MEMORANDUM

TO: Professor Adams
FROM: Mike Hennessy, Jack Manion, Jack Leon
DATE: October 2, 2021
SUBJECT: Water Filter

Introduction

The objective for this module was to be able to explain the processes used to treat drinking water, as well as being tasked with designing, building, and testing a filter to produce one liter of clean water. After demonstrating the filter's use and ability to produce "clean" water, consider and recommend improvements to the filter based on initial testing, and finally present all findings and work in a technical written memo and presentation

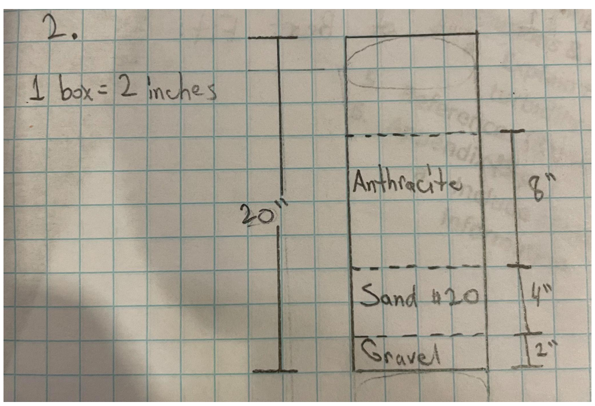
The problem was to design, build, and test a filter when given different media to choose from that will effectively clean a liter of dirty water. The filter must effectively clean one liter of water before ten minutes while using below twenty inches of media. This task is very significant to the fields of civil engineers, more specifically environmental engineers. They are tasked to ensure safe water, air quality, and solid waste management, and sustainable resource management. Civil engineers support the infrastructure needed for communities and ensure the health and safety of those communities.

The basic approach to the problem was to understand how different sizes of media affected the different sizes of contaminants that would have to be filtered out. Then, specific levels of each media were calculated to create the best overall filter that could handle all types of contaminants. After adding each of the specific media to the filter, be sure to repeatedly rinse to flush out all of the contaminants that were originally present. Then, backwash the filter to clean it of any possible contaminants that could be trapped in the filter. Now the filter is prepared to filter dirty water.

Filter Design and Methods

The initial filter design included three layers of media in a twenty inch height tube: two inches of gravel, four inches of sand #20, and eight inches of anthracite. The filter design constraints allotted for a total of twenty inches of filling, with four options of media: sand #20, sand #30, anthracite, and gravel. Gravel was chosen as the bottom layer because it is heavy and prevents clogging of the finer particles above it, so it provides a great base layer. Sand #20 was chosen as the next layer because it is more dense and finer than anthracite. The calculated effective size for the sand media was found to be .734 millimeters using the effective size of media equation (Kawamura, 2000), and the size of sand #20 was .40 millimeters while sand #30's size was .26 millimeters, so sand #20 was chosen as the most effective. Typical design data for dual-media filters shows a depth ratio of 2 inches anthracite to 1 inch of sand (Asano, 2007), so this ratio was used for the filter. The filter was filled no higher than fourteen inches in order to save room for water being flowed in.

In creating the filter, due to challenges measuring the exact depth of the media, the filter consisted of a 2.5 inch bottom layer of gravel, 4.63 inch middle layer of sand #20, and 8.88 inch top layer of anthracite. The anthracite was very dirty and fresh to begin with, so it contaminated the water significantly over the first few trials. The measurements of water coming out of the filter were hard to get exact because the water was being poured into a beaker and beakers are not ideal for measuring. A graduated cylinder would have been better to measure the water because it is more precise. No changes were to the filter due to time constraints.



Figures 1 and 2: The Initial Filter Design and the Initial Filter Prototype

Table 1: Measurements of Materials Used in Filter Design

	Mass (grams)	Depth (inches)
Anthracite	851	8.88
Sand #20	819	4.63
Gravel	454	2.50

Performance Results & Discussion

The results for Group 3's filter are given below in **Tables 2 and 3**.

	Trial 1	Trial 2	Trial 3	Trial 4
Time (sec)	52.89			
Measured Turbidity (NTU)	5.50	12.60	4.62	1.37
Calibrated Turbidity with Turbidimeter 1 (NTU)	5.82	12.86	4.95	1.73

	Trial 1	Trial 2	Trial 3
Time (sec)	49.8	52.8	
Measured Turbidity Before (NTU)	47.9	56.3	54.8
Calibrated Turbidity Before (NTU)	47.8	56.2	54.7
Measured Turbidity After (NTU)	41.4	49.8	44.8
Calibrated Turbidity After (NTU)	41.4	49.7	44.8

Tables 2 and 3: Results for Filtering a Liter of Tap Water (Above) and Dirty Water (Below)

While the filter is capable of filtering tap water, it does not succeed in filtering the dirty water. The filter does filter a liter of water extremely quickly due to a large amount of anthracite in the filter. A large amount of anthracite is also to blame for the ineffectiveness of the filter. If the filter had more sand than anthracite in it, it would be much more successful at filtering the dirty water; however, the time it would take to filter a liter of water would increase.

