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Low-Cost Water Filtration System

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MFET491 - Senior Project
Fall 2023

ACKNOWLEDGEMENTS

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Altstadt Hoffman Plumbing Services

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INTRODUCTION

Water is essential to all life on Earth. Humans use water every day for drinking, bathing, cleaning, and in many other different ways. However, only 2.5% of the total water on Earth is considered fresh potable water, but only 0.775% of this water is accessible to humans (Misachi). Contaminated water sources are responsible for nearly 1 million deaths per year (Water.org). These contaminants can be anything from bacteria to heavy metals or even radioactive materials. This report will explain how the team plans to help mitigate the issues presented with access to clean water. This product will be able to supply potable water to rural areas that are not connected to municipality utilities, and this product also has the capacity to be used globally in the future.

1 BACKGROUND

This product is a whole-home water filtration system. It will be installed between the well and the water heater, or a softener if one exists. This will benefit houses in rural areas that do not have reliable access to municipality utilities. The target population are the elderly who tend to live in these homes. This demographic is more susceptible to diseases, and usually will have a fixed income with little to no room for extraneous expenses. This filter will be competing with products from companies such as Britta, A.O. Smith, and Premier Sales.

1.1 PROBLEM STATEMENT

In some places of the world, there is no access to clean water. The goal of this product will be to provide a product that will allow homeowners to have reliably clean water at a low cost. The target demographic this product will serve are rural homes, not on municipality utilities. Access to clean water is a global issue that is prevalent for many people. However, this issue can never be fully solved, only mitigated. It is important to reduce the exposure to dirty water as much as possible because it can have severe health consequences, sometimes resulting in death.

1.2 Review of Existing Solutions

There are three types of readily available solutions to this issue related to the constructed filter. The first type of solution are Britta products, which are commonly water pitchers, Figure 1, or faucet attachment, Figure 2, which both have removable filters. These water pitchers and attachments are inexpensive, easy to use, and small. The downside of these systems is that they do not filter all the water coming into the home from the water supply.

Figure 1: Britta Pitcher Filter

Figure 2: Britta Faucet Filter

The second type of filtration solution is an A.O. Smith whole home filtration system. This is an inline water filtration system that is easy to use and filters all household water. The downside is that this filter is relatively expensive at $400.00. This cost does not include any replacement filters or installation. This filter also only has a life span of 5 years.

Figure 3: A.O. Smith Water Filtration System

The third type of existing solution is the Premiere Sales Ultra Filtration Series, Figure 4. This is an Inline water filtration system that is easy to use, filters all household water, and is also small. The downside to it is that it is expensive, the retail price is $1,890.00. This does not include any replacement filters or installation costs. These filters also have a life span of only 5 years.

Figure 4: Premier Sales Water Filtration System

2 CONTEXTUALIZED DIAGRAM

The contextualized diagram shows the filters location within the system. The water comes from the well/cistern and goes through the pump then enters the filter. The system was placed in this location to achieve the desired whole home filtration. After the filter comes the water softener, if there is one installed, then the hot water heater where it finally branches off to the respective hot and cold lines. The Contextualized Diagram is shown in Figure 5.

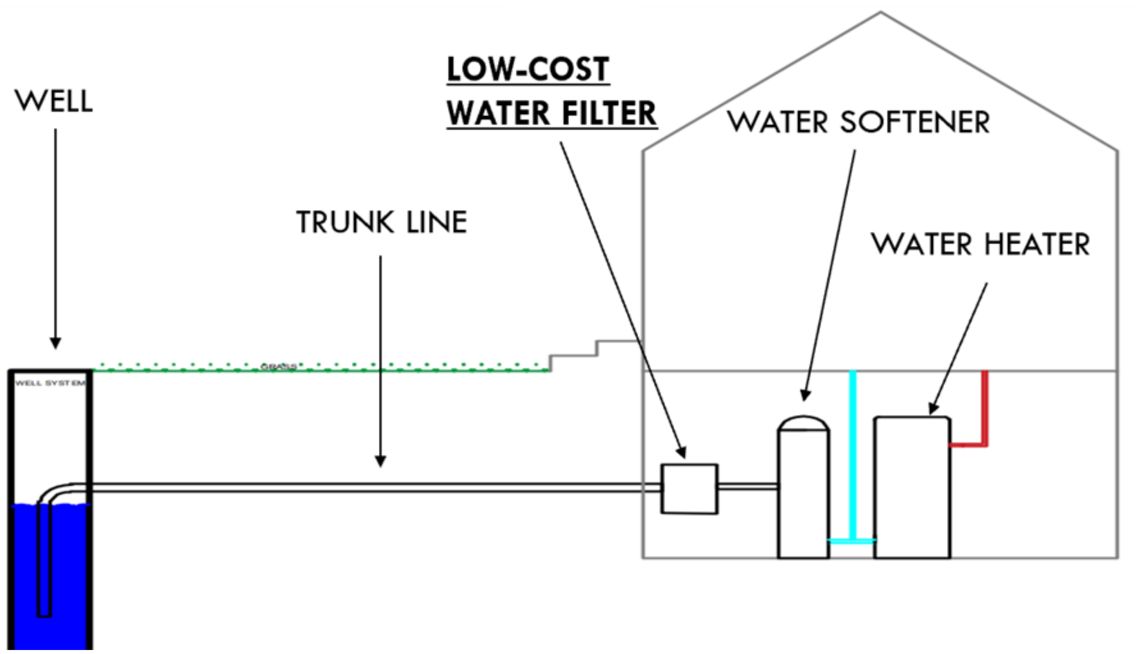

Figure 5: Contextualized Diagram

3 DESIGN CRITERIA

With the aquifer quality rapidly degrading, access to clean water is essential. Many homes that are utilizing well water are inhabited by more elderly people. This age demographic is more susceptible to health issues so clean drinking water is necessary for them. This filter will provide clean water for an entire home. This filter will produce safe and clean drinking water by using activated charcoal as a filtration media. Because activated charcoal has a high surface area, impurities can bond to the surface removing them from the water.

Activated charcoal is also non-toxic and is widely used in hospitals in a process called charcoal apheresis. However, the purposeful ingestion of large quantities of activated charcoal is unhealthy and can cause GI complications, so design safeguards must be in place. This product is intended for use in homes that are not on municipality (city/county) utilities. However, this intention does not limit its use to only the intended group. People who live in homes on well or cistern water tend to have a fixed income with little flexibility. The filter addresses this issue by being easily and cheaply maintained for the duration of its life. The product has the potential to be used globally, not just in its intended demographic. Due to the low complexity of the design and readily available materials, it could be produced and adapted to meet nearly all situations with relative ease.

Cost is one of the most impactful components in this design. The team must consider the fact that the target demographic tends to be on an inflexible budget. Which means the product must be cheap to produce and maintain.

Performance is the other most important component to this design. The product must be able to perform adequately to produce clean and safe water for the duration of its life.

3.1 EPA Recommended Values

While there is no governing body that regulates the quality of water produced by private wells in the United States, the EPA does have a published document containing their recommended contaminant levels for drinking water. The table has been condensed to the contaminants the test strips chosen were able to monitor (Table 1). The table was further edited to highlight the values that saw a change in during the testing phase, all others remained zero throughout the testing. These values are in Table 1 below. The constructed filter must either reduce the contaminant level to meet or exceed the EPA's recommended values. The method of testing we chose was Tespert brand well water testing strips (Figure 24). We chose these because this type of method would be more accurate to what a homeowner would do themselves. While we could have also sent the samples to the water testing lab on town for a more accurate testing, there were several factors that kept us from doing this; having the state test the water samples was very costly at $40.00 or more, the lab that we have access to only tests a few different containment levels, and the test results could have taken months to get back.

