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EVALUATION OF POWDERED ACTIVATED CARBON FOR CONTROL OF TASTE AND ODORS CAUSED BY GEOSMIN

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Master's Program in Civil Engineering

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Dean of the Graduate School

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2018

DEDICATION

This thesis is dedicated to my loving parents, Jose & Teresa Rodriguez. Your love, guidance, and support throughout the years have been a blessing that cannot be put into words.

I also want to dedicate this to my loving sister, Jennifer Rodriguez, for also being a huge support, role model, and blessing in so many ways.

Lastly, and most of all, I want to dedicate this thesis to my son, Aidan Anthony, who is truly the brightest light in my world and who is the absolute inspiration and my motivation to always keep going and to better myself.

Love you all with every ounce of my heart and soul.

EVALUATION OF POWDERED ACTIVATED CARBON FOR CONTROL OF TASTE AND ODORS CAUSED BY GEOSMIN

by

ANTHONY JOE RODRIGUEZ, B.S.C.E.

THESIS

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I would also like to take a moment to thank my committee members for their time, input, and expertise.

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Thank you all. I am very humbled and beyond grateful. Thanks!

ABSTRACT

The primary sources of taste and odor problems associated with surface water supplies spawn from algae and bacterial blooms that secrete odorous chemicals such as Geosmin and MIB. These musty, odorous, organic compounds are usually detectable by the human nose at concentrations of 5 to 10 ppt and can create considerable concern by consumers that can lead to complaints and misconceptions of odors as a water quality problem. Typically, since chemical or ozone treatment can be costly, activated carbon (powdered or granular) is generally employed in the process of removing organic compounds, such as Geosmin and MIB. The research presented here is an evaluation of powdered activated carbon (PAC) for control of taste and odors caused by Geosmin. The project was directed toward: (1) evaluating odor detection limits of Geosmin, (2) determining the PAC dosage and thresholds required for eliminating odor problems, (4) identifying the most effective PAC to use between selected brands, and (5) developing an Adsorption Isotherm to quantify the effective PAC dosage required for the removal of Geosmin at certain concentrations.

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1. INTRODUCTION

The primary sources of taste and odor problems associated with surface water supplies are from algae and bacterial blooms (Huddleston, et al. 2015). Some species of algae and bacteria produce odorous chemicals that exhibit an earthy, musty smell and taste that become present in water distribution systems and are a nuisance to consumers. Geosmin (trans-1, 10-dimethyl-trans-9-decalol) and MIB (2-methylisborneol) are common odorous chemicals that are secreted by algae and bacterial blooms (Aider and Liato 2017; Aoyama 1990). Algae and bacterial blooms occur when light, temperature, and nutrient conditions are favorable in surface water bodies. Typically, spring and winter conditions favor algae blooms, while summer and fall conditions favor Geosmin and MIB producing bacteria that are most common during the month of September. These bacteria (cyanobacteria) are known by several names including "blue-green algae" and are commonly found in eutrophic and shallow waters. As a bloom progresses, bacteria die, releasing these odorous chemicals into the water (Hoehn, R.C. 2002). These musty, odorous, organic compounds are usually detectable by the human nose at concentrations of 5 to 10 parts per trillion (ng/L or ppt) (Aider and Liato 2017; You 2012) and although they are not known to be a public health concern, they can create considerable concern by consumers that can lead to complaints and misconceptions of odors as a water quality problem (Bruce, et al. 2002).

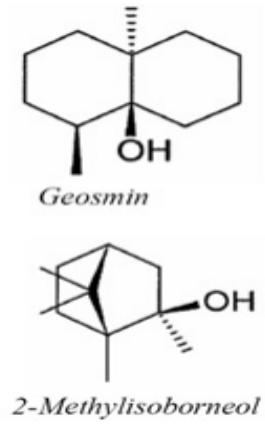

FIGURE 1.1: CHEMICAL STRUCTURE OF GEOSMIN AND 2-METHYLISOBORNEOL (MIB)

1.1 Application of Powdered Activated Carbon in Surface Water Treatment

Many water treatment facilities experience taste and odor problems that affect the public's perception of the water quality coming out of distribution systems. Typically, since chemical treatment can be costly, activated carbon is generally employed in the process of removing organic compounds, such as Geosmin and MIB (Crittenden 2012; Bruce, et al. 2002). Activated carbon is an effective adsorbent because it is a highly porous material and provides a large surface area to which contaminants may adsorb. As water passes through the activated carbon, organic particles and chemicals are trapped through adsorption processes that depend on 5 key factors: the surface area and pore size distribution, the chemical makeup of the carbon source, chemical makeup of the contaminant, water pH and temperature, and the length of contact or exposure time to the carbon (Crittenden 2012; Li, et al. 2012). The two main types of activated carbon used in water treatment applications are granular activated carbon (GAC) and powdered activated carbon (PAC) that are differentiated by particle size. Powdered activated carbon has a particle diameter size of less than 0.1 mm as compared to granular with a mean particle diameter size of 1.2mm (United States Environmental Protection Agency). The increased surface area and pore distribution of powdered activated carbon allows for easier diffusion, thereby increasing adsorption kinetics (Cook, et al. 2001). Whereas GAC is found in media filtration beds, the feed location of PAC can be at any point prior to filtration and is most commonly used in the flash mixer or flocculator, since these pieces of equipment will mix PAC in the water very well and will settle in subsequent processes (United States Environmental Protection Agency).

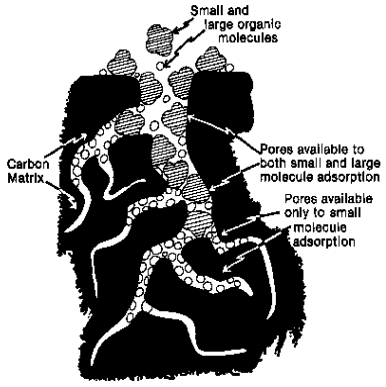

FIGURE 1.2: ACTIVATED CARBON MATRIX (UNITED STATES ENVIRONMENTAL PROTECTION AGENCY)

1.2 Surface Water Treatment Processes: Coagulation and Flocculation

Coagulation and flocculation are essential components of conventional water treatment systems for the process of removing colloidal particles that are too small for gravitational settling or filtration processes alone (Davis 2010; Sawyer 2003). Surface water supplies contain organic (algae, bacteria, cysts of protozoa, viruses) and inorganic (clay, silt, and mineral oxides from erosion) particles that are suspended in water. Suspended particles range in diameter from 0.1µm to 100 µm (Figure 1.3). In addition, particulate and dissolved organic matter or NOM (natural organic matter) may be present. NOM is a product of decay and leaching of organic detritus and is a precursor to the formation of disinfection byproducts (Crittenden 2012; Davis 2010).

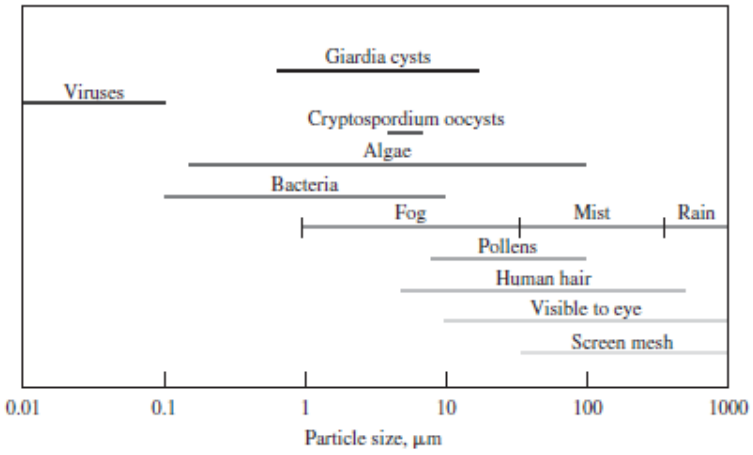

FIGURE 1.3: PARTICULATES IN WATER AND REFERENCE SIZES (DAVIS 2010)

The objective of coagulation is to turn small colloidal particles into larger particles of flocs. The subsequent process after coagulation is flocculation, where flocs are either created as precipitants or as suspended particles. The flocs are then removed in the subsequent processes of settling (sedimentation) and filtration (Figure 1.4) (Crittenden 2012; Davis 2010). Coagulants are typically added to the flash mixer where it is dispersed and mixed well. Flash mixers typically have detention times of 20-60 seconds at speeds of about 100-150 rpm. The water is then passed through flocculators for a detention time of 20-30 minutes, with typical mixing speeds of 25-45 rpm (usually decreasing along the length of the basin). The flocs then enter the sedimentation basin where gravitational settling occurs in typical detention times of 1.5-2 hours. Any floc that does not settle is then captured by granular media filtration in the subsequent process (Crittenden 2012; Davis 2010)

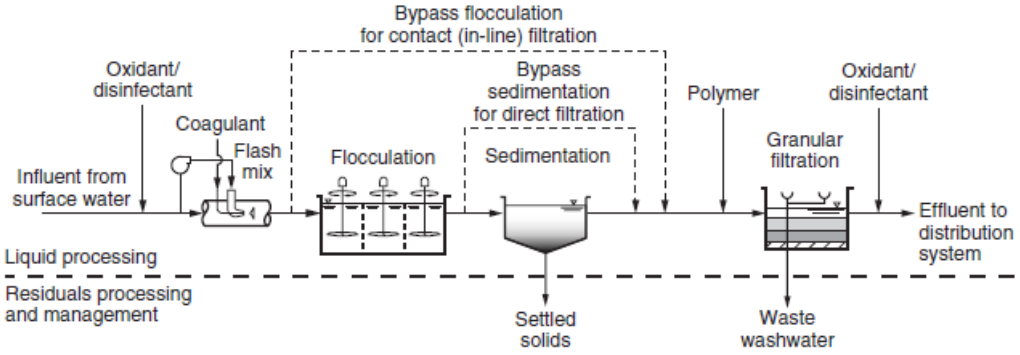

FIGURE 1.4: TYPICAL WATER TREATMENT PROCESSES AND COAGULANT FEED LOCATION (CRITTENDEN 2012)

For the purpose of this discussion, coagulation refers to the addition of one of more chemicals to condition small particles for subsequent processes such as flocculation and settling. There are four mechanisms by which colloidal particles can be coagulated: (1) compression of the double-layer, (2) charge neutralization, (3) entrapment in a precipitate, and (4) interparticle bridging (Sawyer 2003). Typically, several mechanisms are applied simultaneously. Coagulants such as alum ($Al_2(SO_4)_3$), ferric chloride ($FeCl_3$), and ferric sulfate ($Fe_2(SO_4)_3$) are typically used as they hydrolyze rapidly when mixed in the water to be treated. Coagulation by addition of hydrolyzing salts such as alum and iron involve: (1) destabilization of small suspended and

colloidal particles, (2) adsorption and/or reaction of portions of the colloidal and dissolved NOM to particles, and (3) creation of a floc of particles that will sweep through the water, enmeshing small suspended, colloidal, and dissolved matter as they settle (Crittenden 2012; Davis 2010).

2. PROBLEM

The El Paso Water Utilities (EPW) currently supplies 90% of municipal water in the El Paso County. With the capability of treating 100 million gallons per day, three surface water treatment plants treat water from the Rio Grande during a seven-month irrigation season, typically from March through September (El Paso Water). Exposure to sunlight and other favorable water conditions during the hot months of July through September allow algae and bacterial blooms to occur within the Rio Grande River. During these months, taste and odor problems begin to arise as these blooms secrete odorous chemicals such as Geosmin and MIB. During the summer months of 2016, an intense, prolonged taste and odor episode throughout downtown El Paso brought concern to citizens. This concern led El Paso Water to consult with the university to seek alternatives that could be implemented in the summer of 2017 for controlling this problem, should it arise.

3. OBJECTIVE

The objective of this project was to compare and evaluate the performance and removal of Geosmin using various PACs. The project was directed toward: (1) evaluating odor detection limits of Geosmin, (2) determining the PAC dosage and thresholds required for eliminating odor problems, (3) identifying the most effective PAC to use at the Jonathan Rogers treatment plant, and (4) developing an Adsorption Isotherm to quantify the effective PAC dosage required for the removal of Geosmin at certain concentrations. Brands of PAC were selected in consultation with El Paso Water personnel.

Due to budgetary and time constraints, as well as the need for proper equipment to analyze the quantity of Geosmin in the water, it was imperative to develop a method of testing the effectiveness of removal without having to package and ship samples out to an analytical laboratory after every experiment. Samples that were sent to the lab were then compared to the percent removal of several dyes, indicators, and food colorings to see whether such would be representative of the removal of Geosmin in the water. Once the results were confirmed and replicated, PAC effectiveness could be determined using dyes and a spectrophotometer in addition to the Geosmin analyzes obtained from the analytical laboratory.

4. METHODOLOGY

4.1. General

The initial threshold for odor detection was confirmed in deionized (DI) water using several concentrations of Geosmin and asking student volunteers to participate in a smelling survey. This was also done with various concentrations of PACs as well as various mixing times and speeds to simulate treatment processes to determine a benchmark for PAC dosage. After determining a benchmark for the PAC concentration, PAC samples were then tested with selected dyes in tap and river water with Geosmin. A spectrophotometer was used to measure absorbance of each dye at different PAC concentrations and a rank was established for each PAC performance. After ranking and identifying the best performing PAC based on percent removal, samples were then sent to a consulting laboratory and an adsorption isotherm was developed to quantify the amount of PAC needed to treat a certain concentration of Geosmin. Detailed procedures are described in the following sections.

4.2. Odor Observance of Geosmin in Water

Before evaluating the effectiveness of each PAC sample, several students were asked to participate in a smell experiment using different concentrations of Geosmin. With an original concentration of 500,000 ng/L of Geosmin in the standard solution, a stock solution of Geosmin was created in DI water with a 1:1000 dilution. The stock solution was then used to prepare six 200 mL samples with dilution factors of 200, 100, 50, 20, 10, and 1 to yield concentrations of 2.5, 5, 10, 25, 50, and 500 ng/L, respectively. After mixing for 30 seconds with a magnetic stirrer, the solutions were put into wide-mouth Erlenmeyer flasks and heated to a standard 45^0C. Students were then asked to smell the solutions. At 25 ng/L, 100% of participants were able to detect the odor. Therefore a concentration of 25 ng/L and above of Geosmin was used to spike future samples for testing.

TABLE 4.1: SMELL DETECTION RESULTS FOR GEOSMIN IN DEIONIZED WATER

Date	Dilution Factor	Geosmin (ng/L)	Mix Time	Smell 1=yes 0=no										% Detected	Comments
1/11/17	200,000	2.5	30 sec	0	0	0	0	0						0.0%	Standard Geosmin Solution= 500,000 ng/L ; DI Water; Rapid Mix; 5 Participants
	100,000	5	30 sec	0	0	0	1	0						20.0%	
	50,000	10	30 sec	1	0	1	1	1						80.0%	
	20,000	25	30 sec	1	1	1	1	1						100.0%	
	10,000	50	30 sec	1	1	1	1	1						100.0%	
	1000	500	30 sec	1	1	1	1	1						100.0%	

4.3. Preliminary Testing for Odor Observance of Geosmin Treated with PAC

Further odor experiments were conducted to determine a threshold for the detection of Geosmin. First, all water was dechlorinated. This was done by adding a pinch of sodium thiosulfate into the containers of collected sample water and mixing them well. Sodium thiosulfate is an odorless powder that reduces chlorine and has been used experimentally as a wastewater-dechlorinating agent (Worley 2000). The water was then tested for chlorine using 10 mL of the sample and adding a HACH DPD total chlorine reagent powder pillow. A color change to pink indicated that chlorine was still present in the water, so another pinch of sodium thiosulfate was added. This was repeated until the water remained clear after the addition of the indicator pillow. Once dechlorinated, a liter of water was poured into a jar-test apparatus.

Preliminary tests using PAC were conducted using the Darco KB-M (M-2213) PAC (as this PAC was available off-hand in the lab) and concentrations of 5, 10, 15, 50 and 100 mg/L were added to 1-liter samples that were prepared in a jar-test apparatus. Geosmin concentrations were established at 50 ng/l and 100 ng/L. Solutions were then mixed for 20, 15, and 10 minutes at 45 rpm after the PAC was added (to simulate flocculators in a treatment plant). After settling for 15 minutes, samples were taken from the top of the solutions, filtered through glass fiber filters, and put into wide-mouth Erlenmeyer flasks and heated to 45^0C. Tests conducted 1/19, 1/23, and 1/24 showed that at 15 mg/L PAC and a mixing time of 20 minutes was not sufficient to completely remove the odor of Geosmin, so subsequent tests were mixed for 20 minutes with various PAC

concentrations. Participants were then asked to smell each sample and it was determined that at a concentration of 50 mg/L of KB-M PAC and 20 minutes mixing time, no odor was detected.

TABLE 4.2: SMELL DETECTION FOR GEOSMIN IN DI WATER USING VARIOUS KB-M PAC CONCENTRATIONS

Date	Dilution Factor	Geosmin (ng/L)	PAC (mg/L)	Mix Time	Participant Smell 1=yes 0=no										% Detected	Comments
1/19/17	5000	100	15	20 min	0	0	1	1							50%	45 rpm; DI Water;
	5000	100	15	15 min	0	1	1	1							75%	
	5000	100	15	10 min	0	1	1	1							75%	
1/23/17	10000	50	10	20 min	1	0	1	0							50%	Same as previous
1/24/17	10000	50	15	20 min	0	0	1								33%	Same as previous
	10000	50	5	20 min	1	0	1								66%	
1/30/17	5000	100	100	20 min	0	0	0								0%	Same as Previous
	5000	100	50	20 min	0	0	0								0%	

To further simulate treatment processes and the application of powdered activated carbon, samples of river water (collected just after the bar rack) and tap water were added to the jar-test apparatus. An initial test of 6 samples was administered with the first sample consisting of 1-L of river water each, 100 ng/L of Geosmin, 10 mg/L of Ferric Chloride ($FeCl_3$) and 40 mg/L PAC. The second sample was like the first, except with 50 mg/L PAC. The next two samples contained 1-L of river water, 100 ng/L of Geosmin, no $FeCl_3$, and 50 mg/L of PAC in each sample. The final two samples contained 1-L of tap water, 10 ng/l of Geosmin (to simulate thresholds to sensitive populations), and 10 mg/L of $FeCl_3$ with no PAC added. Using a 6-paddle jar-test lab stirrer, samples were then mixed for 1 minute at 100 rpm (rapid mix), 20 minutes at 30 rpm (flocculation mixing), and allowed to settle for 10 minutes. This was done to simulate water treatment processes in a typical surface water treatment plant. Samples were carefully poured from the top, as to not disturb sediments from the bottom of the jar. The first two samples were filtered through a glass fiber filter using a vacuum flask as was one of each of the next two. Two were not filtered to determine the effect of the filter itself. These initial results were inconclusive because there was

difficulty distinguishing the smell of Geosmin in the river water, as it smelt foul of a different odor. Results can be seen in Appendix A, 1/31/17.

Several tests were then conducted in the same manner, except using tap water to avoid smell complications. Three 1-liter samples of dechlorinated tap water were put into a jar-test apparatus with 50 ng/L of Geosmin in each. Ten mg/L of $FeCl_3$ was added with PAC concentrations of 0, 10, 25, and 50 mg/L. The water was mixed with a 6-paddle jar-test stirrer for 5 minutes at 68 rpm and allowed to settle for 10 minutes. This test was administered on 2/8, 2/10, 2/13 and 2/14 as shown in Table 4.3. On 2/14, it was found odor detection decreased above PAC concentrations of 25 mg/L and that at 50 mg/L of PAC, no odor detection was observed. This confirmed initial detection results conducted on 1/30 and can be seen in Table 4.3.

TABLE 4.3: EVALUATION OF PAC DOSAGE THROUGH ODOR OBSERVANCE

Date	Dilution Factor	Geosmin (ng/L)	PAC (mg/L)	Mix Time	Smell 1=yes 0=no										% Detected	Comments
2/8/17	-	50	50	5 min	0	0	0	0	0	0					0%	Dechlorinated Tap Water; 68 rpm; no filter; 10 mg/L FeCl
	-	50	25	5 min	0	0	0	0	0	1					17%	
	-	50	10	5 min	1	1	1	1	0	1					83%	
2/10/17	-	50	50	5 min	0	0									0%	Dechlorinated Tap Water; 68 rpm; no filter; 10 mg/L FeCl
	-	50	25	5 min	0	0									0%	
	-	50	10	5 min	1	1									100%	
2/13/17	-	50	50	5 min	1	0	0	0	0						20%	River Water; 68 rpm; no filter; 10 mg/L FeCl
	-	50	25	5 min	1	1	1	1	0						80%	
	-	50	10	5 min	1	1	1	1	1						100%	
2/14/17	-	50	100	5 min	0	0	0								0%	River Water; 68 rpm; no filter; 10 mg/L FeCl
	-	50	50	5 min	0	0	0								0%	
	-	50	25	5 min	1	1	1								100%	

Next, an odor detection test was conducted to compare EPW's standard PAC purification and the KB-M PAC used in the above tests. Utilizing the same methods as above, concentrations of 25 ng/L of Geosmin were subjected to PAC concentrations of 0, 10, 25, and 50 mg/L. The KB-M PAC performed better than EPW's standard as can be seen in Table 4.4.

TABLE 4.4: EVALUATION OF EPW STANDARD AND KB-M PAC THROUGH ODOR OBSERVANCE

Date	Geosmin (ng/L)	PAC (mg/L)	Mix Time	Smell 1=yes 0=no										% Detected	Comments
4/24/17	25	100	20 min	0	0	0	0	0	1	0				14%	Dechlorinated Tap Water; 45 rpm; filtered; 10 mg/L FeCl; EPW Std PAC
EPW	25	Blank	20 min	1	1	0	0	0	1	1				57%	
	25	50	20 min	1	1	0	0	1	0	1				57%	
	25	25	20 min	1	1	1	1	1	1	1				100%	
	25	Blank	20 min	1	1	1	0	0	0	0				43%	
	25	Blank	20 min	0	1	1	1	0	0	0				43%	
4/24/17	25	Blank	20 min	1	1	1	1	0	1	1				86%	Dechlorinated Tap Water; 45 rpm; filtered; 10 mg/L FeCl; KB-M PAC
KB-M	25	50	20 min	0	0	0	0	0	0	0				0%	
	25	25	20 min	1	0	1	0	1	1	1				71%	
	25	Blank	20 min	1	1	0	0	0	0	0				29%	
	25	10	20 min	1	1	1	1	1	1	1				100%	

4.4. Comparison of Geosmin removal through Color Removal

Utilizing the PACs chosen in consultation with EPW personnel (see Table 4.5), Geosmin removal was tested and simulated by the use of 8 different colors or dyes. The list and abbreviations of colors are listed in Table 4.6.

TABLE 4.5: POWDERED ACTIVATED CARBON KEY

PAC KEY	
Key	**Full Name**
BL Pulv	Calgon BL Pulv
C Pulv	Calgon C Pulv
EPW Norit	EPW Cabot Norit
EPW Std	EPW Standard
Hydro B	Hydrodarco B (M-1091)
Hydro M	Hydrodarco M (M-226 #4)
Hydro S	Hydrodarco S (M-2209)
Hydro W	Hydrodarco W (M-2242)
KB-M	Darco KB-M (M-2213
Nichem	Nichem FHJ-400
Pulsorb	Pulsorb WR260-90
WPH	WPH 1000

TABLE 4.6: COLOR DYE KEY

Color Key	
Key	**Full Name**
MB	Methylene Blue
FL	Fluorescein
RFC	Red Food Coloring
BFC	Blue Food Coloring
YFC	Yellow Food Coloring
RD	Red Dye (Carmine)
YD	Yellow Dye (Aniline Yellow)
PD	Purple Dye (Rit)

4.4.1. USE OF DYES AND INDICATORS AS A MEANS OF QUANTITATIVE ANALYSIS

The subject of indicators and dyes is complex and of such magnitude that it will only be discussed to the extent of quantitative analysis. It is common practice in biochemistry, biology, medicine, and analytical chemistry to dye or stain microorganisms through the use of colorants in order to 'visually' confirm and quantify a known chemical substance (Zollinger 2003). A number of organic compounds (synthetic or natural) undergo color changes in certain well-defined environments (typically in certain pH ranges) (Sawyer 2003). Dyes can be either organic or inorganic compounds and are characterized by their ability to absorb or emit light on a specific wavelength (Reusch 2013; International Agency for Research on Cancer 2010). Samples of both dyes and indicators can then be inserted into a spectrophotometer to quantify the known substance.

