Year Three Group Project

Final Report

Project: Water Filtration

Instructor: Jean Roberts

Team Members: Asher Chakupa, Augustine Ofosu-Appiah, Enam Ata Ahorlu, Kevin Kwaku Attakumah, Stanley Agudu

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Cohort B

Introduction to the problem

According to the World Health Organization (WHO), 2 billion people lack access to safely managed drinking water, with poor communities often being the most affected. (WHO, n.d.) Even though access to water in Ghana is improved significantly, one person out of every ten must spend more than 30 minutes to access an improved source of drinking water. Another 11 per cent of the population still drinks from the surface and other unsafe water sources. (UNICEF, n.d.)

Moreover, only four per cent of households treat water suitably before drinking, and 93 per cent of households do not treat water at all. There is a strong link between poverty and collection time for water, with the poorest people over 20 times more likely to spend more than 30 minutes collecting water than wealthier people. There are also inequities within regions, with households in the Northern Region 16 times more likely to have to spend more than 30 minutes collecting water than those in Greater Accra. (UNICEF Ghana)

Over the past few months, we have been developing a water filtration solution to solve the issue of lack of clean and potable water in the Suhum community, Eastern region, Ghana. In this report, we would be discussing our design journey and how we came to settle on our final solution.

1.0 Phase 1 Summary

1.1 Problem Statement

Access to clean and safe drinking water is a basic human right, yet the people of Suhum in the Eastern Region of Ghana are still struggling with this issue due to poverty and isolation. Suhum faces severe problems of contaminated water sources, causing serious health implications for its residents. The current water sources in this community are unclean and contain hazardous chemicals and pollutants, making them unsafe for consumption. This lack of access to clean drinking water is affecting the health and well-being of the community, leading to high incidences of waterborne diseases and illnesses.

The need for an effective water filtration system is dire and immediate, as the community is unable to afford alternative sources of clean water. The solution to this problem is the implementation of a water filtration system that can effectively remove contaminants and impurities from the water, making it safe for consumption. This will improve the community's health and well-being and ensure a sustainable source of clean water for years to come.

Figure 1: Polluted water bodies as sources of water for the people of Miawani, Suhum.

1.2 Related current technologies

In our bid to find practical solutions for handling the challenge of polluted water sources, we evaluated various technological options available today for purifying contaminated waters. We discovered common approaches used worldwide such as reverse osmosis featuring semipermeable membranes proficient at removing contaminants such as microorganisms, dissolved salts, metals, and chemicals effectively. We also discovered more niche, less common, and revolutionary options such as the SteriPEN, another water filtration device. It is a portable water purification device that effectively kills bacteria, viruses, and protozoa using UV-C light technology. In summary, below is a list of the key discoveries related to finding similar technologies related to our project:

- Reverse Osmosis filters
- Ultraviolet disinfection
- Ceramic filtration
- SteriPEN
- Xylem filters from MIT Researchers in India
- Super Sand in China

In the end, we decided to keep these projects in mind and draw inspiration from them when we reached our ideation stage, especially considering the efficiency of ceramic filtration.

1.3 User Needs and Requirements

The key outcome we seek for this project is a reduction in waterborne diseases and an increase in healthy living for the users. This will lead to an increase in production for those who depend on water for their businesses as well as their lifestyle.

Below we have a table of user needs along with their corresponding measurements.

Design Requirements

User Need	Measure	Unit of measurement	Good value	Better Value
Efficiency	Microbe concentration	Microbes per cm^3	>0.001	>0.0001
Affordability	Cost of product	Cedis/Product	50-100	Less than 50
Portability	Weight/mass	kilogram/gram	1.5kg - 5kg	<1.5kg

Cleanliness	Turbidity	Nephelometric Turbidity Units (NTU)	<1 NTU	<0.7 NTU
Lifespan	Mean Time to Failure	Years/Months	<6 months	One year
Usability	Simplicity	Number of steps to operate	Five steps	Two steps
Convenience	Time required to filter	Liters/hour	10 liters/hour	20 liters/hour
Sufficiency	The volume of water filtered	Liters/person	10-15 liters/person	>15 liters/person
Safety	Toxicity	pH level	6.5 - 6.9	7.0 - 7.2

Below are a few questions that helped us in finalizing our design question:

- What if there was a way for people in rural communities to drink water from streams without contracting diseases?
- What if there was a way for people not to have to pay large amounts of money for purifying water?
- What if there was a household chemical water treatment method to disinfect water for purity? Through these questions, our initial design question was changed from.
- “How might we provide clean water to reduce the spread of waterborne diseases?” to
- “How might we provide sufficient clean water for people in rural communities?”
- With all this, we were able to finalize our design requirements which are stated below:
- The device should be easily portable.
- The device should always be easily accessible and usable 24 hours a day.
- The device should be easily used by people with low literacy.
- The device should provide clean water at a fast rate of about 10 –20 litres per hour.

- The device should have a simple maintenance procedure.
- The filter should be easily replaceable.

1.4 Some important aspects of the context to consider.

- **Electricity supply as a constraint depending on the community and the device**: The availability and cost of electricity will determine the type of product we can make. This is because the electricity capacity becomes a limiting factor in the design process.
- **Amount of water filtered per use:** This comes down to the capacity being observed. Depending on the user feedback, we must determine the optimal capacity of our design such that it can provide enough filtered water at a go or the average amount it can provide in a day.
- **Impurities of water to be purified:** This consideration influences the filtration type. Here we consider the type of water we are purifying. We must consider what the impurities are to determine which filtration process best fits. It also informs the types of chemicals that may be needed to remove certain impurities if they are present.
- **The intended use of the water:** The intended use of the water decides the level of cleanliness of the water. If the water is meant to be drinking water or used for cooking, then it must be much cleaner than if the water is going to be used for flushing or washing cars.

1.5 Observations Made While Shadowing User

Our main methods of shadowing were online research and proxy user interviews. We managed to identify and talk to two proxy users, each providing us with information regarding one of our two user categories—children and adults. We learned that the Kwame Ntow stream, where residents get their water from, is shared with pigs and other livestock, which are vectors of various bacteria. Isaac, a 20-year-old proxy user who has previously visited the area, disclosed to us how children face complications ranging from itchy bodies to downright illness.

We discovered that the stream is their only source of water for all purposes, including drinking, bathing, cooking, and washing. The proxy user explained to us how rice cooked using the stream's unhygienic water has a brown color, almost like the rice had been mixed in mud. We found that the absence of alternative sources is to blame rather than the citizens' lack of knowledge about water sanitation for the lack of access to clean water. We found that the locals are knowledgeable about water sanitation and even employ some techniques to cleanse water, including boiling it for three days. However, this approach is insufficient to deliver pure and safe water.

The stream water contains several small particles, including feces of livestock and even residue from dead bodies buried in a nearby cemetery (Bamson, 2021). Boiling the water may kill some of the bacteria, but it does not make the water entirely safe to drink because the particles will still be in the water. A fine filter and some energies are required to filter out these small particles. This is why we are currently researching carbon filters and reverse osmosis as a possible solution for this part of the problem. More on this will be discussed later in this paper.

1.6 Responses Provided to Questions About the Challenge Faced

The main challenge our users face is access to safe water. Because they use the water for all purposes, solutions that only purify small volumes of water would not suffice. For example, at least one bucket of water is required for bathing, and twice that is needed for washing. Simply providing the user with a bottle, whose capacity could be at most 2 litres or so, would not entirely solve the issue. However, the other half of our target users also responded that, in fact, a small portable device is very necessary because some children are too young to carry large volumes of water over long distances. We are currently considering a solution concept that comprises both variations to satisfy both user categories.

1.7 Reflection and Project Research Discussion

After thorough research, our team discovered that there were many methods for solving this problem, ranging from the use of chemical coagulants to mechanical reverse-osmosis filters. Given the wide range of possible solutions and existing methods in water filtration, our team decided that irrespective of the wide variety available, our solution should mainly be shaped by the environment, problems, and opinions of the community we aim to help since they are the main stakeholders, and the solution should be tailored to fit their needs. In analyzing some of the existing solutions and grading them by parameters such as cost, simplicity, effectiveness, and production rate, we realized that each filter was uniquely designed for a specific use-case scenario and target market.

Therefore, we narrowed down ways that some current technologies can be used to address this issue under these categories:

Point-of-use filtration systems: Simple, low-cost point-of-use filtration systems such as ceramic filters and bio-sand filters can provide clean drinking water at the household level. These systems are easy to maintain and do not require a large amount of water to be produced at once, which is a major advantage in areas with limited water supplies. Further research on these showed that they are also very effective when the holes are small and fine enough. These can be used in water bottles, cans, drums, etc.

Solar-powered systems: In areas without access to electricity, solar-powered water filtration systems can be used. These systems can power UV light or reverse osmosis technology to purify water and do not require an external power source.

Community-scale filtration systems: Community-scale filtration systems can be installed in larger communities. These systems can be powered by renewable energy sources, such as wind or solar power, and can provide clean water to a large number of people. Also, a community-scale borehole with an in-built mechanical filter could be very effective.

It is important to note that while these technologies can be useful in addressing water filtration in small, poor communities, a holistic approach that also addresses the root causes of water contamination is necessary to ensure long-term, sustainable solutions. This might include improving sanitation and waste management practices, promoting responsible land use, and educating communities on safe water handling practices. The cost of water filtration systems for poor communities can vary, but simple household filtration systems can cost anywhere from a few dollars to a few hundred dollars, depending on the technology and the scale of implementation. Regular maintenance and replacement of filters are crucial for the effective functioning of filtration systems. This can be a challenge in poor communities, as resources and knowledge may be limited. The lifespan of a water filtration system can vary depending on the technology, but many household filtration systems last for several years with proper maintenance.

2.0 Phase 2 Summary

2.1.1 Brainstorming

The team started Phase 2 by brainstorming ideas for our water filtration device based on the design requirements set in Phase 1. We each came up with individual ideas using techniques like triggered brain walking and mind mapping. The team presented our ideas to each other and combined them to form a list of 125 ideas but noticed that each person's ideas had slight similarities. We further brainstormed and narrowed our scope to four ideas, with one eventually being chosen as the present idea for Phase 3: a barrel-size, mechanically powered filtration device with a capacity of 50 litres and a fast filtration rate. We eliminated the electrolysis and distiller concepts due to inefficiencies and slow filtration rates. The team planned to continue refining their idea by testing and obtaining feedback from potential users and stakeholders.