Table 1: EPA Recommended Maximum Allowable Contaminants

Contaminant	**Maximum allowable (ppm)**
Nitrate	10
Nitrite	1
Total Hardness	N.A.
Free Chlorine	4
Total Chlorine	4
Bromine	1
Micro-Plastics (MPS)	0
Copper	1.3
Iron	0.3
Lead	0
Nickle	0.1
Sulfite	250
Cyanuric Acid	200

Carbonate	180 (suggested)
Total Alkalinity	30-400 (suggested)
pH	6.5-8.5 (suggested)

3.2 *DESIGN CRITERIA MAIN POINTS*

With these factors in mind, the project's evaluation was set to these three points:

1) Must cost under $350.00.
2) Must remove all tested contaminants.
3) Make safe, drinkable water.

4 CONCEPTUAL DESIGN

This will be a pressurized water filtration system constructed entirely out of PVC that conforms to the NSF/ANSI 61 standard regarding material used for potable water systems. This system can also mate with any different pipe material with the correct connectors. For example, these materials could include PVC, CPVC, PEX, copper or any other materials. Due to the system being located on the trunkline, before any water softeners or heaters, it will provide clean water to an entire home, not just one outlet.

4.1 *CAD ASSEMBLED SYSTEM DESIGN*

This is a fully assembled system as a CAD model. In the pictures below (Figures 6,7) the water flows from left to right, as indicated by the blue arrow.

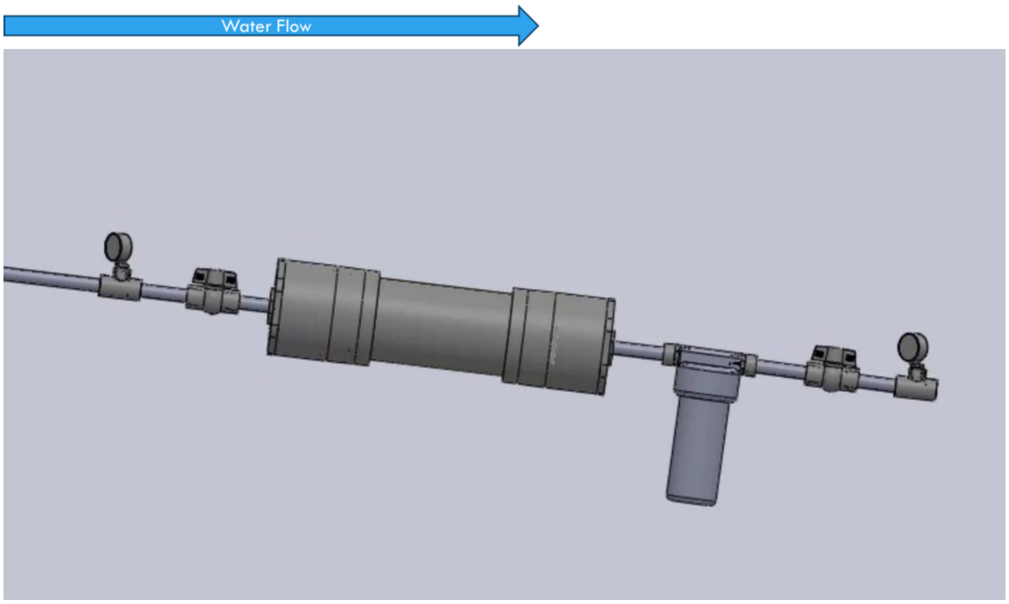

Figure 6: Fully Assembled System Design

4.2 *CAD CONSTRUCTED FILTER BODY.*

The constructed filter body is comprised of 8 components: two 6-inch to 1-inch PVC reducer bushings, a water diffusion plate, two 6-inch PVC couplers, one 6-inch gravity drain line, and one puck filter screen and its associated holder. The water will flow from left to right as indicated by the blue arrow.

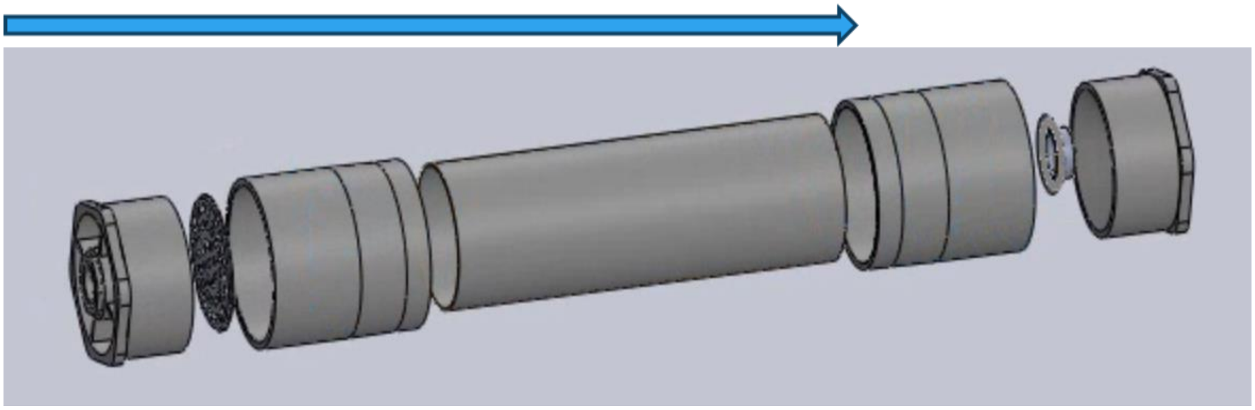

Figure 7: Constructed Filter Body

4.3 DIFFUSION PLATE AND SCREEN HOLDER

These components are the diffusion plate and screen holder which are found inside the constructed filter body. The filter screen used is a 304 stainless steel espresso puck screen with a mesh fineness of 100µm and maximum rated pressure of 20bar. This screen was optimal due to its readily availability, low cost, corrosive resistance properties, mesh fineness, and ultimate strength.

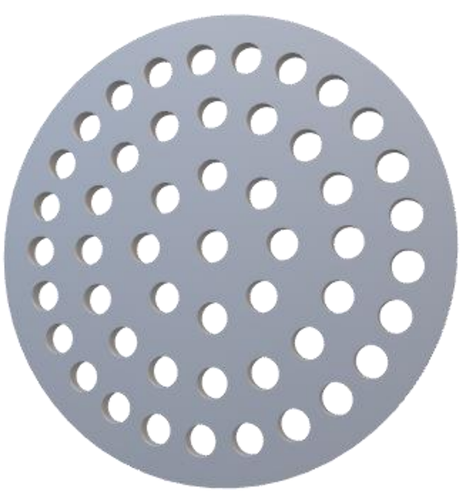

Figure 9: Water Diffusion Plate

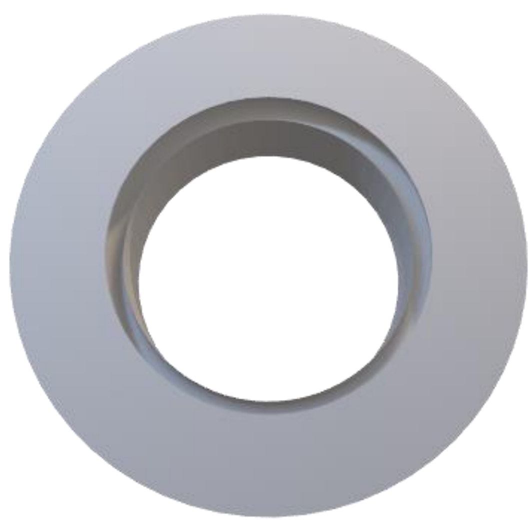

Figure 8: Puck Filter Screen Holder

4.4 A.O. SMITH LARGE SEDIMENT FILTER

The A.O. Smith Large Sediment filter is intended to catch any filtrate blowby if there is a puck filter screen failure. Having the large sediment filter installed after the charcoal filter can also allow for the homeowner to visually inspect the water quality being produced as well as diagnose any major problems. While the manufacturer states the life of these filters is only six months, this is due to the filter filtering out all contaminants, not being the secondary filter. Due to this the filter will last longer than 6 months.

