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Importance of Siloxane Removal in Power and Oil & Gas Industrial Equipment

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***ABSTRACT**: This article describes about siloxanes and importance of their removal in various power or oil and gas industries. Also different technologies of siloxane removal are elaborated along with the vendors available in the market if need to be bid for various projects depending on the product requirements of yield along with efficiency.*
***KEYWORDS**: Bulk Media, Regenerative, Liquid Solvents/Scavengers, landfill, TSA, PSA*

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I. INTRODUCTION

The term siloxane refers to a subgroup of silicones containing Si-O bonds with organic radicals bonded to the silicon atom; the organic radicals can include methyl, ethyl and other organic functional groups. Organic silicon compounds in landfill gas are predominantly present as organo-siloxanes or silicones. Major sources of these compounds in landfill gas include household and industrial sources such as:

- cosmetics (carrier oils)
- detergents (anti-frothing agents)
- building materials (impregnating oils)
- paper coatings
- textiles.

Name	Formula	MW	Vapor Pressure mmHg 77° F	Abbreviations	Boiling Point ° F	Water Solubility (mg/l)25° C
Hexamethylcyclotrisiloxane	C12H18O3Si3	222	10	D3	275	1.56
Octamethylcyclotetrasiloxane	C8H24O4Si4	297	1.3	D4	348	0.056
Decamethylcyclopentasiloxane	C10H30O5Si5	371	0.4	D5	412	0.017
Dodecamethylcyclohexasiloxane	C12H36O6Si6	445	0.02	D6	473	0.005
Hexamethyldisiloxane	C6H18Si2O	162	31	L2, MM	224	0.93
Octamethyltrisiloxane	C8H24Si3O2	236	3.9	L3, MDM		0.035
Decamethyltetrasiloxane	C10H30Si4O3	310	0.55	L4, MD2M		
Dodecamethylpentasiloxane	C12H36Si5O4	384	0.07	L5, MD3M		

Table 1 : **Selected cyclic and linear organosiloxane properties**

Siloxane concentrations are generally higher in digester gas than in landfill gas. As a result, it is somewhat easier to reliably quantify siloxanes in digester gas. Landfill gas may contain significant quantities of other siloxane compounds such as D3 and D6, plus L2 through L5. D4 and D5 may represent only slightly more than a majority of the siloxanes in some landfill gases to over 90 percent of the total in others. Infrequently siloxanes not listed on Table 1, such as trimethylsilanol, are found.

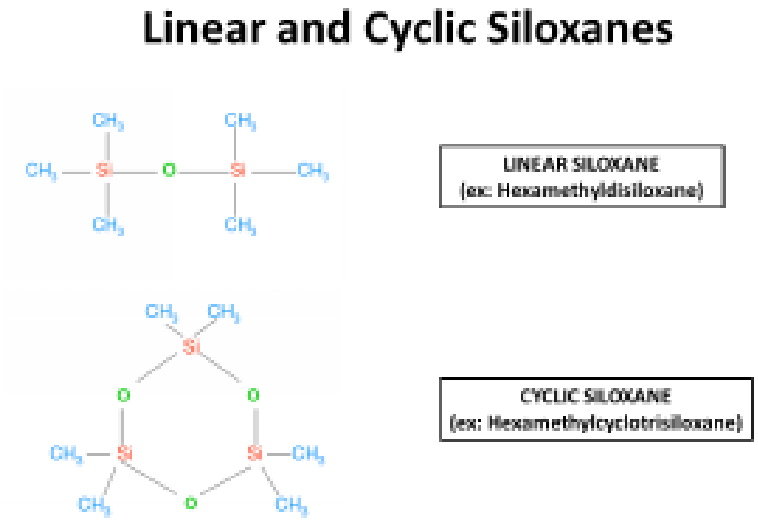

Fig: 1 Siloxane Structures

II. IMPORTANCE OF SILOXANE REMOVAL

Even at levels of 0.5 ppm, siloxane can cause significant damage and fouling of engines, turbines, boilers, fuel cells, and the catalysts they employ to produce energy from biogas. Siloxane damage leads to higher costs and decreased life span of energy generation equipment. The typical manufacturer Siloxane limits are shown below in Table 2

