Supplementary material

Experimental validation of a test to estimate the remaining adsorption capacity of granular activated carbon for taste and odour compounds

Yifeng Huang[1], Zhijie Nie[1], Jie Yuan[1], Audrey Murray[1], Yi Li[1], Gwen Woods-Chabane[1], Ron Hofmann[1,]*

[1]Drinking Water Research Group, Department of Civil & Mineral Engineering, University of Toronto, 35 St. George Street, Toronto, Ontario, Canada, M5S 1A4

Summary

11 pages including 4 Tables and 6 Figures

Section 1

Table S1. Water characteristics

Parameters	*Plant A*	*Plant B*	*Plant C*	*Plant D*	*Plant E*	*Toronto tap water*
TOC (mg/L)	1.95	3.32	3.85	-	2.5	2.99
UV_{254}	0.026	0.044	-	0.018	-	0.029
pH	7.57	7.76	7.48	7.96	7.64	6.90
Turbidity (NTU)	0.30	0.35	1.27	0.227	0.3	0.05
Alkalinity (mg $CaCO_3$/L)	90.4	113	-	94.4	94	90
Residual total chlorine (mg/L)	0.02	0.14	-	0.07	-	1.38
Temperature at test (℃)	10	17.4	25.3	8.0	-	18

Table S2. Test parameters for Figure 2. All tests used air-dried GAC, with the representative size fraction and feed T&O concentration of ~100 ng/L.

	Plant A		**Plant B**		**Plant C**		**Plant D**	
	Pilot	Minicolumn	Pilot	Minicolumn	Pilot	Minicolumn	Pilot	Minicolumn
GAC type	Bituminous coal-based Type A		Type A		Type A		Type B	
Service time (year)	0.5, 1.5, 2.5, 3.5		4.2, 5.5		1 & 2, 1.5 & 2.5		3.2 & 4.2, 3.7 & 4.7, 4.5 & 5.5	
Column diameter (mm)	25.4	25	25.4	25	25.4	25	25.4	25
GAC depth	0.8m	10cm	2.8m	10cm	0.8/1m	10cm	1.3m	10cm
EBCT (min)	11.7		22		6.3		4.1	
Flow rate (mL/min)	35	4	64	2	64/80	8	161	12
Temperature	10 ℃	Room temperature	17.4 ℃	Room temperature	25.3 ℃	Room temperature	8 ℃	Room temperature

Section 2

2.1. Test apparatus

Figure S1 shows the pilot-scale column setup and minicolumn setup.