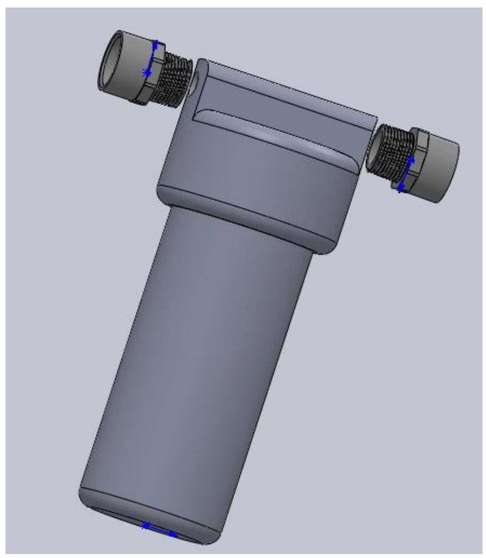

Figure 10: A.O. Smith Large Sediment Filter

4.5 BALL VALVES AND PRESSURE GAUGES

There are two 1-inch ball vales that allow the homeowner to isolate the filter from the rest of the home for service with minimal water loss. There are also two pressure gauges within the system. These gauges were strategically placed to allow for the monitoring of the system's internal conditions and diagnose any major issues.

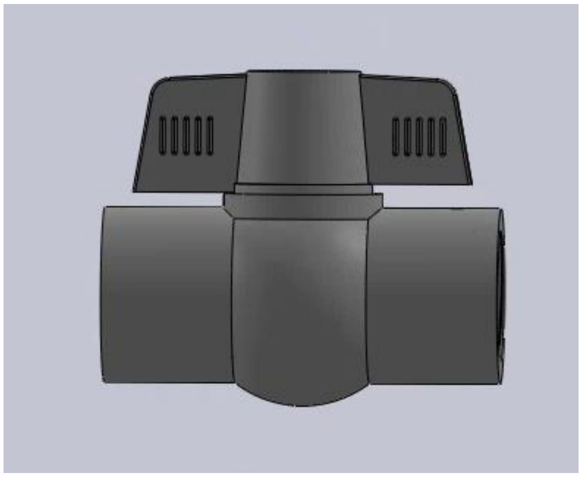

Figure 11: 1-inch PVC Ball Valve

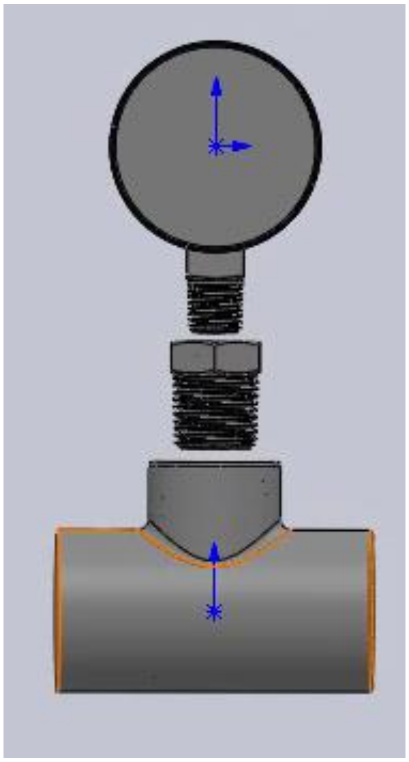

Figure 12: Pressure Gauge

5 SYSTEM HIERARCHY

The system hierarchy has two main components, each with their own sub-assemblies. The housing component consists of piping and hardware. The filter component consists of the charcoal filtrate, diffusion plate, and the filter screen.

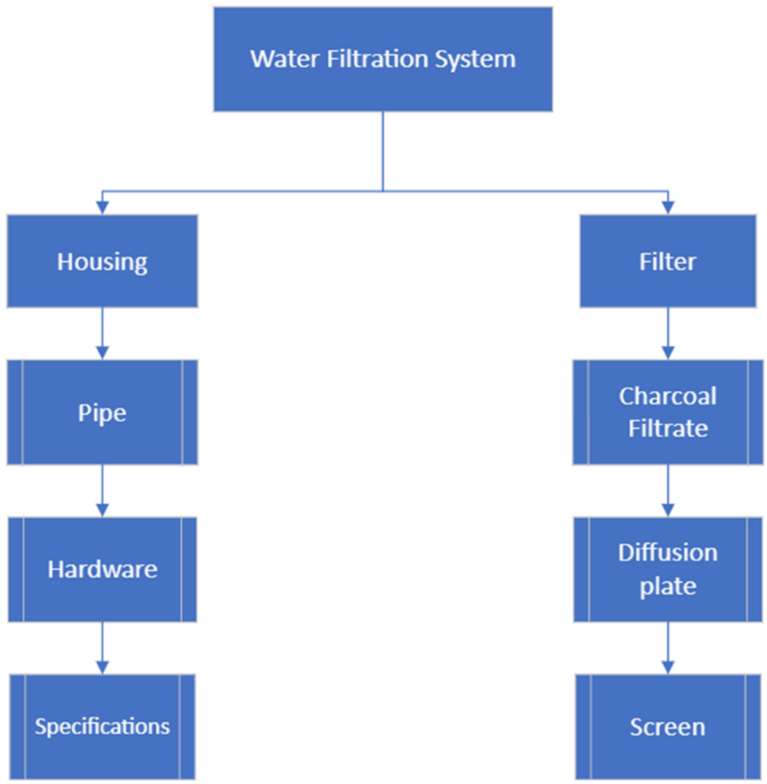

Figure 13: System Hierarchy

5.1 *HOUSING SUBASSEMBLY*

The systems housing is comprised of the pipe feeding the system, the hardware holding the filters together, and the specifications that go along with the housing subsystem.

5.1.1 Pipe

The pipe sub-assembly is comprised of several different components. The components are as follows: One 18 inch long, 6 inch wide, SDR 35 Gravity drain line for the filters main body. 10 feet total of 1 inch schedule 40 PVC pipe. Two 6-inch to 1-inch PVC bushing reducers. Two 6-inch PVC couplers, attaching the reducer bushing to the 6-inch filter body.

5.1.2 Hardware

The hardware sub-assembly is also comprised of several different components which are as follows: Two 1-inch PVC ball valves. Two single dial pressure gauges to read inlet and outlet pressure. One A.O. smith off the shelf large sediment filter to catch any possible blow by from the charcoal filter.

5.1.3 Specifications

The specifications for all components used in the housing are as follows: According to Charlotte Pipe, their 6-inch SDR 35 Gravity drainpipe has a burst pressure of 117.5 psi. The 1-inch schedule 40 PVC pipe is rated for 450 psi for cold water. The 1-inch ball valve is rated for 150 psi for cold water. The pressure gauges are rated for a maximum of 200 psi. While SDR 35 piping is not approved for potable water usage, it was selected for the purpose of prototyping to its lower cost and because it was readily accessible in 24-inch segments where the NSF approved piping was sold by 20-foot segments. In a real installation the filter will conform to NSF/ANSI 61, which is the standard that governs the materials to be used for potable water.

5.2 Filter Subassembly

The filter is comprised of charcoal filtrate, a diffusion plate, and a filter screen. These objects are held within the systems housing of the low-cost water filter.

