

BIOFILTRATION

- ◆ *Project Report*
- ◆ *Scale-Up and Design Guide*

**CENTER FOR
Waste Reduction
TECHNOLOGIES**



AMERICAN INSTITUTE OF
CHEMICAL ENGINEERS

CENTER FOR WASTE REDUCTION TECHNOLOGIES

of the

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

3 Park Avenue

New York, New York 10016-5901 USA

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American Institute of Chemical Engineers
Center for Waste Reduction Technologies
3 Park Avenue
New York, New York 10016-5901

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Executive Summary

This report summarizes the first phase of a collaborative project focused on gathering technology information on the application of biofiltration to control volatile organic compound (VOC) emissions. The project is being conducted by a group of interested member companies under the American Institute of Chemical Engineers, Center for Waste Reduction Technologies. This project intends to define what is known about biofiltration, using available literature and the team's collective experience, to identify and address some of the important knowledge gaps and provide new validated information—all clearly documented in one place. This documentation will be available for use by practitioners who are faced with evaluating and implementing VOC treatment solutions.

The project essentially consists of the following technical elements that result from six project tasks:

- An assessment of project participants' collective experiences with biofiltration at bench-, pilot-, and full-scale applications (Task 1). Many of the participating project companies have had their own experiences with biofiltration, and these have been compiled into an electronic database called the *Experience Database*. It is available to project participants in electronic form, and is included on the CD ROM submitted in conjunction with this final Project Report.
- Categorization of the regime of applicability for biofiltration; that is, the vent stream characteristics and application requirements that affect the efficacy of biofiltration and that should be evaluated when initially considering a possible biofilter application (Task 2). In order to address the regime of applicability, two database tools were developed and are included herein to help the practitioner identify whether a specific application is a good candidate for biofiltration. The first tool is a *Literature Database*, which was compiled from a total listing of over 400 technical papers and journal articles. The second tool is a *Compound Database*, which was prepared to consolidate physico-chemical parameters pertinent to assessing a specific constituent's applicability for treatment within a biofilter.
- An evaluation of the parameters which require consideration when embarking upon bench-, pilot-, or full-scale operation of biofilters—specifically, the key data that should be gathered during bench- and pilot-scale treatability evaluations. Also includes a checklist that can be used to improve the effectiveness of these evaluations, and biofilter design components and operational parameters that should be considered when implementing a pilot- or full-scale system (Tasks 3,

- 4, and 5). Due to the more highly detailed and technical nature of the assessment of regime of applicability and the biofilter scale-up and design checklist, the deliverables from Tasks 2, 3, 4, and 5 have been prepared in a separate companion report, the *Biofilter Scale-up and Design Guide*.
- A comparison of biofiltration to alternative emission control technologies, particularly with respect to the economics of installation and operation (Task 6). Four representative cases of interest to the sponsors of the project were selected and cost model predictions were performed to screen for technologies that may be cost-competitive for the selected conditions. A Request for Budgetary Quotation was issued to vendors. After determining which of the technologies provided lowest-cost options for each of the cases, the comparative costs among the technologies were summarized. When ranked by estimated annualized operating costs, each case has a slightly different mix of technologies that provide the lowest costs. All four cases appear to illustrate that quotations on biofilters can vary widely for the same emission control problem, and that for the cases selected, biofiltration did not offer the capital or annualized operating cost advantages that were expected.

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Cytec	Owens Corning
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Technical information such as that compiled in this document does not come together as cost effectively as this project was able to achieve without significant voluntary contribution from a variety of project team members, their peers, and technical advisory staff. The collaborative team authors and contributors would like to thank the supporting staff within their own companies, as well as the contributions made by special technical consultants **Dr. Gero Leson and Petra Pless**, Leson Environmental Consultants (especially Project Report Sections 2 and 3 and the Design Guide), and **Dr. Vic Engleman**, Engleman Associates, Inc. (Project Report Section 5), for their extensive contributions to the project.

