



# **Availability of Safe Drinking Water**

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Kathryn Nafziger, Oak Hills High School

Rachel Rice, Hamilton High School

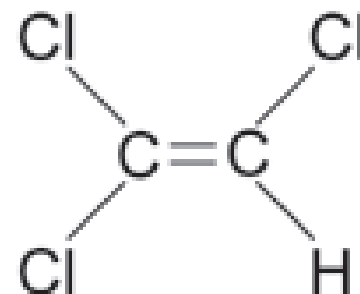


# Overview of Presentation

- Research
  - Background Information
  - Experiments Completed
- Classroom Implementation Plan

# Background Information

- Trichloroethylene (TCE) is a volatile organic compound (VOC), often found in professional cleaning products
- TCE in drinking water can have adverse health effects
  - Liver damage
  - Increased risk of cancer
- Regulated by the EPA
- Maximum Contaminant Level (MCL) is 5µg/L





# Background Information

- Nanoparticles (NP) material with two dimensions less than 100 nm
- The high production and use of the NP is manifested by high release of NP into the environment and natural water
- $\text{SiO}_2$ ,  $\text{TiO}_2$ , and  $\text{Fe}_2\text{O}_3$  are some of the most common NPs in the water system



# Research Objective

- To study the impact of the presence of different nanoparticles (NPs), in the water environment, on the removal of TCE by activated carbon in the presence of humic acid.
  - To determine the most appropriate method to complete the study
    - Adsorption Isotherms
    - Adsorption Kinetics
    - Breakthrough Studies utilizing Rapid Small Column Tests (RSCT)



# Long Term Goal

- To determine the time a large scale column will function to keep water within the MCL set by the EPA at 5  $\mu\text{g/L}$  TCE

# Instrumentation

**Auto Sampler, Purge  
and Trap, Gas  
Chromatography**



**UV-Vis Spectroscopy**



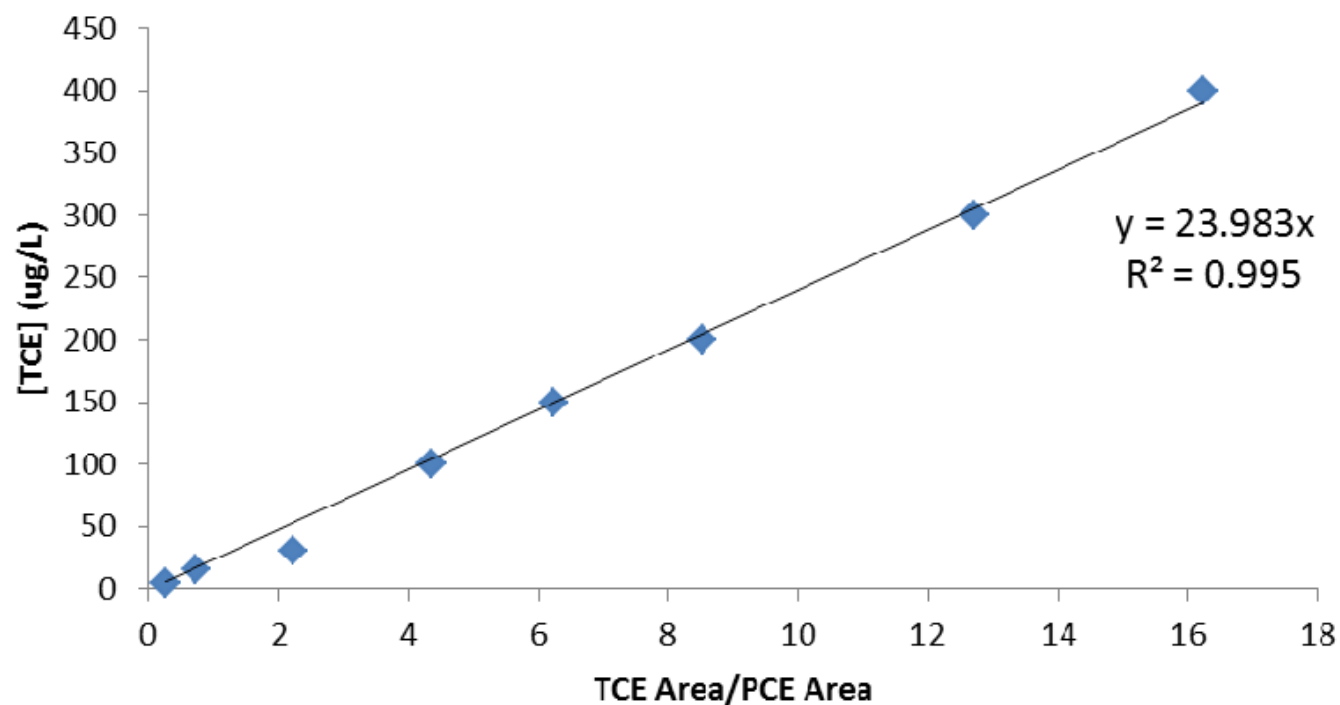
# Methods for Calibration of [TCE]