5.2.1 Charcoal Filtrate

The filtration media is activated charcoal. Activated charcoal is widely used as a filter media for water filtration. The charcoal was crushed to a volume of 0.5 cubic-inches or smaller. It was then activated, by soaking in lemon juice and water, over a period of a week then loaded into the filter body. There are a multitude of ways to activate charcoal, but this was the easiest, safest, and cheapest way to do so (wanow M).

5.2.2 Diffusion Plate

A diffusion plate was added on top of the charcoal filtrate to even disperse the water across all the filtration media. This also regulates the pressure and helps mitigate channeling, which would decrease the effectiveness of the filter. The diffusion plate itself was 3D printed using ASA with a 50% infill using a gyroid pattern. A Gyroid pattern was chosen because this infill type provides support on all walls and faces. ASA was chosen as the material because it is highly resistant material.

5.2.3 Screen

The screen chosen was a 304 stainless steel espresso screen with a fineness of 100µm. This screen is designed to be used at pressures up to 20-bar and is reusable. When the homeowner services their filter, this screen can be easily removed, cleaned, and reinstalled.

6 FULLY ASSEMBLED SYSTEM

This is the fully assembled system. The water flows from left to right. The water Feeds in from the hose on the left side where it passes through the ball valve, then the inlet side pressure gauge, our constructed filter, the A.O. Smith large Sediment filter, the outlet pressure gauge, the final ball valve.

Figure 14: Constructed Filter

7 SYSTEM TESTS

The Low-cost water filter system had three separate tests ran on it, these tests showed its strengths of reaching desirable psi levels, filtering out contaminants, and making clean, drinkable water. It also showed its failure analysis in action.

7.1 SYSTEM TEST ONE AND RESULTS

Test one was completed by running water through the testing pipe to ensure that the system will reach at least 40psi before it would be attached to the filter body. The parts used within this test include a PVC adapter to connect the pipe and hose together, a ball valve to regulate and build pressure, and a pressure gauge to read the pressure. The result of this test was 48 psi, which is in between the normal 40- 60 psi (Gallagher) that wells within a home produce.

7.2 SYSTEM TEST TWO AND RESULTS

Test two consisted of gluing and cementing the system together and running an initial test to make sure water would pass through the system. Once the water passed through the system without breaking any of the joints, water was collected in a glass mason jar, and noticed the water was a dark grey color. So, the water ran longer to clear this charcoal residue. Once the water was clear, another sample was collected, and tested, in this test it was noticed that the pH had lowered, compared to the spigot. The water ran for another 5 minutes and was tested. The results are shown below in Table 2. After the water was tested and showed all allowable numbers, the team taste tested the water, and found that the water was very drinkable, other than the initial charcoal flavor, the flavor will dissipate after running the water, which this is expected with any carbon-based filter in the very beginning.

As the pH lowered and became better, there was a drop in cyanuric acid carbonate and alkalinity, the numbers are shown in Table 2 below.

7.2.1 Test Results

This is the spigot baseline and Britta test results compared to the low-cost filter test. The filter is labeled constructed filter, and as you can see, the pH is the lowest of all the other baselines, and compared to the water from the spigot, the day of the test, hardness, carbonate, and alkalinity have all lowered also. Once again this is all that was tested due to the other contaminate levels remaining zero throughout the duration of the test.

Table 2: Testing Results

Contaminate	Spigot Baseline	Britta	Constructed Filter	Maximum Allowable
Total Hardness	**120**	**0**	**50**	**N.A.**
Sulfite	**0**	**0**	**0**	**250**
Cyanuric Acid	**0**	**0**	**0**	**200**

Carbonate	**240**	**180**	**180**	**180 (suggested)**
Total Alkalinity	**240**	**120**	**180**	**30-400 (suggested)**
pH	**8**	**7.6**	**6.8**	**6.5-8.5 (suggested)**

7.3 System Test Three and Results

Test three consisted of digging dirt from Dr. Ely's yard and mixing it with water in a 50/50 mixture. This mixture is called a "dirt slurry." The dirt slurry (2 containers) was poured into the hose attachment on the testing pipe shown below in Figure 14. The hose was then connected back on the hose attachment.

Water was run through the system for 30 seconds, to clear the old, already tested good water, out of the system. Once the 30 seconds mark was achieved, a water sample was taken. This sample was not yet clear, so it was tested after 60 seconds. At this point the water became clear, drinkable water that had no increase in the amount of tested for contaminants within it. This water also tasted better than the previous, charcoal flavored water originally tasted in System Test 2.

The team believes that there was no change of contaminants within the test due to the test strips only testing for inorganics and heavy metals and inorganics, which are what most common households test for, not the organic items placed into the system.

This test also showed a failure of the system. The system had 2 pressure gauges that read inlet and outlet pressure. If one of these spikes or drops there could be an error within the filter body. While performing this test, the outlet pressure gauge dropped significantly, which resulted in a clogged system. This clog could be from digging up a rock, a piece of grass, or even a tiny stick. All these factors could have been the reason for the pressure drop. Due to having a change of parts from what was ordered, the filter body would have needed to be cut open to diagnose the issues.

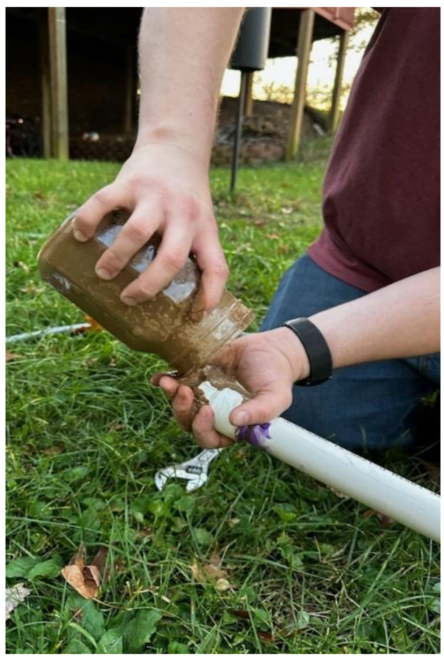

Figure 15: Dirt Slurry

7.4 SYSTEM TEST 3 WATER APPEARANCES

As mentioned above, the supply side pipe of the pipe was filled with a dirt slurry to test the filter's capability. This method of testing is more extreme than a well would probably ever see as it simulates a total well integrity failure, or cave-in. After introducing the slurry and allowing the filter to push out the existing clean water, there was a major difference in the water clarity within 30 seconds and 1 minute.

Figure 16: Filter Time Milestones

8 BUDGET

The University gave the project a total budget of $500.00, with a goal to produce the prototype for less than $350.00 (Table 3). The team succeeded in completing the project under budget with a total of $322.24, even with the extra components included. There is also an actual instillation estimate from a local plumbing company, Altstadt Hoffman Plumbing, of $140.00. There was then a cost estimate for a live installation, which excludes the extra components, materials, and uses the materials that conform to the NSF/ANSI 61 standard which governs the materials used for potable water (Table 4). This expected actual costs table also includes the estimate installation fee from the plumbing company.