Table 2 : Manufacturer siloxane limits

Engine Manufacturer	**Siloxane, mg/m3 in Landfill Gas**
Caterpillar	28
Jenbacher	10
Waukesha	25
Deutz	5
Engine Manufacturer	**Siloxane, mg/m3 in Landfill Gas**
Solar Turbines	0.1
IR Microturbines	0.06
Capstone Microturbines	0.03

Table 2 : Manufacturer siloxane limits

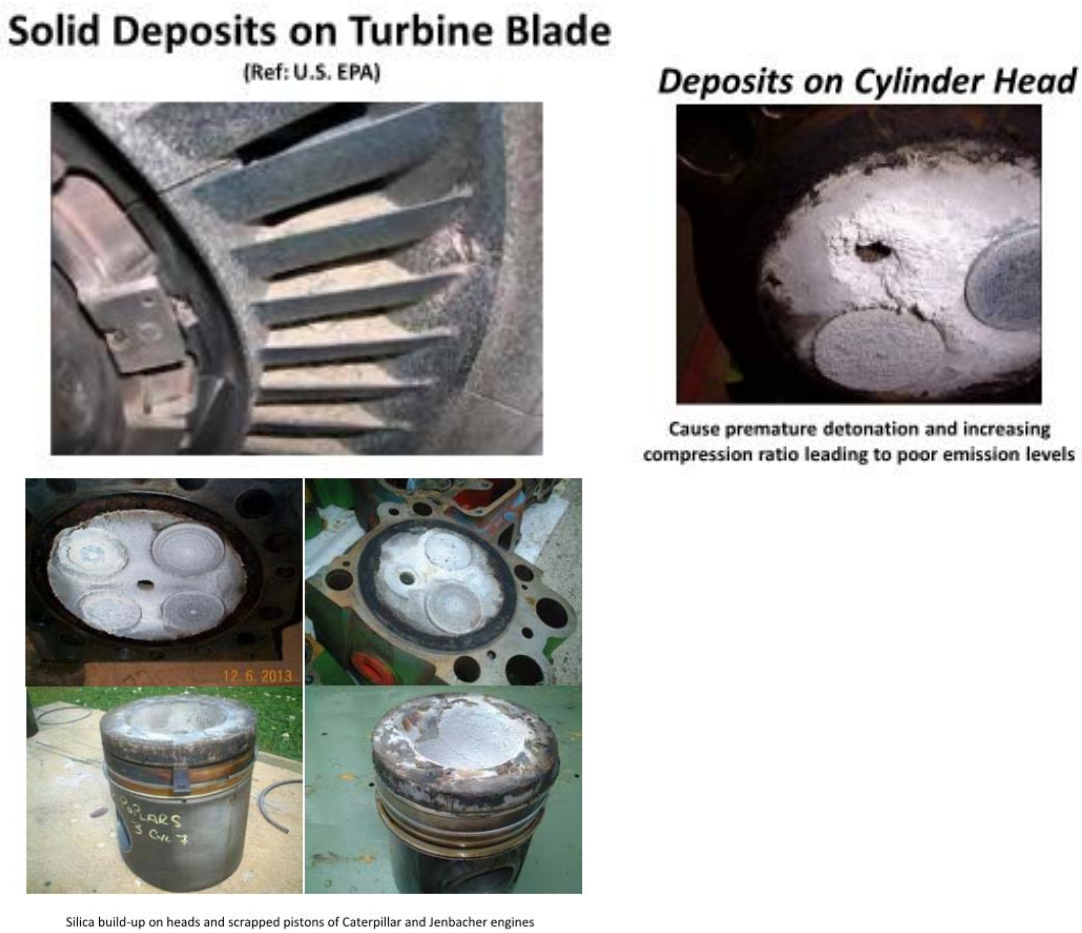

Fig: 2 Combustion of siloxanes yields silicon dioxide (SiO2), the white solid powder

III. SILOXANE REMOVAL TECHNOLOGIES

Depending on the quantity and composition of Landfill gas the following methods are used.

