TEAM RESEARCH PROJECT REPORT

Project 1: Availability of Safe Drinking Water

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**"Sustainable Engineering for Urban Needs:
Research Experiences for Middle and High School Teachers"**

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Goal and Objectives: The goal and objectives for the research and lesson plan are as follows:

Research: The primary focus of this research is to evaluate the impact of Titanium dioxide nanoparticles (TiO_2 NPs) and Natural Organic Matter (NOM) on the removal of Volatile Organic Compounds (VOCs) by GAC. In this study the effect of TiO_2 NPs was looked at in the presence and absence of Humic Acid (HA) in order to closely mimic the natural surface waters conditions. HA is commonly found in natural water as the result of the breakdown of NOM. TCE was selected in this study to represent VOCs due to its abundance as a groundwater contaminant. The secondary objectives of the research were to conduct TCE adsorption isotherms in Powdered Activated Carbon (PAC) in the presence and absence of HA and TiO_2 NPs. This information can be used to calculate Freundlich isotherm constants for all Trichloroethylene (TCE) adsorption onto PAC. Seminars and help in literature search on ther topic were first conducted to educate the high school and elementary school teachers about the topic and to help them develop lessons from the research conducted to teach engineering concepts to the students.

Lesson Plan: The purpose of the lesson was to take engineering concepts, applications, and approaches that the teachers learned in the research and turn them into a useable classroom lesson. The research lab that they worked in was one associated with environmental engineering. The focus of the lab was to study the effects of nanoparticles on water filtration. To turn this into a lesson the teachers focused on ways to connect their students to find different ways to filter water and linking the concepts learned to standards associated with the grade level. This approach provided a means for the teachers to teach inquiry driven lesson to the students, which will allow them to actual see the properties first hand as opposed to just having abstract examples to think about. The goals of the lessons for the students were:

- Work cooperatively in groups to come up with a filter design.
- Construct a water filter that is functional.
- Test the functionality of the device.
- Learn about different careers involved with Environmental Engineering.
- Use observations to determine what is occurring to dirty water and try to draw to conclusions to why this is occurring.
- Identify chemical and physical changes associated with cleaning water.
- Use the pH scale to measure the purity of water.

Research Tasks Undertaken: The purpose of this experiment was to test the effect of TiO_2 on Activated Carbon (AC) ability to adsorb Trichloroethylene (TCE) in the presence and absence of of Humic Acid (HA). In order to study this, a calibration curve had to be made which can be used to find the ability of AC to adsorb TCE. To do this, tests are performed with different amounts of TiO_2 NPs to test its full effect on AC.

Methodologies Used: A 25g/l TCE stock solution was prepared in methanol to overcome the solubility of TCE in water issues. This stock solution was then diluted to make 20 mg/l TCE in methanol. This new stock solution was used to prepare the calibration curves samples. A stock solution of tetrachloroethylene (PCE) was prepared in methanol at concentration level of 60 mg/l to be used as internal standard.

All TCE samples were analyzed using a purge and trap interference method and a gas chromatograph (GC). Six calibration points were generated using TCE concentrations, namely 15, 30, 50, 100, 200, 300, 400 µg/l TCE, and a 25 µl of PCE stock was added to all calibration samples. The levels of TCE were created by diluting the TCE stock solution with a mixture of super Quality (Q) water that has been buffed with 0.001 M KH_2PO_4 and adjusted to pH 7 with 10M NaOH. These samples were injected into the GC and their corresponding areas under the curve were then plotted against concentrations. Linear regression analysis was then preformed and the slope was used to obtain TCE concentrations of the isotherm samples.

Powder Activated Carbon (PAC) was created before experimental isotherms were created. This was accomplished by cleaning GAC multiple times with nano-pure water, which helped remove fines. After this it was placed in a drying oven at 105° C for two whole days to help remove any moisture. Following this it was crushed in a carbon mill and grounded up using a 120 mesh sieve. The product was stored in desiccators until brought to the lab for use.

In order to fully test the effects of TiO_2 NPs and HA on AC ability to adsorb TCE multiple isotherm sets with varying amounts of AC and TiO_2 NPs were performed. There were six different sets of isotherms, which consisted of 8 experimental bottles and 2 blanks for each set, except for the sets with 3mg/l TiO_2 which had 8 experimental bottles and 4 blanks. The blanks did not contain any AC while the 8 experimental bottles had varying amounts of AC. The amount of AC in the isotherms was set at a range from 3.8 to 40 mg within ± 0.5 mg (3.8, 6.0, 8.2, 11.4, 15.5, 20.9, 29.3, 40 mg). The table below shows the details for all parameters in each isotherm set.

