

Biofiltration

A Lean Emissions Abatement Technology

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Table I Biological Processes - Historical Development [Adapted from Ref. 2]

Year	Device	Description	Microbes
1957	Biofilter	Open Earth Filter	Natural soil microorganisms
1964	Biofilter	Open Earth Filter	Natural soil microorganisms
1966	Biofilter	Earth Filter with Compost as Carrier Material	Natural soil microorganisms
1973	Trickling Filter	Trickling Filter with glass beads as pecking	Activated sludge
1975	Trickling Filter	Single stage trickling filter	Biological lean
1978	Bioscrubber	Two-stage bioscrubber with activated sludge basin	Activated sludge - water mixture
1979	Biofilter	Closed bioreactor with biologically active compost	Activated sludge-water mixture
1984	Biofilter	Earth filter with filter material made of wood compost	Activated sludge-water mixture
1984	Biofilter	Packed tower design with activated charcoal as carrier material	Single cell cultures immobilized on activated charcoal
1986	Biofilter ³	Multi-stage closed bioreactor (BIOTON ³)	natural microorganisms and special cultures
1986	Membrane Reactor	Permeation reactor with silicon rubber membrane	Activated sludge
1988	Bioscrubber ²	Parallel flow with peckings	Cultured microorganisms
1990	Biotrickling Filter ⁴	Packed-tower design based on trickling filter concept	Special cultures

COMPOUND BIODEGRADABILITY

Many of the compounds encountered in gaseous effluents from the chemical process industry are amenable to treatment through biofiltration. Typically, compounds that are lightweight, water soluble, and contain oxygen atoms (e.g. alcohols, aldehydes, ketones, etc.) are easily degradable. Aromatic and halogenated compounds are difficult to degrade, and require inoculation with specific microbial species, additional nutrients and possibly an additional carbon source.

