

ACTIVATED CARBON ADSORPTION FOR TREATMENT OF VOC EMISSIONS

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A review of the characteristics of activated carbon and its applicability to emission control of VOC's. Design and costs of carbon systems are also discussed.

INTRODUCTION

The principal use of vapor phase activated carbon in the environmental field is for the removal of volatile organic compounds such as hydrocarbons, solvents, toxic gases and organic based odors. In addition, chemically impregnated activated carbons can be used to control certain inorganic pollutants such as hydrogen sulfide, mercury, or radon.

When properly applied, the adsorption process will remove pollutants for which it is designed, to virtually non-detectable levels. In fact one of the first large-scale uses of activated carbon was in military gas masks where complete contaminant removal is essential. Carbon adsorption is equally effective on single component emissions as well as complex mixtures of pollutants.

In the industrial area, the most common applications of activated carbon are for process off-gases, tank vent emissions, work area air purification, and odor control, either within the plant or related to plant exhausts. Additionally, activated carbon is used in the hazardous waste remediation area to treat off-gases from air strippers and from soil vapor extraction remediation projects.

EVALUATION OF ALTERNATIVE TREATMENT PROCESSES	LOW VOC LEVELS	HIGH VOC LEVELS	CONTINUOUS LOADS	INTERMITTENT LOADS	HALOGENATED ORGANICS	TEMP>150F	TEMP<150F	HIGH FLOWS	LOW FLOWS	HIGH HUMIDITY	INORGANIC PARTICLES
ACTIVATED CARBON	•		•	•	•		•	•	•		
THERMALOXIDATION		•	•			•			•	•	
SCRUBBERS	•	•	•			•	•	•	•		
PARTICULATE FILTERS			•	•			•			•	•
CATALYTIC OXIDATION		•	•			•			•	•	

TABLE I

APPLICATION CONSIDERATIONS

One of the major issues that must first be addressed when evaluating a specific environmental VOC problem is what treatment technology to consider. For a given situation there are likely a number of treatment alternatives that appear to have some utility.

The first step in this evaluation is to effectively characterize the application. You will need to know at least the following information:

- Flow Rate** - Continuous vs intermittent
- Contaminants Present** - individual contaminants, concentration and variability
- Temperature** - Average and maximum
- Flammability** - Upper and lower explosive limits

Once you have characterized your problem, each technology can be considered for its ability to deal with the conditions identified. As an example, *Table I* lists some of the more common technologies used to control industrial vapor phase pollutants, and the conditions under which they might be most favorably applied. I can't stress enough the importance of this review, as this is where most technical solutions fail. If you solve the wrong problem or pick a technical solution that does not respond to all the variables of your application, poor performance will likely result.

HOW IT WORKS

In the adsorption process, molecules of a contaminated gas are attracted to and accumulate on the surface of the activated carbon. Carbon is a commonly used adsorbent due to its very large surface area. It can be made from a variety of base materials including coal, wood and coconut shells, and is manufactured or activated in a high temperature controlled oxidation process. A pound of highly activated carbon has a surface area approaching 140 acres.

CROSS SECTION OF CARBON

This *Figure 1* presents an artist's rendition of the cross section of an activated carbon particle. Note that almost all of the surface area available for adsorption is associated with its internal pore structure. Also note the relative change in pore diameters, going from very large at the granule surface boundary, to much smaller within the particle interior. Balancing of the large and small pore volumes during the activation process is what makes individual activated carbons perform differently. Molecules of a contaminant tend to adsorb most strongly in areas where the pore diameter of the adsorbent is close to the molecular diameter of the compound.

While most organic compounds will adsorb on activated carbon to some degree, the adsorption process is most effective on higher molecular weight and high boiling point compounds.

