To:

Attention: David Goldstein

Project #: 8005008

REFERENCE NO: MEIC-8005008-PG

Date: 9/22/2014

SUBJECT: Comparative analysis of smoking devices

Dear Mr. Goldstein,

MEI-Charlton, Inc. (MEIC) was retained by Precision Glass Works (PGW) to perform a comparative analysis of three water filter smoking devices. You have told us that this water filter device testing is being done to support your patent claims which relate to novel modifications of traditional laboratory glassware, in this case a gas-washing (Dreschel) bottle, so that it may be used to prove or disprove an assertion made by the US Surgeon General in 1963 that water filtration may remove harmful constituents (particulates and water solubles) from tobacco smoke. The said apparatus itself consist of an extremely coarse gas washing bottle with an attached conduit below the disc connecting to structures which support another, demountable, coarse fritted disc. This acts as pre-filter to keep particulate matter out of the water sample, assuring clean sample. The pre-filter is secured in place by close-fitting ground joint, and connects to combustion chamber by ground joint as well. Used as intended, tobacco, preferably high tar/high nicotine, would be burned under vacuum with combustion gas sucked through the water sample. The tobqcco sample is small, probably – 20 cc, so the exposed water sample should show good concentration of particulates/chemicals. *You further told us that you* believe that your design is consistent with good laboratory practice, and will show some harm reduction. Accordingly, it was agreed that MEIC will evaluate the submitted frits via the following scope of the work:

Using the PGW provided apparatus and operation instructions/protocol to perform following tests using a 30cc water sample.

a. The apparatus itself consists of a combustion device (bowl) mounted by ground joint to adapter
b. containing fritted glass pre-filter to prevent particulates from contaminating water sample. The
c. combustion device and pre-filters attach by ground joint to a coarse-fritted gas washing bottle with ~30 cc water in the bottom.
d. Tobacco smoke will be drawn by vacuum through the apparatus.

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Said smoke bubbled water sample will then be tested for the presence of carcinogenic compounds known to be present in tobacco smoke.

1) Tobacco Sample Preparation
2) Take samples and assess the water quality at 3 nos intervals (within the total burn time) of exposure
3) for carcinogenic content.
4) Using the total tobacco burn time determine rate of smoke and smoke flow at one given vacuum
5) pressure value

To achieve the above following detailed tests were performed:

1) Bubble analysis via digital photography
2) Filtering properties of tobacco smoke through water
3) End smoke particle analysis for efficacy and carcinogenic properties

The results from this testing and analysis are as follows.

1. Bubble analysis

Three tobacco smoking devices were submitted to MEIC (**Figure 1**) designated at large frit (LF), medium frit (MF) and toker 2 (T2). Each device was tested against typical negative pressur exerted by the human lung to allow the air bubbles to form in the chamber. A vacuum pump was used to replicate the conditions for each device and air bubbles were measured using digital photography methods in conjunction with ImageJ. The experimental setup is shown in **Figure 2**. The devices with fritted glass pieces had two stages of air bubbles. Representative photographs are shown in **Figures 3-5**. All data collected is given in **Table 1.** The smallest bubbles (Stage I) were observed in the MF samples at an average of 1.69 mm, followed by the LF at 2.08. The largest bubbles (Stage II) were observed in the device not containing a fritted glass piece (T2) and had an average small bubble size of 13.85 mm. This trend held true for the large bubbles observed as well.

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Figure 1: Photograph of the three water pipes submitted for filtration efficacy.

Figure 2: Photograph of the experimental setup used during testing.

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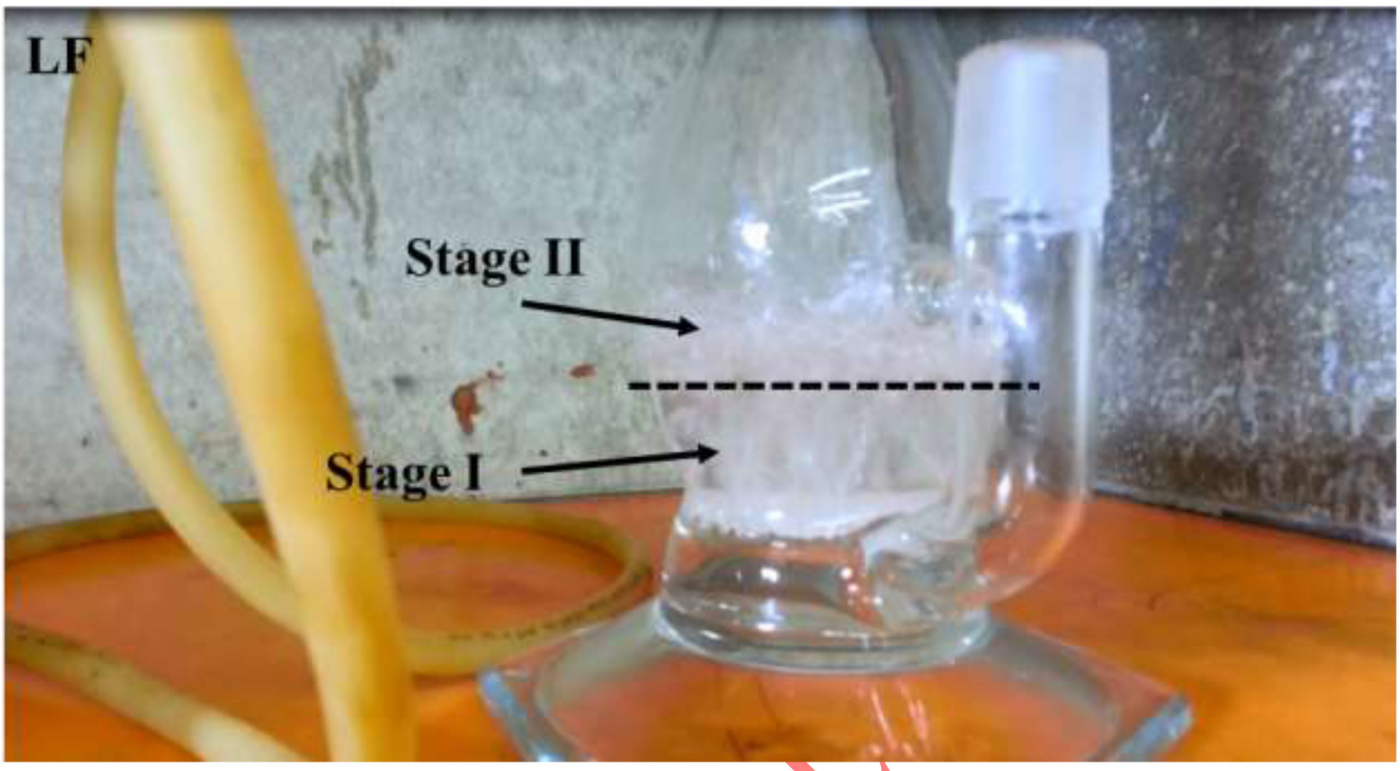

Figure 3: Photograph depicting the two stages of bubbles that existed in the LF system.