- Prepared solutions with known concentrations of TCE in buffered H<sub>2</sub>O
- Added internal standard tetrachloroethylene (PCE)



# Calibration Curve for [TCE] in GC

Calibration Curve of TCE for GC

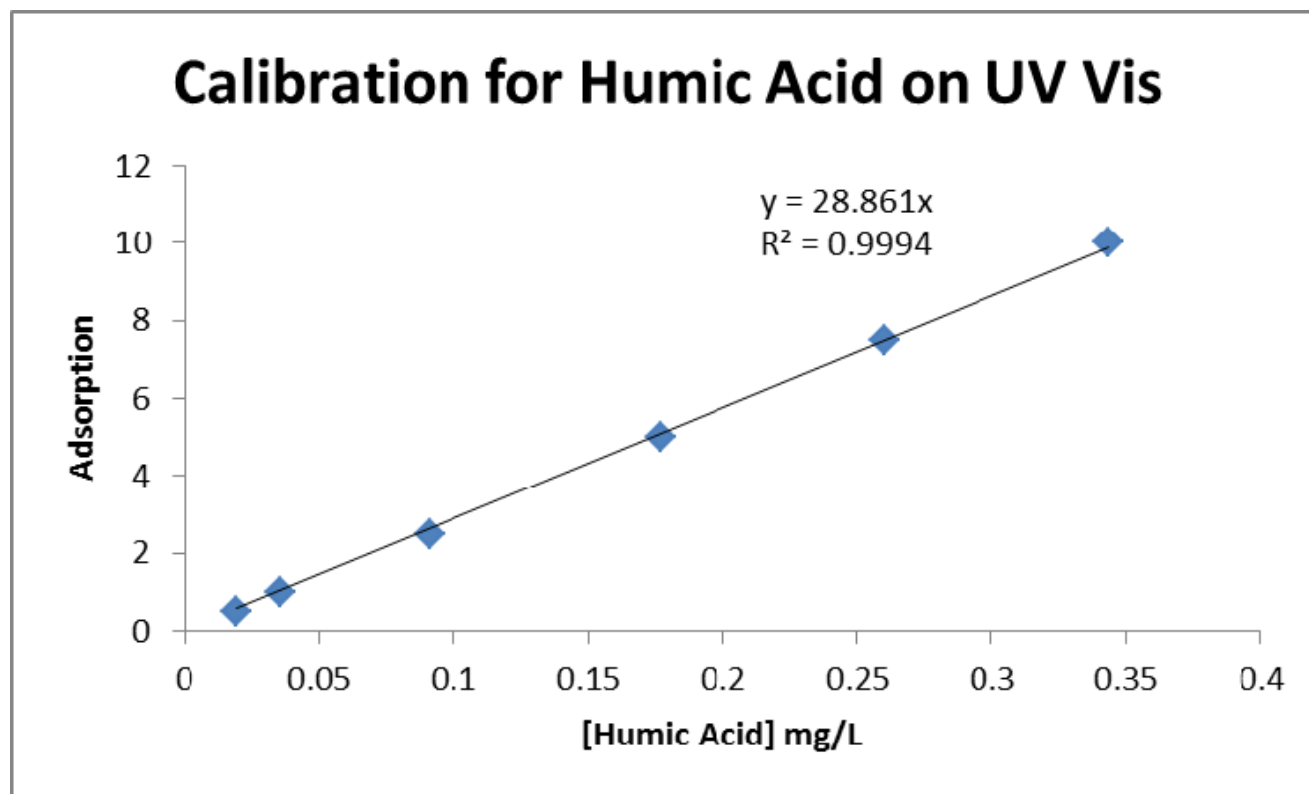




# Methods for Calibration of [Humic Acid]

- Prepared solutions with known concentrations of humic acid in buffered H<sub>2</sub>O

# Calibration Curve for Humic Acid on GC





# Isotherm Experiment Purpose

- To determine the effects of nanoparticles on TCE adsorption by activated carbon under equilibrium.

