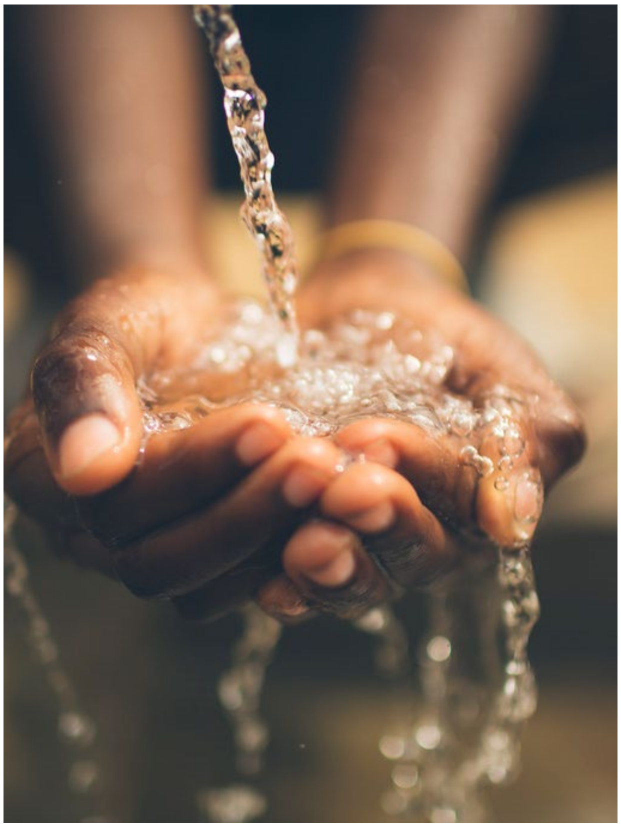

ENGINEERING DESIGN 2021

"Identify a need in a developing country, and design a project that will enable that community to fulfill that need"

ABSTRACT

The global water crisis is growing in magnitude, becoming a looming threat to many communities around the world. This project seeks to propose and expand upon solutions to bring clean water to impoverished communities in the Democratic Republic of the Congo. The goal is to improve upon the quality and availability of drinking water. After deliberation, it was decided that a system comprised of a modified centrifugal pump, underground piping, and a gravity-based filtration tank utilizing the rivers of the DRC would be the most effective at providing safe drinking water to the peoples and communities in need.

TEAM 2082-1

2021 NATIONAL TSA VIRTUAL CONFERENCE

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IDENTIFICATION AND DEFINITION OF PROBLEM

The design challenge for the 2021 National TSA Conference is “to identify a need in a developing country and design a project that will enable that community to fulfill that need”. With the goal of providing large-scale, constant access to basic necessities, our focus was centered on addressing the most prevalent crisis. According to Maslow’s hierarchy of human needs, humans’ physiological and biological needs must be satisfied first before social- and esteem-related goals are pursued. The four essential physiological needs are food, air, water, and shelter – without these, the body cannot function optimally. Naturally, these physiological needs must be prioritized when selecting a problem to address within a developing community.

Out of the four needs above, fulfilling the need for clean water certainly has the most widespread impact. Aside from being essential to public health, clean drinking water provides societal benefits that extend far beyond basic nutrition. According to the World Health Organization, steady access to drinking water paves the way for economic prosperity by relieving financial burdens and eliminating the need for long and risky journeys to collect water. Furthermore, water’s usage in sanitation makes it vital to maintaining good health within a community; specifically, it reduces the transmission of waterborne diseases, including cholera, diarrhea, and typhoid. Through this line of reasoning, we focused our solution towards making clean water accessible to those suffering from the global water crisis.

The United Nations loosely classifies ‘developing countries’ as those with sub-standard economic conditions. Although there is no consensus on which countries are developing countries, nations with large sectors of their population lacking a basic human need are easy to identify. After researching a range of economically deficient countries whose populations suffer from a disproportionate lack of access to an adequate water supply, our team chose to tackle the water crisis in the Democratic Republic of Congo (DRC). Not only is the DRC the second largest country in Africa, but it is also among the most affected by the water crisis despite it being the continent’s most water-rich country. The Water Project, a non-profit dedicated to making clean water accessible in impoverished communities, found that since the Second Congo War in the early 21st century, most Congolese died from diseases and complications connected to lack of clean water. Despite numerous attempts to address the DRC’s water crisis, including structural and governmental reforms, a lack of financial initiative has hindered significant progress.

Furthermore, the population of the DRC faces a unique set of sociopolitical and gender inequalities that make it an excellent empowerment candidate. Though the DRC was our project’s community of focus, while designing a solution we gave great consideration to versatility so that it could be employed in other communities, not just limited to the DRC. With the consideration that the aforementioned issues are most severe in rural areas, we reframed the theme into a design challenge, written below:

“How can we make clean water accessible to rural communities in the Democratic Republic of Congo?”