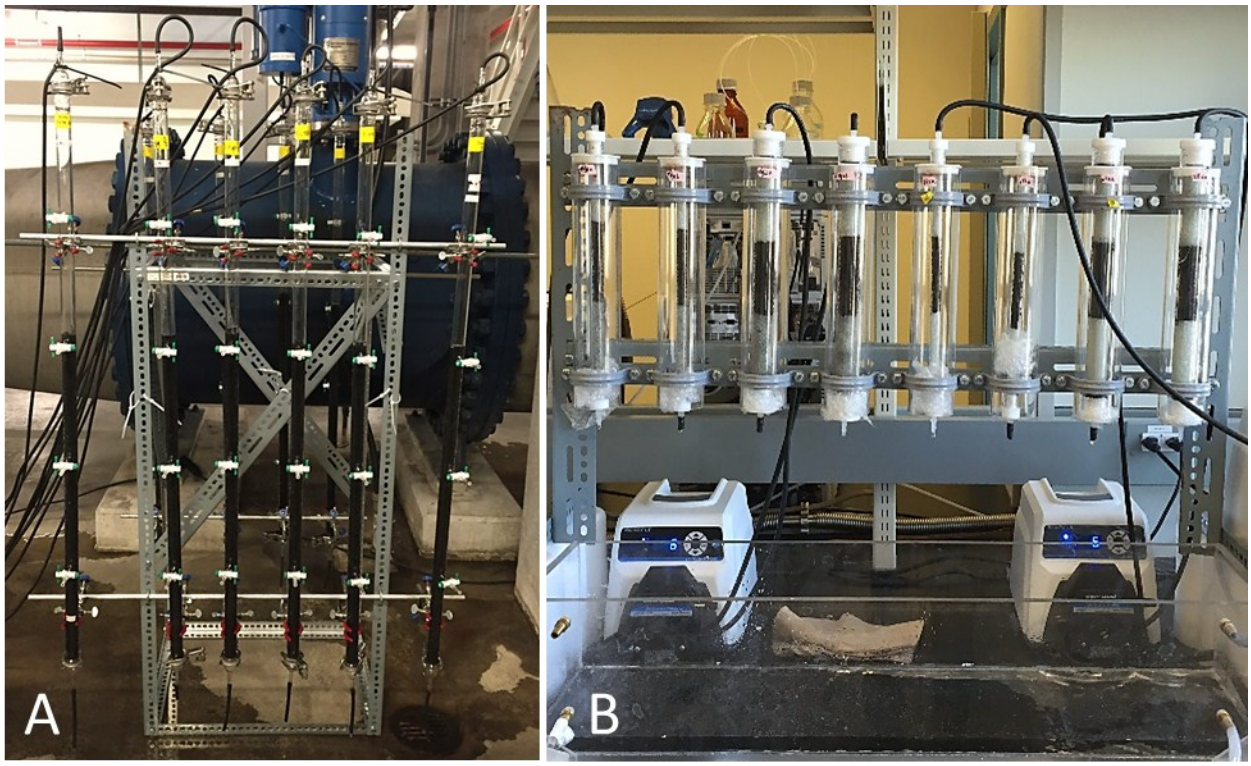

Figure S1. a) pilot-scale column test onsite and b) minicolumn test in the lab

2.2. Determining geosmin/MIB system losses

Blank tests were conducted to determine the possible geosmin/MIB system loss in the column systems. Possible loss of T&O compounds could be through adsorption onto column walls and tubing as well as evaporation during sampling.

For the minicolumn tests, the spiked influent was loaded in the columns packed with glass beads for 8 hours of continuous flow. Two types of glass minicolumns with different internal diameters (i.e., ID=11mm and ID=25mm) were used. Figure S2 shows that negligible adsorption occurred for both compounds in the blank minicolumn systems without GAC. For pilot-scale columns, an empty column was loaded with a continuous influent spiked with MIB and geosmin at a concentration of 100 ng/L for more than 40 h. As shown in Figure S3, the average system loss was -1.6 ± 8.0% for MIB and 8.8 ± 6.6% for geosmin. The results showed that the loss of T&O compounds within a blank pilot-scale column system without GAC was negligible. Toronto tap water was used for the blank tests.

