BIOFILTER ECONOMICS AND PERFORMANCE

By

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INTRODUCTION

Biofiltration has proven effective at treating odorous gas streams emitted from various types of facilities including wastewater treatment plants, sewage pump stations, solid waste processing facilities, and composting facilities. Widespread acceptance of biofilter systems has been limited due to mixed results and lack of understanding at some facilities (*Williams 1994*). Significant information and understanding of operating parameters has developed over the past few years which has led to more biofilter installations. This understanding has been obtained through pilot studies by vendors and owners on existing gas streams, trial and error by operators at existing full scale systems, and published research by private firms and universities. Most designers and operators of waste processing facilities have experience with other types of odor control equipment, such as thermal oxidizers, chemical scrubbers, or activated carbon, and have found biofilters to be more effective at treating odorous gas streams both in odor removal efficiencies and economically. As a result, numerous biofilters have been installed to retrofit existing waste processing facilities and included in the design of new facilities to provide effective odor control. This paper outlines the economic considerations for a biofilter system and provides case history information including capital costs and removal efficiencies at operating waste processing facilities.

ECONOMIC CONSIDERATIONS

Several factors affect the capital and operating costs of biofilter systems. The sections below outline these considerations as they relate to constructing and operating an open bed biofilter system for odor control.

Capital

Pre-treatment - Pre-treatment of gas streams to improve biofilter operations include removing particulate matter, cooling, and humidifying. Often times some type of spray system, either coarse or atomizing nozzles, is used to pre-treat the gas stream. Typical applications may be at totally enclosed composting facilities for dust removal, for cooling of compost offgas, and humidifying exhaust gas from various enclosed odorous tanks. Complex pre-treatment systems result in increased biofilter system cost.

Concentration and Biodegradability of Compounds - Biofilters are effective at treating relatively low concentrations of odorous compounds in exhaust gas from waste processing facilities. Odorous gas streams from some facilities that may result in high concentrations of particular compounds may result in increasing the size of the biofilter. This determination is made by evaluating the mass loading and biodegradability of specific compounds to determine the size of the biofilter. Increasing the biofilter size will increase the capital cost of constructing the system.

Quantity of Air Being Treated - Generally, the more air being treated, the greater the size and cost of a biofilter system.

Removal Efficiency Requirements - Normally the design basis for an odor control system is to remove as many odorous compounds as possible. In some applications a lower removal efficiency may be deemed appropriate for reducing odor problems, while in other applications a greater safety factor to ensure maximum achievable odor treatment may be desired. These design considerations will effect the biofilter size and cost.

Ductwork - Often times the cost to collect and transport the odorous gas from the source to an area appropriate for the biofilter is actually more expensive than constructing the biofilter itself. Ductwork will normally be constructed from corrosion resistant materials such as plastics, fiberglass, stainless steel, or aluminum. The further the odor source is located from the biofilter site, the higher the ductwork cost.

Available Space - Space limitations may result in requiring walls to contain the media, special earth work techniques, or equipment access concerns that could increase the construction cost of the system.

Degree of Automation Desired - A higher degree of automation for monitoring such process variables as temperature, pressure, airflow rate, or equipment status will result in increased capital costs.

Degree of Flexibility - The degree of flexibility for biofilter systems normally includes the number of blowers or the number of biofilter cells. Generally, the greater the flexibility in the total system, the greater the capital cost. This results from increased ductwork costs, increased installation costs, and increased air dampers/controls.

Design Factors - Design factors such as detailed pre-treatment systems, unusual site conditions or complex collection systems may result in increased engineering costs. In addition, such factors as pilot studies or permitting requirements may increase capital costs.

Operating Costs

Electricity - Generally, electricity to operate the blower(s) is the largest portion of the operating cost for a biofilter system. Electricity for water pumps, controls, etc. will add minimal cost.

Media Replacement - The second largest operating cost is generally media replacement. Depending on various factors, media replacement will typically occur after several years of operation. The cost for media replacement consists of removing the old media, obtaining new media, and placing the new media.

