APPENDIX B

POWDERED ACTIVATED CARBON PERFORMANCE TESTING

Sec. B.1.1 Performance Based Evaluation for the Removal of MIB and Geosmin

The powdered activated carbon (PAC) evaluation test procedure used in the standard is established to assist a utility in choosing the best PAC for taste and odor removal in addition to the necessary dose to meet the treatment objective.

Sec B.1.2 Reagents and Equipment

B.1.2.1 Reagents

a. Raw water. Collect raw water in a 5 gallon High Density Polyethylene (HDPE) carboy. Transfer 18 liters of the raw water to a second HDPE carboy (e.g., volumetrically using a 1 L graduated cylinder or use a second carboy calibrated to 18 L).

b. Test MIB/geosmin solution. To prepare a 50 ng/L MIB and geosmin solution matrix, add 9.0 uL of the reagent 100 ug/mL MIB and geosmin solution (Supelco, Bellefonte, PA) to the 18 liters of raw water. Magnetically mix for 30 minutes. *Note: If it is known that MIB/geosmin concentrations are other than 50 ng/L, one can still follow this step because at these concentrations the initial concentration will not impact percent removal. In addition, if it is known that MIB and/or geosmin is present in the raw water, determine concentration present via Standard Methods for the Examination of Water and Wastewater 20th Edition 6040B. In this case, there is no need to spike the raw water as previously described.*

c. Powdered activated carbon slurry. Prepare a homogenous PAC slurry with a concentration of 10,000 mg of "as-received" powdered activated carbon per liter of organic free water. For example, weigh out 1.0 g of "as-received" powdered activated carbon. Transfer activated carbon to 100 mL of organic free water in a 100 mL glass vial. Seal vial with screw-on Teflon top. Magnetically stir for 10 minutes. When not in use, PAC slurry should be stored in a desiccator. Prior to using PAC slurry for test, mix again for 10 minutes.

d. Test coagulant solution. Prepare a 10,000 mg/L concentrated coagulant solution by first weighing 5000 mg of coagulant. Transfer weighed coagulant to 500 mL of organic free water in an amber glass bottle and magnetically mix for 10 minutes. Store in a cool, dark place.

e. Other chemicals (e.g., polymers, oxidants, etc.). If other treatment chemicals are added during the full scale purification of raw water, then prepare concentrated solutions as per (d).

B.1.2.2 Equipment

a. Jar testing apparatus
b. Timer
c. Vacuum filter apparatus and 0.45 um filter paper

Sec. B.1.3 Performance Test Procedure

Preparation

1. Evaluate and record unit operations of full scale plant to determine the time scale for the addition of various treatment chemicals (i.e., at what time in the plant are the individual chemicals added). These times should mirror those times used during the jar testing experiment below.

2. Evaluate and record the known concentration of treatment chemicals (e.g., coagulant, polymer, oxidant, etc.) added during full scale operation and prepare test solutions for these chemicals as discussed in (d) under *1.2.1 Reagents*. These concentrations should mirror those used during the jar testing experiment.

3. If historically PAC is used at the full scale plant for taste and odor removal, then PAC doses for the jar testing experiment should surround these historical concentrations. Otherwise, doses of 0, 10, 20, 30, and 40 mg/L should be adequate to establish a dose response curve that can be used to evaluate the performance of the activated carbons. The zero addition will serve as the control. The sixth jar should serve as a duplicate for quality control purposes. A tighter tolerance of PAC doses can be used once the initial curve has been established, if so desired.

4. Evaluate full scale treatment objective for MIB and geosmin removal (i.e., what are the target plant effluent MIB and geosmin concentrations). The odor threshold concentrations for MIB and geosmin are between 9 and 15 ng/L, so the treatment objective should be less than this range. (Note: the exact treatment objective is dependent upon the sensitivity of the customers.)

To best explain the performance test procedure, an example will be used with generic chemical doses and contact times. The following example pertains to a water utility that doses PAC at the raw water intake, allowing for a contact time of 5 minutes before reaching the rapid mix basin. 80 mg/L of alum is added at the rapid mix basin, which when combined with flocculation lasts 20 minutes. Subsequently, the water settles for 2 hours. (Clearly, this portion of the procedure requires careful attention so that the jar testing experiment accurately mimics full scale operation.)

Procedure

a. Transfer 2 liters of the test MIB/geosmin solution to each jar of the jar testing apparatus.

b. Turn on mixer to 60-80 rpm (or G equivalent).

c. To each jar, simultaneously add 0, 2, 4, 6, 8 and 8 mL (these volumes correspond to PAC doses of 0, 10, 20, 30, 40, and 40 mg/L, respectively) of the PAC slurry. (The second 40 mg/L dose is for quality control purposes.) Start timer. Mix each jar at 60-80 rpm (or G equivalent) for 5 minutes.

d. At the end of the 5 minutes, to each jar simultaneously add 160 mL (equivalent to 80 mg/L) of the coagulant slurry. Reduce mixing speed to 30 rpm (or G equivalent) for 20 minutes.

e. At 25 minutes (5 minutes at 60-80 rpm and 20 minutes at 30 rpm), cease mixing and let jar contents settle for 2 hours.

f. After settling, collect, with as little disturbance as possible, approximately 1200 mL of settled water and immediately vacuum filter.

g. Transfer filtrate to analysis containers (See *Standard Methods for the Examination of Water and Wastewater 20th Edition 6040B* for the analysis of MIB and geosmin in water).

