As Seen In WasteAdvantage magazine
The Advantage in the Waste and Recycling Industry

Biogas Cleaning and Conditioning: A Requirement for Optimal Operation of CHP Systems

For the adequate use of biogas as biofuel in CHP-equipment or for biomethane production, it requires a previous conditioning to remove or reduce all of the dangerous compounds. Biolimp-siloxa is a multi-purpose plant technology to consider in reducing all pollutants.

By Dr. J. Reina Hernández

Biogas is a gaseous mixture formed mainly by methane (CH_4), CO_2 and traces of other components. Biogas has dangerous compounds that must be removed for its use as biofuel. For an adequate use of biogas as biofuel in CHP (combined heat and power) equipment or for biomethane production, it requires a previous conditioning to remove or reduce all of the dangerous compounds like water vapor, dust, particle, foam, siloxanes, H_2S and heavy hydrocarbon—all of them dangerous for the useful life of the machine used for this application. This article will describe a technology called biolimp-siloxa, its development and its application for biogas cleaning.

Currently, two types of biogas are in production:

1. *Biogas from uncontrolled systems or produced naturally, such as landfill gas.* This kind of biogas is characterized by the presence of moisture (water vapor), siloxanes, halogenated and heavy hydrocarbons, and, sometimes, hydrogen sulfide (H_2S).
2. *Biogas from controlled systems, i.e. the anaerobic biodigestion process.* In this case, the process and the reactor can be selected the same way as the operating conditions. There are wide range of possibilities related with this kind of process and its equipment.

According to the waste source/raw material to be treated, the biogas can be split into:

- *Biogas from wastewater treatment plant or sewage gas.* This is the most complex due to their pollutants. Siloxanes, H_2S, NH_3, foam, particles and water vapor, and hydrocarbon in minor quantities appear in it.
- *Biogas from organic fraction of municipal solid waste.* This biogas has pollutants like H_2S, NH_3, foam, particles and water vapour and, in some cases, hydrocarbon.
- *Biogas from waste farming.* In this, biogas mainly appears like pollutants H_2S, NH_3, foam, particles and water vapor.
- *Biogas from food industries, like beer, dairy and meat.* In this case, there are a variety as there are several material (organic fraction involved) of interest to this process, but the biogas is also recognized for the high quantity of: H_2S , NH_3, foam and water vapor.

For these reasons, using the biogas as biofuel requires removing all dangerous components. Biolimb-siloxane technology is a multipurpose plant to reduce all the pollutants. **Table 1** shows the different kinds of biogas according to its source and its typical composition.

Why Does the Quality of Biogas Need to be Improved?

For many applications, the quality of biogas has to be improved. Biogas cleaning is essential for:

1. The optimal operation of machines involved in its use as a biofuel, such as engines, turbines, boilers, fuel cells, vehicles, etc.

2. Reduced cost of maintenance (repairs, spare parts and oil changes) of the machines involved in this type of installation.

3. For the long useful life of the machines and equipment used for pumping, extraction and compression (blowers and compressors).

Table 1:
The different kinds of biogas according to its source and its typical composition. Table courtesy of Coombs. J. (1990) and completed by Reina. J. (2010)

Gases	Residuos Agrícolas *Agricultural Waste*	Lodos de depuradora *WWTP Sludge*	Residuos Industriales *Industrial Waste*	Vertederos, RSU *MSW Landfills*	Efecto *Effect*
	(%)	(%)	(%)	(%)	
Metano / *Methane*	50-80	50-80	50-70	45-65	Combustible
CO2	30-50	20-50	30-50	34-55	Inerte | *Inert*
Vap H2O	Saturación | *Saturation*	Saturación | *Saturation*	Saturación | *Saturation*	Saturación | *Saturation*	Perjudicial | *Harmful*
H2	0-2	0-5	0-2	0-1	Combustible
H2S	100-7000 ppm	0-1	0-8	0,5-3000 ppm	Corrosivo | *Corrosive*
NH3	50-100 mg/m³	Trazas | *Traces*	Trazas | *Traces*	Trazas | *Traces*	Corrosivo | *Corrosive*
CO	0-1	0-1	0-1	Trazas | *Traces*	Combustible
N2	0-1	0-3	0-1	0-20	Inerte | *Inert*
O2	0-1	0-1	0-1	0-5	Corrosivo | *Corrosive*
Siloxanos | *Siloxanes*	NR	0-100 mg/m³	NR	0-50 mg/m³	Abrasivo | *Abrasive*
HCH	NR	Trazas | *Traces*	NR	10-4000 mg/m³	Perjudicial | *Harmful*