Table 3: Prototype Costs

Item (Prototype Costs)	quantity	cost ($)
PVC Adapter T	2	6.22
Teflon Tape	1	0.89
Ball Valve	2	9.8
PVC Adapter 1	1	1.65
PVC Adapter 2	2	4.22
PVC Reducer Bushing	2	84.98
A.O Smith Filter Housing	1	29.99
PVC Purple Primer	1	9.27
IO-ft. PVC Pipe	1	7.56
Pressure Gauge	2	23.96
Lump Charcoal (hardwood only)	1	13.47
100% Lemon Juice (1.8L.)	2	12.96
ASA Filament	1	20.79

A.O Smith Sediment Filter	1	16.99
6-in. PVC Gravity Drain Line	1	15.27
All-Purpose Cement (PVC)	1	10.28
Espresso Screens	2	25.48
NDS 6-in PVC Coupling	2	16.76
¼-in. x ½-in. Threaded Male Adapter Bushing	2	11.7
	Total Cost	322.24

Table 4: Expected Actual Costs for Live Install

Item (Expected Actual Costs)	**quantity**	**cost ($)**
PVC Adapter T	2	$ 6.22
Teflon Tape	1	$ 0.89
Ball Valve	2	$ 9.80
PVC Adapter 1	1	$ 1.65

PVC Adapter 2	2	$ 4.22
PVC Reducer Bushing	2	$ 84.98
A.O Smith Filter Housing	1	$ 29.99
PVC Purple Primer	1	$ 9.27
4’ PVC Pipe	1	$ 3.02
Pressure Gauge	2	$ 23.96
Lump Charcoal (hardwood only)	1	$ 13.47
100% Lemon Juice	2	$ 12.96
ASA Filament	1	$ 2.00
A.O Smith Large Sediment Filter	1	$ 16.99
PVC DWV PE Solid Core Pipe	1	$ 12.30
All-Purpose Cement (PVC)	1	$ 10.28
Puck Filter Screens	1	$ 12.74
NDS 6-in PVC Sewer and Drain Coupling	2	$ 16.76
1/4in x 1/2in Threaded Male Adapter Bushing	2	$ 11.70

	Parts Cost	$ 283.20
	Install Cost	$ 140.00
	Total Cost	$ 423.20

9 CAPITALIZED WORTH OF EQUIVALENCE

The calculated capitalized worth of equivalence for the constructed filter compared to competitive products was built. Capitalized worth equivalence was chosen over an A/P calculation because capitalized worth is more commonly used for permanent installations and construction projects where they have an "infinite" life. The initial costs and replacement costs of each system were found by visiting the manufacturer's suggested retailer's website and pricing the replacements out and applying the $140.00 installation quote to each system, except the Britta. Each system, except the Britta, has a manufacturer suggested life of no more than 5 years. It is also estimated that the constructed filter will also have a life of 5 years. The produced filter also priced, at the time of this documents creation, that a homeowner could buy 5lbs of activated charcoal for $24.00, which is roughly the amount of filtrate the filter system used. To address Brittas' short life, which the manufacturer states last no more than two months, which calculated the cost of replacements every two months for five years. This allows the team to make an equitable comparison. Table 5, shown below shows that the constructed filter system is significantly cheaper over an "infinite" life. These calculations were performed using a federal interest rate, at the time, of 3%. Additionally, the price of the prototype was used in this calculation instead of the expected actual costs because these were real costs, not theoretical.

Table 5: Capitalized Worth of Equivalence

Filtration System	Initial Costs ($)	Replacement Costs ($)	Capitalized Worth ($)
Our Filter	462.24	24.00	612.96
Britta	33.58	189.67	1,226.71
A.O. Smith	540.00	540.00	3,931.20
Premier Sales	2,030.00	2,030.00	14,778.40

10 EVALUATION CRITERIA

The project exceeded the evaluation criteria set for it. It was well under the $350.00 budget limit and filtered out all the tested contaminants nearly as efficiently as the 12 stage Britta filter.

11 PROJECT CHALLENGES

Several challenges were faced in this project due to wrong components, poor manufacturing, and missing orders. These issues caused the project to take longer to complete, however were easily overcome.

11.1 WRONG COMPONENTS

The reducers ordered for this project were 6-inch to 1 inch with a certain style. The company shipped 6-inch to 2-inch reducers with a 2-inch to 1-inch reducer plastic welded into it. Which was also a different style than what was originally ordered. Because of this change the proto prototype became solid and glued, rather than removable and clamped, which added two extra components. If the project was to be reconstructed, it would need to have the original components ordered.

11.2 FAULTY COMPONENTS

The pressure gauges that received were not assembled in the same manner. The first gauge that was fitted to the pipe was easy to separate from its accompanying nut. The second one, however, had red Loctite on the threads locking it together. The team broke it trying to get the gauge and nut apart which halted testing until a new one could be purchased.

11.3 SHIPMENTS

There was also a shipped order that was delayed from distributions for several days. This slowed down the building stage significantly. After the package was received, it appeared to have destroyed threads on one of the socket adapters, which was required for this component, which made the adapter totally unusable.

Even though there were several challenges faced, the team was able to adapt to them, and get the prototype finished on time and within budget.

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Appendix 1: Schedule

GANTT CHART

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
2		Pre Senior Design Power Point	91 days	Tue 4/18/23	Tue 8/22/23	
3		Pre Senior Design Report	91 days	Tue 4/18/23	Tue 8/22/23	
1		Summer	77 days	Mon 5/8/23	Tue 8/22/23	
5		BOM	30 days	Tue 8/22/23	Mon 10/2/23	
22		Senior Design Presentation	50 days	Tue 8/22/23	Mon 10/30/23	
23		Senior Design Report	63 days	Tue 8/22/23	Thu 11/16/23	
4		CAD Drawings	40 days	Mon 8/28/23	Fri 10/20/23	1
6		Order Materials pt.1	1 day	Mon 10/2/23	Mon 10/2/23	5
7		Wait for Materials	10 days	Wed 10/4/23	Tue 10/17/23	6
9		Crush Charcoal	1 day	Tue 10/17/23	Tue 10/17/23	7
8		3D Print	3 days	Wed 10/18/23	Fri 10/20/23	7
10		Allow Charcoal to Soak	5 days	Wed 10/18/23	Tue 10/24/23	9
11		Order Material pt.2	1 day	Mon 10/23/23	Mon 10/23/23	
12		Wait for Materials	7 days	Tue 10/24/23	Wed 11/1/23	11
14		Construct filter body	4 days	Sun 10/29/23	Wed 11/1/23	12
13		Test Water Quality	1 day	Tue 10/31/23	Tue 10/31/23	
15		Test system #1	1 day	Wed 11/1/23	Wed 11/1/23	
16		Senior PDR Due	5 days	Mon 10/30/23	Fri 11/3/23	22
18		Test System #2	1 day	Mon 11/6/23	Mon 11/6/23	15
20		Attach second filter	1 day	Tue 11/7/23	Tue 11/7/23	
21		Test System #3	1 day	Tue 11/7/23	Tue 11/7/23	20
17		Senior Rough Draft Due	1 day	Fri 11/17/23	Fri 11/17/23	23
19		Senior Poster Due	1 day	Fri 11/24/23	Fri 11/24/23	
24		Final Presentation	1 day	Fri 12/1/23	Fri 12/1/23	16
27		Poster Night	1 day	Thu 12/7/23	Thu 12/7/23	19
25		Final Report Due	1 day	Fri 12/8/23	Fri 12/8/23	17
26		Report to SOAR	1 day	Fri 12/8/23	Fri 12/8/23	