2.1.2 Ideation

We spent several weeks researching existing water filtration devices and reviewing company product specifications and scientific literature. Based on this information, we developed multiple design concepts for a water filtration device, with each design having its own advantages and disadvantages. One key idea that emerged was using filter paper for the final product design. We were able to finalize their best four designs based on efficiency and ease of use. These designs include a mechanically powered bottle and tank, a small water-resistant device that coagulates impurities, a stationary water distiller, and an electrolysis system in a large tank. We noted that aesthetics will be considered once the final design is complete. We planned to test the various parts of their design concept, conduct continuous research, and obtain feedback from potential users and stakeholders to produce a final product that is both innovative and effective.

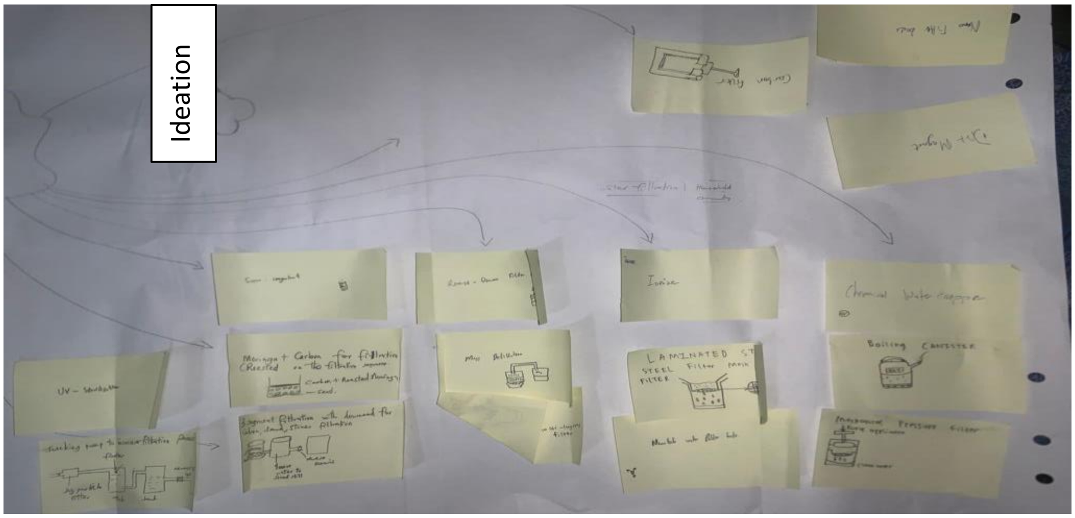


Figure 2: Ideation board showing our Idea Map

2.1.3 Selection process

The team took a careful approach in selecting the design of our solution, considering several factors such as safety, cost, ease of use, portability, convenience, and lifespan. We also kept in mind the low-income status of their target users, who face an urgent need for clean and safe water due to frequent diarrhoea outbreaks. To address this issue, we decided to incorporate a distiller and a UV light into our solution to kill microorganisms effectively. we discarded the idea of using electrolysis as it was not feasible without access to the power grid or a solar panel, which would increase the cost. We also considered using a Super Coagulant, Distiller, and Electrolysis in a large tank near the Kwame Ntow stream but realized it was not feasible for our target users due to lack of access to the power grid and high costs. Additionally, there were license costs and regulations associated with planting a tank on the stream.

The team considered design requirements such as cost efficiency, safety, and ease of use, and the financial capabilities of their target users. We decided to incorporate a distiller and UV light into their solution but eliminated electrolysis due to cost and lack of access to power. We also discarded the idea of a big tank solution due to regulatory issues and cost. After merging the remaining solutions, the team proposed a model with several sections for water filtration. The coagulation process uses natural coagulants, and the filtration process involves bio-sand filtration, activated charcoal, and UV light. This solution is effective and sustainable, as the natural coagulant Moringa Seeds are locally available in Ghana.

Design Requirements

User Need	What we a re measuring?	How to measure ?	Good Value	Better Value
Safe	Microbes Toxicity	Microbes per cubic cm	>0.001 3.9 - 7.2	>0.00001 7-7.1
Cheap	Cost of production and Cost of selling	Cedis per product	50-100 Cedics	Less than 50 Cedis
Sufficient	Volume Filtered	Litres per person	60L to 70L	More than 70L
Ease of use	Simplicity	Number of steps to Operate	5 -6 Steps	2-3 Steps
Portable	Weight or Mass	kgs and grams	greater than 1.5kg less than 5kg	less than 5kg
Convinient	Time to filter Time to treat the water	Litres per hour Litres per mins	8-10 L per hour	15 - 20 hour
Clean	Turbiditiy test Eye Test Microscopy	Nephelometric Turbidity Units (NTU)	Less than 1 NTU	Less than 0.7 NTU
Life Span	Mean time to failure	Years or Months	6-12 Months	12 -16 Months

2.2 Prototype and testing

After ideation, our next task was to create a prototype and test it. We had arrived at a tentative idea of what we wanted our final idea to look like and we also knew exactly what we wanted out product to achieve. Through prototyping and testing, we could test the efficacy and feasibility of some of the ideas we had and measure their performance in the specific things we wanted. We conducted various tests on several low-fidelity prototypes, one of which was a nanopore filter made of cloth with a spacing of approximately 100 micrometres between the fabric.

To measure its efficiency in separating water from dirt, we mixed tap water with dirt and tested the capacity, turbidity, and filter speed of the prototype. However, we identified several deficiencies in the filtering mechanism. For instance, the filter speed was too slow, with only 10 millilitres filtered after 2 minutes. We discovered that pouring water with higher pressure directly onto the filter increased the filter speed and resulted in more valuable rates. Additionally, the 1.5-litre bottle we used had inadequate capacity, so we needed a larger container. Furthermore, the filtered water had a turbidity of 20, while the unclean water had a turbidity of at least 100. Although many impurities were removed, the turbidity we obtained was higher than the desired level of less than 10, necessitating a finer filter or an additional filtration step. However, the prototype was simple enough to use, which was satisfactory.

Through testing, we were able to identify the subsystems needed to produce an ideal solution to our problem. These subsystems include the containment unit, filtration bed, gravel filtration subsystem, coagulant subsystem, and wheels. To improve the filtration system, we decided on a circular shape for the container as it has no sharp corners, ensuring the gravel filtration bed covers the entire area and prevents water from passing through without being filtered. We also added UV lights to the final containment unit to address our design requirement of microbe concentration. In terms of the filtration bed, we decided to use existing filter paper rather than printing out filter beds, as it is cheaper and faster. For the coagulation filter unit, we chose to use gravity instead of mechanical or electrical pumping, as it is the most efficient and cost-effective method. By elevating the coagulation system tank and attaching it to a slant downwards, water pressure and gravity will bring the water to the next unit.

When discussing our idea with our peers, they gave us two suggestions. Firstly, they suggested that we use more mechanical processes for filtration as it is generally cheaper than electrical or chemical methods. Secondly, they suggested we look at Norax care (tap filters) as an existing innovative solution to guide us towards the way forward. These suggestions influenced our decisions, and we incorporated them into our solution, resulting in a more mechanical nature to our solution.

2.3 Concept Evaluation

In product development, concept evaluation plays a crucial role in determining which product ideas are worth pursuing. After brainstorming and ideation, we narrowed down our options to five solutions that we believed were the most effective for our project based on our target group, available resources, and time. These ideas were a Coagulant Decantation System, a Distillation Tank, a Large-Scale Electrolysis Tank, the Carbon Mesh Aqua Filter, and UV Light Filtration. To evaluate these ideas, we used our design requirements from Phase 1 of the project, which were created based on user feedback, research, and relevant factors for solving the problem. We used two methods for concept evaluation, a Pugh chart and a chart to grade each idea amongst themselves.

During our evaluation process, we considered various factors, including the effectiveness, affordability, scalability, power source requirement, maintenance, and limitations of each idea. For instance, the UV Light Filtration method is highly effective, easy to use, and requires no chemicals or consumables, but it may not be as effective at removing some contaminants and requires a power source. On the other hand, the Coagulant Decantation System is simple, low-cost, and effective at removing larger particles and organic matter from water, but it may not be as effective at treating large volumes of water or removing a wide range of contaminants as other methods.

		Rating	Mechanical Filters(Ceramic/Graphite)	Score	Super Coagulant + Decantation	Score	Distillation Tank	Score	Large-scale Electrolysis Tank	Score	CarbonMesh AquaFilter (CMAF)	Score	UV Filtration	Score
Features	Capacity	3	0	0	0	0	3	9	2	6	0	0	N/A	
	Mobility	2	0	0	2	4	-3	-6	-3	-6	0	0	0	0
	Turbidity	4	0	0	1	4	3	12	2	8	2	8	-1	-4
	Toxicity and pH	4	0	0	0	0	2	8	2	8	2	8	0	0
	Cost	5	0	0	-1	-5	-3	-15	-3	-15	1	5	0	0
	Lifespan	3	0	0	2	6	2	6	2	6	1	3	1	3
	Filter time	4	0	0	-1	-4	-3	-12	-3	-12	2	8	-1	-4
	Microbe concentration	4	0	0	0	0	3	12	3	12	2	8	3	12
	Simplicity	3	0	0	0	0	-3	-9	-2	-6	0	0	1	3
	TOTAL		0	0	3	5	1	5	0	1	10	40	3	10

Figure 3: Pugh Chart comparing identified solutions to the mechanical filter as a standard.

					Ideas							
		Rating	Super Coagulant + Decantation	Score	Distillation Tank	Score	Large-scale Electrolysis Tank	Score	CarbonMesh AquaFilter (CMAF)	Score	UV Filtration	Score
Features	Capacity	3	6	18	7	21	7	21	6	18	N/A	
	Mobility	2	7	14	3	6	2	4	7	14	8	16
	Turbidity	4	9	36	9	36	7	28	8	32	4	16
	Toxicity and pH	4	6	24	8	32	8	32	7	28	5	20
	Cost	5	6	30	1	5	1	5	6	30	6	30
	Lifespan	3	5	15	7	21	7	21	7	21	6	18
	Filter time	4	4	16	3	12	3	12	7	28	7	28
	Microbe concentration	4	4	16	9	36	8	32	7	28	10	40
	Simplicity	3	4	12	3	9	2	6	7	21	7	21
	TOTAL		51	181	50	178	45	161	62	220	53	189

Figure 4: Direct Comparison Pugh Chart comparing possible solutions against each other.

