

Comparison of Cassette Odor Control Scrubbers and Traditional Deep Bed Odor Control Scrubbers

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ABSTRACT

Traditional activated carbon odor control equipment for the waste water industry uses deep bed configurations with 36 inches of media. Non-traditional activated carbon odor scrubbers use cassettes holding “V”-shaped media beds with total bed depth ranging from 3 to 12 inches. The Cassette Systems have a wider velocity range that provides opportunity to reduce the system pressure drop, save energy, and reduce the total life cycle cost relative to traditional Deep Bed Adsorbers.

The life cycle costs will differ based on the initial capital costs, cost of media replacement, cost of labor for media replacement, number of media replacements per year, media disposal, and energy consumption of the system. A life cycle valuation was performed for an airflow of 5,500 cubic feet per minute and a hydrogen sulfide design concentration of 5.5 parts per million by volume. The Cassette System using a high capacity carbon achieved a lower life cycle cost over a 10 year period than the Deep Bed Adsorber odor control unit using standard KOH impregnated carbon.

KEYWORDS

Odor Control, Energy Consumption, Life Cycle Cost, Deep Bed Adsorber, Cassette

INTRODUCTION

Traditional activated carbon odor control equipment for the waste water industry uses deep bed configurations with 36 inches of media. One label for this equipment is a Deep Bed Adsorber which has vertical airflow through a bed of media or through two beds of media arranged in parallel (Dual Bed Adsorber). These vessels range in volume from less than 30 ft³ of media to large vessels holding more than 200 ft³ of media. The typical velocities in these scrubbers are 50-70 feet per minute (fpm) to optimize residence time, pressure drop, and scrubber size.

Non-traditional activated carbon odor scrubbers use cassettes holding “V”-shaped media beds with total bed depths ranging from 3 to 12 inches. They have horizontal airflow through the V-bank cassettes holding from 2 ft³ of media to more than 150 ft³. Cassette odor control equipment contains less media than the deep bed systems, but the development of higher capacity media may allow these to take over some functions of previous deep bed systems. Typical velocities in these scrubbers range from less than 200 to 250 fpm.

Cassette systems offer the benefits of lower pressure drop, lower associated energy consumption, less time required for media replacement, reduced footprint, and reduced initial cost. One main

consideration is the media service life of cassette systems. This paper investigates these parameters and makes recommendations for future research.

PRESSURE DROP

All activated carbon odor control scrubbers require energy to draw air out of the odor source and through the odor control media. The energy of such a scrubber is directly related to the pressure drop through the system. The pressure drop characteristics of deep bed systems and cassette systems differ as follows. Deep Bed Adsorbers typically hold media in a vertical media bed. Gravity, media weight, system vibration, and airflow cause the media to pack itself tighter over time. For this reason most carbon manufacturers publish two pressure drops for media - loose pack and dense pack. Dense pack is intended to simulate the ultimate pressure drop achieved if the carbon bed packed ideally. In some applications the dense pack pressure drop may be achieved during the life of the media bed while in others it may not, depending on length of operation time, amount of vibration, and physical properties of the carbon media. Cassette systems operate differently. Cassettes hold the media in a “V” arrangement; the air typically hitting the point of the “V” (see Figure 1). Air flows through both legs of the “V” and out the open end. Each cassette “V” bed is typically 1-3 inches deep and holds between 0.5 and 2 ft³ of media. Manufacturers who supply cassettes with media in them typically fill the cassettes under vibration so that the media is essentially in a dense pack state and does not suffer from significant packing over time.

