PROGRESS REPORT

PROJECT TITLE: **Field applicable agricultural surface runoff treatment via activated carbon filters**
PROJECT NUMBER:**0000000036**
REPORTING PERIOD: **Second quarterly report with due date of Friday, September 29, 2023.**
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1.) PROJECT ACTIVITIES COMPLETED DURING THE REPORTING PERIOD. (*Describe project progress specific to goals, objectives, and deliverables identified in the project workplan.*)
Project group worked on Tasks 4, and, 5 during the second quarter of the project duration.

Tasks 4: Testing the filter performance in lab

As mentioned in the first two quarterly reports, we considered different designs for the prototype of the field filter. Main objective is to provide as high volumetric flowrate as possible with the maximum excess nutrient treatment. To be able to achieve the goal, we came up with the design proposed in the previous quarterly report. We are currently using a 2-inch diameter filter as a prototype with an inline static mixer to mix the proposed treatment agent, a 12-inches long sand filter and a membrane filter. Please see the Figure 1 for the prototype. The proposed treatment agent is Powdered Activated Carbon (PAC). Activated Carbon is frequently used in drinking water treatment, usually in the granular form. However, for a faster treatment, a larger surface area is required. This can be provided by the powdered format. The only impractical aspect of PACs that they will require filtration after the treatment. The combination of sand and membrane filters achieve the filtering post treatment

Figure 1. Prototype of field filter.

To be able to measure the treatment efficiency of the proposed design, we conducted a series of experiments for Task 4. In the previous quarterly report, we shared the results of the experiments conducted with standard solutions of phosphate (TP) and nitrate (TN). For these experiments influent (water to be treated) were prepared by mixing deionized (DI) water with known concentrations of phosphate and nitrate for separate Total Phosphate (TP) treatment and Total Nitrate (TN) treatment experiments. Using 0.1 g/L concentration of PAC added to the system as the treatment agent, we could observe treatment efficiencies up to 97% and 57% for TP and TN, respectively.

Next, we conducted experiments with influents created by mixing top soil with water. Top soil experiments are more challenging due to external factors that may affect the treatment and/or accurate concentration measurement such as turbidity, pH, existence of other chemicals, and the like. We created our influent by mixing top soil that is sieved to have only particles smaller than 0.85 mm (for consistency) at a 10 g/L rate. This influent has higher turbidity, total suspended solid (TSS), TP and TN concentrations than what we usually have in drainage water. With 0.1 g/L PAC mixed via inline static mixer, for short experiments (< 20 minutes) the treatment efficiency of the filter was 67% and 52% for TN and TP, respectively.

Out next task was to measure the volumetric flowrate of the filter. This aspect of the filter will require an improvement in the future. While we still do not need a reservoir and a long mixing time, our filter is still working slower than we would like. Through a series of laboratory experiments (please see Table1) we found that the flow capacity of the 2-inch filter is 4.06 Gallon per hour. This capacity can be increased using a pressurized flow via a simple pump operated closed system, and/or a larger filter.

Table 1. Volumetric flow rate capacities of the different components of the filter and the filter (combined)

	Volumetric flowrate (in CFS)	Volumetric flowrate (in GPH)
In-line static mixer	4.14×10^{-4}	11.15
Sand filter (12 inches)	6.83×10^{-5}	1.83
Membrane filter	4.71×10^{-4}	12.68
Combination	1.51×10^{-4}	4.06

To be able to get the filter to the desired level of operation, we wanted to test its performance in long experiments. To be able to perform long experiments, first, we formulated and tested a practical way of supplying the PAC continuously at the selected concentration. The PAC solutions were supplied to the influent container right before the solution is supplied to the in-line mixer at a constant rate via a peristaltic pump. For our experiments, the peristaltic pump was operated at 1.4 GPH. While using a pump that is operated via electricity is not the ideal solution for site application, a simple battery-operated pump or a sustainable energy source (such as solar or wind) can solve the electricity problem for on-site applications.