3.0 Paper Sketches

Throughout our design journey, we used paper sketches extensively for two main reasons. First, they helped us to effectively communicate the concepts of our ideas to each other and to our feedback group and proxy user. As was mentioned earlier, the scope of our project was more skewed towards developing a more convenient structure for filtration than it was towards building a more effective filtration mechanism than the ones already in use. Our aim was to use the mechanisms in any creative combination feasible to develop a cleverly designed and handy device. The paper sketches were extremely helpful when it came to explaining our ideas to each other.

Second, we used the paper sketches to map out our ideas and for data visualization, of sorts. In more than one occasion, we were able to develop the idea or generate new ideas just by putting them on paper. Now, all the sketches we drew, starting from the brainstorming stage right down to the final design, are perhaps too many to fit in these couple dozen pages. We have split this section into two parts. The first part would be a brief discussion of some of the sketches we generated during our design journey, and how the ideas evolved into the final product. The second section would be more detailed than the first, as it would focus on only the sketches of our final design.

3.0.1 Initial Sketches

After our brainstorming stage, we culled 3 ideas from the bunch for further consideration and development towards a final product. The sketches of these ideas are displayed and explained below.

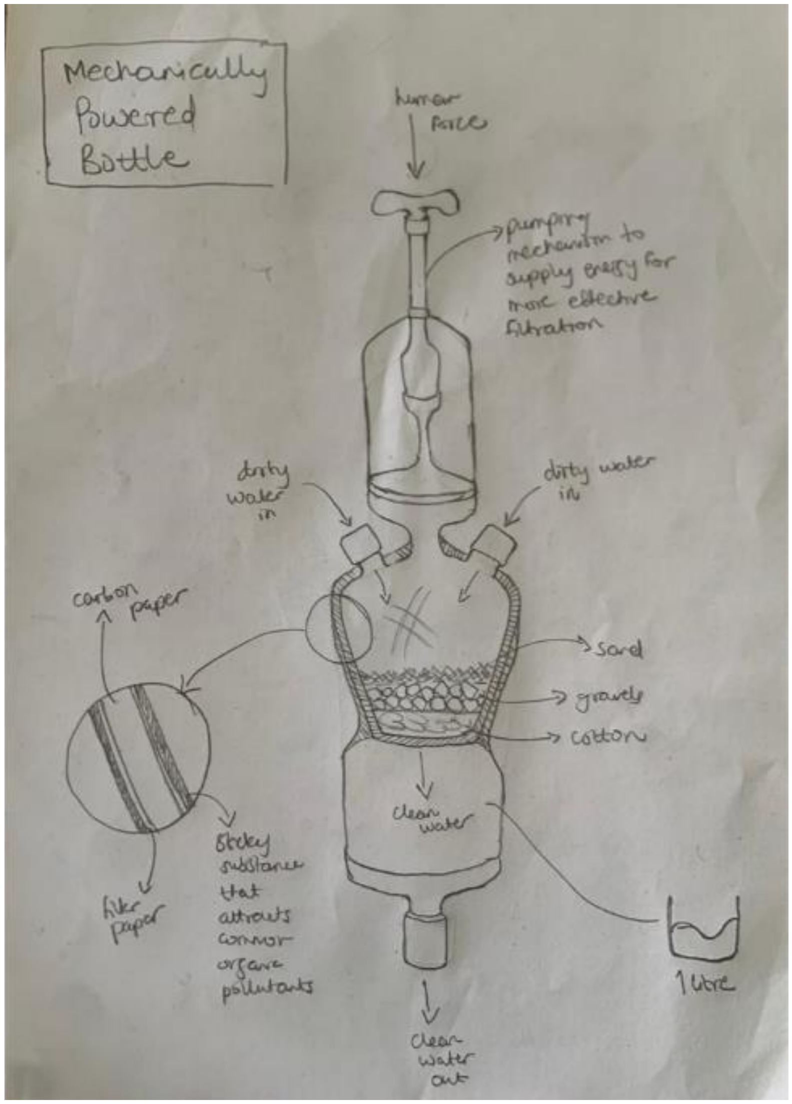


Figure 5: Mechanically Powered Bottle

This idea was a combination of at least 4 others. It was intended to be a small hand-held water filtration device. It was meant to filter water with energy obtained from a small pump system planted on its body as shown in the figure. With a volume of 1 litre and a variable filtration rate depending on how fast the user pumped, this idea showed the highest potential of surviving our next stages of more rigorous analyses of ideas.

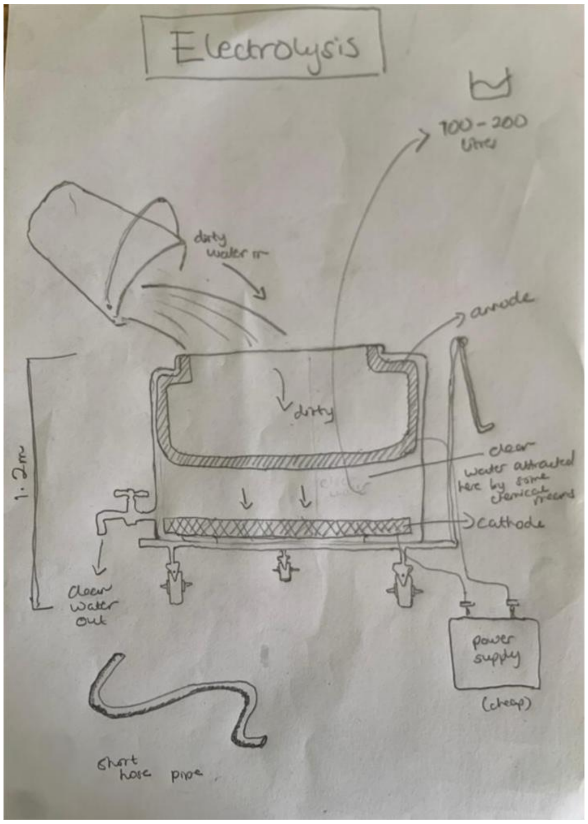


Figure 2: Electrolysis Tank

This idea consisted of a big, mobile tank, of volume ranging from 100 to 200 litres. The concept here was to make use of electricity to extract water from its impurities through electrolysis. The main thing in the pros column for this idea was that, it could handle large amounts of water at a time.

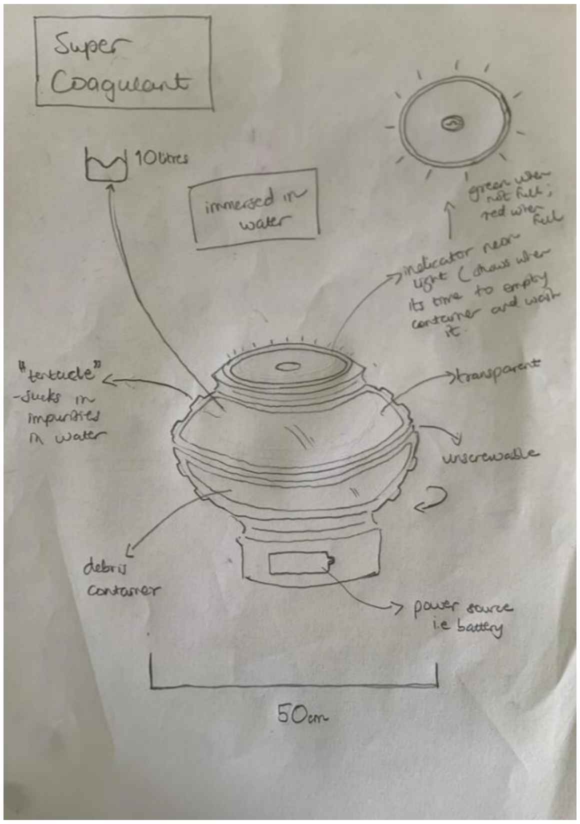
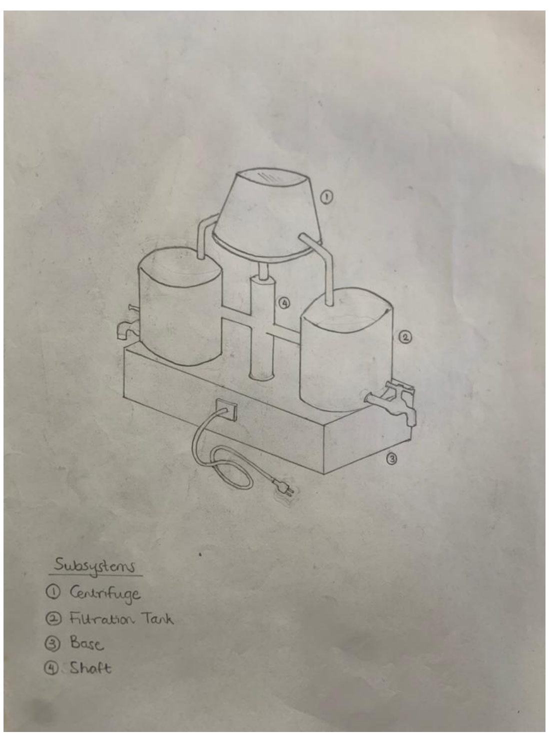
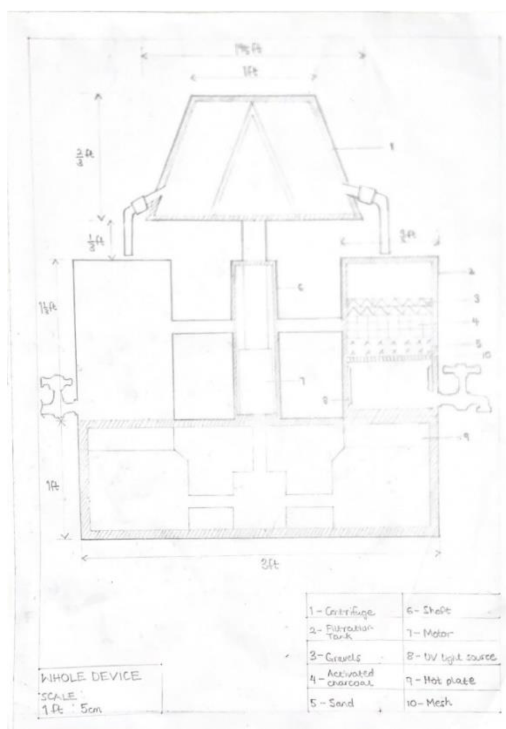


Figure 3:Super coagulant

This was intended to be a small device with the size of about two adult male fists combined. It operates by attracting impurities and collecting them into its body when submerged in dirty water. It had one-way holes we referred to as “tentacles” around its body for achieving this.

