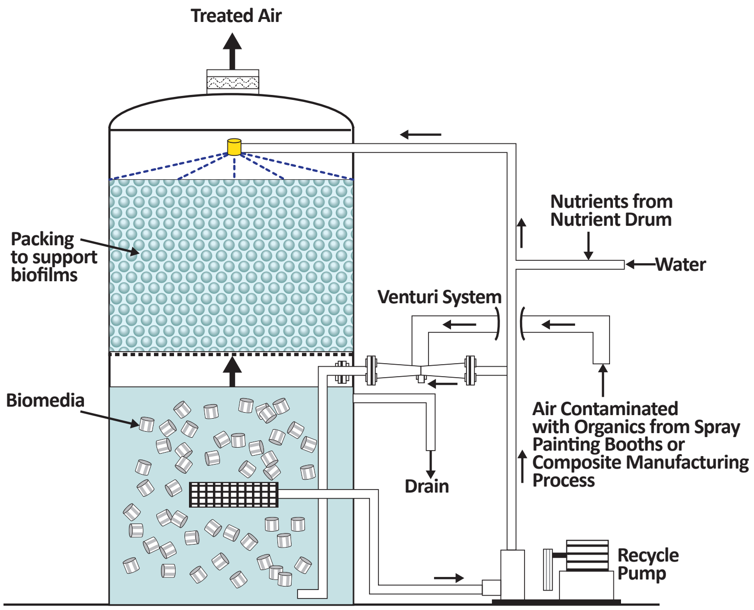
BIOTRICKLING FILTERS FOR TREATING EMISSIONS OF VOLATILE ORGANICS COMPOUNDS (VOCs)

Air emissions from contaminated sites contain a variety of hydrocarbons, such as benzene, toluene, ethyl benzene, chlorinated volatiles and other organics. Technologies used to control emissions of volatile organics (VOCs) from include: (1) thermal and catalytic oxidizers; (2) carbon adsorption; (3) condensers; and (4) biofilters. Thermal and catalytic oxidizers use high temperature to oxidize the chemicals to carbon dioxide and water. Typically, they use natural gas to effectively maintain the destruction temperature needed to prevent the emission of unburnt hydrocarbons. Due to increases in natural gas prices and due to high operating temperatures, thermal and catalytic oxidizers have a high investment and operating cost. Carbon adsorption removes the organic vapors by selective adsorption on activated carbon. While this is not a treatment system, the activated carbon is periodically removed when saturated and either destroyed or regenerated using high temperature to desorb the organics from the carbon surface and reactivate the carbon. Activated carbon replacement is a recurring cost which can be substantial especially if the organic concentrations in the gas phase are high. Also, activated carbons saturated with hydrocarbons are a fire hazard that have to be handled carefully to prevent fugitive air emissions of the adsorbed compounds. Condensers, utilize a low temperature to condense the organics into a liquid phase which can be separated from the gas phase. Typically, condensers can only reduce the concentration of volatile organics but not eliminate them and they cannot reduce the concentrations enough for direct discharge into ambient air.

Biofilters use living bacteria to biologically convert the organics to carbon dioxide and water. There are two kinds of biofilters: (1) Naturally-bioactive media, which includes biofilters using peat, compost, soil, wood bark type of media that contains active microorganisms naturally present within the media; and (2) synthetic media biofilters, which utilize a high surface area plastic, ceramic, or foam type of media, which has to be initially inoculated with active bacteria. Naturally bioactive media biofilters have many disadvantages, which includes periodic replacement of media, high pressure drop, clogging due to biomass growth, low biodegradation rates and large footprint. For treating volatile organic compounds, such as in spray painting and composite manufacturing applications, naturally-bioactive media biofilters cannot function very long before clogging due to biomass growth. Synthetic media biofilters have been successfully used for controlling volatile compound emissions. These filters handle biomass growth by allowing excess biomass to slough-off from the surface of the media and is then washed off by the trickling water. The synthetic biomedia used in these filters is capable of being washed down to enable the excess biomass growth to be removed from the filter bed. In the case of biotreating volatile organics, handling excessive biomass growth is one major issue. Another important issue is residence time of the organics in the biotreatment zone. Typically, some volatile organics, such as xylenes, are slow to biodegrade, due to the presence of tertiary carbons on the molecular structure. It has been known that branched hydrocarbons are more difficult to biodegrade than straight chains. In a typical biotrickling filter, gas-phase residence time has to be less than 2 minutes to maintain a reasonable size of the treatment system. However, some of the branched hydrocarbons require more residence time than 2 minutes to enable complete biodegradation. Finally, intermittent operation of the processes generating the organic emissions also limits use of biotrickling filters, since without the availability of the organic compounds, biomass cannot be sustained within the biotrickling filter.

PCC, in collaboration with PRD Tech, Inc., Leader in biofiltration technology and implementation, brings together the leading edge technology with the extensive experience of PCC in VOC destruction and project implementation.

Figure 1. Schematic of the Dual-Phase Biotrickling Filter Process.