INFORMATION GATHERING & EXPLANATION OF IMPORTANCE

The Democratic Republic of Congo is home to 101 million people, making it the third most populous country in Africa and 13th in the World. At first glance, it seems counter-intuitive that the DRC would lack clean drinking water. It is by far Africa's most water-rich country, with rivers and lakes comprising 3.5% of its surface area. Impressively, one river dominates the water supply: the Congo River. The Congo River and its river basin account for 98% of the DRC's surface area, providing an incredibly extensive river network.

Despite this, the Democratic Republic of Congo finds itself at the epicenter of a worsening water crisis. In fact, according to UNICEF, following international sanitation efforts, only 52% of the population gained access to an "improved water source", and an even smaller 29% has access to "improved sanitation facilities". In rural areas, 33 million people – 71% of the DRC's rural population – lack access to the barest minimum standard of water. These people must get their drinking water from streams and other open-air water sources. The situation is so dire that the UN Environmental Programme described one such river, the Gombe, as "effectively little more than open sewers".

For Congolese, clean drinking water is impossibly expensive. A whopping 71.34% of the population live in extreme poverty, a number far higher than many of the DRC's neighbors. Much of the clean drinking water comes in the form of plastic water bottles. Pollution aside, the 1 USD cost per bottle is simply unaffordable for the average Congolese that makes 2 USD a day.

Furthermore, the DRC's deteriorating water infrastructure is being exacerbated by underinvestment and social conflict. The government does not have the resources to renovate their infrastructure, instead relying on rusting, decrepit pipes. This has led to many health issues caused by drinking contaminated water, including malnutrition, Ebola, cholera, diarrhea, and typhoid. Water related complications also contribute to the DRC's 8.48% child mortality rate. In fact, more Congolese died from lack of clean water related causes than any other factor since the end of Africa's First World War in 1998. These issues will unfortunately only increase in magnitude as the DRC experiences a rapid 4% annual population growth.

The destruction of the DRC's infrastructure is in a large part due to the conflicts referred to as the First Congo War and Second Congo War. In 1994, tensions between ethnic groups in neighboring Rwanda erupted into a genocidal conflict, resulting in 2 million refugees flooding into the DRC. Rwanda, whose government had been overthrown, invaded the DRC and took over the government. Following this, Ugandan and Rwandan coalition forces invaded the country once again, but this time, neighboring countries aided the DRC, allowing for UN peacekeeping intervention and the stabilization of the DRC's government. Since then, the DRC's infrastructure has never recovered, with its structurally weak water governance lagging severely behind the standards of other low-income countries.

Indeed, the Democratic Republic of the Congo's water crisis was sparked largely by its conflicts with neighboring countries. The conflicts led to many Congolese to suffering the plight of severe poverty and the destruction of its water infrastructure, and the crisis continues on due to the lack of government attention and investments to fix the problem. However, the abundance of water in the country proves to be a significant geographic advantage that can and must be utilized to solve its water crisis. Making clean drinking water accessible to the DRC's rural areas must be a humanitarian priority.

PHOTOGRAPHS OF THE PROTOTYPE/MODEL

Given the pervasiveness and seriousness of the water crisis in the DRC, an engineered solution would tackle the following three issues within the provision of clean water to rural areas: collecting a sufficient water supply, distributing it from the principal source to the communities, and ridding it of harmful contaminants. Our forefront solution (see Page 8) addresses these three obstacles with a modified centrifugal diffuser pump, an underground network of HDPE piping, and a storage tank with a built-in gravitational sediment filter respectively. The HDPE piping was excluded from the modeling process since manufacturers regularly mass-produce them, leaving the pump and filtration tank for us to model.

Due to time and resource limitations, accurate models of the modified centrifugal pump and water tank could not be built and tested. However, we developed a realistic prototype of both these systems using computer-aided design (see Fig. 1 & 2).