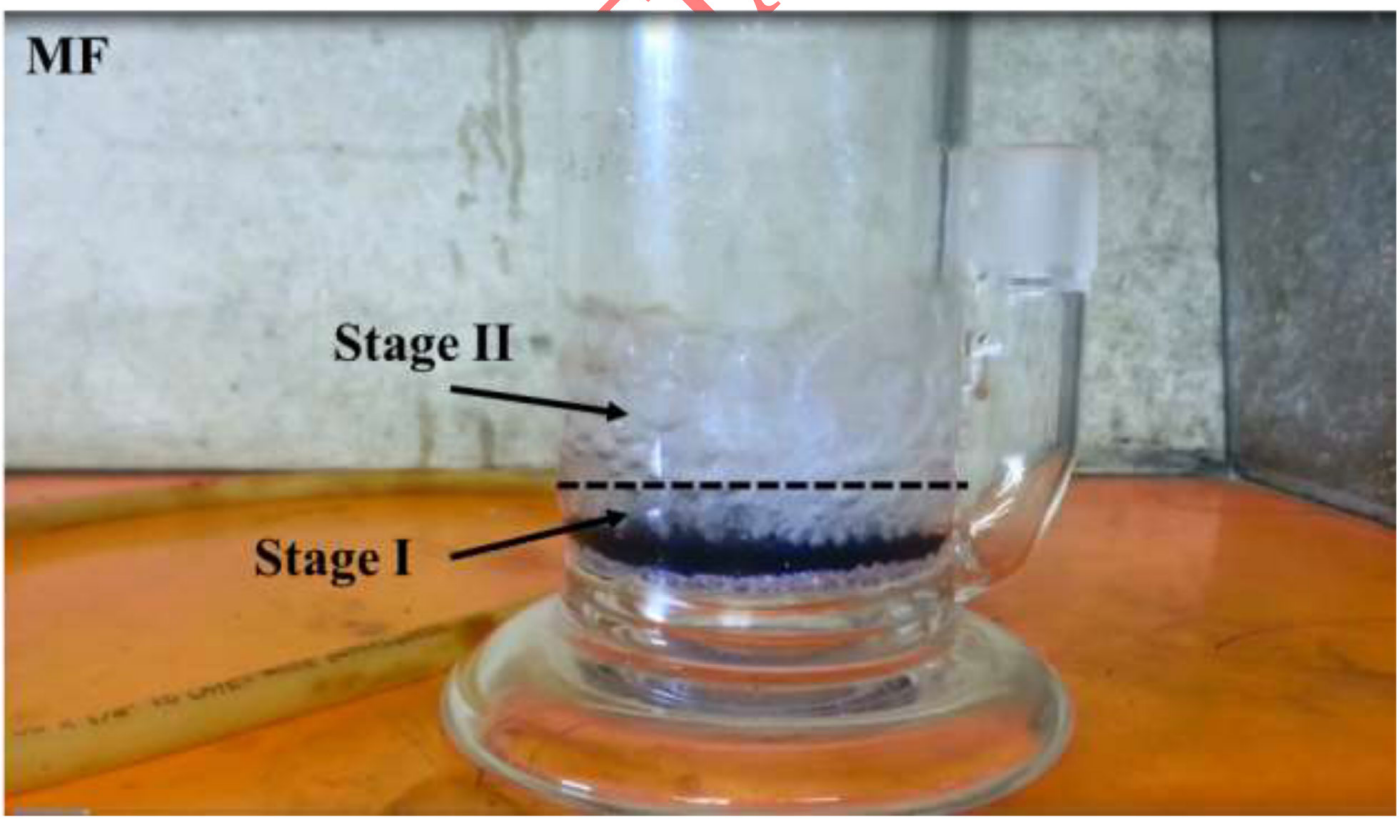

Figure 4: Photograph depicting the two stages of bubbles that existed in the MF system.

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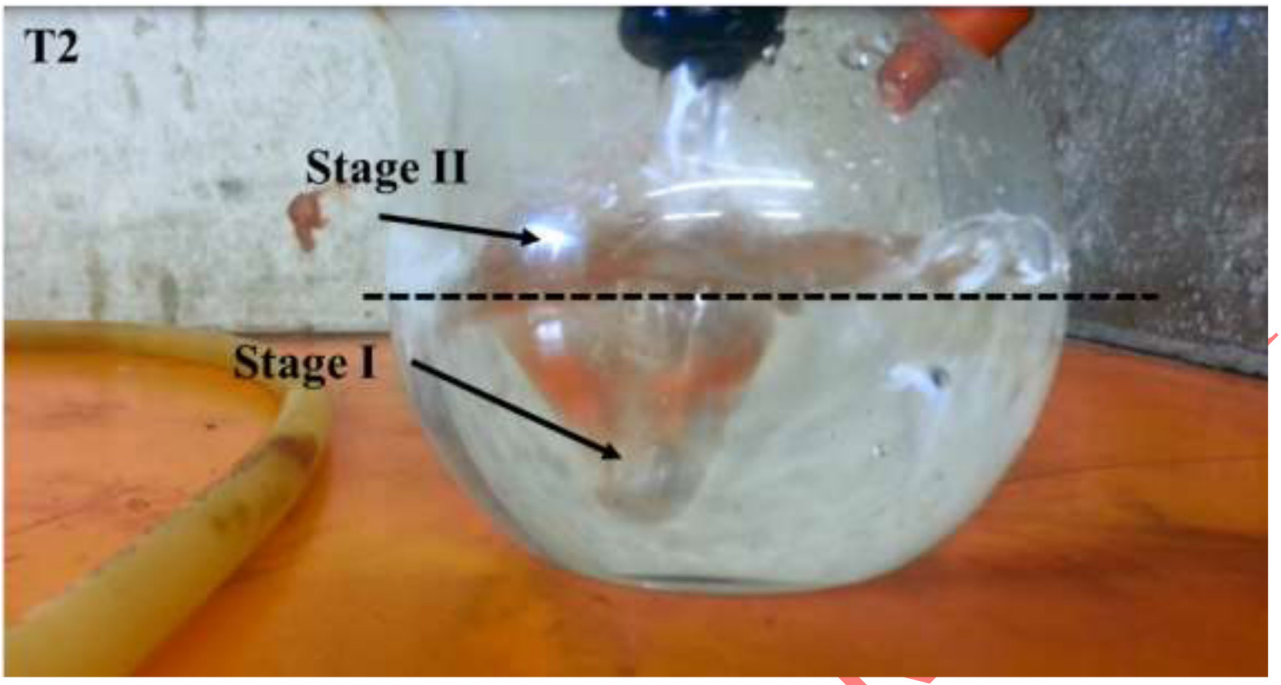