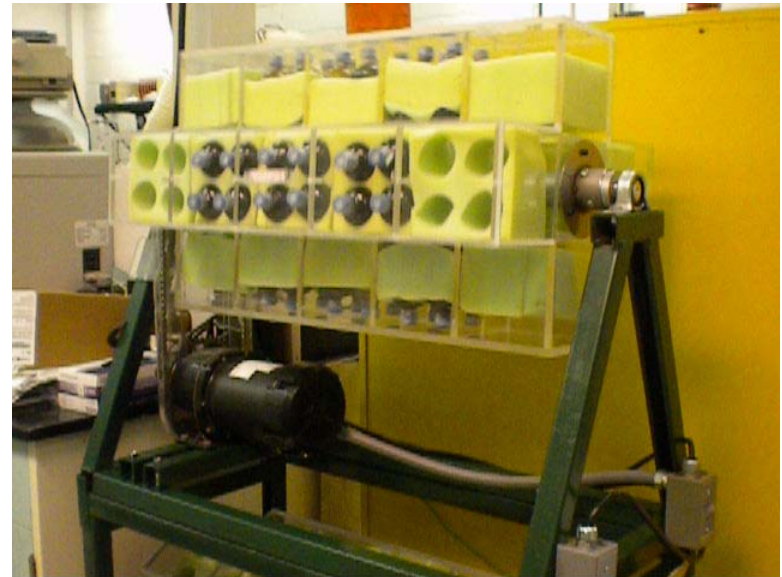


# Preparation of Isotherm

- Bottle point technique is used
- Three different initial concentrations of TCE
- Different masses of powdered activated carbon (PAC) are used in each bottle
- Four blanks for each initial concentration with no PAC. (Two with no NP, two with NP)

# Isotherm Experiment Methods

- Equilibrium experiment (10 days)
- Controls: Volume, time, and [Humic Acid]
- Variables: [TCE] and Carbon Mass