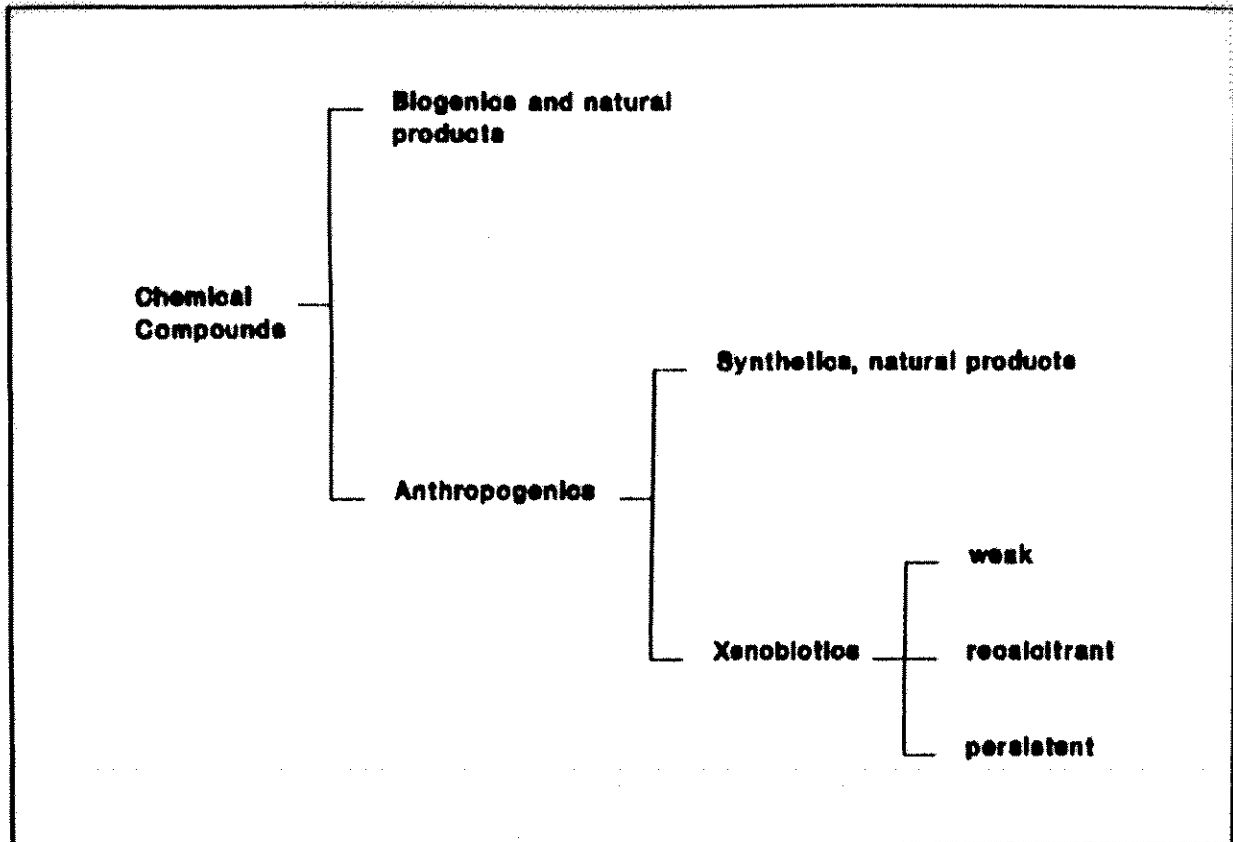


Figure 1 Biodegradability of Compounds [Adapted from Ref. 13].

Not all compounds are biodegradable. There are many compounds that are persistent in nature leading to the solid waste problems we are currently experiencing throughout the world. Figure 1 shows how chemical compounds can be classified according to their biodegradability.

Anthropogenic or man-made compounds are hard to degrade compared to biogenics which are of natural origin. Anthropogenics that resemble biogenics (synthetics and weak xenobiotics) in structure are much more easily degradable than recalcitrant (e.g. halogenated hydrocarbons) and persistent compounds (e.g. polystyrene), that have unnatural chemical structures which are not recognized by microorganisms.

TYPES OF BIOLOGICAL PROCESSES

There are three basic types of biological processes that are used for air pollution control: bioscrubbers, biofilters, and trickling filters. They can be distinguished by whether the liquid phase is stationary or moving and whether the microorganisms are immobilized or dispersed, as shown in Figure 2.

		Aqueous Phase	
		Moving	Stationary
Microbial flora	Dispersed	Bioscrubbers	
	Immobilized	Trickling filters	Biofilters

Figure 2 Distinctions between Biological Processes for Air Pollution Control [Adapted from Ref. 13].

A bioscrubber consists of two units, a scrubber and a regeneration basin, as shown in Figure 3. In the scrubber the soluble gases and oxygen are continuously absorbed into water. Biological oxidation occurs in the regeneration unit which is typically an activated sludge basin in a wastewater treatment plant. The absorption and subsequent oxidation of any compound is higher if its concentration in aqueous phase is low and its solubility is high.