Figure 5: Photograph depicting the two stages of bubbles that existed in the T2 system.

Table 1: Calculated data from digital bubble analysis.

Stage	Sample					
	LF		MF		T2	
Stage I (mm)	AVG	SD	AVG	SD	AVG	SD
	2.08	0.36	1.69	0.15	13.85	5.34
Stage II (mm)	AVG	SD	AVG	SD	AVG	SD
	5.10	2.20	4.60	1.99	27.83	5.53

2. Water analysis

10 grams of cigarette tobacco were burned at 1 gram intervals in each of the smoking devices at a negative pressure similar to human performance. The LF device was filled with 100 mL of water, the MF device with 60 mL of water and the T2 device with 140 mL of water. Water amounts chosed were based on optimal bubble formation via visual inspection. After each 1 gram interval, the water in all three devices were measured for pH, viscosity, density and turbidity. All data was corrected or normalized to account for the variations in starting water levels. All data is summarized in **Table 5**.

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2.1 pH

pH was measured using an Accumet meter with matching probe (Fisher Scientific). All solutions showed a trend towards increasing alkalinity throughout the testing (**Figure 6**). The MF device had a sharp increase in pH at around 3 grams of tobacco burned, followed by a slight decrease and then steady level. The LF and T2 devices also had increases in pH around 3 grams, but was more gradual overall. The pH levels in the MF device indicate that significantly more particles were collected from the smoke throughout the study than either the LF or T2. The LF and T2 devices had similar pH profiles throughout the study, although the LF device shows that particle collection was also more efficient from the first gram of tobacco burned. **Overall, pH results indicate that the LF and MF devices both showed more efficient particle absorption and smoke cleaning properties.** Data is given in **Table 2**.

Table 2: pH data collected during the course of the experiment for all three devices.

Measurement	Tobacco Burned (g)									
	Device	1	2	3	4	5	6	7	8	9	10
pH	LF	7.4	7.43	7.76	7.96	7.95	7.75	7.68	7.84	7.92	7.96
	MF	7.45	7.16	6.88	9.03	8.25	8.25	8.26	8.01	8.33	8.33
	T2	6.39	6.96	6.93	7.35	7.31	7.36	7.6	7.71	7.92	7.87

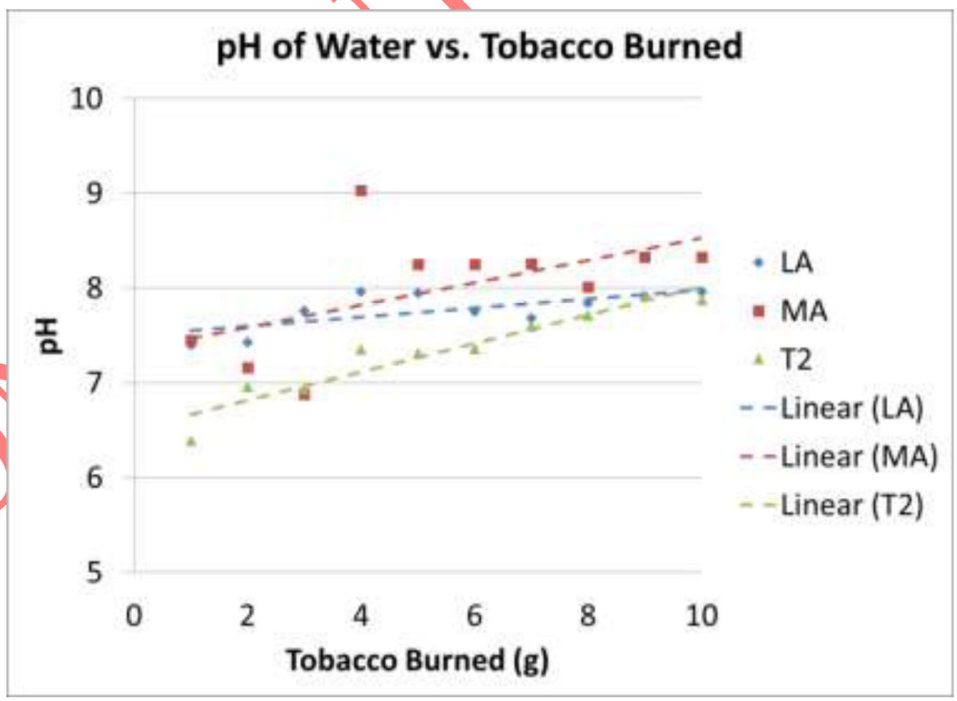

Figure 6: Graph plotting the pH data vs. the amount of tobacco burned for all three devices.