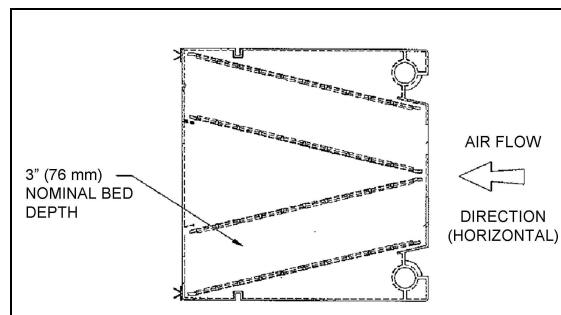


Figure 1 – Cassette with 3 inch “V”-Bank

Deep Bed Adsorber design pressure drop values vary between manufacturers. The differences may be due to media physical properties, different media holding screens, varying system feedback of manufacturers, and level of safety incorporated in design. Loose and dense pack pressure drops per foot of bed at 60 fpm range from 0.7 to 0.9 inches water gauge (iwg) and 1.2 to 1.8 iwg, see Table 1. Manufacturers also design their systems upon different basis. Certain manufacturers use values close to loose pack while more conservative manufacturers use dense pack pressure drops to design the system. Cassette system pressure drops also differ depending on the media type, size, “V” bed shape, and media holding screen. Cassette pressure drop values vary from 0.9 to 1.3 iwg with 3 inch deep “V” beds and cassette depths of 12 inches at 250 fpm.

Table 1 – Deep Bed Adsorber Pressure Drop of Various Manufacturers (AAF, 2009A; Calgon, 2007; Siemens, 2008)

Media	ΔP	
	(iwg/ ft of bed, 60 fpm)	
	Loose Pack	Dense Pack
Manufacturer A	0.9	1.5
Manufacturer B	0.7	1.8
Manufacturer C	0.7	1.2

Media are 4 mm extruded carbon pellets

Table 2 – Cassette Pressure Drop of Various Manufacturers (AAF, 2009B; Camfil; Purafil, 2006)

Cassette	ΔP
	(iwg, 250 fpm)
Manufacturer D	1.3
Manufacturer E	1.3
Manufacturer F	0.9

Pressure drops are for 4 mm extruded carbon pellets or maximum pressure drop reported.

System pressure drop is then the pressure drop sum of each media bed foot in a Deep Bed Adsorber or each pass of cassettes in a Cassette System. Figure 2 compares the pressure drop of a Deep Bed Adsorber using 36 inches of media in the path of airflow to Cassette System using a total of 12 inches of media in the path of airflow (4 passes of cassettes). The Deep Bed Adsorber pressure drop was calculated by taking the average of the above values to estimate a typical design pressure drop. This may be different than methods used by typical odor control engineers, but is similar to methods HVAC engineers use to size blowers for particulate filters. This approach balances the need to provide adequate airflow and conserve energy versus the other methods. If an engineer uses loose pack pressure drop values to design a blower, the airflow will eventually decrease as the media packs, but the energy usage will be the lowest. If an engineer uses dense pack pressure drop values, the airflow will be high initially and over time may come down to the design value, but the energy usage will be high. The lines labeled C and D represent Cassette and Deep Bed systems, respectfully. The cassette systems have a wider velocity range that provides opportunity to reduce the system pressure drop and save energy. The greatest difference is 2.0 iwg between the typical Deep Bed Adsorber at 70 fpm and the Cassette System at 200 fpm. By applying Equation 1 to a 3,000 cubic feet per minute (cfm) system, this pressure drop difference can add up to an annual savings of 9,025 kWh and 12,202 lb of CO₂ emissions (assuming 1.352 lb CO₂ / kWh). At a New England energy rate of 17.56 cents/kWh¹ in Connecticut, this can save \$1,585 each year. At a South Atlantic rate of 6.61 cents/kWh in Georgia, this can save \$597 each year. At a Pacific Contiguous rate of 11.75 cents/kWh in California, this can save \$1,060 each year.

$$\text{energy consumption (kWh)} = (Q \times \Delta P \times t) / (\text{fan} \times \text{motor} \times \text{drive efficiency} \times 1000) \quad (1)$$

Q = volumetric flow rate m³/sec

ΔP = pressure drop in Pa

t = time in hrs

¹ These rates are from the EIA's Electric Power Monthly for industrial rates in August of 2009.

