Carbon: Optimized Activated Carbons for MTBE Removal in POU/POE Systems—Coconut vs. Coal

By Mark R. Stouffer

Summary: *Coconut shell activated carbon optimized for MTBE adsorption can reduce MTBE to non-detect levels in point-of-use (POU) applications and can meet the stringent requirements of NSF Standard 53. Control over raw material and activation conditions and a rigorous quality assurance program are required to consistently meet performance standards. High quality coconut shell carbon is preferred over coal-based carbon for these and point-of-entry (POE) applications.*

Methyl tertiary-butyl ether (MTBE) is the most common oxygenated fuel additive used in reformulated gasoline. Its health effects are not known, but the U.S. Environmental Protection Agency (USEPA) has classified it as a possible carcinogen. If MTBE is present in drinking water, concentrations as low as 2 parts per billion (ppb) can cause odor and taste problems.

The contamination of ground and surface water with MTBE is a rapidly growing problem throughout the United States. Recent media attention has increased public awareness of this problem; consequently, regulations on MTBE in water are becoming more stringent. For example, New York recently proposed lowering the limit for water from 50 ppb to 10 ppb. In California, a new action level of 13 ppb was established earlier this year.

Since discovery of the problem, remediation of contaminated groundwater has been practiced using activated carbon adsorption. Even though removal of MTBE from water using activated carbon is effective, its removal is difficult due to its high solubility and due to the presence of other organic species in groundwater. Organic species normally present with MTBE (e.g., gasoline components, benzene and toluene) are more strongly adsorbed by activated carbon, leading to problems with competitive adsorption. Other methods for MTBE removal exist, but their capital costs exceed the cost of liquid-phase carbon adsorption. Given that using activated carbons for MTBE removal is effective and less expensive, it's advantageous to optimize carbon in its ability to remove MTBE.

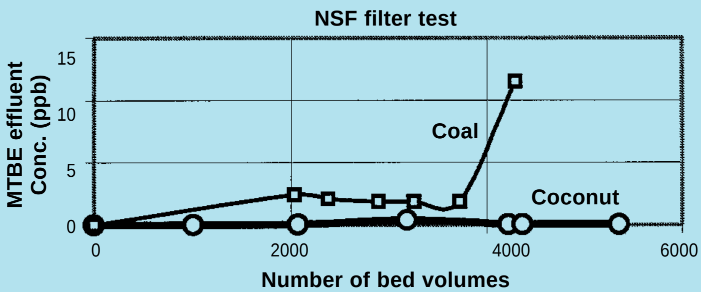
The removal of organics in water that are weakly adsorbed and are present in trace concentrations (low ppb) requires an activated carbon with a predominance of high-energy pores (micropores). Coconut shell activated carbon has traditionally been used for such applications, e.g., removal of trihalomethanes (THM). Coconut char, produced by carbonization of coconut shell, is a better raw material than alternatives (e.g., coal or wood char) for the generation of micropores during the steam activation process.

In addition to isotherm capacity, the retentivity of the carbon for the adsorbate is critical if low effluent concentrations of MTBE are to be maintained. Since MTBE concentrations and background organic concentrations are typically variable, the desorption of MTBE should be considered. It's widely accepted in the activated carbon industry that coconut shell carbons have higher retentivity than coal-based carbons.

Water filter testing

Dynamic testing of water filter cartridges using the protocol established by ANSI/NSF Standard 53 (Health Effects of Water Treatment Systems) was conducted by one activated carbon producer, with the results given here. Figure 1 shows data for commercial water filters made from two different types of activated carbon—a coconut shell carbon that was optimized for MTBE removal, and a coal-based carbon that showed good performance in laboratory testing. Both filters used a molded carbon block produced from 80 x 325 mesh activated carbon.

Figure 1. NSF filter test results of a MTBE optimized coconut shell carbon (open circles) and a quality coal-based filter (open squares)



As shown, both filters removed MTBE to non-detect levels (1 ppb based on purge-and-trap gas chromatography and flame ionization detection). The current effluent standard for NSF certification of MTBE removal is 5 ppb. The filter manufactured from coconut shell activated carbon lasted substantially longer, indicating a higher capacity for MTBE. Even after 2,800 gallons of water was treated, the filter made from the coconut shell carbon reduced MTBE to below 1 ppb, and below reported taste and odor thresholds. The coal-based carbon filter met the current 5 ppb NSF standard for MTBE removal but didn't last as long as the coconut carbon filter.

The superior performance of high quality coconut shell activated carbon compared to coal-based carbon is in agreement with the recent findings of others.[1,2]

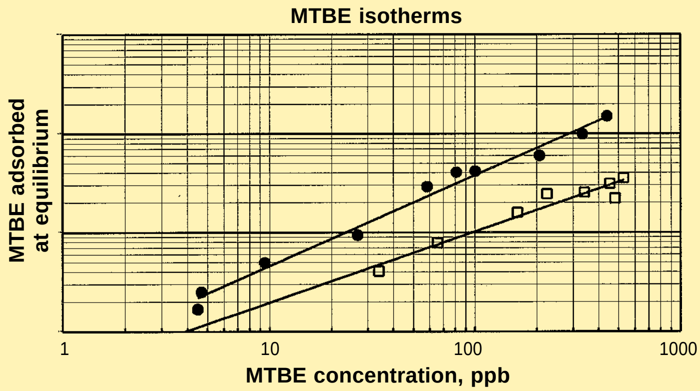
Lab optimization of carbons

The carbons used in the filters tested above were selected based on a laboratory development program. This program was initiated to optimize both coconut shell and coal-based carbon for MTBE adsorption. The focus was to maximize microporosity; that is, the volume of pores with diameters less than about 20 angstroms (1 angstrom = 10^{-8} centimeters or 3.937 x 10^{-9} inches). Adsorption theory holds that micropores are required to maximize a carbon's trace capacity—the capacity to remove trace levels of weakly adsorbed species.