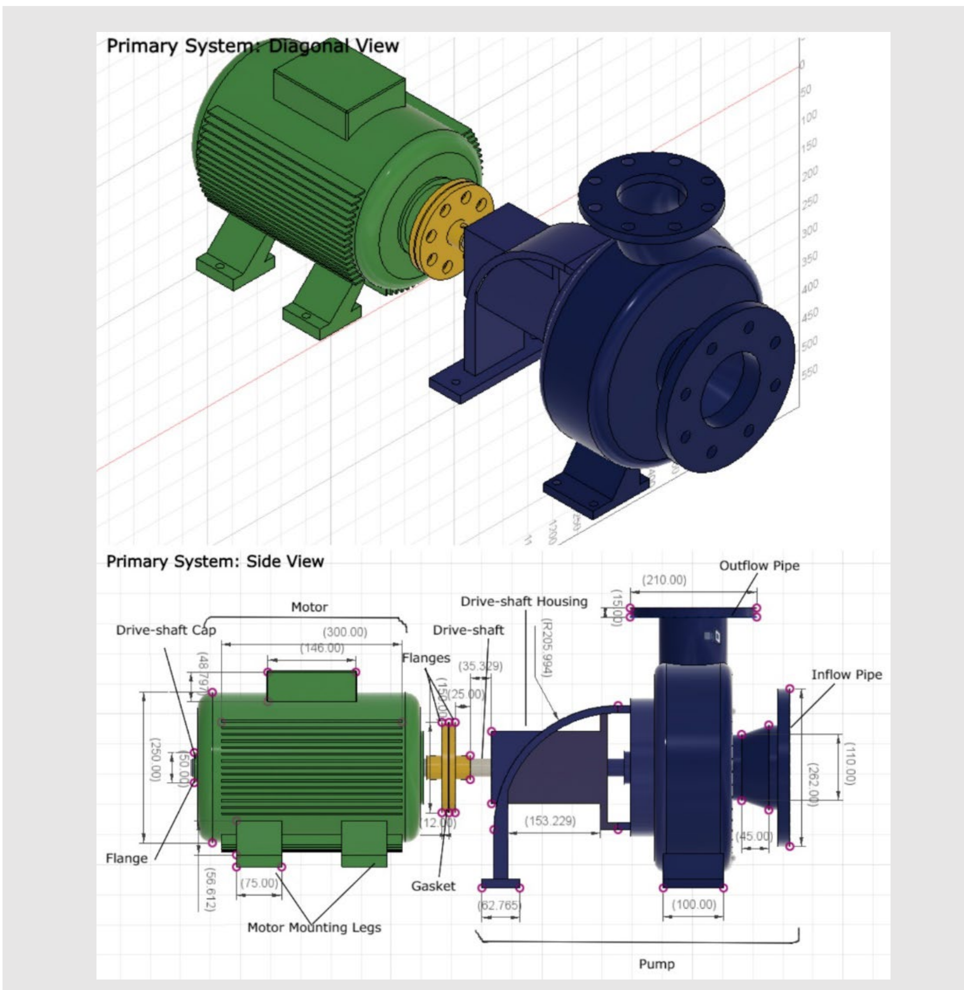

Fig.1: CDC's water collection system - the motor and the centrifugal diffuser pump - drawn using CAD and dimensioned in mm.