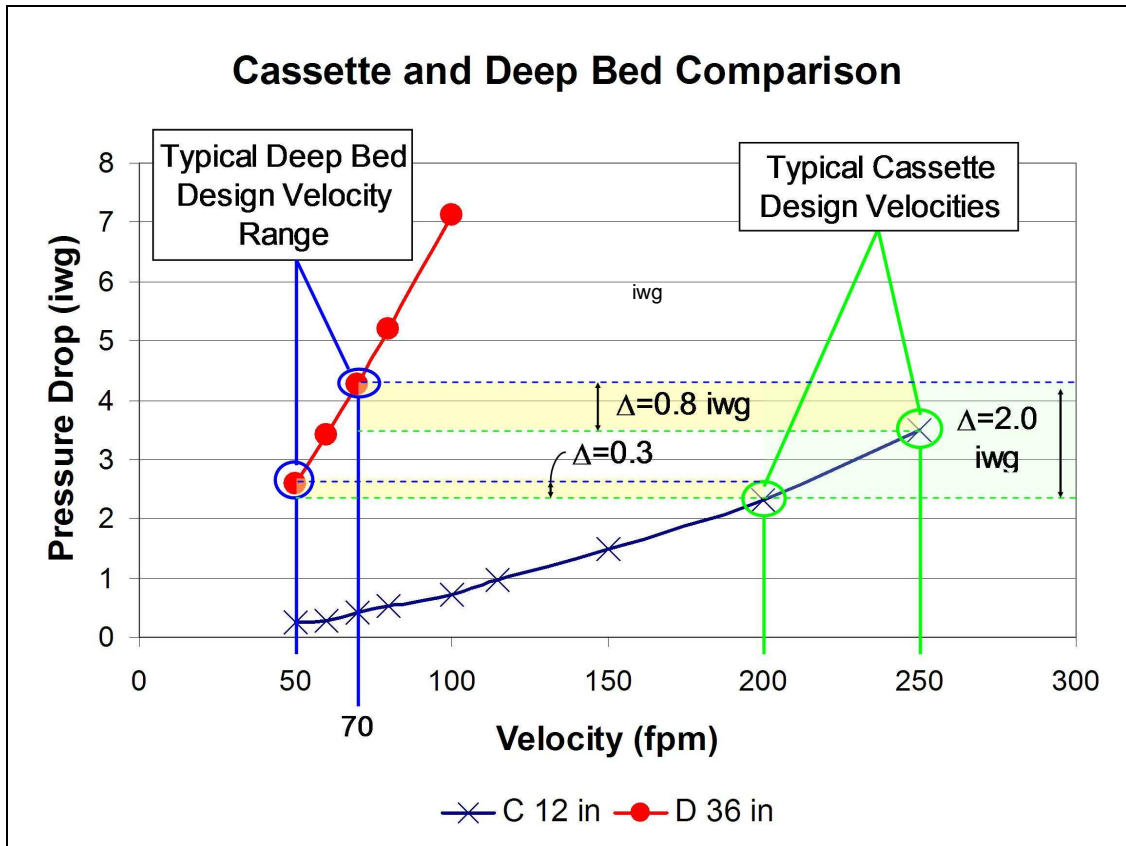


Figure 2 – Graph Comparing Deep Bed Adsorber and Cassette System Pressure Drops

MEDIA LIFE

The ASTM D 6646 capacity for hydrogen sulfide is a common media specification. Media manufacturers also use this capacity to estimate the amount of media used at an application – media usage. If this capacity is used as a basis for estimating the life of a cassette system, Figure 2 shows the resulting system life for a 4 pass system operating at 200 fpm. These numbers add in a safety factor of 20% to account for media usage from other compounds besides hydrogen sulfide. From these curves, a reasonable life of approximately 6 months can be achieved at hydrogen sulfide concentrations of approximately 5.5 parts per million by volume (ppmv).