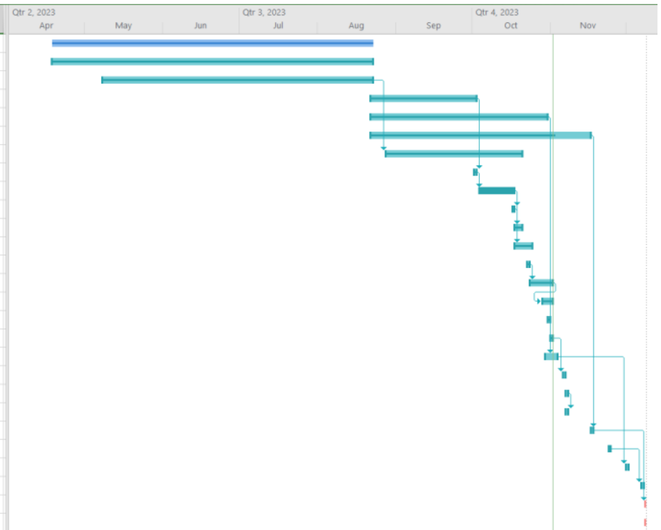

Figure 17: Project Schedule

APPENDIX 2: FMEA

Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Causes/ Mechanisms of failure	Occur	Current process controls	Detect	RPN
Water Filter	Filter does not meet purity standards	Filter was manufactured Incorrectly	10	Incorrectly Manufactured	3	Replace with working filter	10	300
Water Filter	Filter does not meet purity standards	Replacement time	6	Filter does not last a long time	10	Buy a new filter before guage is low	4	240
Shut off Valve in	Water continues to run into the filter system	High pressure water will spray	8	Filter removed before valve is completely shut	2	Filter cannot come off until valve is shut	9	144
Shut Off Valve in	Water continues to run into the filter system	High pressure water will spray	8	Clamps not secured into place	2	Filter cannot come off until valve is shut	9	90
Shut off valve Out	Water backflows from inside the housing.	User may get water on them	5	Clamps not secured into place	2	Filter cannot come off until valve is shut	9	90
Shut off valve Out	Water backflows from inside the housing.	Air gets into water line	5	Clamps not secured into place	2	Filter cannot come off until valve is shut	9	90
Water Filter	Filter does not meet purity standards	Clogged	10	Debreis inside of filter	3	Unclamp, unclogg, re-screw	2	60
Outlet Guage	No reading	Unable to diagnose issues	6	Wears down overtime	6	Replace with working	1	36
Water Filter	Filter does not meet purity standards	Not screwed inall the way	5	User didn't tighten the filter	3	tighten filter	2	30
Inlet Guage	No reading	Unable to see inlet pressure	2	Wears down overtime	6	guage	1	12

Figure 18: FMEA

APPENDIX 3: PIPE SPECIFICATION

A

Pipe Dimension Reference Chart

Pipe Type O.D. Size SDR		LH PIP 91	80 PIP 51	100 PIP 41	125 PIP 32.5	CL 63 IPS 64	CL 100 IPS 41	SEWER PSM 35	CL 125 IPS 32.5	CL 160 IPS 26	CL 200 IPS 21	40 DWV IPS —	80 DWV IPS —	SCH 40 IPS —	SCH 80 IPS —	C-900 CI DR 18
4"	O.D.	4.130	4.130	4.130	4.130	4.500	4.500	4.215	4.500	4.500	4.500	4.500	4.500	4.500	4.500	4.800
	I.D.	4.000	3.968	3.928	3.876	4.360	4.280	3.89	4.224	4.154	4.072	3.998	3.786	3.998	3.786	4.22
	Wall	.065	.081	.101	.127	.070	.110	0.125	.138	.173	.214	.237	.337	.237	.337	.267
	PSI	43	80	100	125	63	100	117.5	125	160	200	100	100	220	320	150
6"	O.D.	6.140	6.140	6.140	6.140	6.625	6.625	6.275	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.900
	I.D.	6.000	5.898	5.840	5.762	6.417	6.301	5.742	6.217	6.115	5.993	6.031	5.709	6.031	5.709	6.08
	Wall	.070	.121	.150	.189	.104	.162	0.18	.204	.255	.316	.280	.432	.280	.432	.383
	PSI	43	80	100	125	63	100	117.5	125	160	200	100	100	180	280	150
8"	O.D.	8.160	8.160	8.160	8.160	8.625	8.625	8.4	8.625	8.625	8.625	8.625	8.625	8.625	8.625	9.050
	I.D.	7.984	7.840	7.762	7.658	8.355	8.205	7.665	8.095	7.961	7.805	7.943	7.565	7.943	7.565	7.97
	Wall	.088	.160	.199	.251	.135	.210	.024	.265	.332	.410	.322	.500	.322	.500	.503
	PSI	43	80	100	125	63	100	117.5	125	160	200	100	100	160	250	150
10"	O.D.	10.200	10.200	10.200	10.200	10.750	10.750	10.5	10.750	10.750	10.750	10.750	10.750	10.750	10.750	11.100
	I.D.	9.980	9.800	9.702	9.572	10.414	10.226	9.563	10.088	9.924	9.748	9.976	9.492	9.976	9.492	9.78
	Wall	.110	.200	.249	.314	.168	.262	0.3	.331	.413	.511	.365	.593	.365	.593	.617
	PSI	43	80	100	125	63	100	117.5	125	160	200	100	100	140	230	150
12"	O.D.	12.240	12.240	12.240	12.240	12.750	12.750	12.5	12.750	12.750	12.750	12.750	12.750	12.750	12.750	13.200
	I.D.	11.975	11.760	11.642	11.486	12.352	12.128	11.361	11.966	11.770	11.538	11.890	11.294	11.890	11.294	11.63
	Wall	.132	.240	.299	.377	.199	.311	0.36	.392	.490	.606	.406	.687	.406	.687	.733
	PSI	43	80	100	125	63	100	117.5	125	160	200	100	100	130	230	150
14"	O.D.	14.280	14.280	14.280	14.280	*	*	*	*	14	*	14.000	14.000	14.000	14.000	15.3
	I.D.	14.000	13.720	13.584	13.402					12.86		13.072	12.410	13.072	12.410	13.48
	Wall	.140	.280	.348	.439					0.538		.438	.750	.438	.750	0.85
	PSI	43	80	100	125					160		100	100	130	220	235
15"	O.D.	15.300	15.300	15.300	15.300	*	*	15.3	*	*	*	*	*	*	*	*
	I.D.	14.970	14.700	14.550	14.358			13.898								
	Wall	.165	.300	.375	.471			0.44								
	PSI	43	80	100	125			117.5								
16"	O.D.	*	*	*	*	*	*	*	*	16	*	16.000	16.000	16.000	16.000	17.4
	I.D.									14.696		14.940	14.214	14.940	14.214	15.33
	Wall									0.615		.500	.843	.500	.843	0.967
	PSI									160		100	100	130	220	235
18"	O.D.	18.360	18.701	18.701	18.701	*	18.000	18.701	*	18.000	*	18	18.000	18	18.000	19.5
	I.D.	17.964	17.967	17.789	17.551		17.122	17.629		16.616		16.808	16.014	16.808	16.014	17.83
	Wall	.198	.367	.456	.575		.439	0.536		.692		0.562	.937	0.582	.937	1.083
	PSI	43	80	100	125		100	117.5		160		100	100	120	220	235
20"	O.D.	20.400	*	*	*	*	20.000	*	*	20.000	*	20	20	20	20	21.6
	I.D.	19.962					19.026			18.462		18.863	17.814	18.863	17.614	19.03
	Wall	.219					.487			.769		0.533	1.031	0.533	1.031	1.2
	PSI	43					100			160		100	100	120	220	235
21"	O.D.	*	22.047	22.047	22.047	*	*	22.047	*	*	*	*	*	*	*	*
	I.D.		21.183	20.971	20.691			20.783								
	Wall		.432	.538	.678			0.632								
	PSI		80	100	125			117.5								
24"	O.D.	*	24.803	24.803	24.803	*	24.000	24.8	*	24	*	24	24	24	24	25.800
	I.D.		23.831	23.593	23.277		22.748	23.381		22.043		22.54	21.418	22.54	21.418	23.73
	Wall		.486	.605	.763		.585	0.711		0.923		0.687	1.218	0.687	1.218	1.200

Figure 19: Spears Dimensions and Pressure Ratings (Spears manufacturing)

