Filter Paper Study

As part of PFE's commitment to continuous improvement of the plastic recycling industry, PFE looks closely at every aspect of the standards it performs. As part of this effort, PFE looked at a filtration standard for inks and adhesives and discovered an area of improvement. Currently, this water filtration standard calls for an 11-micron Whatman filter, and PFE suspects that a 10-micron, wet strengthened filter will perform better without affecting results. Between the filters there are two main differences, other than the intended application; the 10-micron filter has a significantly higher burst strength and shorter filtering time because it is designed for wet applications.

11-micron Filter Papers	10-micron Filter Papers
0.25 psi wet burst strength	2.6 psi wet burst strength
150 sec/100 mL speed*	80 sec/100 mL filtering speed*
Traditionally used with gases and soil	Traditionally used with liquids

***Herzberg filtration speed:** The time taken to filter 100 mL of water at 20°C through a filter area of 10 cm² at a constant pressure of a five-centimeter water column.*

When considering historical data PFE has produced, we can look at the time it takes tap water and control wash water to filter through the 11-micron filters. The control being the retained wash water from a standard PET wash of control PET bottle flake. When pulling the filtering time from multiple projects, we can see a large standard deviation. PFE believes this can be explained by the small perforations that can form in the filters, because they are not designed for a wet application.

Variable	Average Time (s)	Standard Deviation (s)	Standard Deviation (%)
Tap Water	53	23	43.40%
Control Water	225	102	45.52%

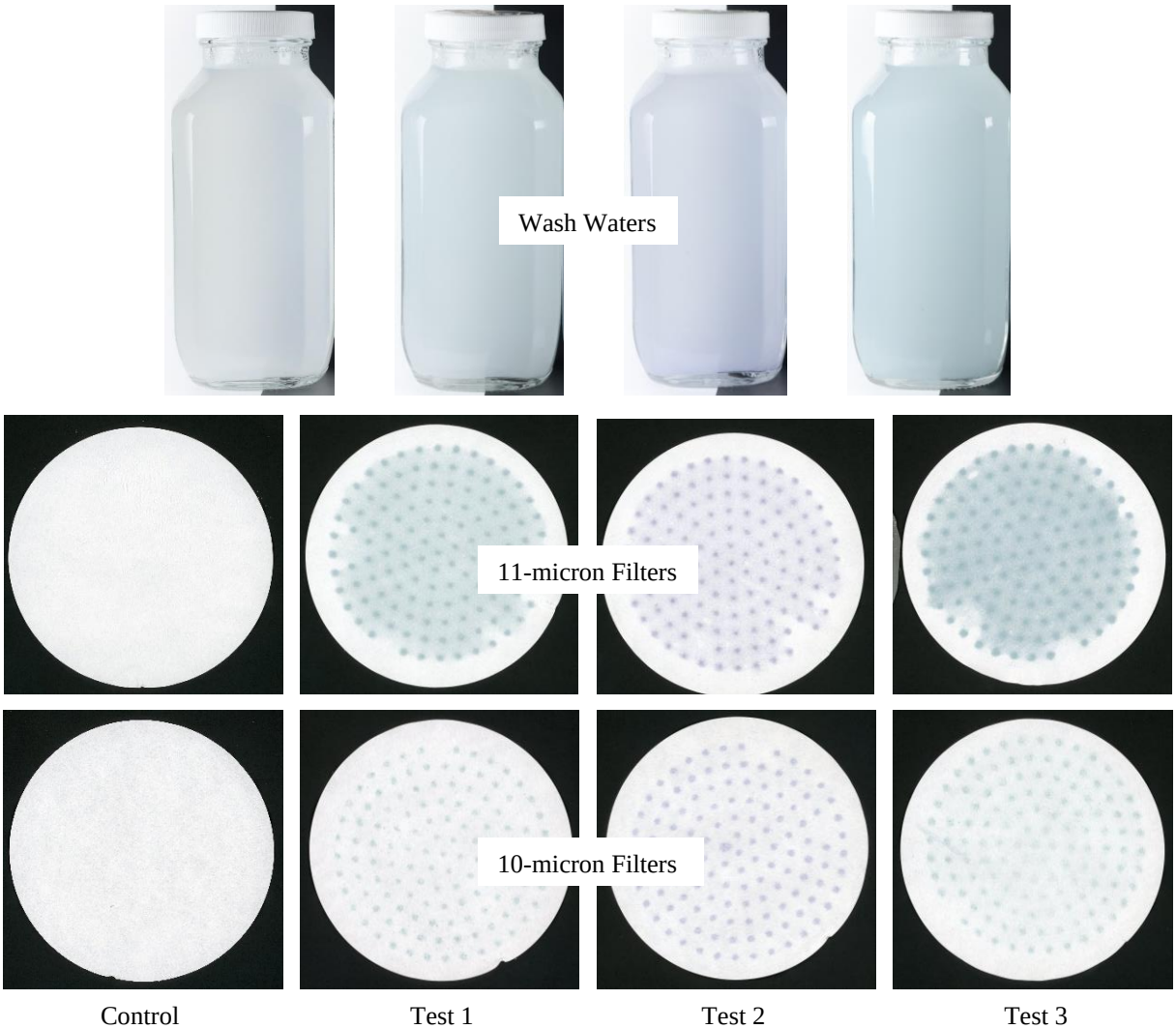
85 magnitude microscope image of filter paper.

To test that the newly proposed filters do not affect the water filtration results, PFE designed an experiment running tap water, control wash water, and test wash water through each filter. Once filtered, a color analysis can be done to find if there is a visible difference between the filtered water produced.

