Engineering Report:
Bench-Scale Study of Organoclay and GAC Treatment

submitted to

Risk Assessment and Management Group, Inc.

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Background

H_2O'C Engineering was retained on February 23, 2005 to perform a fast-track, bench-scale study of the use of an organoclay followed by GAC to treat contaminated surface water. Objectives were to:

1. Estimate the carbon dosage (usage rate) that will be required in full-scale application. This estimate will be used as a basis for development of cost estimates for full-scale water treatment, and to assess the cost-effectiveness of activated carbon relative to other technologies.

2. Confirm that activated carbon and/or the combination of activated clay/activated carbon treatment is capable of achieving the required discharge criteria.

3. Estimate the sorptive capacity of organoclay, to determine if organoclay would be a cost-effective pretreatment step.

Testing Protocol

The four-column test setup pictured below was constructed. Source water from Pond #1 was applied to the columns by gravity. Flows averaged approximately 50 ml/min. (0.013 gal/min.).

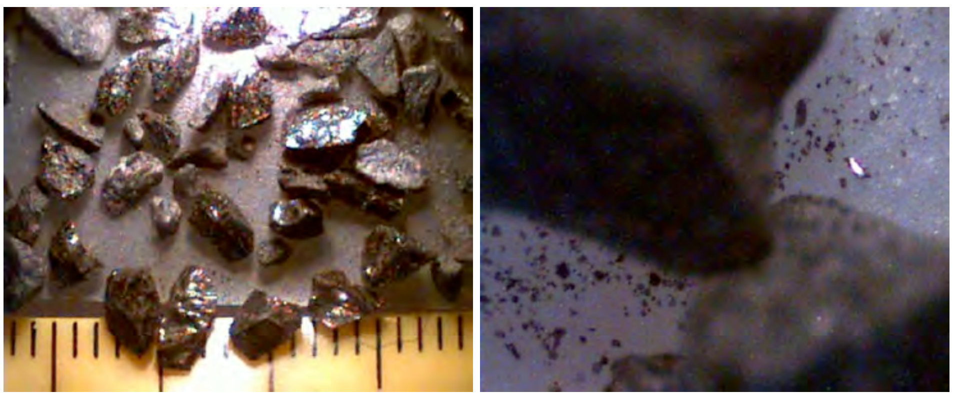
PVC columns were 1" inner diameter; 0.0055 sq. ft. cross-sectional area. The medium in each column was two feet deep, resulting in a bed volume of 0.01 cubic feet (0.0748 gallons).

Hydraulic loading rate averaged 2.4 gpm/sq. ft. Empty bed contact time (per two-foot column) averaged 5.8 minutes.

Media

The media used in the columns included *'Biomin'*, a proprietary 'organoclay' which is a blend of irregular, angular shards of crushed anthracite coal (70%) coated with attached bentonite clay material that has been modified with quaternary amines (30%). The media particle size covers a broad range with much of the anthracite between 2 and 4 mm. Under higher magnification (60x, right photo), fragments of clay and anthracite can be seen to have spalled from the larger anthracite particles. Sorption of oily residues reportedly causes the clay to swell.

Presumably, the bentonite clay portion this media *absorbs* emulsified petroleum, oil and surfactants, making it a useful adjunct for removal or suspended or entrained organic matter from wastewaters contaminated with petroleum and surface-active agents.



***'Biomin'* organoclay (mm scale) and fines spalled from surface of the medium**

Virgin, bituminous coal-based, granular activated carbon was used in the three 2-foot deep columns following the organoclay pretreatment column. This GAC material is more uniform in particle size and has far greater porosity for the *adsorption* of dissolved organic solutes. While smaller in size (1-3 mm), it is more rounded in shape than crushed anthracite coal, leading to higher hydraulic efficiency (lower head loss).

GAC granules (mm scale) and 6x magnification showing rounded edges

Control of Foaming

Initial (2 hour) tests illustrated the control of foaming achieved by passing Pond #1 wastewater through the 2-foot deep organoclay column and the 6 feet of GAC. As shown below, the influent wastewater formed a small, but highly stable foam upon moderate shaking. This foam persisted for more than one-half hour. Equal agitation of the effluent from the organoclay column resulted in temporary foam that disappeared in about 15 seconds. Still more vigorous shaking of the GAC effluent created no foam whatsoever.

