

A Look at PAC and GAC Based Remediation Programs

There has been a disturbing trend in the environmental remediation industry that few, if any consulting engineering firms, experts or academics are addressing. More specifically, as an industry, rather than question the validity of claims made by “non-destructive” technologies, the environmental remediation industry has blindly accepted these products.

More and more consulting engineers are utilizing products like BOS 100, BOS 200 and PlumeStop, without regard to physical chemistry and the nature of Activated Carbon (AC). Without exception, any AC based product relies on adsorption and absorption. It is important to understand both processes and the differences between them when applying these products

The major difference between adsorption and absorption is that one is a surface process and the other a bulk process.

Adsorption — takes place on the surface of a substrate.

Absorption — one substance enters the bulk, or volume, of another substance (e.g. a liquid absorbed by a solid).

Additionally, desorption needs to be applied to the equation. **Desorption** is the release of one substance from another, either from the surface or through the surface. Desorption can occur when an equilibrium situation is altered. As an example, at equilibrium, the amount of carbon dioxide entering and leaving the water from the AC will be the same, and the carbon dioxide concentration in the water will be constant. If the water temperature decreases, the equilibrium and solubility are changed, and the carbon dioxide will desorb from the AC, increasing the carbon dioxide content of the bulk water.

To graphically understand how these three phenomenon act (adsorption, absorption and desorption), three graphs are presented for discussion: the adsorption of metals by AC, the absorption of CO₂ and CH₄ by AC and the desorption of TCE by various media.

Relating the physical chemistry occurring in the various AC products to the in-situ applications for the degradation of chlorinated volatile organic compounds (CVOCs), results in an understanding of the biological inhibitory effects seen by Kameryn McGee, in the 8/2018 paper, “*The Influence of In-Situ Carbon on Biodegradation of Chlorinated Solvents*”. (https://tigerprints.clemson.edu/cgi/viewcontent.cgi?article=3932&context=all_theses)

Figure 1 shows the high adsorption capabilities of GAC for heavy metals. As a consequence, the metals’ concentrations present a toxic environment at the surface of the AC

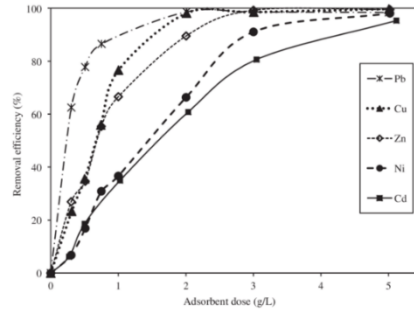


Figure 1: Adsorption of select metals to GAC

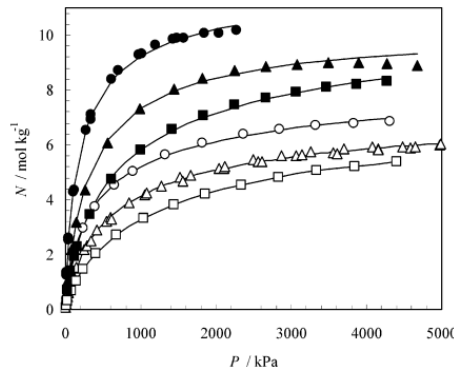


Figure 2: Absorption isotherms of methane and carbon dioxide on GAC: Solid figures represent CO₂ at various temperatures and hollow figures represent CH₄ at various temperatures.

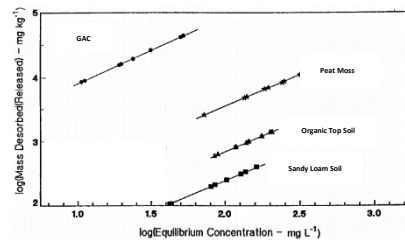


Figure 3: Desorption isotherms of TCE on various media.

Figure 2 provides evidence that AC products have a high affinity for both CO₂ and CH₄. This affinity for CO₂ is nearly twice that for CH₄. These affinities in conjunction with the observation made by McGee that AC has been shown to facilitate interspecies electron transfer begins to explain the inhibitory effects AC products have on reductive dechlorination. As McGee notes, “not only does the activated carbon assist in the movement of electrons from non-methanogens, either the Dhc (*Dehalococcoides ethenogenes* strain 195) or other non-methanogen organisms present in the environment, to methanogens”, the CO₂ absorbed by the AC provides an abundant supply of electron

acceptors. Methanogens use CO₂ taken up from their growth environment as the carbon substrate for growth. They use some CO₂ as the ultimate oxidizing agent of an electron transport chain which, by a chemiosmotic mechanism, maintains a transmembrane electrochemical ion gradient which powers ATP production. In AC products in which zero-valent-iron (ZVI) is added, the ZVI further provides, via hydrolysis more hydrogen and hydroxide at the AC surface. Additionally, a methanogen can electromethanogenically produce methane without exogenously-supplied hydrogen. In the reaction, the methanogen utilizes molecular hydrogen, which was evolved by the abiotic electrochemical reaction, for the hydrogenotrophic methanogenesis. In totality, the AC products function particularly well as methanogen incubators. The evolved methane then is readily absorbed to the AC.

The Freundlich constants, k and 1/n for methane are 1.188 and 1.167 respectively. The Freundlich constants for Trichloroethylene (TCE) are 28 (k) and 0.62 (1/n). Given these vastly differing sorptive properties, it is little wonder that initially, AC products demonstrate a high removal efficacy for TCE when emplaced into the subsurface. It is this initial “disappearance” of the targeted compound of concern that offers many consulting engineers and state agencies hope for a rapid remediation process.

However, over a short period of time the molar loading of the AC by CH₄ accelerates the desorption of the TCE before equilibrium is reached (**Figure 3**). Without the benefit of reductive dechlorination at the surface of the AC by *Dehalococcoides ethenogenes* (Dhc) the sorbed CVOCs are released into the bulk groundwater well ahead of the AC/water system reaching equilibrium.

K. McGee, concludes, “In the presence of high mass loading of both GAC and PAC amended bottles, there is no evidence of dechlorination, or very minimal as seen with the lipid amended initial series batch incubations.” McGee also addresses low AC mass loading cases with, “Cis-DCE is present in both low mass loading rates of PAC and GAC in the electron donor series but is present in higher concentrations in the no carbon amendments. VC and ethene are present in small concentrations in the low mass loading of PAC and in higher concentration in the no carbon amended incubations for all electron donor incubations, however there is no complete dechlorination in any bottles.”

The environmental industry’s rush to a “silver bullet” as presented by vendor claims has again been brought into question by quantitative analysis. Unfortunately, the case against AC based CVOC remediation was in front of us all the time, if we as an industry had looked at the physical chemistry of AC.