Bulk Media (Non-Regenerative):

Normally this method is typically used if the landfill gas < 800-1000 SCFM, This is non-regenerative adsorption tower with activated carbon or silica gel or activated alumina as the adsorbents. Siloxane is physically removed from landfill gas by the contaminant gas molecules selectively adhering to the surface of very porous materials called adsorbents. The adsorbent comes in granular form and is packed into a tower to get good contact between it and the gas being treated. As the landfill gas flows through this bed of adsorbent material, it gradually becomes loaded with siloxanes until it can no longer take on any more. The media need to be replaced everytime its loaded, so this involves high capital cost and operational cost for more than 1000 SCFM landfill gas. The rough quote(USD) would be around 150K to 200K for the adsorption skid.

Fig: 3 Different Bulk Media

Regenerative:

This is the most economical method for landfill gas greater than 1000 SCFM. This process involves same steps of adsorption as mentioned in the non-regenerative method but the difference is instead of replacing the loaded bed, it switched offline using valves and then heated to high temperature, typically above 300°F. Under these conditions the adsorbent can no longer hold onto siloxanes and they are released. Afterwards the bed is cooled down at which the tower is fully regenerated and ready to be switched back online for the next cycle. This regeneration cycle may vary from from 6 to 10 hrs and standby around 14 to 18 hrs while the online one for 24 hrs.Important factors to consider are Dehydration /Refrigeration System and Pressure drop-Booster Blower.

At low pressures, heat is the only option available for regeneration and the process is called Temperature Swing Adsorption (TSA). If the operating pressure is at 60 psig or above, there is possibility of dropping the pressure which releases the adsorbed gas and allow for regeneration. This technique is called Pressure Swing Adsorption (PSA).

The rough quote (USD) from vendors based on quantity of landfill gas for siloxane removal skid would be up to
500K for 1000-2500 SCFM
750K for 2500-4000 SCFM
1 to 1.5 Million for more than 4000 or 8000 SCFM

Liquid Solvents/Scavengers

This technology is used for combined removal of Siloxanes and H2S by using liquid solvent absorption. This is currently being handled by single provider NRGTek Inc. Other contaminants are also removed depending on the specifications and landfill gas composition.