The longer a filter goes between backwashes, the more turbidity in filtered water due to remnant contaminants in the filter pores (Hendricks, 2006). The more trials that occurred, the slow increase of turbidity also occurred due to the contaminants of older trials.

Conclusion

While the filter was effective in tap water, the design failed when it came to the water mixed with fine clay. The height and general nature of the design of the filter were the roots of this failure. Thus, a filter designed specifically for fine particle filtering would be much more effective.

Recommendation

Group 3 recommends revising the filter in the following ways: use 30-sand instead of 20-sand, flip the ratio between anthracite and sand, and use a taller filter. This new design focuses on filtering fine particles from drinking water, which would make the filter much more effective at filtering the dirty water with fine clay.

References

Asano, Takashi, Franklin Burton, and Harold Leverenz. *Water reuse: issues, technologies, and applications*. McGraw-Hill Education, 2007.

Hendricks, David. *Fundamentals of water treatment unit processes: physical, chemical, and biological.* CrcPress, 2016.

Kawamura, Susumu. *Integrated design and operation of water treatment facilities.* John Wiley & Sons, 2000.

Appendix

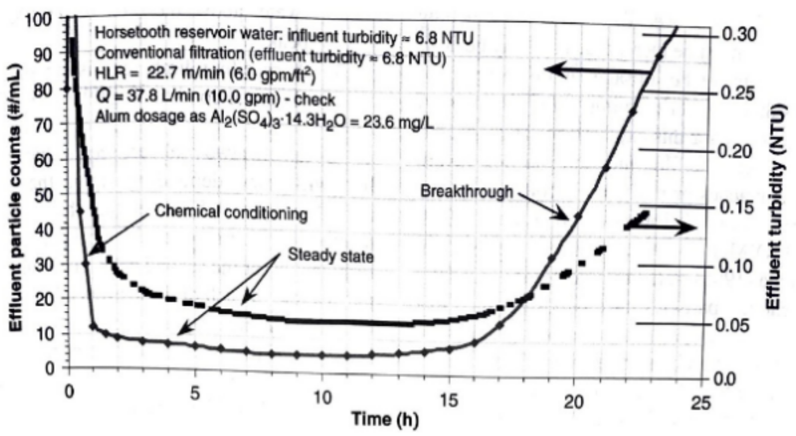


Figure 3: Correlation Between Time and Turbidity of a Pilot Filter (Hendricks, 2006)

Turbidimeter #1	
Measured Value	Real Value
0.365	0.1
19.1	20
204	200
1024	1000
3961	4000

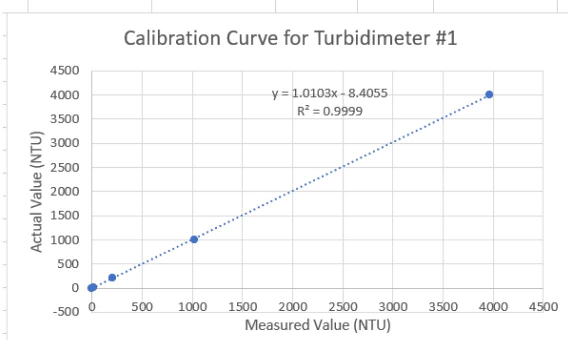


Figure 4: Calibration Curve for Turbidimeter #1 Comparing the Measured Values to the Actual Values.

	Turbidimeter #2	
	Measured Value	Real Value
	0.335	0.1
	20.2	20
	201	200
	1009	1000
	3968	4000

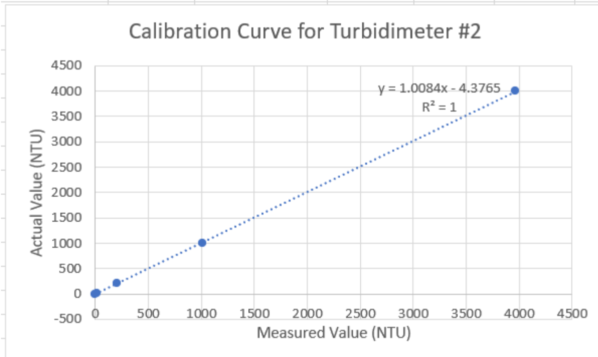


Figure 5: Calibration Curve for Turbidimeter #2 Comparing the Measured Values to the Actual Values.

$$d_1 = d_2 \left(\frac{\rho_2 - \rho_w}{\rho_1 - \rho_w}\right)^{0.667}$$

Figure 6: Kawamura's equation for effective size of media (Kawamura, 2000).