Periodic Inspection and Testing - Labor and laboratory costs associated with monitoring and checking the biofilter system are typically minimal.

Equipment Maintenance - There a few mechanical parts associated with a biofilter system. As a result, maintenance costs are typically minimal.

Sidestream Treatment - The only sidestream requiring further treatment is wastewater from the biofilter drain system. This amount is normally small and results in minimal cost. There is no disposal cost for the media as it does not require further treatment prior to uses such as landscaping.

CASE HISTORIES

Several facilities have recently constructed open bed biofilter systems for odor control. Most facilities have installed open bed systems instead of totally enclosed systems for economic reasons. The increased process control provided by totally enclosing a biofilter has not justified the additional capital expenditure as documented by the successful odor control by numerous open bed systems. The reasons for installation of biofilter systems vary from facility to facility and include: reacting to odor complaints from neighbors, installing odor control to reduce odorous emissions from new facilities, and complying with regulatory requirements. The technique used for reducing overall odor emissions from waste processing facilities varies from facility to facility. Some facilities collect and treat the most odorous gas streams as is the case with composting facilities that operate with negative aeration and treat gas pulled through the compost piles with a biofilter. Other facilities have pinpointed specific areas within a facility that result in the most significant odorous emission and collect gas from that source and treat with a biofilter as is the case with covering various type tanks and treating exhaust through a biofilter. Some facilities totally enclose the entire treatment area and collect all of the building air. This is the case with a totally enclosed composting facility which treats all building exhaust through a biofilter system. Table 1 summarizes the case history information by outlining the design and operating data for several facilities as well as the capital cost and the removal efficiency where available. Of the facilities described, several have not conducted detailed testing for odor or specific compound removal efficiencies. This generally results from the analytical costs involved in conducting such testing. As a result, actual data in specific compound removal efficiency is limited. More subjective analyses from owners and operators, such as there are no odors from the biofilter surface and no odor complaints since the biofilter was installed, have been used to evaluate biofilter effectiveness.

The capital costs indicated in Table 1 are the total capital cost for the biofilter system including design, construction, and startup. The odorous gas collection system for each case is not included in the capital cost as collection systems vary from simple ducts to elaborate ducting and controls. The inclusion of collection systems can significantly increase the cost of installing an odor control system and would be required with any odor control technology selected. Therefore, including the collection system costs may skew the biofilter cost data and not accurately allow comparisons of capital costs between different odor control technologies. Operating and maintenance (O & M) costs for biofilter systems are generally not tabulated by operators. Therefore, actual operating costs are difficult to determine. The major operating cost for a biofilter is normally electricity to operate the blower followed by periodic media replacement. Through the use of locally available materials, facilities are able to lower media replacement costs. Detailed economic analyses have been performed for biofilter systems to estimate O & M costs. These estimates are normally accurate because electricity use is easily calculated. Total O & M costs normally range from $2 - $14 per CFM of exhaust gas treated (*Williams and Boyette 1995*). The following sections describe various biofilter systems.

Cape May County Municipal Utilities Authority (CMCMUA), Cape May Court House, NJ - CMCMUA operates a 20 dry ton per day in vessel composting facility in Cape May Court House, New Jersey. Biosolids are composted in an in-vessel system for 14 days, followed by an aerated static pile curing process for 21 days. Fourteen days of aerated curing is performed under negative aeration with exhaust gas treated through a biofilter system. The negative aeration used in the curing process is accomplished through the use of continuously operating blowers. The biofilter was designed to treat a total of 2,400 CFM at a loading rate of 4 CFM/SF. Pre-treatment of the exhaust air is accomplished through either of two spray chambers designed to cool the exhaust gas prior to treatment by the biofilter. The exhaust air from the curing blowers is collected through a ducting system maintained under negative pressure by two biofilter blowers. Each of the biofilter blowers serves either of two equal size biofilters. The biofilter media consists of locally available yard waste compost and wood chips. The biofilter was placed in service in July 1996 and was constructed for a total capital cost of $49,800. The biofilter has been treating odors with the operators commenting that no odors from the biofilter surface are noticeable. Performance testing of the biofilter system is scheduled for September 1996 (*Donofrio 1996*).

