AVAILABLE CONTROL TECHNOLOGIES FOR H_2S REMOVAL FROM LANDFILL GAS

Hay Road Landfill
Vacaville, California

Prepared for

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1. EXECUTIVE SUMMARY

GC Environmental (GCE) was retained by the Recology to evaluate the processes to remove hydrogen sulfide (H_2S) from landfill gas (LFG) at the Hay Road Landfill located at 6426 Hay Road, Vacaville, CA in Solano County. The purpose of this evaluation was to provide a cost comparison of the various processes. The processes evaluated include solid scavengers (SulfaTreat and iron sponge), liquid scavengers (Enviroscrub and Champion Chemical), and liquid redox (LO-CAT). The results of the evaluation will be used by the Yolo-Solano Air Quality Management District in a BACT analysis for H2S removal from landfill gas. For this evaluation the flow rate was assumed to be 1500 SCFM and the H2S content was assumed to be 950 ppmv. The costs are based on an effluent H2S concentration of 40 ppmv in the product gas.

2. SOLID SCAVENGERS

Solid scavengers remove H_2S by causing a reaction between iron oxide and H_2S. The iron oxide is impregnated onto a carrier media like ceramic balls or redwood bark. A tank is then filled with the activated media forming a bed. As landfill gas passes through the bed a chemical reaction between the iron oxide and H2S forms an iron sulfate, thus removing the H2S from the landfill gas. A drain is located at the bottom of the vessel is used to remove water produced by the reaction.

The activated media will eventually be spent and require replacement. The life of the media is a function of the H2S concentration and the gas flow rate. The presence of oxygen in the gas will reactivate the iron oxide surface coating generating elemental sulfur in the process. The elemental sulfur eventually coats the media blinding the iron oxide to the landfill gas and the system stops working. The buildup of elemental sulfur can also fill the voids in the bed, impeding the flow of LFG through the vessel. The media will need to be replaced when the pressure drop across the vessel is too large or H2S removal efficiency is inadequate.

Currently, the oxygen produced at the landfill is averaging 1%. This oxygen will cause the bed to continuously regenerate. This in turn will extend the life of the bed up to 100%. However, the oxygen content in the gas is expected to drop over time as the landfill expands. To offset a loss in oxygen in the LFG, air can be introduced into the process to continuously regenerate the media.

To support continuous operation, maximize media H_2S adsorption capacity, and limit downtime during replacement, it is common to install two vessels in a lead-lag arrangement. The lead vessel will act as the primary absorber and the second vessel will be utilized as a gas polisher. When the lead vessel's media is no longer able to remove H2S the gas flow through the vessels will switched (through the use of valves) and the new lead vessel will be the primary absorber. The lag vessel will be filled with new

media. Two common forms of media used for solid scavengers include Iron Sponge and SulfaTreat.

a. Iron Sponge

Iron Sponge is hydrated ferric oxide impregnated wood chips and has been used for over 100 years to remove H_2S from gas. H_2S reacts with Iron Sponge in the following reaction.

$$2FeO + 6HS \rightarrow 2FeS + 6HO \quad (1)$$

The iron sulfide produced in reaction 1 can be oxidized regenerating the iron oxide in the following reaction.

$$2FeS + 3O \rightarrow 2FeO + 6S \quad (2)$$

Iron Sponge is susceptible to fires when elevated levels of oxygen are, causing an exothermic reaction (2). This can be controlled by limiting the rate that oxygen enters the vessel and keeping the media wet. A temperature sensor can be used to monitor the vessel for excessive heat output.

The vessel size required to treat 1500 SCFM of LFG is 18' in diameter with a 5' bed height. Pressure drop through the vessel operating at near atmospheric pressure is 1 psig. Each vessel would hold 1272 bushels of media. Current Iron Sponge bulk prices are $11.00 a bushel, plus freight. Each bushel is approximately 50lbs and occupies 1 ft^3.

It is assumed that the spent iron sponge will be disposed of in the landfill at no cost. By running the system at the maximum flow of 1500 SCFM with slipstream oxygen regeneration, the media would require replacement approximately every 110 days.