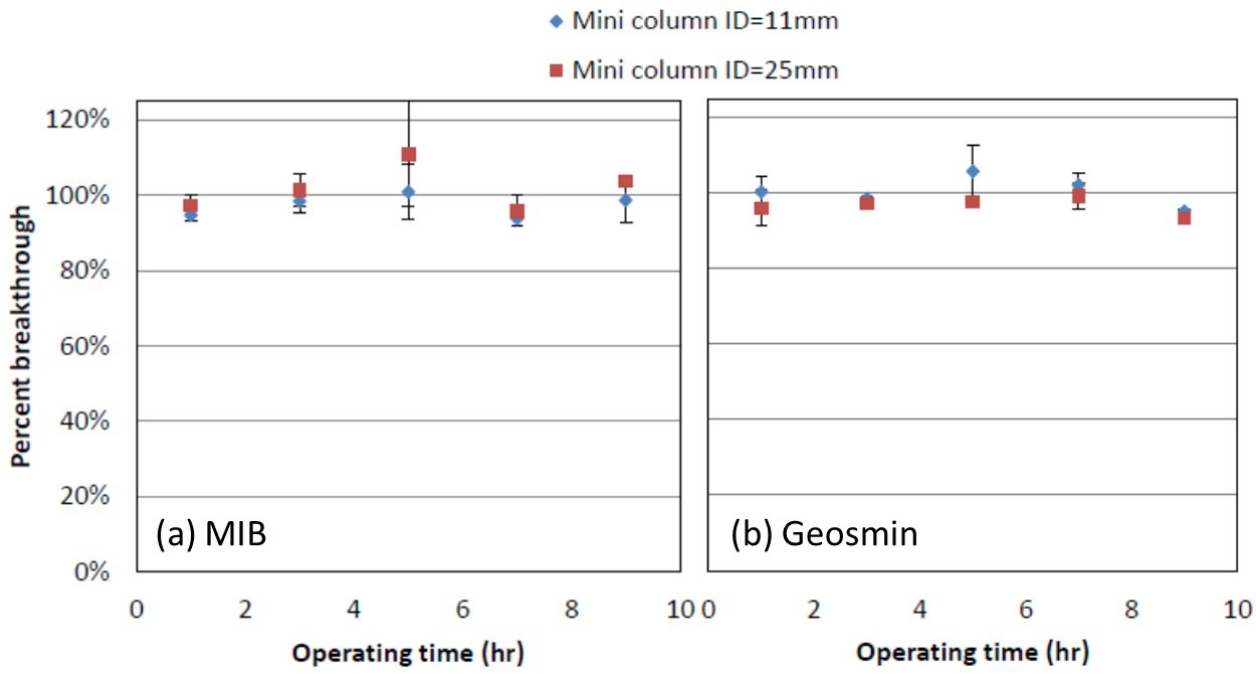

Figure S2. Breakthrough of a) MIB and b) geosmin over 8 hours through a blank minicolumn system packed with glass beads (error bars represent the max/min values of samples from duplicate columns)