Wavelength Absorbed (nm)	Colour Absorbed	Colour Observed
400–435	Violet	Yellow-Green
435–480	Blue	Yellow
480–490	Green-Blue	Orange
490–500	Blue-Green	Red
500–560	Green	Purple
560–580	Yellow-Green	Violet
580–595	Yellow	Blue
595–605	Orange	Green-Blue
605–700	Red	Blue-Green

FIGURE 4.1: WAVELENGTH OF LIGHT ABSORPTION VS. COLOR (INTERNATIONAL AGENCY FOR RESEARCH ON CANCER 2010)

4.4.1.1 SPECTROPHOTOMETER

A spectrophotometer is an instrument used to measure how much light is absorbed in a chemical substance. A typical spectrophotometer consists of a light source, a collimator, a monochromator, a wavelength selector, a cuvette for sample solution, a photoelectric detector, and a digital display or a meter. The basic principle behind this instrument is that each compound (in this case, the dye) absorbs or transmits over a certain range of wavelength, as listed above. Through this, the amount (or in this case, amount removed) or concentration of a known substance can be determined by measuring the intensity of light detected (National Institute of Standards and Technology). This can then be used to quantify the known substance, or in this case, the removal of Geosmin.

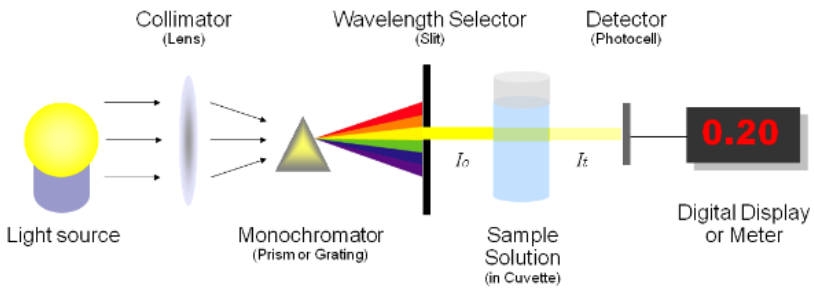

FIGURE 4.2: BASIC STRUCTURE OF SPECTROPHOTOMETERS (ILLUSTRATED BY HEESUN SHIM; VO 2015)

4.4.2. TESTING OF PACS FOR COLOR REMOVAL

For evaluating color removal by PAC, 8 colors were chosen (Table 4.6). One liter of tap water was poured into a jar-test container, dechlorinated, and color was added and mixed well. The amount of dye added to the water was based on obtaining an initial absorbance in the range of 1.0 to 2.0. Various concentrations of PAC (typically concentrations of 0, 15, 30, 50, 75, and 100 mg/L) were then added and stirred for 20 minutes at 45 rpm using the jar-test apparatus (the various concentrations of PAC were added at 3-minute intervals to allow time for filtration of the samples when the mixing stopped). Approximately 500 mL of the samples were then filtered through a

glass fiber filter using a vacuum flask. A spectrophotometer was used to measure the amount of substance remaining within the solution. This was done using a MicroLAB FS-522 visual spectrophotometer and software. After opening the program and choosing the appropriate experiment type ("Spectrophotometer"), a new experiment was initialized and the appropriate wavelength (in the visible range of 380 – 720 nm) was selected for the dye. Using a clean, smudge free cuvette (or wiping vials thoroughly with a kimwipe), 10 mL of a sample was pipetted into the cuvette that was placed in the sample holder. The absorbance was then measured and the results were recorded as absorbance (abs). A plot of Absorbance vs. PAC as well as Percent Removed vs. PAC was created. The PACs were ranked based on percent absorbance removed. Percent removal was calculated using Eq. 4.1:

$$\%\ Removal = \frac{initial\ absorbance - measured\ absorbance}{initial\ absorbance} \quad \text{Eq. 4.1}$$

Percent removal for Geosmin was calculated using Eq. 4.2:

$$\%\ Removal = \frac{initial\ concentration\ with\ no\ PAC - concentration\ with\ added\ PAC}{initial\ concentration\ with\ no\ PAC} \quad \text{Eq. 4.2}$$

Dividing the value of *% Removal* by the PAC concentration, *% removal per mg of PAC* was also calculated.

The KB-M and EPW Std PACs were used in the first removal test. The initial colors tested were fluorescein and methylene blue. Ten mg/L and an absorbance wavelength of 465 nm were chosen for fluorescein, while 5 mg/L and an absorbance wavelength of 660 nm were chosen for methylene blue. Twenty-Five ng/L of Geosmin were mixed into 1-liter jar-test containers and concentrations of 0, 25, 50, and 100 mg/L of PAC was added along with 10 mg/L of $FeCl_3$. Solutions were then mixed for 20 minutes at 45 rpm (3 minutes apart to allow for filtering and measuring of each sample). Approximately 500 mL of the samples were filtered through a glass fiber filter and 10 mL were then pipetted into a clean cuvette and measured using the spectrophotometer. Initial results indicated that there was correlation between the PAC dose and absorbance or percent removed. As the PAC concentration increased, the absorbance decreased, thus increasing the percent removed. The results are shown in Figures 4.3 and 4.4

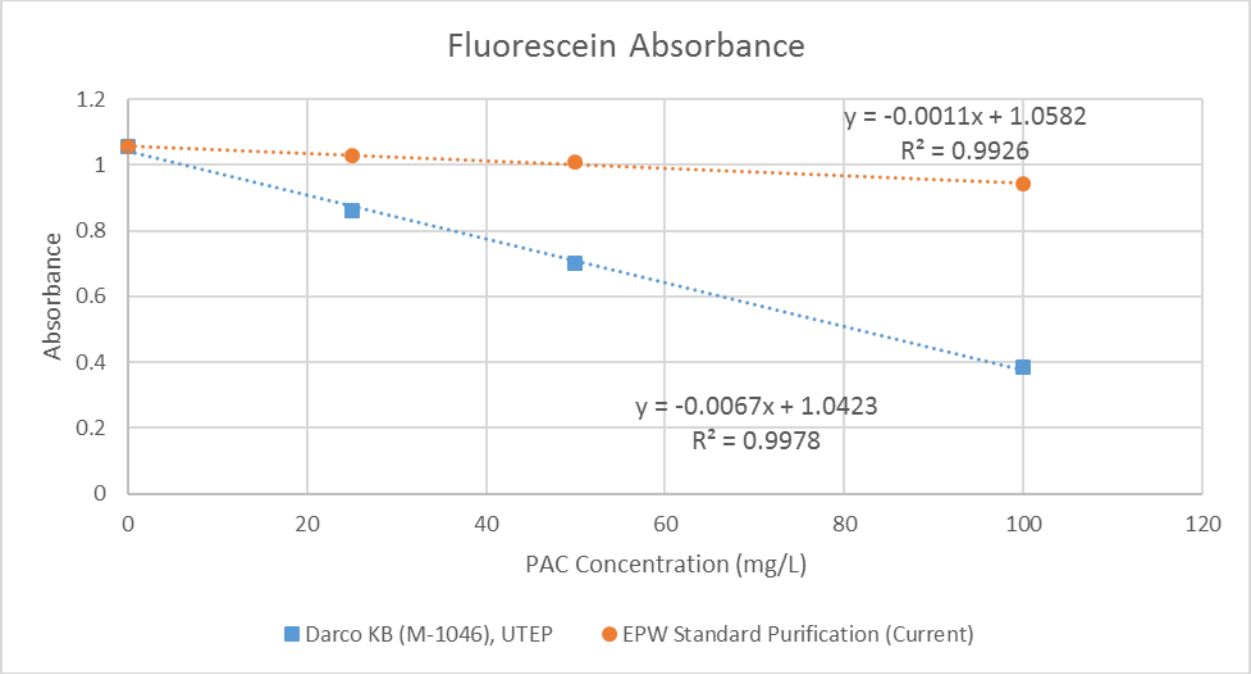

FIGURE 4.3: FLUORESCEIN ABSORBANCE VS. PAC CONCENTRATION (APR. 23, 2017 RESULTS)

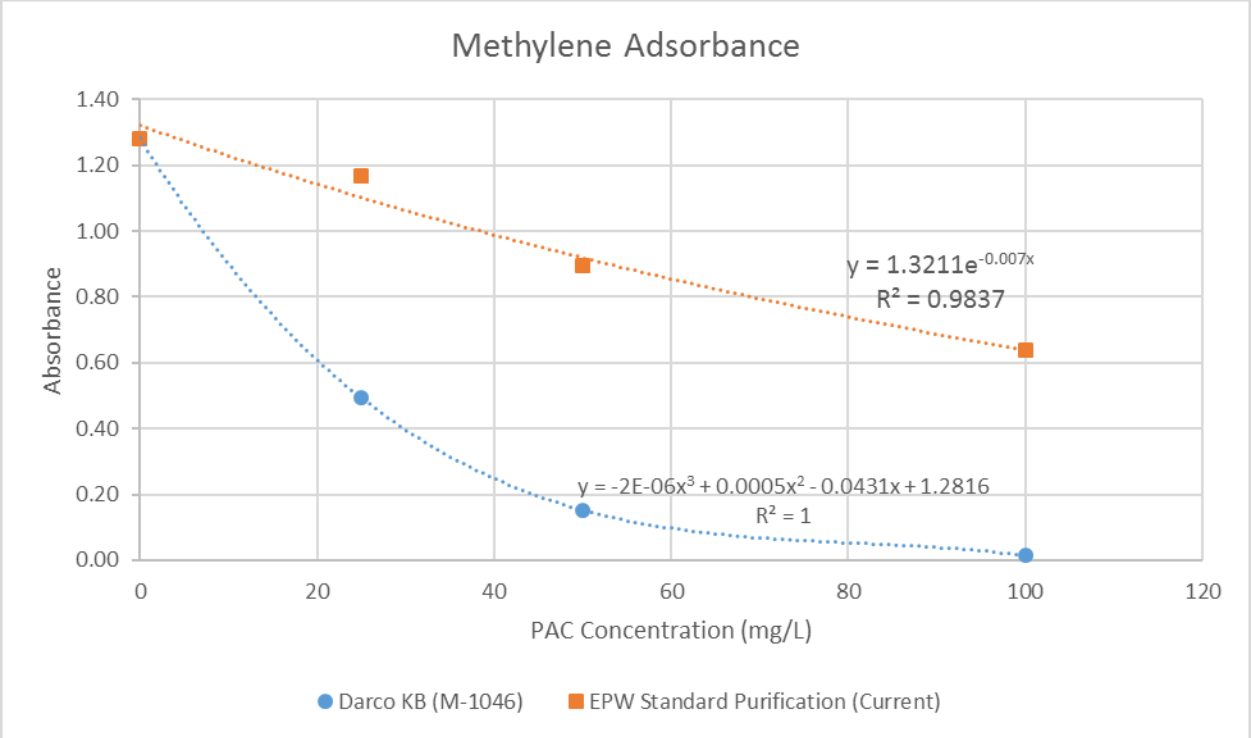

FIGURE 4.4: METHYLENE BLUE ABSORBANCE VS. PAC CONCENTRATION (APR. 23, 2017 RESULTS)

The experiment was repeated at a later date utilizing EPW Std and Norit PACs as well as the same concentrations and procedures as mentioned above. The results exhibited the same trends as before and can be seen in Figures 4.5 and 4.6.

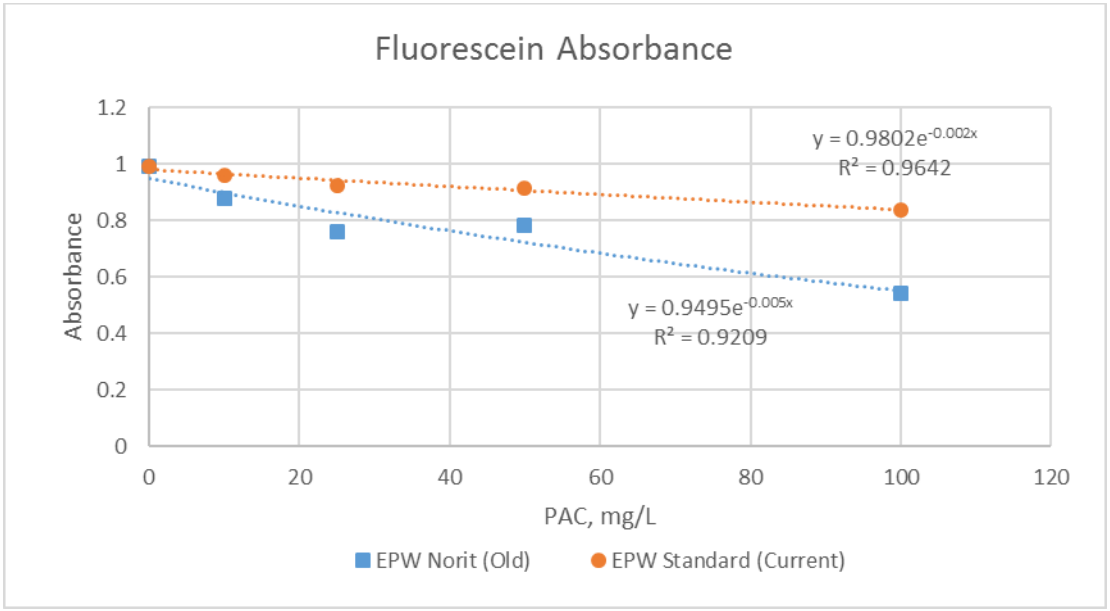

FIGURE 4.5: FLUORESCEIN ABSORBANCE VS. PAC CONCENTRATION (APR. 26, 2017 RESULTS)

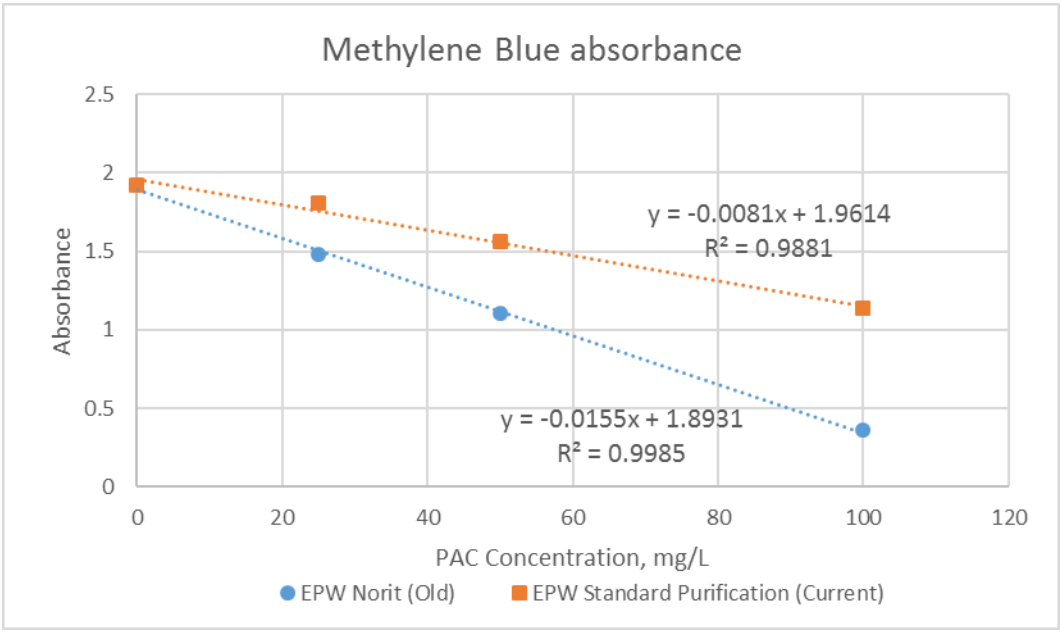

FIGURE 4.6: METHYLENE BLUE ABSORBANCE VS. PAC CONCENTRATION (APR. 26, 2017 RESULTS)

After initial tests with fluorescein and methylene blue, it was decided to test all remaining 5 PACs using methylene blue. Utilizing the same concentrations and procedures as above, methylene blue absorbance was measured for all remaining PAC samples. The results were similar to those obtained previously, meaning that as the PAC concentration increased, absorbance decreased, indicating that percent removal was also increased with increasing PAC concentrations, as shown in Figure 4.7.

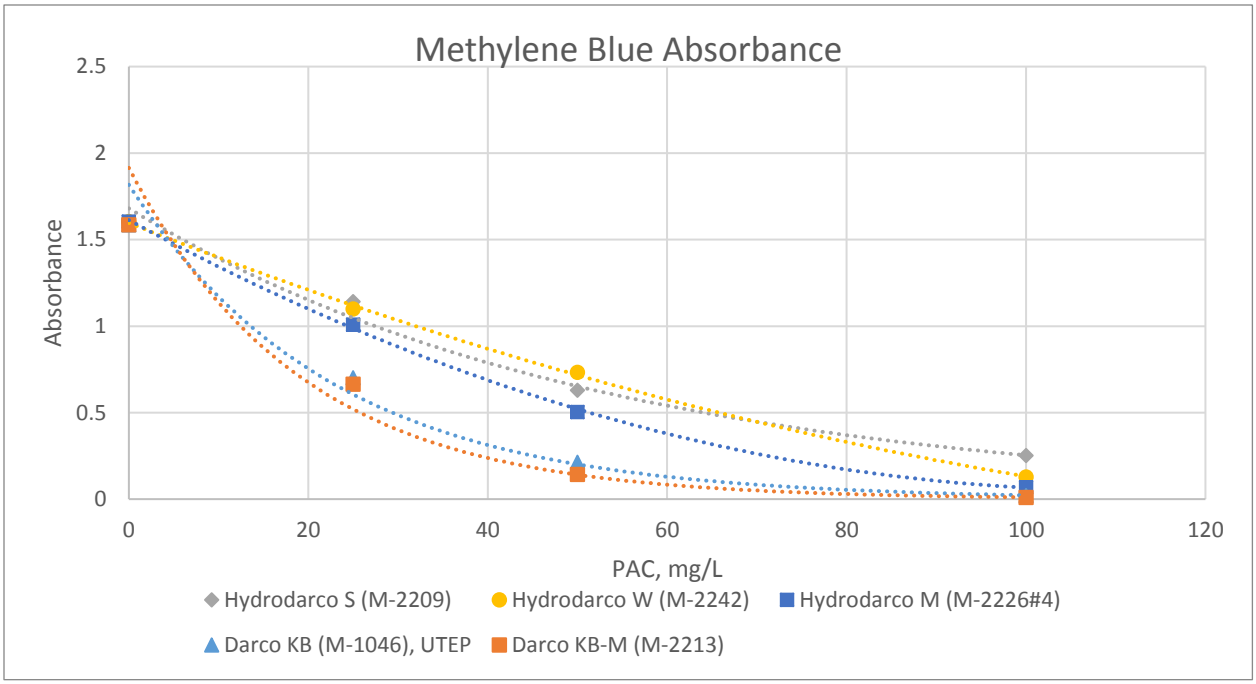

FIGURE 4.7: METHYLENE BLUE ABSORBANCE VS. PAC CONCENTRATION (MAY 8, 2017 RESULTS)

Further tests were conducted in the same manner and procedures discussed above using different colors (as well as the same dyes mentioned above for further testing) except river water was used instead of tap water. The results were similar to that of tap water, as shown in Figure 4.8 with fluorescein.

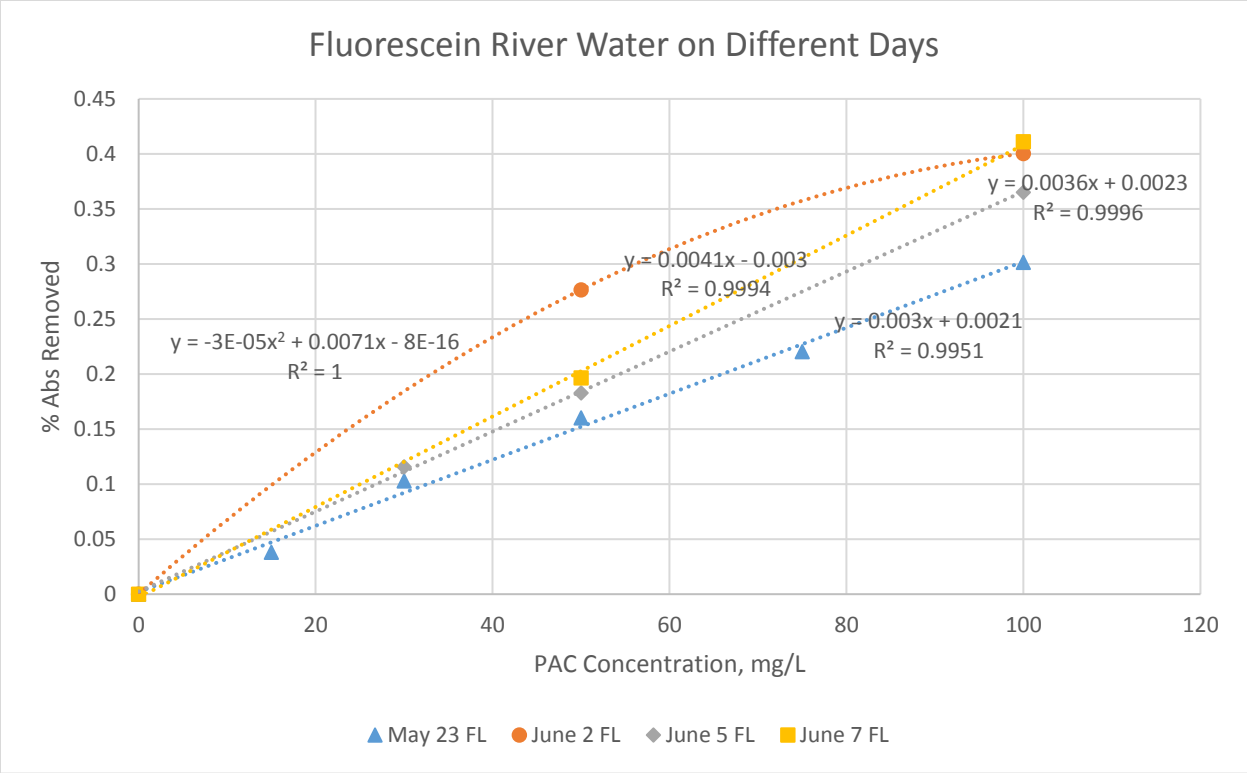

FIGURE 4.8: FLUORESCEIN ABSORBANCE REMOVAL VS. PAC CONCENTRATION FOR VARIOUS DAYS

Using concentrations of 25 and 50 ppm PAC, ranks based on percent removal (Eq. 4.1) (1 being highest percent removal and 12 indicating the lowest percent removal) were also established and are listed with each of the 12 individual PAC color experiments (as seen in Appendix B). An averaged rank from both concentrations of PAC was taken and then an overall average of each color experiment was calculated. Results based on rankings indicated WPH was the highest performing PAC and are compiled in Table 4.7.

TABLE 4.7: COMPILED PAC RANKINGS THROUGH PERCENT COLOR REMOVAL USING TAP WATER

Date	Color	PAC ID Rank											
		Hydro W	Hydro S	Hydro M	Pulsorb	WPH	KBM	BL Pulv	C Pulv	Nichem	EPW Std	EPW Norit	Hydro B
17-May	BFC	10	3	5	9	2	1	7	8	11	12	4	6
19-May	FL	9	4	6	2	1	5	3	7	11	12	8	10
30-May	YFC	11	8	9	2	1	4	5	3	7	12	6	10
30-May	RFC	6	3	4	7	2	1	9	10	11	12	5	8
31-May	YFC	10	6	9	2	1	4	5	3	11	12	7	8
31-May	RD	5	1	3	7	6	2	9	11	12	10	4	8
1-Jun	YD	9	5	10	4	1	6	7	3	2	12	8	11
1-Jun	PD	7	1	2	9	8	3	10	6	11	12	4	5
Mean		8	4	6	5	3	3	7	6	10	12	6	8
Median		9	3.5	5.5	5.5	1.5	3.5	7	6.5	11	12	5.5	8

*Color (Dye) abbreviations listed in table 4.6

On average, WPH performed 4 times better than EPW Std and was overall ranked the highest. EPW Std (the PAC currently being used at the utility plant) performed the worst of all PACs tested.

4.5. Evaluation of Geosmin Removal through Consulting Laboratory

A consulting laboratory (Analytical Environmental Laboratories (AEL), Tyler Texas; a NELAP accredited lab) was used to confirm fluorescein dye to lab results on percent removal of Geosmin to percent removal of absorbance. Using the EPW Std. PAC, samples on 5/22 and 6/5 were spiked with 50 ng/L and 30 ng/L of Geosmin respectively. All water was dechlorinated prior to testing. River water consisted of 0.01, 15, 20, 50, 75, and 100 mg/L of PAC. Ten mg/L of $FeCl_3$ was added with the PAC and stirred for 20 minutes at 50 rpm. Tap water was also used in order to see if there was a difference in removal percentages. Samples were then filtered through a glass fiber filter and were placed in a 40 mL amber VOA vial with zero headspace. Vials were then packaged, iced and shipped to the laboratory. It was also observed that tap water could be used to compare effectiveness of the various PACs without having to collect and spike raw river water. The variance in percentages can be accredited to the fact that the river water contained initial concentrations of Geosmin. The results also revealed that as PAC concentration increases, the percent removal of Geosmin increases. These results were similar to previous dye tests. Results of

6/5 dye test and lab test are seen in Table 4.8 and 4.9 respectively and both days were plotted in Figure 4.9.