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2.2 Viscosity

Viscosity was measured using a Brookfiel LVF dial viscometer with the largest spindle size (#1) available. The plot of specific viscosity vs tobacco burned is given in **Figure 7.** From the data it is apparent that the both of the devices containing the fritted glass pieces were able to collect and dissolve more particels than the T2 device with an average of 150% higher viscosity. The viscosity of the water on all of the devices had an "up and down" pattern indicating a tendancy for particle agglomeration and either precipitation (down) or dissolution (up). The MF showed slightly better particle cleaning properties than the LF device reaching a saturation point at about 250 (cp/cp) at around 6 grams, while the LF device reached that point at about 10 grams of tobacco burned. **Collective results show a stark difference in the ability of the both the fritted devices to collect particles when compared to the standard T2 device, which showed no noticeable increase in viscosity throughout the experiment**. Data is given in **Table 3**.

Table 3: Specific viscosity data collected during the course of the experiment for all three devices.

Measurement	Tobacco Burned (g)									
	Device	1	3	3	5	6	7	7	8	9	10
Specific Viscosity	LF	1.00	1.00	1.20	1.50	2.00	2.00	1.50	2.00	2.05	2.46
	MF	1.00	1.00	1.50	1.50	1.20	2.46	2.46	1.88	2.46	2.46
	T2	0.00	0.00	0.00	0.00	0.73	1.31	0.00	0.00	0.00	0.00

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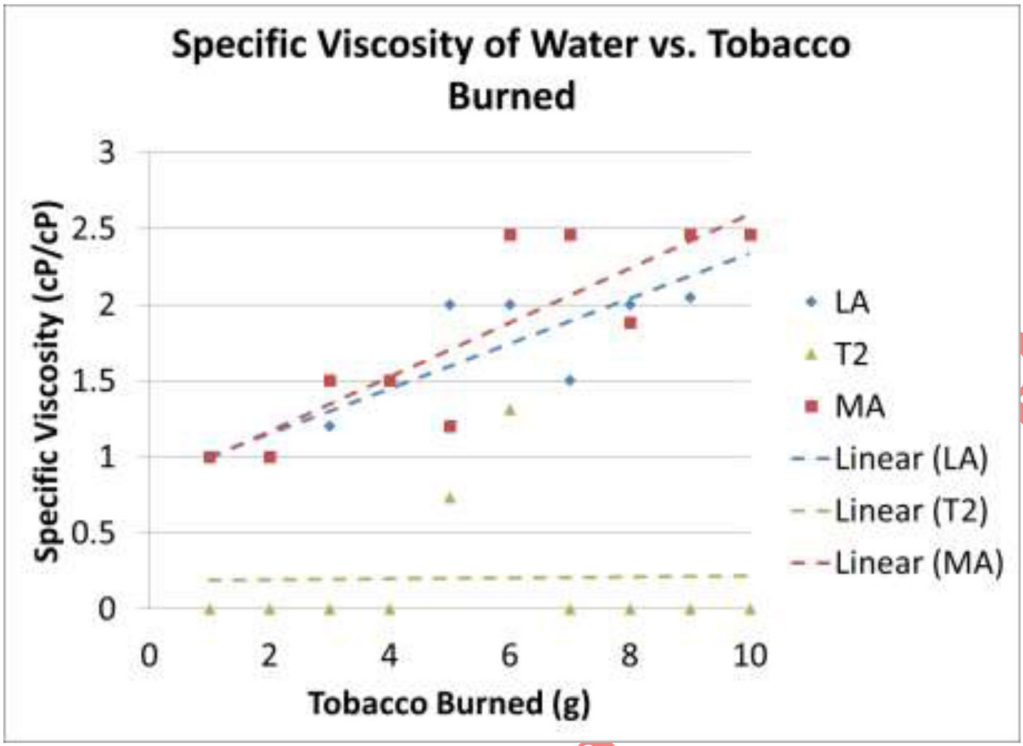

Figure 7: Graph plotting the specific viscosity vs. the amount of tobacco burned for all three devices.

2.3 Density/Specific Gravity

Density was measured using a precision scale and a micropipette. Specific gravity was calculated using the same distilled water used in the experiments as the base density. **Figure 8** shows the collected data from this portion of the testing. The MF model, again, showed inceased initial capacity to collect particles from the smoke passing thorught he water, although the LF model beginning at 5 grams surpassed the density of the MF device. **The T2 device had consistently lower density measurements than either of the fritted devices.** The LF device seemed to reach a maxima at 6 grams at a specific gravity of about 1.12 correlating well to the decrease in viscosity measured at the same point. A decrease in specific gravity was observed afterwards indicating particle precipitation from the water. Data is given in **Table 4**.

Table 4: Specific gravity data collected during the course of the experiment for all three devices.

Measurement	Tobacco Burned (g)										
	Device	1	2	3	4	5	6	7	8	9	10
Viscosity	LF	0.959	1.010	1.010	1.051	1.051	1.122	1.092	1.092	1.071	1.071
	MF	1.020	1.041	1.051	1.041	1.051	1.051	1.051	1.041	1.051	1.061
	T2	0.980	0.990	0.990	0.990	1.000	0.990	0.990	1.031	1.020	1.031