In the next stage of our design, we combined aspects of the 3 mentioned ideas to form one for user feedback from our proxy user and peer review from another team in our class. The diagrams of the resulting idea are shown in Figure5.





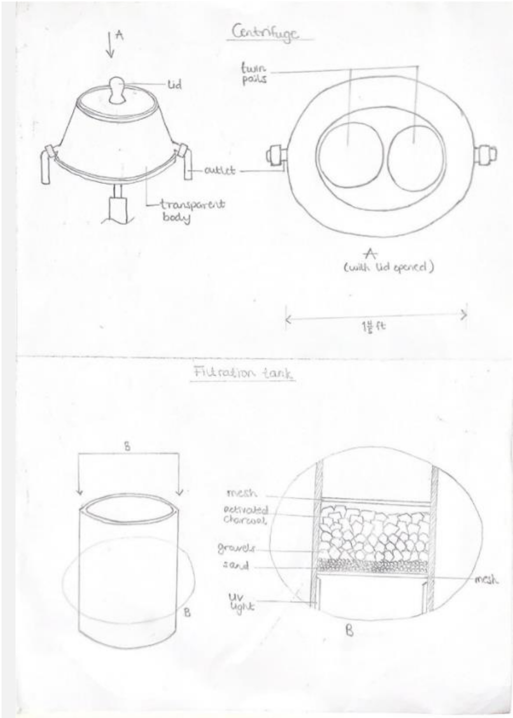


Figure 4: Combinational Solution of Proposed Ideas

The above new idea consisted of 4 main subsystems: a centrifuge, twin filtration tanks, a shaft and a base as labeled in the diagram above. The centrifuge is powered by a motor embedded in the shaft to separate particle impurities from the water. After this is done, the water is sent through the filtration tanks for further purification. These tanks contain fine meshes and sand and gravels for separating the water from the much smaller particles. It also has a UV chamber for shedding UV light on the water for more cleansing. The bottom of the twin tanks where the clean water is collected sits on top of the base subsystem. This base contains a hot plate for heating the water for an even extra level of purification. The system was meant to be powered by an AC power source.

The device's dependency on an electrical power source and its overall sophistication, for instance, its need for constant maintenance by professionals, contributed to its remodification and scaling for the final solution. In the next section, we would discuss the sketch and mechanism of the final design in detail.

3.0.2 Final Design Sketch

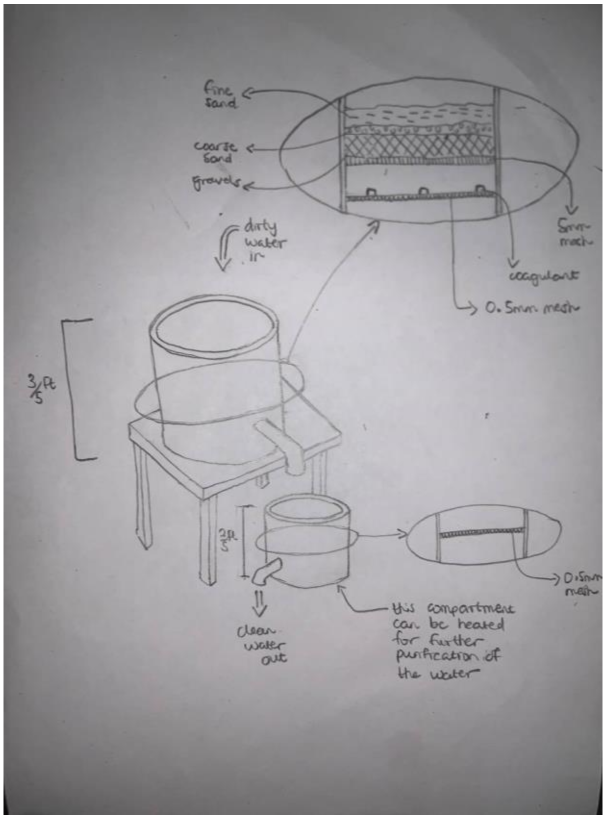


Figure 5: Final Sketch

This final design consists of two tanks for filtration and no electrical power needed. It receives dirty, polluted water at the upper tank, where the water is passed through layers of sand, gravel and meshes to separate it from particles of varying size. Coagulant is spread over the surface of one mesh to allow impurities to clump together and become easy to sieve away. The bottom tank receives the 90-percent-filtered water from the upper tank for a final sieving. It can be boiled with any heat source to intensify the purification.

3.1 Detailed Design

Using SolidWorks our team has designed a 3D model of water filtration model with a multi-chambered system that is an effective solution for purifying water. The model is comprised of several compartments, each playing a crucial role in the purification process. These compartments include the plunger, the decanting and coagulation unit, the filtration chamber, taps, filters and the platform, as shown in the diagram below in Figure 1.1 and Figure 1.2.

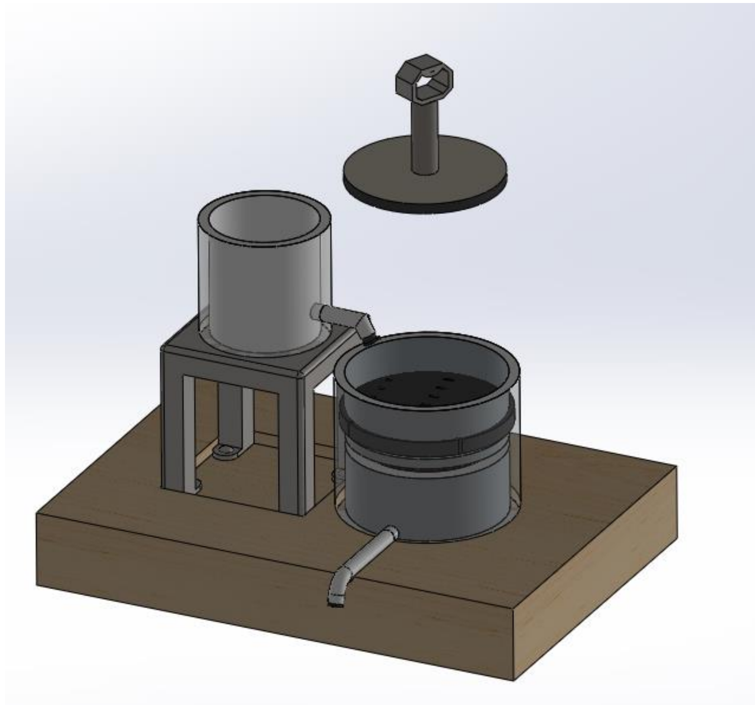


Figure 6: Water Filtration System

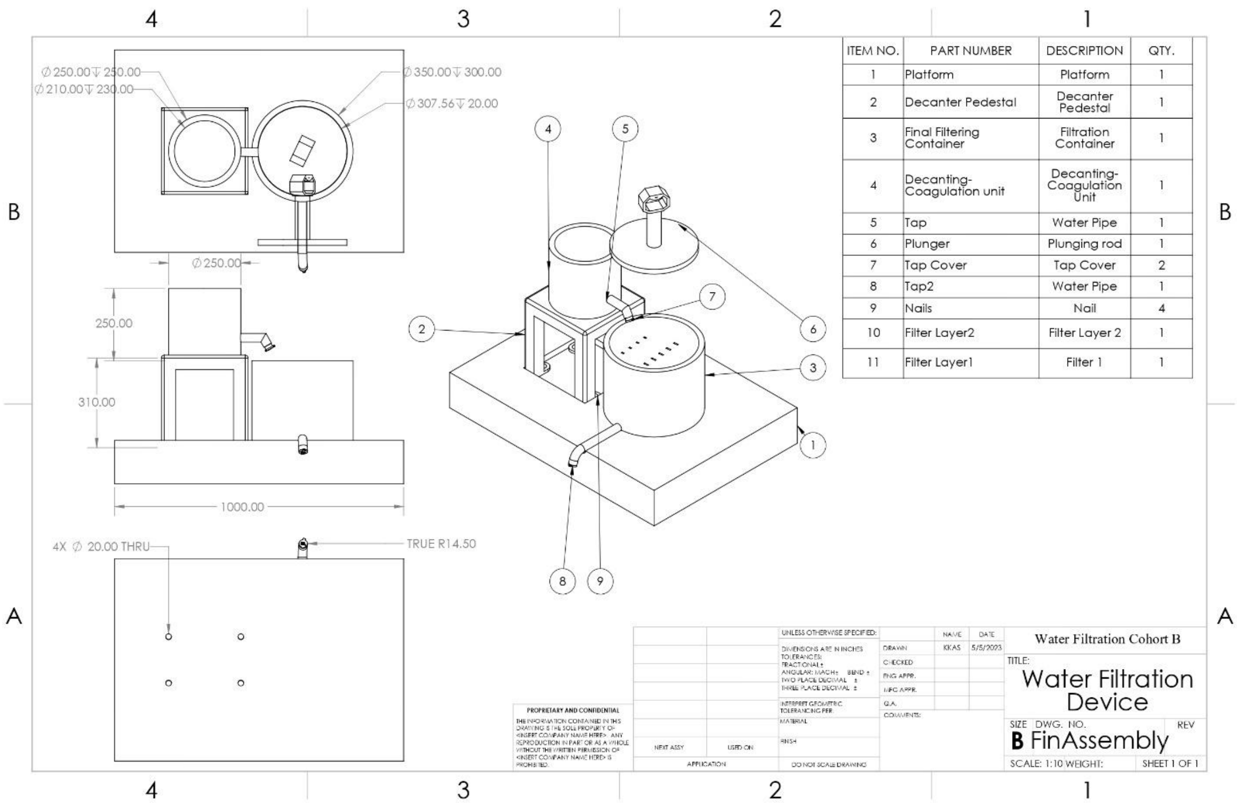


Figure 9: Technical Drawing of Water Filtration System

3.1.1 The Plunger

To ensure that our water filtration process was accessible to individuals from low-income families, we carefully considered our stakeholders and implemented cost-effective measures. The plunger remained the starting point, pushing water into the decanting and coagulation chamber. We recognized that mechanical effort would be necessary to expedite the filtration process, especially for our target audience of individuals. Therefore, we included an airtight circular plunger in our design, which prevented the process from relying solely on gravity, which would have been time-consuming.