A detailed breakdown of estimated costs can be seen in figure 1, attached. The system was sized for 1500 SCFM with 950 ppm H_2S and continuous oxygen regeneration. Estimated capital costs are $317,154 with yearly O&M of $226,438. SulfaTreat
SulfaTreat is similar to Iron Sponge, using of iron oxide to react with H2S but it uses an inert ceramic base instead of impregnating wood. This prevents fires from occurring when excess oxygen is present. SulfaTreat has a smaller and more consistent shape than Iron Sponge allowing more media to fit into a given vessel. The consistent shape also aids in media change out and prevention of channels through the media.

Suggested vessel size is 7.5'x 29' box with a 6' bed depth. Each vessel would hold 80,000 lbs of SulfaTreat media. Current prices for SulfaTreat are $0.52/lb. At 1500 SCFM and 950 ppmv H_2S with 1% oxygen, the media would last approximately 75 days and remove 13,200 lbs of sulfur.

A detailed breakdown of estimated costs can be seen in figure 2 attached. The system was sized for 1500scfm with 950ppm H_2S and 1% oxygen. Estimated capital costs are $343,106 with yearly O&M of $249,220. Since SulfaTreat and Iron Sponge are very

similar processes the main difference in cost is the media. It is assumed that the spent SulfaTreat will be disposed in the landfill for no cost.

3. LIQUID SCAVENGERS

Liquid chemical scavengers are a proprietary solution of triazine and water. In a continuous operation chemical scavengers can employ several methods to contact the H2S with the scavenger. Two common methods include atomizing the scavenger into the gas stream under high pressure or using an absorber tower to contact the chemical with the landfill gas. The H_2S reacts with the triazine in the process removing the H2S. The spent chemical scavenger is removed by a dump valve or in the water removal process. It is assumed the spent triazine will be commingled with the leachate produced at the Landfill and disposed of offsite. It is further assumed that because the quantity will be small, there will be no disposal cost.

Liquid scavengers must vary the amount of triazine injected depending on the gas flow rate, removal efficiency (i.e. if the contact between the chemical and the gas is poor then more chemical will be required), and the H_2S concentration in the gas. This requires the use of a dose controller and periodic gas testing making the process more complicated than solid scavengers. Capital costs are less than solid scavengers since large vessels are not required. Two common liquid scavengers that have been used are Enviroscrub and Champion chemical.

a. Champion

Champion suggests either using a bubble tower or atomizers to mix the gas with the liquid scavenger. The atomizers would incur less of pressure drop on the system and are considerably less expensive only requiring a long section of pipe to contact the chemical scavenger with the gas. The manufacturer suggests the use of Gas Treat 160 which costs $7.5/gallon. Each gallon could treat 1 lb of H_2S, depending on the reaction efficiency of process.

At a max flow of 1500 SCFM the system would require 180 gallons per day. The installation costs for a liquid scavenger system are estimated at $37,796. While this is a significant cost savings over solid scavengers the high costs of the triazine can offset this saving over the life of the system. Yearly O&M costs are estimated at $580,443 for flow rates of 1500 SCFM at 950 ppmv H_2S. A detailed breakdown of estimated cost can be seen in figure 3, attached. Enviroscrub

With the given timeframe, Enviroscrub was not able to provide quotes for their system.

b. Merichem

Estimates of the liquid media, provided by Merichem, are approximately $10/lb of H_2S removed. This is not cost effective for applications producing more than 100lbs of sulfur

per day. At 1500 SCFM and 950 ppmv the landfill is producing 180lbs of H_2S per day, making a liquid scavenger system not a cost effective solution.

4. LIQUID REDOX

A common liquid redox process for controlling H_2S is the LO-CAT process, licensed by Gas Technology Products. Using an iron based aqueous solution, a reduction-oxidation reaction with the H_2S occurs. This is accelerated through the use of a chelated iron catalyst.

$$HS + 2Fe \rightarrow 2H + S + 2Fe \quad (2)$$

$$\frac{1}{2}O + HO \rightarrow 2EOHF + 2Fe \quad (3)$$

The sulfur produced from the LO-CAT process is in the form of a solid filter cake. This byproduct can be sold as a fertilizer to offset the cost of operation. The LO-CAT O&M costs are typically very low, but require high capital costs. At current H_2S levels, this process is only economically feasible at flow rates greater than 5 MMscfd, or approximately 3400 SCFM. It is unlikely the landfill will ever be able to utilize this process.