We also wanted to test the performance of the filter via Turbidity treatment first. The reason for testing the turbidity first to determine whether the sand and membrane filters fail in short durations. Since the TN and TP experiments have high costs, we wanted to check the physical performance of the filter before testing for chemical treatment. Please see Figures 2 and 3. We conducted two long experiments over several days. First one lasted 570 minutes (Figure 1) and the second one lasted 370 minute. The influent was prepared using 10 grams of sieved topsoil per liter of DI water, as it was in other experiments. Due to the distribution of topsoil particle sizes, there was some variance in the supplied influent turbidity, which is expected. As provided in the figures, for both experiments the filter provided a consistent treatment at about 83% and 76% efficiencies, for Experiment I and Experiment II, respectively.

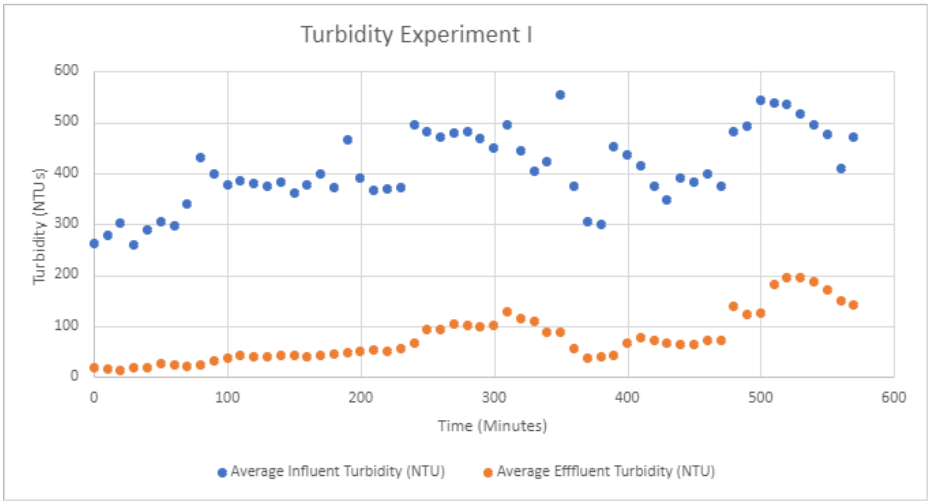

Figure 2. The data of Turbidity Experiment I (measured 01/2023)

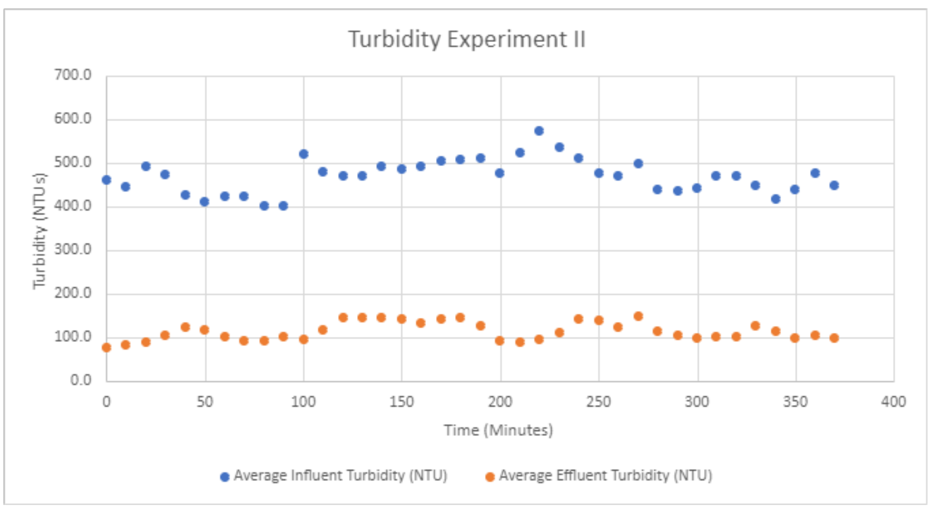

Figure 3. The data of Turbidity Experiment II (measured 02/2023)

The maintenance between the experiments were performed by simply dismembering the three parts of the filter, mixer, sand filter and membrane, and rinsing the parts with tap water. In our final report, we will describe the maintenance procedure in more detail under Task 6.