A wide variety of commercial and developmental carbons was evaluated for MTBE removal using an 8-point isotherm technique based on the ASTM Standard Practice D3860-89a. The carbons included coconut shell carbons and coal-based carbons that were produced from different raw material sources and activated under different process conditions.

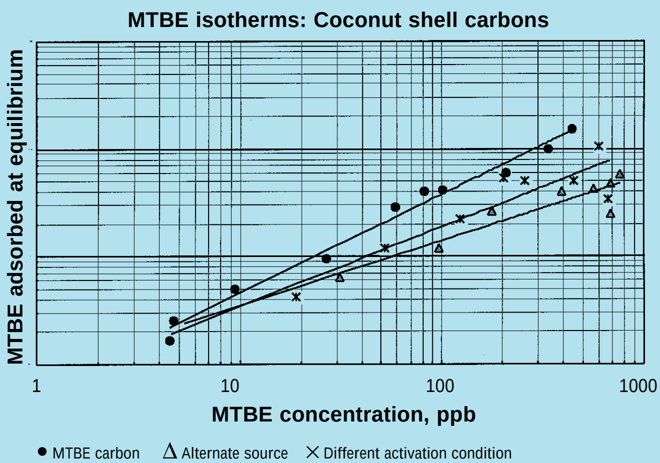
Based on the results of the optimization program, a carbon was selected for its capacity for MTBE in POU / POE applications. The carbon is coconut shell based and has a large micropore volume, as determined by nitrogen adsorption. Figure 2 shows the equilibrium capacity of this carbon compared to a conventional coal-based carbon. The data shows that the coconut shell carbon, designed for MTBE removal, has a capacity two to three times higher than the coal-based carbon. The coal-based carbon reference is a high-quality carbon that's considered an industry standard for potable water treatment. The absolute capacity of carbon for MTBE depends heavily on other contaminants present in the test water. Therefore, the isotherm plots show relative capacities. Results of filter testing (described above) confirm results of isotherm testing.

Figure 2. MTBE isotherms of an optimized coconut shell carbon (filled circles) and a high quality coal-based carbon (open squares)



Although coconut shell provides an excellent raw material for generating microporosity, the control of the raw material source and activation conditions are critical to assure high MTBE capacity. Figure 3 shows the equilibrium capacities for two other coconut shell carbons: 1) one from a different raw material source, and 2) one produced under different activation conditions. This figure clearly demonstrates the importance of maintaining a well-defined carbon source and a stringent quality assurance program.

Figure 3. MTBE isotherms of coconut shell carbons with different raw material sources and activation methods

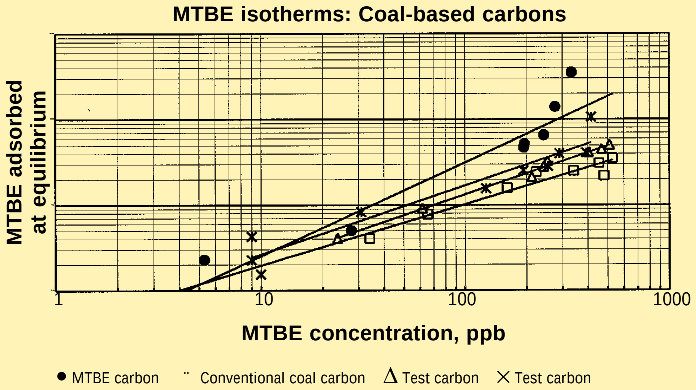


A coal-based carbon was also optimized for MTBE removal. Figure 4 shows the variation in MTBE capacity for several of the coal-based carbons evaluated in the lab test program. The carbon selected for its MTBE capacity has a higher micropore volume.

Remediation notes

In remediation applications, water generally contains other organics that are more strongly adsorbed than MTBE. Also, the treatment objectives are usually not as stringent as for POU / POE applications. For these reasons a coal-based carbon or a combination of coal-based and coconut shell carbons are preferred for remediation applications. The coal-based carbon designed for MTBE removal, referenced in Figure 3, has been used in numerous remediation

Figure 4. MTBE isotherms of optimized coal-based carbons compared to the coconut shell carbon (filled circles)



projects. Typically, a series of adsorbers is used, with the upstream adsorber used for heavy organics removal (e.g., BTEX) and the downstream adsorber(s) used for MTBE. If very low effluent concentrations are required, a coconut shell carbon can be used in the final adsorber(s) as a polishing step.

Conclusion

High-quality coconut shell activated carbon is the preferred adsorbent to remove MTBE from drinking water in POU/POE systems. It provides the high trace capacity and high retentivity needed to remove low ppb levels of MTBE. It also provides superior hardness, low dust levels and low extractable metals levels. Achieving consistently high MTBE reduction, however, requires a well-defined source of raw material, consistent manufacturing process conditions and a stringent quality assurance program. Water filters manufactured from coconut shell carbon that has been optimized for MTBE removal can meet the performance standards of NSF 53 and provide substantial service life. q

References

1. Suffet, Irwin, et al., "Sorption for removing methyl tertiary butyl ether from drinking water," Proceedings, Annual Conference, American Water Works Association, Denver, 1999, 319-336.

2. Shih, T., M. Wangpaichitr and I. Suffet, "Evaluation of GAC technology for the removal of methyl tertiary butyl ether (MTBE) from drinking water," Preprints, ACS Division of Environmental Chemistry, Vol. 40 (1), March 2000.

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