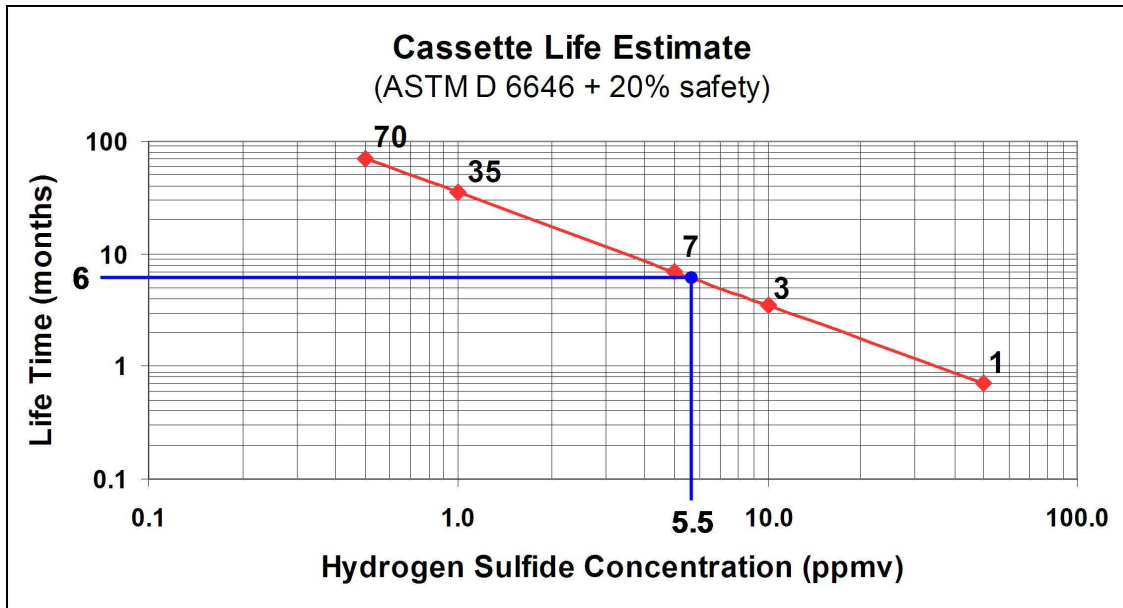


Figure 3 –Cassette System Media Life Estimates at Various Hydrogen Sulfide Concentrations When Operating at 200 fpm

LIFE CYCLE COMPARISON

The question remains whether the life cycle cost and any benefits justify the use of a Cassette System over a Deep Bed Adsorber. The life cycle costs will differ based on the initial capital costs, cost of media replacement, cost of labor for media replacement, number of media replacements per year, media disposal, and energy consumption of the system. Additional items that will not be considered in detail are the weight differences and associated shipping costs and carbon dioxide emissions due to transportation.

A life cycle valuation was performed on the case shown in Table 3. The airflow was 5,500 cfm. The hydrogen sulfide design concentration was 5.5 ppmv. The Deep Bed Adsorber design used a standard KOH media with a hydrogen sulfide capacity of 0.14 g/cc while the Cassette System used a high capacity carbon media with a capacity of 0.28 g/cc. The electricity cost was 0.08 \$/kWh representing an average condition for the United States. The specifics of each system are shown in Table 4. Actual capital costs and media costs are not shown to protect the manufacturers' pricing information.