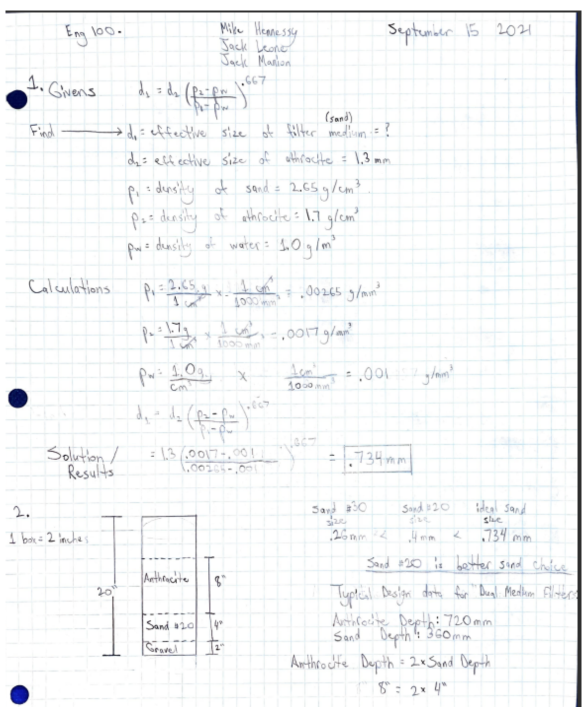
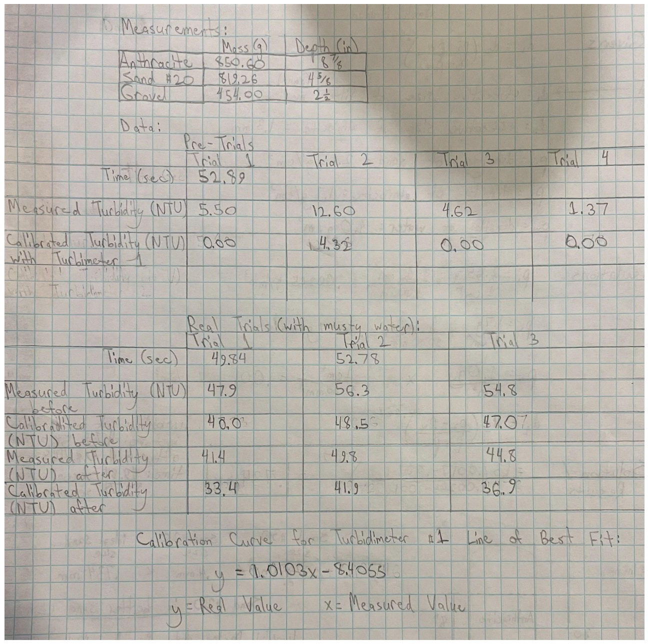


Figure 7: Initial calculations and sketches of the design.



Measurements:

	Mass (g)	Depth (in)
Anthracite	850.60	8 7/8
Sand #20	819.26	4 5/16
Gravel	454.00	2 1/2

Data:

Pre-Trials

	Trial 1	Trial 2	Trial 3	Trial 4
Time (sec)	52.89			
Measured Turbidity (NTU)	5.50	12.60	4.62	1.37
Calibrated Turbidity (NTU) with Turbimeter 1	0.00	4.32	0.00	0.00

Real Trials (with musty water):

	Trial 1	Trial 2	Trial 3
Time (sec)	49.84	52.78	
Measured Turbidity (NTU) before	47.9	56.3	54.8
Calibradited Turbidity (NTU) before	40.0	48.5	47.0
Measured Turbidity (NTU) after	41.4	49.8	44.8
Calibrated Turbidity (NTU) after	33.4	41.9	36.9

Calibration Curve for Turbidimeter #1 Line of Best Fit:

$y = 1.0103x - 8.4055$

y = Real Value x = Measured Value

Figure 8: Calculations of the calibrated turbidity from the measured turbidity, along with initial measurements.

Characteristic	Unit	Value[b] Range	Typical
	Dual-medium Anthracite (ρ = 1.60)		
Depth	mm	360–900	720
Effective size	mm	0.8–2.0	1.3
Uniformity coefficient	unitless	1.3–1.6	≤1.5
	Sand (ρ = 2.65)		
Depth	mm	180–360	360
Effective size	mm	0.4–0.8	0.65
Uniformity coefficient	unitless	1.2–1.6	≤1.5
Filtration rate	L/m^2·min	80–400	200

Figure 9: Typical design data for dual-medium depth filters (Asano, 2007).