NR. No reportados | *NR. Not Reported.*
HCH. Hidrocarburos pesados y halogenados (Cl,F,Br) | *HHC. Heavy hydrocarbons and halogenated compounds (Cl,F,Br)*

Figure 1:
View of the Biolimp-Siloxa technology.

Figure 2:
View of scrubber-economizer.
Images courtesy of Energy & Waste SLNE.

4. Improved emissions from exhaust gases of the machines involved in energy production like engines, turbines and boilers.

5. Avoid toxic concentrations for the worker related with the operation of this type of plant, especially H_2S and aldehydes emissions.

6. Avoid accumulation of condensate in the piping system, as well as acid production and the bad operation of the piping system.

There are different compounds—H_2S, water vapor, siloxanes and halogenated compounds—that must be removed in order for its effective use as biofuel. Below are some of the reasons for removing these types of compounds.

Water Vapor

The water vapor dramatically decreases the lower heat value of biogas. It must be removed due to how it affects the energetic yield of the CHP (engines, turbines, boilers, burners, etc.). Therefore, it is appropriate to reduce the content of water vapor by any technique before using the biofuel.

This removal is also necessary to prevent accumulation of condensation in the gas line and, with it, the formation of corrosive acids and poor performance of the installation. This increases the cost of operation of the plant.

Halogenated and Heavy Hydrocarbons

Both hydrocarbons of high molecular weight and halogenated compounds, particularly those with chlorine and fluorine, should be eliminated. These kinds of components cause corrosion in the engines, mainly in the combustion chamber, valves and cylinderhead. They also produce aldehydes emissions in the flue gases as well as exhaust gases. This increases the environmental pollution by effect of flue gas at the atmosphere. Therefore, they must be removed.

Hydrogen Sulfide (H_2S)

Biogas desulphurisation is necessary; the aim is to prevent corrosion and avoid the formation of toxic H_2S concentrations (the maximal workplace concentration allowing is 5 ppm). When biogas is burned SO_2/SO_3 is emitted, which is even more poisonous than H2S. At the same time, SO_2 lowers the dew point in the stack gas. The sulphurous acid formed (H_2SO_3) is highly corrosive. For that reason, it must be removed.

Siloxanes

Among the components of greatest impact for using biogas as biofuel are found in siloxanes. This type of compound has made damage to CHP-equipment and, for that reason, it must be removed from the biogas. The siloxane in the biogas is abrasive, causing damage to the internal parts of the machines. This effect is due to the deposition of silica in the different internal parts of the CHP. The siloxanes removal process allows for longer life of the machines involved in the energy production.

All of these compounds above cause damage in the CHP system (used for energy generation) and raise the operation cost of the cogeneration plant. In many cases, the economic aspect of this kind of installation fail due to the reasons mentioned before.

Biolimp-Siloxa Technology in Action

Biolimp-siloxa technology is a multipurpose plant for biogas cleaning. In it, are different unit operations combined with the aim to get a high level of biogas cleaning, among them, cooling, condensation, washing, filtration and adsorption on activated carbon. All operations achieve a high removal yield of water vapor, particle, foam, siloxanes, H2S and heavy hydrocarbon from the biogas.