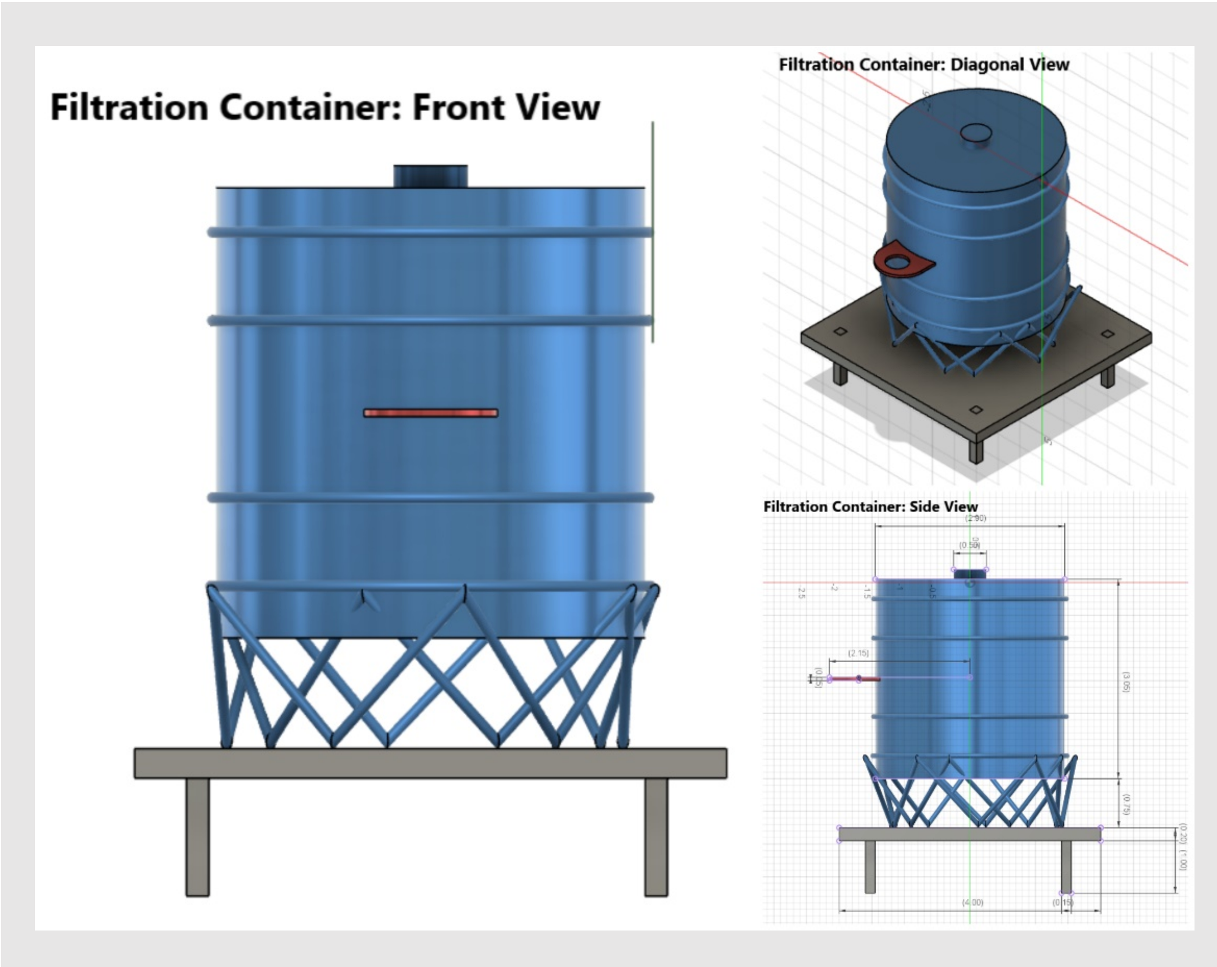

Fig. 2: 3-D CAD drawing of the water filtration tank.

Additional images of these prototypes, including cross-sectional perspectives, can be found on Pages 10-12.

Despite our logistical constraints, we sought a way to design, prototype, build, and iteratively test another component of our solution: the water filter. We began with a dimensioned technical drawing of the filter (see Fig. 3). We then used CAD to three-dimensionally model the filter (see Fig. 4). More images and further explanation of the filtration tank can be found on Page 8.

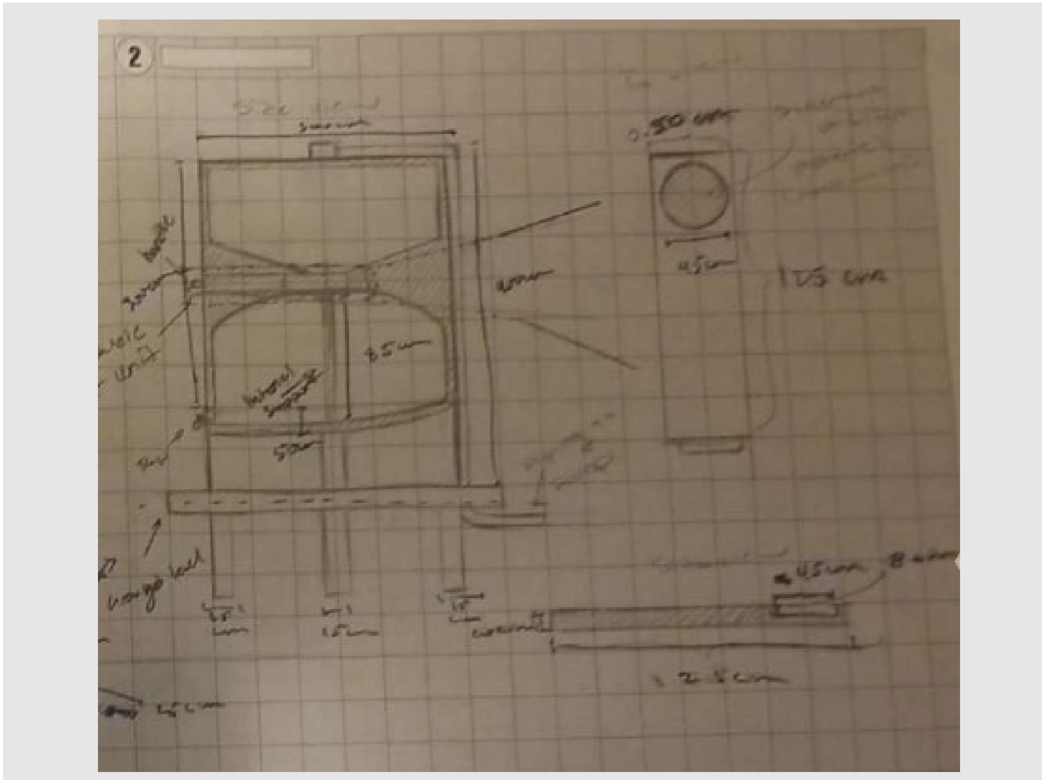

Fig. 3: Dimensioned and labeled technical drawing of the CDC's removable water filter.