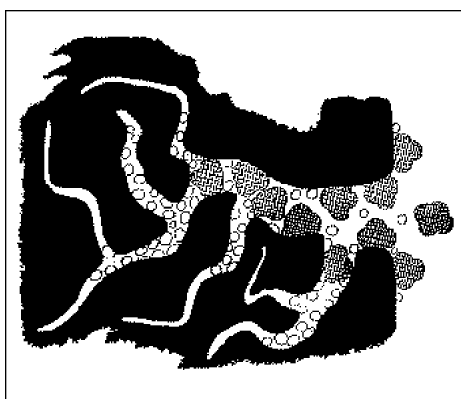


FIGURE 1

LIST OF ORGANIC COMPOUNDS

RELATIVE ADSORPTION RATE				
		MOLECULAR WEIGHT	BOILING POINT	CARBON CAPACITY %
STRONGER	NITROBENZENE	123	211 C	51
	TETRACHLOROETHANE	166	147 C	40
	TETRACHLOROETHYLENE	165	121 C	35
	STYRENE	104	145 C	25
	XYLENE	106	138 C	21
	NAPATHYLENE	128	217 C	20
	TOLUENE	92	111 C	20
	BENZENE	78	80 C	12
	MTBE	88	55 C	12
	HEXANE	86	68 C	7
WEAKER	ETHYL ACRYLATE	100	57 C	5
	DIDHOROETHANE	99	99 C	7
	METHYL ETHYLKETONE	72	80 C	4
	METHYLENE CHLORIDE	84	40 C	2
	ACRILONITRILE	53	74 C	2
	ACETONE	58	56 C	0.8
	VINYLCHLORIDE	62	neg 14 C	0.7
	CHLOROETHANE	64	12 C	0.5
	BROMOTRI FLOROMETHANE	149	neg 58 C	0.13
	METHANE	16	neg 161 C	0.0003

TABLE II

Compounds having a molecular weight over 50 and a boiling point greater than 50 degrees centigrade are good candidates for adsorption. *TABLE II* presents a representative list of organic compounds and their relative adsorption strength. Organic contaminants are often classified as weakly, moderately, or strongly adsorbed. You will note that a compound such as nitrobenzene having a molecular weight of 123 and a boiling point of 211 C is characterized as a very strong adsorber. On the other hand a compound such as methane which has a molecular weight of 16 and a boiling point of -161 C is a very weakly adsorbed compound. In fact, at this capacity, for all practical purposes, methane removal with activated carbon would not be cost effective.

ABSORPTION CAPACITY

Physical adsorption is dependant on the characteristics of the contaminant to be adsorbed, the temperature of the gas stream to be processed, and the concentration of the contaminant in the gas stream. The adsorption capacity for a particular contaminant represents the amount of the contaminant that can be adsorbed on a unit weight of activated carbon consumed at the conditions present in the application. Typical adsorption capacities for moderately adsorbed compounds range from 5 to 30 percent of the weight of the carbon.

TRICHLOROETHYLENE ISOTHERM

The adsorption isotherm plot shows the influence of concentration on adsorption capacity. *Figure II* presents an adsorption isotherm used to predict adsorption capacity for trichloroethylene. Note how the adsorption capacity varies from 20 to 65 percent over the concentration range of 10 to 10000 ppm in the gas stream.

A series of isotherms at differing temperatures shows the influence of temperature on adsorption capacity. In *Figure III* you can see the effect of temperature on the same trichloroethylene compound. At 100ppm the capacity of activated carbon for trichloroethylene varies from 17 to 40 percent as the temperature changes from 140 to 32 degrees F.

Fortunately, most carbon suppliers have developed isotherms for a range of environmental contaminants. At Carbtrol we have built a computerized database of adsorption isotherms so that we can easily model most environmental applications. By supplying to us the gas flow rate, the contaminant concentration and the temperature of the gas stream, a carbon usage prediction can be made.

