Ground Water, Surface Water, and Leachate

Vapour Phase Carbon Adsorption

Introduction:

In this process, the gases are pumped through a series of canisters or columns containing activated carbon to which organic contaminants sorb. To make such a process effective for a long period of time there is a need for the replacement or regeneration of the activated carbon.

Description:

Vapour-phase carbon adsorption is a remediation technology in which pollutants are removed from air by physical adsorption onto activated carbon grains. In essence this is the transfer of air carried pollutants onto the solid phase. The form of carbon has been "activated" for this purpose by processing it to create porous particles with a large internal surface area (300 to 2,500 square meters per gram of carbon) that attracts and adsorbs organic molecules as well as certain metal and inorganic molecules.
Commercial grades of activated carbon are available for specific use in vapour-phase applications. The granular form of activated carbon is typically used in packed beds through which the contaminated air flows until the concentration of contaminants in the effluent from the carbon bed exceeds a predefined concentration. Granular-activated carbon (GAC) systems typically consist of one or more vessels filled with carbon connected in series and/or parallel operating under atmospheric, negative, or positive pressure. The carbon can then be regenerated in place, regenerated at an off-site facility, or disposed of, depending upon economic considerations.

Carbon can be used in conjunction with steam reforming. Steam reforming is a technology designed to destroy halogenated solvents (such as carbon tetrachloride, chloroform, TCE and TCA) sorbed to activated carbon by reaction with superheated steam (steam reforming).

Another more recent technology related to vapour phase carbon sorption is the Brayton-cycle heat pump (BCHP). This technology created by Idaho National Engineering Laboratory offers a method for VOC recovery and recycling. A Brayton-cycle heat pump can condense volatile organic compounds (VOCs) from an air stream, which offers the potential for both recovery and either on-site or off-site recycle of a wide range of VOCs. The VOC-laden air stream can come from either vapour vacuum extraction of soil or air stripping of contaminated ground water.

The technology consists of activated carbon adsorbers located at each extraction well, plus a truck-mounted BCHP to regenerate the adsorbers on a periodic basis. The VOC-laden air from the well is passed through the carbon bed, adsorbing the VOCs. When the bed becomes saturated, hot nitrogen from the regenerator is used to desorb the VOCs from the bed. The nitrogen passes through a chiller, is compressed, and is then cooled in a recuperator, where 50% to 80% of the organics are recovered. The partially depleted nitrogen stream is then expanded through a turbine, lowering the temperature to as low as -100ºC and condensing the remaining organics. The clean nitrogen passes through the recuperator to cool the VOC-laden nitrogen before returning to the carbon bed. The only outputs will be the clean off-gas from the well and a small amount of recovered organics.

Applicability:

Vapour-phase carbon adsorption is not suggested to eliminate high contaminant concentrations from effluent air streams. Economics support pre-treatment of the VOC stream, followed by a vapour-phase GAC system as a polishing step.

Limitations:

- Spent carbon transport may require hazardous waste handling.
- The sorbed contaminants must be destroyed, often by thermal treatment.
- At higher humidity's (those exceeding 50%) the capacity of the carbon can be greatly impaired.
- Elevated temperatures from SVE pumps (greater than 38° C) inhibit sorption capacity.
- Biological growth on carbon or high particulate loadings can reduce flow through the bed.
- Some compounds, such as ketones, may cause carbon bed fires because of their high heat release upon adsorption.

Data Needs:

Factors affecting sorption can be temperature, type of carbon, type and concentration of contaminant, residence time in the bed and in gas phase adsorption, and humidity. At high temperatures, the volatility of compounds increases, consequently reducing their affinity for carbon. Compounds are adsorbed better at high pH. Activated carbon is available from manufacturers in a range of grades with different properties and affinities for adsorption of contaminants. Therefore, it is often essential to carry out adsorption tests with a particular contaminated stream on a selection of activated carbons from a number of manufacturers to isolate a carbon that will be most efficient for an exact application.

Performance Data:

For gaseous systems, linear bed velocities typically range between 2 and 30 m per minute, although velocities as high as 65 m per minute have been used, and residence times range from one tenth of a second to a minute.

If there is insignificant or no contamination, a batch isotherm test is generally enough to design the system. It is also feasible to use historical data that are obtainable from vendors for a variety of contaminants to achieve initial design estimates and to substantiate test results. Isotherm tests can be employed to evaluate different forms of carbon and to investigate the effect of temperature on performance. If the use of regenerated carbon is intended, tests should be performed with regenerated carbon to attain a more pragmatic estimate of the average sorptive capacity that can be expected during operation. Regenerated carbon costs less but may have a lower adsorptive capacity than new carbon.

Cost:

Equipment costs range from less than £ 2500 for a 1 m^3 min^{-1} unit to £30,000 for a 200 m^3 min^{-1} unit. Carbon cost is in the range of £ 10 per kg.