Our collaboration partner in this area, PRD Tech, Inc., has developed a **Dual-Phase Biotrickling Filter** that addresses all of the above issues by using a liquid-phase reactor for treating volatile organic emissions from contaminated sites. Figure 1 shows a schematic of the skid-mounted treatment system. The system consists of a liquid-phase bioreactor, containing neutrally-buoyant high surface area biomedia, which treats the water soluble compounds and a packed bed above the bioreactor for treating the hydrophobic compounds. Air contaminated with volatile organics from the spray painting booths or composite manufacturing process is drawn by the venturi system and discharged at the bottom of the bioreactor. A recycle pump is used to operate the venturi system, which also supplies liquid to a spray head located above the packed bed, containing high surface area media for supporting active biofilms. Compounds which are not treated in the bioreactor are biodegraded in the packed bed above the bioreactor. Water with mineral nutrients is added to the spray liquid and excess water overflows from the liquid bioreactor into the drain. There are several advantages of this design, when compared with a conventional biotrickling filter or a liquid-phase bioreactor:

- Particulate emissions from the site enter the liquid phase bioreactor and do not clog the packed bed;
- Hydrophobic compounds, such as xylenes, adsorb on the biomedia, present in the liquid-phase bioreactor, thereby enabling more treatment time for these slowly degrading compounds;
- Water-insoluble compounds that are not treated in the liquid phase, get biodegraded in the packed bed, above the bioreactor liquid;
- Clogging of media in biotrickling filters is eliminated by using a liquid-phase bioreactor for removing the bulk of the organics;
- The process may not need a gas blower, which requires frequent maintenance;
- Aerobic conditions are easily maintained in the bioreactor due to vigorous mixing by the air-liquid stream that is discharged at the bottom of the bioreactor; and
- The system can treat emissions from intermittent processes, since when no organics are being supplied in the incoming air, there is a supply of soluble organics in the liquid phase and in the gas phase flowing through the packing media.

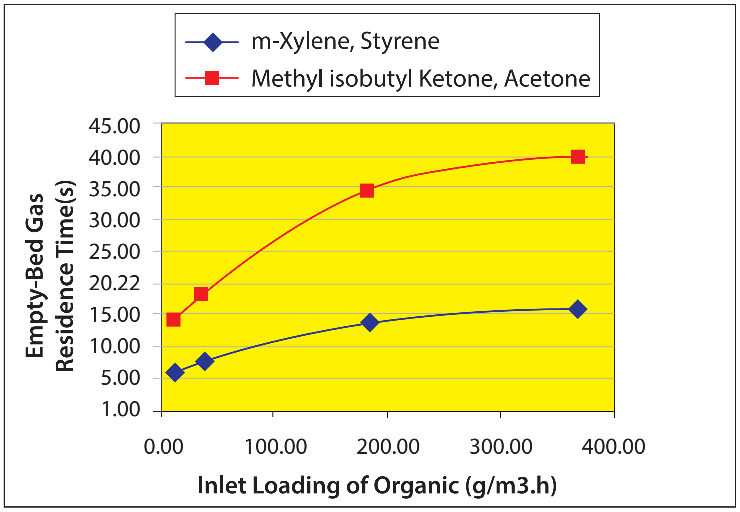
The above process has been tested with a variety of organics, such as xylenes, toluene, acetone, formaldehyde, benzene, methanol, methylene chloride, phenol, hexane, heptane, styrene, acrylonitrile, ethyl benzene, p-cumene, methyl ethyl benzene, methyl ethyl ketone, and terpenes. The performance of the bioreactor system depends on the Henry's Law Constant, Octanol-Water Partition coefficient, and Biodegradation Rate Constant. Table 1 below summarizes these parameters for some of the organics that were tested in the bioreactor system.

Table 1. Critical Parameters for the Contaminants.

Compound	Mol. Weight	Henry's Law Constant (atm/mol. m3)	Ln(Octanol-Water Coefficient	Biodeg. Rate Constant (g/s.g biomass)
P-Xylene	106.2	7.44×10^{-3}	3.15	31.1
Toluene	92.4	6.42×10^{-3}	2.69	73.5
Acetone	58.0	2.5×10^{-5}	-0.24	1.3
Styrene	104.2	2.61×10^{-3}	3.16	31.1
Methanol	32.0	5.2×10^{-6}	-0.7	18.0
Hexane	86.2	0.768	2.73	15.3
nHeptane	100.02	2.02	3.16	15.3
Methyl isobutyl Ketone	100.2	3.9×10^{-4}	1.38	0.74
Ethanol	46.1	3.03×10^{-5}	-0.32	8.8

The performance of the bioreactor system for some of these organics is shown below in Figure 2.

Figure 2. Loading versus Gas Residence time for 100% Treatment Efficiency.



The bioreactor system is capable of treating 100% of the inlet loading of the organic in the gas phase in 40 seconds of gas-phase residence time in the packed bed media.

PCC supplies the complete skid-mounted Bioreactor system, with automatic controls, which has to connected to the gas flow, inlet water and drain.

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