Why Activated Carbon Makes Sense for PCB Remediation

By Jeff Marmarelli TIGG Corporation

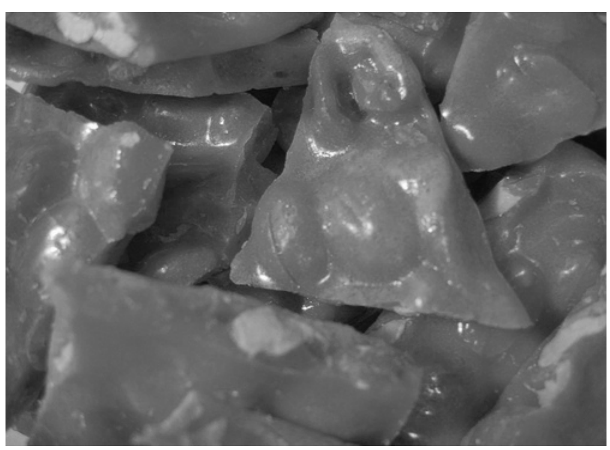
For about 50 years, polychlorinated biphenyls (PCBs) were commonly used in industrial materials including, caulking, cutting oils, inks, paints and as dielectric fluids in electrical equipment such as transformers and capacitors. Concerns over health effects led to a North American ban of manufacturing PCBs in 1977. By the mid-1980s, an initiative was started to clean up contaminated areas and to phase out PCB-containing equipment and products that were still in use. This cleanup effort continues today.

Careless disposal practices and accidental discharges in the past contribute to the present amount of PCBs in groundwater and in sediments of rivers and lakes. Growing public and government concern over health hazards has led to new practices to safely remove and dispose of PCBs. Residual contamination has been effectively treated by systems using activated carbon adsorption media.

Activated carbon is widely used for the adsorption of many contaminants from liquid and air streams. The activated carbon is produced from carbonaceous organic substances including bituminous coal, coconut shell, lignite, bone, wood and other materials. It is used in many applications such as food production and liquid decolorization.

Adsorption results from a physical process in which layers of atoms or molecules of one substance are attracted onto the surface structure of another substance. Activated carbon's extremely high surface area within its extensive pore structure makes it an ideal adsorbent. One pound of activated carbon has the surface area equivalent to six football fields.

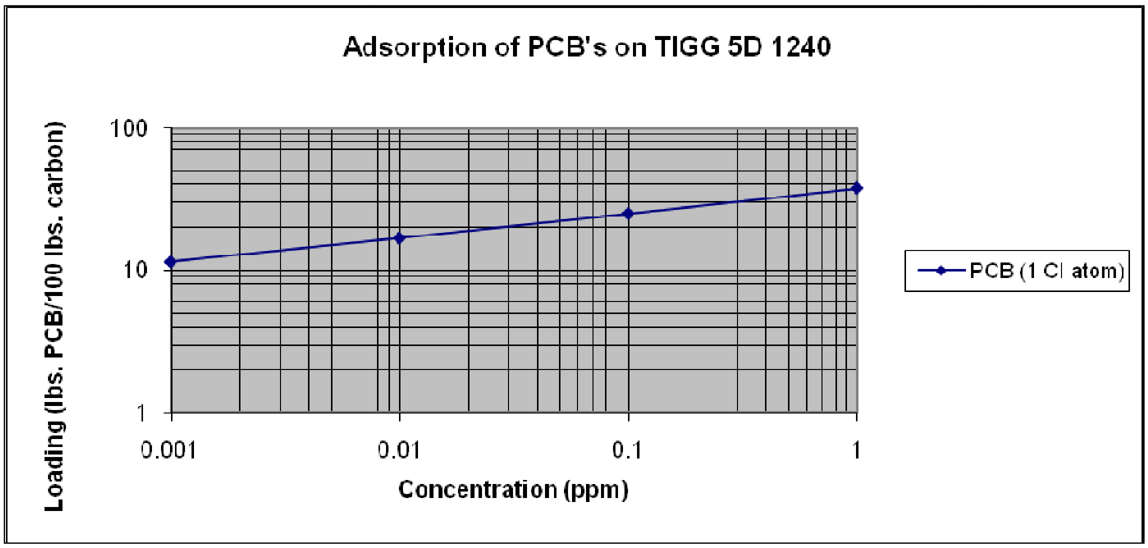
Activated carbon exhibits a graphitic plate structure, and one may liken the formation of adsorption surfaces to a box of peanut brittle, with the highest energy adsorption sites formed at the intersections of the plates (see image below). The iodine number is used as a general measurement of the surface area of the activated carbon. These numbers generally range from 900-1100 for higher quality carbons.