Central Contra Costa Sanitary District (CCCSD), Martinez, CA - CCCSD operates a 45 MGD activated sludge secondary wastewater treatment plant (WWTP). To reduce odorous emissions from the facility, CCCSD installed covers on three dissolved air flotation (DAF) tanks. A ducting system was installed to collect odorous air and reduce corrosion inside the tanks. The biofilter system treats 3,500 CFM of odorous exhaust gas. The system consists of in-line spray nozzles to increase humidity of exhaust gas and two equal size cells to treat the odorous gas. The media consists of locally available yard waste compost and wood chips. The biofilter is 700 square feet and designed at a loading rate of 5 CFM/SF. The media is four feet deep and the nominal open bed residence time is 48 seconds. System pressures and temperatures are continuously monitored and recorded. The biofilter began operation in July 1996. The total capital cost of the biofilter system not including covers or collection ducting was $129,700. Performance testing of the odor removal efficiency of the system is scheduled for September 1996 (*Kaweah 1996; Pomroy 1996*).

Davenport, Iowa - The city of Davenport operates a 28 dry tons per day aerated static pile biosolids composting facility. The mixing and composting areas are totally enclosed with 210,000 CFM of exhaust treated through a biofiltration system. The system includes two separate biofilters with each one divided into four separate cells. Each cell has its own individual blower with an in-line spray nozzle for humidification. The biofilter media consists of yard waste compost and wood chips and is four feet deep. The biofilter was designed at 5 CFM/SF and the total treatment area of the biofilter is 42,000 square feet. The biofilter system was constructed for $495,500 and began operations in June 1995. Odor removal testing on two cells was conducted in October 1995 and the resulting removal efficiencies averaged 86% (*Plett 1996; Zarn 1995; E&A 1996*).

East Hampton, New York - East Hampton operates a 35 tons per day agitated bed municipal solid waste (MSW)/biosolids composting facility. MSW/biosolids composting is conducted inside a totally enclosed building. A biofilter is located adjacent to the building and treats 50,000 CFM of building exhaust gas. The facility began operations in March 1995. The biofilter media consists of wood chips and leaf compost with media placed three feet deep. The biofilter was designed at 5 CFM/SF with a residence time of 36 seconds. The total capital cost of the biofilter was $135,400. No odor testing of the system has been performed, but facility operators have not noticed any odors from the biofilter surface (*Alix 1995*).

Everett, Washington - The city of Everett is constructing a biofilter to treat odorous emissions from the head works area of the WWTP. The biofilter was designed to treat 15,000 CFM of exhaust gas at a loading rate of 2.67 CFM/SF. The media will be placed four feet deep and the residence time will be 90 seconds. The media will consist of locally available compost and wood chips. Pre-treatment of the gas consists of in-line spray nozzles for humidification. The biofilter consists of two separate 2,810 SF cells with each cell having its own individual blower. The biofilter is scheduled to be operational at the end of 1996 (*Sasser 1996*).

Harrisonburg - Rockingham Regional Sewer Authority (HRRSA), Mount Crawford, VA - HRRSA constructed a 5.5 dry tons per day biosolids composting facility which began operations in December 1995. 3,150 CFM of exhaust gas from the composting process is collected and treated through a biofilter system to reduce odors from the compost facility. The system consists of a spray chamber to humidify and cool exhaust gas. The biofilter was designed at a loading rate of 4 CFM/SF and is 790 square feet. The media consists of biosolids compost and wood chips and was placed four feet deep. The system was installed for a total capital cost of $58,000 (*Harman 1995*).

Hoosac Water Quality District, MA - Hoosac operates an aerated static pile biosolids composting facility. The facility received numerous odor complaints from neighbors of the facility. As a result, four biofilters were constructed to treat 15,600 CFM of compost process exhaust gas. The biofilter media consists of locally available wood chips and leaf compost placed three feet deep. The biofilters were placed in service in 1992 and have eliminated odor complaints from neighbors of the facility. Odor removal efficiency by the biofilter has been measured at 61% to 94%. Hoosac is currently expanding the capacity of the composting facility which will include construction of additional biofilters for odor control from the additional composting areas (*E&A 1993*).