Calculations

a. Once analysis of the samples from the jar test procedure has been completed, including a control (i.e., zero carbon jar), determine the percentage of MIB and geosmin removed for each carbon dose, using the following equation:

$$Percent\ Removed = \frac{Control\ Concentration - Final\ Concentration}{Control\ Concentration} * 100$$

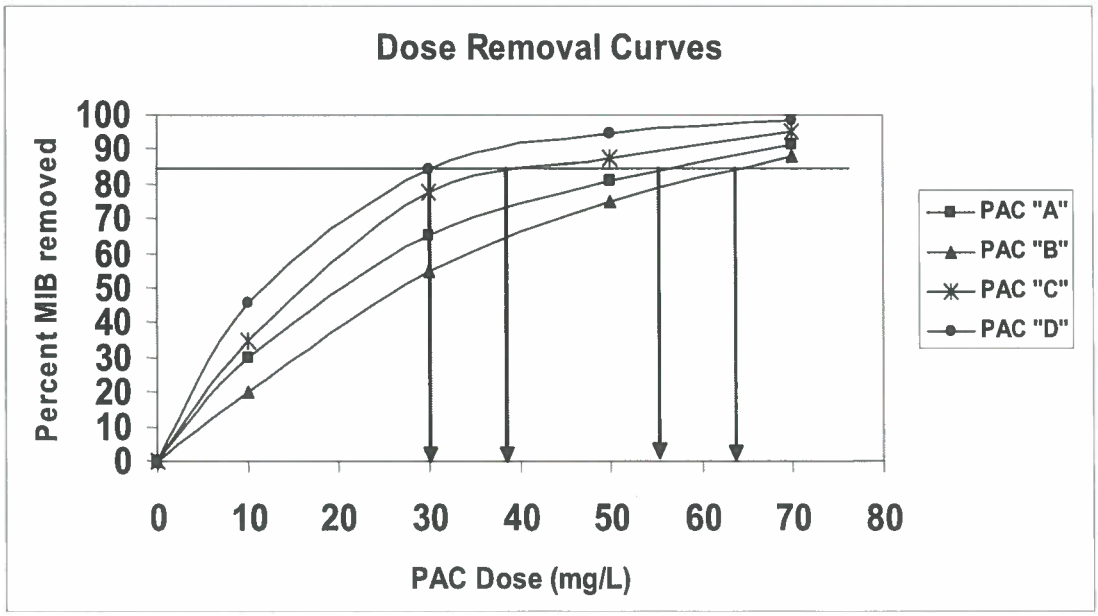
For example, if the control MIB concentration is determined to be 50 ng/L and the final MIB concentration from a particular PAC dose is 8 ng/L, the percent removal achieved by that carbon dose is 84%.

b. Plot the carbon doses on the x-axis and the percent removals on the y-axis for each PAC. The connection of points on the plot results in a dose removal or response curve.

c. The figure can then be used to develop performance factors which can be used subsequently to develop weighted PAC costs for the carbons of interest. Additionally, once it is determined which carbon is favored, its curve can be used for determining the proper PAC dose during taste and odor episodes. This is detailed in the example below.

The example below outlines the method to determine performance factors for those carbons evaluated once the dose removal curves have been graphed.

Example of calculation of PAC dose-equivalent performance factors



a. The control for MIB (i.e., concentration in raw water or spiked concentration) = 50 ng/L

b. The treatment target concentration = 8 ng/L, therefore 84 percent removal is required.

c. Follow from the y-axis at 84 percent MIB removal to the right to the point at which it intercepts each PAC curve. Draw a line down to the x-axis to the corresponding dose. Repeat for each PAC curve and record corresponding dose. For example, the line from 84 percent MIB removal intercepts PAC "D" at a dose of 30 mg/L.

d. Divide the dose for each PAC that achieves the target removal (i.e., 84 %) by the smallest dose of the PAC that achieves the target removal. This determines the relative performance factors. For example,

- PAC "D" = 30/30 = 1.00
- PAC "C" = 38/30 = 1.27
- PAC "A" = 55/30 = 1.83
- PAC "B" = 63/30 = 2.10

e. Determine the weighted cost (i.e., cost based on performance) by multiplying each PAC cost by its performance factor determined in step (d) above. Example costs are used in Table 1 below.

Table 1. Example weighted cost determined by performance factors

PAC	Cost/ton	Performance Factor	Weighted Cost
D	$1000	1.00	$1000
C	$895	1.27	$1137
A	$1010	1.83	$1848
B	$800	2.10	$1680

f. Repeat Calculations a through e for Geosmin.

g. Final weighted cost determination can be made based on MIB factors, geosmin factors, or combination of the two. The Utility should use historical data to determine which is appropriate. If no historical data is available, an average of the MIB factor and the geosmin factor is a reasonable approach to determining the final weighted cost.