge Retention Time

The retention time for the microbes in the anaerobic biodigester, often times controls the hydraulic retention time due to the slow rate of cell synthesis in a biodigester.

Tank Reactor

A biodigester that operates with a simple influent and effluent coming out of a tank where material is retained long enough to be broken down.

Upflow Anaerobic Sludge Blanket

A granulated sludge technology

Retrieved from "http://www.appropedia.org/Biogas_start_up"

Categories: Anaerobic digester | Appropriate technology | Biofuel | Biogas | Composting | Energy | Environment | Fertilizer | Food and agriculture | Gasification | How tos | Soil | Sustainability | Technology transfer

---

- [1 watching user]
- Page was last modified 19:09, 8 June 2010. Based on work by

Chriswaterguy's bot, Lonny Grafman, Appropedia user The.biogas.project and Appropedia anonymous user 190.56.94.218.

-