After careful consideration, we determined that metal would be a suitable material for our plunger, given its strength and resistance to wear and tear. Additionally, we incorporated a rubber circular surface on the plunger to prevent rusting, which was necessary since the plunger would be in contact with both air and water. By selecting materials that were both strong and resistant to corrosion, we were able to design a plunger that would last longer and require less frequent replacement, making our water filtration process more sustainable over time. The handle at the top can be fitted with a lever to increase mechanical advantage. An image of the 3D design of the plunger is shown in Figure 2.1 and a detailed engineering drawing in Figure 2.2

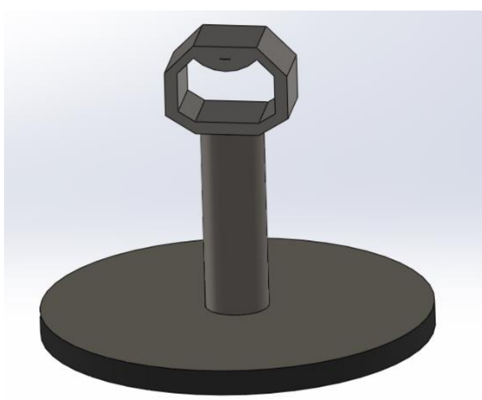


Figure 10: Plunger CAD Model

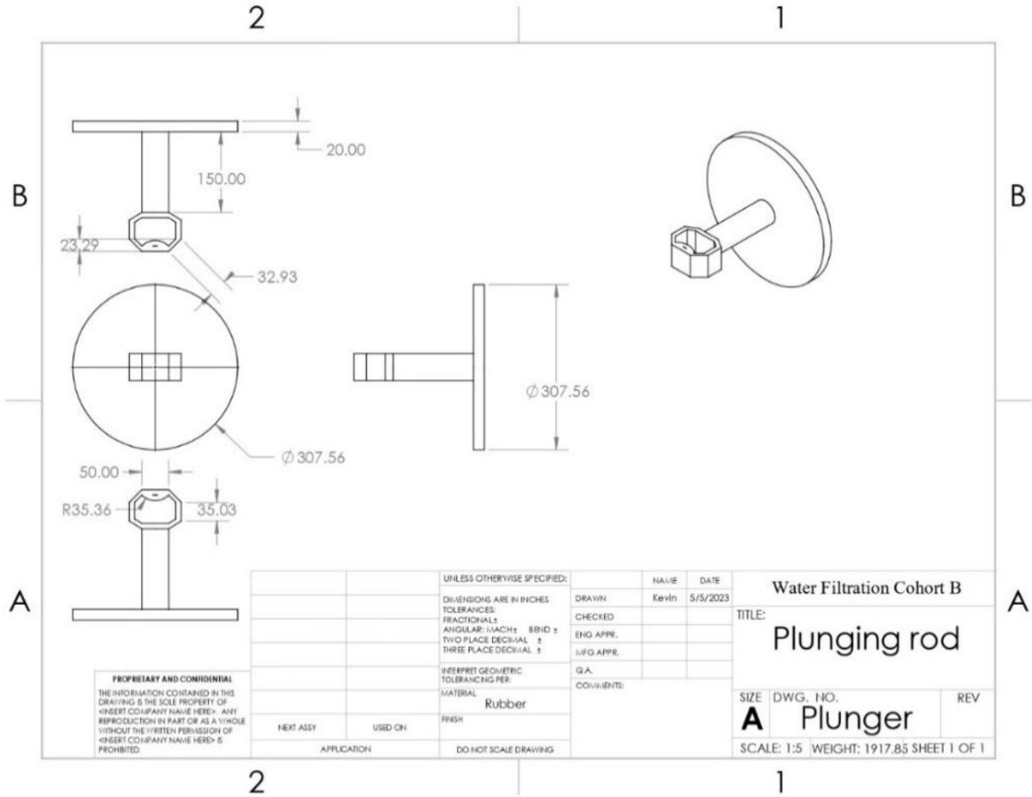


Figure 11: Technical Drawing of The Plunger

3.1.2 The Decanter Pedestal

A decanter pedestal serves as a platform for holding the decanting and coagulation unit. This platform can be constructed using various materials and can be of different sizes depending on the scale of the decanting process. For larger operations, a concrete platform can be built to hold the massive water tank where the decanting occurs. On a smaller scale, a steel or wooden stand can be used to elevate the decanting unit, allowing water to increase in pressure as it gains potential energy. This increase in pressure can lead to an improved rate of filtration. Regardless of the size or material used, a decanter pedestal plays a crucial role in the decanting process by providing a stable and elevated platform for the decanting and coagulation unit.

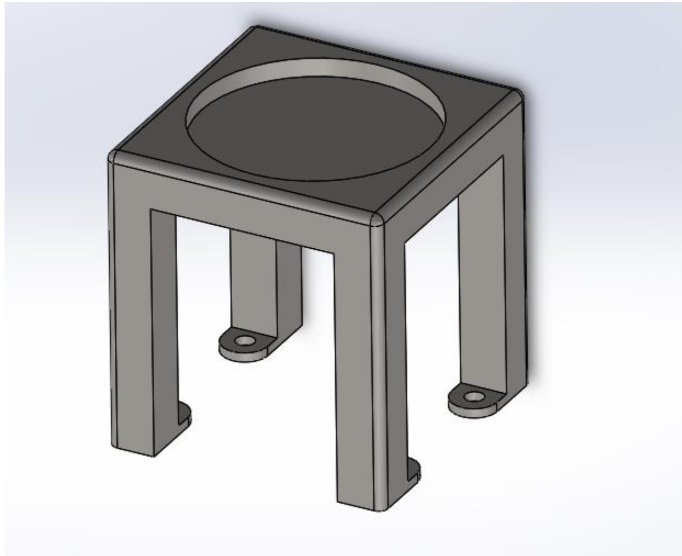


Figure 12: Decanter Pedestal CAD Model

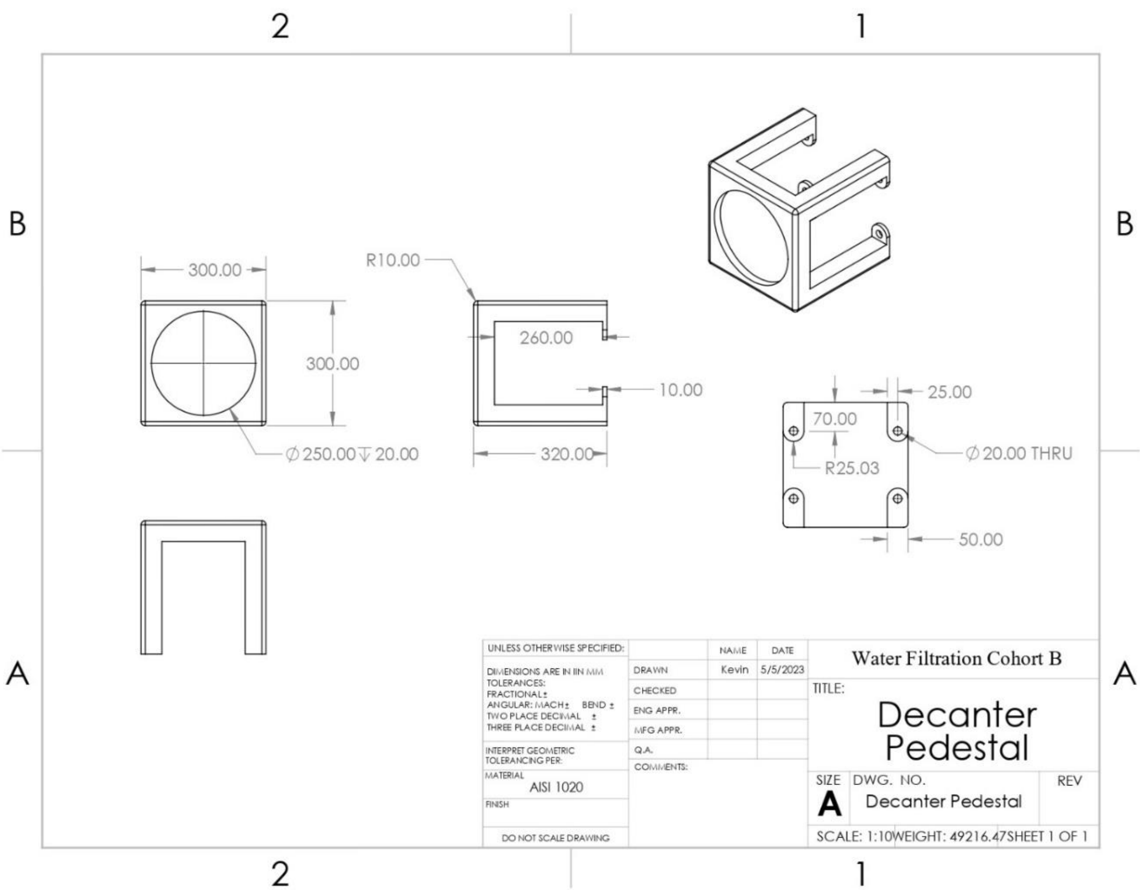


Figure 13: Technical Drawing of a Decanter Pedestal

The Filter

3.1.3 Filter

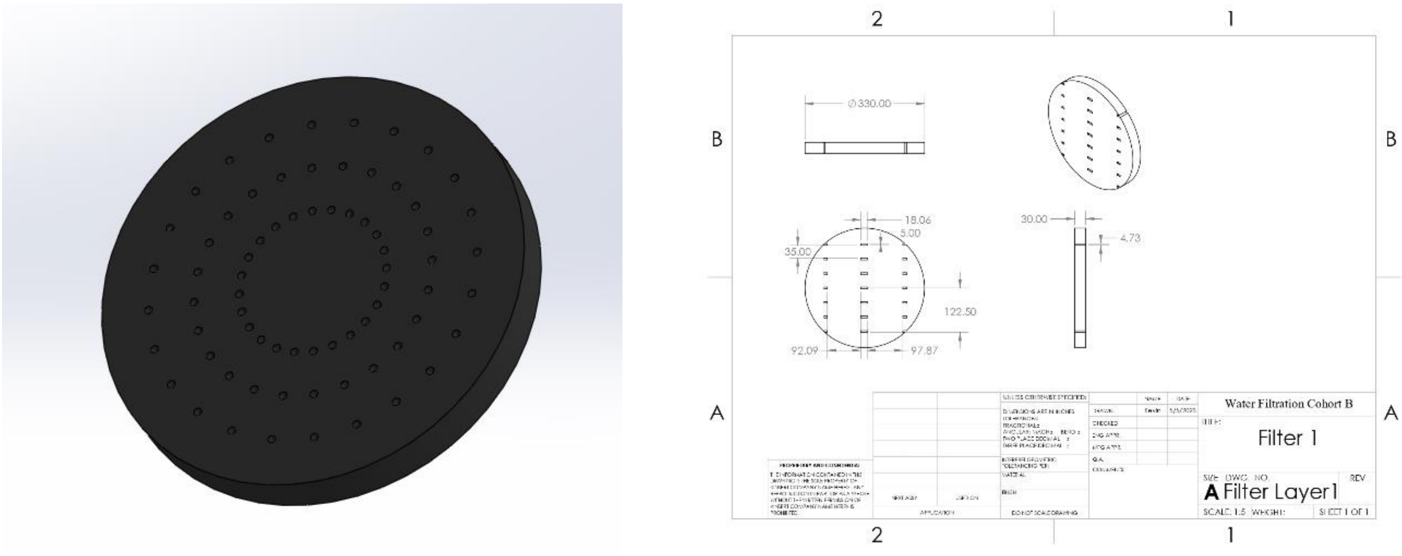


Figure 14: Filter CAD Model (left) and Technical Drawing (right)