Rivanna Water and Sewer Authority (RWSA), Charlottesville, VA - The RWSA operates a 15 MGD pump station located adjacent to the Rivanna River in Charlottesville, Virginia. Neighbors are within approximately 150 feet of the pump station and had complained about odorous emissions from the wet well. Based on capital constraints, RWSA initially installed a counteractant agent spray system which resulted in a slight reduction in odor problems at the facility. In 1995 RWSA installed a biofilter system to treat the 2,825 CFM of wet well exhaust to provide more effective odor treatment. The system includes a spray chamber to humidify the air. The biofilter was designed at 5 CFM/SF and is 565 square feet in size. The system began operations in September 1995. Odor removal efficiencies were measured at 76% in October 1995. Since the biofilter has been in operation, no odor complaints have resulted from the pump station. The lower odor removal efficiency was due to low odor levels of the inlet gas, 75 D/T. The outlet odor level was 18 D/T which is typical of well operating biofilters. The biofilter was constructed by the authority for a total capital cost of $41,300 (*E&A 1995; Wescoat 1996*).

Sevierville, TN - Bedminister Corporation operates a 225 tons per day municipal solid waste and municipal biosolids co-composting facility in Sevierville, Tennessee. The MSW and biosolids are loaded into an in-vessel composting system followed by an aerated static pile curing. The aerated static pile curing occurs in a totally enclosed building with 80,000 CFM of building exhaust treated through a biofiltration system. The biofilter is comprised of two blowers and five individual cells which are approximately 3,960 square feet each and was constructed in 1995. Performance testing of the biofilter was conducted in 1996. Odor removal efficiency of 91% was obtained. Specific compound removal efficiencies were also measured with a total volatile organic compounds (VOC's) removal efficiency of 93% obtained (*E&A 1996*).

UNISYN, Wiamanilo, HI - UNISYN operates a food waste digestion facility in Wiamanilo, Hawaii. In an effort to reduce odorous emissions from the facility and resulting off site odor impacts, the facility installed covers over the receiving tank, two storage tanks, and the harvest tank. A ducting system was installed to collect odorous air for treatment by a biofilter system. A temporary biofilter was constructed in two weeks utilizing on site personnel and local contractors to meet facility permit requirements. The biofilter was designed to treat 2,500 CFM of exhaust gas. The biofilter is 625 square feet and designed at a loading rate of 4 CFM/SF with media three feet six inches deep. The media consists of compost and overs from a local yard waste composting facility. The temporary system was installed for $11,400 not including tank covers and collection ducting. The system began operations in September 1995. Performance testing was conducted in October 1995. Inlet odor concentrations ranged from 13,700 to 25,100 D/T and a 82% removal efficiency was obtained. A total reduced sulfur (TRS) removal efficiency of 99+% was also obtained (*E&A 1995*).

Western Lake Superior Sanitary District (WLSSD), Duluth, MN - The WLSSD operates a 45 MGD WWTP. The facility has received odor complaints from residents in Duluth's lower west end neighborhood resulting from the WWTP. In on-going efforts to reduce odorous emission from the plant, the district is installing a biofilter system to treat exhaust gases from the building enclosing the grit room, the sludge thickener room, and the in-feed screw pumps. Wastewater channel air is normally used as make-up air for a solid waste incinerator. In the event the incinerator is down for maintenance, the channel air will be diverted to the biofilter system. Phase I of the exhaust collection system includes ducting from the channel air, grit room, and thickener room. Phase II of the exhaust gas collection system will include influent screw pump covers and ducting to the biofilter system. The biofilter system is designed to treat 50,000 CFM of exhaust gas with hydrogen sulfide concentration estimated at 1 - 20 ppmv. Exhaust gas is pre-treated through a spray chamber designed to increase humidity and remove particle matter prior to treatment by the biofilter. The spray chamber consists of an existing concrete channel that was modified with a compressed air/water spray nozzle system. The biofilter system includes three individual cells with each designed to treat 16,670 CFM of exhaust air. The biofilter is 11,800 square feet and designed at a loading rate of 4.2 CFM/SF. The media consists of yard waste produced by the district and wood chips from a local paper mill. The media is four feet deep with a nominal open bed residence time of 57 seconds. Construction of the biofilter system began in August 1996, and the system is anticipated to be on-line by November 1996. Total capital cost of the biofilter system was $387,000 (*Hamel 1996*).