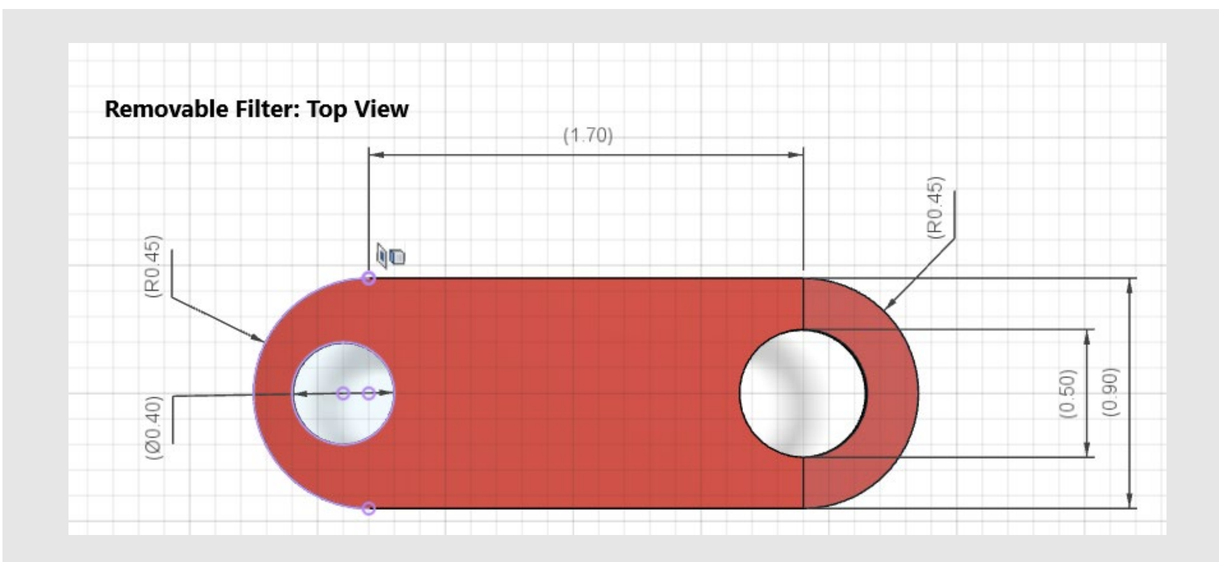

Fig. 4: 3-D model of the removable sediment filter.

Finally, we built and iteratively tested the filter method – a fine physical barrier – with a scaled down version of the water tank to visualize the filtration process (see Fig. 5).

Fig. 5: Images of the physical model of filter before (top) and after (bottom) filtration Trial #4. Filtered roughly 70% of sediments from the murky water sample, leaving relatively clean and clear water.

SOLUTION #1: “BABYLON”

Our first proposal to the Congo Water Crisis does not require advanced technology but does require implementation on a large scale. A large area of land will be modified to have regular sloped indentations into the soil. The indentations would then be lined with a fabric that blocks dirt but still allows for the flow of water. Plastic perforated piping wrapped in the same fabric but with larger pores will be placed at the bottom of each divot. Then, layers of progressively larger particles of sediment, clay, silt, sand, and pebbles will be placed on top of the piping, before being covered the previously mentioned fabric and a layer of topsoil. Various plants and crops will be planted on the soil, holding it in place to prevent movement of the soil and the layers of filtration material. Taking inspiration from the ancient garden, this proposal was named “Babylon”.

Babylon takes advantage of the DRC’s high level of precipitation. Rainfall on the area of land covered by Babylon will be absorbed by the soil, before being directed by the slope of the indentations into the layers of sediment. The layers of sediment will use gravity filtration to remove most contaminants before flowing into the piping. The piping itself will be slightly angled, allowing water to flow in one direction towards an artificial underground reservoir near populations. The filtered water can then be pumped upwards via a traditional hand pump.

Common nylon septic filter fabric will be used to line the indentations and to cover the piping and sediments. This fabric is cheap, temperature resistant, water resistant, and filters soil, making it the ideal candidate. The piping will be made from high density polyethylene (HDPE). HDPE is resists heat and contamination and is very durable, minimizing the need for maintenance and maximizing lifespan. In addition, HDPE is recyclable, limiting environmental impact. Filter gravel will be used to filter the water, and each progressive layer from the surface will have finer particles to progressively remove contaminants and maximize water flow.

After an initial investment, Babylon maintains itself, and would require minimal inspections for it to function. It is easily scalable, as higher demand for water would only require more land area. However, the proposal is heavily dependent on regional rainfall. Should a location receive less precipitation or be experiencing a drought, Babylon would be unable to compensate for long periods of time, as storage capacity is not indefinite. However, in a country like the DRC where regular rainfall is expected, this issue is minimized. As such, Babylon remains a viable solution to the defined problem.

SOLUTION #2: CENTRIFUGAL DISTRIBUTOR AND CLEANSER

Our second proposal to address the Congo Water Crisis is a compound water transportation and purification system. The solution, named Centrifugal Distributor and Cleanser (CDC), is a system comprised of three components: a water collection pump, a transportation network, and a storage tank. Each individual component is not a standalone solution, but rather a cog in a collective system. A modified centrifugal pump redirects fast-flowing river water through piping that leads to large cylindrical tanks located in various rural communities. When the river water reaches the tank's capacity, intake is suspended via a volume-based pump activator. A filter composed of layers of fine sediments will filter the water via gravity. The water flows to a secondary storage container underneath, where communities will be able to access water via a tap.