# Isotherm Experiment Results

- Equilibrium quotient

$$q_e = \frac{(C_o - C_e)V}{m}$$

- Freundlich isotherm equation

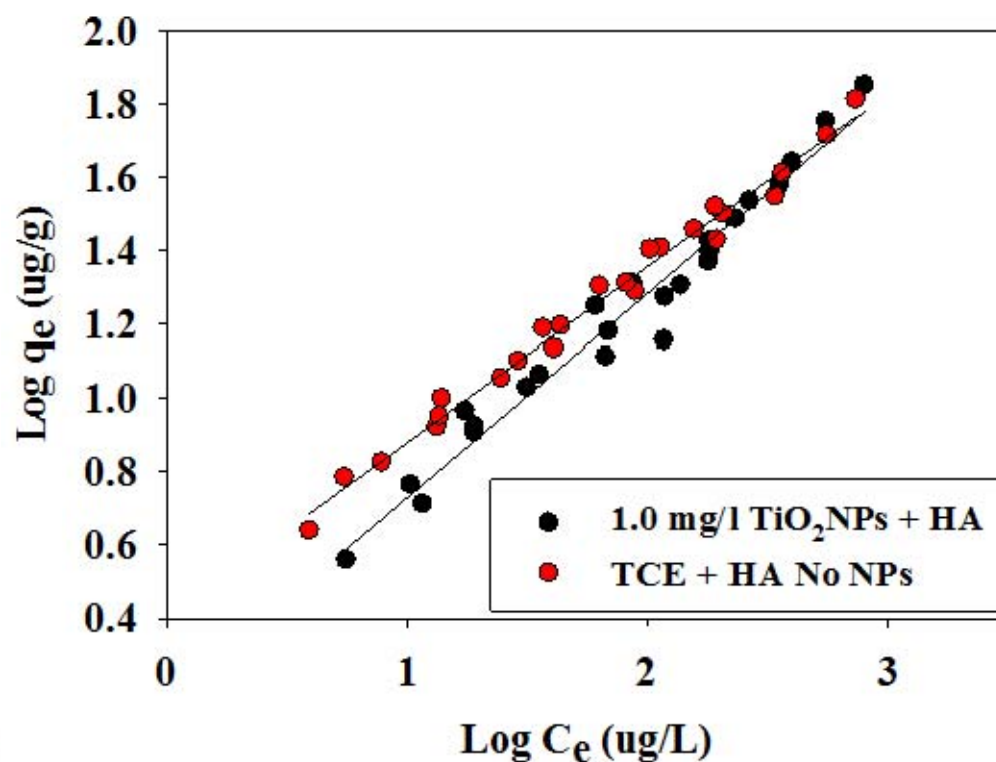
$$q_e = kC_e^{1/n}$$

- Log of the equation produces a straight line

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# Isotherm Experiment Results

TCE Adsorption Isotherm  
in the presence and absence of  $\text{TiO}_2\text{NP}$





# Isotherm Experiment Conclusions

- At high concentrations of TCE and small amounts of carbon, the presence of  $\text{TiO}_2$  NPs decreases the adsorption of TCE
- Humic acid adsorption is not dependent upon the carbon dosage
- $\approx 0.01$  mg humic acid adsorbed in each bottle



# Kinetics Experiment Purpose

- To study rate at which the adsorption of TCE by carbon takes place in the presence of humic acid and in the absence and presence of NP's