Final lab experiment that we will report in this document is the low PAC concentration treatment efficiency experiment. As it was explained in the first quarterly report, the activated carbons are usually used at much lower concentrations for treatments that take longer periods. To test our theory of decreasing the treatment time by increasing the concentration, we wanted to conduct two long experiments to test the treatment efficiency of TSS, TP and TN: one with lower PAC concentration (0.1 mg/L) and one with higher PAC concentration (0.1 g/L). The results of the first experiment are provided in Table 2 and Figures 4 – 6. As given Table 2 and Figure 4, the Turbidity treatment was at about 72% for the entire experiment and the effluent turbidity was at a constant level even though the influent turbidity fluctuated due to the TSS distribution of the topsoil suspension. Similarly, a consistent TP treatment was achieved at an average of 33% efficiency (Figure 6). One result that was not satisfactory was the TN treatment. Both its overall efficiency (only at 10%) and its fluctuations provided signs of low treatment for the entire duration of the experiment.

The data of the experiment performed with higher PAC concentration (0.1 g/L) along with the discussion on the comparison between performance observed in two experiments will be provided in the final report.

Table 3. The treatment efficiency of prototype with 0.1 mg/L PAC as treatment agent.

Time (minutes)	Turbidity Treatment Efficiency (%)	TN Treatment Efficiency (%)	TP Treatment Efficiency (%)
0	80%	25%	34%
10	76%	23%	31%
20	78%	8%	19%
30	79%	7%	32%
40	72%	-13%	26%
50	63%	-16%	27%
60	71%	4%	31%
70	75%	7%	36%
80	73%	15%	30%
90	65%	2%	40%
100	65%	1%	35%
110	65%	-3%	35%
120	64%	2%	48%
130	74%	25%	28%
140	75%	19%	25%
150	74%	23%	47%
160	70%	17%	33%
170	71%	3%	30%
180	80%	25%	34%
AVERAGE	**72%**	**10%**	**33%**

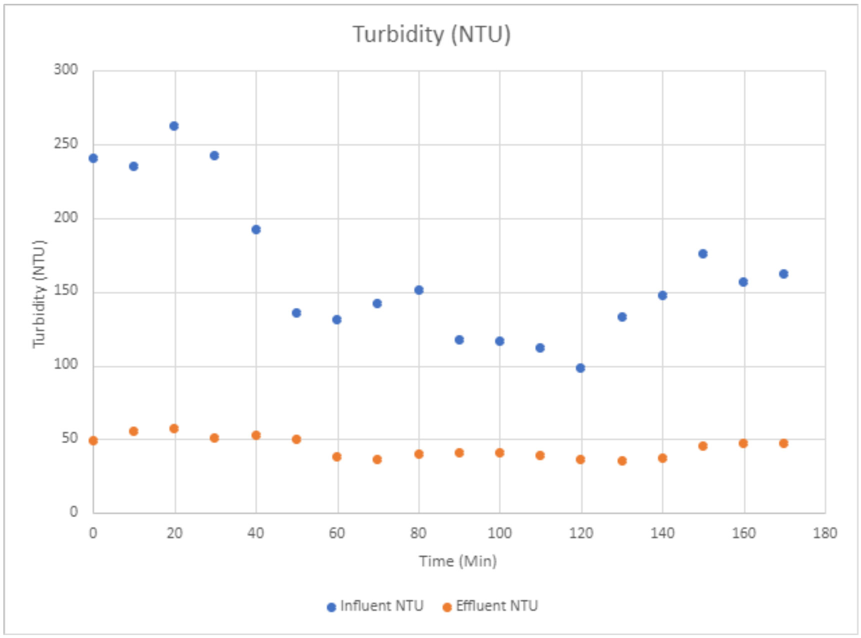

Figure 4. Turbidity treatment efficiency of the prototype filter with 0.1 mg/L PAC as treatment agent.