The sand and charcoal filter in the water filtration system is designed to remove the impurities and particles present in the water, making it clearer and free from visible dirt. However, this filtration process alone does not purify the water to a completely safe and drinkable level. To achieve complete purification of the water, the partially permeable filter is used. This filter is designed to remove the remaining impurities and bacteria that may still be present in the water even after passing through the sand and charcoal filter.

The partially permeable filter works by allowing only clean water molecules to pass through its pores while trapping and removing any impurities, including bacteria and viruses. This ensures that the water is purified to a safe and drinkable level, free from any harmful contaminants.

Therefore, while the sand and charcoal filter is crucial in removing visible dirt and impurities, it is the partially permeable filter that completes the purification process, making the water safe for consumption.

3.1.4 The Tap and Tap Cover

Figure 15: Tap and Tap Cover CAD models

The tap plays a crucial role in regulating the flow of water from one compartment to another. It allows the water to move at a steady pace, ensuring that each compartment has enough time to carry out its purification function effectively. The cap on the tap also serves a crucial purpose in maintaining the flow of water during the filtration process. It allows the water to continue flowing when necessary, ensuring that the filtration process remains uninterrupted.

During the coagulation process, the tap is closed to prevent the movement of water as the dirt settles at the bottom of the tank. Once the dirt has settled, the tap is opened, and the water is decanted out of the tank. The remaining less dirty water then continues to be thoroughly filtered through the sand and charcoal filter until it reaches the partially permeable filter. This ensures that the water undergoes a thorough purification process, with each compartment playing its role effectively.

3.1.5 The Collecting Can

After the water has undergone the purification process in the water filtration system, the clean and purified water is collected in a separate compartment, ready for use or storage. This compartment is the final stage in the water filtration system, where the purified water is stored before being collected by stakeholders.

The purified water collected in this compartment is free from any impurities, bacteria, or viruses that may be harmful to human health. This water can be used for various purposes, such as drinking, cooking, washing, and irrigation. The importance of the tap and cap in regulating the flow of water is critical at this stage, ensuring that the purified water is collected without any risk of contamination. The tap and cap work together to maintain the flow of the purified water, while also preventing any external contaminants from entering the system.

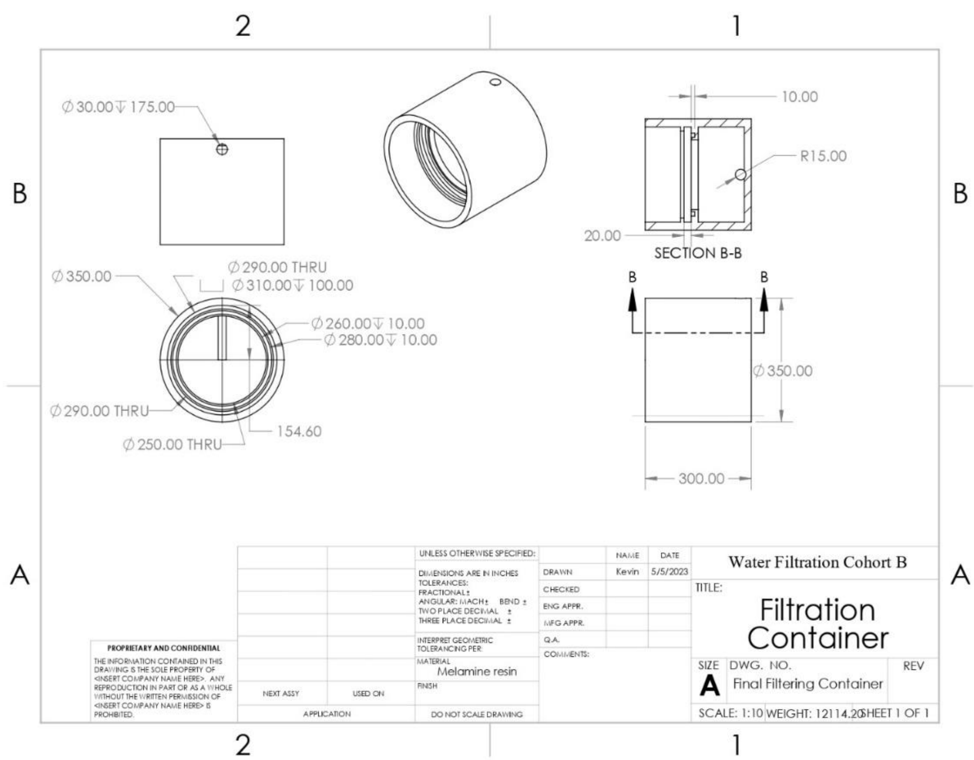


Figure 16: Technical Drawing of a Filter Container

3.2 Simulations

For the testing and simulation procedure we took each subsystem of the filtration process starting with the first container as shown below:

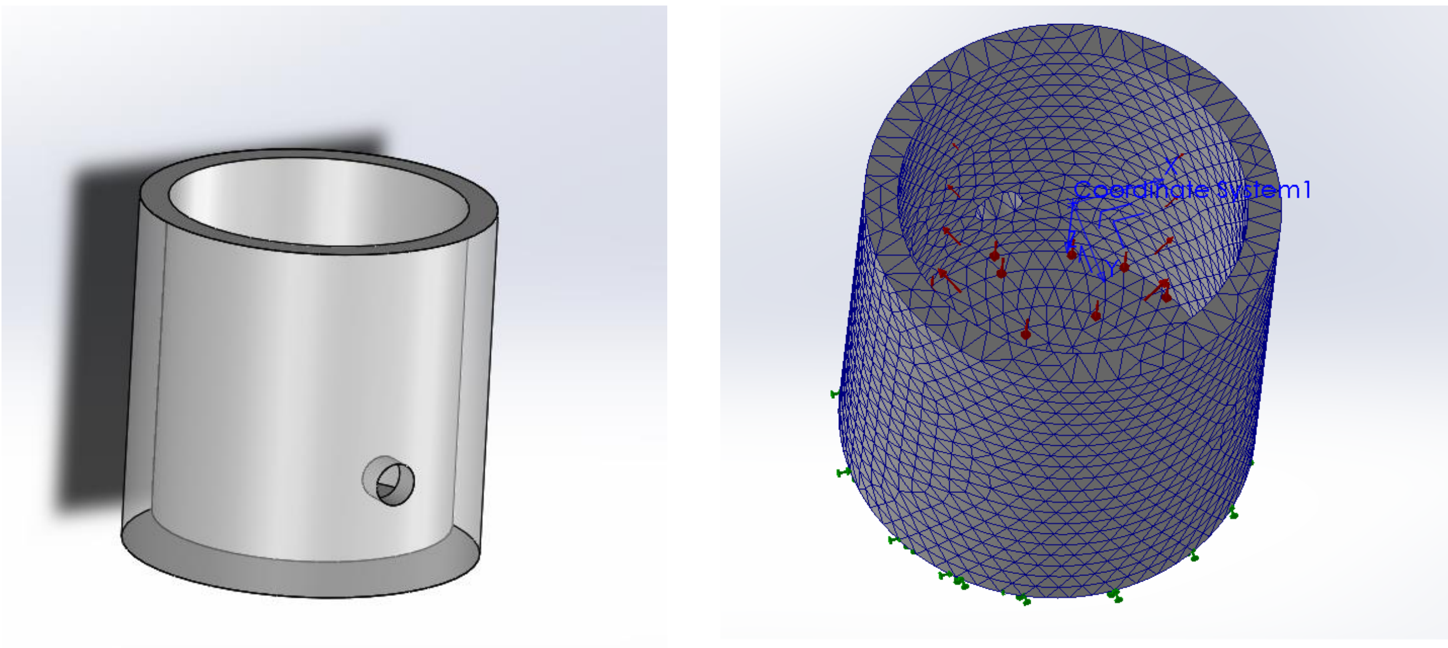


Figure 17: Coagulation Container (left) and Mesh of coagulation container(right)

Using the material melamine resin as the base material for the container the results of applying water pressure are shown below:

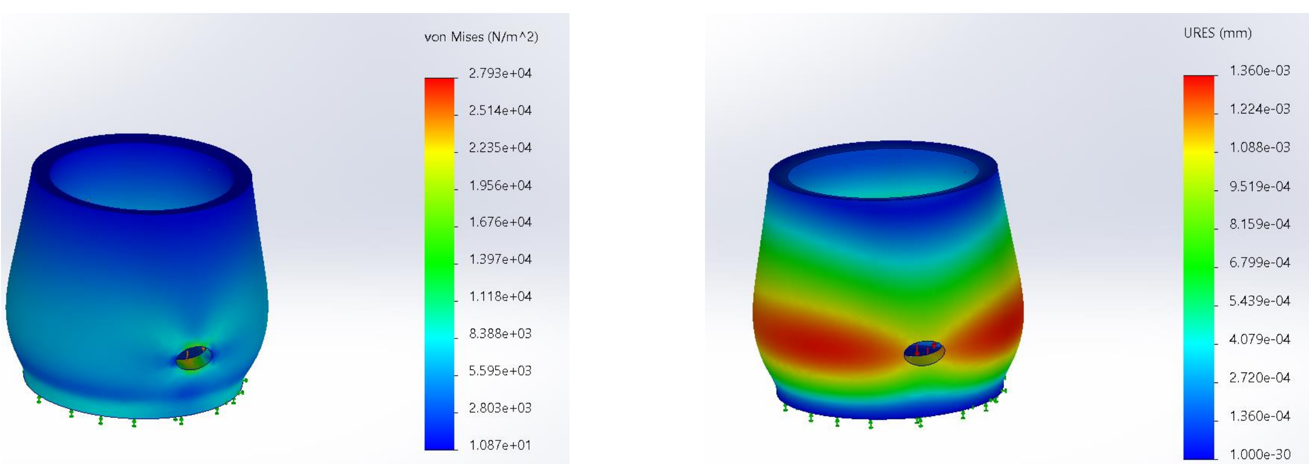


Figure 18: Maximum stress simulation (left) and maximum displacement simulation result (right)