Initial Column Effluents reduced in Foam, Color, Odor and Turbidity

Microscopic Examination

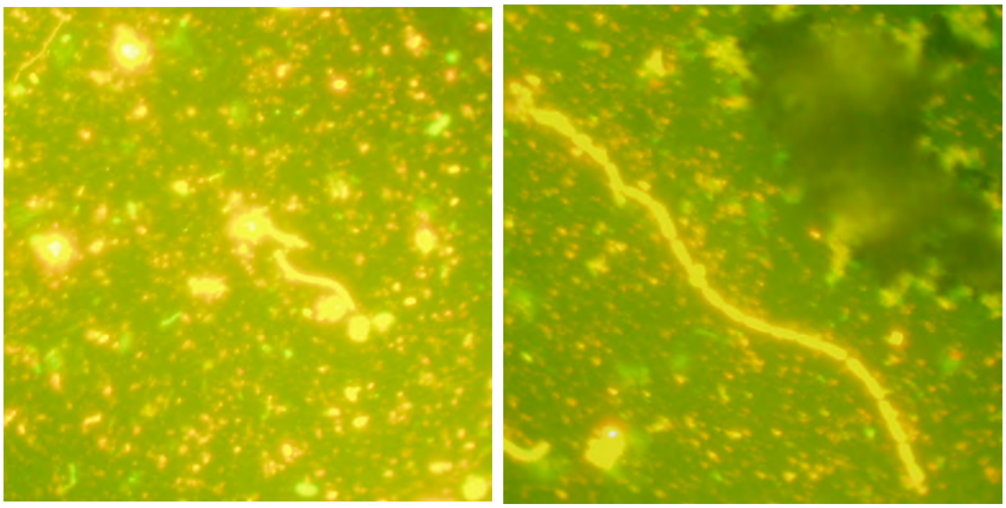
Portions of the Pond #1 water and treated GAC III (final) column effluent were passed through a 0.22 µm neutron-track-etched polycarbonate membrane, stained with acridine orange, then examined using epifluorescence microscopy. This procedure allows the detection, enumeration and photographing of micrometer-sized particles, including bacterial cells.

Nikon microscope with epifluorescence attachment

Hach ratio turbidimeter

The micrographs below indicate the diversity of particles in the pond water. These include rod-shaped and filamentous bacteria plus an assortment of debris. The micrograph on the right shows a large filamentous organism.

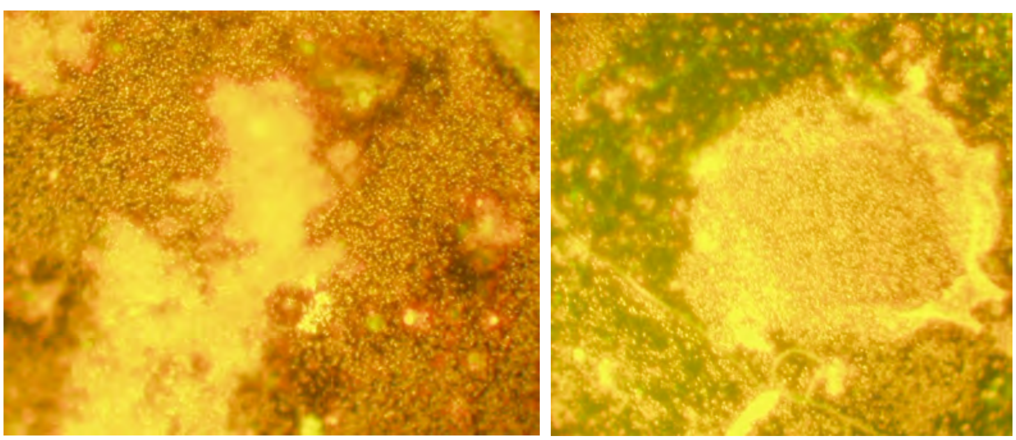
These particles in the pond water are not agglomerated and tended to blind the polycarbonate membrane readily during filtration. The addition of a coagulant to this water might create floc that would be large and dense enough to settle before being applied to any sorption medium.