The modified centrifugal pump leverages the enormous discharge rate of local rivers. Seeing as the Congo River has the second fastest rate of flow in the world, there is a tremendous opportunity to harness its hydropower in nearing communities. Periodically placed along river inlets, free-flow kinetic energy turbines encourage the direction to reach a modified centrifugal pump made of galvanized steel due to its durability and corrosion resistance. As the pump draws water perpendicularly from the inlet, the water creates a suction such that even more water is drawn in. Depending on the target community's proximity to the pump and demand for water, one pump may be enough to serve several communities.

From here, the water is pumped through high-density polyethylene (HDPE), a non-corrosive, cheap, and durable piping option. Unlike cross-linked polyethene (PEX), HDPE is recyclable, and it allows for welded joints, making it a more versatile and well-suited option overall. Aside from being flexible and cheap, HDPE is much more resistant to physical and environmental degradation such as corrosion, tears, and bursts.

Ultimately, the pipes deliver water to cylindrical storage tanks placed centrally within communities. The tank's volume ranges between 10-15 cubic meters depending on the community's size and water demands, will primarily be made of galvanized steel, for its reflective and sanitary qualities make it an excellent candidate for a long-lasting water container. Not only is the tank as a storage container for the community's water, but it is also the site at which purification will take place. A two-layered tank system will be used. The two tanks will be separated by a membrane of fine sediment, which will purify the water via gravity filtration. This membrane will need to be cleaned on a semi-regular basis. Furthermore, monochloramine (NH_2Cl), will serve as an optional disinfectant after filtration. The monochloramine takes the form of a dilute aqueous solution and can be added in the proper ration when the water level of the tank nears its capacity.

A drawback of the CDC is that the monochloramine solution must be replaced regularly as it depletes. Additionally, the storage tanks will need to be cleaned in monthly intervals. However, this is a much more preferrable inconvenience than the DRC's current means of procuring water. Additionally, the installation of pumps, piping, and tanks may impose a considerable upfront financial burden. Despite this, the CDC enables on-demand water consumption in an efficient, sanitary fashion, and is well-deserving of heavy consideration.

SOLUTION #3: "HERMES"

Our third and final proposal to tackle the Congo Water Crisis would both develop the Congo's infrastructure and increase access to water on a large scale. Nicknamed "Hermes" after the Greek god of travel, the system uses square slabs of gravel to form contiguous roads. As water passes over the road slabs, it drops through small pores to an underground collection system. These pores function similarly to a colander, in that they collect larger particles such as sediments through gravity but allow the smaller liquid particles to pass through. Under the ground, pipes will then receive the water and transport it to an underground container in individual communities. This container has a small compartment for pre-packaged chlorine, which is used to kill off any remaining bacteria in the water. People in the communities can now operate a hand pump or tap to access the water.

The system capitalizes on the geographic advantages of the DRC, including the high average of 42 inches of annual precipitation. The high amount of rainwater that falls is currently not collected or utilized in any meaningful, systemic fashion, but has great potential to alleviate the burden of the current water crisis. Rainwater itself is clean and drinkable, but sediments from riverbanks could easily seep into the water. To deal with this, the system leverages the depth of the underground piping component. The underground piping system allows for gravity to act as a force to separate sediments from the rainwater as they fall through the pores in the road. After the water has passed through the pipes and arrives at individual communities, the rainwater may still contain some bacteria, so a safe amount of chlorine proportional to the quantity of water in the storage container is applied to ensure that the water is clean and drinkable.

The two most important factors to be considered in this solution is the effect of water on the road material and the cost of the road material. To best address both of these, gravel is selected the road material. Unlike asphalt or concrete, gravel allows water to easily seep into the ground without causing the road to crack or be damaged. Gravel also contains small holes through which water may seep into the underground system, removing the need for more expensive permeable pavement that would be necessary with an asphalt or concrete road. Gravel is both installed and maintained more quickly than its alternatives, with the roads being usable a week after initial installation and the maintenance only requiring more gravel be added to the road. The road itself is easily maintained as individual slabs of gravel are easily taken and replaced when they begin to deteriorate. Gravel roads are also less than half the cost of paved ones, meaning the entire system would be much more cost-efficient with gravel. Gravel's disadvantages, which include snow/ice maintenance and dusty roads, are all non-important in the hot and wet Congolese climate. Thus, gravel's advantages align best with the requirements of the road material for the system to function properly, and its disadvantages are either negligible or nonexistent in the Congolese environment.

When compared to many of its low-income neighbors, Congolese road infrastructure lags significantly behind. There is only 1 km of paved road per 1000 km^2 of land, and only 14 km of unpaved road per 1000 km^2 of land, compared to 16 km and 68 km in other low-income countries, respectively. The Hermes system is beneficial beyond just improving water accessibility, as it develops this infrastructure across the country, connecting rural towns to the capital city of Kinshasa. It would even benefit the economy, as 30% of businesses identify the lack of road infrastructure as a major business constraint. However, Congolese citizens mostly travel through waterways and may not be as eager to give up this mode of transportation for roads. Overall, Hermes would creatively provide solutions to lagging road infrastructure, the Congolese water crisis, and boost the economy, taking advantage of what the country already has and building on it with a simple and effective system.