The Cassette System houses much less media than the Deep Bed Adsorber, 60 ft³ versus 235 ft³. Two factors that help overcome this difference are the high capacity media and the lower pressure drop. The weight differences of the system make the cassette system easier to support and install; the media weight differences alone are approximately 1,700 lb versus 8,000 lb. The cassette system has a much lower residence time, 0.7 versus 2.6 seconds. This is much quicker than traditional designs, but work has shown that residence times down to 0.4 seconds can still effectively remove hydrogen sulfide at 25 ppm with a chemisorptive media (Stanley, 2008). For these systems, the ASTM D 6646 hydrogen sulfide capacity was used as an estimate of media life. The resulting Cassette System media life is shorter; 7 months versus 14 months. However,

Table 3 - Life Cycle Valuation Assumptions

Parameter	Value
Airflow	5,500 cfm
Efficiency – Drive	90%
Efficiency – Fan	80%
Efficiency – Motor	95%
Electricity Cost	0.08 \$ / kWh
H ₂ S Concentration	5.5 ppmv
Inflation – Electricity	7%
Inflation – Labor	3%
Inflation – Media	3%
Labor	30 \$ / hr
Operating Hours	8,760 hr

Table 4 - Life Cycle Valuation System Properties

Parameter	Deep Bed Adsorber	Cassette System
Capital Expenditure Ratio	2.0	1.0
Media Cost Ratio	1.7	1.0
Equipment Face Area	79	30 ft ²
Equipment Face Velocity	70	183 fpm
Equipment Vessel Diameter	10	n/a ft
Media Hydrogen Sulfide Capacity*	0.14	0.28 g / cc
Media Pressure Drop (total system)	4.3	2.0 iwg
Media Replacement Labor Time	n/a	9 hr
Media Residence Time	2.6	0.7 sec
Media Service Life	14	7 months
Media Usage**	204	104 ft ³ / yr
Media Volume	235	60 ft ³
Media Weight	7,990	1680 lb

* The Deep Bed Adsorber uses a standard KOH impregnated media. The Cassette System uses a high capacity media.

** ASTM D 6646 + 20% Safety

the change out of the media only requires manual labor to remove and replace cassettes while the Deep Bed Adsorber requires a vacuum truck and shipping of the media to a landfill. Typical spent cassettes and media are disposed as normal commercial waste in existing site dumpsters and require no additional costs besides labor.

The results of the life cycle valuation calculations are displayed in Table 5. The Cassette System annual energy consumption and associated carbon dioxide emissions are approximately 47% of the Deep Bed Adsorber's. This is due to the Cassette System's lower pressure drop; it saves approximately \$1,500 in first year's energy cost versus the Deep Bed Adsorber. The Cassette System annual media replacement and disposal cost is much less than the Deep Bed Adsorber due to less labor and resources required, \$556 versus \$2379 in the second year. Finally, the 10 year total cost including capital, disposal, energy, media, and labor is lower for the Cassette System, \$312,009 versus \$323,448.

Table 5 – Life Cycle Valuation Results

Parameter	Deep Bed Adsorber	Cassette System
Annual CO ₂ Emissions ⁺	24	11 ton
Annual Energy Consumption ⁺⁺	35,450	16,488 kWh
Year 1 - Annual Energy Cost	\$ 2,836	\$ 1,319
Year 1 - Media Replacement Labor & Disposal Cost	\$ 0	\$ 270
Year 2 - Media Replacement Labor & Disposal Cost	\$ 2379	\$ 556
10 Year Total Cost (capital + disposal + energy + labor + media)	\$ 323,448	\$ 312,009

⁺ Assuming 1.352 lb CO₂ / kWh

⁺⁺ Based on Equation 1

CONCLUSIONS AND RECOMMENDATIONS

This work has shown that a Cassette System odor control unit using high capacity media can have a lower life cycle cost over a 10 year period than a Deep Bed Adsorber odor control unit using standard KOH impregnated carbon. The downsides to the Cassette System are less media content, shorter media residence time, and shorter media service life. The benefits of the cassette system are lower capital expenditure, lower media pressure drop, lower energy consumption and associated carbon dioxide emissions, lower media replacement and disposal costs, less time required for media replacement, smaller equipment footprint, and smaller overall weight.

In this work it was assumed that the ASTM D 6646 hydrogen sulfide capacities were good estimates of media life for both Deep Bed Adsorbers and Cassette Systems. While these capacities have been used historically for estimating life of both system types, future work should evaluate the best method to estimate service life for either system.

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