Activated carbons tend to adsorb organic compounds with increasing affinity as adsorbate (the material being adsorbed) molecular weight, boiling point, and refractive index increase and as solubility decreases. Thus, activated carbon has a high affinity for PCBs due to their high molecular weight, high indices of refraction, and very low solubilities. PCBs have a very large molecular structure and for effective adsorption will require an activated carbon with a compatible pore size. Different base materials will yield different pore structures. For example, the pore structure of coal-based carbon will better accommodate these types of molecules as compared to coconut-based carbon. The latter are more suited to smaller molecular weight compounds with low boiling points and, therefore, are not as effective in this application.

The surface loading of adsorbate on activated carbon varies with the concentration and conditions in the fluid stream. In order to evaluate the economic potential of an application, the activated carbon isotherms can be developed for the particular compound at a given set of conditions. Many isotherms are already available for various compounds, including PCBs. They can be obtained from carbon manufacturers, purifications companies, and EPA literature. They also can be developed in the lab using simple procedures.

The figure below illustrates an isotherm for a PCB molecule with one chlorine atom on TIGG 5D 1240 coal-based activated carbon. As with any testing, these isotherms are performed under controlled laboratory conditions. Actual performance in the field can be affected by factors associated with the treatment system.



When dealing with PCB contaminated groundwater, the solubility of the PCB isomers in the water can typically range between 20 parts per billion (ppb) and 60 ppb with solubilities generally below 1 part per million. Above these levels, the PCBs will be found as free product. As illustrated by the isotherm, PCBs are readily adsorbed by activated carbon, with the example of the PCB isomer with only one chlorine atom (the lowest affinity for all PCB isomers) showing excellent loading on the carbon, even at 1 ppb levels. The result is that effluent levels below 1 ppb are achievable.

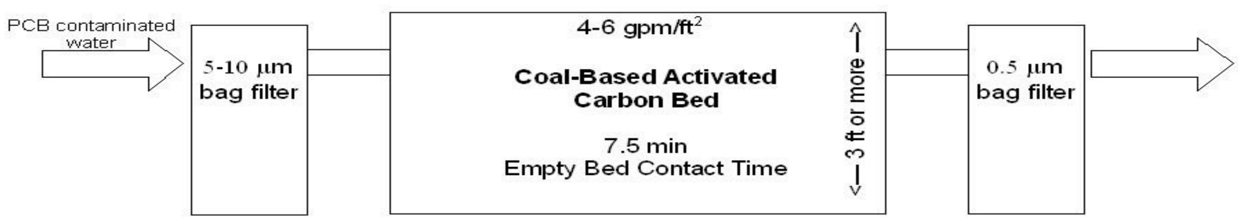
Treatment of this water depends not only on keeping the carbon "clean" for proper kinetic transference of the molecules but also the contact time allowed for the adsorption to take place. Field experience has shown that often under turbid conditions, the PCB levels in the effluent following the carbon adsorbers in the treatment train can be as high as 5 ppb. The reason for the higher than expected levels in the effluent is that the PCBs will attach to colloidal material in the water or any carbon fines and pass through the bed without being adsorbed.

In order to help decrease these residual levels, upstream and downstream filtration is required. Typically a 5-10 micron bagfilter is installed prior to the carbon bed and a 0.5 micron bagfilter is installed after the carbon bed, prior to discharge. These processes remove most suspended solids that may be entering the carbon and essentially "plugging" the bed of the carbon, thus limiting adsorption. Furthermore, this filtration will help capture any solids that could pass from the carbon bed and could be making their way through to the effluent. Other steps may be required for applications where filtration alone will be insufficient, such as when submicronic colloidal solids are suspended in the influent water.

In addition to the pre- and post-filtration of the carbon bed, the carbon bed needs to be properly sized. Both the bed surface area and the carbon bed depth affect removal efficiency. About seven to eight minutes empty-bed contact time (EBCT, or time to pass fluid through a given actual volume of carbon present as a theoretically open volume) is optimal for proper adsorption. Typically, a minimum of three feet of carbon bed depth is required. The surface area is typically designed to promote a superficial velocity of four to six gallons per minute per square foot. Slower velocities can be used, but very low velocities should be avoided as this may promote the occurrence of channeling, or the liquid seeking a path of least resistance through the carbon bed, resulting in poor distribution.

Typical PCB Removal System

(varies according to specific applications)



Overall, activated carbon adsorption is an effective way of reducing PCB contamination in groundwater. Successful results can be achieved with a properly designed system that addresses solids-control including both pre-filtration and post-filtration, along with proper carbon selection and bed design parameters including bed surface area, depth, and contact time.

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