Use of Carbon Derived from Almond Shells to Filter Municipal Drinking Water Supplies

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Changing spent carbon from GAC vessels requires good coordination of labor, new materials and water system requirements.

Background

Decades have passed since DBCP was last used in California, but the compound still persists in San Joaquin Valley groundwater. Activated carbon is considered a best technology treatment technique by the EPA for DBCP removal from water. In the City of Fresno alone, 30+ activated carbon filtration sites account for the utilization of nearly 700,000 pounds of activated carbon. One of the DBCP-contaminated wells operated by the Fresno Dept. of Public Utilities' Water Division was utilized in this study to compare the performance of granular activated carbon (GAC) prepared from almond shells with coal-based Calgon F-300 activated carbon.

Fresno Water Division, Site T1 in SE Fresno. Well # 184 (center) was used to challenge almond shell GAC with DBCP removal from contaminated water.

Objectives

- Ascertain the effectiveness of using activated carbon made from almond shells to remove various concentrations of Dibromochloro-propane (DBCP), formerly a widely used soil fumigant, from municipal water systems.
- Compare the effectiveness of almond shell-based activated carbon with that of the currently used standard form of activated carbon in terms of their ability to meet both USEPA and local contamination-reduction requirements.

Field Study Results

The experimental columns were in continual operation from December 2011 through June 2012. Particle size distributions of the activated carbons used in the experiments are shown in Figure 1. As both carbon types have the same distribution, void volumes, packing characteristics, and contact times were the same for both carbons. A noticeable difference was the bulk density of the materials were quite different; 0.22 kg/L for almond shell GAC and 0.64 kg/L for F-300. Thus, approximately three times as much carbon was used in the column filter containing the commercial carbon.

Figure 2 provides the results of the column study. The inlet concentration averaged 0.28 µg/L and varied only slightly over the duration of the study. The effluent concentration was below the method detection limit (0.006 µg/L) for about 85 days in the almond shell GAC filter. Then, the effluent concentration slowly increased over approximately 90 days until 50% breakthrough was reached, at which time the experiment was halted. However, it should be noted that the almond shell GAC column still removed DBCP to below the regulatory limit of 0.20 µg/L.

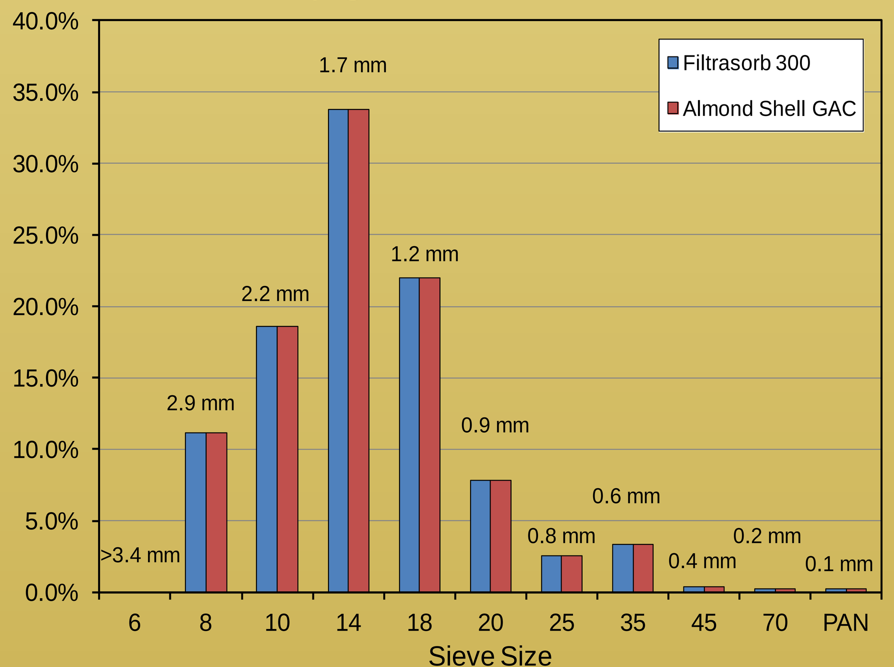

Figure 1. Particle size distribution of commercial activated carbon (F-300) and the GAC made from almond shells.

