Switchgrass/Biochar Stormwater Filter Media

Figure 1: 8-inch Compost Filter Sock

Erosion and sediment control is an important part of construction site and infrastructure buildout activities. It's not just about building roads, bridges, and highways; it's also about doing it responsibly and protecting the environment. **Keeping mud from leaving the site matters.**

In the early 2000s, a new construction site perimeter control device called Compost Filter Sock (CFS or just filter sock) was introduced in the United States. As part of a green infrastructure movement, it offered great promise for improved sediment and pollution retention for construction activities. Early companies to offer such products were Filtrexx and FilterMitt. Later came Siltsock.net, Tuff Sock, Siltworm, e-Tube, and MKB Company.

In February 2008, at a meeting in Altoona, Pennsylvania, the PA DEP (Department of Environmental Protection) revealed some bold new thinking. "We like to see CFS" was gentle code for "we want to see CFS." Civil engineers across the state got the subtle message; **Pennsylvania has been a springboard to nationwide CFS acceptance.** Sixteen years later, CFS and variations such as switchgrass filter sock and rice hull filter sock are commonly used all over the US. Thank you, PA DEP, for that bold vision to help make the water a little cleaner.

Just how common is filter sock? Let's look at the numbers. We estimate that yearly at least 200,000 coiled pallets of filter sock are deployed in the United States for sediment and waterborne pollution retention during construction activities. That's about 20,000,000 linear feet – and this doesn't include blown-in sock or tubular straw wattles or excelsior logs. CFS usage is growing every year. At 2.5-3 cubic yards of "biomass as a filter media" per coiled pallet, this represents over 500,000 cubic yards of biomass. Bottom line – filter sock is now mainstream across much of the U.S. **But there is a problem...**

Compost Doesn't Mean Compost Anymore

Early on, the word "compost" in the name meant **land clearing and yard waste aged/turned according to specific methods while monitoring time and temperature to arrive at an optimal and "certified" compost product** (certified like the US Compost Council STA Program). *To a large degree, this process was to take "hard" cellulose and make "soft" cellulose that has a higher affinity to hold on to pollutants.* The problem was, there just wasn't enough certified compost to keep up with filter sock demand—no way, not even close. So, about a decade ago, the strict "certified" compost idea kind of fell to the wayside and average-Joe land clearing debris and yard waste were accepted. The early high-minded compost acceptance standards—certified, particle size, CO2 evolution, salt content, etc.—were relaxed.

Today, we see lots of "who knows" filter sock with lots of variety between producers—different feed stock, particle sizing, composting (or no composting) practices. It's hard to predict the field performance from one manufacturer to another, and from one day to another. At the same time, newer fill materials such as switchgrass and biochar offer an interesting path forward for filter sock—one beyond the original thinking of 20+ years ago.

Designing and Testing the Next Generation Filter Media – Char21™ SW

We decided to look for a way to get back on track with predictable filter sock performance. In mid-2023 we began a "high-minded" investigation. Could a "next gen" blended filter media be designed to take filter sock to Figure 1 – 18-inch Compost Filter Sock the next level of performance, one that leveraged all the knowledge and experience gained over the past 20 years? We think yes. First, we created a wish list for the new filter media, and we didn't pull any punches:

The Char21™ SW Filter Media – the Wish List

1. **Shelf Stability –** Most filter socks made today are not shelf stable – the fill will continue to break down while in the tubes, coiled up on a pallet in a warehouse. We want a fill where the socks could be made and warehoused months in advance with no nasty side effects during storage (like growing mushrooms). **We do not want compost, composted material, or compost particles.**
2. **Light Weight –** Most filter sock media is >500 lbs. per cubic yard. A typical coiled pallet could easily weigh 1500 pounds and is often quite the challenge for installers to handle. We want filter media at more like 300 lb. per cubic yard, or about 850 lbs. per coiled pallet. We can coil more on a pallet, and it's just easier for the installers in the field to handle.
3. **Consistency –** Land clearing debris can vary greatly from day to day at the same filling factory – types of wood, grind/chip, age, moisture, etc. can all vary and lead to unpredictable sock performance in the field. We want a recipe that can be assembled with little product variation – day after day.
4. **Decommissioning –** An original promise of using certified compost was that at the end of the construction activities, the compost could be left on-site and spread as a soil amendment. Today's reality – a lot of the land clearing debris filter sock is required to be completely removed from the jobsite because too much "woody" debris inhibits revegetation. *It usually costs more to remove the product than it did to install it.* This problem is (in part) what gave rise to using switchgrass and rice hull fill, which are much more restoration-friendly.
5. **Silt and Pollution Retention –** We wanted a filter media that could go beyond sediment retention and could clearly demonstrate an affinity for other pollutants in the stormwater such as hydrocarbons, cadmium, and chromium (to name a few).
6. **Longevity –** We wanted filter media to still be effectively performing in the field at 12 months and beyond. Lightweight cellulose, like straw, won't hold up that long.
7. **Common Materials and Meeting Scale –** We need readily available materials at an industrial scale – nothing too specialized and difficult to get.
8. **Biodegradable Netting –** The filter sock industry has been trying to move to biodegradable netting for a good while – both cotton and lyocell netting are available but haven't really caught on. Heck, over 20 years ago the original filter sock netting from John Engwer at FilterMitt was (and we think still is) biodegradable burlap. The problem is the 500 lb. per cubic yard filter media sock needs plastic to hold together because it's just so heavy. Also, wood chips can have sharp edges and be a bit acidic, which can quickly break down the biodegradable netting, usually too quickly. We don't think the netting is the problem; we think the filter media is the problem. The bio-net bogey – filter media at 300 lbs. per cubic yard, no sharp edges, and pH neutral.