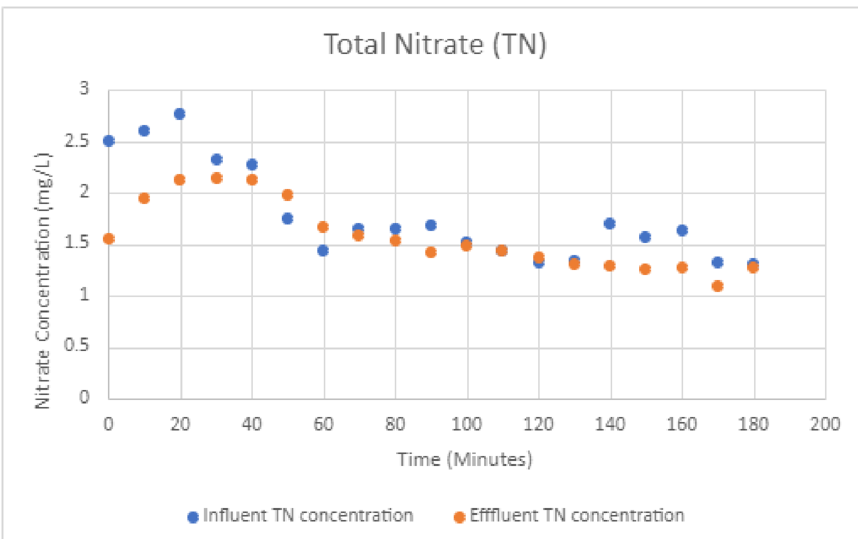

Figure 5. TN treatment efficiency of the prototype filter with 0.1 mg/L PAC as treatment agent.

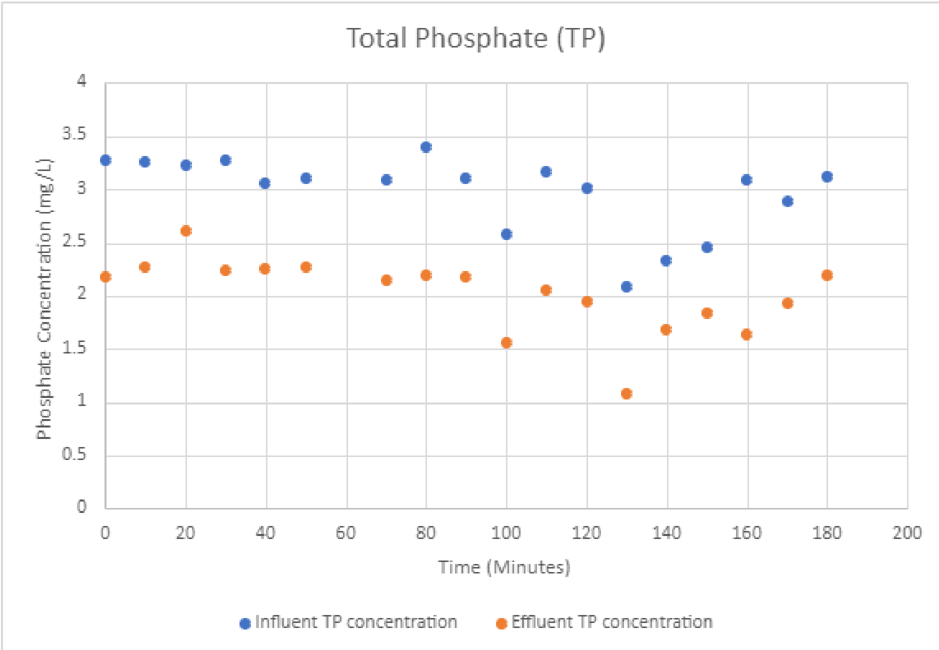

Figure 6. TP treatment efficiency of the prototype filter with 0.1 mg/L PAC as treatment agent.