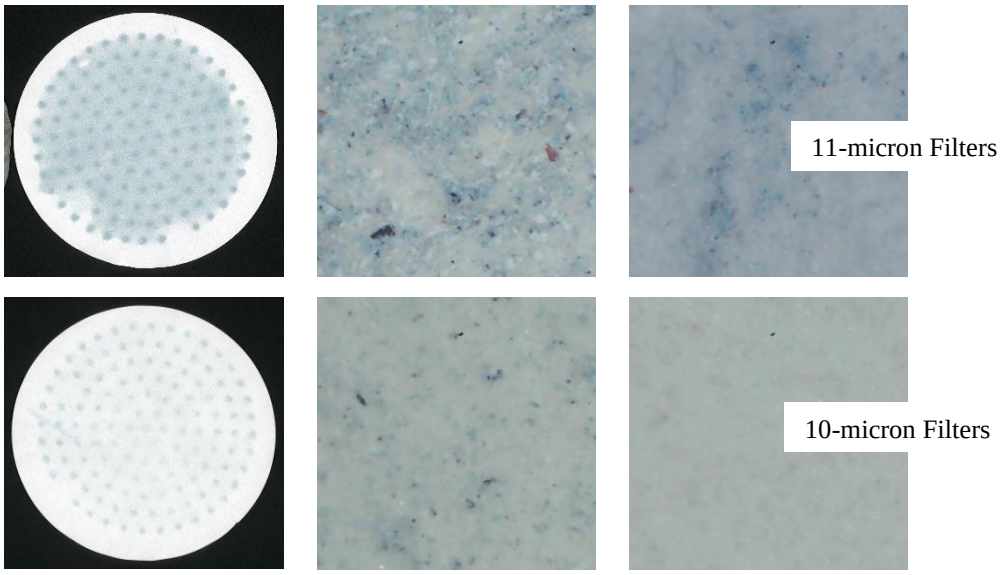
Starting with tap water, PFE found that the 10-micron, wet strengthened filter showed more consistent filtering times when processing tap water; this is shown by the lower standard deviation in the filter time results. PFE has also noticed that pre-wetting the filter with a small amount of tap water aids in the consistency of the results, as well as keeping the vacuum level at approximately 10 mmHg.

Variable	11-micron filter	10-micron filter
Average Filter Time (s)	289.04	208.04
Standard Deviation (%)	**18.63%**	**7.58%**

After comparing tap water filtering, PFE tested control and test waters from previous projects. PFE chose these materials specifically because there is a distinct color difference between all three variables and the control. The control is the retained wash water from control PET bottles and the tests consist of three different shrink sleeve labels blended with the control bottle flake. When we looked at the differences in the filters, we observed that the 11-micron filter appears to hold more of the colored material from the wash water.



Looking closer at the test 3 filter, PFE observed that the colored material is being pulled all the way through the filter media rather than just through the holes of the Buchner funnel. PFE believes this is happening because the filter is not designed for the application and the material is getting trapped underneath the filter media, rather than being pulled through.



Next, PFE decided to look at the color values of the filtered water produced from both types of filter papers. When looking at color values, we can look at the L*a*b* color space, which is a three-dimensional representation of a color's white and black, red and green, and blue and yellow values. Delta E* is a measure of the difference between two L*a*b* values (like the hypotenuse of a triangle). When considering delta E*, a value of less than 3.5 is considered undetectable by an inexperienced observer and is the value we will base the results.

PFE utilized a spectrophotometer to do this color testing. The spectrophotometer was set up in transmittance mode and calibrated using pure black and white standards. The filtered water was transferred into a new cuvette and loaded into the machine. Between each reading, the cuvette was emptied, and new water was transferred in. The results represent the average value of five color readings.

When comparing the average data from filtering the control, test 1 and test 2 waters, PFE found that there is no visible difference between the 10 and the 11-micron filters as the ΔE* is less than 3.5. When comparing the average data from filtering the test 3 waters, PFE did find that there is a visible difference between the 10 and the 11-micron filters as the ΔE* is greater than 3.5; however, both filtered waters would receive the same rating when using the water evaluation standard that this testing was based on.

	Control		Test 1		Test 2		Test 3	
Color Values	**11-micron filter**	**10-micron filter**	**11-micron filter**	**10-micron filter**	**11-micron filter**	**10-micron filter**	**11-micron filter**	**10-micron filter**
L*	38.30	38.33	37.61	35.09	36.13	33.64	34.12	28.68
a*	-0.08	-0.09	-0.03	-0.06	-0.21	-0.25	-0.08	-0.03
b*	-0.18	-0.11	-0.13	0.26	-0.70	-1.09	-0.27	0.03
ΔE	**0.09**		**2.55**		**2.53**		**5.45**	

Utilizing the observed results, PFE found the following to be true:

1. The wet strengthened filters provide much more consistent results than the number one Whatman filters currently used in common testing standards.
2. All filtered waters produced from the 10 and 11-micron filters would receive the same rating during current water evaluations for visual quality, meaning that this change would not cause major issues with past, future or current results of the water filtration standard.
3. The current Whatman filters allow for perforations that affect the filtering time and results significantly, the wet strengthened ones did not show this issue because they are better designed for the application.
4. On average, the 11-micron filter collected more material than the 10-micron; however, the color of the filtered water was not significantly affected.
5. Industry filtration would utilize a wet strengthened filter, meaning this change would better align with the currently used materials.