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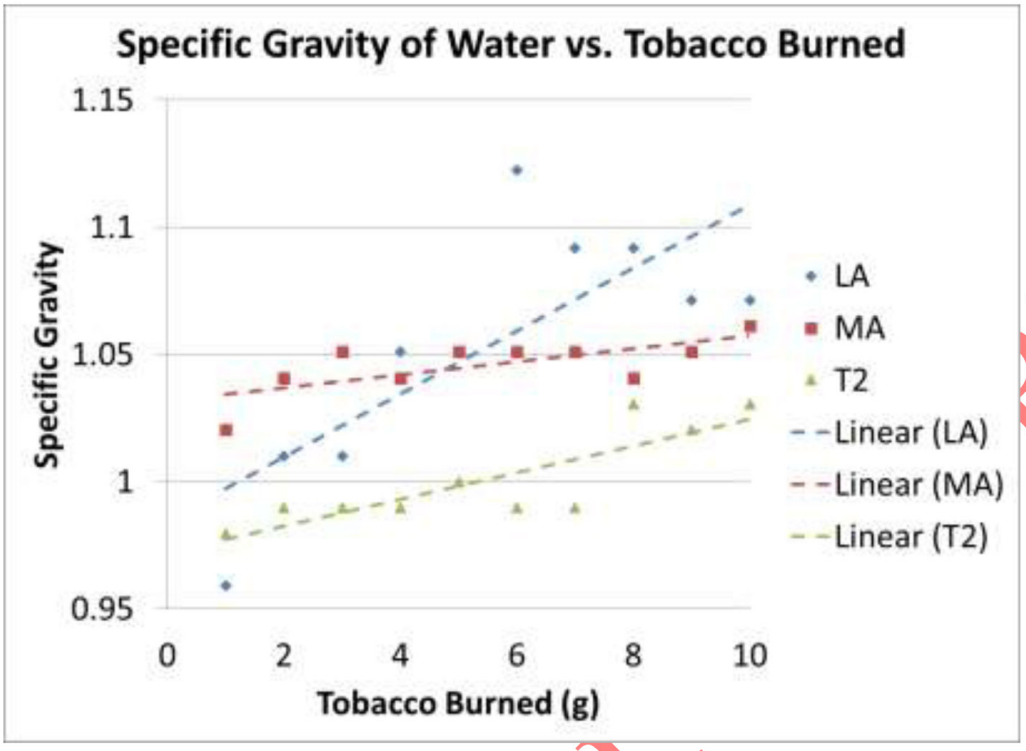

Figure 8: Graph plotting the specific gravity vs. the amount of tobacco burned for all three devices.

2.4 Turbidity

Turbidity measurements were taken using a LaMotte 2020e turbidity measurement system. Turbidity measured the cloudiness or haziness of the fluid in relation to small particle suspension. The data (**Figure 9**) is consistent with other data from this study showing a better initial capacity for the MF device to collect particles and the MF and LF devices significantly outperforming the T2 device. At about 5 grams, however, the MF device surpasses the LF device indicating a clear affinity for particle collection throughough the study. **Figure 10** shows photographs of the water solutions at specific time intervals. The differences in color intensity are noticeable between both devices containing the fritted glass and the standard device. **Overall results show that both of the fritted devices significantly outperform the standard T2 device in particle collection.** Data is given in **Table 5**.

Table 5: Corrected turbidity data collected during the experiment for all three devices.

Measurement	Tobacco Burned (g)										
	Device	1	2	3	4	5	6	7	8	9	10
Viscosity	LF	7.39	34.93	49.36	69.93	75.43	80.00	87.14	90.00	95.72	94.29
	MF	14.33	29.59	48.47	64.34	80.20	91.78	100.36	120.52	124.38	127.81
	T2	3.05	4.34	4.66	6.54	8.47	11.30	14.50	19.60	24.90	29.70

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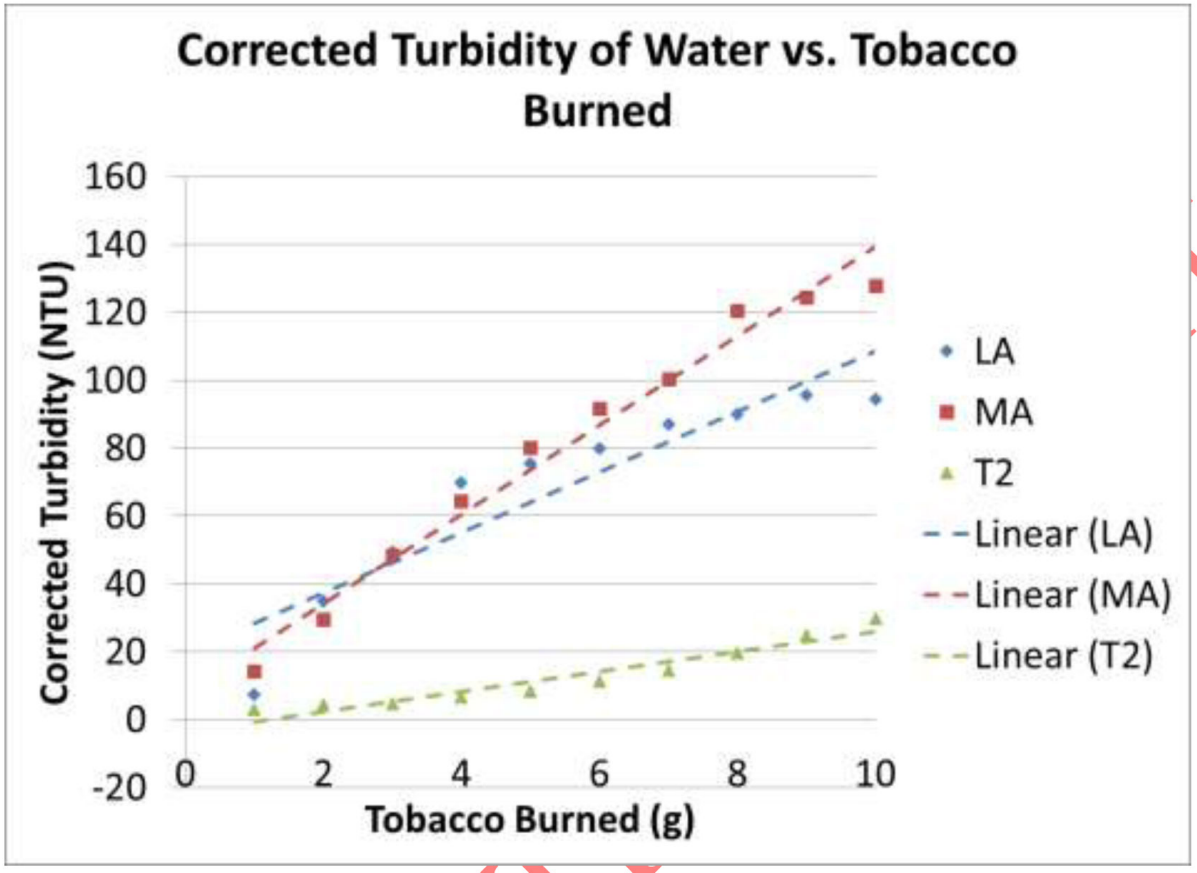

Figure 9: Graph plotting the corrected turbidity vs. the amount of tobacco burned for all three devices.