Pond water showing wide diversity of particles and microorganisms

The final GAC column effluent appears to contain massive numbers of very small, discrete particles in a gelatinous matrix which, again, readily blinded the polycarbonate membrane. Although smaller than bacteria typically observed in pond water, it is speculated that these particles are microbacteria that have grown on the surface of the biologically-active granular activated carbon medium.

If so, the impact that this microbial growth has on the removal of the organic matter accumulated on the GAC is not known.



GAC column effluent appears to contain masses of small bacterial cells

Analytical Results

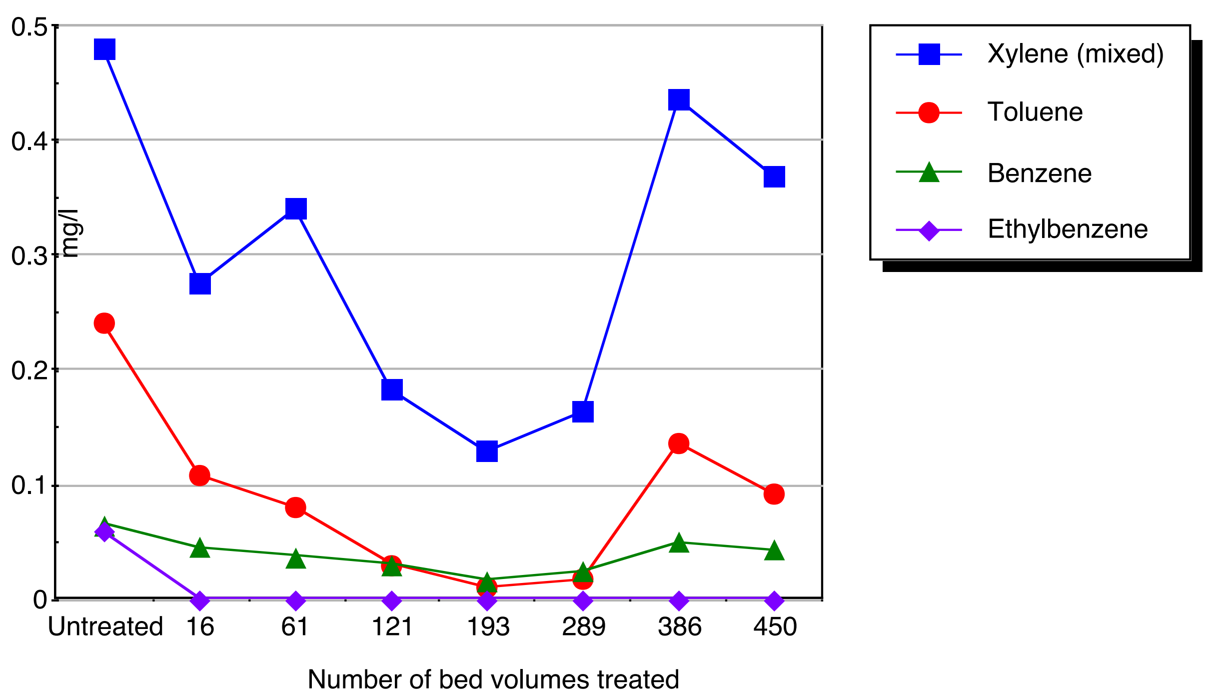
Although the Pond #1 water was turbid, had a strong odor, pronounced color, and foamed on shaking, the analytical results for BTEX and MTBE indicated that only a modest concentration (<1 mg/l) of these constituents were in the influent to the treatment columns.

Based on the anticipated economic feasibility of treating the Pond water with GAC, the period of column operations was selected to apply a cumulative TOC loading of, at least, 10% of the GAC column weight. Over the period of applying this load, approximately 55% of the influent BTEX was removed on the organoclay column. However, after the passage of only 16 bed volumes through this column, foaming of the effluent was evident. Foaming, as well as color, was observed in all subsequent organoclay column samplings.