TABLE 4.8: RESULTS OF FLUORESCEIN TEST (EPW STD PAC, RIVER WATER, 6/5/17)

Sample ID	PAC Concentration	Abs 465 nm	% removed	% removed/mg PAC
Blank	0	0	0.00%	0.00%
FL filtered river blank	0	0.635649	0.00%	0.00%
EPW FL filtered river	30	0.562155	11.56%	0.39%
EPW FL filtered river	50	0.519394	18.29%	0.37%
EPW FL filtered river	100	0.403508	36.52%	0.37%

TABLE 4.9: LAB RESULTS OF GEOSMIN REMOVAL (EPW STD PAC, RIVER WATER, 6/5/17)

PAC, mg/L	Geosmin, ng/L	% Removal	Removal q, ng/g	Amt Removed, ng/L
0.01	34.5	0.0%	0.00	0.0
15	19.8	42.6%	0.98	14.7
30	15.7	54.5%	0.63	18.8
50	7.38	78.6%	0.54	27.1
75	4.77	86.2%	0.40	29.7

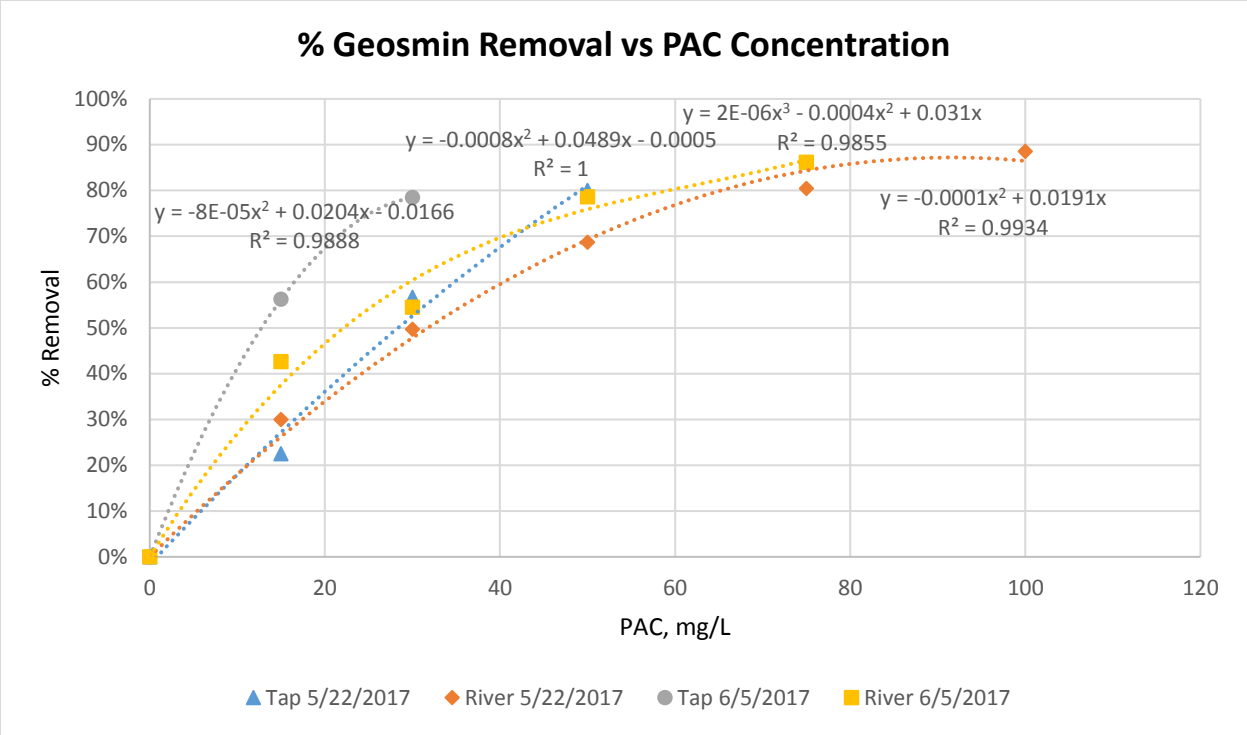

FIGURE 4.9: PERCENT GEOSMIN REMOVAL VS PAC CONCENTRATION

4.5.1. COMPARISON OF FLUORESCEIN REMOVAL TO LAB RESULTS OF GEOSMIN REMOVAL

A complied plot of percent removal vs PAC concentrations over various days was created to observe the trends of lab and dye results and it was observed that both results produced similar trends, as seen in Figure 4.10.

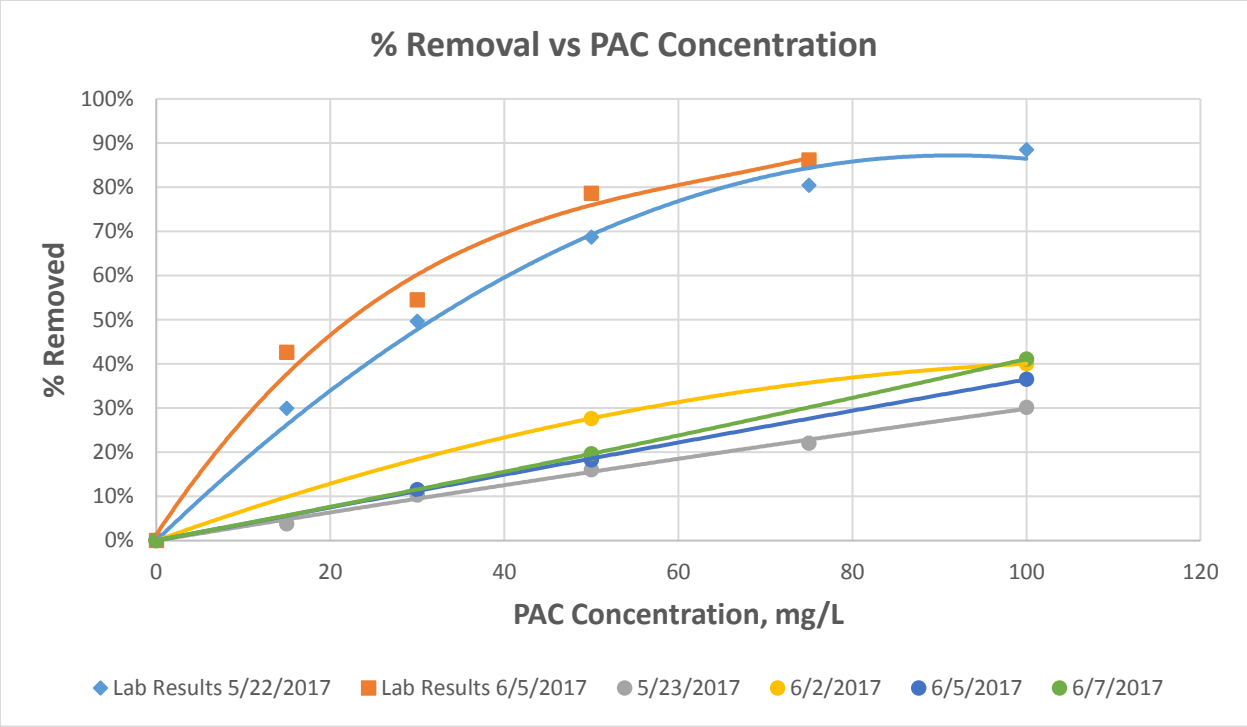

FIGURE 4.10: PERCENT REMOVAL RESULTS OF FLUORESCEIN AND LAB TESTS

It was observed that a relationship could be made between the percent of absorbance (abs) removed from fluorescein and the percent of Geosmin removed. This was done by taking an average of percent of abs removal for PAC concentrations of 0, 15, 30, 50, 75, and 100 mg/L. Any missing data was estimated utilizing trendlines in order to have an estimated average for each PAC concentration. An average of percent Geosmin removed using the river water was also calculated for both lab results. Using these averages (Table 4.10), a plot was created (Figure 4.10). A multiplier was also established by taking the average percent Geosmin removed and dividing it by the average percent Abs removed. A polynomial trendline was used to establish a relationship between the percent abs removed and the percentage of Geosmin removed. The relationship or multiplier could now be used to calculate an estimated percent of Geosmin removed and to overall quantify an estimated Geosmin concentration. Results can be seen in Table 4.10 and Figures 4.11, 4.12, and 4.13.

TABLE 4.10: AVERAGE MULTIPLIER TABLE

PAC Concentration, mg/L	Avg % Gesomin Removed	Avg % Abs Removed	Avg Multiplier
0.01	0.01%	0.00%	0.00
15	36.29%	5.49%	6.61
30	52.08%	11.76%	4.43
50	73.65%	20.41%	3.61
75	83.32%	28.20%	2.96
100	94.26%	36.95%	2.55

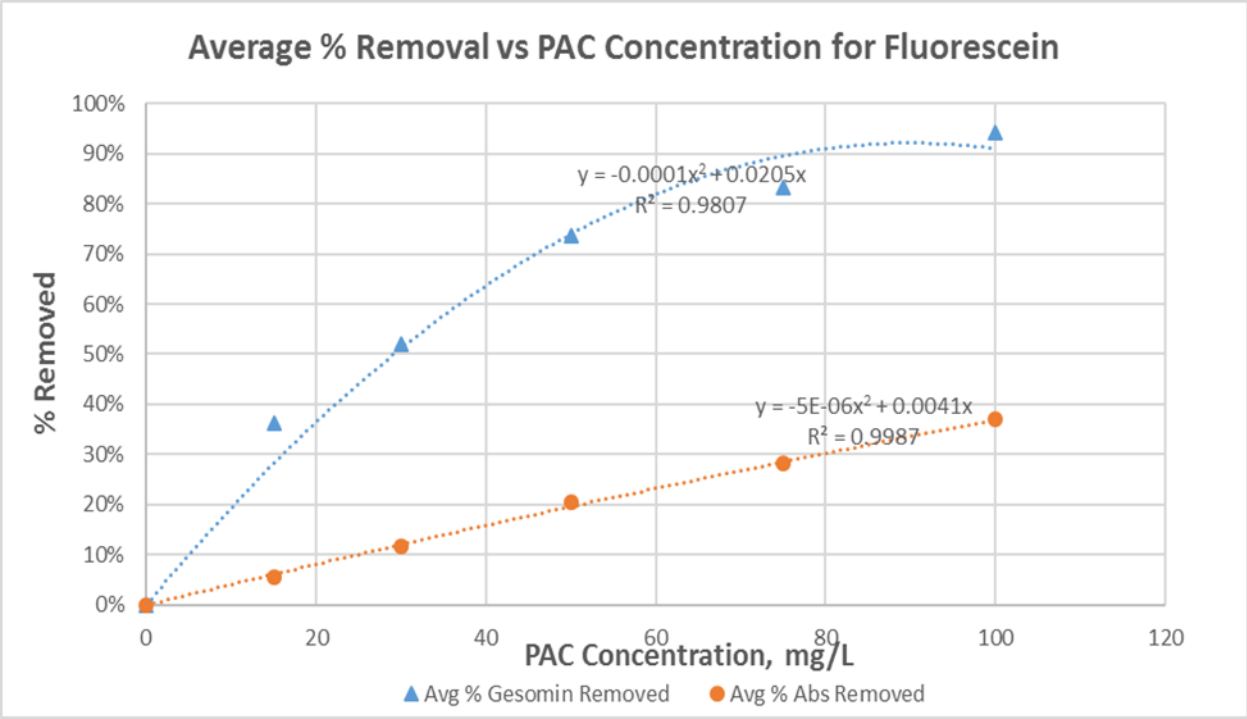

FIGURE 4.11: AVERAGED RESULTS FOR COMPARISON OF FLUORESCEIN TEST WITH GEOSMIN REMOVAL

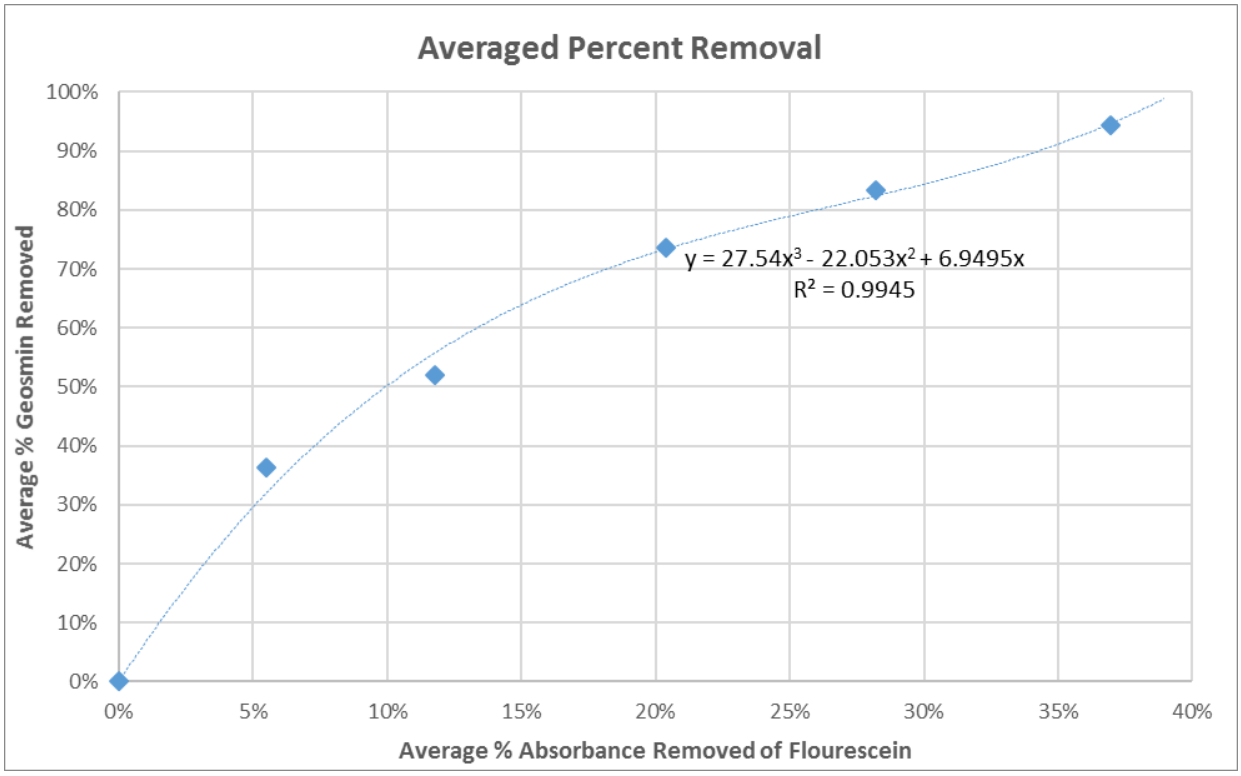

FIGURE 4.12: RELATIONSHIP FOR AVERAGED RESULTS OF FLUORESCEIN TEST WITH GEOSMIN REMOVAL

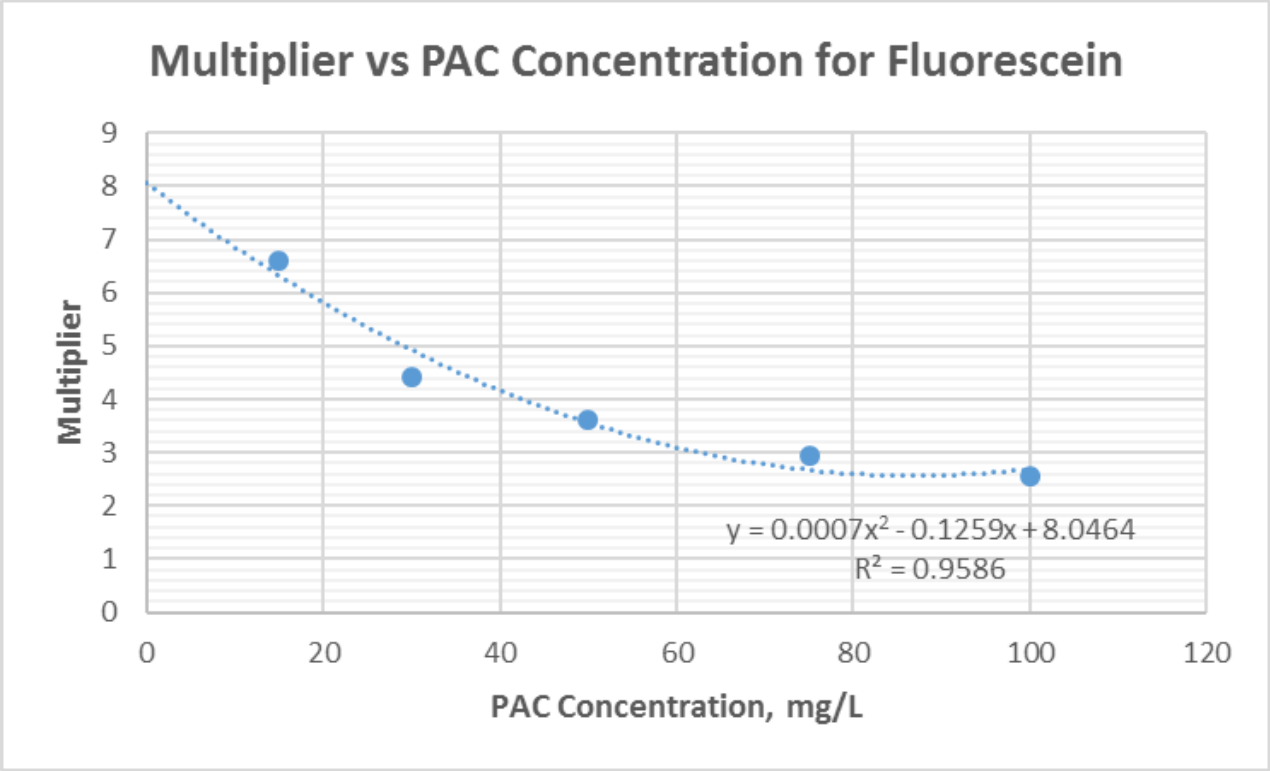

FIGURE 4.13: MULTIPLIER PLOT

It should be noted that this relationship or multiplier can be developed with any dye, as all dyes tested exhibited the same increased removal with increased PAC concentrations as observed with fluorescein (Figure 4.14). Due to these results, color ranks were used to determine the most effective PAC.

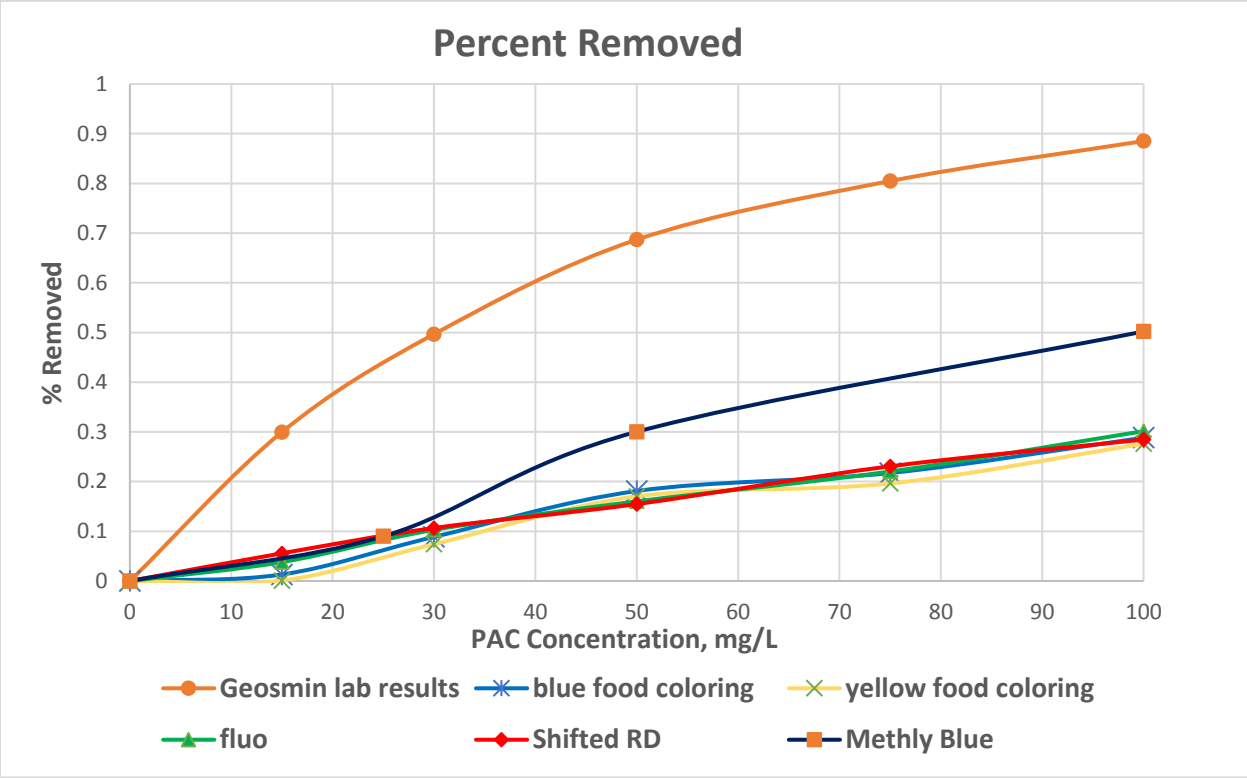

FIGURE 4.14: COMBINED PERCENT REMOVAL PLOT

4.6. Adsorption Isotherm

An adsorption isotherm is a quantitative relationship describing the relationship between the adsorbate in solution (mass/volume) and its sorbed concentration (mass of contaminant/mass of adsorbent). In this case, the Geosmin is the adsorbate, and the removal of Geosmin is the sorbed concentration. Two main isotherms used in environmental chemistry are the Langmuir and Freundlich isotherms. A Freundlich isotherm was chosen as it assumes there exists a distribution of sites on the adsorbent that have different affinities for different adsorbates (such as PAC) with

each site behaving according to the Langmuir isotherm (Sawyer 2003). Adsorption from solutions can be expressed by the following equation:

$$q = KC^{1/n} \quad \text{Eq. 4.3}$$

Where: q = sorbed concentration (mass of Geosmin removed /mass of PAC used) (mg/kg)

K = capacity of adsorbent (constant and unitless)

C = aqueous concentration of adsorbate (mass/volume) (ng/L)

n = measure for how the affinity of adsorbate changes with adsorption density change

Evaluation of coefficients K and n can then be accomplished using the linearized form of Eq. 4.3:

$$\log q = \log K + \frac{1}{n}\log C \quad \text{Eq. 4.4}$$

Using Eq. 4.3, a plot was created of log q vs. log C. A trendline was then set and the equation displayed was used to relate Eq. 4.3 with the equation of a straight line:

$$y = mx + b \quad \text{Eq. 4.5}$$

Where: $y = \log q$

$m = 1/\text{n}$

$x = \log C$

$b = \log K$

The numerical values of m and b obtained from the displayed trendline equation were then used to determine the affinity n and the capacity constant K (Sawyer 2003).

4.6.1. RESULTS

It was determined that the average capacity constant was $K = 0.216$ and $1/n = 0.452$ and can be seen in Table 4.11 and Figure 4.15.

TABLE 4.11: LINEARIZED FREUNDLICH ADSORPTION ISOTHERM CALCULATIONS: EPW STD PAC

q, mg/kg	log q	C, ng/L	log C	1/n	log K	K		
1.19	0.075547	41.6	1.619093331	0.452	-0.65628	0.221	*EPWPAC	
0.98	-0.00877	29.9	1.475671188	0.452	-0.67578	0.211		
0.82	-0.08831	18.6	1.269512944	0.452	-0.66213	0.218		
0.64	-0.19563	11.6	1.064457989	0.452	-0.67677	0.210		
0.53	-0.27918	6.82	0.833784375	0.452	-0.65605	0.221	**Avg K =**	**0.216**

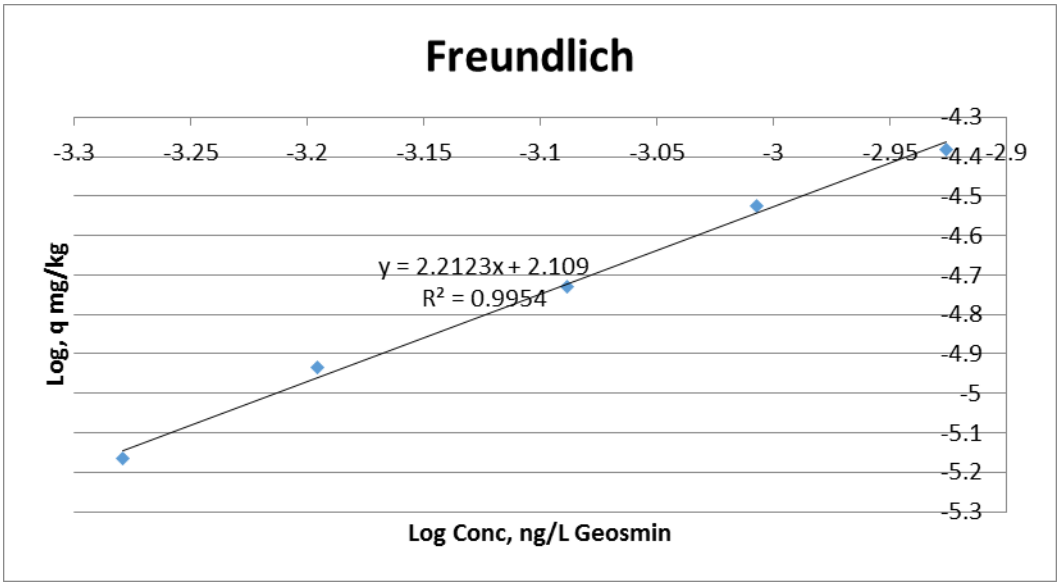

FIGURE 4.15: LINEARIZED FREUNDLICH ADSORPTION ISOTHERM

A Freundlich Adsorption Isotherm plot of q vs. C was then created using Eq. 4.3, with C values in increments of 5 ng/L Geosmin and substituting the averaged K and n values:

$$q = (0.216)C^{1/(0.452)} \qquad \text{Eq. 4.5}$$

According to the calculated isotherm, at a target concentration of 5 ng/L Geosmin, q approximates to 0.447 mg of Geosmin removed for every 1 kg of PAC added for treatment. Results can be seen in Table 4.12 and Figure 4.16.