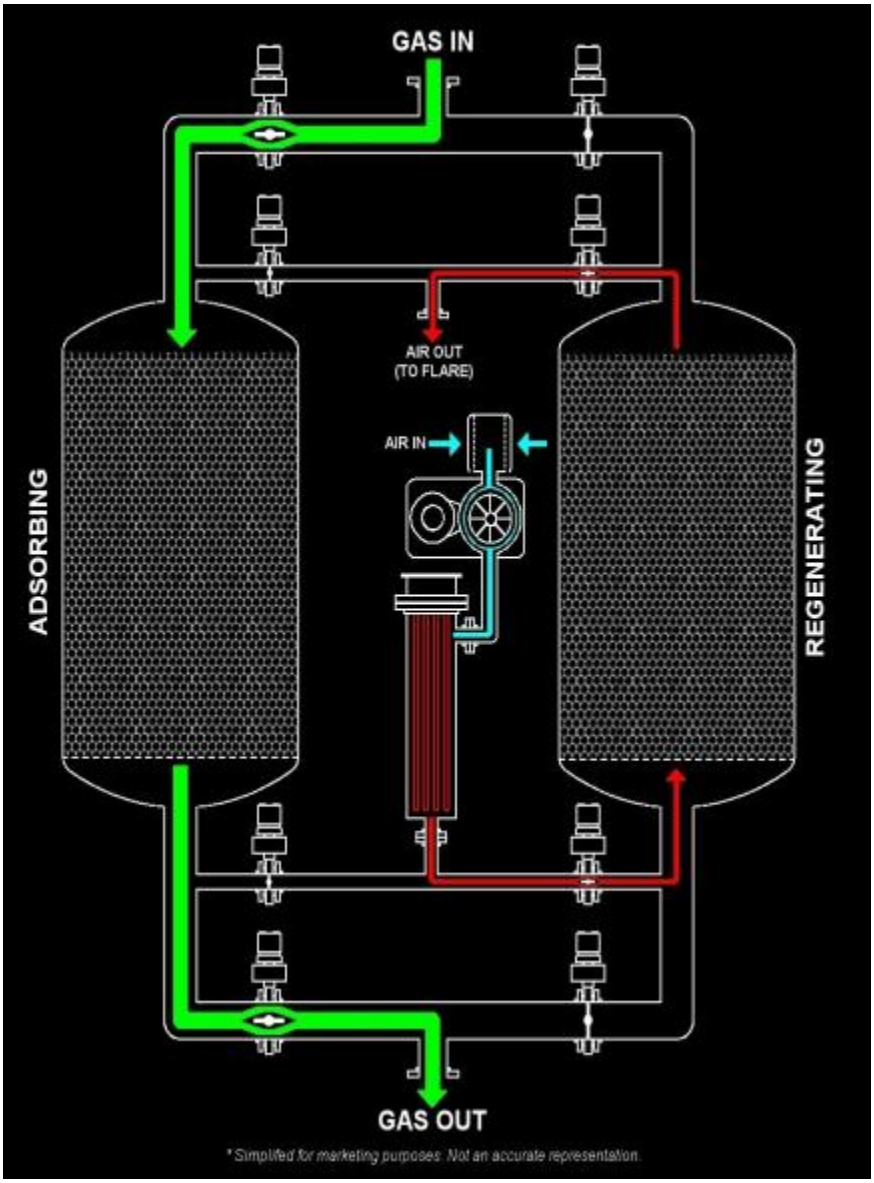

Fig: 3 Regenerative Technology

Multiple providers for the non-regenerative and regenerative adsorption of Siloxane Removal are:
Willexa Energy*: 704-560-8895*
Parker(GES): *Kevin Ray kevin.ray@parker.com 704-607-1563*
Advance biogas systems(Enerdyne Power systems): *abs@landfillgroup.com Terry Reno 828-298-6611* ***& GC Environmental ,Inc.(GCE):****Dan Waineo 503-234-7984*
Venture: *Bill Slatosky bslatosky@ventureengr.com 412-231-5890 ext.305*
Xebec: *832-532-8741*
DCL America Inc.: *1-800-872-1968*
Clean Methane Systems(CMS)*: Charles charlesr@methanesys.com 503-691-0811*
Pioneer Air Systems,Inc*.: 423-346-6693*
Carbtrol:*1-855-247-6926*

NRGTek: Subra Iyer siyer@nrgtekusa.com 714-279-9190

IV. CONCLUSION

It's important to removes siloxanes for better yield and efficiency. Different siloxane removal technologies can be chosen depending on the product requirements and also considering CAPEX and OPEX. Also lesson learned from the past projects can provide guidance for better judgement.

REFERENCES

[1]. NW Regional SWANA Symposium,Troutdale, Oregon, April 30,2015
[2]. Xebec-Treatment Solutions For Landfill Gas Fuel Applications,White Paper October 2007
[3]. Siloxanes in Landfill and Digester Gas Update, Ed Wheless Los Angeles County Sanitation Districts Whittier, California; Jeffrey Pierce SCS Energy Long Beach, California
[4]. Approaches concerning siloxane removal from biogas-A review by Gabriela Soreanu, Michel Beland, Patricia Falletta, Kara Edmonson, Lewina Syoboda, Mohamad Al-Jamal and Peter Seto