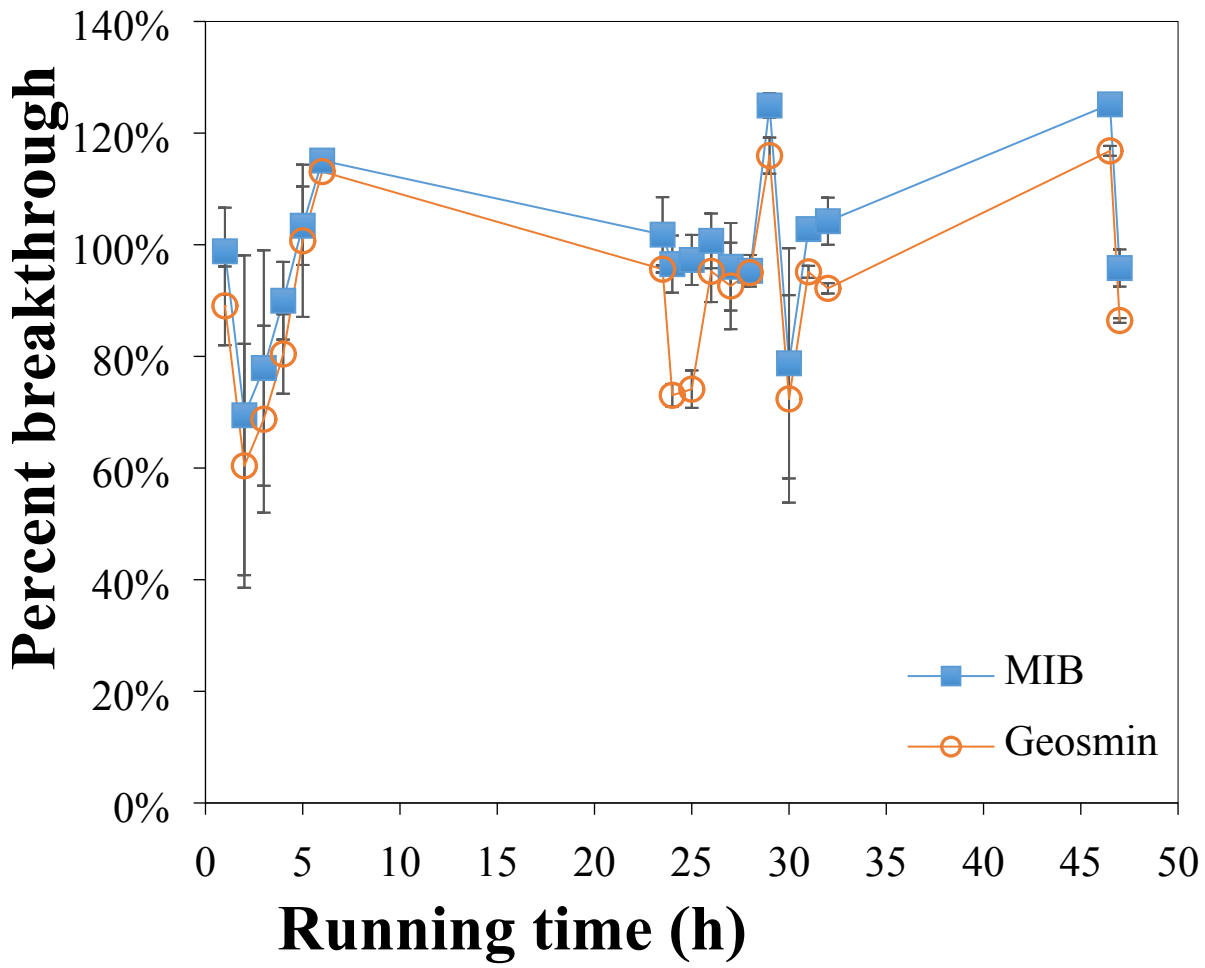

Figure S3. Breakthrough of MIB and geosmin from an empty pilot-scale column (error bars represent max/min values of two replicate samples from one column)

2.3. Sieve method and GAC size distribution

The wet pre-loaded GAC directly collected from water treatment plants was sieved using the US Standard Sieve Test so as to obtain the representative fraction for the minicolumn test. Air-dried GAC was obtained by drying the wet GAC at room temperature for 48 h while the oven-dried GAC was obtained by baking the wet GAC at 105℃ overnight. The sieve analysis was conducted according to the following procedures:

1. GAC samples were collected using a core sampler from full-scale filters during a backwash. Samples were taken at different locations throughout the filter bed to be representative of the entire filter. GAC samples were stored wet at 4^{o}C in the dark before use.
2. For dry sieve tests, GAC samples were dried in air at room temperature or baked in an oven prior to sieve analysis; for the wet sieve test, GAC samples were drained and sieved while remaining wet.
3. Sieves (#8, 10, 12, 14, 16, 18, 20, 25) were weighed and stacked in order of sieve size. Table S3 gives the particle size for each sieve level.
4. GAC samples were put into the first layer of the sieve, and the sieves were placed on a shaker and shaken for 6 min.
5. After shaking was complete, each sieve was weighed again, and the weight of the GAC in each sieve was determined.

GAC samples from all 4 WTPs were wet sieved for use in minicolumn tests. Comparison of the dry and wet sieve analyses were only conducted using GAC from Plant B. Figure S4 shows the particle size distribution of GAC from Plant B. The representative size fraction of air-dried GAC from Plant B was determined to be particles retained in sieve # 12, weighing 17%,

while the representative size fraction of wet GAC was retained in sieve #8, weighing 59%. This shows that the wet sieve method could not separate GAC particles well.

Table S3. GAC particle size for each sieve level using the USA Standard Sieve Test.

Sieve level	Range of diameter (mm)	Sieve level	Range of diameter (mm)
#8	> 2.38	#18	1.00 - 1.18
#10	2.00 - 2.38	#20	0.85 - 1.00
#12	1.70 - 2.00	#25	0.71 - 0.85
#14	1.40 - 1.70	<#25	< 0.71
#16	1.18 - 1.40		