That's a lot of wish list (nobody said this would be easy).

Shelve stable, light weight, consistent, a true "grass-growing" soil amendment at decommissioning, awesome pollution and sediment retention, last at least a year, cost effective, and actually works with biodegradable netting.

The first thing we realized is that no one material will do everything we want. We need to blend together several effective materials and take a **"broad spectrum" pollution retention approach.** After much investigation, here are the best four materials (we think) to bring together - drum roll please:

CHOPPED SWITCHGRASS

The choice for the bulk soft-cellulose component was an obvious one – un-composted chopped switchgrass. Tens of thousands of tons of this biomass are grown every year in Pennsylvania, nearby states, and nearby Canadian provinces. Switchgrass filter sock (like MKB Company's SwitchSoxx) has been in the US market since 2017, and millions of linear feet have been installed and decommissioned on construction sites (personally, we have plenty of experience making switchgrass filter sock). For sure, we are going to start with switchgrass. **But what is switchgrass?**

Switchgrass is a deep-rooted native perennial that can grow over 8 feet tall. Once a switchgrass stand is established, it can survive for 10-20 years with just a little care and feeding. It is often grown on marginal farmlands via the USDA's Conservation Reserve Enhancement Program (CREP). In the last few decades, switchgrass was also planted as a promising way to produce bioenergy from farmland, but that concept has not really materialized (our observation) on a large scale. Switchgrass is typically harvested into bales just like straw.

Figure 2: Chopped un-composted switchgrass

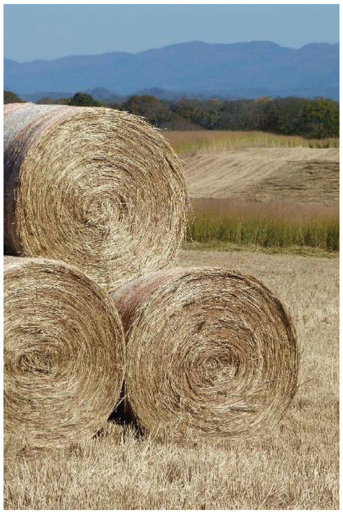

Figure 3: Photo of switchgrass harvest in East Tennessee by P. McDaniels, courtesy UTIA

Lots of university studies have been done on switchgrass – bioenergy, carbon sequestration in the extensive root structure, and something called "phytoremediation" – another promising technology using living plants to clean up soil, air, and water that have been contaminated with things like heavy metals.

But let's not be confused – we are not planting switchgrass to remove pollutants from soil. We're chopping up harvested bales of switchgrass, mixing in inert additives that show pollution affinity, and running simulated polluted stormwater through that mixture.

BIOCHAR

Meanwhile, in a far-off galaxy and seemingly unrelated... biochar production in the United States is growing, and upstart manufacturers have been patiently waiting for demand to increase. They're just missing one thing – THE KILLER APP! Biochar needs to find its place in large-scale applications – to date, no large-scale usage momentum has emerged, just several smaller initiatives using a bit of biochar here and there, once in a while.

Figure 4: Metzler large chunk biochar

Let's be honest, the biochar manufacturers NEED a large-scale application to justify the business case for manufacturing biochar in the first place. Otherwise, it's a solution looking for a problem, and that can be hard on the pocketbook. But hold on, ample studies, reports, and papers about the merits of biochar being used to remove pollution from stormwater have been published. A large body of evidence is out there (just go to Google and search "biochar" and "stormwater"). *We think putting biochar in stormwater filter socks just makes sense.*

But all biochar is not the same. We wanted a large chunk material (not a powdery, sugar-type consistency) made from hardwoods so the chunks would hold together better over time as part of the filter matrix. We also want an 80%+ carbon content—the higher the carbon content, the better. So, hardwoods, large biochar chunks, tested at 80%+ carbon content. Metzler Forest Products in Reedsville, PA, is making just such a material.