The simulation results showed an expanded bottom proving the principle of pressure increasing with depth which meant the bottom half of the container would require strenghtening to withstand excessive pressure. AISI 1020 steel was the material we chose for the platform and the following figures show the simulation process and results:

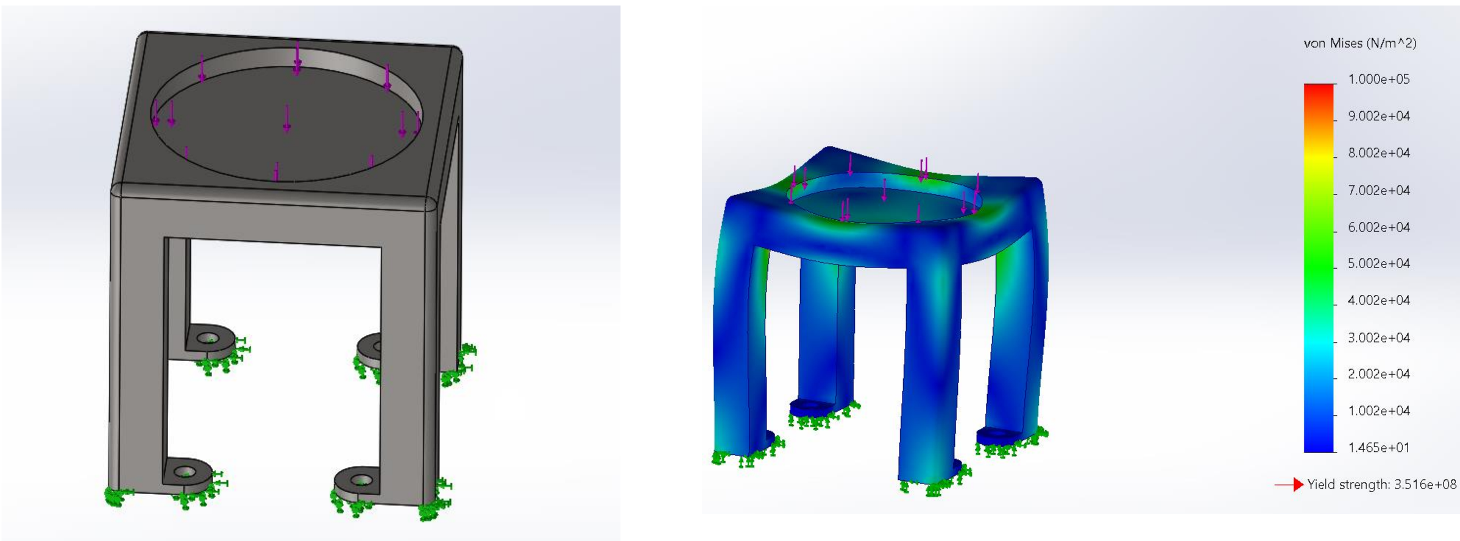


Figure 19: Coagulation unit stand with a force of 100N applied & maximum stress simulation result.

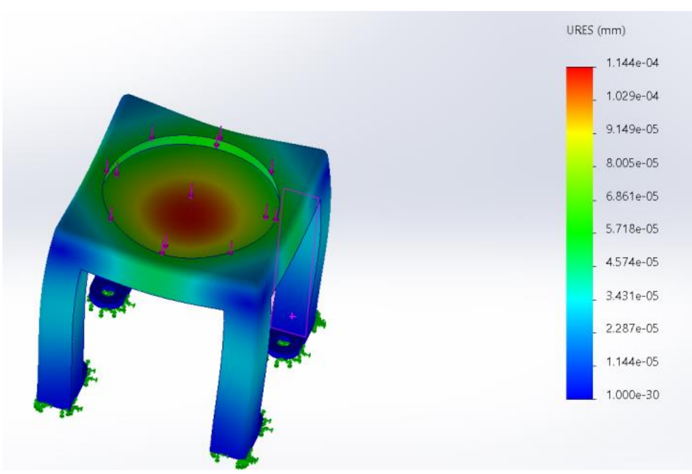
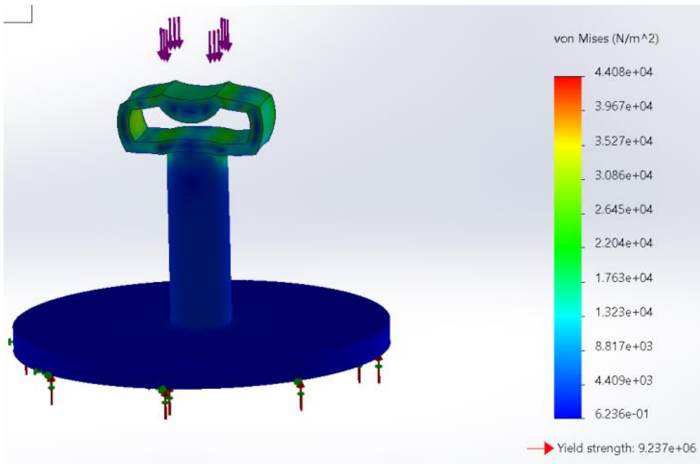


Figure 20: Maximum displacement simulation result.

From the simulation results, the stand required extra support to prevent further deformation over time which we considered when fabricating. The plunger for applying force to the water in the second container therefore increasing the filtration rate was to be made of rubber. The following figures show the simulation procedure for this subsystem:



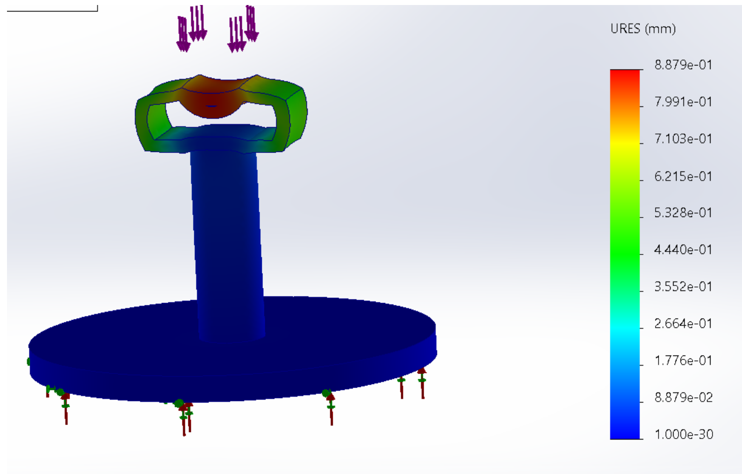
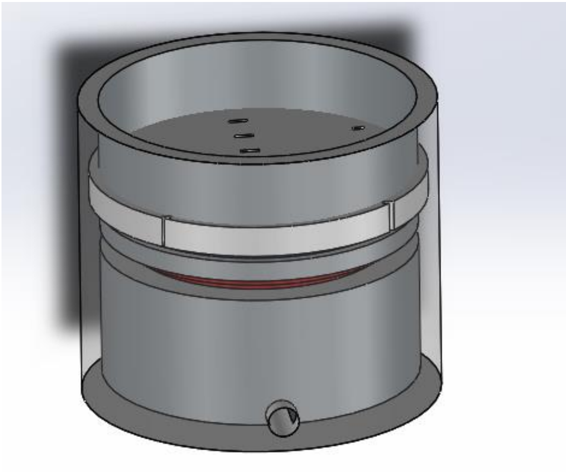
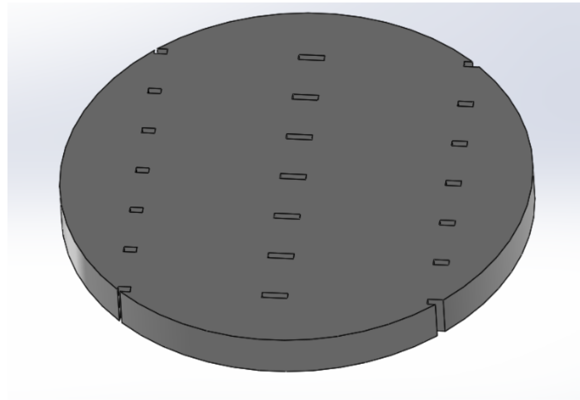


Figure 21: Plunger for force application (left) and Maximum stress simulation result (right)

Maximum displacement simulation result.

The results for this showed the need to strengthen the handle of the plunger to reduce the deformation effect and increase its lifespan. The final filtration container consisted of two filtration layers which are shown in the images below:

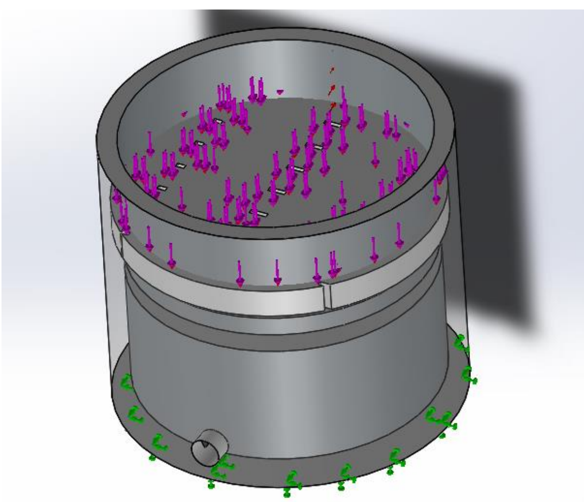


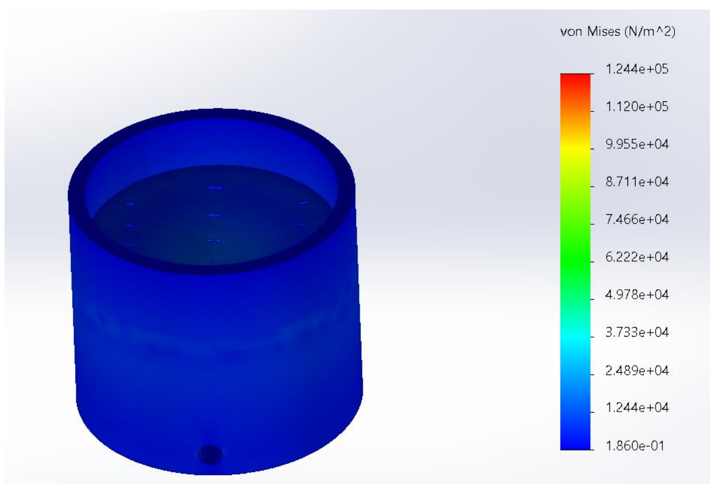


Filter arrangement in final filtration container.