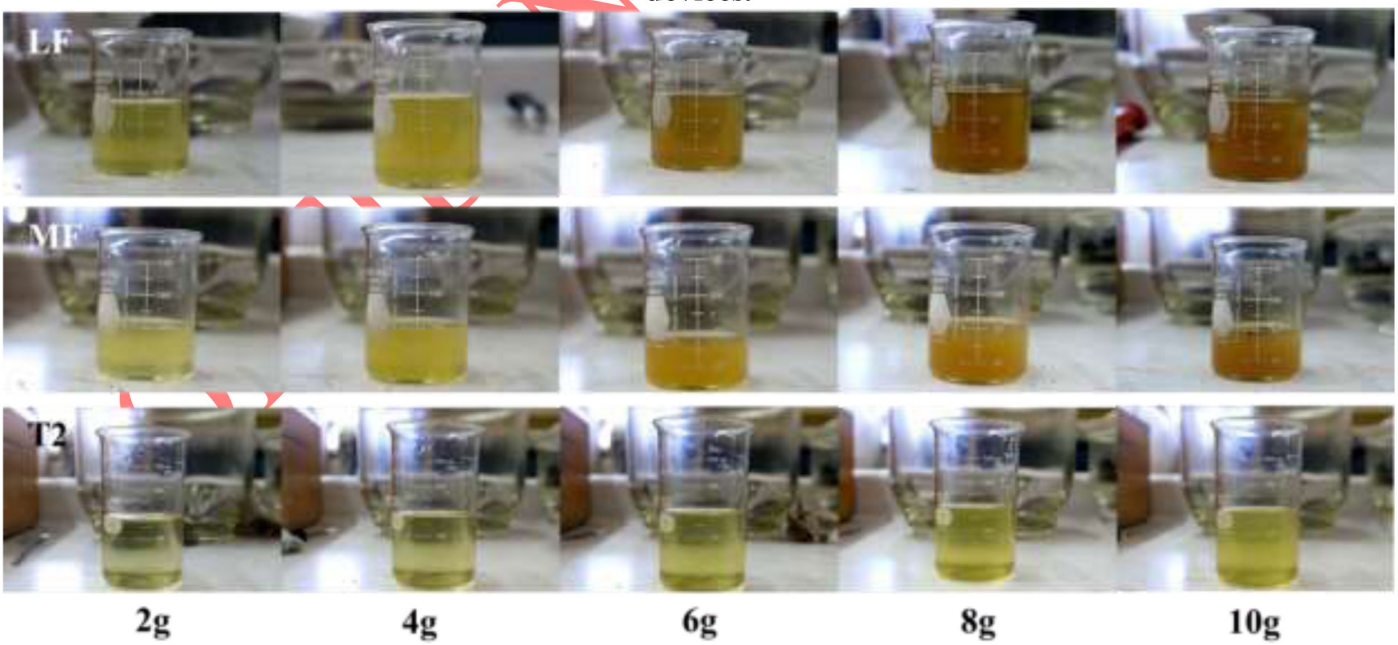

Figure 10: Photographs showing color change in water samples at 2g intervals for all 3 samples.

2.5 Carcinogen analysis

After all 10 grams had been burned, the water was collected and subjected to a standard carcinogen analysis test for poly aromatic hydrocarbons (PAH's). PAH's have long been known to be a primary concern as cancer causing agents, expecially as a result from partially combusted organic materials, such as tobacco. While PAH's are varied in composition, they all have low water solubility and have similar UV absorption properties. Because PAH's have poor solubility in water (see turbidity results), the water samples were thoroughly mixed before any samples were collected and measured to ensure a uniform suspension of PAH's and other tar particles in the solution. Samples were then diluted by 2x and a full UV-Vis spectrum was measured (**Figure 11**). As seen from the graph, data becomes saturated below 350 nm wavelength. This indicates a high level of PAH's, as this is the region where absorption peaks are common. A standard was chosen (p-naptholbenzein), where the saturation would not pose a significant problem. The absorption peak at 448nm was used as a basis for PAH concentration. The data collected is not inclusive of all PAH's, but should give a good estimate on the efficacy of the devices. Standard curve data is given in **Figure 12**. The standard curve had an excellent fit at R_2 = 0.9934, giving a high confidence for the data. Calculated data is given in **Table 6**. **The MF water had nearly 200% more PAH concentration than did the T2 and the LF had about 144% more than the T2.**