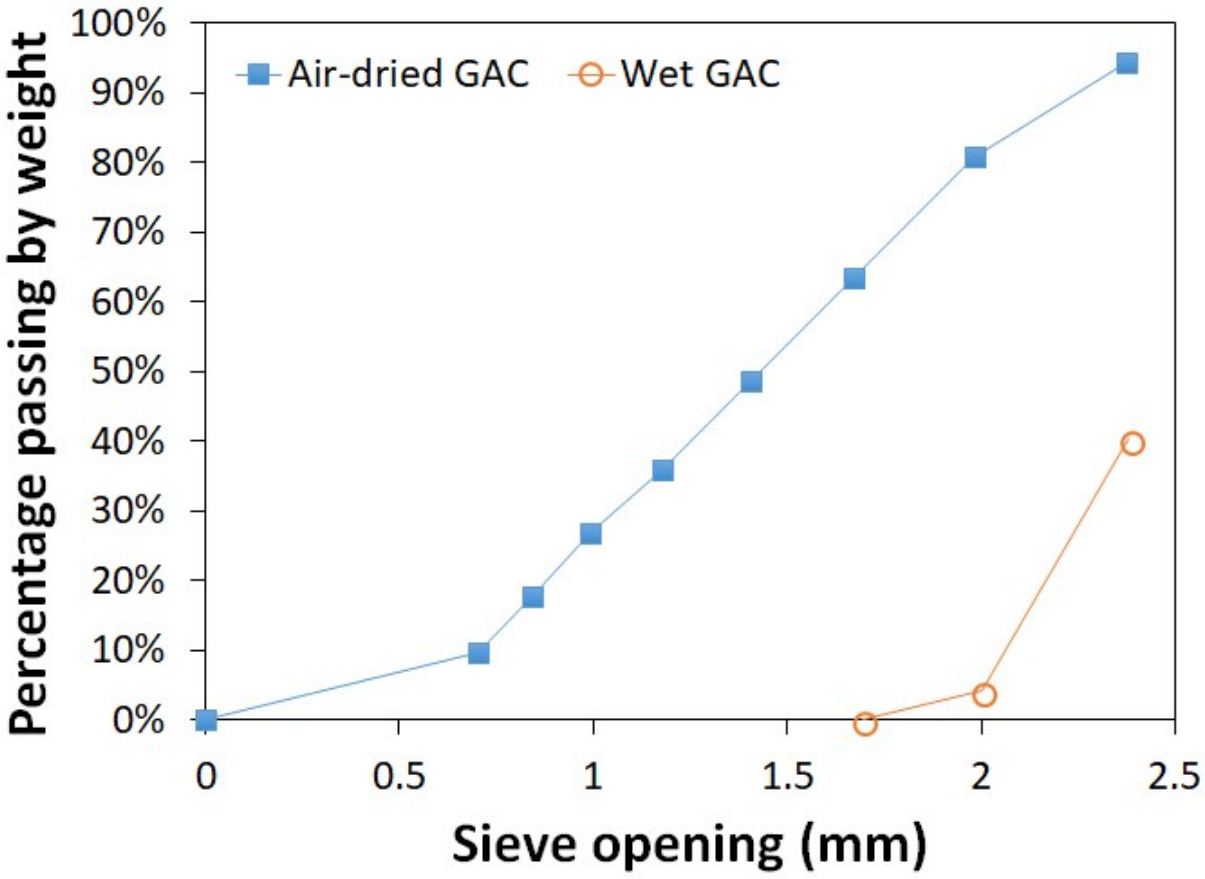

Figure S4. An example of particle size distributions of wet and air-dried GAC samples from Plant B

2.4. Temperature effect

To examine the temperature impact on performance of pilot-scale and minicolumn tests, two pilot-scale columns and two minicolumns were packed with 5.5 year old GAC from Plant B and were continuously fed with T&O spiked dechlorinated Toronto tap water at an EBCT of 4 min. To control the temperature during the test, the system was set up in a walk-in cold chamber. Before the test, the feed water was stored in the chamber until reaching a thermal equilibrium. After running for over 200 bed volumes, headspace free samples of influent and effluent were collected in amber vials.