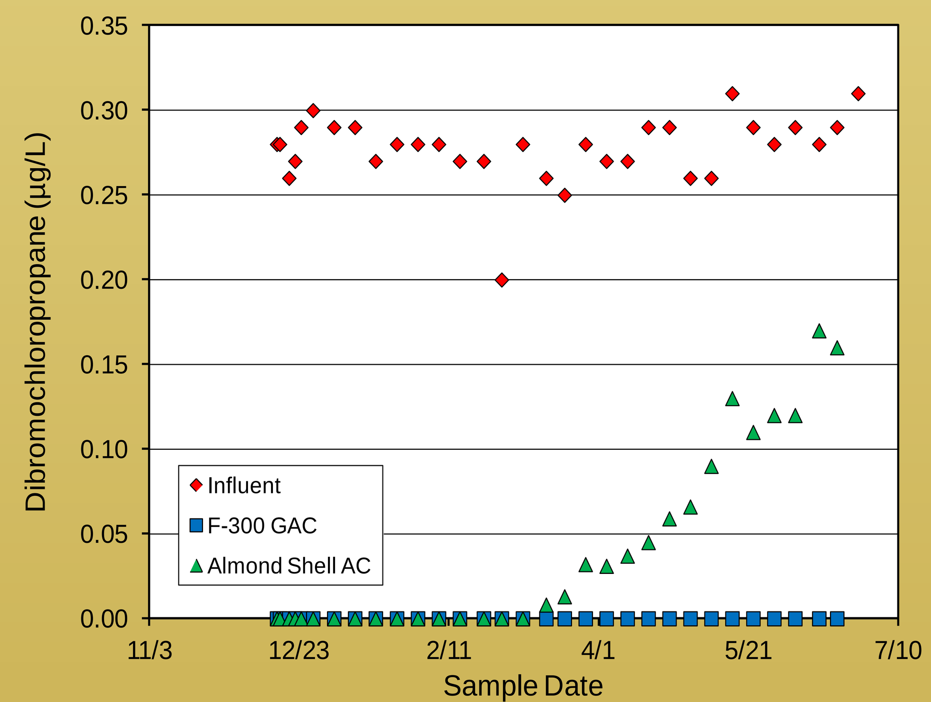

Figure 2. DBCP concentrations of Well # 184 influent , and effluents from experimental columns.

The F-300 carbon continued to remove DBCP to below detection throughout the experiment (Figure 2). This was expected as the F-300 column contained a larger weigh of carbon (due to its higher density) and thus will last longer. However, it is anticipated that the type (shape) of breakthrough curve seen for the almond shell GAC would be the same for the commercial carbon due to its similarity in particle size.

The shape of the curve, representing the effluent, can be described by modeling the breakthrough based on the adsorption of DBCP and the fluid transport in the adsorber column (Rosen, 1954). Modeling of the breakthrough profile demonstrated that the system is mass transfer limited in the film surrounding the adsorbent particles. If the adsorption rate had been limited by the diffusion *in the particle*, a much steeper breakthrough curve would have been expected (Figure 3).