Biochar producers, pay attention right here—we believe we have found a meaningful large-scale application for biochar. And just like that, we have our second material.

RE-ACTIVATED CARBON

Wait, you meant activated carbon? No, you read it right – re-activated carbon. It's well known that activated carbon (also called active carbon or activated charcoal) has been around for a long time and is used in many applications related to water purification. What's less known is that "spent" activated carbon can be responsibly "reinvigorated" and brought back to 95% of the original effectiveness by re-baking it back at the production factory. The released pollution is captured during the re-activation process, and the material is ready to go again.

Figure 5: Large chunk biochar (top) next to re-activated carbon (bottom) in Char21 SW

An added benefit – re-activated carbon typically costs much less to buy and ship because it's a recycled product that ships from a regional recycling center, not the original production factory, which is often in another country. Re-activated carbon appears to be a good choice for our "broad spectrum" approach for pollutant affinity. We have our third material.

CALCIUM SILICATE AGGREGATE (CSA)

CSA is a processed/refined/cleaned version of "slag." What is slag? According to the Britannica Dictionary, slag is "the material that is left when rocks that contain metal are heated to get the metal out." It's a fine gray powder that is very inert and often used in Acid Mine Drainage (AMD) applications to increase pH and precipitate out metals. It's also been land-applied for **decades** on agricultural fields to improve crop yields because it's an excellent plant-available source of silicon.

Figure 6: CSA being added to Char21 SW

CSA is also being studied for an important emerging application – carbon sequestration. Our interest in including CSA is to **increase the pH of stormwater** and precipitate out heavy metals. It's cheap, readily available, and proven. We have our fourth and final material.

The Test – 20 Simulated Rain Events

We wanted to assess this filter media's ability to retain waterborne pollutants over 3 months and 20 simulated rain events. We did not focus on sediment retention—that work has already been studied for basic switchgrass filter sock via multiple ASTM 5141 examinations. It is already accepted that chopped switchgrass exhibits excellent and consistent hydraulic flow and sediment retention in the 5141 ASTM test. Again, switchgrass filter sock has been in the market at least since 2017, and its sediment handling is well understood. **We wanted to go beyond sediment.**

Several previous studies have used vertical tubes filled with filter media to study waterborne pollution retention while passing the polluted water vertically downward through the tube. The other option would be to make socks and pass water through horizontally. Although this approach mimics socks laying on the ground in the field, we think the vertical column test will more consistently reveal the trending effects of the filter media on waterborne pollution after each simulated rain event over multiple months.

The following pollutants were selected: Cadmium, Chromium, Copper, Zinc, Nickel, Lead, Ammonium-Nitrogen, Motor Oil, gasoline, and off-road red-dye diesel. We decided on the dosing rates (shown in the results table) of each pollutant and worked with the chemistry lab in Colorado to mix up 50 ml bottles with the right amount of concentration for all of the pollutants, except gasoline, diesel, and motor oil, which were locally sourced.

Figure 7: 6-inch diameter, 48-inch tall pipes filled with Char21 SW, with a mesh screen securing the media. Polluted water was poured in from the top, and filtered water exited the bottom. Two pipes were used per pollutant.

Figure 8: Pouring polluted water into tubes

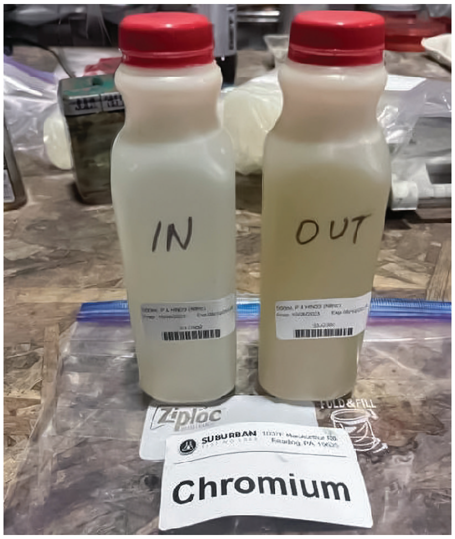

Figure 9 - Collected in/out rain event 20 Chromium sample heading to Suburban Lab