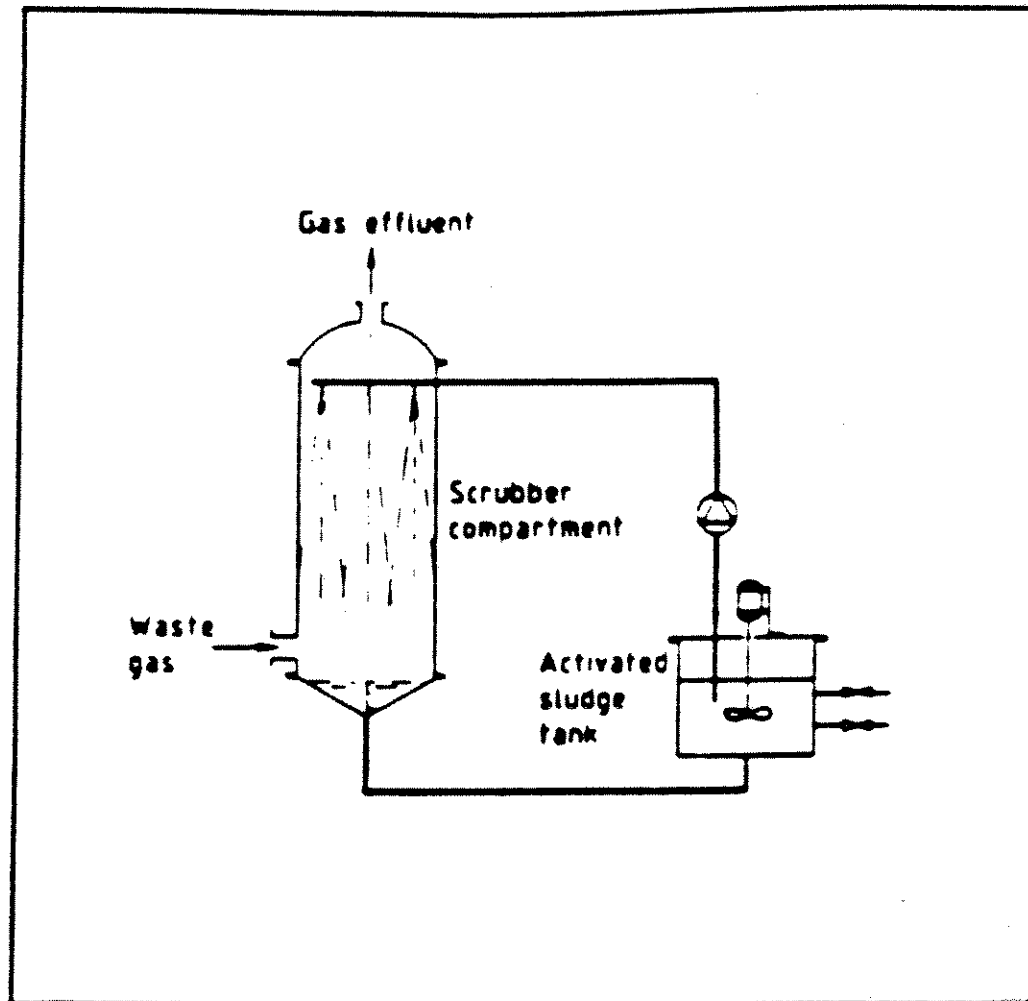


Figure 3 Bioscrubber

A biofilter (Figure 4) consists of a filter bed, made of natural materials (e.g. compost), which is kept wet with sprayers that continuously supply sufficient water to maintain high humidity. Thus, the compounds are directly absorbed into the biofilm from gas phase and oxidized, under optimal conditions. The natural filter materials supply the nutrients necessary for microbial survival. Biofilters are commercially available¹⁴⁻¹⁹ as modular, turn-key, and/or specifically designed units. The rest of this paper is devoted to a discussion of biofilters