# Kinetics Experiment Methods

- Control: Carbon Mass, Volume, [TCE], and [Humic Acid]
- Variable: Time

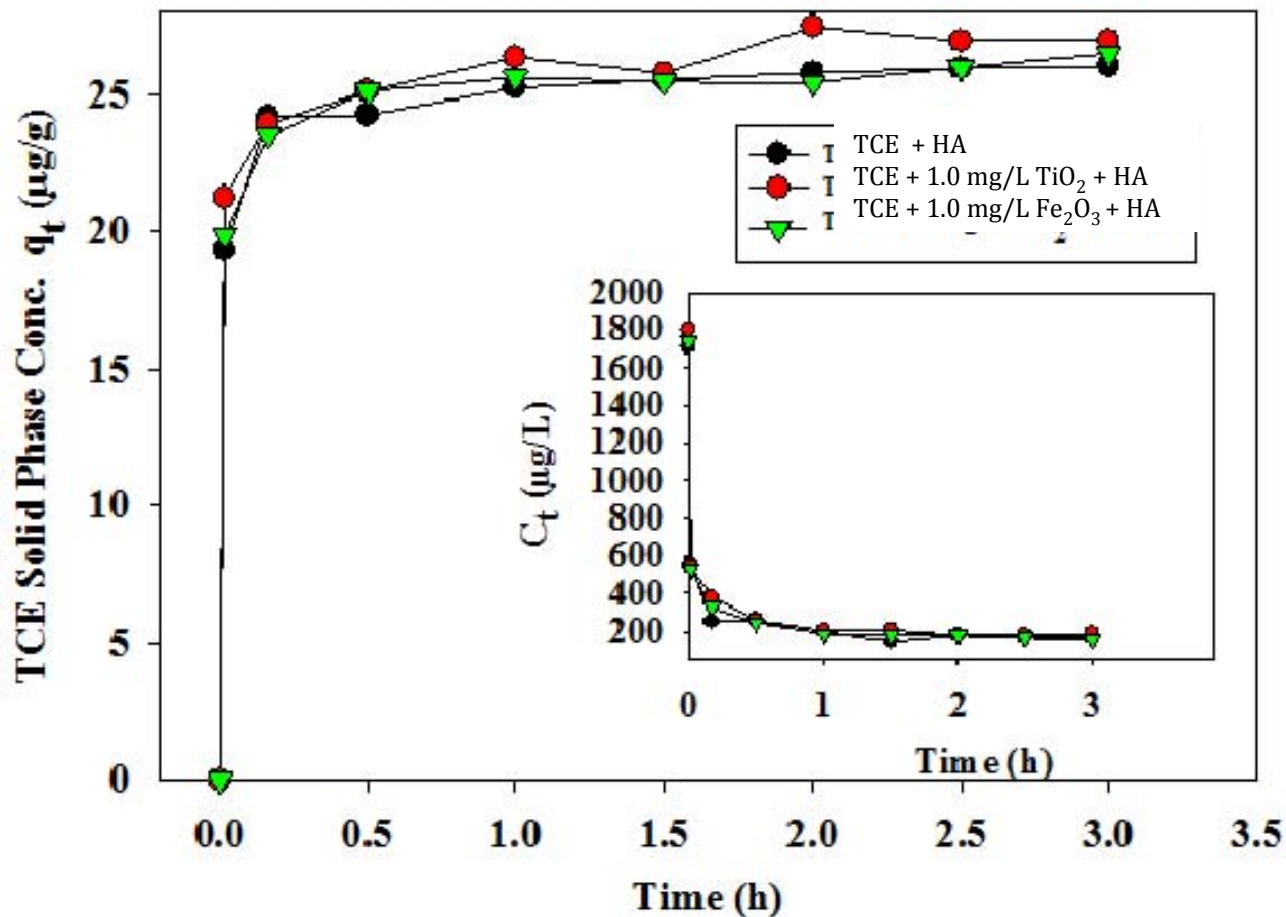
# Kinetics Data Analysis

- $q_t$  is a quotient with amount adsorbed per milligram of carbon
- Useful for comparing experiments due the volatility of TCE