1. For each pollutant, two 6-inch diameter, 48-inch sections of N-12 smooth-wall pipe were filled to 36 inches with the Char21™ SW filter media. The media was not tamped down. A fine plastic mesh had previously been zip-tied to the bottom of each tube to retain the filter media but allow the water to pass through.
2. Pollutants were tested separately. We didn't want to get into the complexity of affinity competition between the pollutants.
3. Before any simulated rain events, we poured 15 liters of water through each tube to rinse and wet the filter media.
4. All water for the test was sourced from a public water tap at Metlzer Forest Products. The local water authority's recent test results were obtained and studied—no excesses or concerning amounts of foreign pollutants, pH, solids, etc., were found.
5. For each simulated rain event, 6 liters of water was spiked with 4.5 ml of the pollutant (provided by ERA Lab from Golden, CO). Three liters were poured through both tubes for each pollutant. For simulated rain events 1, 10, and 20, a small water sample was collected before pouring into the tubes. The outputs for each tube were poured together, and a single output sample was collected. Suburban Labs of Reading, PA, provided collection paperwork, bottles, labeled Ziploc bags, filters, etc.
6. The duration between simulated rain events was randomized—the interval could range from a few hours to a few weeks. Our thinking was to simulate a random interval. At each rain event, each pollutant was poured. The total testing duration for the 20 simulated rain events was 3 months.
7. We reached out to 5 different water testing labs to analyze our before and after samples at simulated rain events 1, 10, and 20. We picked Suburban Lab in Reading, PA—about a 90-minute drive away. Suburban Lab instructed us on how to collect the samples and provided all the necessary kits to do the work (bottles, jars, filters, labels, etc.). We did this for all pollutants except gasoline, diesel, and motor oil. For these pollutants, we estimated the capture affinity percentage by observing the output.
8. The Char21™ SW blend ratios were as follows: 20 5-gallon buckets of chopped, uncompressed switchgrass; 5 5-gallon buckets of large chunk hardwood Metzler biochar; 1 5-gallon bucket of re-activated carbon; and 1 5-gallon bucket of Calcium Silicate Aggregate. The pile was thoroughly mixed by hand before being put into the tubes.
9. 20 simulated rain events were conducted between the beginning of December 2023 and the end of February 2024.

Hypothesis

We thought the ability of the filter media to sequester these pollutants across 20 simulated rain events would diminish by varying degrees over the 3 months of testing.

Test Results

Pollutant	Target Dosing mg/L	RAIN 1 Input mg/L	RAIN 1 Output mg/L	RAIN 1 Change %	RAIN 10 Input mg/L	RAIN 10 Output mg/L	RAIN 10 Change %	RAIN 20 Input mg/L	RAIN 20 Output mg/L	RAIN 20 Change %
Cadmium	0.05	0.053	0.004	92%	0.034	0.006	82%	0.042	0.002	95%
Zinc	1	1.33	0.282	79%	0.682	0.15	78%	1.12	0.1	91%
Nickel	5	5.34	1.38	74%	3.94	1.33	66%	0.926	0.139	85%
Chromium	1	0.94	0.253	73%	0.68	0.283	58%	0.83	0.178	79%
Copper	1	1.08	0.407	62%	0.688	0.254	63%	0.926	0.139	85%
Ammonium-Nitrogen	9	8.18	3.98	51%	7.04	3.38	52%	10.3	2.48	76%
Lead	2	2.33	1.92	18%	1.36	0.967	29%	3.65	2.71	26%
Gasoline	10 ml	10 ml	<1 mL	>90%	10 ml	<1 mL	>97%	10 ml	<0.5 mL	>97%
Diesel	10 ml	10 ml	<1 mL	>90%	10 ml	<1 mL	>97%	10 ml	<0.5 mL	>97%
Motor Oil	10 ml	10 ml	<0.5 mL	>95%	10 ml	<0.5 mL	>97%	10 ml	<0.5 mL	>97%
pH		7.03	8.04	1.01	7.05	7.49	0.44	7.05	7.97	0.94

Discussion

Our hypothesis was simple and seemingly predictable— as the number of rain events increased, the filter media's ability to retain pollutants would decrease. Essentially, the classic "spent" thinking. Our hypothesis was **dead wrong.**

In the above table, you can see the affinity results were excellent and surprisingly high at the 20th simulated rain event. This ran counter to our hypothesis—that affinity would decrease over time, and the material would become spent. The opposite happened. **The filter media affinity was higher after 3 months and 20 simulated polluted rain events than it was on day 1.** To say we were surprised is an understatement. What is going on here?

We have a theory—the symphony of a broad-spectrum approach. We know that switchgrass decomposes slowly in nature. We also know that our other additives—biochar, re-activated carbon, and calcium silicate—will be most active early on and become spent over time. At the beginning of the test, the "non-decayed" switchgrass starts as a reasonably effective bio-reactive soft cellulose with good initial pollution affinity, which increases over time as it biodegrades. It goes from good to great over time. Conversely, the additives start with very high affinity in the beginning, then become spent as time progresses. The symphony of a broad-spectrum approach.
Wow. Didn't see that coming...

Observation of Char21™ SW after 3 months

At the end of the 3-month test, we waited 2 weeks and then emptied some of the tubes to inspect the material. The switchgrass had dried and changed from a bright, crisp yellow to a darker tan color.