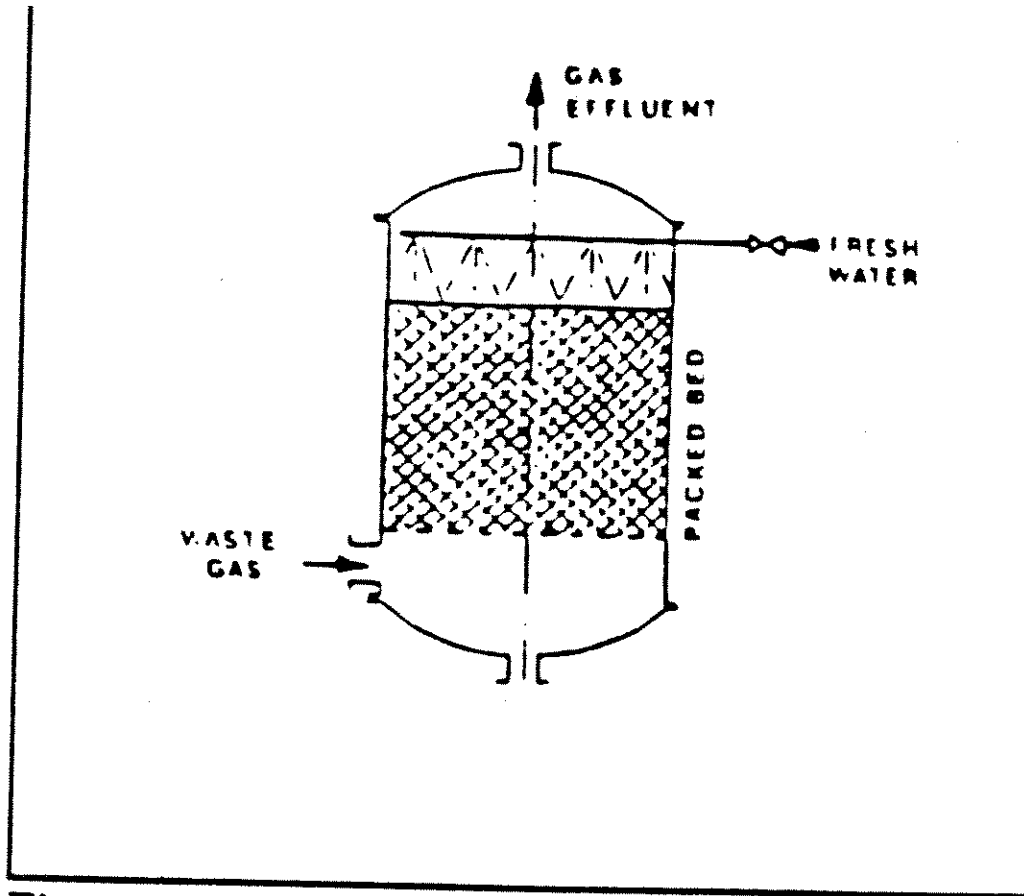
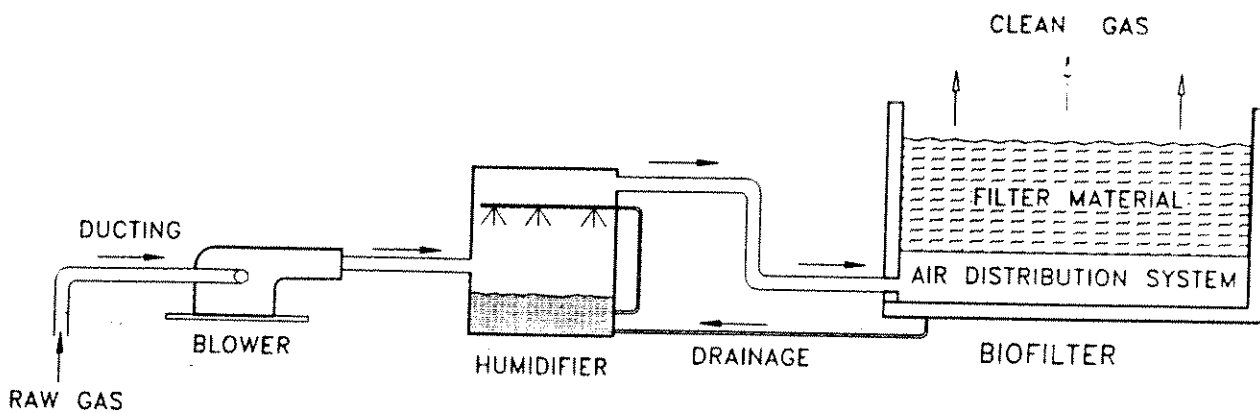


Figure 4 Biofilter



* Schematic of an open single-bed biofilter system.

Table II **Operating Parameters for Biotower-type Biofilters**

Retention time required	> 15 seconds
Filter bed temperature	15 - 45 °C (60 - 113°F)
Filter bed pH	7 - 8
Filter bed moisture content	50% - 70% (by weight)
Influent gas humidity	80% - 100%
Filter media porosity	80% - 90%
Maximum surface loading	500 m ³ /(m ² .hour) (27 cfm/sq. ft.)
Pressure drop (1 meter bed)	< 0.25 kPa (< 12 in. of water)
Maximum pollutants concentration	1 g/m ³ (total) (pure Methanol - 765 ppm) (pure Ethanol - 530 ppm) (pure Acetone - 400 ppm)
Maximum filter elimination capacity	200 g/h/m ² (8 lbm/day/yd ²)
Filter life	2 - 5 years

As shown in Figure 5, there are three operational regions in a biofilter, i.e. reaction controlled, diffusion controlled, and 100% conversion. When the concentrations are very low the elimination capacity is equal to inlet load or complete conversion can be expected. At high influent concentrations, the system is in the reaction controlled region, whereby all the biological activity in the biofilm is completely utilized. The diffusion controlled region is in between the other two regions.