TABLE 4.12: CALCULATED FREUNDLICH ADSORPTION ISOTHERM: EPW STD PAC

q, mg/kg	C, ng/L	1/n	K
0.447	5	0.452	0.216
0.612	10	0.452	0.216
0.735	15	0.452	0.216
0.837	20	0.452	0.216
0.926	25	0.452	0.216
1.005	30	0.452	0.216
1.078	35	0.452	0.216
1.145	40	0.452	0.216
1.208	45	0.452	0.216

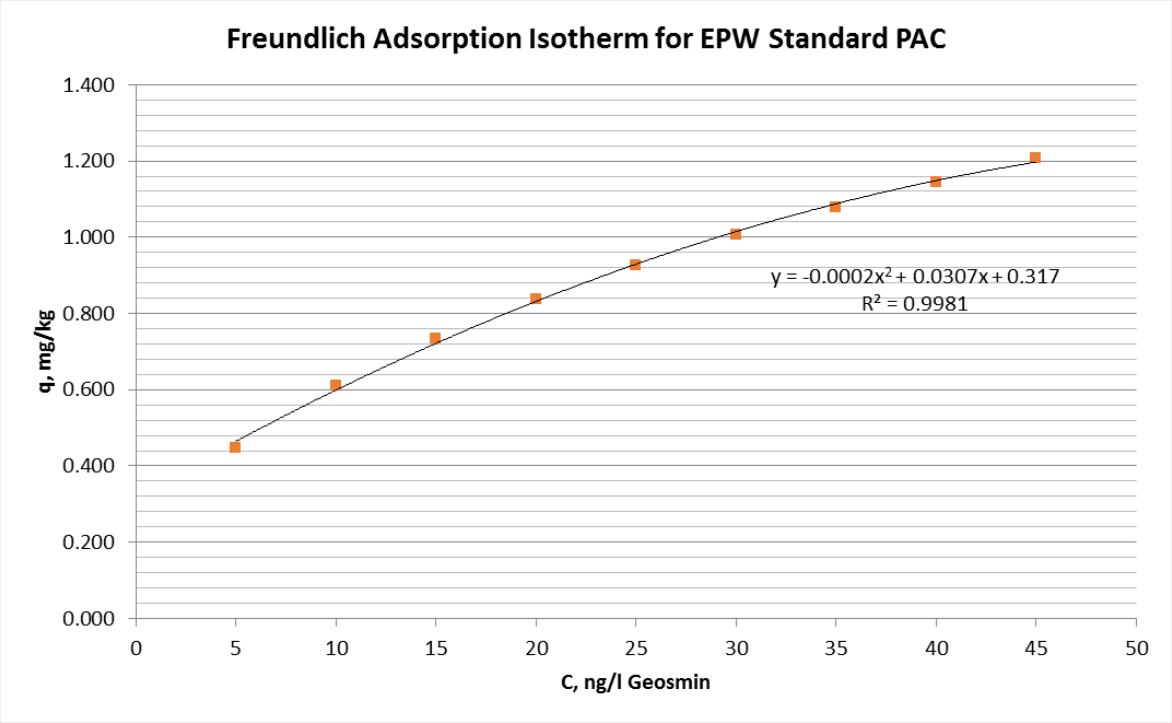

FIGURE 4.16: FREUNDLICH ADSORPTION ISOTHERM

4.7. Cost Analysis

From the calculated isotherm and table, the amount of PAC required to remove a certain concentration of Geosmin per day could now be estimated. According to the isotherm, at a target limit of 5 ng/L, *q* approximated to 0.447 mg Geosmin removed per kg of PAC added. For a worst-case scenario of 20 ng/L (15 ng/L required to remove) and at a flow rate of 40 million gallons per

day, the amount of PAC required approximates to 5,077 kg (11,193 lbs.) per day of the EPW Std PAC. At 50 lbs. a bag, the number of bags needed for one day would be approximately 224 bags per day. With a market cost of $0.57 per lb., the cost per day would approximate to $6,380 per day for the Johnathan Rogers treatment plant (flowrates and prices provided by EPW personnel and the Calgon Carbon Corporation, manufacturers of EPW Std and MPH-1000 PACs).

4.7.1. Cost Analysis of Top Performing PAC: WPH

It was observed during dye testing that the WPH PAC performed, on average, approximately 4 times better than EPW Std. The costs of WPH are almost twice as much as EPW Std (at $0.95 per lb.). However, even at this price and assuming the isotherm as before with removal to be an estimated 4 times as much, it would take approximately 1270 kg of WPH PAC to treat a worst-case scenario of 20 ng/L of Geosmin in the water. This would equate to a total cost of $2,658 per day ($0.066/ kgal), possibly saving the utility a minimum of $3,600 per day. It is recommended that an isotherm be created for the WPH PAC as adsorbent affinities would possibly increase the amount of mg of Geosmin removed per kg PAC, thus increasing savings.

5. CONCLUSIONS

Based on the results of this study, the following conclusions can be made:

1) Initial detection limits to sensitive populations of Geosmin through odor testing was confirmed to be in the parts per trillion or ng/L range. At 5 ppt, 20% of participants observed an odor in the water. At 10 ppt, detection increased to 80%. At 25 ppt, 100% of participants were able to detect the odor.
2) Preliminary testing of PAC with KB-M PAC showed that as the concentration of PAC increases, detection percentages decrease. Odor detection limits were found to decrease substantially above PAC concentrations of 25 mg/L and were completely undetectable at 50 mg/L.
3) A concentration of 33.6 mg/L of EPW Std PAC was approximated to treat 20 ppt of Geosmin to a target limit of 5 ppt, thus confirming a necessary range of 25 – 50 mg/L PAC for odor elimination.
4) The usage of dyes can be used to experimentally evaluate PAC performance by developing a relationship between the percent absorbance removed and the actual percent Geosmin removed. This relationship can be used to estimate the percentage of Geosmin removed, as well as to quantify the concentration of Geosmin present after PAC treatment.

5.1. Recommendations

Based on the results of this study, the following is recommended:

1) An Adsorption Isotherm should be developed for each individual PAC chosen from the top performing PACs.
2) A full-scale evaluation of WPH and the top performing PACs should be conducted at the water treatment plant to verify the lab results.
3) Addition of PAC should be considered and tested in different locations (i.e. inlets, flash mixers, and flocculators) to ensure optimum PAC performance.

5. 2. Alternative Solutions

Studies have shown that typical disinfection processes or the use of chlorine and chloramines to mask odors or eliminate Geosmin and MIB do not work (Kim et al. 2016; Oestman et al. 2004). Typically, it is common to add more chlorine during ultraviolet (UV) disinfection as the oxidation of these compounds are increased. However, aside from costs, detention times are dramatically increased (up to 40 minutes of UV contact time) and byproducts are of concern (Kim et al. 2016). Another recommendation for the degradation of these compounds is through the use of hydrogen peroxide and UV. UV/H_2O_2 treatment has been shown to create advanced oxidation conditions in shorter detention times, thus eliminating up to 90% of the compounds, and UV/H_2O_2 is also inexpensive in comparison to UV/chlorine as well as PAC treatment (Jo et al. 2011; Rosenfeldt et al. 2005). Utilizing a Masterflex Microprocessing Pump Drive with a WEDCO/Ideal Horizons IH-1 UV lamp and a stainless-steel water contact vessel, a single experiment was conducted to examine the effect of the treatment and initial results revealed that at a maximum detention time of 3 minutes, and a dose of 3 mg/L of 50 % H_2O_2, 100% of Geosmin was removed (Table 5.1 and Figure 5.1). Due to these initial results, it is also recommended that UV/H_2O_2 be further evaluated and tested to confirm the effectiveness and benefits of UV treatment.

TABLE 5.1: UV/H_2O_2 RESULTS

Date	Initial Geosmin Conc, ng/l	Detention Time DT, min	H_2O_2, mg/L	Final Geosmin Conc, ng/L	Removal, ng/L	Removal %	DT*H2O2
6/26/2017	30	0.01	2.4	27.6	2.4	8 %	0.024
Samples	30	3	3	0	30	100 %	9
sent to	30	1.2	3	0	30	100 %	3.6
AEL Labs	30	0.4	3	5.09	24.91	83 %	1.2
	30	0.4	5	2.15	27.85	93 %	2
	30	0.6	10	0	30	100 %	6

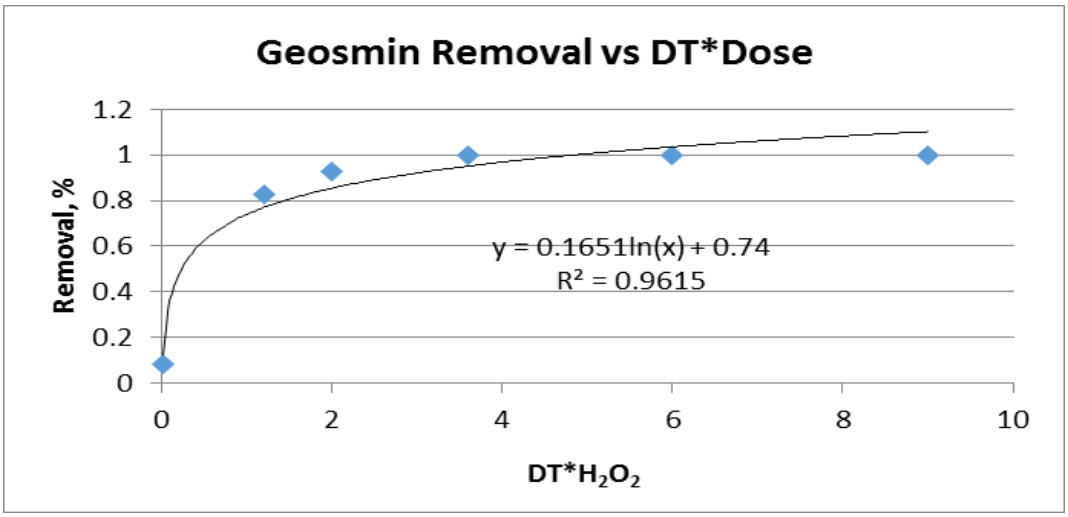

FIGURE 5.1: PLOT OF UV/H_2O_2 RESULTS: % REMOVAL VS. DT* H_2O_2

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APPENDIX A: COMPILED RAW DATA OF ODOR DETECTION TESTS

TABLE A.1: RAW DATA FOR ODOR DETECTION RESULTS

Date	Dilution Factor	Geosmin (ng/L)	PAC (mg/L)	Mix Time	Smell 1=yes 0=no										% Detected	Comments
1/11/17	200,000	2.5	-	30 sec	0	0	0	0	0						0%	Original Geosmin = 500,000 ng/L *for remainder of testing; DI Water; 5 Participants
	100,000	5	-	30 sec	0	0	0	1	0						20%	
	50,000	10	-	30 sec	1	0	1	1	1						80%	
	20,000	25	-	30 sec	1	1	1	1	1						100%	
	10,000	50	-	30 sec	1	1	1	1	1						100%	
	1000	500	-	30 sec	1	1	1	1	1						100%	
1/17/17	5000	100	5	30 sec	1	1	1								100%	DI Water; 3 Participants
	5000	100	10	30 sec	1	1	1								100%	
	5000	100	15	30 sec	1	1	1								100%	
	5000	100	15	30 sec	1	1	1								100%	
1/19/17	5000	100	15	20 min	0	0	1	1							50%	DI Water; 4 Participants
	5000	100	15	15 min	0	1	1	1							75%	
	5000	100	15	10 min	0	1	1	1							75%	
1/23/17	10000	50	10	20 min	1	0	1	0							50%	Same as previous
1/24/17	10000	50	15	20 min	0	0	1								33%	DI Water; 3 Participants
	10000	50	5	20 min	1	0	1								66%	
1/30/17	5000	100	100	20 min	0	0	0								0%	Same as Previous
	5000	100	50	20 min	0	0	0								0%	
1/31/17	-	100	50	20 min	0	1	0	1	1						60%	River - Filtered
	-	100	40	20 min	1	0	0	1	1						60%	River - Filter
Inconclusive test	-	100	50	20 min	0	1	1	0	0						40%	River (no FeCl/Filter)
River Smelt bad	-	100	50	20 min	0	0	0	0	0						0%	River (no FeCl) - Filtered
	-	10	0	-	1	1	1	0	1						80%	Tap (no FeCl/Filter)
	-	10	0	-	0	1	0	0	0						20%	Tap (no FeCl) - Filtered
2/8/17	-	50	50	5 min	0	0	0	0	0	0					0%	Dechlorinated Tap Water; 68 rpm; no filter; 10 mg/L FeCl
	-	50	25	5 min	0	0	0	0	0	1					17%	
	-	50	10	5 min	1	1	1	1	0	1					83%	
2/10/17	-	50	50	5 min	0	0									0%	Dechlorinated Tap Water; 68 rpm; no filter; 10 mg/L FeCl
	-	50	25	5 min	0	0									0%	
	-	50	10	5 min	1	1									100%	
2/13/17	-	50	50	5 min	1	0	0	0	0						20%	River Water; 68 rpm; no filter; 10 mg/L FeCl
	-	50	25	5 min	1	1	1	1	0						80%	
	-	50	10	5 min	1	1	1	1	1						100%	

TABLE A.1.2: RAW DATA FOR ODOR DETECTION RESULTS

Date	Dilution Factor	Geosmin (ng/L)	PAC (mg/L)	Mix Time	Smell 1=yes 0=no										% Detected	Comments
2/14/17	-	50	100	5 min	0	0	0								0%	River Water; 68 rpm; no filter; 10 mg/L FeCl
	-	50	50	5 min	0	0	0								0%	
	-	50	25	5 min	1	1	1								100%	
4/13/17	-	30	100	15 min	1	0	0	0	1						40%	Primary Clarifier Water; 35 rpm; no filter; 10 mg/L FeCl
	-	30	50	15 min	1	1	1	1	1						100%	
	-	30	30	15 min	1	1	1	1	0						80%	
	-	30	20	15 min	1	1	1	1	0						80%	
	-	30	10	15 min	1	1	1	1	0						80%	
	-	30	5	15 min	0	0	0	1	1						40%	
4/20/17	-	25	100	15 min	1	1	1								100%	Secondary Clarifier Water; 35 rpm; no filter; 10 mg/L FeCl
	-	25	50	15 min	1	1	1								100%	
	-	25	30	15 min	1	1	1								100%	
	-	25	20	15 min	1	1	1								100%	
	-	25	10	15 min	1	1	1								100%	
	-	25	5	15 min	1	1	1								100%	
4/24/17	-	25	100	20 min	0	0	0	0	0	1	0				14%	Dechlorinated Tap Water; 45 rpm; filtered; 10 mg/L FeCl; EPW Std PAC
	-	25	Blank	20 min	1	1	0	0	0	1	1				57%	
	-	25	50	20 min	1	1	0	0	1	0	1				57%	
	-	25	25	20 min	1	1	1	1	1	1	1				100%	
	-	25	Blank	20 min	1	1	1	0	0	0	0				43%	
	-	25	Blank	20 min	0	1	1	1	0	0	0				43%	
4/24/17	-	25	Blank	20 min	1	1	1	1	0	1	1				86%	Dechlorinated Tap Water; 45 rpm; filtered; 10 mg/L FeCl; UTEP KBM PAC
	-	25	50	20 min	0	0	0	0	0	0	0				0%	
	-	25	25	20 min	1	0	1	0	1	1	1				71%	
	-	25	Blank	20 min	1	1	0	0	0	0	0				29%	
	-	25	10	20 min	1	1	1	1	1	1	1				100%	

TABLE A.1.3: RAW DATA FOR ODOR DETECTION RESULTS

Date					Smell 1=yes 0=no										Comments
4/27/17					***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***0***	DI Water; Filtered; 10 mg/L FeCl; Mixed 20 min @ 45 rpm; 25 ppt Geosmin
	Key:	**PAC and concentration (ppm)**			0	0	0	1	0	1	0	0	0	1	
	1	Blank			0	0	0	0	0	0	0	0	0	1	
	2	EPWU Norit 150			0	0	0	0	0	0	1	1	1	1	
	3	Blank			0	0	0	1	0	0	0	0	0	1	
	4	SP 200			0	1	0	0	0	1	0	1	0	1	
	5	SP 150			0	0	0	0	1	0	1	1	0	0	
	6	Blank			0	0	0	0	0	0	0	0	0	0	
	7	SP 100			0	0	0	0	0	0	0	0	0	1	
	8	Blank			0	0	0	0	0	0	1	0	0	1	
	9	SP 50			0	0	0	1	0	0	0	0	0	1	
	0	SP 25			0	0	1	1	0	0	1	1	0	1	
					0	0	0	1	0	1	0	0	0	1	
					0	0	0	1	1	0	0	0	1	0	
					0	0	0	0	0	0	0	0	0	1	
					0	0	0	0	0	0	0	0	0	1	

APPENDIX B: PAC BRANDS, DESCRIPTIONS, AND SPECIFICATIONS

*Descriptions and specifications given upon availability to information through company website.

TABLE B.1: PAC BRANDS AND DESCRIPTIONS

Brand		PAC	ID	Description
Calgon Carbon				
		WPH 1000	**WPH**	WPH carbon is a virgin, PAC specifically designed for use in treatment of potable water and is ideally suited for removal of taste and odor-causing compounds such as geosmin and MIB. Meets all applicable AWWA standards per specification B-600 and is certifed to ANSI/NSF Standar 61 for use in potable water treament
		Pulsorb WP260-90	**Pulsorb**	PULSORB Series of virgin coal-based powdered activated carbons are designed to provide a rapid rate of adsorption and high adsorbate loading capacity. These powdered activated carbons are exceptionally effective at removal of impurities including taste, color, odor and other organics from water, food and beverage products.
		C. Pulv	**C. Pulv**	BL, CP and GW type powdered activated carbons are pulverized to amesh size that assures a rapid rate of adsorption and high capacity. They are produced from select grades of bituminous coal resulting in a product of high density.
		BL. Pulv	**BL. Pulv**	BL, CP and GW type powdered activated carbons are pulverized to amesh size that assures a rapid rate of adsorption and high capacity. They are produced from select grades of bituminous coal resulting in a product of high density.

TABLE B.2.2: PAC BRANDS AND DESCRIPTIONS

Brand		PAC	ID	Description
Cabot Norit				
		HydroDarco B	**Hydro B**	Powdered activated carbon produced by steam activation of lignite coal. Finely milled to obtain a high degree of suspension, with a high capacity for adsorption of organics that cause taste and odor problems in drinking water supplies.
		HydroDarco C	**Hydro C**	Powdered activated carbon produced by steam activation of lignite coal. It is used to remove toxic organics along with biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total organic carbon (TOC) from industrial and municipal wastewaters
		HydroDarco M	**Hydro M**	Powdered activated carbon that is finely milled to obtain a high degree of suspension. It is used for the removal of tastes, odors and other organics from potable water supplies.
		Hydrodarco W	**Hyrdo W**	Powdered activated carbon produced by steam activation of lignite coal. Finely milled to obtain a high degree of suspension, with a high capacity for adsorption of organics that cause taste and odor problems in drinking water supplies.
		Darco KB-M	**KBM**	An activated carbon with exceptional adsorptive properties for a wide range of applications particularly in the chemical and food industries. It is especially effective in adsorbing high molecular weight organics such as proteins and large color bodies.
		EPW Cabot Norit	**EPW Norit**	Powdered activated carbon produced by steam activation of vegetable raw materials. It has a high adsorptive capacity for the removal of dissolved organic material of both low and high molecular weight in potable water treatment.

TABLE B.3.3: PAC BRANDS AND DESCRIPTIONS

Brand		PAC	ID	Description
Nichem				
		Nichem FHJ-400	**Nichem**	No information provided by Company Website

APPENDIX C: COMPILED RAW DATA OF COLOR REMOVAL TESTS AND SPECTROPHOTOMETRY RESULTS

April 23, 2017:

- Color added and mixed in stock bucket with dechlorinated Tap water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$ and PAC Mixed together at same time
- Samples mixed 3 minutes apart for 20 min. at 45 rpm
- Filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength.

TABLE C.4: RAW DATA OF DYE REMOVAL TEST: FLUORESCEIN AND METHYLENE BLUE. APR 23

Dye	Date	Sample ID	PAC (mg/L)	Absorbance 465 nm	% Removal	Comments
Fluorescein	4/23/17	Blank	0	0	0.00%	10 mg/L dye; 25 ppt Geosmin; 45 rpm for 20 minutes; filtered with glass fiber filters
5 g/L stock		Filtered 0	0	1.05677	0.00%	
10 mg/L desired		utep 25	25	0.862742	18.36%	
CV=CV		epw 25	25	1.027688	2.75%	
2 mL added		utep 50	50	0.699671	33.79%	
		epw 50	50	1.007771	4.64%	
		utep 100	100	0.384052	63.66%	
		epw 100	100	0.942237	10.84%	
Dye	Date	Sample ID	PAC (mg/L)	Absorbance 660 nm	% Removal	Comments
Methylene Blue	4/23/17	Blank	0	0	0.00%	5 mg/L dye; 25 ppt Geosmin; 45 rpm for 20 minutes; filtered with glass fiber filters
5 mg/L		0ppm	0	1.469668	0.00%	
		Filtered0	0	1.281595	0.00%	
		EPW25	25	1.166366	8.99%	
		UTEP25	25	0.493545	61.49%	
		EPW50	50	0.896853	30.02%	
		UTEP50	50	0.152906	88.07%	
		EPW100	100	0.638232	50.20%	
		UTEP100	100	0.013732	98.93%	

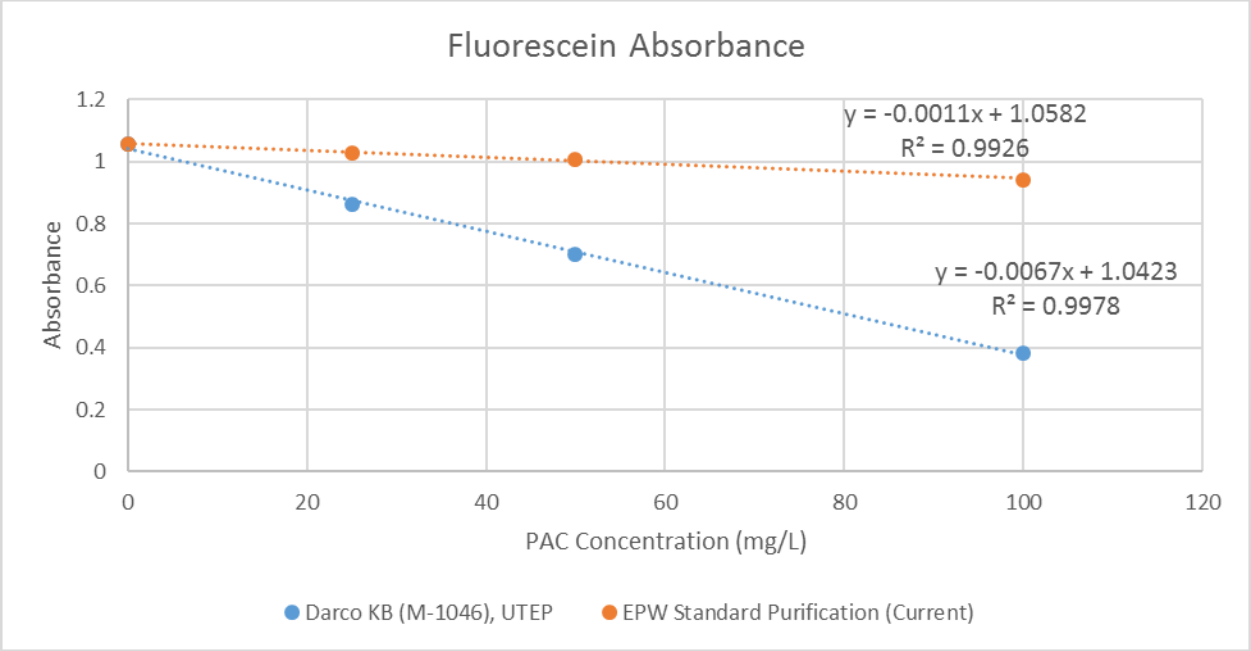

FIGURE C.1: FLUORESCEIN ABSORBANCE PLOT. APR 23

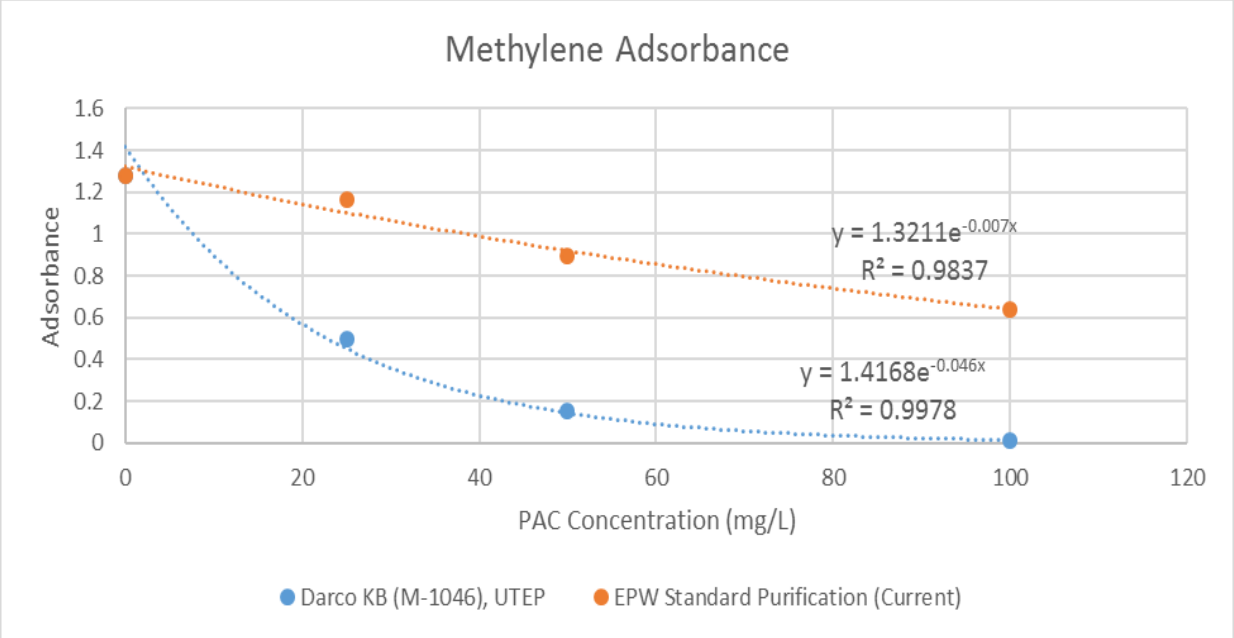

FIGURE C.2: METHYLENE BLUE ABSORBANCE PLOT APR 23

April 26, 2017:

- Color added and mixed in stock bucket with dechlorinated Tap water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$ and PAC Mixed together at same time
- Samples mixed 3 minutes apart for 20 min. at 45 rpm
- Filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength.