The switchgrass was physically intact, but the canes were slightly easier to break than fresh switchgrass. The 3-month-old material appeared to be in the early stages of degradation. This aligns with our experience over the last 6 years with basic switchgrass filter sock—showing a functional longevity of at least 12 months (functional longevity being defined as the sock holding its shape, the netting holding together and, water passing through with sediment being stopped).

Figure 10: Freshly mixed Char21 before rain event 1

Figure 11: Char21 two weeks after rain event 20

Conculsions

1. Our hypothesis was wrong – Char21™ SW pollution affinity **increased** over time sequential rain events.
2. Char21™ SW meets all the items on the wish list. As a practical matter, shelf stability, lighter weight, consistent blend, and longevity are very important. Demonstrated pollution affinity and (finally) a +12-month fill that should allow natural netting to last longer – are compelling.

Final Thoughts

More testing can and should be done. How many rain events over how many months before the effectiveness declines? What is the best natural netting for Char21™ SW filter socks? What affinity does Char21™ SW have for other pollutants like PFAs? More to come.

E&S regulators and designing engineers must be willing to push through new products that demonstrate better environmental outcomes.

Char21™ SW appears to be one of them.

About the Authors

Mike Zock and Nelson Peachey have worked together in the erosion and sediment control industry for more than 15 years. In 2010, they started a small manufacturing company that efficiently filled palletized filter sock in a factory setting. Although no longer directly involved, Mike and Nelson are proud to be "originals" in what has now become MKB Company. MKB recently acquired both Filtrexx and Siltsock.net and is now a major nationwide manufacturer of filter sock, blanketing and other erosion and sediment control products.

Neither Mr. Zock nor Mr. Peachey received direct compensation for doing this testing. Mr. Peachey does farm switchgrass in central Pennsylvania.

Recognitions

Special thanks to Shawn Grushecky PhD, Associate Professor for Energy Land Management in the School of Natural Resources at West Virgina University. Dr. Grushecky was instrumental in coordinating project funding - this work is part of the MASBio (Mid-Atlantic Biomass Consortium for Value-Added Products) project which is supported by the Agriculture and Food Research Initiative Competitive Grant no. 2020-68012-31881 from the USDA National Institute of Food and Agriculture. We thank him for his patience and guidance during the entire process.

This test would not have been possible without the diligent efforts of Pat Sherren from Metzler Forest Products. Also, special thanks to John Campbell who runs the biochar production facility at Metzler Forest Products. John graciously allowed us to invade his production area, occasionally borrow his tools, and quite often, commandeer his water hoses. Also, a thank you goes out to Bob Onyshko from Harsco for supplying the CSA.

Appendix A –Pictures from Test

Figure 12: Chopped switchgrass approx. one inch long.

Figure 13: Large chunk hardwood biochar with +80% carbon content.

Figure 14: Switchgrass and biochar side-by-side before being blended.

Figure 15: Another biochar picture. Notice the consistency and lack of powdery material.

Figure 16: Re-activated carbon and CSA added before blending.

Figure 17: Blended Char21™ SW just before loading into tubes.

Figure 18: Closeup of blend – switchgrass, biochar, re-activated carbon, and CSA.

Figure 19: A closeup comparative view of the biochar and the re-activated carbon. The re-activated carbon is smaller and harder, the biochar is larger and softer. Both activated materials are used as part of a broad-spectrum affinity.

Figure 20: Measuring bulk density of the biochar. Since bucket weighs 2.2 lbs., the sampled biochar is about 9.5 lbs. per 5-gallon bucket. 41 buckets per cubic yard calculates to 389 lbs. per cubic yard.

Figure 21: Measuring the bulk density of the re-activated carbon. Removing the bucket weight leaves about 23 lbs. but the bucket is slightly underfilled. Filled we estimate the 5-gallon bucket at 24.5 lbs. of re-activated carbon or about 1,000 lbs. per cubic yard.