Figure 1 shows an overview of the biolimp-siloxane technology. This plant, located on the Arico Landfill in Tenerife Island, Spain, was started up in 2008. It has a 3,000 Nm^3/h biogas treatment capacity. Its equipment includes a scrubber-economizer, heat exchanger, condensate pote, mist separator and filter equipment. The scrubber-recuperator is an important part of the technology, due to the fact that it minimizes thermal power consumption (cooling) and prepares the biogas for the active carbon filter.

The scrubber-economizer recovers around 10 to 25 percent of the energy from biogas cooling. The level of energy recovered depends upon the biogas temperature and flow. This means that the equipment reduces the amount of active carbon for biogas cleaning and, hence, increases its life. This reduces the operational cost of the process. However, the scrubber-economizer cannot be applied in all cases of biogas cleaning. In order to use it, a preliminary study of the biogas cleaning process conditions is required (biogas flow, pressure available and temperature are required in order for the scrubber-economizer to be used). **Figure 2** shows an overview of the scrubber-economizer. This equipment is located between dryer by cooling and the active carbon filter.

Another important factor is the vertical position of the heat exchanger equipment (biogas dryer by cooling). Its position improves the heat transfer coefficient and facilitates drainage of the condensates to the bottom of the equipment. This avoids the possibility of water freezing in the tubes in the winter season and the incorrect operation of this equipment. This technology has been applied both to the landfill and in the WWTP plant with good results in both cases.

The plant can be split into two parts. The first part is related to the gross removal. This step involves removing water vapor, heavy hydrocarbon, particle and a certain amount of siloxane by cooling until 2º C, condensation and drying. This step includes cooling, condensation and drying of biogas.

The second step relates to removing siloxanes, traces of H_2S and low molecular weight hydrocarbon by adsorption on the activated carbon. This step plays a fundamental role in the right selection of the activated carbon, the biogas velocity in the carbon activated bed and the size of the active carbon filter.

In some cases, the biogas is required to be cooled due to the temperature rising by the pressure increase by blower pressure. In this case, it is necessary for the biogas to be cooled again. A good working temperature level is between 20 to 30º C to deliver biogas for an active carbon filter. **Table 2** shows the results achieved in the practical application of this technology in the biogas cleaning from the landfill (Arico landfills,Tenerife Island). Also shown is the removal efficiency for each component and the energy savings it gets with the use of energy recuperator/economizer.

Flujo | *Flow*	3,000,00	Nm³/h		
Temp Entrada | *Temp inlet*	50 °C			
Presión Entrada | *Pressure inlet*	- 200 mbar			
Componentes | *Components*	**Inlet (mg/Nm³)**	**Outlet (mg/Nm³)**	**Remoción *Removal* %**	**Ahorro de energía *Energy saving* %**
Siloxanos | *Siloxanes*	38	< 1	> 97,3	21
H2S | *H2S*	120	< 1	> 99,2	
BTEX | *BTEX*	750	< 5	> 99,3	
Hidrocarburos | *Hydrocarbons*	3957	< 20	> 99,5	
Peso CA | *Weight CA*	10.000,00	kg		
Nº Filtros | *Nº. Filters*	2			
Vida util | *Lifespan*	2	meses | *months*		
Costo CA | *Cost CA*	1,9	€/kg		

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Table 2: The results achieved in the practical application of using biolimp-siloxa technology in cleaning the biogas from the landfill.

The technology can work both in a suction line as well as in a biogas pressure line. It has different configurations depending on the type of cleaning desired and the plant type (landfill or WWTP). Table 2 shows the result of the biolimp-siloxa technology used in the biogas landfill cleaning. The technology is currently applied in different biogas production facilities in Spain and in South America with good results.

Conclusions

Biolimp-siloxa technology is a suitable technique for biogas cleaning. The plant has different unit operations of chemical engineering inside of the technology. This combination allows for siloxane removal less than 3 mg/m³ with low power consumption and with removal yield around 97 percent or more. | **WA**

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