TABLE C.2: RAW DATA OF DYE REMOVAL TEST: FLUORESCEIN AND METHYLENE BLUE. APR 26

Dye	Date	Sample ID	PAC (mg/L)	Absorbance 465 nm	% Removal	Comments
Fluorescein	4/26/17	Blank	0	0	0.00%	10 mg/L Fluorescein; 25 ppt Geosmin; 45 rpm for 20 minutes; filtered with glass fiber filters
5 g/L stock		Blank w/dye	0	0.992903	0.00%	
10 mg/L desired		EPW Std 10	10	0.96165	0.00%	
CV=CV		EPW Norit 10	10	0.877758	8.72%	
2 mL added		EPW Std 25	25	0.925743	3.73%	
		EPW Norit 25	25	0.761841	20.78%	
		EPW std 50	50	0.914094	4.95%	
		EPW Norit 50	50	0.783139	18.56%	
		EPW Std 100	100	0.839493	12.70%	
		EPW Norit 100	100	0.541614	38.30%	
Dye	Date	Sample ID	PAC (mg/L)	Absorbance 660 nm	% Removal	Comments
Methylene Blue	4/26/17	Blank	0	0	0.00%	5 mg/L Methylene Blue; 25 ppt Geosmin; 45 rpm for 20 minutes; filtered with glass fiber filters
5 mg/L		Blank W/dye	0	1.920757	0.00%	
		EPW Std 25	25	1.806813	0.00%	
		EPW Norit 25	25	1.481424	18.01%	
		EPW std 50	50	1.565825	13.34%	
		EPW Norit 50	50	1.102154	39.00%	
		EPW Std 100	100	1.134919	37.19%	
		EPW Norit 100	100	0.361534	79.99%	

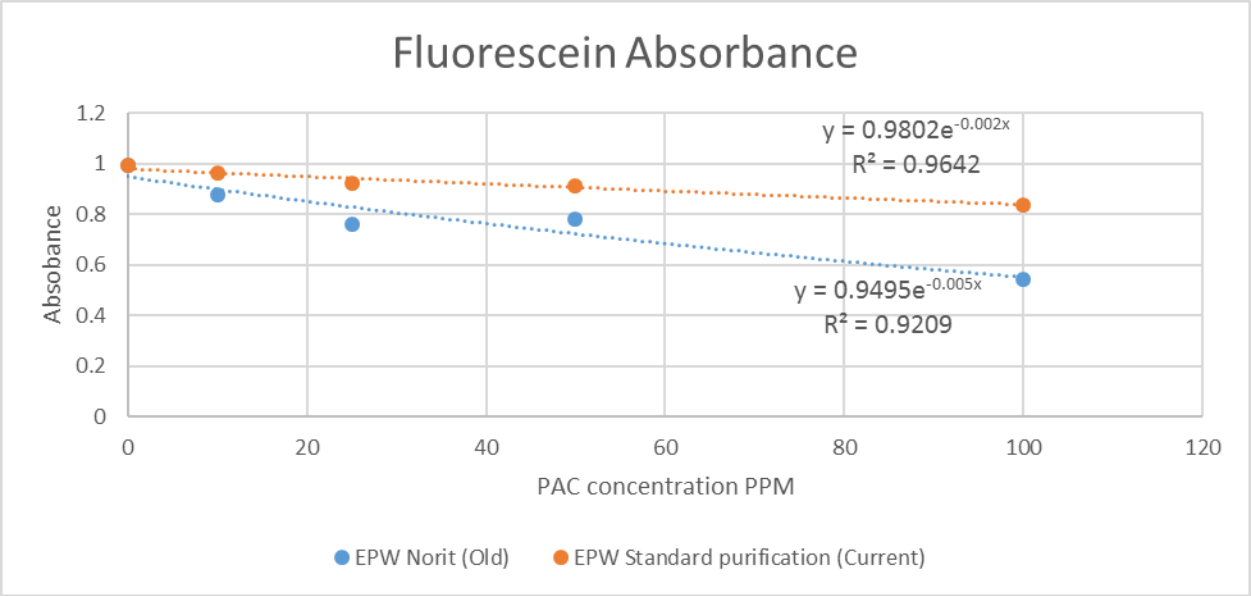

FIGURE C.3: FLUORESCEIN ABSORBANCE PLOT. APR 26

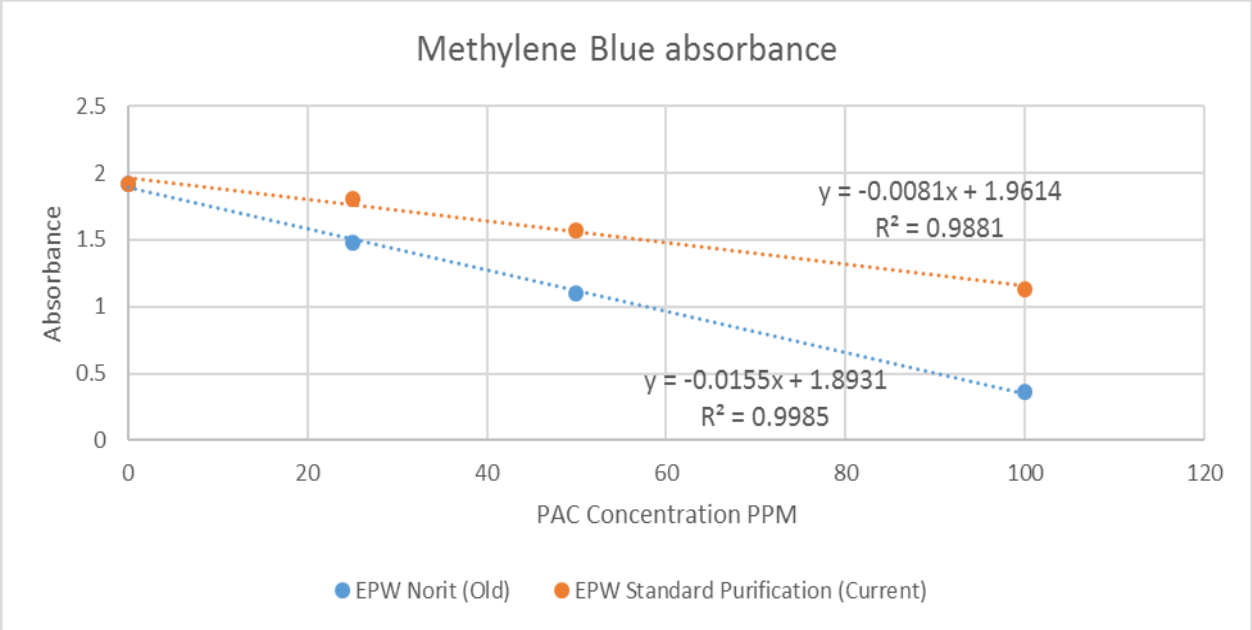

FIGURE C.4: METHYLENE BLUE ABSORBANCE PLOT APR 26

May 8, 2017:

- Color added and mixed in stock bucket with dechlorinated Tap water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$ and PAC Mixed together at same time
- Samples mixed 3 minutes apart for 20 min. at 41 rpm
- Filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength.

TABLE C.3: RAW DATA OF DYE REMOVAL TEST: METHYLENE BLUE. MAY 8

Dye	Date	Sample ID	PAC (mg/L)	Absorbance 660 nm	% Removal	Comments
Methyl Blue	5/8/17	Blank	0	0	-	5 mg/L Methylene Blue; 25 ppt Geosmin; 41 rpm for 20 minutes; filtered with glass fiber filters
Test 1		Unfiltered blank	0	1.744732	-	
5 mg/L		Filtered blank	0	1.604699	0.00%	
		Hydro S 25	25	1.141614	28.86%	
		Hydro W 25	25	1.0984	31.55%	
		Hydro M 25	25	1.008821	37.13%	
		Hydro S 50	50	0.628999	60.80%	
		Hydro W 50	50	0.732409	54.36%	
		Hydro M 50	50	0.503939	68.60%	
		Hydro S 100	100	0.252755	84.25%	
		Hydro W 100	100	0.128602	91.99%	
		Hydro M 100	100	0.069222	95.69%	
Test 2		Blank	0	0		
		Filtered blank	0	1.586037	0.00%	
		UTEP 25	25	0.700497	55.83%	
		KB-M 25	25	0.664016	58.13%	
		UTEP 50	50	0.212324	86.61%	
		KB-M 50	50	0.142426	91.02%	
		UTEP 100	100	0.020985	98.68%	
		KB-M 100	100	0.009738	99.39%	

*Found that the percent removed by filters ~ 8% therefore, filter is not a significant factor

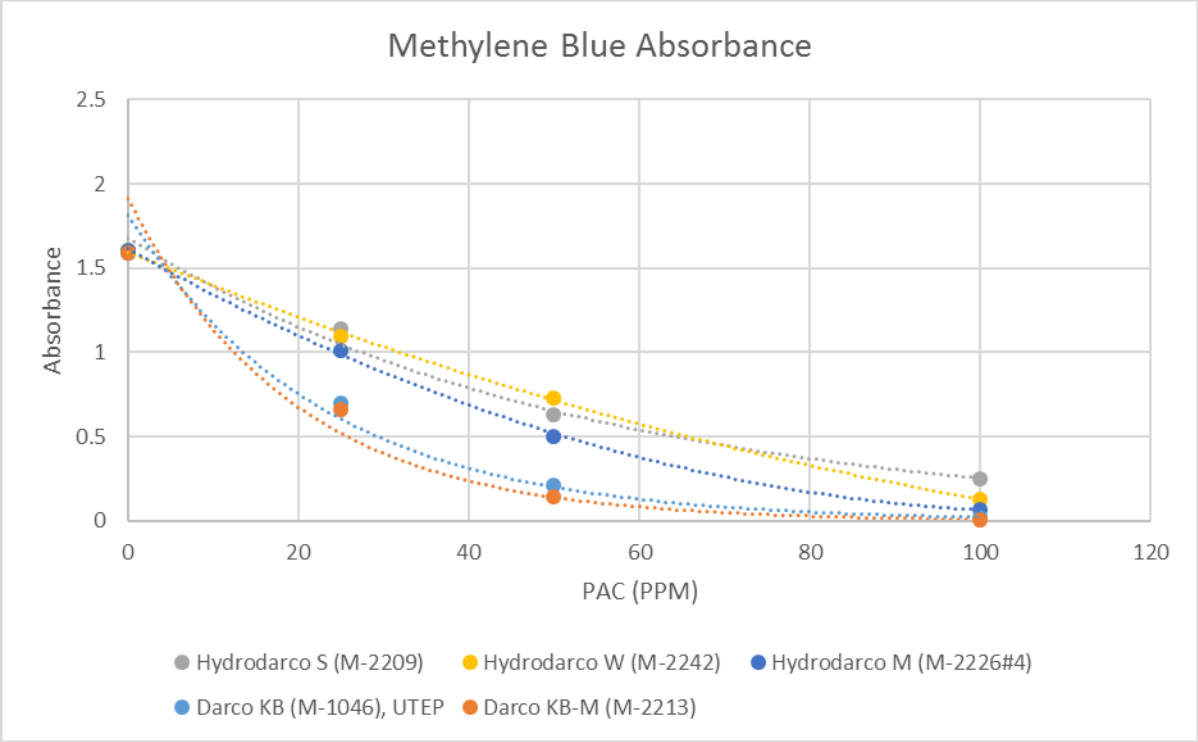

FIGURE C.5: METHYLENE BLUE ABSORBANCE PLOT APR 26

May 17, 2017:

- Color added and mixed in stock bucket with dechlorinated Tap water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$ and PAC Mixed together at same time
- Samples mixed 3 minutes apart for 20 min. at 45 rpm and allowed to settle for 3 minutes
- 500 mL Filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength.

TABLE C.4: RAW DATA OF DYE REMOVAL TEST: BLUE DYE (BFC). MAY 17

Dye	Date	Sample ID	PAC (mg/L)	Absorbance 635 nm	% Abs Removal	% removed per mg PAC	Rank
Blue (BFC)	5/17/17	Blank	0	0	0.00%	0.00%	
Test 1		Initial Blue	0	0.393122	0.00%	0.00%	
25 ppm PAC		hydro W-25	25	0.327073	16.80%	0.67%	8
.01mL/L		Pulsorb 25	25	0.295029	24.95%	1.00%	3
dye		WPH-1000 25	25	0.267433	31.97%	1.28%	2
		Hydro S-25	25	0.306173	22.12%	0.88%	4
		Darco KB-M 25	25	0.212313	45.99%	1.84%	1
		Hydro-M 25	25	0.313249	20.32%	0.81%	5
		BL-25	25	0.316053	19.60%	0.78%	6
		EPW Norit-25	25	0.325633	17.17%	0.69%	7
		Calgon C-25	25	0.357009	9.19%	0.37%	11
		Hydro B-25	25	0.349669	11.05%	0.44%	9
		FMJ-400-25	25	0.360931	8.19%	0.33%	12
		EPW standard- 25	25	0.351272	10.65%	0.43%	10
Blue (BFC)		Blank	0	0	0.00%	0.00%	
Test 2		Initial Blue	0	0.41099	0.00%	0.00%	
50 ppm PAC		Hydro-W- 50	50	0.30692	25.32%	0.51%	10
.01 mL/L		Pulsorb 50	50	0.302404	26.42%	0.53%	9
dye		WPH-1000- 50	50	0.154139	62.50%	1.25%	2
		Hydro-S- 50	50	0.202289	50.78%	1.02%	3
		Darco KB-M 50	50	0.106439	74.10%	1.48%	1
		Hydro-M- 50	50	0.249468	39.30%	0.79%	5
		BL-50	50	0.279885	31.90%	0.64%	7
		EPW Norit 50	50	0.206859	49.67%	0.99%	4
		Calgon C- 50	50	0.28689	30.20%	0.60%	8
		Hydro B- 50	50	0.255605	37.81%	0.76%	6
		FMJ-400-- 50	50	0.338576	17.62%	0.35%	11
		EPW Standard- 50	50	0.355354	13.54%	0.27%	12

* found that some 25 ppm PAC removed more per gram than 50 ppm, which did not make sense. We attributed it to the fact that the dye had propylene glycol, which may not have color. PAC may have adsorbed some of this colorless organic first, which would explain why 25 ppm removed more per gram, depending on the affinities of certain PACS.

May 19, 2017:

- Color added and mixed in stock bucket with dechlorinated Tap water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$ and PAC Mixed together at same time
- Samples mixed 3 minutes apart for 20 min. at 45 rpm and allowed to settle for 3 minutes
- Filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength.

TABLE C.5: RAW DATA OF DYE REMOVAL TEST: FLUORESCEIN. MAY 19

Dye	Date	Sample ID	PAC (mg/L)	Absorbance 465 nm	% Abs Removal	% removed per mg PAC	Rank
Fluorescein	5/17/17	Blank	0	0	0.00%	-	
Test 1		flurescein initial	0	0.638362	0.00%	0.00%	
25 ppm PAC		Pulsorb 25	25	0.455856	16.80%	5.72%	5
5mg/L		Hydro S 25	25	0.426299	24.95%	6.64%	3
dye		WPH 25	25	0.319716	31.97%	9.98%	1
		KB-M 25	25	0.422049	22.12%	6.78%	2
		Hydro M 25	25	0.490273	45.99%	4.64%	7
		Hydro W 25	25	0.495847	20.32%	4.47%	8
		BL 25	25	0.452387	19.60%	5.83%	4
		EPW Norit 25	25	0.527142	17.17%	3.48%	9
		Calgon C 25	25	0.485819	9.19%	4.78%	6
		Hydro B 25	25	0.564487	11.05%	2.31%	11
		Nichem 25	25	0.554128	8.19%	2.64%	10
		EPW Standard 25	25	0.582612	10.65%	1.75%	12
Fluorescein		Blank	0	0	0.00%	0.00%	
Test 2		Initial	0	0.624187	0.00%	0.00%	
50 ppm PAC		Hydro W-50	50	0.375736	39.80%	0.80%	9
5mg/L		Pulsorb-50	50	0.222515	64.35%	1.29%	2
dye		Hydro S-50	50	0.318896	48.91%	0.98%	4
		WPH-50	50	0.071888	88.48%	1.77%	1
		Hydro M-50	50	0.334368	46.43%	0.93%	6
		Darco KBM-50	50	0.324695	47.98%	0.96%	5
		BL-50	50	0.313569	49.76%	1.00%	3
		EPW norit -50	50	0.368502	40.96%	0.82%	8
		Calgon C -50	50	0.342653	45.10%	0.90%	7
		Hydro B -50	50	0.404087	35.26%	0.71%	10
		Nichem -50	50	0.413433	33.76%	0.68%	11
		EPW standard -50	50	0.518702	16.90%	0.34%	12

May 23, 2017:

- Color added and mixed in stock bucket with dechlorinated water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$ and PAC Mixed together at same time
- Samples mixed 3 minutes apart for 20 min. at 45 rpm and allowed to settle for 3 minutes
- 500 mL Filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength

TABLE C.6: RAW DATA OF DYE REMOVAL TEST: METHYLENE BLUE AND FLUORESCEIN. MAY 23

Dye	Date	Sample ID	PAC (mg/L)	Absorbance	% Abs Removal	% removed per mg PAC	Rank
Methyl Blue	5/23/17	Blank	0	0	-	-	
2 mg/L		Methyl Blue Blank	0	0.730935	0.00%	0.00%	
25ppm PAC		KBM 25	25	0.159245	78.21%	3.13%	1
Abs 660 nm		EPW standard 25	25	0.548139	25.01%	1.00%	6
Tap Water		Hydro W 25	25	0.340888	53.36%	2.13%	3
		EPW Norit	25	0.356253	51.26%	2.05%	4
		Nichem	25	0.287139	60.72%	2.43%	2
		Hydrodarco-B	25	0.430725	41.07%	1.64%	5
Methyl Blue		KBM 50	50	0.01993	97.27%	1.95%	1
2 mg/L		EPW Norit 50	50	0.10478	85.66%	1.71%	4
25ppm PAC		EPW Standard 50	50	0.402049	45.00%	0.90%	6
Abs 660 nm		Nichem 50	50	0.085134	88.35%	1.77%	2
Tap Water		Hydro W 50	50	0.089834	87.71%	1.75%	3
		Hydro B 50	50	0.160399	78.06%	1.56%	5
Test 2		Blank	0	0	0.00%	0.00%	
Fluorescein		Fluo riv 0	0	0.655284	0.00%	0.00%	
EPW Std		Fluo riv 15	15	0.630357	39.80%	3.80%	
PAC		Fluo riv 30	30	0.587901	64.35%	10.28%	
River Water		Fluo riv 50	50	0.550294	48.91%	16.02%	
Abs 465 nm		Fluo riv 75	75	0.510907	88.48%	22.03%	
5 mg/L		Fluo riv 100	100	0.457756	46.43%	30.14%	

*EPW Std. observed to still be least effective

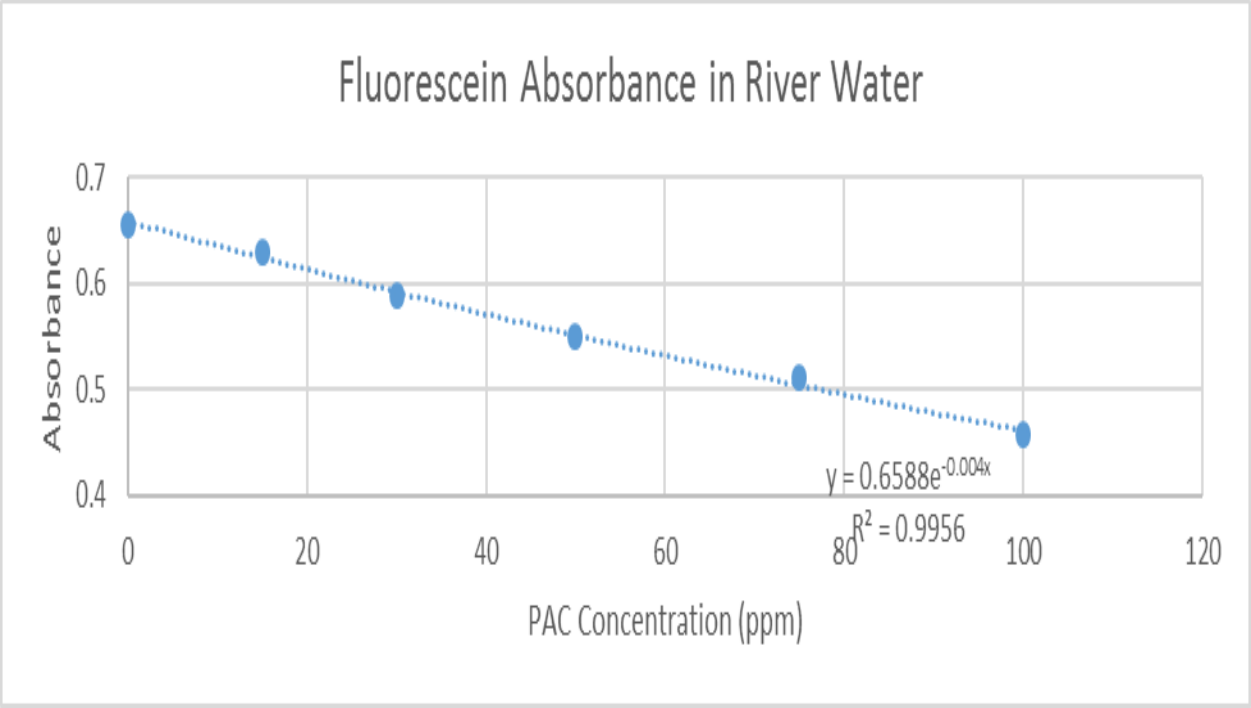

FIGURE C.6: FLUORESCEIN ABSORBANCE PLOT. MAY 23

May 24, 2017:

- Color added and mixed in stock bucket with dechlorinated water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$ and PAC Mixed together at same time
- Samples mixed 3 minutes apart for 20 min. at 50 rpm
- Settled for 3 minutes before filtering
- 500 mL filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength

TABLE C.7: RAW DATA OF DYE REMOVAL TEST: BLUE DYE (BFC). MAY 24

Dye	Date	Sample ID	PAC (mg/L)	Absorbance 465 nm	% Abs Removal	% removed per mg PAC	Rank
Blue (BFC)	5/24/17	Blank	0	0	-	-	
2 mg/L		Filtered Sample	0	0.386256	0.00%	0.00%	
Tap Water		Hydro S-25	25	0.262293	73.77%	2.95%	1
		Calgon 25	25	0.325385	67.46%	2.70%	3
		EPW Norit 25	25	0.294378	70.56%	2.82%	2
		Nichem 25	25	0.363826	63.62%	2.54%	4
		Hydro B 25	25	0.294085	70.59%	2.82%	2
		EPW std 25	25	0.366935	63.31%	2.53%	5
		Hydro S 50	50	0.116944	88.31%	1.77%	1
		Calgon 50	50	0.263111	73.69%	1.47%	4
		EPW Norit 50	50	0.175849	82.42%	1.65%	2
		Nichem 50	50	0.307407	69.26%	1.39%	5
		Hydro B 50	50	0.232289	76.77%	1.54%	3
		EPW std 50	50	0.331174	66.88%	1.34%	6
Blue (BFC)		Blank	0	0	-	-	
Test 2		Filtered blank	0	0.372341	0.00%	0.00%	
EPW Std		blue dye riv 15	15	0.367442	1.32%	0.09%	
PAC		blue dye riv 30	30	0.339321	8.87%	0.30%	
River Water		blue dye riv 50	50	0.304929	18.10%	0.36%	
		blue dye riv 75	75	0.291433	21.73%	0.29%	
		blue dye riv 100	100	0.265018	28.82%	0.29%	

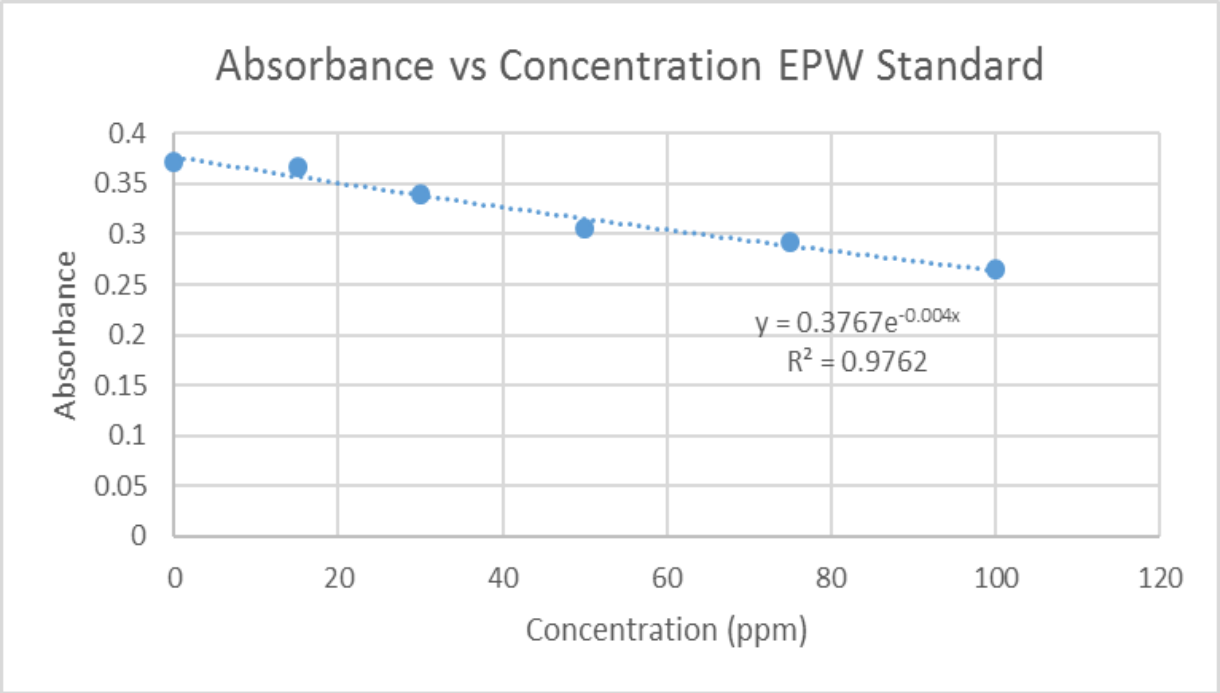

FIGURE C.7: BLUE DYE (BFC) ABSORBANCE PLOT USING EPW STD PAC. MAY 24

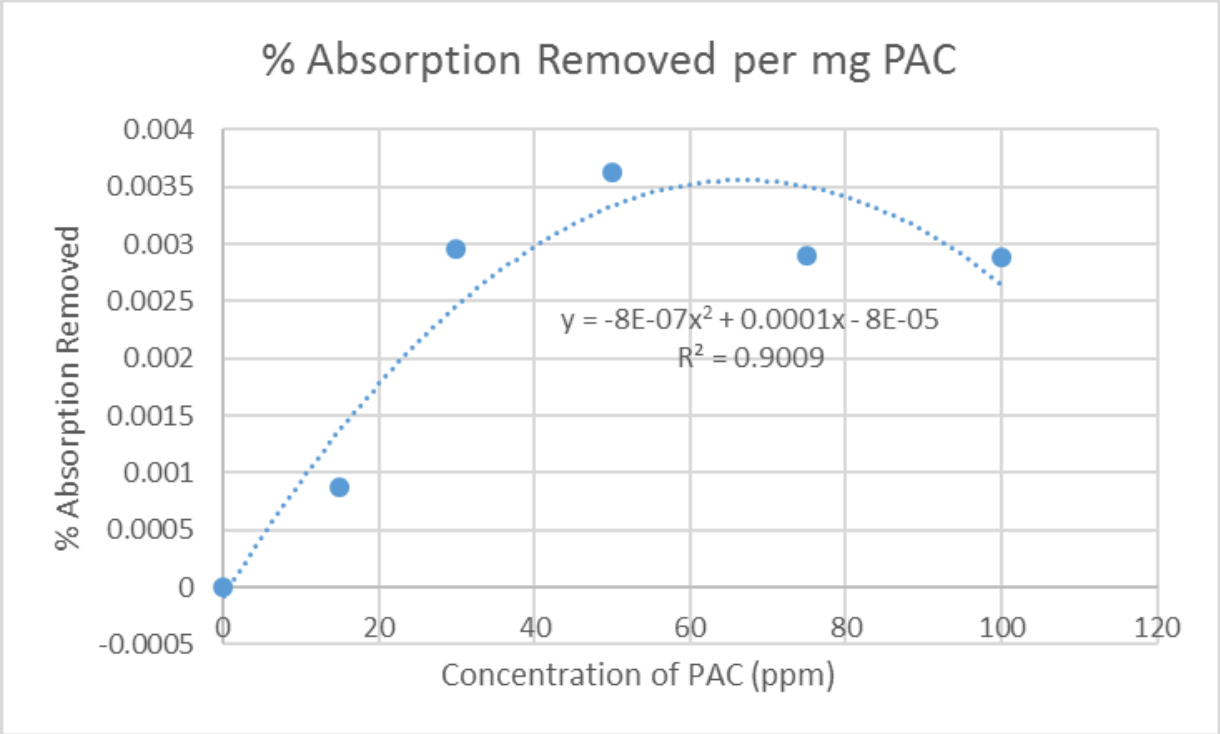

FIGURE C.8: BLUE DYE (BFC) % ABSORBANCE PER MG PAC PLOT USING EPW STD PAC. MAY 24

May 25, 2017:

- Color added and mixed in stock bucket with river water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$ and PAC Mixed together at same time
- Samples mixed 3 minutes apart for 20 min. at 50 rpm
- Settled for 3 minutes before filtering
- 500 mL filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength

TABLE C.8: RAW DATA OF DYE REMOVAL TEST: YELLOW DYE. MAY 25

Dye	Date	Sample ID	PAC (mg/L)	Absorbance 405 nm	% Abs Removal	% removed per mg PAC
Yellow Dye	5/25/17	Blank	0	0	0.00%	0.00%
.1 mL/L		yellow blank	0	0.479719	0.00%	0.00%
EPW Std		yellow riv 0	0	0.415153	0.00%	0.00%
River Water		yellow riv 15	15	0.414728	0.10%	0.01%
		yellow riv 30	30	0.384425	7.40%	0.25%
		yellow riv 50	50	0.344434	0.170344	0.003407
		yellow riv 75	75	0.333662	0.196291	0.002617
		yellow riv 100	100	0.300512	0.276142	0.002761

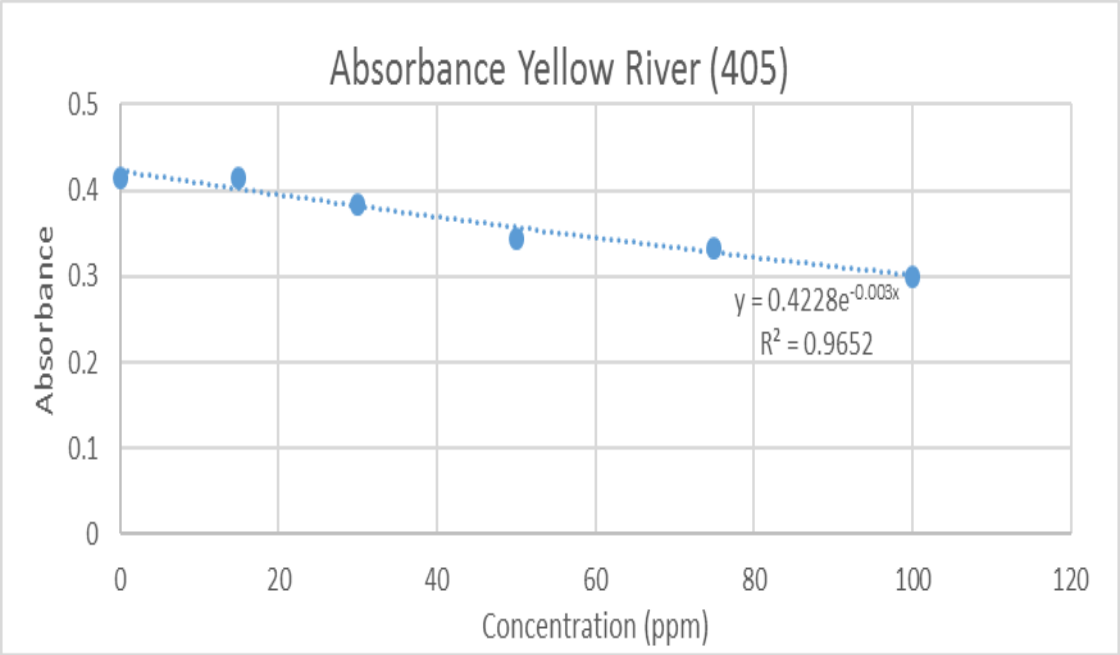

FIGURE C.9: YELLOW DYE ABSORBANCE PLOT. MAY 25

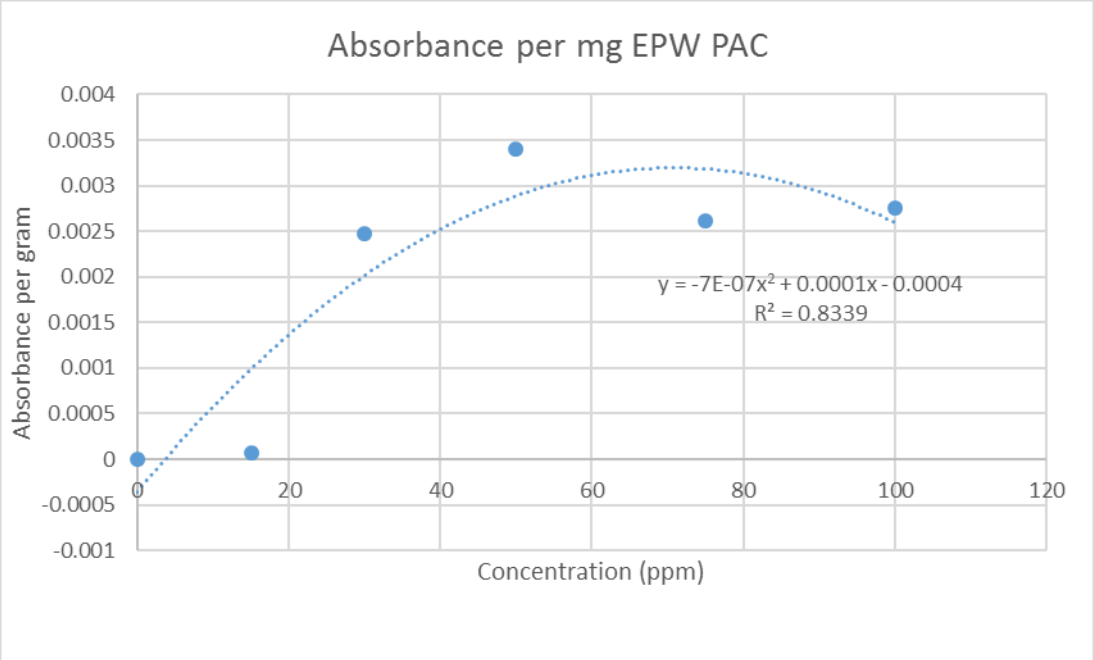

FIGURE C.10: YELLOW DYE ABSORBANCE PER MG EPW STD PAC PLOT. MAY 25

May 25, 2017:

- Color added and mixed in stock bucket with river water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$ and PAC Mixed together at same time
- Samples mixed 3 minutes apart for 20 min. at 50 rpm
- Settled for 5 minutes before filtering
- 500 mL filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength

TABLE C.9: RAW DATA OF DYE REMOVAL TEST: RED DYE. MAY 25

Dye	Date	Sample ID	PAC (mg/L)	Absorbance 502 nm	% Abs Removal	% removed per mg PAC
Red Dye	5/25/17	Blank	0	0		
.1 mL/L		red 0	0	0.223986	0.00%	0.00%
EPW Std		red 15	15	0.218414	2.49%	0.17%
River Water		red 30	30	0.20476	8.58%	0.29%
		red 50	50	0.182496	18.52%	0.37%
		red 75	75	0.143997	0.357116	0.004762
		red 100	100	0.131038	0.414972	0.00415

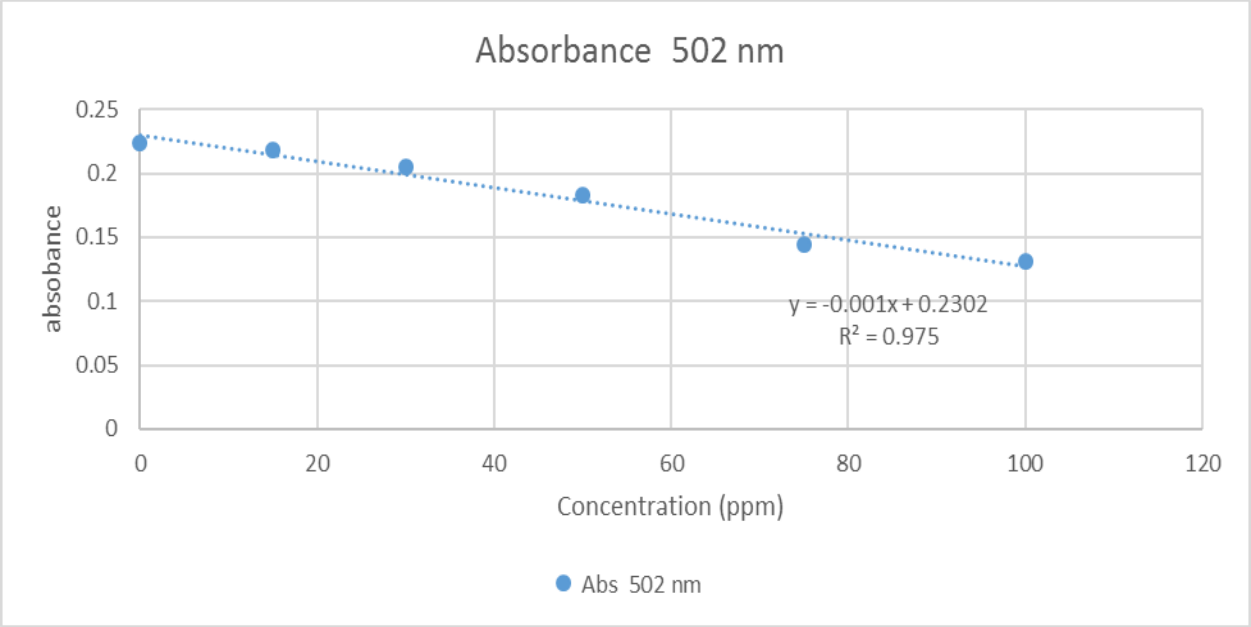

FIGURE C.11: RED DYE ABSORBANCE PLOT. MAY 25

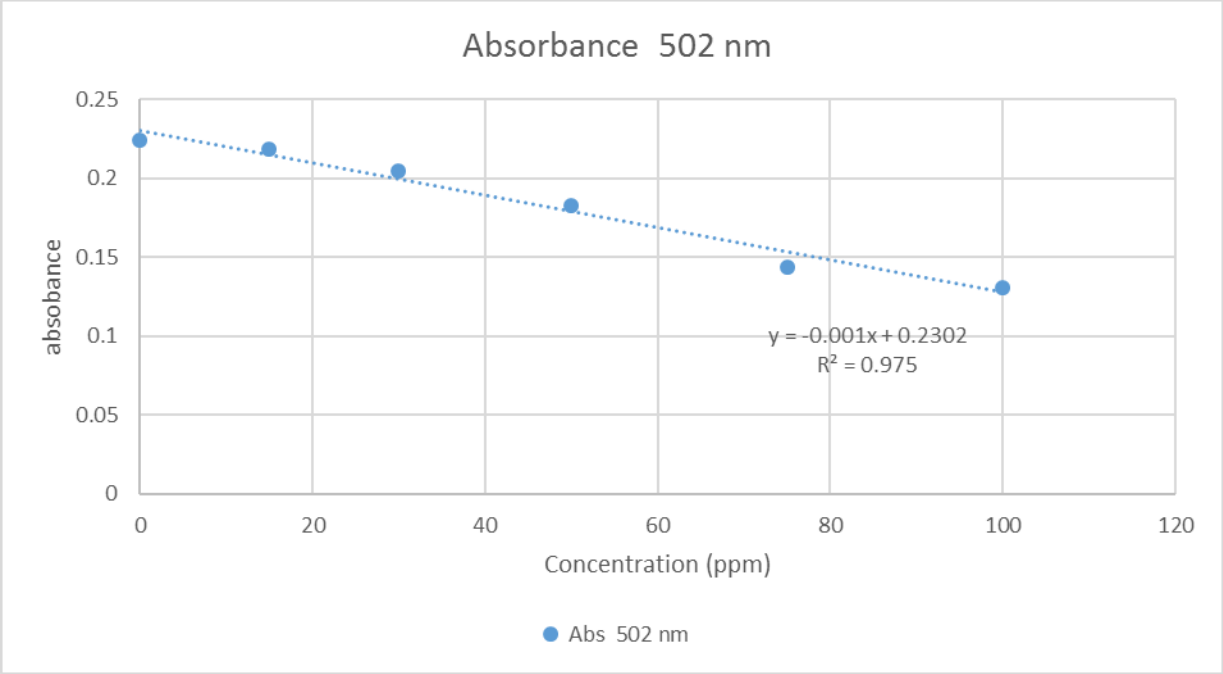

FIGURE C.12: RED DYE ABSORBANCE PER MG EPW STD PAC PLOT. MAY 25

May 30, 2017:

- Color added and mixed in stock bucket with dechlorinated Tap water
- 1 L samples containing 25ppt Geosmin
- NO $FeCl_3$
- Samples mixed 3 minutes apart for 20 min. at 50 rpm
- Settled for 5 minutes before filtering
- 500 mL filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength

TABLE C.10: RAW DATA OF DYE REMOVAL TEST: YELLOW AND RED (RFC) DYE. MAY 30

Dye	Date	Sample ID	PAC (mg/L)	Absorbance nm	% Abs Removal	% removed per mg PAC	Rank
Yellow dye	5/30/17	Blank	0	0	0.00%	0.00%	
0.1 mL/L		Filtered Blank	0	0.358656	0.00%	0.00%	
dye		Hydro W	50	0.273548	23.73%	0.47%	10
Abs 405 nm		Pulsorb	50	0.151623	57.72%	1.15%	2
		Hydro S	50	0.221055	38.37%	0.77%	7
		WPH	50	0.012332	96.56%	1.93%	1
		Hydro M	50	0.236589	34.03%	0.68%	8
		KBM	50	0.176625	50.75%	1.02%	4
		BL Pulv	50	0.183785	48.76%	0.98%	5
		EPW Norit	50	0.216701	39.58%	0.79%	11
		Calgon	50	0.17338	51.66%	1.03%	3
		EPW Std	50	0.287588	19.82%	0.40%	12
		Nichem	50	0.219638	38.76%	0.78%	6
		Hydro B	50	0.242514	32.38%	0.65%	9
Red dye		Blank	0	0	0.00%	0.00%	
0.1 mL/L		Filtered Blank	0	0.264155	0.00%	0.00%	
dye		Hydro W	50	0.166636	36.92%	0.74%	6
Abs 502 nm		Pulsorb	50	0.170856	35.32%	0.71%	7
		Hydro S	50	0.124607	52.83%	1.06%	3
		WPH	50	0.122953	53.45%	1.07%	2
		Hydro M	50	0.129441	51.00%	1.02%	4
		KBM	50	0.098395	62.75%	1.26%	1
		BL Pulv	50	0.179234	0.321482	0.00643	9
		EPW Norit	50	0.145316	44.99%	0.90%	5
		Calgon	50	0.202993	23.15%	0.46%	10
		EPW Std	50	0.242458	8.21%	0.16%	12
		Nichem	50	0.221448	16.17%	0.32%	11
		Hydro B	50	0.178045	32.60%	0.65%	8

May 31, 2017:

- Color added and mixed in stock bucket with dechlorinated Tap water
- 1 L samples containing 25ppt Geosmin
- NO $FeCl_3$ *Found $FeCl_3$ not significant for removal percentages after test
- Samples mixed 3 minutes apart for 20 min. at 50 rpm
- Settled for 5 minutes before filtering
- 500 mL filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength

TABLE C.11: RAW DATA OF DYE REMOVAL TEST: YELLOW AND RED (CARMINE) DYE. MAY 31

Dye	Date	Sample ID	PAC (mg/L)	Absorbance	% Abs Removal	% removed per mg/L PAC	Rank
Yellow dye	5/31/17	Filtered initial	0	0.4493	0.00%	0.00%	
0.1 mL/L		Hydro W	50	0.293455	34.69%	0.69%	10
dye		Pulsorb	50	0.190941	57.50%	1.15%	2
Abs 405 nm		Hydro S	50	0.248933	44.60%	0.89%	6
		WPH	50	0.07616	83.05%	1.66%	1
		Hydro M	50	0.288418	35.81%	0.72%	9
		KBM	50	0.233347	48.06%	0.96%	4
		BL Pulv	50	0.233666	47.99%	0.96%	5
		EPW Norit	50	0.275341	38.72%	0.77%	7
		Calgon	50	0.222429	50.49%	1.01%	3
		EPW std	50	0.340068	24.31%	0.49%	12
		Nichem	50	0.311149	30.75%	0.61%	11
		Hydro B	50	0.283438	36.92%	0.74%	8
		Hydro B	50	0.242514	32.38%	0.65%	9
Carmine		Blank	0	0	0.00%	0.00%	
Added		unfiltered	0	0.213084	0.00%	0.00%	
~300mg/14L		filtered	0	0.140102	0.00%	0.00%	
disovled		Hydro W	50	0.112812	19.48%	0.39%	5
with heat		Pulsorb	50	0.122199	12.78%	0.26%	7
then added		Hydro S	50	0.097008	30.76%	0.62%	1
Abs 502 nm		WPH	50	0.116486	16.86%	0.34%	6
		Hydro M	50	0.099839	28.74%	0.57%	3
		KBM	50	0.099511	0.289725	0.005794	2
		BL Pulv	50	0.125431	10.47%	0.21%	9
		EPW Norit	50	0.106998	23.63%	0.47%	4
		Calgon	50	0.142385	-1.63%	-0.03%	11
		EPW Std	50	0.13795	1.54%	0.03%	10
		Nichem	50	0.147171	-5.05%	-0.10%	12

		Hydro B	50	0.123812	0.116272	0.002325	8

June 1, 2017:

- Color added and mixed in stock bucket with dechlorinated Tap water
- 1 L samples containing 25ppt Geosmin
- NO $FeCl_3$
- Samples mixed 3 minutes apart for 20 min. at 50 rpm
- Settled for 5 minutes before filtering
- 500 mL filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength

TABLE C.12: RAW DATA OF DYE REMOVAL TEST: YELLOW (ANILINE) AND PURPLE DYE. JUNE 1

Dye	Date	Sample ID	PAC (mg/L)	Absorbance	% Abs Removal	% removed per mg/L PAC	Rank
Aniline	6/1/17	Blank	0	0	0.00%	0.00%	
Yellow		Initial filtered	0	0.723707	0.00%	0.00%	10
dye		Hydro W	50	0.100686	86.09%	1.72%	9
300mg/14L		Pulsorb	50	0.039929	94.48%	1.89%	4
Dissolved		Hydro S	50	0.043267	94.02%	1.88%	5
in 300 mL		WPH	50	0	100.00%	2.00%	1
Alcohol First		Hydro M	50	0.120986	83.28%	1.67%	10
then mixed in		KBM	50	0.043267	94.02%	1.88%	6
bucket		BL Pulv	50	0.046526	93.57%	1.87%	7
diluted 1:4 in		EPW Norit	50	0.080955	88.81%	1.78%	8
jars		C Pulv	50	0.036582	94.95%	1.90%	3
Abs 405 nm		EPW Std	50	0.23828	67.08%	1.34%	12
		Nichem	50	0.029664	95.90%	1.92%	2
		Hydro B	50	0.145765	79.86%	1.60%	11
Purple		Blank	0	0	0.00%	0.00%	
Dye		initial filtered	0	0.192103	0.00%	0.00%	
Dissolved		Hydro W	50	0.129271	32.71%	0.65%	6
then filterd		Pulsorb	50	0.137718	28.31%	0.57%	9
then added to		Hydro S	50	0.079573	58.58%	1.17%	1
sample bucket		WPH	50	0.135562	29.43%	0.59%	7
Abs 502 nm		Hydro M	50	0.099545	48.18%	0.96%	2
		KBM	50	0.110819	42.31%	0.85%	3
		BL Pulv	50	0.139592	0.273348	0.55%	8
		EPW Norit	50	0.112139	41.63%	0.83%	4
		C Pulv	50	0.12847	33.12%	0.66%	5
		EPW Std	50	0.165334	13.93%	0.28%	12

		Nichem	50	0.146273	23.86%	0.48%	11
		Hydro B	50	0.114458	40.42%	0.81%	5

*EPW Std consistently least performing PAC

June 2, 2017:

- Color added and mixed in stock bucket with dechlorinated River water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$
- Samples mixed 2 minutes apart for 20 min. at 45 rpm
- Settled for 2 minutes before filtering
- 500 mL filtered with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength

TABLE C.13: RAW DATA OF DYE REMOVAL TEST: RED (RFC) AND FLUORESCEIN. JUNE 2

Dye	Date	Sample ID	PAC (mg/L)	Absorbance	% Abs Removal	% removed per mg/L PAC
Red	6/2/17	Blank	0	0	0.00%	
dye		**EPW Standard PAC**				
0.1 mL/L						
Abs 502 nm		RFC initial	0	0.23506	0.00%	0.00%
		RFC std	15	0.215397	8.37%	0.56%
		RFC std	30	0.197439	16.00%	0.53%
		RFC std	50	0.180446	23.23%	0.46%
		RFC std	75	0.153642	34.64%	0.46%
		RFC std	100	0.134657	42.71%	0.43%
		WPH PAC				
		RFC initial	0	0.23506	0.00%	0.00%
		RFC WPH	15	0.152398	35.17%	2.34%
		RFC WPH	30	0.089946	61.73%	2.06%
		RFC WPH	50	0.058373	75.17%	1.50%
		RFC WPH	75	0.04196	82.15%	1.10%
		RFC WPH	100	0.019819	91.57%	0.92%
Fluorescein		Blank	0	0	0.00%	0.00%
5mg/L		Initial fluo	0	0.599728	0.00%	0.00%
River Water		fluo EPW std	50	0.43386	27.66%	0.55%
Abs 465 nm		fluo EPW std	100	0.359658	0.400298	0.40%

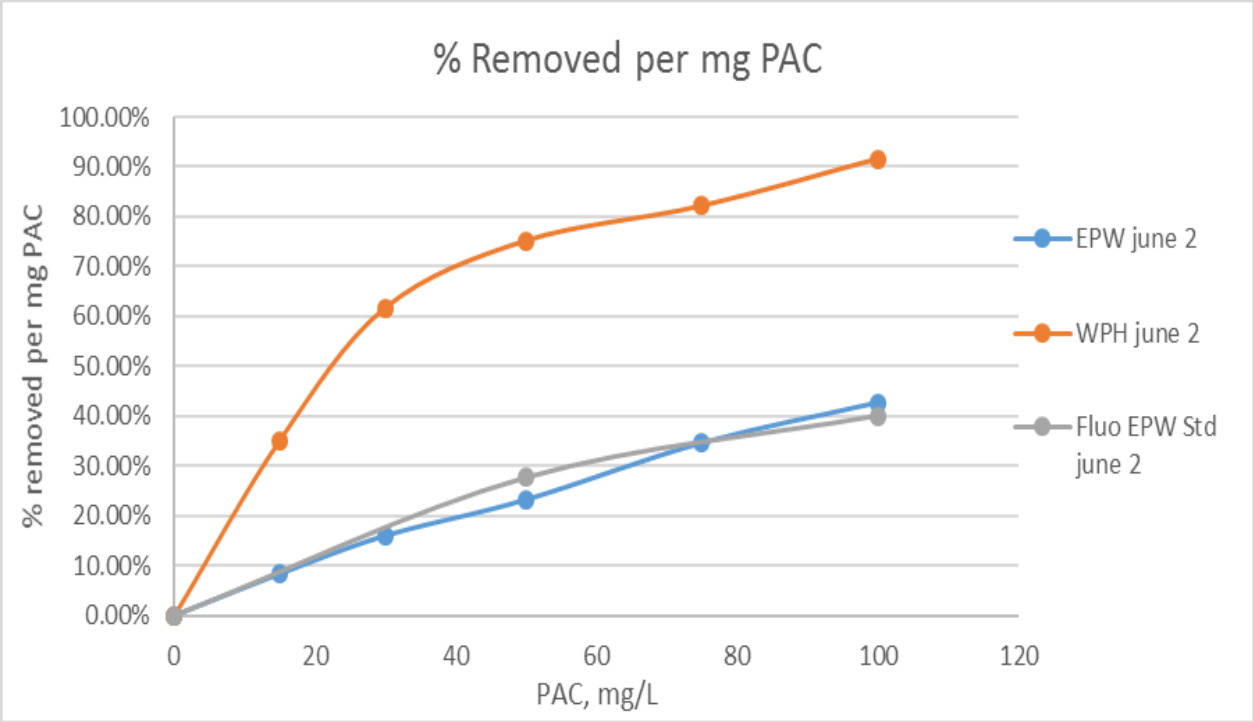

FIGURE C.13: % REMOVED PER MG PAC PLOT. JUNE 2

June 5, 2017:

- Color added and mixed in stock bucket with dechlorinated River water
- 1 L samples containing 30ppt Geosmin
- 10 mg/L $FeCl_3$
- Samples mixed 3 minutes apart for 20 min. at 50 rpm
- Filtered 500 mL with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength
- Tests sent to AEL Laboratory

TABLE C.14: RAW DATA OF DYE REMOVAL TEST: FLUORESCEIN. JUNE 5

Dye	Date	Sample ID	PAC (mg/L)	Absorbance 465 nm	% Abs Removal	% removed per mg/L PAC
Fluorescein	6/5/17	Blank	0	0	0.00%	0.00%
dye		Filtered FL blank	0	0.635649	0.00%	0.00%
10 mg/L		EPW FL river	30	0.562155	11.56%	0.39%
		EPW FL river	50	0.519394	18.29%	0.37%
		EPW FL river	100	0.403508	36.52%	0.37%

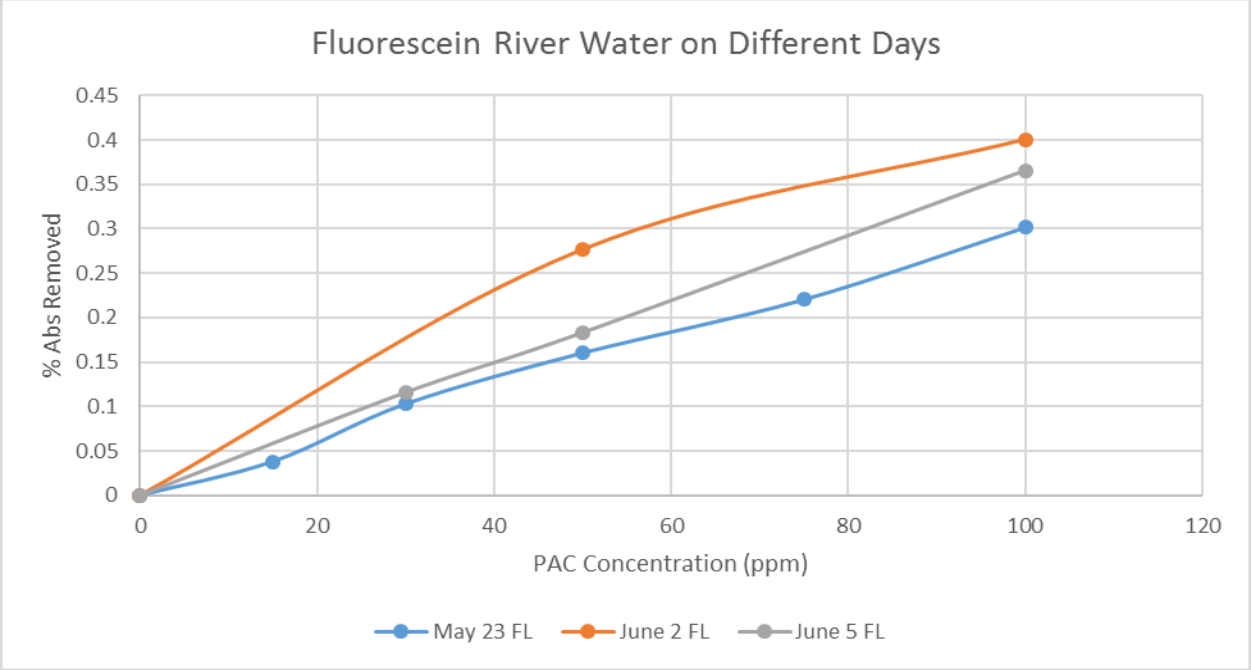

FIGURE C.14: FLUORESCEIN PLOT FOR DIFFERENT DAYS: % ABS REMOVED VS. PAC CONCENTRATION

June 6, 2017:

- Color added and mixed in stock bucket with dechlorinated River water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$
- Samples mixed 3 minutes apart for 20 min. at 50 rpm
- Filtered 500 mL with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength

TABLE C.15: RAW DATA OF DYE REMOVAL TEST: ANILINE YELLOW. JUNE 6

Dye	Date	Sample ID	PAC (mg/L)	Absorbance 465 nm	% Abs Removal	% removed per mg/L PAC	Rank
Analine	6/6/17	Blank	0	0	0.00%	-	
Yellow		initial	0	0.869674	0.00%	-	
75mg/L		Hydro W	30	0.377449	56.60%	1.89%	11
in		Hydro S	30	0.275367	68.34%	2.28%	6
bucket		Hydro M	30	0.293269	66.28%	2.21%	7
		Pulsorb	30	0.233481	73.15%	2.44%	3
		WPH	30	0.049387	94.32%	3.14%	1
		KB-M	30	0.179822	79.32%	2.64%	2
		BL Pulv	30	0.296701	65.88%	2.20%	8
		Calgon	30	0.258841	70.24%	2.34%	5
		Nichem	30	0.247926	71.49%	2.38%	4
		EPW Norit	30	0.325818	62.54%	2.08%	9
		EPW Std	30	0.423899	51.26%	1.71%	12
		Hydrodarco B	30	0.353842	59.31%	1.98%	10

June 7, 2017:

- Color added and mixed in stock bucket with dechlorinated River water
- 1 L samples containing 25ppt Geosmin
- 10 mg/L $FeCl_3$
- Samples mixed 3 minutes apart for 20 min. at 50 rpm
- Filtered 500 mL with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength

TABLE C.16: RAW DATA OF DYE REMOVAL TEST: PURPLE DYE AND FLUORESCEIN. JUNE 7

Dye	Date	Sample ID	PAC (mg/L)	Absorbance	% Abs Removal	% removed per mg/L PAC	Rank
Purple	6/6/17	Blank	0	0	0.00%	0.00%	
Dye		Filterd Blank	0	0.32465	0.00%	0.00%	
6.8 g/14 L		Hydro W	30	0.164442	49.35%	1.64%	7
in		Pulsorb	30	0.177593	45.30%	1.51%	8
bucket		Hydro S	30	0.134994	58.42%	1.95%	3
Abs 502 nm		WPH	30	0.13471	58.51%	1.95%	2
		Hydro M	30	0.145346	55.23%	1.84%	4
		KBM	30	0.129011	60.26%	2.01%	1
		BL Pulv	30	0.185692	42.80%	1.43%	10
		EPW Norit	30	0.151323	53.39%	1.78%	5
		C Pulv	30	0.181371	44.13%	1.47%	9
		EPW Std	30	0.200173	38.34%	1.28%	12
		Nichem	30	0.18864	41.89%	1.40%	11
		Hydro B	30	0.153809	52.62%	1.75%	6
Fluorescein		Blank	0	0	0.00%	0.00%	
5mg/L		Initial fluo	0	0.599728	0.00%	0.00%	
River Water		fluo EPW std	50	0.43386	27.66%	0.55%	
465 nm		fluo EPW std	100	0.359658	40.03%	0.40%	

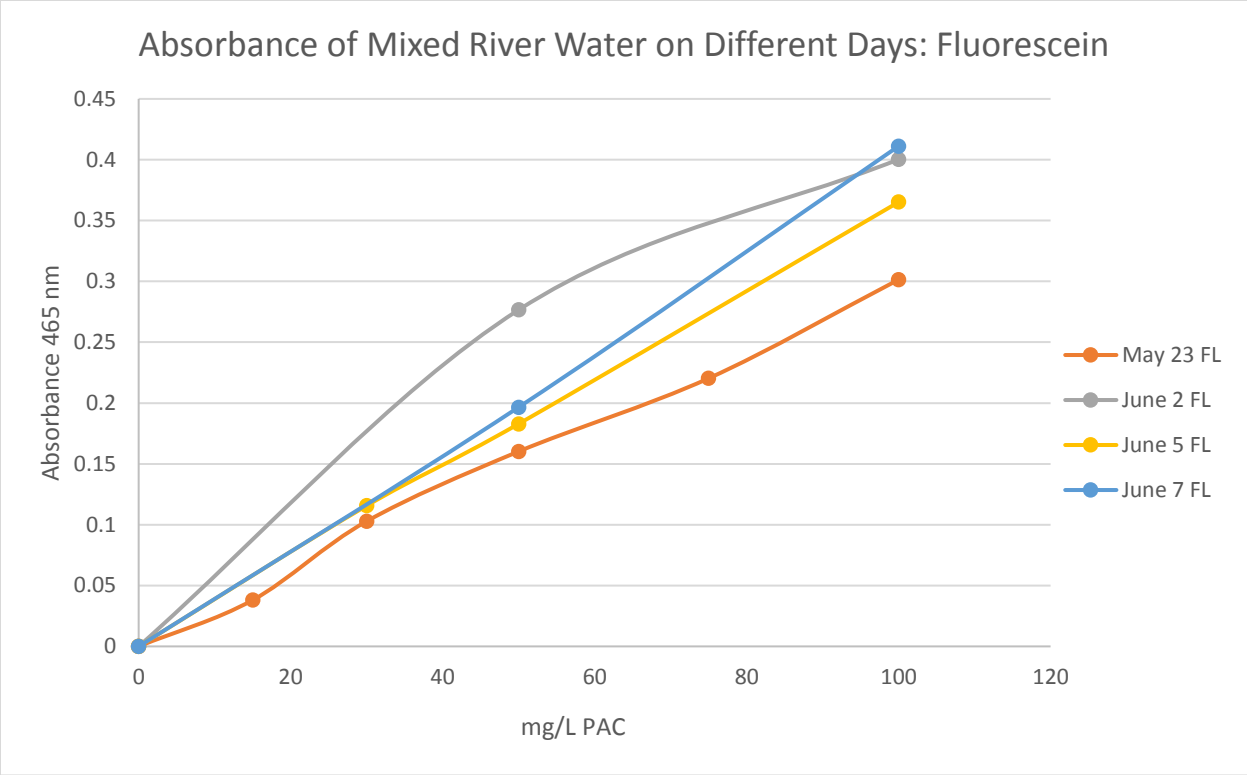

FIGURE C.15: FLUORESCEIN PLOT FOR DIFFERENT DAYS: ABSORBANCE VS. PAC CONCENTRATION

TABLE C.17: PAC RANKS FOR ALL TEST DYAS AND DYES

Date	Color	PAC RANKS											
		Hydro W	Hydro S	Hydro M	Pulsorb	WPH	BL Pulv	KBM	C Pulv	Nichem	EPW Std	EPW Norit	Hydro B
17-May	BFC	10	3	5	9	2	7	1	8	11	12	4	6
19-May	FL	9	4	6	2	1	3	5	7	11	12	8	10
30-May	YFC	11	8	9	2	1	5	4	3	7	12	6	10
30-May	RFC	6	3	4	7	2	9	1	10	11	12	5	8
31-May	YFC	10	6	9	2	1	5	4	3	11	12	7	8
31-May	RD	5	1	3	7	6	9	2	11	12	10	4	8
1-Jun	YD	9	5	10	4	1	7	6	3	2	12	8	11
1-Jun	PD	7	1	2	9	8	10	3	6	11	12	4	5
6-Jun	YD	11	6	7	3	1	8	2	5	4	12	9	10
7-Jun	PD	7	3	4	8	2	10	1	9	11	12	5	6
Mean		8.5	4	5.9	5.3	2.5	7.3	2.9	6.5	9.1	11.8	6	8.2
Median		9	3.5	5.5	5.5	1.5	7.5	2.5	6.5	11	12	5.5	8

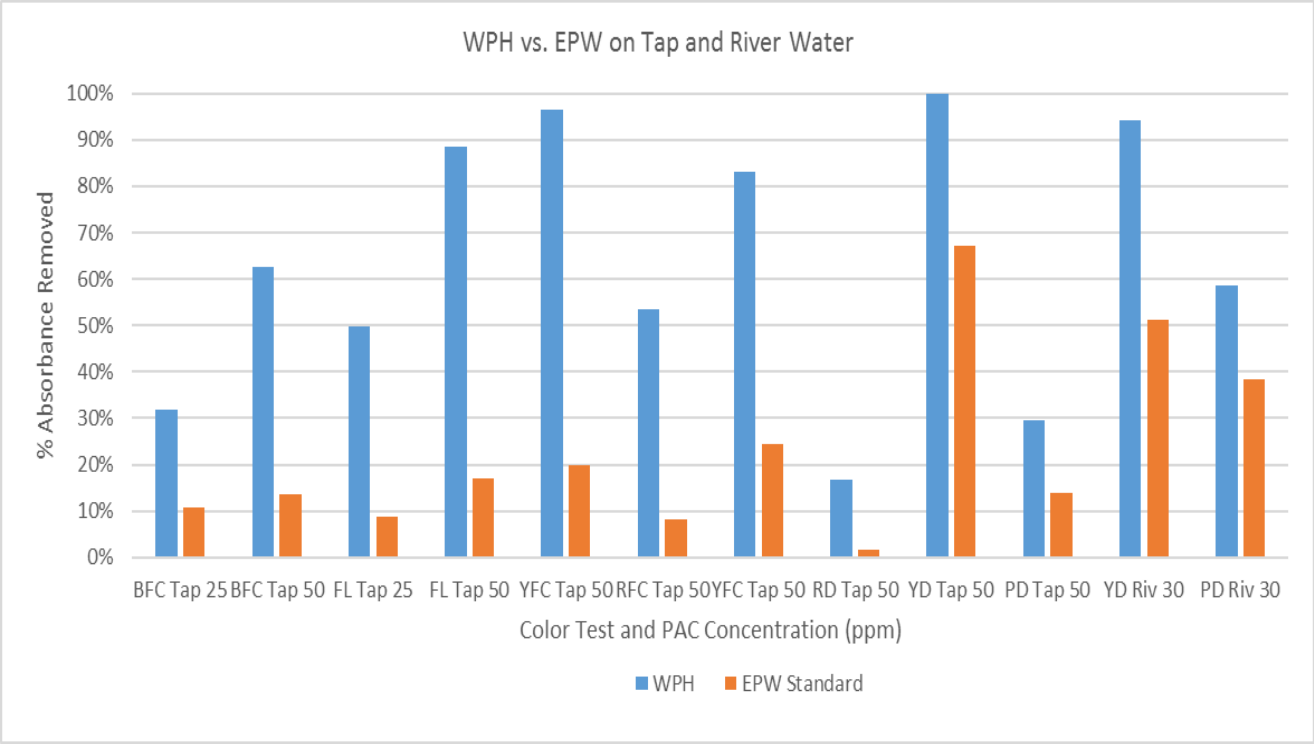

FIGURE C.16: WPH VS. EPW CHART

APPENDIX D: LAB RESULTS AND ADSORPTION ISOTHERM

Lab Results:

- Color added and mixed in stock bucket with dechlorinated River water
- 1 L samples containing Geosmin (5/22- 50 ng/L, 6/5- 30 ng/L)
- 10 mg/L $FeCl_3$
- Samples mixed 3 minutes apart for 20 min. at 50 rpm
- Filtered 500 mL with glass fiber filters and vacuum flask
- measured using MicroLab Spectrophotometry at specified wavelength
- Tests sent to AEL Laboratory following specific packaging and shipping guidelines

TABLE D.1: AEL LABORATORY RESULTS

Date	PAC, mg/L	Geosmin, ng/L	% Removal	Removal q, ng/g
5/22/17	0.01	51.5	0.00%	0
EPW Std	15	39.9	22.52%	0.773
TAP Water	30	22.3	56.70%	0.973
	50	10.3	80.00%	0.824
River Water	0.01	59.4	0.02%	0.000
	15	41.6	29.97%	1.187
	30	29.9	49.66%	0.983
	50	18.6	68.69%	0.816
	75	11.6	80.47%	0.637
	100	6.82	88.52%	0.526
6/5/17	0.01	32.9	0.00%	0
TAP Water	15	14.4	56.23%	1.233
EPW Std	30	7.09	78.45%	0.860
River Water	0.01	34.5	0.00%	0
EPW Std	15	19.8	42.61%	0.980
	30	15.7	54.49%	0.627
	50	7.38	78.61%	0.542
	75	4.77	86.17%	0.396
River Water	0.01	34.5	0.00%	0
WPH	15	9.25	73.19%	1.683
	30	3.08	91.07%	1.047