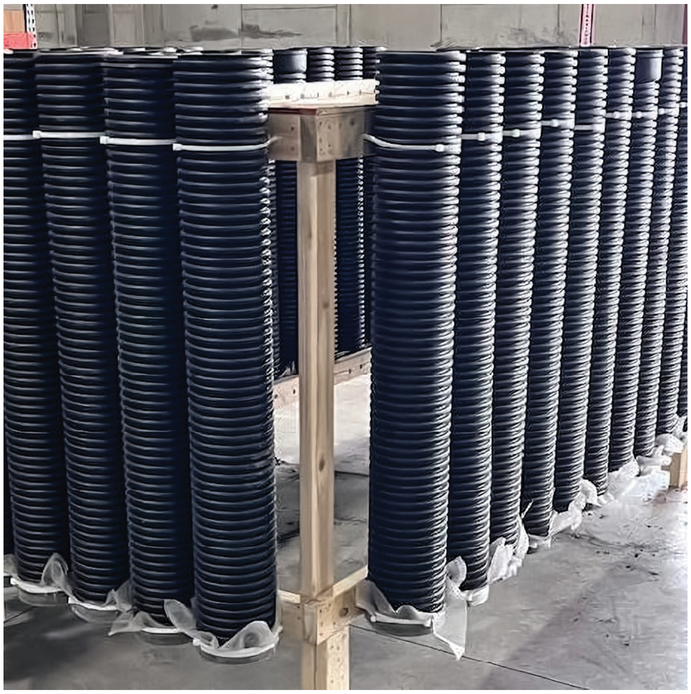

Figure 22: The vertical flow tubes. 48-inch long and 6-inch diameter N-12 smooth wall inside. Tube is filled with 36-inches of lightly compacted Char21™ SW with 12-inches open at top. A plastic mesh screen is zip-tied across the bottom of tube to allow water flow through but not Char21™ SW.

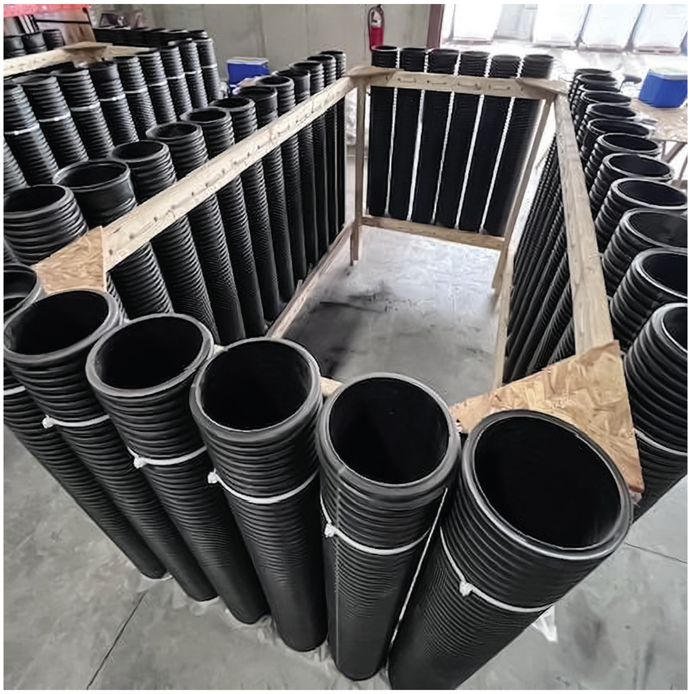

Figure 23: Two rigs are set up – each with 36 tubes available. Not all the tubes were used during this test.

Figure 24: Motor oil, gasoline, and red-die diesel being measured out before being added to water.

Figure 25: Stainless steel buckets were used to prepare 6 liters of polluted water per pollutant. The 50ml bottles from ERA Labs hold the pollutants. Buckets and funnels were rinsed between each pour.

Figure 26: Three 6-liter samples ready to pour. For each pollutant, 2 tubes were set up with 3 liters being poured through each one. On the sample collection days, a small input sample was taken before pouring with the remainder being split between the two tubes. Output water from the two tubes was combined and a sample for the lab was collected.

Figure 27: Lab tech pouring polluted water into top of vertical flow tube using stainless-steel bucket and stainless-steel funnel.

Figure 28: Another picture of lab tech pouring pollutant water. Notice that all vertical tubes in the test were labeled with blue painter's tape. Also notice the small white collection buckets at bottom of vertical flow tubes. Pouring the water into each tube took about 30 seconds. Early on in the test, the observed vertical flow time before water came out the bottom was about 30 seconds. This increased over time to about 40-45 seconds. We believed this was caused by the wetted filter media compressing over time.