MODEL & PROTOTYPE OF MOST PLAUSIBLE SOLUTION

After assessing our three proposals - Babylon, Centrifugal Distributor and Cleanser (CDC), and Hermes – we concluded that CDC was the most plausible and efficient of the three. Our consensus weighed scalability with economic feasibility, effectiveness, and environmental consciousness. CDC excelled in these four aspects, and it could be implemented on a broad scale and in a variety of locations – not just the DRC.

The CDC's water distribution and purification process (see Fig. 6) allows for the fast, efficient movement of water while storing and decontaminating it simultaneously. Unlike Babylon and Hermes, CDC works reliably and mechanically, making it a much more sustainable and consistent means of water distribution.

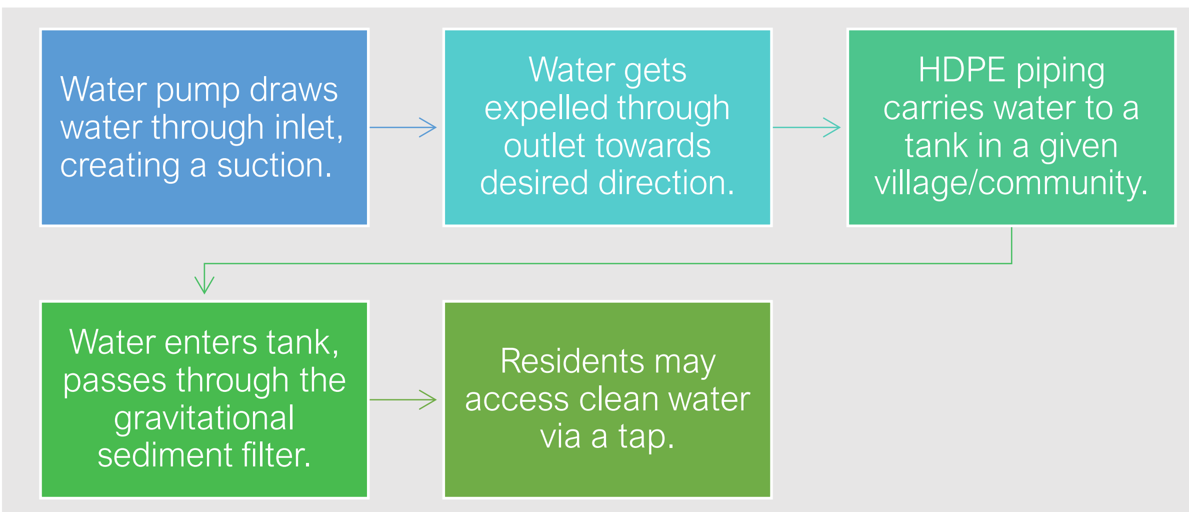

Fig. 6: Centrifugal Distributor and Cleanser solution mapped in a flowchart.

In order to produce accurate prototypes for this solution, two main components had to be designed and modeled: the collection system and the filtering storage unit. These two devices are connected via HDPE piping, so there was no need to redesign the pipes as they are already manufactured and produced regularly. Since the system (see Fig. 7) involves pumping the water through pipes, the two devices that needed to be modeled were the centrifugal diffuser pump and motor.

When designing the pump, we considered several modifications to improve its efficiency. Notably, its impeller that draws in water are designed as forward-curved mixed-flow blades (see Fig. 8). Additionally, the pump features diffusers, or stationary vanes positioned radially around the impeller. Moving water hits these diffusers, reducing internal turbulence by evenly distributing water around the chamber, increasing efficiency and minimizing mechanical strain on the pump. We modeled a cross-section of the pump to visualize this (see Fig. 9).