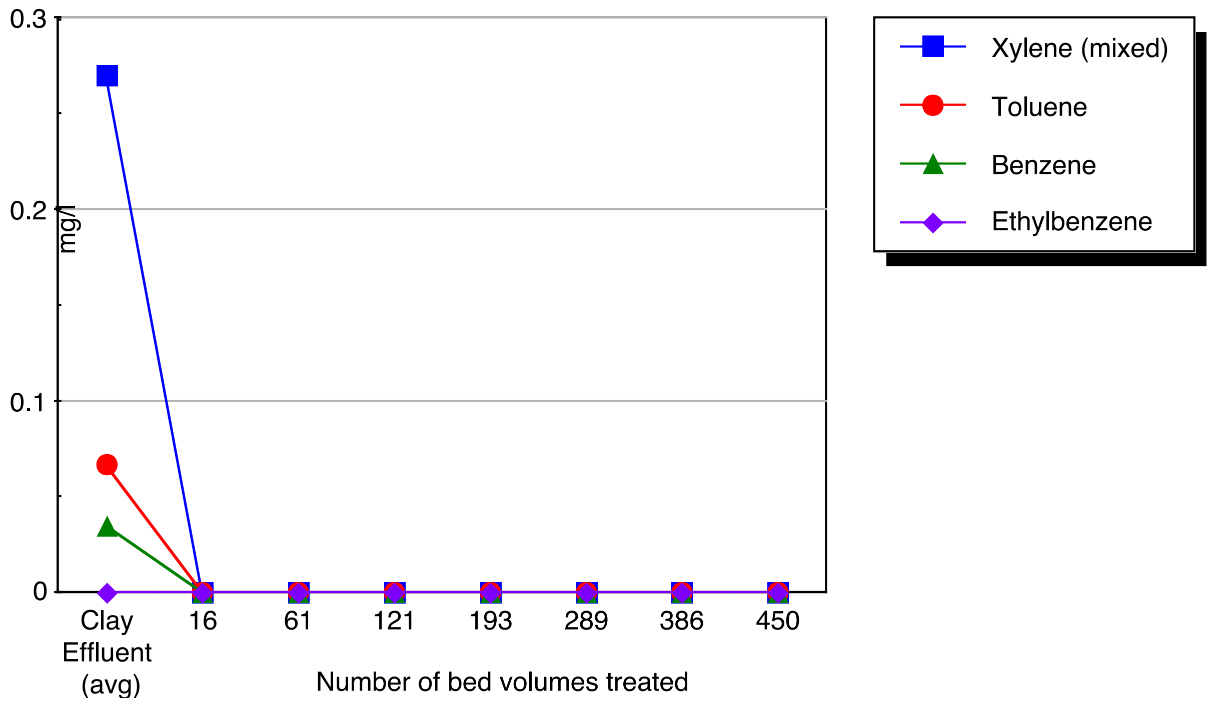
The GAC column that followed the organoclay column never showed tangible evidence of breakthrough or organic matter. The GAC I column effluent never foamed or had a detectable odor or color. However, the samples were slightly turbid, exhibiting a whitish haze.

The BTEX constituents in the organoclay column effluent are plotted below as a function of bed volumes processed. However, all the BTEX that was not removed by the organoclay column was removed to below analytical limits of detection by the first GAC column.

Effluent from Organoclay Column over Time



Effluent from First GAC Column over Time



The analytical results available to date suggest that the column treatment scheme tested would be effective for the removal of BTEX, MTBE, color, odor and foaming agents. The organoclay did achieve substantial, though not complete, removal of these constituents. At the flow rates and EBCT tested, the first column of GAC appeared to capable of reducing the residuals concentrations from the organoclay column to undetectable levels.

The question of the necessity for including the organoclay column in the treatment series is not answered. The implication of the GAC column results is that GAC alone has a strong affinity for the compounds to be removed.

Because even the first carbon column was not exhausted with respect to BTEX, MTBE and foaming agent removals during this study, the carbon usage rate cannot be calculated. However, at the full concentrations of these substances in the Pond #1 water and without organoclay pretreatment, it appears that more than 225 bed volumes can be treated by GAC.

<<Table summarizing the analytical data for the primary indicator parameters>>
<<Data interpretation>>

<<Projection of carbon usage rate>>
<<Expected performance of the activated clay as a pretreatment step>>

<<Laboratory analytical reports>>