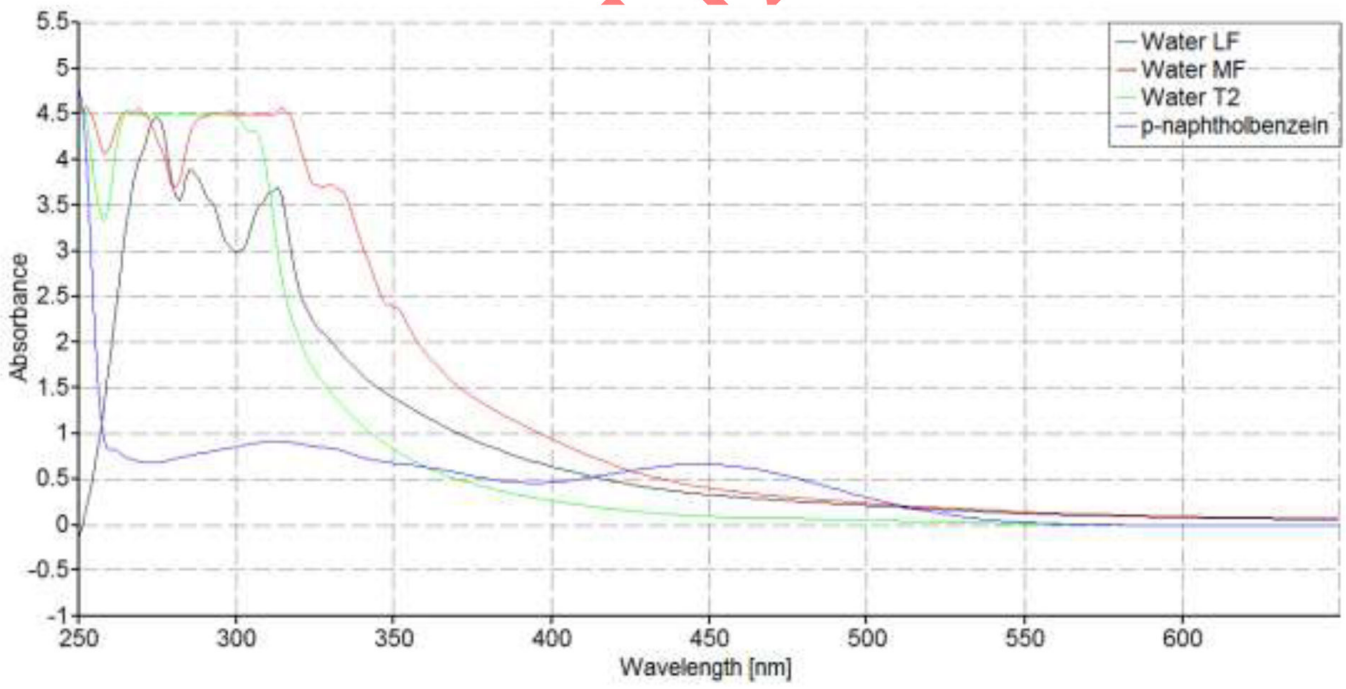

Figure 11: Absorption spectra of water from LF (black), MF (red), T2 (green) and the p-naptholbenzeine standard (blue).

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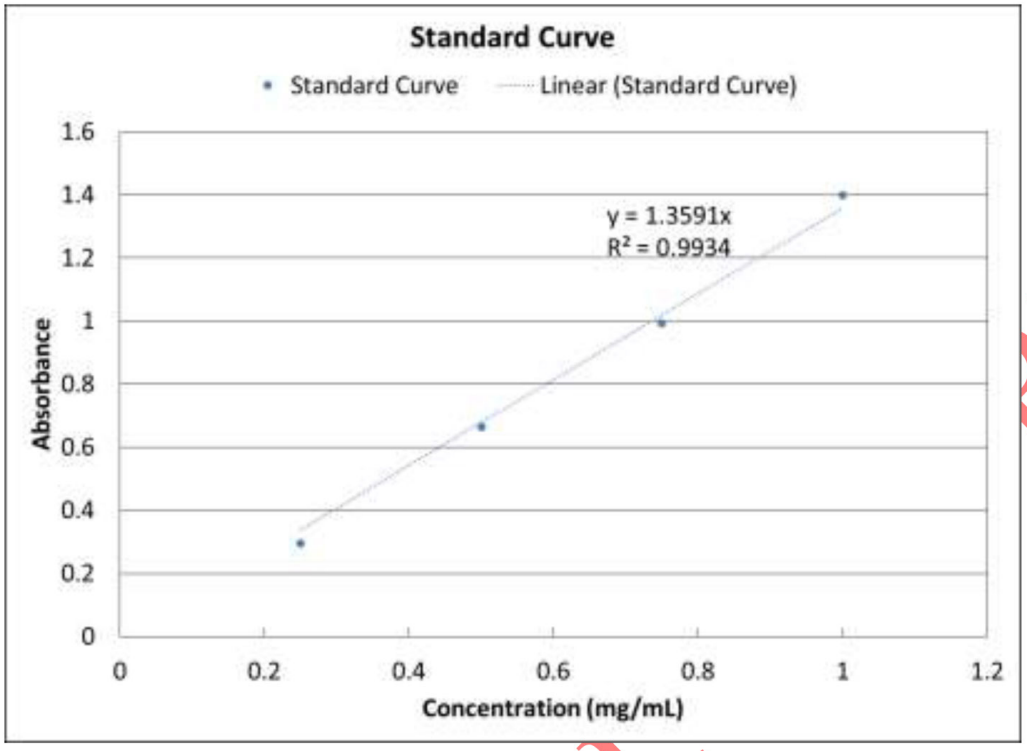


Figure 12: Standard curve and fitting data for the p-naphtolbenzein standard solutions prepared.

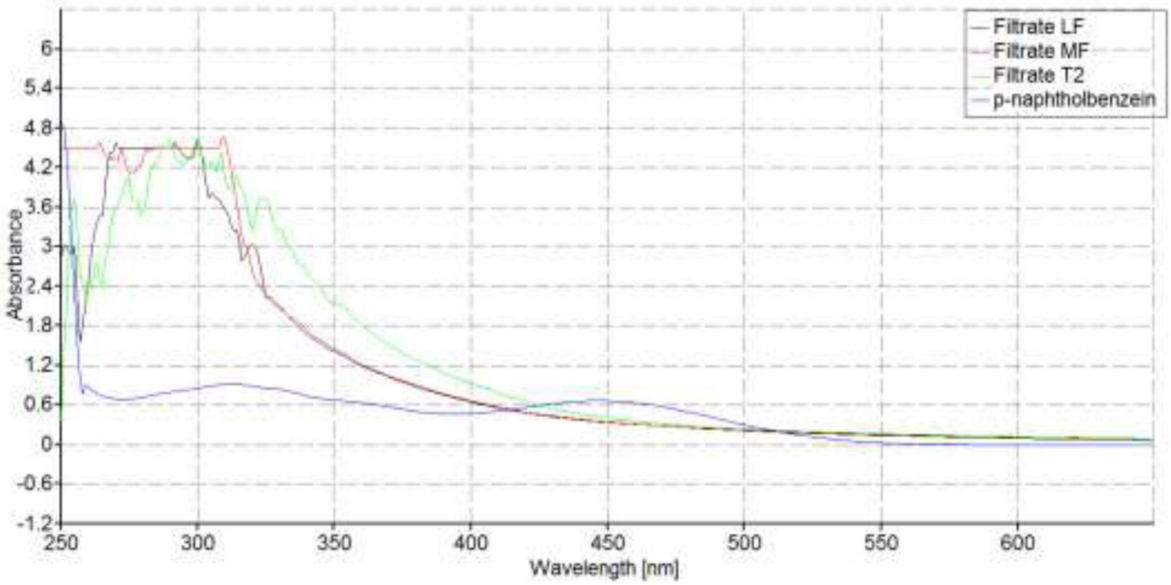
Table 6: PAH concentration data for water collected after 10 grams of tobacco burned.