Tasks 5: Testing the filter performance on site

We tested the performance of the filter on site with a short duration (70 minute) experiment with suggested high PAC (0.1 g/L) as treatment agent. Currently we do not have a developed automated system to provide the PAC to the influent consistently. For that reason, we manually provide the PAC solution to the influent using a syringe system. As a future work, we would love to develop an automated system to sustain the experiment in long runs.

Another note that we would like to provide is that the filter is designed to be placed in the drainage ditch bed (or next to it) along the flow direction. With this configuration, the influent will fill the intake of the filter manually and the effluent will be provided to the ditch as well. To be able to measure the inflow rate and the quality of the effluent accurately, we placed the filter out of the flow for these experiments. Please see Figure 7.

The data from the field experiment are provided in Table 4 and Figures 8 – 10. Overall performance of the filter was satisfactory for this short duration experiment. As given in the table and charts, the treatment during the experiment was consistent for all three indicators.

Figure 7. On-site measurement setup with project researchers Ms. Mounkoka F Goma and Mr. Derek Krumwiede

Table 4. The treatment efficiency of prototype on-site with 0.1 g/L PAC as treatment agent.

Time (m)	Turbidity Treatment (%)	TN Treatment (%)	TP Treatment (%)
0	67.8	21.3	-33.9
10	95.5	29.8	86.5
20	91.9	20.8	82.5
30	94.4	24.6	77.3
40	94.7	38.2	90.6
50	93.5	16.8	79.4
60	92.7	17.0	79.1
70	87.3	16.5	73.4
AVERAGE	**89.7**	**23.1**	**66.8**

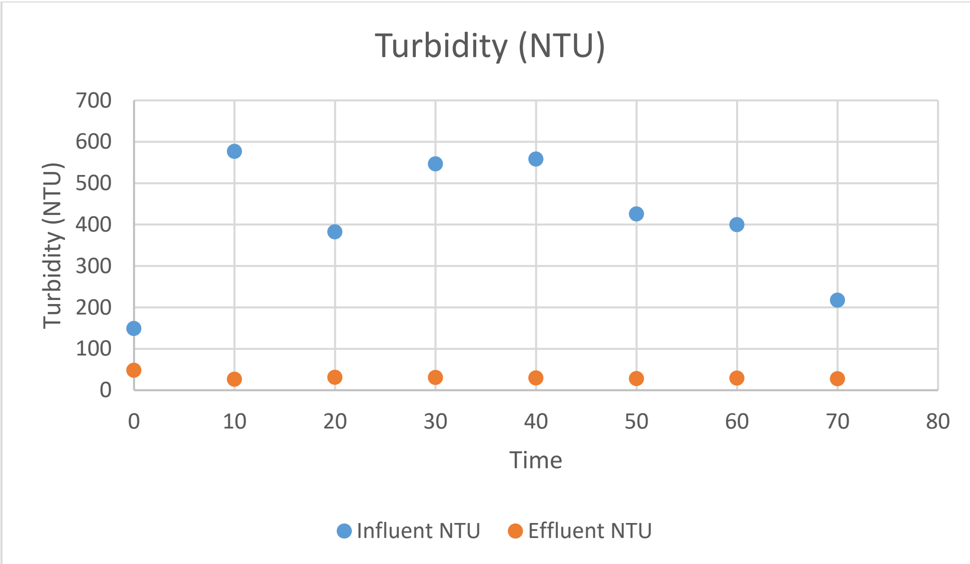

Figure 8. Turbidity treatment efficiency of the prototype filter on-site with 0.1 g/L PAC as treatment agent.