APPENDIX 4: NATIONAL PRIMARY DRINKING WATER REGULATIONS

National Primary Drinking Water Regulations

EPA

Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
Acrylamide	TT[4]	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/ wastewater treatment	zero
Alachlor	0.002	Eye, liver, kidney, or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
Alpha/photon emitters	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
Arsenic	0.010	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards; runoff from glass & electronics production wastes	0
Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
Beta photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04

LEGEND: DISINFECTANT, DISINFECTION BYPRODUCT, INORGANIC CHEMICAL, MICROORGANISM, ORGANIC CHEMICAL, RADIONUCLIDES

Figure 20: EPA Water Regulations 1 (Enviornmental Protection Agency)

National Primary Drinking Water Regulations

EPA 816-F-09-004 | MAY 2009

Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
Chloramines (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort; anemia	Water additive used to control microbes	MRDLG=4[1]
Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
Chlorine (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=4[1]
Chlorine dioxide (as ClO_2)	MRDL=0.8[1]	Anemia; infants, young children, and fetuses of pregnant women: nervous system effects	Water additive used to control microbes	MRDLG=0.8[1]
Chlorite	1.0	Anemia; infants, young children, and fetuses of pregnant women: nervous system effects	Byproduct of drinking water disinfection	0.8
Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
Copper	TT[5]; Action Level=1.3	Short-term exposure: Gastrointestinal distress. Long-term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
Cryptosporidium	TT[7]	Short-term exposure: Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
p-Dichlorobenzene	0.075	Anemia; liver, kidney, or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero

LEGEND: DISINFECTANT; DISINFECTION BYPRODUCT; INORGANIC CHEMICAL; MICROORGANISM; ORGANIC CHEMICAL; RADIONUCLIDES

Figure 21: EPA Water Regulations 2 (Enviornmental Protection Agency)

National Primary Drinking Water Regulations

EPA 816-F-09-004 | MAY 2009

Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	**0.007**
cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	**0.07**
trans-1,2, Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	**0.1**
Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from industrial chemical factories	**zero**
1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	**zero**
Di(2-ethylhexyl) adipate	0.4	Weight loss, liver problems, or possible reproductive difficulties	Discharge from chemical factories	**0.4**
Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	**zero**
Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	**0.007**
Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	**zero**
Diquat	0.02	Cataracts	Runoff from herbicide use	**0.02**
Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	**0.1**
Endrin	0.002	Liver problems	Residue of banned insecticide	**0.002**
Epichlorohydrin	TT[4]	Increased cancer risk; stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	**zero**
Ethylbenzene	0.7	Liver or kidney problems	Discharge from petroleum refineries	**0.7**
Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	**zero**
Fecal coliform and *E. coli*	MCL[6]	Fecal coliforms and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes may cause short term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms. They may pose a special health risk for infants, young children, and people with severely compromised immune systems.	Human and animal fecal waste	**zero[6]**

LEGEND DISINFECTANT · DISINFECTION BYPRODUCT · INORGANIC CHEMICAL · MICROORGANISM · ORGANIC CHEMICAL · RADIONUCLIDES

Figure 22: EPA Water Regulations 3 (Enviornmental Protection Agency)

National Primary Drinking Water Regulations | EPA 816-F-09-004 | MAY 2009

Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
Fluoride	4.0	Bone disease (pain and tenderness of the bones); children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	**4.0**
Giardia lamblia	TT[7]	Short-term exposure: Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	**zero**
Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	**0.7**
Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	**n/a[9]**
Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	**zero**
Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	**zero**
Heterotrophic plate count (HPC)	TT[7]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	**n/a**
Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	**zero**
Hexachloro-cyclopentadiene	0.05	Kidney or stomach problems	Discharge from chemical factories	**0.05**
Lead	TT[5]; Action Level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	**zero**
Legionella	TT[7]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	**zero**
Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, and gardens	**0.0002**
Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	**0.002**
Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, and livestock	**0.04**
Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	**10**

LEGEND: DISINFECTANT · DISINFECTION BYPRODUCT · INORGANIC CHEMICAL · MICROORGANISM · ORGANIC CHEMICAL · RADIONUCLIDES

Figure 23: EPA Water Regulations 4 (Enviornmental Protection Agency)

National Primary Drinking Water Regulations

EPA 816-F-09-004 | MAY 2009

Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1
Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood-preserving factories	zero
Picloram	0.5	Liver problems	Herbicide runoff	0.5
Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum and metal refineries; erosion of natural deposits; discharge from mines	0.05
Simazine	0.004	Problems with blood	Herbicide runoff	0.004
Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
Total Coliforms	5.0 percent[8]	Coliforms are bacteria that indicate that other, potentially harmful bacteria may be present. See fecal coliforms and *E. coli*	Naturally present in the environment	zero
Total Trihalomethanes (TTHMs)	0.080	Liver, kidney, or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a[9]
Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero
2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07

LEGEND: DISINFECTANT · DISINFECTION BYPRODUCT · INORGANIC CHEMICAL · MICROORGANISM · ORGANIC CHEMICAL · RADIONUCLIDES

Figure 24: EPA Water Regulations 5 (Enviornmental Protection Agency)

National Primary Drinking Water Regulations | EPA 816-F-09-004 | MAY 2009

Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.2
1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero
Turbidity	TT[7]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites, and some bacteria. These organisms can cause short term symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a
Uranium	30μg/L	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero
Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
Viruses (enteric)	TT[7]	Short-term exposure: Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

LEGEND DISINFECTANT · DISINFECTION BYPRODUCT · INORGANIC CHEMICAL · MICROORGANISM · ORGANIC CHEMICAL · RADIONUCLIDES

NOTES

1 Definitions
- **Maximum Contaminant Level Goal (MCLG):** The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- **Maximum Contaminant Level (MCL):** The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- **Maximum Residual Disinfectant Level Goal (MRDLG):** The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- **Maximum Residual Disinfectant Level (MRDL):** The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- **Treatment Technique (TT):** A required process intended to reduce the level of a contaminant in drinking water.

2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3 Health effects are from long-term exposure unless specified as short-term exposure.

4 Each water system must certify annually, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05 percent dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01 percent dosed at 20 mg/L (or equivalent).

5 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10 percent of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

6 A routine sample that is fecal coliform-positive or E. coli-positive triggers repeat samples--if any repeat sample is total coliform-positive, the system has an acute MCL violation. A routine sample that is total coliform-positive and fecal coliform-negative or E. coli-negative triggers repeat samples--if any repeat sample is fecal coliform-positive or E. coli-positive, the system has an acute MCL violation. See also Total Coliforms.

7 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:
- ***Cryptosporidium***: 99 percent removal for systems that filter. Unfiltered systems are required to include Cryptosporidium in their existing watershed control provisions.
- **Giardia lamblia**: 99.9 percent removal/inactivation
- **Viruses**: 99.9 percent removal/inactivation
- ***Legionella***: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, according to the treatment techniques in the surface water treatment rule, *Legionella* will also be controlled.
- **Turbidity**: For systems that use conventional or direct filtration, at no time can turbidity (cloudiness of water) go higher than 1 nephelometric turbidity unit (NTU), and samples for turbidity must be less than or equal to 0.3 NTU in at least 95 percent of the samples in any month. Systems that use filtration other than the conventional or direct filtration must follow state limits, which must include turbidity at no time exceeding 5 NTU.
- **HPC**: No more than 500 bacterial colonies per milliliter
- **Long Term 1 Enhanced Surface Water Treatment**: Surface water systems or ground water systems under the direct influence of surface water serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- **Long Term 2 Enhanced Surface Water Treatment**: This rule applies to all surface water systems or ground water systems under the direct influence of surface water. The rule targets additional *Cryptosporidium* treatment requirements for higher risk systems and includes provisions to reduce risks from uncovered finished water storages facilities and to ensure that the systems maintain microbial protection as they take steps to reduce the formation of disinfection byproducts. (Monitoring start dates are staggered by system size. The largest systems (serving at least 100,000 people) will begin monitoring in October 2006 and the smallest systems (serving fewer than 10,000 people) will not begin monitoring until October 2008. After completing monitoring and determining their treatment bin, systems generally have three years to comply with any additional treatment requirements.)
- **Filter Backwash Recycling**: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

8 No more than 5.0 percent samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or E. coli. If two consecutive TC-positive samples, and one is also positive for E. coli or fecal coliforms, system has an acute MCL violation.

