Removal of Volatile Organic Contaminants (VOCs) From the Groundwater Sources of Drinking Water via Granular Activated Carbon Treatment [Project #4440]

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The U.S. Environmental Protection Agency (EPA) is considering setting or lowering the maximum contaminant level (MCL) for several carcinogenic volatile organic contaminants (cVOCs) from their current levels (5 µg/L or 2 µg/L), and a sub-µg/L range is being considered. While current MCLs for organics are commonly attained using granular activated carbon (GAC), an order-of-magnitude reduction may present a challenge to water treatment facilities using GAC. This is especially true when considering the adsorption complexity presented by dissolved organic matter (DOM) and co-solutes in the background matrix of the groundwater (GW) being treated, as both can decrease the adsorption capacity of the target compound. The impact of empty bed contact time (EBCT) on cVOC breakthrough is also not well understood.

The overall goal of this project was to assess the feasibility of GAC for the treatment of cVOCs to sub-µg/L levels using the rapid small scale column test (RSSCT). The project tasks and their objectives were as follows:

- **Task I:** Determine carbon use rates (CURs) at EBCTs of 7.5 min and 15 min for the cVOCs in a GW
- **Task II:**
  - (a) Determine a threshold where cVOC breakthrough normalized to the influent cVOC concentration is independent of the influent cVOC concentration for one cVOC
  - (b) Determine the effects of GW DOM type and concentration on breakthrough of three cVOCs
  - (c) Determine competitive effects between two commonly co-occurring cVOCs in GW on cVOC breakthrough
- **Task III:** Review scale-up method analysis, addressing the current understanding and procedures associated with accurate scale-up

The specific cVOCs evaluated were:
- carbon tetrachloride (CT)
- 1,2-dichloroethane (1,2 DCA)
- 1,2-dichloropropane (1,2 DCP)
- tetrachloroethylene (PCE)
- trichloroethylene (TCE)
- 1,1-dichloroethane (1,1 DCA)
- 1,1,2,2-tetrachloroethane (1,1,2,2 TCA)
- 1,1,1,2-tetrachloroethane (1,1,1,2 TCA)
- 1,2,3-trichloropropane (1,2,3 TCP)

A baseline influent concentration of 5 µg/L was used. The evaluation of benzene, dichloromethane (DCM), and 1,3- butadiene (1,3 BD) was initially proposed, but spiking issues precluded their use and evaluation.

**TASK I**

Breakthrough of PCE and TCE did not occur, even though the columns were run for about 200,000 bed volumes for the 7.5 min EBCT column. This is the equivalent of about three years of operation at the full scale. Breakthrough to 10% and 50% was achieved for six compounds and thus CUR values could be calculated. However, 1,1,2,2 TCA degraded during the run and throughput and CURs could not be calculated. The CUR values were highest for 1,1 DCA and 1,2 DCA at about 0.25 lbs/1,000 gal treated. The CUR values for the other six cVOCs were less than 0.10 lbs/1,000 gal treated and for 1,2,3 TCP, PCE, and TCE the CUR values were less than 0.04 lbs/1,000 gal treated. In most, but not all cases, increasing EBCT to 15 min in all three waters yielded breakthrough at earlier throughput and thus higher CURs, especially for the strongly adsorbing compounds. CUR values below 0.10 lbs/1,000 gal treated are often considered to be economical, but the cost associated with these CURs needs to be compared with that of other treatment technologies.

**TASK II A**

The influent 1,2 DCA concentration, C₀, was varied in the range from 50, 5, 0.5, to 0.1 µg/L in four RSSCTs. 1,2 DCA was chosen as it is a weakly adsorbing compound, which yields earlier breakthrough and higher CURs. Breakthrough with the effluent concentration normalized to the influent concentration was found to be dependent on influent concentration at both EBCTs. In other studies a lack of dependence was found, but the influent concentrations of non-VOCs in these studies were all in the sub-parts per billion (ppb) range, and the background matrices were surface waters at higher dissolved organic carbon (DOC) concentrations. Additional RSSCTs were not conducted at influent concentrations less than 0.1 µg/L. Concentrations lower than this are well below the current maximum contaminant level of 5 µg/L and a target effluent concentration being considered (0.5 µg/L), and thus are less of a concern for drinking water utilities. This finding complicates the use of a single adsorption run to predict the breakthrough behavior at other C₀s.
**TASK II B**

Compared with cVOC breakthrough in the baseline Colorado groundwater (CO II), the higher DOC and specific ultraviolet absorption (SUVA) Florida groundwater (FL GW) yielded earlier breakthrough for 1,1 DCA and 1,2 DCP. Breakthrough of 1,2,3 TCP did not occur in the FL GW. Comparison of 1,1 DCA, 1,2 DCP, and 1,2,3 TCP breakthrough in CO II and FL GW diluted (FL DIL) to the same DOC as CO II, showed earlier breakthrough for all three cVOCs in the FL DIL, which was attributed to the 80% higher SUVA values of the FL DIL DOM. However, comparison of the FL GW and FL DIL cVOC results also showed earlier breakthrough for 1,1 DCA and 1,2 DCP in the FL DIL. This was not expected as both the influent DOC concentration and SUVA values of FL GW were higher, which was expected to yield earlier breakthrough. No explanation for this behavior is apparent.

**TASK II C**

The negative impact of DOM on the breakthrough of 1,2 DCA was greater than that of the presence of two co-solutes, CT and TCE.

**TASK III**

The results from RSSCTs are known to over-predict GAC performance. More paired cVOC data at the bench- and field- (-pilot or -full) are needed before adequate scale-up equations can be developed that will decrease the uncertainty of full-scale predictions.

Additional research in the Task II and III areas would facilitate the use of GAC as a viable technology to remove cVOCs from drinking water to meet proposed EPA regulatory levels.