	TCE	PAC	HA	TiO_2
Baseline Set 1 No HA	1800µg/l	3.8mg-40mg	None	None
Baseline Set 2 with HA	1800µg/l	3.8mg-40mg	5mg/l	None
1mg/l TiO_2 No HA	1800µg/l	3.8mg-40mg	None	1mg/l
1mg/l TiO_2 with HA	1800µg/l	3.8mg-40mg	5mg/l	1mg/l
3mg/l TiO_2 No HA	1800µg/l	3.8mg-40mg	None	3mg/l
3mg/l TiO_2 with HA	1800µg/l	3.8mg-40mg	5mg/l	3mg/l

All isotherms contained the same type of buffed water that was used to create the isotherm curve which was purified super Q water that has been buffed with 0.001 M KH_2PO_4 and adjusted to pH 7 with 10M NaOH. The Isotherms sets were created in pairs with one containing

5mg/l HA and the other not containing HA. The first two sets were baseline sets which contained no TiO_2 NPs, the next two sets contained 1mg/l TiO_2 NPs, and the final two sets contained 3mg/l TiO_2 NPs. The amount of TCE was kept constant for all sets at 1800µl. The procedure for creating these isotherms is as follows:

- Measuring out the different amount of PAC for each isotherm using a lab scale, and then placing them inside 250 ml amber bottles to block out sunlight.
- Load four liters of super Q water buffed with 0.001 M KH_2PO_4 and adjusted to pH 7 with 10M NaOH into a four liter jar.
- 300 µl of TCE stock solution is introduced into 4 liters of super Q buffed water and stirred for 10 minutes using a magnetic stirring rod to attain a TCE concentration of 1800 µg/l
- For sets containing HA add 5mg/l of HA into the mixture.
- The top of the bottle is then blocked off with a stopper with an air bladder that has been filled with nitrogen. This prevents the TCE to reduce volitization into the head space.
- The mixture is then introduced into the 250 ml amber bottles that contain the PAC. The bottles are filled to the top to allow no head space.
- These bottles are then placed into a rotating tumbler for 10 days to achieve equilibrium

After the 10 days in the tumbler the isotherms were then removed from the tumbler. The samples were then filtered using 0.45 nanometer filter paper to remove the AC from the solution. The samples were diluted in order to align the amount of TCE with the calibration curve using super Q water buffed with 0.001 M KH_2PO_4 and adjusted to pH 7 with 10N NaOH. The total volume of each sample was 50 ml. The table below shows the dilution for each sample bottle.

Bottle	Amount of AC	Amount of buffer solution
1	3.8 mg	45 ml
2	6.0mg	45 ml
3	8.2mg	45 ml
4	11.4 mg	40 ml
5	15.5 mg	40 ml
6	20.9 mg	25 ml
7	29.3 mg	25 ml
8	40 mg	0 ml
9	0 mg	45 ml
10	0 mg	45 ml

After the filtration and dilution the bottles 25 µL of PCE was added to each vial to be used as an internal standard. These sample bottles were covered with Teflon septum caps and wrapped in Parafilm. The samples were then placed inside GC and analyzed for the amounts of

TCE and PCE concentrations, which calculated the area for both. This data was then analyzed used the Freundlich equation, and graphed using excel spread sheet.

The pictures below show the participants working on different aspects of the project.

Sara Filling Isotherm Bottles with TCE Buffed Solution

Discussing Calibration Curve Data with Graduate Mentor

Calculating the Amount of AC Needed

Measuring Out the Amount of TiO_2 NPs

Training Received: Training was received to use following equipment:

- Gas chromatography
- Scales
- Water filter
- Syringe filters
- Tumbler
- Pipets
- pH probes

Conclusions: This experiment originally had two standing hypothesis on what could potentially occur: the TiO_2 NPs would attach to the PAC and block the adsorption pores preventing TCE adsorption, or they would behave as adsorption sites and be carried by water

along with TCE to the consumer. However it is not possible to say that the teachers data represents either one of these hypothesis. The amount of TCE adsorption did not decrease with increasing TiO_2 NPs so it is not possible to make the claim that the TiO_2 NPs are blocking adsorption sights using this kind of experiment. Also the data does not support the idea that TiO_2 can act as an adsorbing site itself for TCE, because this also would result in amount of TCE decreasing with increasing amounts of TiO_2 NPs. However the teachers data shows no change in TCE adsorption from the base line experiments that were ran with no TiO_2 NPs , compared to the sets with 1 mg/l TiO_2 NPs and the set containing 3mg/l TiO_2 NPs. Based off of the teachers data new ideas need to be considered in order to explain the phenomena that is occurring. Including use of the column break through studies for TCE in presence and absents of TiO_2 NPs.

Lesson Developed for Classroom Implementation: In this lesson the students will design, create and investigate a homemade water filtration device that will take two days to complete. The students will be put into groups of three and each student will be given a specific job. The three jobs that will be available are: designer/constructor, reader, and on-task manger. Each person in the group will be responsible for reflecting in their science notebooks and answering questions. The purpose of this lesson is to give students a hands-on experience with a variety of the properties with matter while trying to solve the problem of cleaning dirty water. Students will work together in groups of 3 to 4 to select materials that they believe will work best as water filtration system. After selecting their materials, the students will construct and test their filtration devices and record all their observations during this experiment. After cleaning dirty water with their filtration devices students must make conclusions on their filtration devices on how effective it was at cleaning the water. The next day students will design and create a one PowerPoint slide explaining their filter, how it was effective, and where it could be improved.