Filter Layer 1.

This is the first filter layer made of rubber which will hold the gravel and activated charcoal. Below are the simulation results using the required loads:





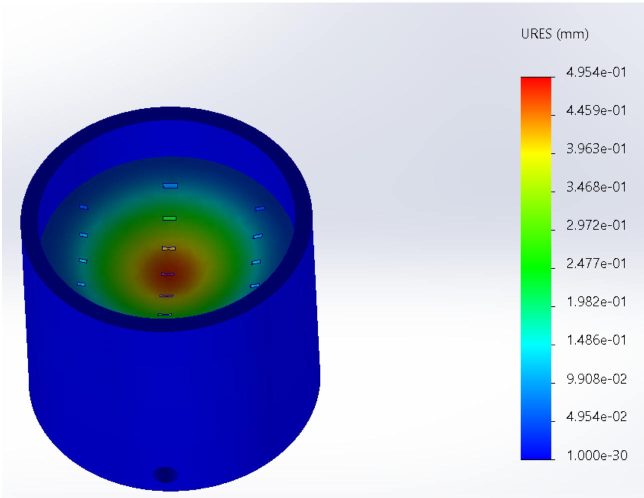


Figure 23: Applied Forces and Fixtures on Filter Layer 1 and Maximum Stress Simulation Result

Maximum displacement simulation result.

From the results filter 1 was going to be adequate until it wore out over time and had to be replaced. For filter 2, a similar procedure like that of filter 1 was applied which is shown below:

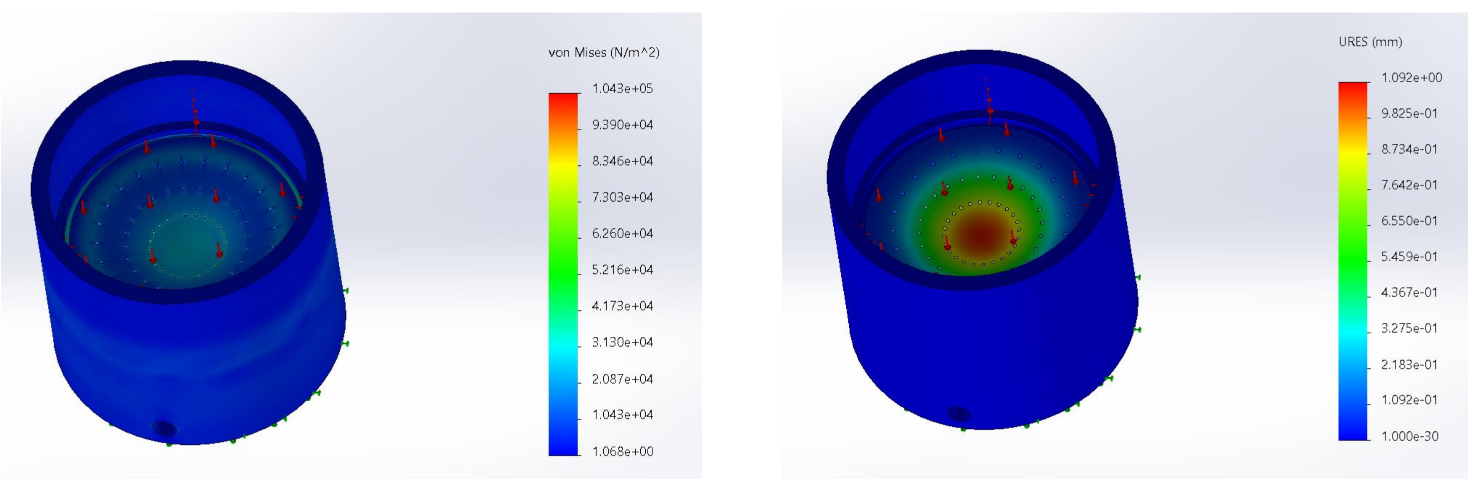


Figure 24: Filter Layer Compartments under stress tests

Filter Layer 2.

The results for the second filter layer show depression as a result of water pressure on the rubber. Strengthening the rubber by increasing its width will help reduce this depression and deformation.

The final part had to do with the final containment unit in which the filtration occurs. The following figures show the simulation process and results:

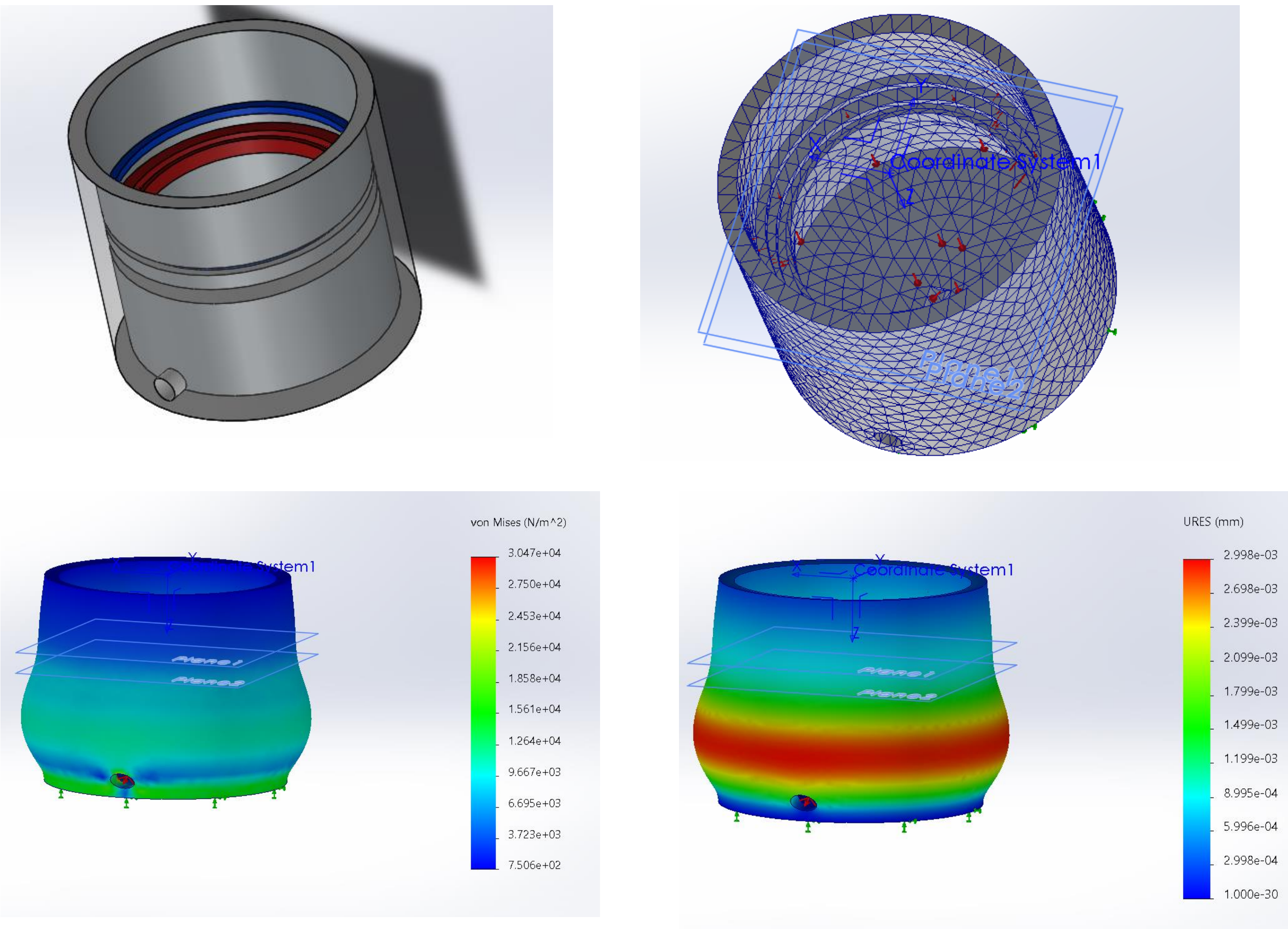


Figure 25: Final Container Compartment Stress Simulation

Final container module.

The simulation results for the final filtration container showed a decreased support at the base just like in the coagulation unit. With these simulation results, we were able to manufacture and fabricate the system using available resources such as metals sheets and using 3d printing techniques to obtain a perfect base for the filtering containers. The images below show the different parts that were fabricated and the final assembly of the pieces.

3D printed coagulation unit

3D printed filter layer 1

3D printed filter layer 2

Final model assembly of fabricated pieces

Conclusion

After assembling and testing the system for our proxy users we got the following as feedback from them:

1. The rate of filtration could be improved to decrease the waiting time for filtered water.
2. The filtered water looked clean compared to the original water source.

This project has been a very informative learning experience. We have learned a lot about the intricacies of project development. We have been through the processes of problem identification and framing to ideation and prototyping and finally on building and testing. Along the processes of this project's development, we had to learn how to obtain information at the start at the same time build up trust amongst ourselves. We had a few miscommunication issues with some of our processes which brought some confusion at one point but eventually this was settled through subsequent meetings as a team.

We learned the essence of teambuilding in the development of a successful project and on learning outside of the things we know as aspiring engineers. With these lessons we were able to finish this project on time amidst the challenges we encountered such as the lack of the required resources for building. All of the lessons we have learned so far will help in our final projects which will have focuses on different fields of society both to help and develop.

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