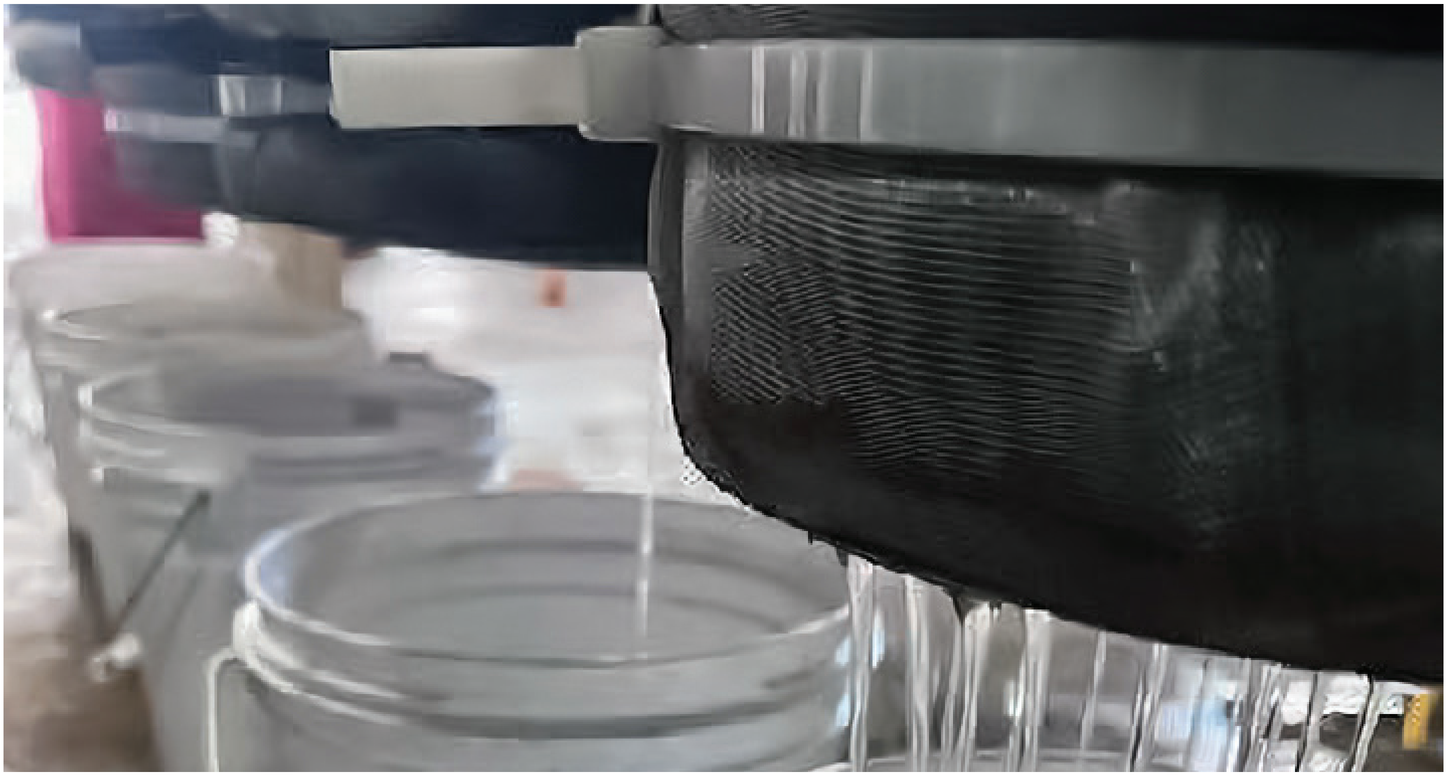

Figure 29: Water being collected at the bottom of each vertical flow tube. Notice the plastic mesh screen zip-tied across bottom of each tube.

Figure 30: For motor oil, diesel, and gasoline the 3 liters per tube were mixed and poured separately so each tube would get the right amount of pollutant in the water. This gave rise to this picture. On the right is motor oil and water ready for the second tube pour, and the bucket directly above it is the output from the first tube pour moments before – almost no oil showing. More interesting was the bucket to the right – red dye diesel set up for the second tube pour (water not yet added). Directly above it is the output from the first tube pour moments before – almost no red dye showing. We observed throughout the 20 simulated rain events – almost no hydrocarbons getting through.