SUMMARY

The case histories discussed outline biofilter systems that have been successful in treating odorous exhaust gas from various types of waste processing facilities. Table 1 outlines the design and operating data as well as the capital cost for these facilities. Odor removal efficiencies have ranged from 76% to 94% for the five biofilters tested. TRS compounds have been reduced by 99% or greater at the two facilities tested. One facility achieved a 93% VOC removal efficiencies. This data, as well as operator comments, indicate that open bed biofilter systems are effective at reducing odorous emissions from waste processing facilities.

The capital cost of a biofilter system is based on several factors including type and quantity of exhaust gas being treated and local site conditions. Table 1 shows the capital cost for several biofilter systems. Figure 1 shows the capital cost range per CFM of exhaust gas treated. Unit costs for smaller biofilter systems are higher due to a greater percentage of the cost resulting from engineering and contractor mobilization. For small biofilters treating less than 15,000 CFM of exhaust gas, capital costs range from approximately $10 to $38 per CFM of air treated. For large biofilters treating more than 100,000 CFM of exhaust gas, capital costs range from approximately $2.50 to $5 per CFM of air treated. Figure 2 shows the capital costs per square foot of biofilter surface area. For smaller biofilters, capital costs range from approximately $45 to $185 per square foot of biofilter surface area. For larger biofilters, capital costs range from approximately $12 to $20 per square foot of biofilter surface area. These capital costs can be used for budgetary estimates and for comparison with other odor control technologies.

Based on the continued documented effectiveness of biofilter systems, more waste processing facilities will view biofiltration as an economically favorable odor control alternative.

TABLE 1 BIOFILTER SUMMARY INFORMATION

Facility	Date in Service	Odorous Gas Source	Flow Rate (CFM)	Loading Rate (CFM/SF)	Size (SF)	Filter Depth (Ft)	Residence Time (Sec)	Media Blend	Removal Efficiency	Capital Cost
CMCMUA, NJ	Jul-96	Compost Process Gas	2,400	4	600	4	60	YW Compost: Wood Chips	NT	$49,800
CCCSD, CA	Jul-96	WWTP Tanks	3,500	5	700	4	48	YW Compost: Wood Chips	NT	$129,700
Davenport, IA	Jun-95	Biosolids Compost Bldg Exhaust	210,000	5	42,000	4	48	YW Compost: Wood Chips	86% Odor	$495,500
East Hampton, NY	Mar-95	MSW/Biosolids Composting Bldg Air	50,000	5	10,000	3	36	Leaf Compost: Wood Chips	NT	$135,400
Everett, WA	UC	WWTP Headworks	15,000	2.67	5,620	4	90	Under Construction	UC	UC
HRRSA, VA	Dec-95	Compost process gas	3,150	4	790	4	48	Biosolids Compost: Wood Chips	NT	$58,000
Hoosac, MA	May-92	Compost process gas	15,600	3.5-5.0	3,600	3	40-60	Leaf Compost: Wood Chips	94% Odor 99% TRS	NA
RWSA, VA	Sep-95	Sewage Pump Station	2,825	5	565	4	48	Biosolids Compost: Wood Chips	76% Odor	$41,300
Sevierville, TN	Nov-95	Compost Bldg Exhaust	80,000	4-5	19,800	2.5-3	30-45	NA	91% Odor 93% VOC	NA
UNISYN, HI	Sep-95	Food Waste Digestion Exhaust	2,500	4	625	3.5	42	YW Compost: Chipped Brush	82% Odor 99% TRS	$11,400
WLSSD, MN	UC	WWTP Headworks	50,000	4.2	11,800	4	57	YW Compost: Wood Chips	UC	$387,000