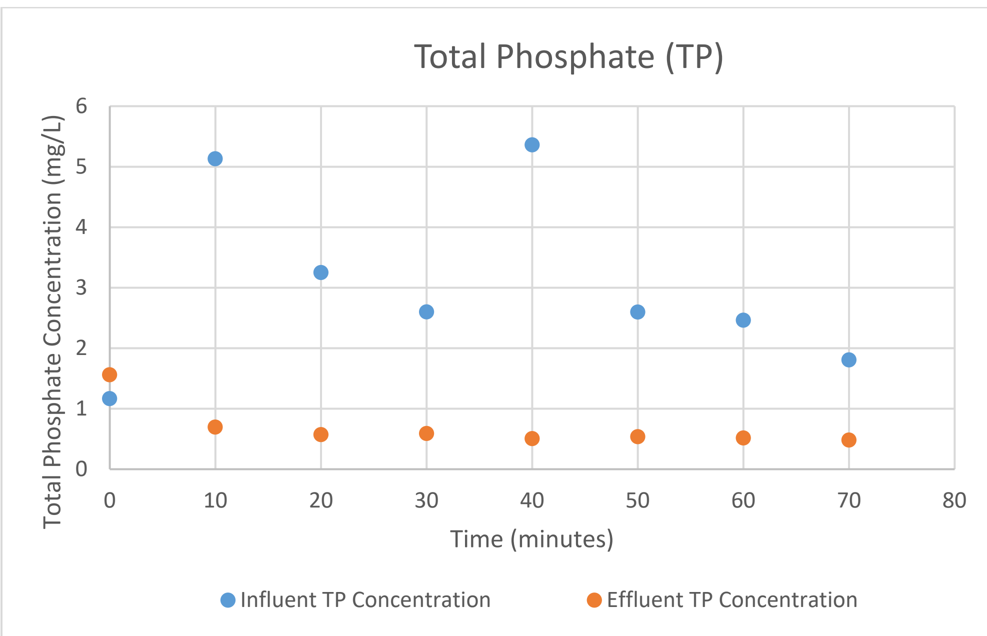

Figure 9. Total Phosphate (TP) treatment efficiency of the prototype filter on-site with 0.1 g/L PAC as treatment agent.