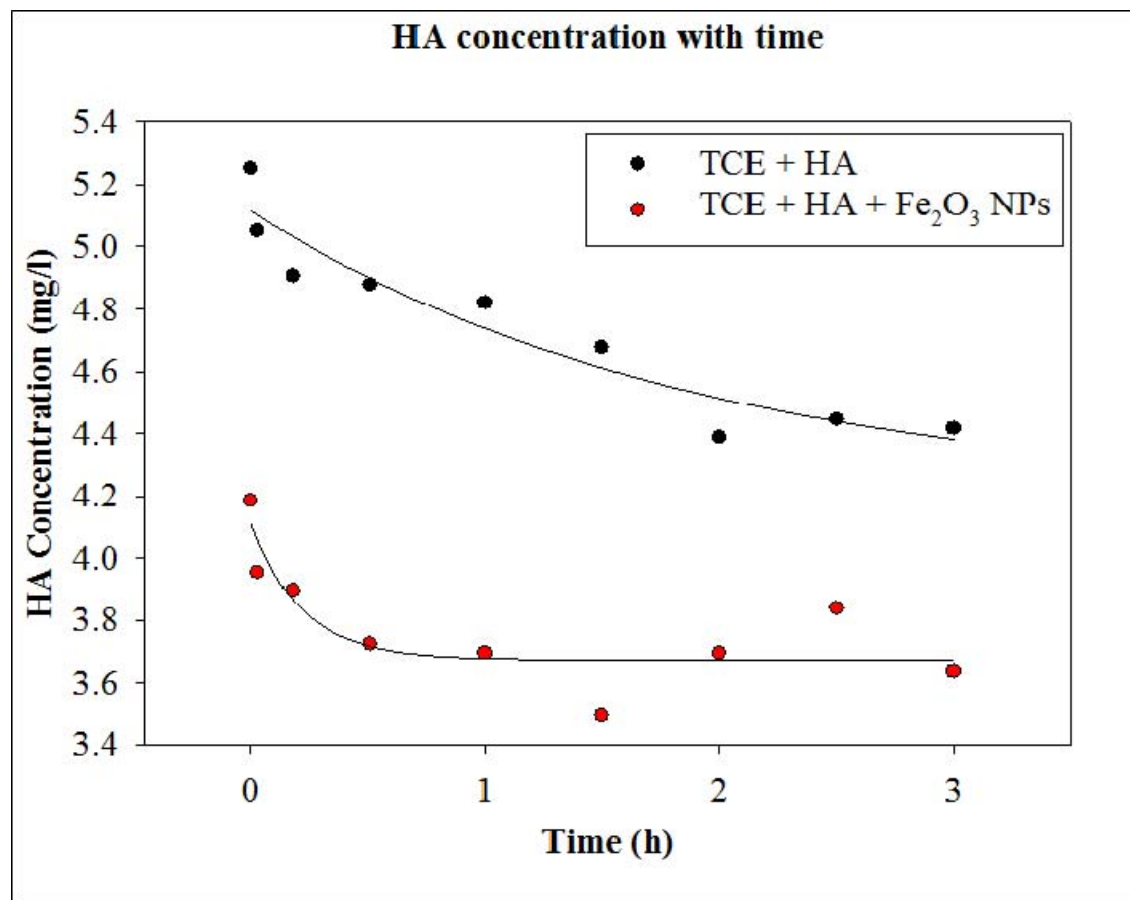
$$q_t = \frac{(C_o - C_t)V}{m}$$

# Kinetics Experiment Results

TCE Adsorption Kinetics in the Presence and Absence of NPs and HA



# Kinetics Experiment Results



# Kinetics Experiment

## Conclusions

- The relative amount of TCE adsorbed is much larger than the relative amount of humic acid adsorbed after 1 minute 45 seconds
- Rationale: TCE molecular size (96 amu) is smaller than humic acid molecular size (1000 – 10000 amu)
- There exists no change in TCE adsorption in the presence and absence of NPs with humic acid



# Column Breakthrough Purpose

- To determine if the rapid small column test (RSCT) predicts the behavior of the large column in the presence of  $\text{TiO}_2$  NPs
- Expensive, time consuming, and impractical to run large scale tests, therefore, RSCTs are desirable.



# Column Breakthrough Methods

- Determine the set-up of both the large and small column using mathematical relationships

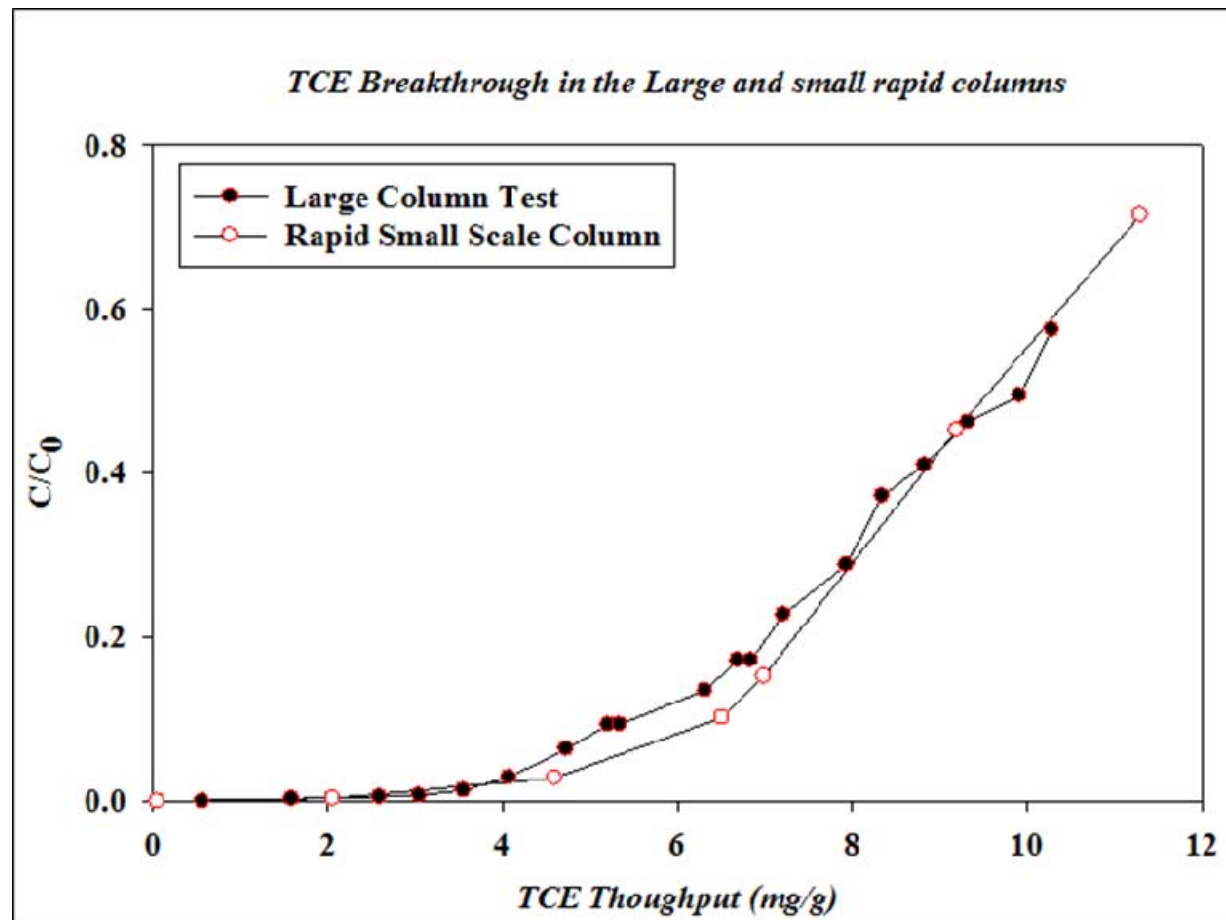
$$\frac{EBCT_{sc}}{EBCT_{LC}} = \left[ \frac{d_{p,sc}}{d_{p,LC}} \right] \quad \frac{V_{sc}}{V_{LC}} = \frac{d_{LC}}{d_{sc}}$$