DESIGN CONSIDERATIONS

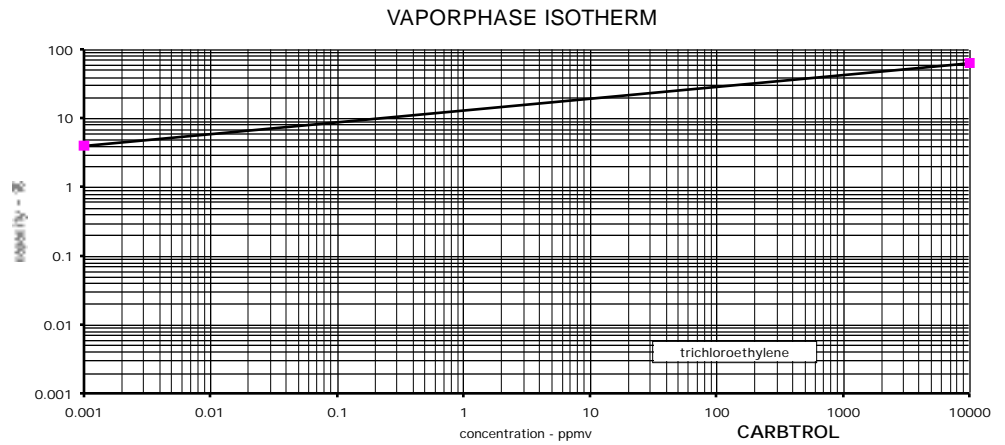


FIGURE II

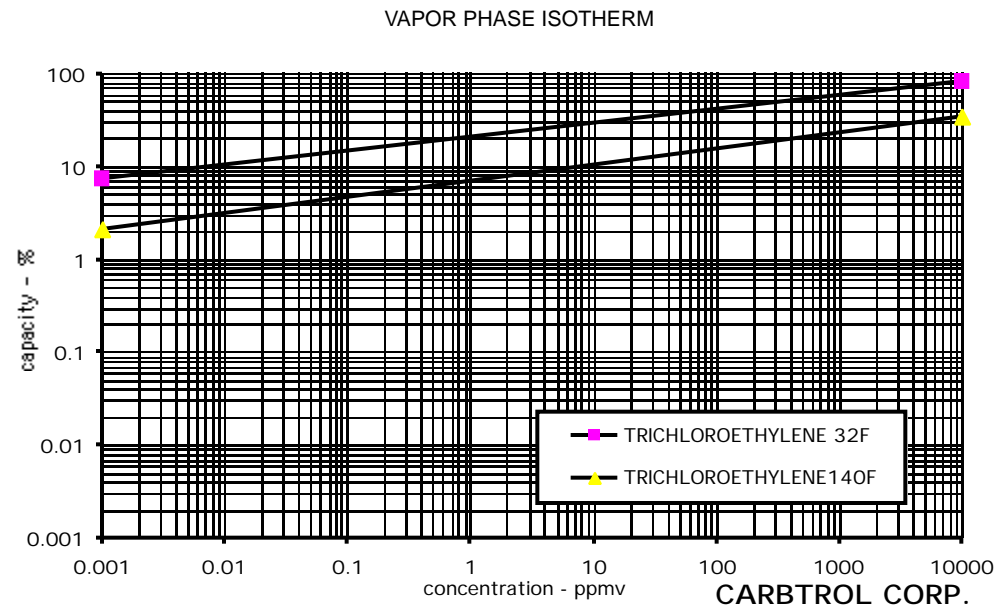
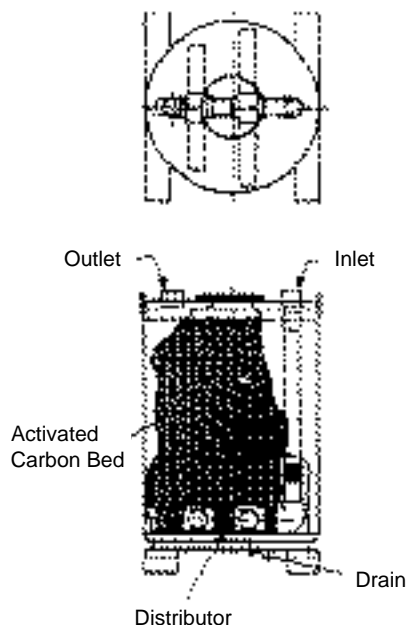


FIGURE III



CARBTRON G-4 ADSORBER

FIGURE IV

Activated carbons used in the air pollution control field are normally supplied in a granular form with a particle size ranging from 1 to 5 millimeters. In the granular form activated carbon can easily be packed into a containment device through which a contaminated gas stream can be processed for purification.

Figure IV shows the cross section of a typical fixed bed vapor phase adsorber. An adsorption system in its simplest form is made of a containment device (drum or vessel), distribution and collection devices to effect proper circulation of the gas stream through the activated carbon bed, and a means for moving the gas stream through the bed (such as a fan, a blower, or pressurized gas displacement). Packed activated carbon beds can be conveniently config-