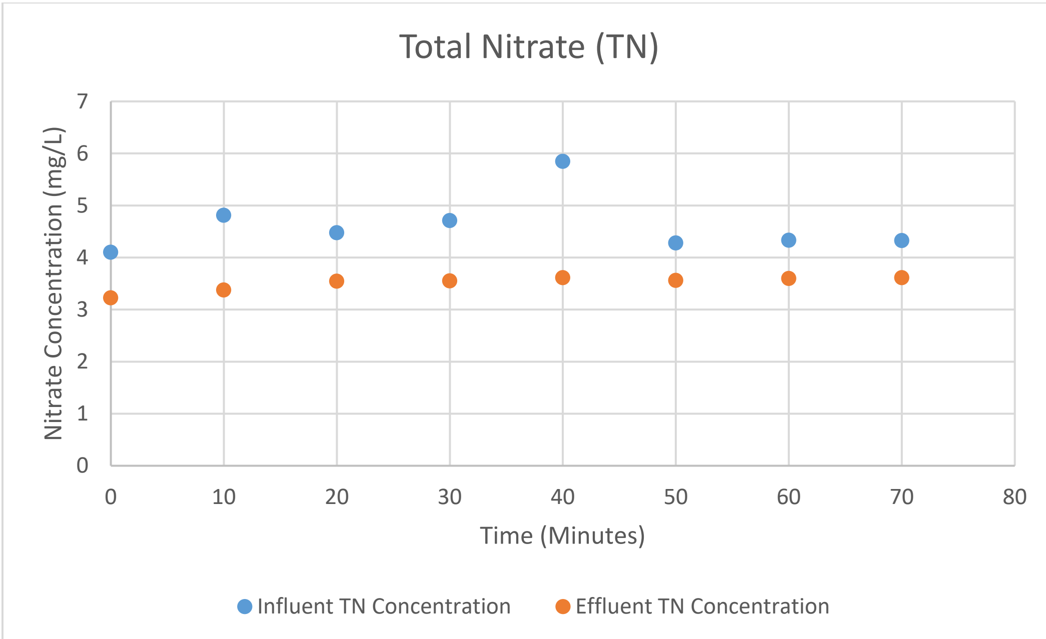

Figure 10. Total Nitrate (TN) treatment efficiency of the prototype filter on-site with 0.1 g/L PAC as treatment agent.

2.) IDENTIFY ANY SIGNIFICANT FINDINGS AND RESULTS OF THE PROJECT TO DATE.
The significant findings of the project during its first quarter are listed below. Please see the answers given to question 1 for the details.

- Testing prototype's treatment efficiency for TP and TN standards via short experiments.
- Testing prototype's treatment efficiency for turbidity, TP, and TN with topsoil solution as influent via short experiments.
- Testing prototype's treatment efficiency for turbidity with topsoil solution as influent via long experiments.
- Testing prototype's treatment efficiency for turbidity, TP, and TN with topsoil solution as influent via long experiments with low concentration treatment agent.
- Testing prototype's treatment efficiency for turbidity, TP, and TN with topsoil solution as influent via long experiments with high concentration treatment agent (*ongoing*).
- Testing prototype's treatment efficiency for turbidity, TP, and TN with natural runoff water as influent via short experiment with high concentration treatment agent.

3.) CHALLENGES ENCOUNTERED. (*Describe any challenges that you encountered related to project progress specific to goals, objectives, and deliverables identified in the project workplan.*)
I will echo the challenges that we encountered during the first two quarterly reports of the project. Our biggest problem was the delayed shipments and waiting times for common laboratory supplies that we use for this research. For instance, we had to change our experiment plans twice because of the delivery delays in TN and TP measurement vials.

As stated in the previous report, another challenge that we encountered was dry summers. Due to the dry summer of 2022, we had to request an extension to deliver the project because we could not test our filter on site. During the extension that was provided we could test the filter, however, we had to test it at a small stream, instead of an agricultural drainage ditch. While hydraulicly, there would not be any difference, we would love to test it at a ditch to have a better idea for TN, TP and turbidity levels of the influent.

4.) FINANCIAL INFORMATION (*Describe any budget challenges and provide specific reasons for deviations from the projected project spending.*)
No budget challenges are experienced thus far. The only expenses were for supplies and undergraduate researcher stipend.

5.) EDUCATION AND OUTREACH ACTIVITES. *(Describe any conferences, workshops, field days, etc attended, number of contacts at each event, and/or publications developed to disseminate project results.)*

The research hired three undergraduate students to work in laboratory and on site, Ms. Mounkoka F Goma, Mr. Juan Sanchez Cubillos, and Mr. Derek Krumwiede. All students enrolled to the safety training offered by Minnesota State University, Mankato. Along with this project, Mounkoka F. Goma and Juan Sanches Cubillos are currently worked on their individual research project that was proposed to Undergraduate Research Center of Minnesota State University, Mankato. Ms. Goma and Mr. Sanches Cubillos's project was inspired by this project and they worked on the mixing efficiencies of different 3D printed inline static mixers for water treatment. They presented their work at National Conference on Undergraduate Research 2023 (April 2023, Eau Claire, WI) and at Undergradaute Research Symposium (URS) at Minnesota State University Mankato (April 2023). For both presentations, our funded research was referred to. For this academic year, Mr. Krumwiede and Ms. Goma are working on another proposal submitted to Undergradaute Research Center of Minnesota State University, Mankato. Their project is also inspired by this proposal. If funded, they will work on manufacturing PAC bricks that will erode over time to replace the manual injection of the PAC for field applications.