9 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:
- **Haloacetic acids**: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- **Trihalomethanes**: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

Figure 25: EPA Water Regulations 6 (Enviornmental Protection Agency)

National Primary Drinking Water Regulations

EPA 816-F-09-004 | MAY 2009

NATIONAL SECONDARY DRINKING WATER REGULATION

National Secondary Drinking Water Regulations are non-enforceable guidelines regarding contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, some states may choose to adopt them as enforceable standards.

Contaminant	Secondary Maximum Contaminant Level
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	Noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

FOR MORE INFORMATION ON EPA'S SAFE DRINKING WATER:

visit: **epa.gov/safewater**

call: **(800) 426-4791**

ADDITIONAL INFORMATION:

To order additional posters or other ground water and drinking water publications, please contact the National Service Center for Environmental Publications at: **(800) 490-9198**, or email: **nscep@bps-lmit.com**.

Figure 26: EPA Water Regulations 7 (Enviornmental Protection Agency)

APPENDIX 5: WATER TESTING STRIPS

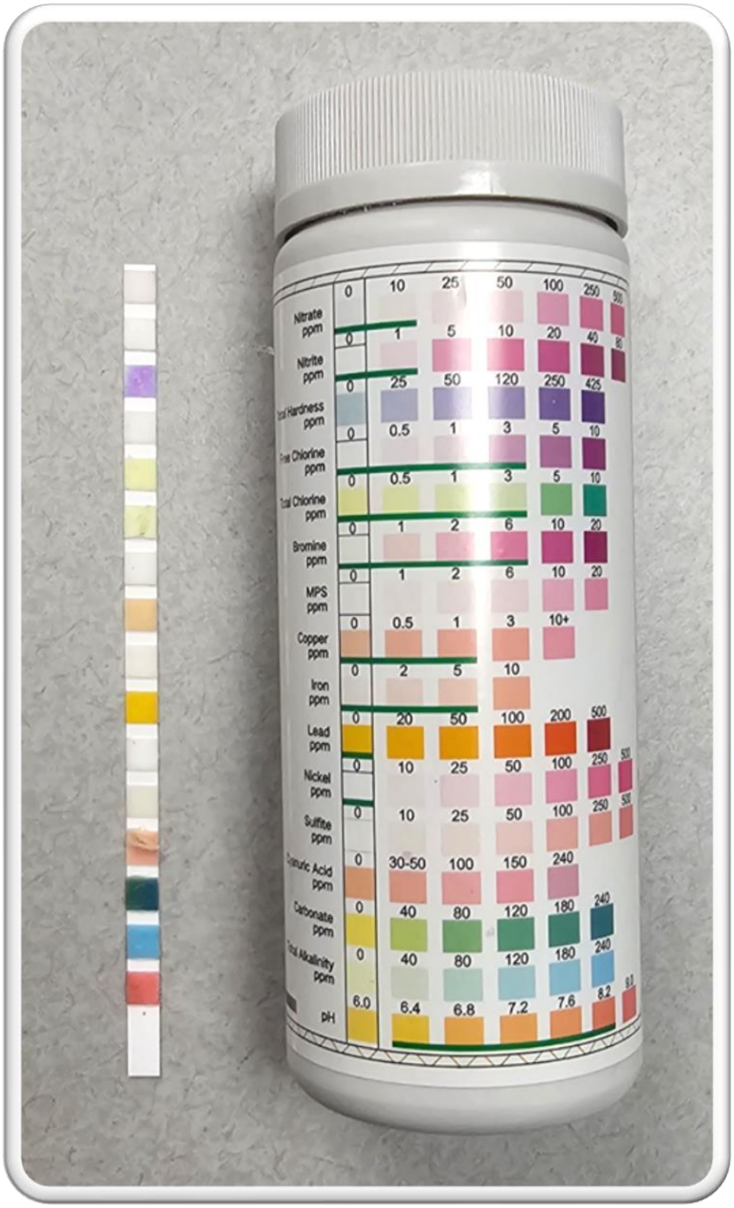

Figure 27: Tespert Well Water Test Strips

APPENDIX 6: PHOTOS

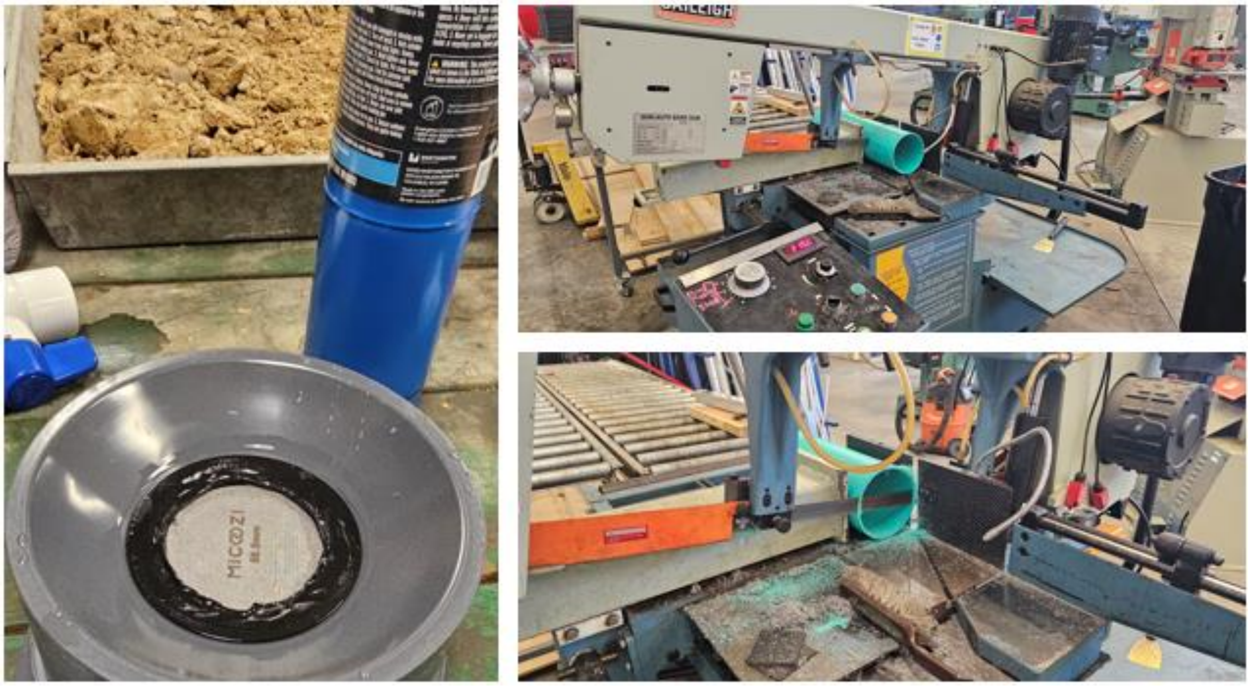

Figure 28: Photo Documentation 1

Figure 29: Photo Documentation 2

Figure 30: Photo Documentation 3

Figure 31: Photo Documentation 4

Figure 32: Photo Documentation 5