- Pack the large column and the small column with calculated amount of PAC based on particle size and diameter of column
- Fill tanks with buffered water (pH 7), TCE, and silica nanoparticles based on the 62.0 L tank

# Column Breakthrough Methods



# Column Breakthrough Results





# Column Breakthrough Conclusions

- The large and small column behave similarly
- The behavior of large scale column beds in water treatment facilities can be predicted by the RSCT.



# Classroom Implementation Plan

- Rachel's Classes
  - Hamilton High School
  - Biology, Grade 10
- Kathryn's Classes
  - Oak Hills High School
  - Chemistry and Societal Issues, Grades 11-12



# Classroom Implementation Plan

## Outline

- Pre-Test on Water Chemistry and Water Quality
- Introduction: Daily Water Usage Log followed by Analysis and Reflection
- Chemistry of Water
- Problem Based Water Filter Lab
- Post-Test on Water Chemistry and Water Quality



# Water Filter Lab

- Problem: Clean 100 mL of River Water
- Performance Criteria
  - Volume of Water Retained
  - pH
  - Turbidity
  - Temperature
  - Cost
- Must design a filter using the materials provided

# Water Filter Lab

Material	Cost
Water Bottle	\$10.00
Sand (1 spoonful)	\$0.50
Gravel (1 spoonful)	\$0.50
Filter paper/coffee filter (1)	\$1.00
Rubber Band (1)	\$0.10
Charcoal (1 spoonful)	\$1.00
Cotton Ball (1)	\$0.50
Cheesecloth (10 cm x 10 cm)	\$1.00
Alum (1 spoonful)	\$1.00
River water (100 mL per group)	Free
Replacement River Water (10 mL)	\$5.00
Extra Lab Paper	\$10.00
Borrow Pen or Pencil	\$5.00



# Water Filter Lab

	10	8	6	4	2	0	Score
<b>Volume (mL)</b>	90-100	80-89.9	70-79.9	60-69.9	50-59.9	Less than 50	
<b>pH</b>	7.0	6.5-6.9 or 7.1-7.5	6.0-6.4 or 7.6-8.0	5.5-5.9 or 8.1-8.5	5.0-5.4 or 8.6-9.0	Less than 5 or Greater than 9	
<b>Turbidity (NTU)</b>	Less than 10	10.1-25.0	25.1-45.0	45.1-70.0	70.1-99.9	Greater than 100	
<b>Temperature</b>	±0°C	±0.5°C	±1.0°C	±1.5°C	±2.0°C	±2.1°C or more	
<b>Cost</b>	Less than \$15.00	\$15.00 - \$17.50	\$17.51 - \$20.00	\$20.01 - \$22.50	\$22.51 - \$25.00	Greater than \$25.00	
<b>Total Score</b>							



# Water Filter Lab

- Reflections on initial designs
- Discuss in groups and class wide ways to improve the filter designs

# Citations

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