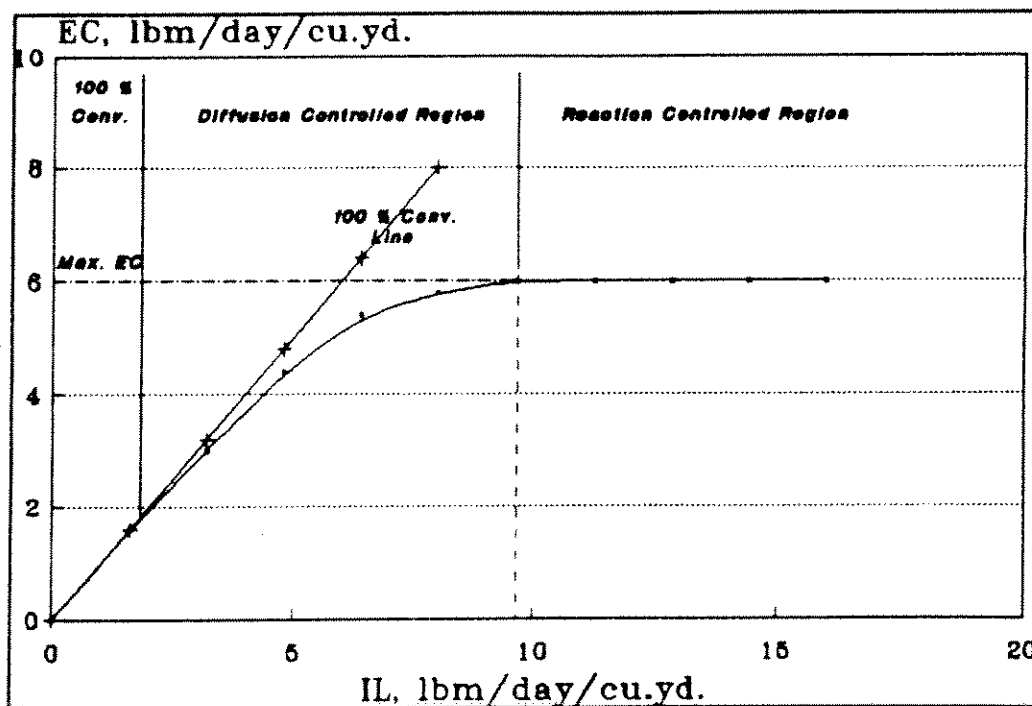


Figure 5 Relationship between Elimination Capacity of a Biofilter and the Inlet Gas Loading.

Because of the uncertainties involved in the biological degradation process, pilot testing (or dimensioning), with a small portable unit, is necessary for every potential application. This testing or dimensioning process allows the determination of scale-up parameters required to obtain a desired removal efficiency. In this process, the elimination capacity, for each compound in the gas stream, and the total volume of filter substrate required are determined.

DISCUSSION

Biofiltration is truly a lean emissions abatement technology. It is applicable to air streams containing low concentrations (< 1000 ppm) of water soluble, organic compounds. The heterotrophic bacteria present oxidize the compounds in a humid, aerobic environment. The basis of design of a full-scale commercial unit is the proper choice of a filter substrate (typically, compost), inoculation of microorganisms, and scale-up from pilot-testing (or dimensioning).

Biofilters have been installed at many locations in Europe. Although there are many earth-type biofilters used for odor control in U.S., no biotower designs have been installed for control of other emissions from chemical plants. Earth biofilters (many vendors) are not as reliable or controllable, as biotowers and could be source of potential groundwater problems. Biotowers afford better control because of their closed design and are much more reliable. Most chemical companies throughout Europe and in U.S. seem to prefer the biotower design (only two vendors). Du Pont, like Monsanto, 3M, GE, Shell, etc., is assessing the implementation of this technology at its plant sites throughout the U.S. The first attempt in evaluating this technology is being conducted at the Du Pont-Howson plant site in Soest, The Netherlands, for control of acetone emissions.

The vendor-installed investment cost (\$20 per cfm) for biotower-type design is comparable to other technologies used for control of volatile organic compounds such as regenerative incineration, reactive scrubbing, etc. Nevertheless, biofiltration has a major advantage in terms of its low operating costs. Typically, the annual operating costs²³ for treatment of contaminated air compare as follows: biofiltration - \$5 - \$14 per cfm; scrubbing - \$18 - \$47 per cfm; incineration - \$105 - \$168 per cfm; and carbon adsorption - \$179 - \$210 per cfm.

There are, however, many questions and issues that have to be resolved before the existing technology is widely accepted in the U.S. For example: Are there supplemental nutrient or carbon-source requirements for certain classes of compounds? How is hypersalination dealt with? Will the exhausted filter material be classified as a hazardous waste and how will it be handled? How frequently does the bed have to be replaced? How will the biofilter respond to variations in volumetric flow, concentration, and composition? Will the degradation be complete for all compounds in a mixture? What secondary compounds are generated in the metabolic oxidation process? and Are there secondary pollution or odor issues that have to be dealt with?