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Scott Berger
Owens Corning
Project Coordinator

Dennis Peters
CH2M HILL
Project Manager

Acronyms and Abbreviations

AIChE	American Institute of Chemical Engineers
APC	air pollution control
BACT	best available control technology
BTEX	benzene, toluene, ethylbenzene, and xylenes
cm	centimeters
CO	catalytic oxidizer
Conc	concentrator
CWRT	Center for Waste Reduction Technologies
DREs	destruction removal efficiencies
EBRT	empty bed residence (retention) time
EC	elimination capacity
EPA	Environmental Protection Agency
ESP	electrostatic precipitator
FRP	fiberglass-reinforced plastic
ft ³	cubic feet
GAC	granular activated carbon
HAPs	hazardous air pollutants
MACT	most achievable control technology
mg/m ² -min	milligrams per square meter per minute
m ³ /m ² -min	cubic meters (air) per square meter per minute
ppbv	parts per billion by volume
ppmv	parts per million by volume
QsBR	quantitative structure biodegradation relationship
RCOs	regenerative catalytic oxidizers
RE	removal efficiency
RFBQ	request for budgetary quotations
RTOs	regenerative thermal oxidizers
scfm	standard cubic feet per minute
TO	thermal oxidizer
VFD	variable frequency drive
VOCs	volatile organic compounds

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Introduction

In 1995 the Center for Waste Reduction Technologies (CWRT) began examining biofiltration, an emerging volatile organic compound (VOC) emission control technology, for applications in the chemical manufacturing industry. A group of interested CWRT member company representatives gathered at a commercial manufacturing facility in Springfield, Missouri to review the operational experiences of the facility's biofilter. In the course of this review, it became evident that a number of CWRT companies had interest in or experience with the application of biofiltration to control VOC emissions at their own manufacturing plants or project sites. An informal collaborative team convened at subsequent meetings for further technology and application data sharing, as well as to develop a collaborative project focused on gathering technology information of interest to the group. In early 1997, a collaborative project titled "Evaluation of Biofiltration as an Energy-Efficient Low-Waste Alternative for Treating Dilute Vent Streams" was initiated by 11 corporate collaborators under the coordination of CWRT. In the fall of 1997, a twelfth sponsor joined the collaborative team.

This report summarizes the information gathered and assimilated through the execution of this collaborative project. Details of the structure of the project as well as the nature of the collaborative arrangement can be secured from CWRT (Jo Rogers, Director, CWRT, 212/591-7727). The remainder of this report focuses on the context of the project and the deliverables produced in conjunction with various project tasks.

1.1 Background

Biofiltration is an emerging energy-efficient technology for the control of VOC emissions. During the past few years it has been used increasingly in U.S. applications for treating high volume, low concentration air streams. It has been used extensively for over 40 years in the U.S. and Europe for the control of odors from wastewater treatment and handling facilities, rendering plants, composting facilities, and other odor-producing facilities. It is an attractive alternative to conventional control technologies (e.g., thermal oxidizers, scrubbers), and is thought to offer potentially lower capital and operating costs. Further, biofiltration has the advantage of generating a smaller amount of secondary waste than other competing processes.

Biofiltration is defined as the processing of gaseous vent streams using a bed of media (such as peat or soil). Vent gas is passed through the bed, where the VOCs are adsorbed by the media and biodegraded by resident microorganisms. A more detailed description of biofiltration is provided in **Section 2** of this report. Related biological VOC control systems, such as bioscrubbers and biotrickling filters, were not the primary focus of this project. However, many of the data gathered, applications considered, and concepts discussed in this report apply to these systems as well.

This project defines what is known through the available literature and the team's collective experience of biofiltration to identify and address some of the important knowledge gaps, and to provide new validated information—all clearly documented in one place for use by practitioners who are faced with evaluating and implementing VOC treatment solutions. Preliminary knowledge gaps were identified by national experts who were invited to speak at a meeting of CWRT member representatives. Based on their input, and specific data needs of the member companies, several tasks for this project were conceived. These tasks and the planned deliverables are summarized in Table 1-1.

1.2 Project Tasks and Organization

The project essentially consists of the following technical elements (as indicated in Table 1-1):

- An assessment of project participants' collective experiences with biofiltration applications at bench-, pilot-, and full-scale (Task 1).
- Categorization of the regime of applicability for biofiltration; that is, the vent stream characteristics and application requirements that affect the efficacy of biofiltration and should be evaluated when initially considering a possible biofilter application (Task 2).
- An evaluation of the parameters which require consideration when embarking upon bench-, pilot-, or full-scale operation of biofilters—specifically, the key data that should be gathered during bench- and pilot-scale treatability evaluations. Also, development of a checklist that could be used to improve the effectiveness of these evaluations, and biofilter design components and operational parameters that should be considered when implementing a pilot- or full-scale system (Tasks 3, 4, and 5).
- A comparison of biofiltration to alternative emission control technologies, particularly with respect to the economics of installation and operation (Task 6).