5. Thiopaq

Thiopaq has is a two step process that is used to remove H2S using sodium hydroxide solution and then bacteria in an oxygen rich environment to regenerate the NaOH creating elemental sulfur. This process is reported to be capital intensive, but very economical to operate. Due to time constraints costs for this process could not be obtained. GCE is continuing to pursue this cost and will provide it when we obtain sufficient information for a process in this size.

6. LIMITATIONS

The use of this report is limited to the client and only for the purposes stated, within a reasonable time from its issuance. Site conditions (both on site and off site) or other factors may change over time, and additional work may be required with the passage of time. Any party other than the client who wishes to use this report shall notify GC Environmental of such intended use. Based on the intended use of the report, GC Environmental may require additional work be performed and an updated report be issued. Non-compliance with any of these requirements by the client or anyone else will release GC Environmental from any liability resulting from the use of this report by any unauthorized party.

The calculations performed assume that the refuse composition will not change with time. While specific LFG production rates are included in this report, they are impossible to accurately predict. No warranty is expressed or implied.

This investigation and report were conducted and prepared in general accordance with the accepted standard of care that existed in California at the time the report was written. Judgments leading to conclusions and recommendations were generally made with an incomplete knowledge of the facility. The consultant should be notified for additional consultation if the client wishes to reduce the uncertainties beyond the level associated with this report.

FIGURE 1
Iron Sponge
Cost Breakdown

Capital				
Item	Unit	Qty	Price	Total
Container	ea	2	$80,000.00	$160,000.00
Valves	ea	9	$1,000.00	$9,000.00
Controls/Instrumentation	ls	1	$15,000.00	$15,000.00
Piping	ft	100	$100.00	$10,000.00
Media	lb	127200	$0.22	$27,984.00
Freight	ea	2	$4,500.00	$9,000.00
Installation	ea	1	$20,000.00	$20,000.00
Tax @ 8.375%	ea	1	$21,774,00	$21,774.00
Engineering @ 20%	ea	1	$44,397.00	$44,397.00

Capital Total **$317,155**

O&M at 1500 SCFM

Item	Unit	Qty/year	Price	Total
Media	lb	844,145	$0.22	$185,721.00
Freight	ea	3.32	$4,500.00	$14,931.82
Replacement Labor	ea	3.32	$1,500.00	$4,977.27
Tax @ 8.375%	ea	1	$17,499.00	$17,499.00

O&M Total **$226,438**

FIGURE 2
SulfaTreat
Cost Breakdown

Capital

Item	Unit	Qty	Price	Total
Container	ea	2	$65,000.00	$130,000.00
Valves	ea	9	$1,000.00	$9,000.00
Piping	ft	100	$100.00	$10,000.00
Controls/Instrumentation	ls	1	$10,000.00	$10,000.00
Media	lb	160000	$0.52	$83,200.00
Freight	delivery	2	$4,500.00	$9,000.00
Installation	ea	1	$20,000.00	$20,000.00
Tax @ 8.375%	ea	1	$23,466.75	$23,466.75
Engineering @ 20%	ea	1	$48,440.00	$48,440.00

Capital Total **$343,106.75**

O&M at 1500 SCFM

Item	Unit	Qty/year	Price	Total
Media	lb	389333	$0.52	$202,453.33
Freight	ea	4.87	$4,500.00	$21,900.00
Replacement Labor	ea	4.87	$1,500.00	$7,300.00
Tax @ 8.375%	ea	1	$17,566.84	$17,566.84

O&M Total **$249,220.18**

FIGURE 3
Champion
Cost Breakdown

Capital				
Item	Unit	Qty	Price	Total
Atomizers	ea	5	$1,000.00	$5,000.00
Valves	ea	3	$1,000.00	$3,000.00
Piping	ft	30	$100.00	$3,000.00
Controls/Instrumentation	ls	1	$10,000.00	$10,000.00
Installation	ls	1	$10,000.00	$10,000.00
Tax @ 8.375%	ls	1	$2,596.25	$2,596.25
Engineering @ 20%	ls	1	$4,200.00	$4,200.00
			Capital Total	**$37,796.25**

O&M at 1500 SCFM

Item	Unit	Qty/year	Price	Total
Media	gal	65910	$7.50	$494,326.80
Freight	ea	7.30	$4,500.00	$32,850.00
Replacement Labor	ea	7.30	$1,500.00	$10,950.00
Tax @ 8.375%	ea	1	$42,316.93	$42,316.93
			O&M Total	**$580,443.73**