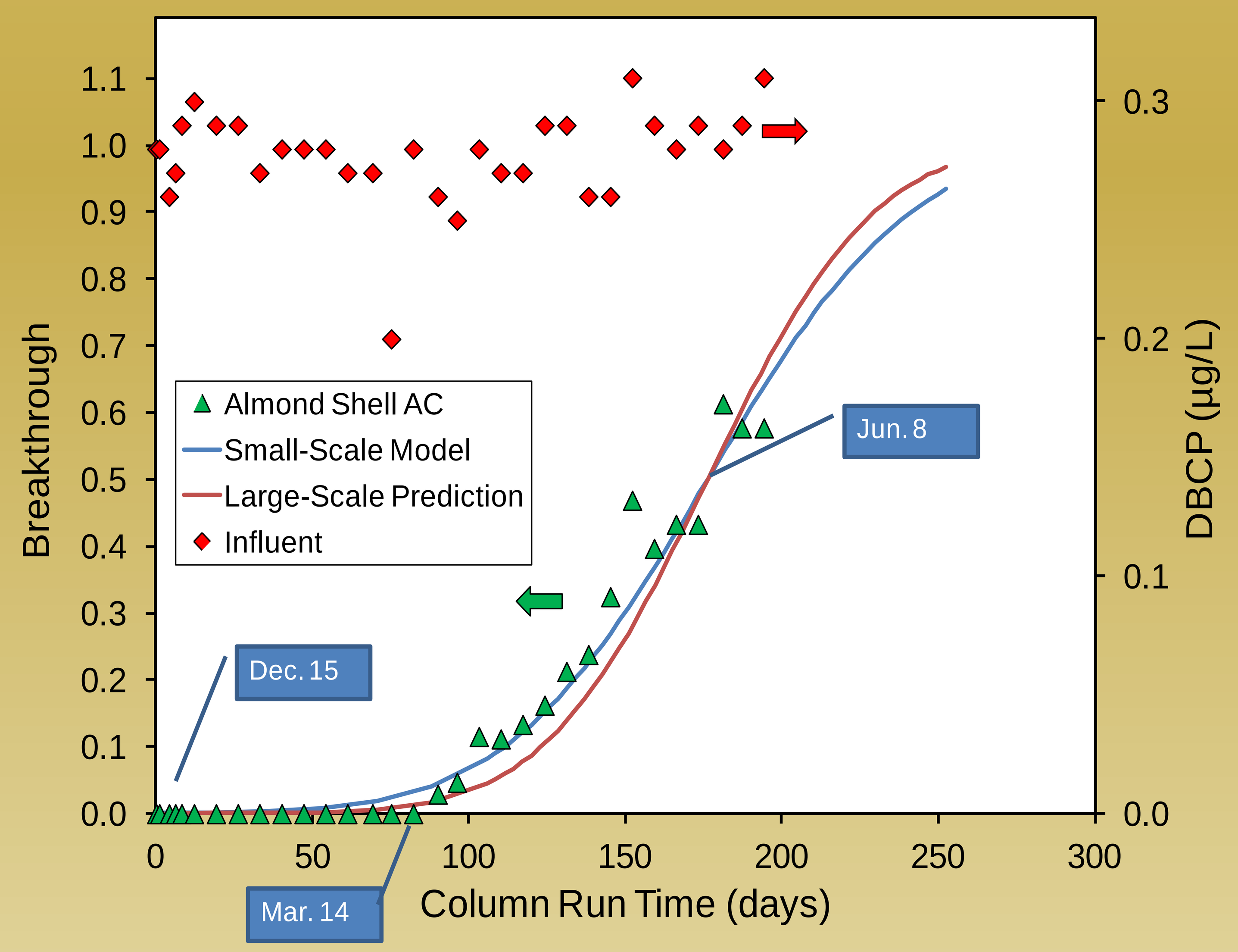

Figure 3. Column studies demonstrated that 100% of the DBCP could be removed for at least 14,000 bed volumes (90 days of operation), and that a mathematical model allowed predictability of large-scale systems.

A 'Model 12' vessel filled with 740 ft^3 of GAC for DBCP removal. Almond shell GAC filter columns were installed at the inflow to this vessel.

Methods & Procedures

- Ground almond shells were pyrolyzed at 650-700°C for 1 hr under nitrogen and steam activated at 800°C for 45 min.
- Glass columns were packed with GAC from almond shells or F-300, the coal-based GAC commonly used for DBCP removal.
- Particle size distributions of almond shell GAC and F-300 were matched.
- Flow rate of DBCP-tainted well water was controlled (34.5 ml/min) such that contact time in the glass columns matched that within the full scale Model 12 vessels.
- Effluents from columns were sampled weekly and analyzed by a certified laboratory for DBCP.

Almond shell GAC and F-300 experimental columns mounted aside the sampling ports of a Model 12 vessel.

Conclusions

- Steam-activated almond shell GAC successfully adsorbed DBCP from tainted municipal well water.
- The column breakthrough profile for the almond shell GAC follows a system which is mass transfer limited in the film surrounding the adsorbent particles.
- Almond shell GAC was substantially less dense than commercial F-300, impacting filter longevity.

References

Rosen, J.B. 1954. General numeric solution for solid diffusion in fixed beds. Ind. Eng. Chem. 46(8):1590-1594.

Acknowledgements

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