Section 3

3.1. Test duration for minicolumn test

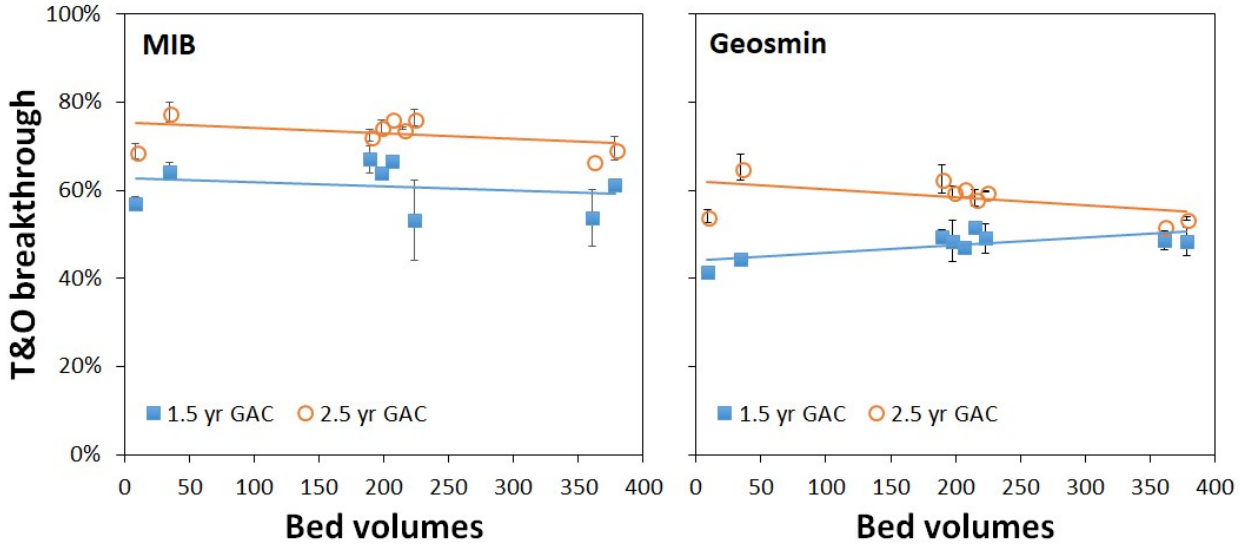

Figure S5. Breakthrough of MIB and geosmin vs. bed volume from the minicolumn test using pre-loaded GAC from Plant C. EBCT was 6.3 min. Column ID: 2.5 cm.

3.2. Statistical analysis

Table S4. Regression statistics of the MIB and geosmin breakthrough from pilot- and bench-scale column tests (Degrees of freedom=15)

Compounds	Slope (95% confidence interval)	Intercept (95% confidence interval)	R^2	Lin's coefficient
MIB	1.042 (0.838, 1.247)	0.00687 (-0.107, 0.121)	0.895	0.9347
Geosmin	0.983 (0.779, 1.187)	0.0133 (-0.0605, 0.087)	0.884	0.9385

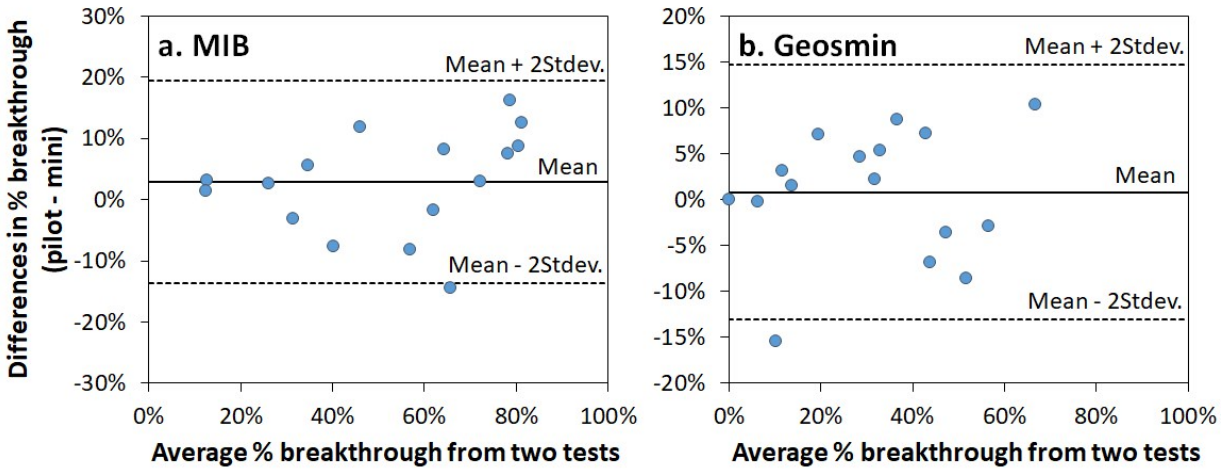

Figure S6. The differences between the breakthrough results of the pilot-scale column test and the minicolumn test plotted against the average breakthrough results from the two tests