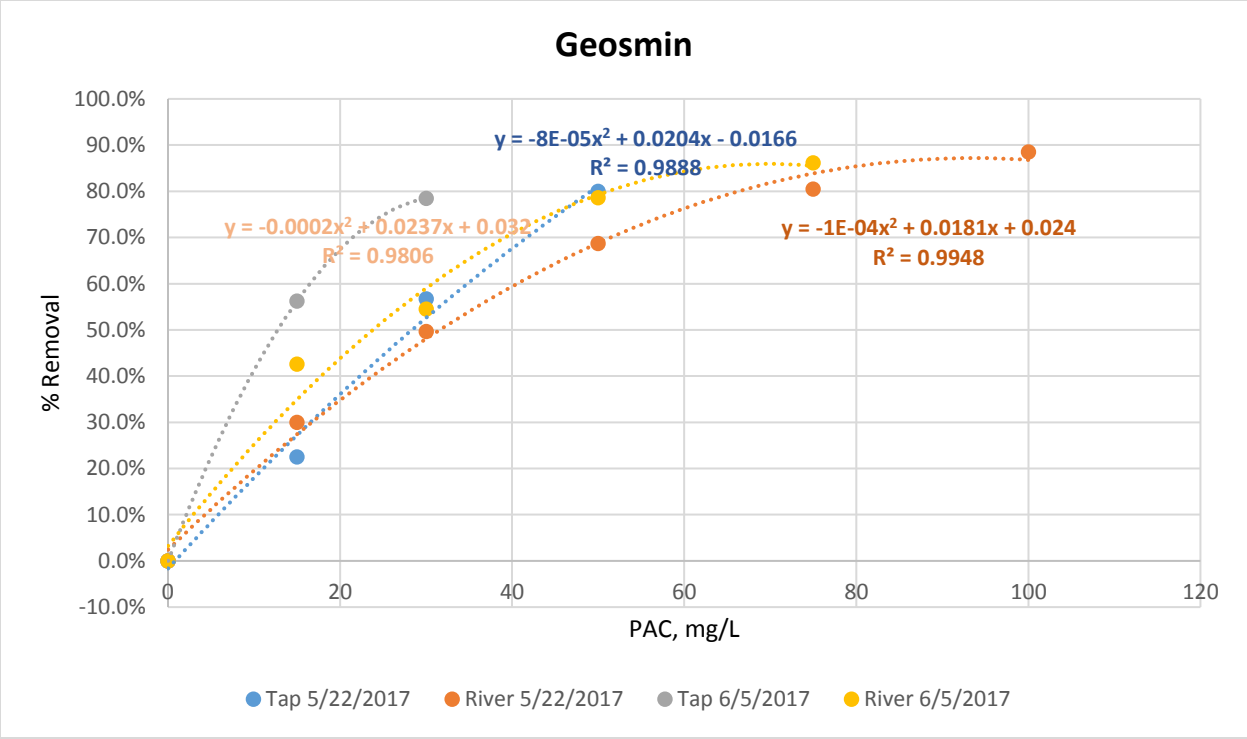

FIGURE D.1: PLOT OF AEL LABORATORY RESULTS: % REMOVAL VS. PAC, MG/L

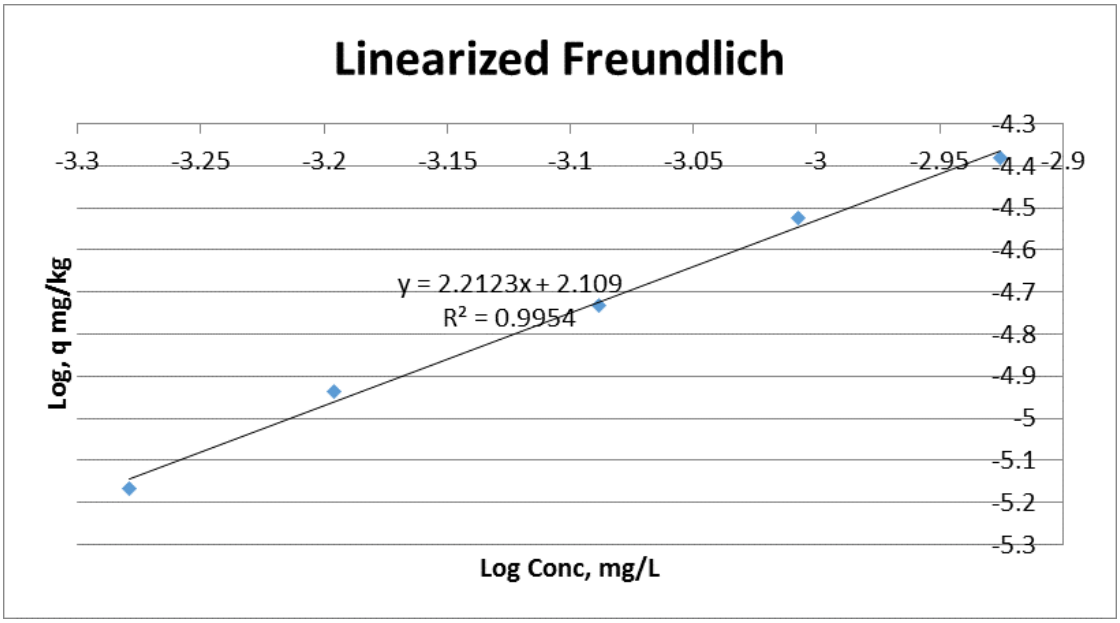

FIGURE D.2: PLOT OF AEL LABORATORY RESULTS: LINEARIZED FREUNDLICH PLOT

TABLE D.2: AEL LABORATORY RESULTS: CALCULATED FREUNDLICH ISOTHERM FOR 5/22

log q = log K_F + 1/n(log C)								
q, mg/kg	log q	C, mg/L	log C	1/n	log K	K		
1.19	0.075547	41.6	1.619093331	0.452	-0.65628	0.221		
0.98	-0.00877	29.9	1.475671188	0.452	-0.67578	0.211		
0.82	-0.08831	18.6	1.269512944	0.452	-0.66213	0.218		
0.64	-0.19563	11.6	1.064457989	0.452	-0.67677	0.210		
0.53	-0.27918	6.82	0.833784375	0.452	-0.65605	0.221	**Avg =**	**0.216**

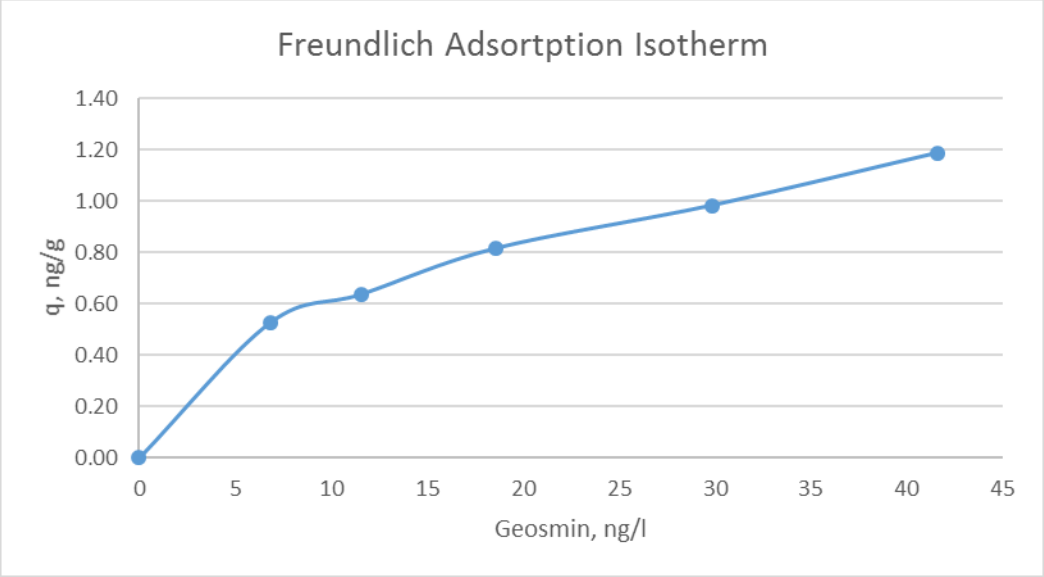

FIGURE D.3: PLOT OF AEL LABORATORY RESULTS: LINEARIZED FREUNDLICH PLOT

TABLE D.3: COST ESTIMATES OF EPW STANDARD PAC TREATMENT

Assume ng/L in water =	20
Flow mgd=	20
total mg in water =	1514
removal req'd, mg =	1135.5
kg PAC needed =	2538.39
Pounds PAC needed =	5596.185
No. of 50 lb bags/day =	111.9237
Cost/day at $0.57/lb =	3189.825
Cost/1000 gal	0.159491

APPENDIX E: AEL LAB AND UV/H_2O_2 RESULTS

TABLE E.1: AEL ANALYSIS RESULTS

Date	Sample	Geosmin Conc, ng/L	MIB Conc, ng/L	Comments
6/5/2017	River raw	0.96	4.76	Noticeable increase of MIB and Geosmin from River to Filters
	Primary effluent P1	1.72	4.27	
	Top Fil 4	2.88	13.5	
	Bottom Fil 4	2.93	5.21	
	Top Fil 2	1.66	7.21	
	Bottom Fil 2	0	4.3	
6/19/2017	River raw	< 1	< 5	Noticeable increase of MIB and Geosmin particularly in Secondary basins
	Primary Effluent Plant 1 10 ft.	<1	< 5	
	Primary Effluent Plant 1 8 ft.	< 1	< 5	
	Primary Effluent Plant 1 4 ft.	< 1	5.46	
	Primary Effluent Plant 2 10 ft.	<1	< 5	
	Primary Effluent Plant 2 8 ft.	<1	< 5	
	Primary Effluent Plant 2 4 ft.	<1	< 5	
	Plant 1 Secondary A1-2	< 1	7.79	
	Plant 1 Secondary B1-2	<1	9.39	
	Plant 1 Secondary B4-6	<1	7.57	
	Plant 1 Top Fil 3	<1	11.4	
	Plant 1 Bottom Fil 3	<1	< 5	

TABLE E.2: AEL UV/H_2O_2 RESULTS

Date	Initial Geosmin Conc, ng/l	Detention Time DT, min	H_2O_2, mg/L	Final Geosmin Conc, ng/L	Removal	Removal %	DT*H2O2
6/26/2017	30	0.01	2.4	27.6	2.4	0.08	0.024
	30	3	3	0	30	1	9
	30	1.2	3	0	30	1	3.6
	30	0.4	3	5.09	24.91	0.830333	1.2
	30	0.4	5	2.15	27.85	0.928333	2
	30	0.6	10	0	30	1	6

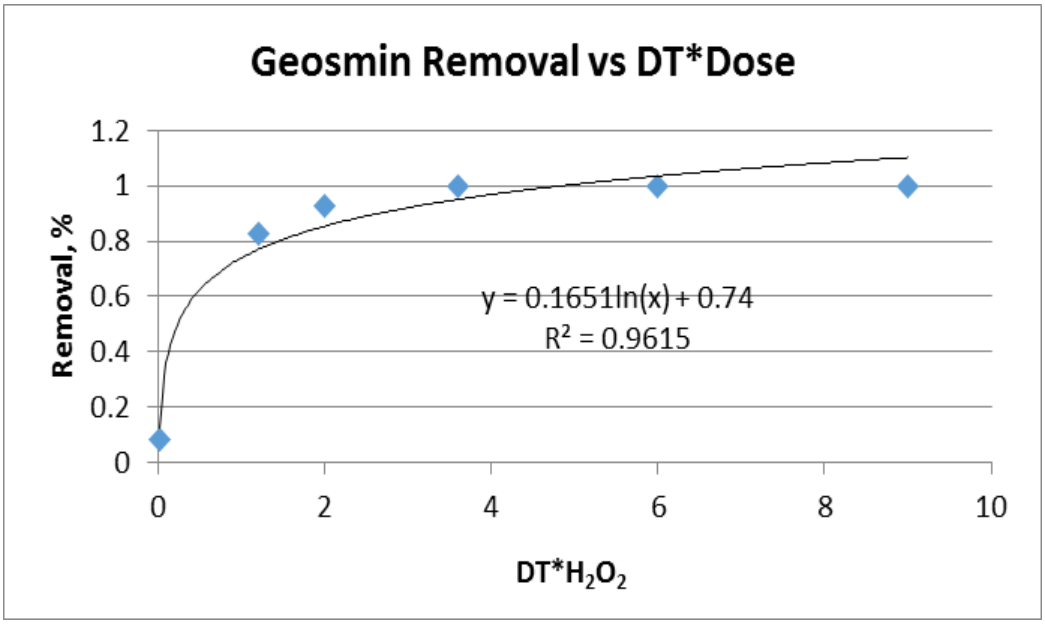

FIGURE E.1: PLOT OF UV/H_2O_2 RESULTS: % REMOVAL VS. DT* H_2O_2

APPENDIX F: ANALYTICAL ENVIRONMENTAL LABORATORIES RAW RESULTS

ANALYTICAL ENVIRONMENTAL LABORATORIES

NELAP Accredited

Certificate T104704280-08-TX

nelap

Analytical Report

1034246

For

UT El Paso/Dept. of Civil Eng
Anthony Tarquin
500 W. University/Eng. Anex A-225
El Paso, TX 79968

Thursday, May 25, 2017

Approved by Don Crozier

Don Crozier, Laboratory Manager

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Job Number 1034246 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	05/22/2017	Laboratory ID:	1034246-1
Time Sampled:	11:10 AM	Date Received:	05/24/2017
Project Name:		Time Received:	1:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	TAP 0		
Sample Type:	Grab	Receiving Flags	TP1

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC
Geosmin	51.5*	ng/l	1.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.
Sample Flag Definitions:
TP1 = Insufficient thermal preservation (sample received above acceptable temperature range).

Job Number 1034246 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	05/22/2017	Laboratory ID:	1034246-2
Time Sampled:	11:13 AM	Date Received:	05/24/2017
Project Name:		Time Received:	1:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	TAP 15		
Sample Type:	Grab	Receiving Flags	TP1

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00	SF	SM 6040D-2011 Mod	1086771	5/24/17	AAC
Geosmin	39.9*	ng/l	1.00	SF	SM 6040D-2011 Mod	1086771	5/24/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034246 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	05/22/2017	Laboratory ID:	1034246-3
Time Sampled:	11:16 AM	Date Received:	05/24/2017
Project Name:		Time Received:	1:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	TAP 30		
Sample Type:	Grab	Receiving Flags	TP1

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC
Geosmin	22.3*	ng/l	1.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034246 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	05/22/2017	Laboratory ID:	1034246-4
Time Sampled:	11:20 AM	Date Received:	05/24/2017
Project Name:		Time Received:	1:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	TAP 50		
Sample Type:	Grab	Receiving Flags	TP1

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC
Geosmin	10.3*	ng/l	1.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034246 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	05/22/2017	Laboratory ID:	1034246-5
Time Sampled:	11:23 AM	Date Received:	05/24/2017
Project Name:		Time Received:	1:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	RIV 0		
Sample Type:	Grab	Receiving Flags	TP1

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC
Geosmin	59.4*	ng/l	1.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034246 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	05/22/2017	Laboratory ID:	1034246-6
Time Sampled:	11:27 AM	Date Received:	05/24/2017
Project Name:		Time Received:	1:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	RIV 15		
Sample Type:	Grab	Receiving Flags	TP1

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC
Geosmin	41.6*	ng/l	1.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034246 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	05/22/2017	Laboratory ID:	1034246-7
Time Sampled:	11:30 AM	Date Received:	05/24/2017
Project Name:		Time Received:	1:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	RIV 30		
Sample Type:	Grab	Receiving Flags	TP1

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC
Geosmin	29.9*	ng/l	1.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034246 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	05/22/2017	Laboratory ID:	1034246-8
Time Sampled:	11:34 AM	Date Received:	05/24/2017
Project Name:		Time Received:	1:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	RIV 50		
Sample Type:	Grab	Receiving Flags	TP1

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC
Geosmin	18.6*	ng/l	1.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number **1034246** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**05/22/2017**	Laboratory ID:	**1034246-9**
Time Sampled:	**11:40 AM**	Date Received:	**05/24/2017**
Project Name:		Time Received:	**1:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**RIV 75**		
Sample Type:	**Grab**	Receiving Flags	**TP1**

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC
Geosmin	11.6*	ng/l	1.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number **1034246** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**05/22/2017**	Laboratory ID:	**1034246-10**
Time Sampled:	**11:43 AM**	Date Received:	**05/24/2017**
Project Name:		Time Received:	**1:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**RIV 100**		
Sample Type:	**Grab**	Receiving Flags	**TP1**

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC
Geosmin	6.82*	ng/l	1.00		SM 6040D-2011 Mod	1086771	5/24/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

ANALYTICAL ENVIRONMENTAL LABORATORIES

NELAP Accredited

Certificate T104704280-08-TX

Analytical Report

1034398

For

UT El Paso/Dept. of Civil Eng

Anthony Tarquin

500 W. University/Eng. Anex A-225

El Paso, TX 79968

Thursday, June 08, 2017

Approved by _____

~~Don~~ Crozier, ~~Laboratory~~ Manager

Kent Technical

6/8/17

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Job Number **1034398** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**06/05/2017**	Laboratory ID:	**1034398-1**
Time Sampled:	**10:30 AM**	Date Received:	**06/07/2017**
Project Name:	**UTEP/EL PASO WATER GEOSMIN**	Time Received:	**12:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**RIVRAW**		
Sample Type:	**Grab**	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	4.76*	1	ng/l	J	0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	0.960*	1	ng/l	J	0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number **1034398** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**06/05/2017**	Laboratory ID:	**1034398-2**
Time Sampled:	**10:33 AM**	Date Received:	**06/07/2017**
Project Name:	**UTEP/EL PASO WATER GEOSMIN**	Time Received:	**12:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**PRIP1**		
Sample Type:	**Grab**	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	4.27*	1	ng/l	J	0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	1.72*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number **1034398** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**06/05/2017**	Laboratory ID:	**1034398-3**
Time Sampled:	**10:37 AM**	Date Received:	**06/07/2017**
Project Name:	**UTEP/EL PASO WATER GEOSMIN**	Time Received:	**12:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**TFIL4P1**		
Sample Type:	**Grab**	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	13.5*	1	ng/l		0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	2.88*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034398 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/05/2017	Laboratory ID:	1034398-4
Time Sampled:	10:40 AM	Date Received:	06/07/2017
Project Name:	UTEP/EL PASO WATER GEOSMIN	Time Received:	12:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	BFIL4P1		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	5.21*	1	ng/l		0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	2.93*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034398 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/05/2017	Laboratory ID:	1034398-5
Time Sampled:	10:43 AM	Date Received:	06/07/2017
Project Name:	UTEP/EL PASO WATER GEOSMIN	Time Received:	12:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	TFIL2P2		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	7.21*	1	ng/l		0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	1.66*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034398 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/05/2017	Laboratory ID:	1034398-6
Time Sampled:	10:46 AM	Date Received:	06/07/2017
Project Name:	UTEP/EL PASO WATER GEOSMIN	Time Received:	12:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	BFIL2P2		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	4.30*	1	ng/l	J	0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	<0.360*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number **1034398** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**06/05/2017**	Laboratory ID:	**1034398-7**
Time Sampled:	**10:50 AM**	Date Received:	**06/07/2017**
Project Name:	**UTEP/EL PASO WATER GEOSMIN**	Time Received:	**12:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**DI-GEO30**		
Sample Type:	**Grab**	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	1.81*	1	ng/l	J	0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	32.9*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number **1034398** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**06/05/2017**	Laboratory ID:	**1034398-8**
Time Sampled:	**10:53 AM**	Date Received:	**06/07/2017**
Project Name:	**UTEP/EL PASO WATER GEOSMIN**	Time Received:	**12:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**TAPEPW15**		
Sample Type:	**Grab**	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	2.38*	1	ng/l	J	0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	14.4*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number **1034398** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**06/05/2017**	Laboratory ID:	**1034398-9**
Time Sampled:	**10:57 AM**	Date Received:	**06/07/2017**
Project Name:	**UTEP/EL PASO WATER GEOSMIN**	Time Received:	**12:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**TAPEPW30**		
Sample Type:	**Grab**	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	2.76*	1	ng/l	J	0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	7.09*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034398 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/05/2017	Laboratory ID:	1034398-10
Time Sampled:	11:00 AM	Date Received:	06/07/2017
Project Name:	UTEP/EL PASO WATER GEOSMIN	Time Received:	12:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	RIVEPW15		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	8.13*	1	ng/l		0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	19.8*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034398 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/05/2017	Laboratory ID:	1034398-11
Time Sampled:	11:03 AM	Date Received:	06/07/2017
Project Name:	UTEP/EL PASO WATER GEOSMIN	Time Received:	12:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	RIVEPW30		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	3.77*	1	ng/l	J	0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	15.7*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034398 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/05/2017	Laboratory ID:	1034398-12
Time Sampled:	11:07 AM	Date Received:	06/07/2017
Project Name:	UTEP/EL PASO WATER GEOSMIN	Time Received:	12:00 PM
Project Number:		Matrix:	Aqueous
Sample Description	RIVEPW50		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	6.70*	1	ng/l		0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	7.38*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

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Job Number **1034398** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**06/05/2017**	Laboratory ID:	**1034398-13**
Time Sampled:	**11:10 AM**	Date Received:	**06/07/2017**
Project Name:	**UTEP/EL PASO WATER GEOSMIN**	Time Received:	**12:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**RIVEPW75**		
Sample Type:	**Grab**	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	2.02*	1	ng/l	J	0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	4.77*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

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Job Number **1034398** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**06/05/2017**	Laboratory ID:	**1034398-14**
Time Sampled:	**11:15 AM**	Date Received:	**06/07/2017**
Project Name:	**UTEP/EL PASO WATER GEOSMIN**	Time Received:	**12:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**RIVWPH15**		
Sample Type:	**Grab**	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	4.50*	1	ng/l	J	0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	9.25*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

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Job Number **1034398** Customer: **UT El Paso/Dept. of Civil Eng** Attn: **Anthony Tarquin**

Date Sampled:	**06/05/2017**	Laboratory ID:	**1034398-15**
Time Sampled:	**11:20 AM**	Date Received:	**06/07/2017**
Project Name:	**UTEP/EL PASO WATER GEOSMIN**	Time Received:	**12:00 PM**
Project Number:		Matrix:	**Aqueous**
Sample Description	**RIVWPH30**		
Sample Type:	**Grab**	Receiving Flags	

Analysis	Result	Dilution	Unit	Flag	MDL	MQL	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040										
2-Methylisoborneol	2.32*	1	ng/l	J	0.908	5.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC
Geosmin	3.08*	1	ng/l		0.360	1.00	SM 6040D-2011 Mod	1086951	6/8/17	AAC

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ANALYTICAL ENVIRONMENTAL LABORATORIES

NELAP Accredited
Certificate T104704280-08-TX

Analytical Report

1034523

For

UT El Paso/Dept. of Civil Eng
Anthony Tarquin
500 W. University/Eng. Anex A-225
El Paso, TX 79968

Thursday, June 22, 2017

Approved by _____
Don Crozier, Laboratory Manager

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Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-1
Time Sampled:	9:00 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	RivRaw		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00		SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-2
Time Sampled:	9:05 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P1PRI0		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-3
Time Sampled:	9:10 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P1PRI4		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	5.46*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-4
Time Sampled:	9:15 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P1PRI8		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-5
Time Sampled:	9:20 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P2PRI0		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-6
Time Sampled:	9:25 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P2PRI4		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00		SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-7
Time Sampled:	9:30 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P2PRI8		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-8
Time Sampled:	9:35 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P1SECA1-2		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	7.79*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-9
Time Sampled:	9:40 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P1SECA3-4		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-10
Time Sampled:	9:45 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P1SECB1-3		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	9.39*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-11
Time Sampled:	9:50 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P1SECB4-6		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	7.57*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-12
Time Sampled:	9:55 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P1FIL3T		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	11.4*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-13
Time Sampled:	10:00 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P1FIL3B		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	9.02*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	2.38*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087141	6/21/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-14
Time Sampled:	10:05 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P2FIL1T		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1087141	6/21/17	AAC
Geosmin	<1.00*	ng/l	1.00		SM 6040D-2011 Mod	1087141	6/21/17	AAC

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Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-15
Time Sampled:	10:10 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	P2FIL1B		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087147	6/22/17	AAC
Geosmin	<1.00*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087147	6/22/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-16
Time Sampled:	10:30 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	30GDTOHP3		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00	SF	SM 6040D-2011 Mod	1087147	6/22/17	AAC
Geosmin	27.6*	ng/l	1.00	SF	SM 6040D-2011 Mod	1087147	6/22/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-17
Time Sampled:	10:35 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	30GDT3HP3		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1087147	6/22/17	AAC
Geosmin	<1.00*	ng/l	1.00		SM 6040D-2011 Mod	1087147	6/22/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-18
Time Sampled:	10:40 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	30GDT1.2HP3		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1087147	6/22/17	AAC
Geosmin	<1.00*	ng/l	1.00		SM 6040D-2011 Mod	1087147	6/22/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-19
Time Sampled:	10:45 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	30GDT0.4HP3		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1087147	6/22/17	AAC
Geosmin	5.09*	ng/l	1.00		SM 6040D-2011 Mod	1087147	6/22/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-20
Time Sampled:	10:50 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	30GDT0.4HP5		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1087147	6/22/17	AAC
Geosmin	2.15*	ng/l	1.00		SM 6040D-2011 Mod	1087147	6/22/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

Job Number 1034523 Customer: UT El Paso/Dept. of Civil Eng Attn: Anthony Tarquin

Date Sampled:	06/19/2017	Laboratory ID:	1034523-21
Time Sampled:	10:55 AM	Date Received:	06/21/2017
Project Name:	EPW Geosmin - Plant & UV	Time Received:	1:30 PM
Project Number:		Matrix:	Aqueous
Sample Description	30GDT0.6HP10		
Sample Type:	Grab	Receiving Flags	

Analysis	Result	Unit	MQL	Flag	Test Method	QA	Date	Tech
Drinking Water Odor Compounds 6040								
2-Methylisoborneol	<5.00*	ng/l	5.00		SM 6040D-2011 Mod	1087147	6/22/17	AAC
Geosmin	<1.00*	ng/l	1.00		SM 6040D-2011 Mod	1087147	6/22/17	AAC

Any tests indicated with "*" next to result are not included in current NELAC fields of accreditation.

VITA

Anthony Rodriguez earned his Bachelor of Science in Civil Engineering degree in 2016 from the University of Texas at El Paso and was enrolled into the Master of Science in Environmental Engineering in January of 2017. While pursuing his degree, Mr. Rodriguez has had the opportunity to work on several wastewater projects for a local utility companies such as El Paso Water, as well as an industrial wastewater recovery system for the El Paso Electric Company. Additionally, Mr. Rodriguez worked as a teaching assistant for the department of Civil Engineering. In May of 2017, Mr. Rodriguez became a certified Engineer in Training (EIT) for the state of Texas. Mr. Rodriguez will continue and looks forward to working on the improvement of water treatment systems in the most sustainable way possible to meet the demand of current and future generations.

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