NOTES

UC - Under Construction
NA - Not Available
NT - Not Tested
YW - Yard Waste

MSW - Municipal Solid Waste
TRS - Total Reduced Sulfur Compounds
VOC - Volatile Organic Compounds

FIGURE 1 BIOFILTER CAPITAL COST PER CFM OF AIR TREATED

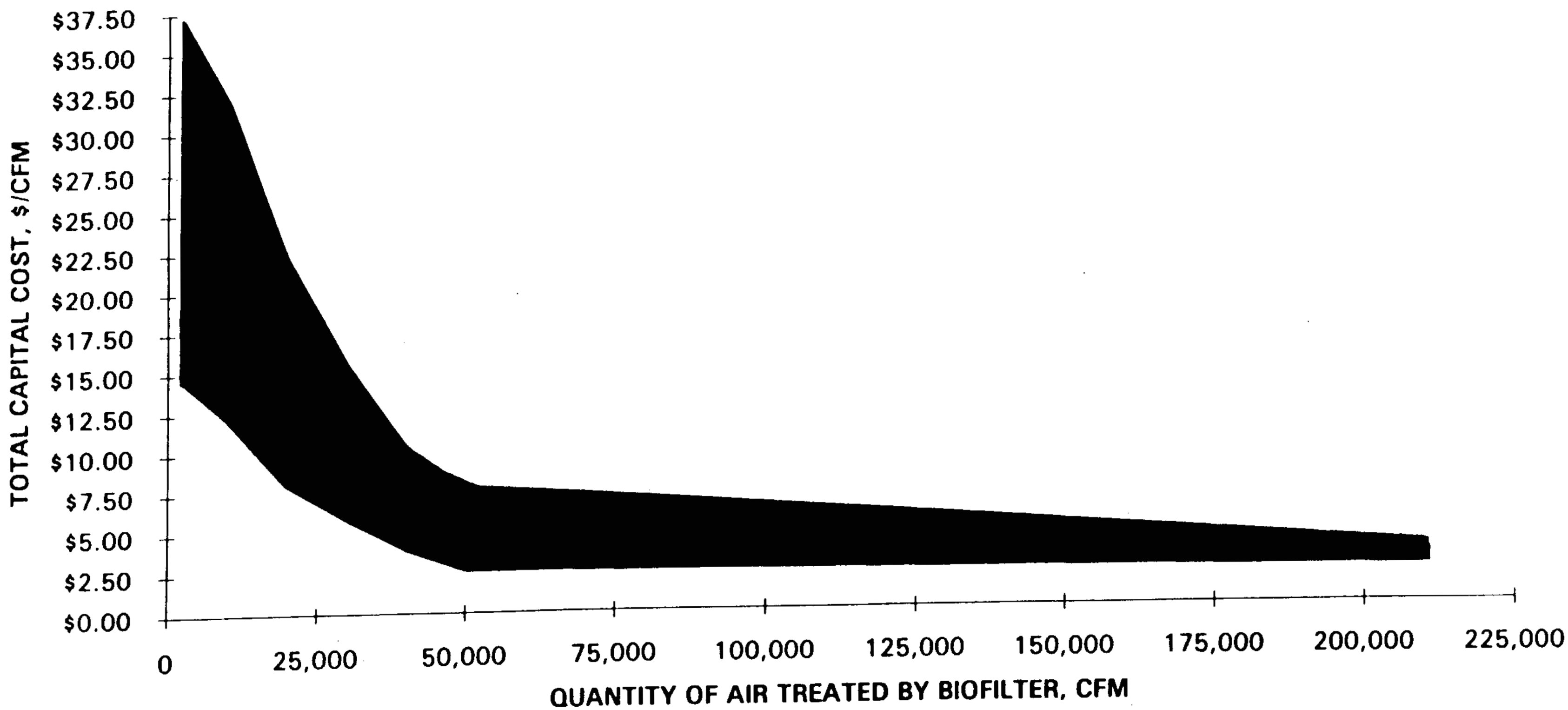
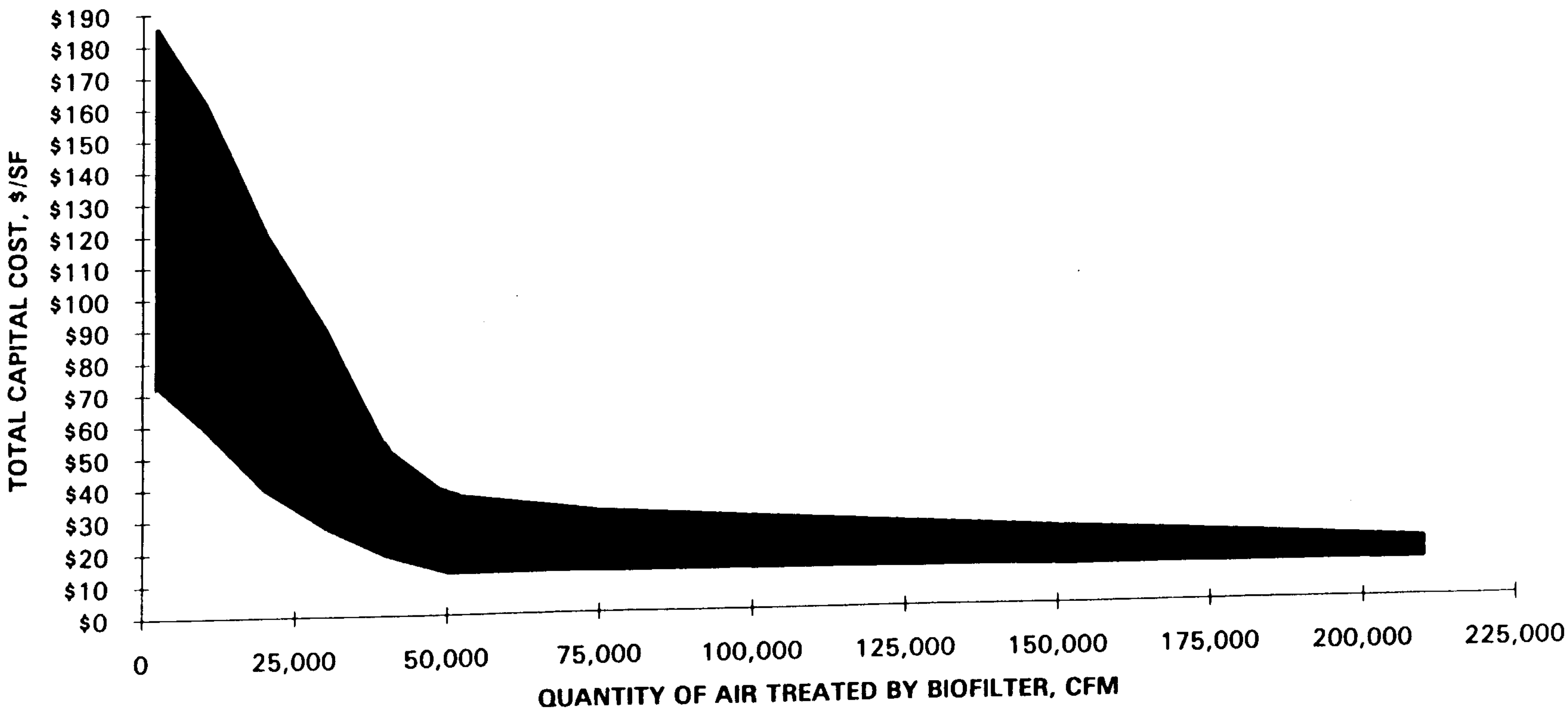


FIGURE 2 BIOFILTER CAPITAL COST PER SQUARE FOOT OF TREATMENT AREA



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