TABLE 1-1**Project Task Descriptions and Deliverables**

Task No.	Task Title	Task Description	Planned Deliverable(s)
1	Preliminary Knowledge Sharing	Gather collaborator experience with biofiltration into a simple format to establish extent of experience and in-house knowledge.	Simple database summarizing collaborator biofiltration experience.
2	Regime of Applicability	Assemble a methodology/database that would serve as a tool for establishing whether biofiltration is a candidate for control of a particular VOC-containing emission stream.	Electronic database and supporting documentation.
3	Current Knowledge Gaps	Conduct a critical assessment of the current practice used to design and scale-up biofilters, and data gaps that pertain to scale-up.	Report describing scale-up data gaps for insertion into project report.
4	Best Scale-up Practice	Assimilate information from experts and existing technical literature; document current methods for design of full-scale biofilters from pilot-scale data; describe critical scale-up parameters and use of experimental data in biofilter design.	Report describing scale-up practices for insertion into project report.
5	Scale-up Checklist	Develop a checklist for small-scale testing which covers the important methods, equipment and control elements which supply the critical larger-scale design parameters.	Checklist and supporting explanatory text for insertion into the project report.
6	Alternative Technology Cost Comparison	Prepare a comparative cost analysis on specific, representative VOC emission sources applicable to biofiltration. Solicit and review quotations from biofiltration and alternative treatment technology vendors.	Report on biofiltration vendor equipment, alternative (competing) technologies, and comparative costs for treatment options of selected representative streams.
7	Proposal for Phases 2&3 Experimental Program	Propose an experimental program which addresses the key knowledge gaps that would be considered in a Phase 2 project.	Proposal and recommendations for insertion into the project report.
8, 10	Draft Technology Summary Report	Collect, review, edit, and assimilate deliverables from Tasks 1 through 7 into a draft project summary report to be distributed to all collaborators for review.	Draft and final project report.
9	Collaborators' Review of Report	All collaborators are expected to provide review comments on the draft project summary report.	Written review comments submitted to the project management team.
11	Project Coordination	Provide ongoing day-to-day coordination of task execution; provide project guidelines; participate on the management team; provide monthly status reports; track schedule and budgets.	Regular communication with task leaders; project guidelines; monthly status reports; assist with coordination of project meetings and teleconferences.

Figure 1-1 depicts the inter-relationship of project tasks and the process for conducting an assessment of a specific biofiltration application. With a given application in mind, a practitioner will follow the basic path that begins with the “CHARACTERISTICS OF APPLICATION” box in Figure 1-1, and ends in either the “FULL-SCALE BIOFILTER DESIGN” box or one of the paths that end in “No.” The “No” result suggests that biofiltration will not be a viable or preferred solution for the application. Along the way, the practitioner will need to address increasingly focused levels of screening that begin with an initial paper assessment (do the basic characteristics of the emission and site characteristics indicate biofiltration is a plausible alternative?) and continue through bench-scale testing (if necessary), pilot unit operation, an economic evaluation, and final scale-up and design. While these steps don’t include all of the components required for a proper technology assessment (this project did not address regulatory agency requirements or full life-cycle analysis), they were the steps deemed most critical to the collaborative team at the onset of this project.

1.3 Report Organization

The remaining sections of this report present the results of the four primary technical elements mentioned above. **Section 2** summarizes basic technology history and function, and explains the experience database, which documents project participants’ corporate experiences with biofiltration. **Section 3** introduces the concept of regime of applicability and explains the literature and compound databases that were compiled in support of Task 2. **Section 4** summarizes the evaluation of biofilter scale-up and design practices produced by Tasks 3, 4, and 5. **Section 5** contains the results of the alternative technology cost comparison prepared in Task 6. Supporting appendices at the end of the report contain more detailed data, including convenient units and unit conversions (**Appendix A**), database output (**Appendix B**), and results of vendor quotations (**Appendices C and D**).

Due to the more highly detailed and technical nature of the assessment of regime of applicability and the biofilter scale-up and design checklist, the deliverables from Tasks 2, 3, 4, and 5 have been prepared in a separate companion report, the ***Biofilter Scale-up and Design Guide***. There is a significant benefit to providing this information as its own document. Practitioners faced with an application can go to a single reference that contains technology-specific guidance to assist them from the early phase of an evaluation (i.e., literature search and assessing technology applicability) through the final phases of system design (e.g., sizing, materials of construction, operational control system specifications). **The Biofilter Scale-Up and Design Guide** is a more useful, concise resource without the project-specific results and general descriptions that are contained in this report.