Sample ID	PAH Concentration (mg/mL)	Percent Increase from T2
Water LF	0.5694	144.93%
Water MF	0.6752	190.43%
Water T2	0.2325	0.00%

3. Smoke Filtrate Analysis

The smoke leaving the devices was collected using quantitative filter paper. After the experiment, the filter paper was dried and weighed to determine the total smoke particles collected (**Table 7**). After weighing, the filters were placed in ethanol with stirring to dissolve the particles for absorbtion measurement. Specra were measured as in the same manner as the water (**Figure 13**). Concentration data are given in **Table 8**. The smoke collected from the MF device had the largest decrease in PAH concentration of about 10%, while the LF device had about a 5% decrease when compared to the T2 device. It is important to note that the PAH differences between the smoke collected and the water samples are due to inneficiencies in the ability to collect 100% of the particles from smoke and the

subsequent extraction process from the filter paper. While not a perfect measurement, the data still follows the same trend as seen with previous data. *It is also of significance to note that the T2 device was the only device in the study that had a higher concentration of particulate matter collected from the smoke than from the water, lending even more credence to the efficacy of the fritted glass pieces in the filtration process.*



b

Figure 13: Absorption spectra of filtrate from LF (black), MF (red), T2 (green) and the p-naptholbenzeine standard (blue).

Table 7: Weight data for particles collected in analytical filters.

Sample ID	Total Weight of Particles Collected (mg)	Percent Difference from T2
LF	727	-4.91%
MF	622.8	-18.53%
T2	764.5	n/a

Table 8: PAH concentration data for filtrate collected after 10 grams of tobacco burned.

Sample ID	PAH Concentration (mg/mL)	Percent Decrease From T2
Water LF	0.2917	-4.96%
Water MF	0.2766	-9.88%
Water T2	0.3069	0.00%

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Table 9 gives a summary of all of the data collected from this set of tests.

Table 9: Summary data for all experiments conducted on the LF, MF and T2 smoking devices.

Device	Measurement	Tobacco Burned (in g)									
		1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
LF	pH	7.40	7.43	7.76	7.96	7.95	7.75	7.68	7.84	7.92	7.96
	Specific Viscosity	1.00	1.00	1.20	1.50	2.00	2.00	1.50	2.00	2.05	2.46
	Specific Gravity	0.96	1.01	1.01	1.05	1.05	1.12	1.09	1.09	1.07	1.07
	Corrected Turbidity (NTU)	7.39	34.93	49.36	69.93	75.43	80.00	87.14	90.00	95.72	94.29
	PAH Conc. Water (mg/mL)	0.57									
	PAH Conc. Filtrate (mg/mL)	0.29									
	Total particles Collected (mg)	727									
	Measurement	Tobacco Burned (in g)									
MF		1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
	pH	7.45	7.16	6.88	9.03	8.25	8.25	8.26	8.01	8.33	8.33
	Specific Viscosity	1.00	1.00	1.50	1.50	1.20	2.46	2.46	1.88	2.46	2.46
	Specific Gravity	1.02	1.04	1.05	1.04	1.05	1.05	1.05	1.04	1.05	1.06
	Corrected Turbidity (NTU)	14.33	29.59	48.47	64.34	80.20	91.78	100.36	120.52	124.38	127.81
	PAH Conc. Water (mg/mL)	0.67									
	PAH Conc. Filtrate (mg/mL)	0.23									
	Total Particles Collected (mg)	622									
T2	Measurement	Tobacco Burned (in g)									
		1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
	pH	6.39	6.96	6.93	7.35	7.31	7.36	7.60	7.71	7.92	7.87
	Specific Viscosity	0.00	0.00	0.00	0.00	0.73	1.31	0.00	0.00	0.00	0.00
	Specific Gravity	0.98	0.99	0.99	0.99	1.00	0.99	0.99	1.03	1.02	1.03
	Corrected Turbidity (NTU)	3.05	4.34	4.66	6.54	8.47	11.30	14.50	19.60	24.90	29.70
	PAH Conc. Water (mg/mL)	0.23									
	PAH Conc. Filtrate (mg/mL)	0.31									
	Total Particles Collected (mg)	765									

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Conclusion

The smoking device with the medium frit measured the largest surface area to volume ratio of the bubbles in both stages and was found to have the best filtration properties. Following this trend, the piece with the large frit (second largest surface area to volume ratio of bubbles), also had increased filtration properties when compared to the T2 device that contained no fritted element. While the T2 device was able to filter some of the particulate mass from the smoke, it was concluded in all tests performed that the filtration efficacy was significantly less than that of the pieces with the fritted glass. In addition to the ability to filter particulate mass from the smoke, the devices including the fritted glass features were particularly effective in removing PAH's from the smoke, which are known to be carcinogenic, when compared to the standard T2 device.

The data in this report corresponds well with literature transport phenomena knowledge. Henry's law states that when a gas is in contact with the surface of a liquid, the amount of gas that will go into solution is proportional to the partial pressure of that gas. It is also known that the smaller the bubble greater the equilibrium pressure and higher contact surface area. So, in short, creating smaller bubbles maximizes the gas flux and results in better gas transfer between the media. The device tested seems to do just that.

Recommendation:

The collected waters should be analyzed for confirmation of the specific PAH species.

If you have any further questions, please do not hesitate to contact us.

Report Prepared by

Gary Fielding, PhD
Associate Sceintist
Mechanical & Materials Engineering

Repoert Released by

Business and Contracts
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authorized representatives may choose to use the results of this report at their own risk and have agreed to hold MEIC, its officers, employees, principals, stockholders (past, present and future) and their successors free of any responsibility whatsoever. Client further agrees to reimburse any damages and the cost/fees to defend that MEIC may incur if a lawsuit or damages are awarded against MEIC, hereunder any prevailing laws.

MEIC

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Project #: 8005008
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b. containing fritted glass pre-filter to prevent particulates from contaminating water sample. The
c. combustion device and pre-filters attach by ground joint to a coarse-fritted gas washing bottle with ~30 cc water in the bottom.
d. Tobacco smoke will be drawn by vacuum through the apparatus.

MEIC_8005008_PG-1.pdf

RoosterTestResults.pdf