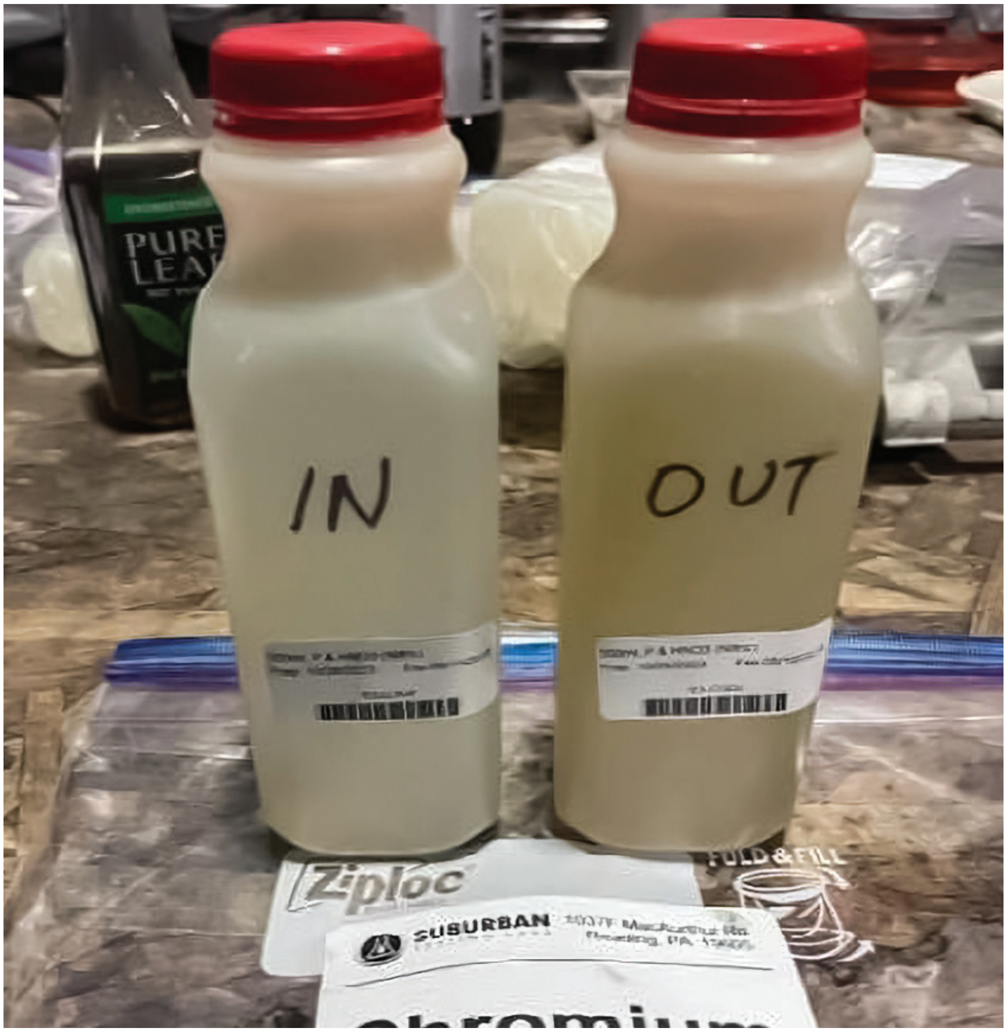

Figure 31: Bottles and labeled plastic baggy provided by Suburban Testing Labs for sample collection. This picture shows the input and output water sample for Chromium collected during rain event 10.

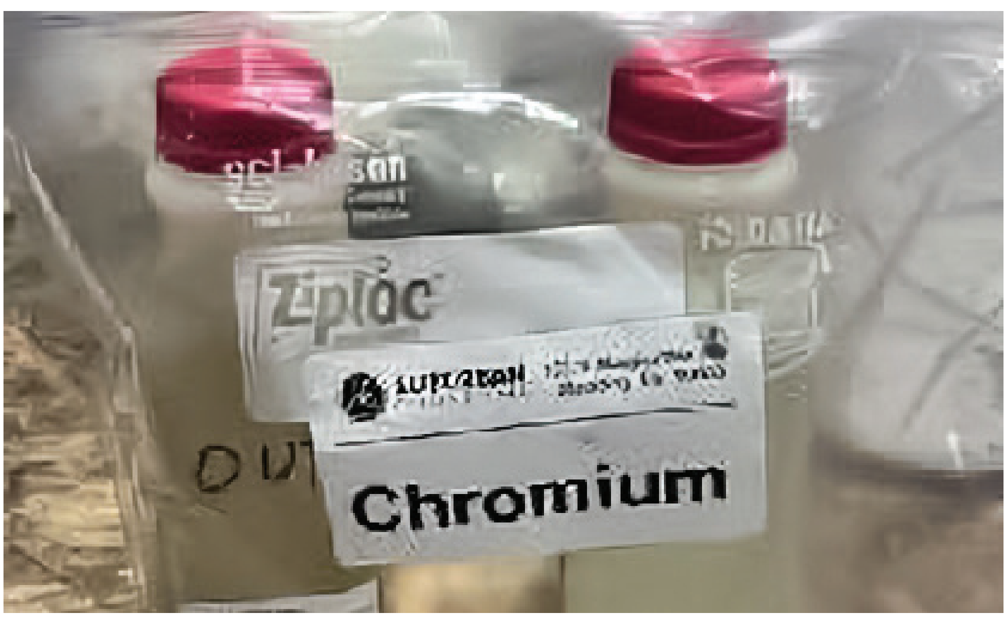

Figure 32: Same as Figure 31 with bottles in baggy. Notice the output water has a minor amount of color. We saw this for most of the output samples – a small amount of brownish color would come with the beginning output flow and then diminish. We think this was coming from both the switchgrass and the biochar. It was very minor.

Figure 33: Picture of Char21™ SW fill removed from a vertical tube after the 3 months and 20 rain events. Notice the dark color. We think the switchgrass is beginning to decay in the vertical tube and contributed to the increase of pollutant affinity we observed.

Figure 34: Dried sample of Char21™ SW removed from the vertical tube after 3 months and 20 rain events. Also shown are the 50 ml pollutant bottles used from ERA Lab. Also shown is a piece of switchgrass, a quarter, a piece of re-activated carbon, and a chunk of biochar.

Figure 35: Same as Figure 34. The filter media is quite dark, but nothing is falling apart. Our observation is the media pollution affinity has not begun to diminish.