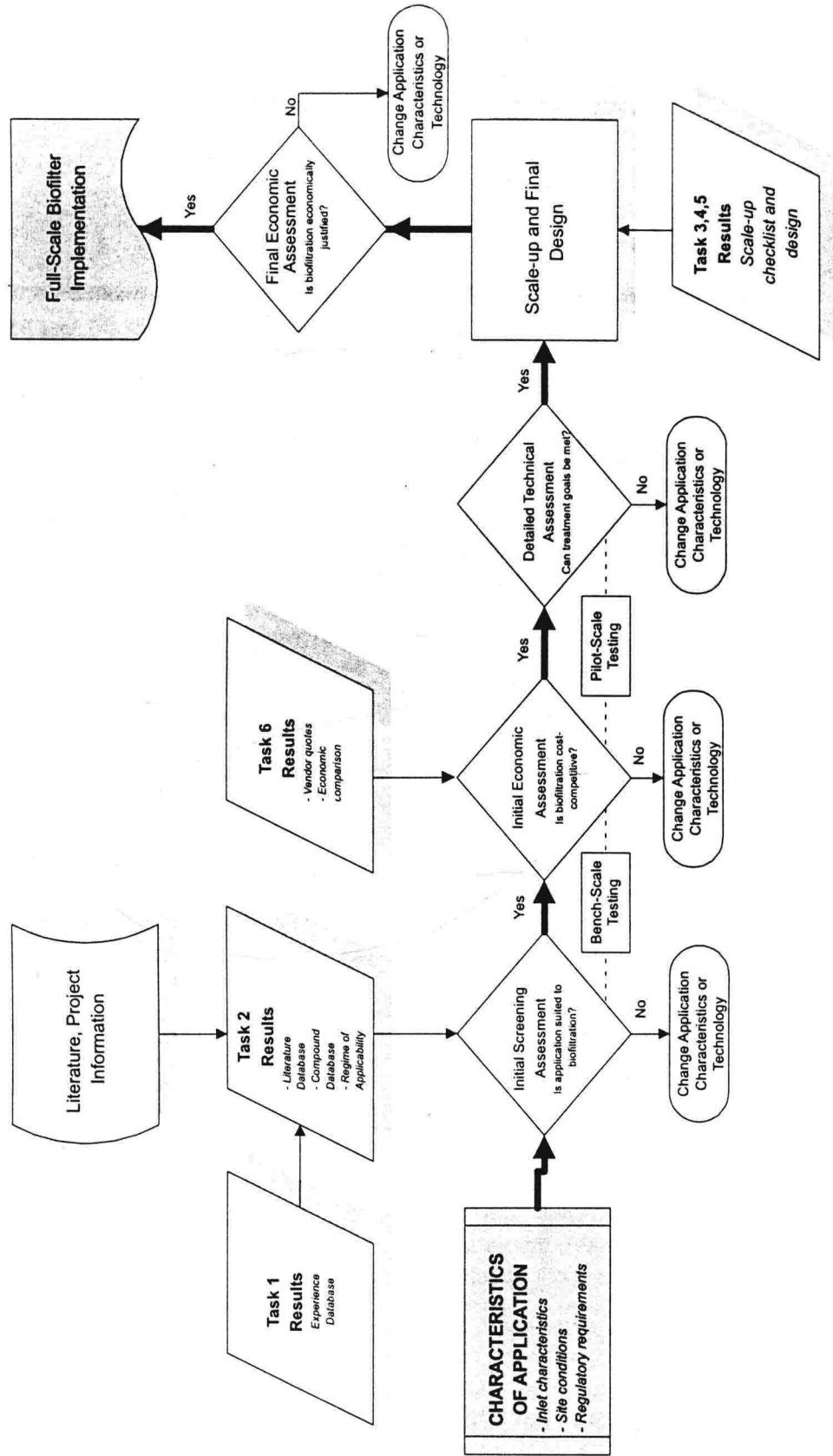


Figure 1-1
Process Schematic Overlay of a Typical
Biofilter Application Evaluation with
CWRT Project Tasks