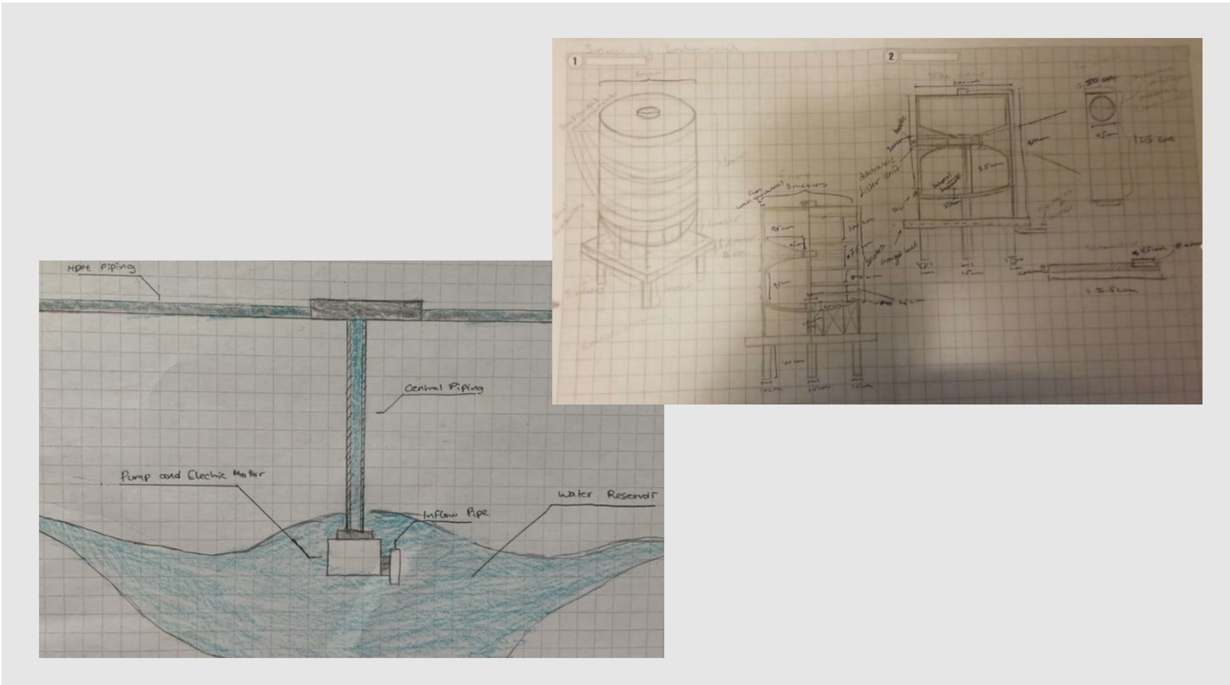

Fig. 7: Centrifugal Distributor and Cleanser's process visualized with a rough sketch/ engineering drawing.

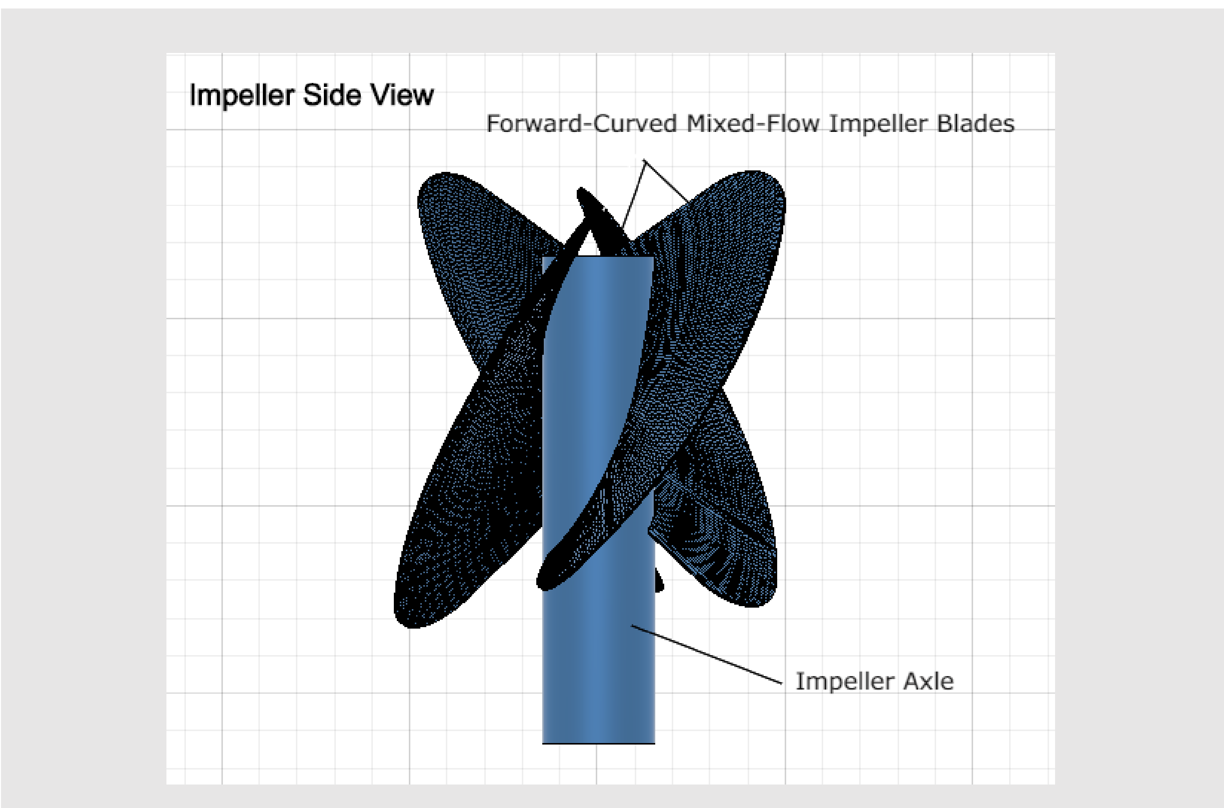

Fig. 8: CAD drawing of the impeller device on the CDC's modified centrifugal diffuser pump.

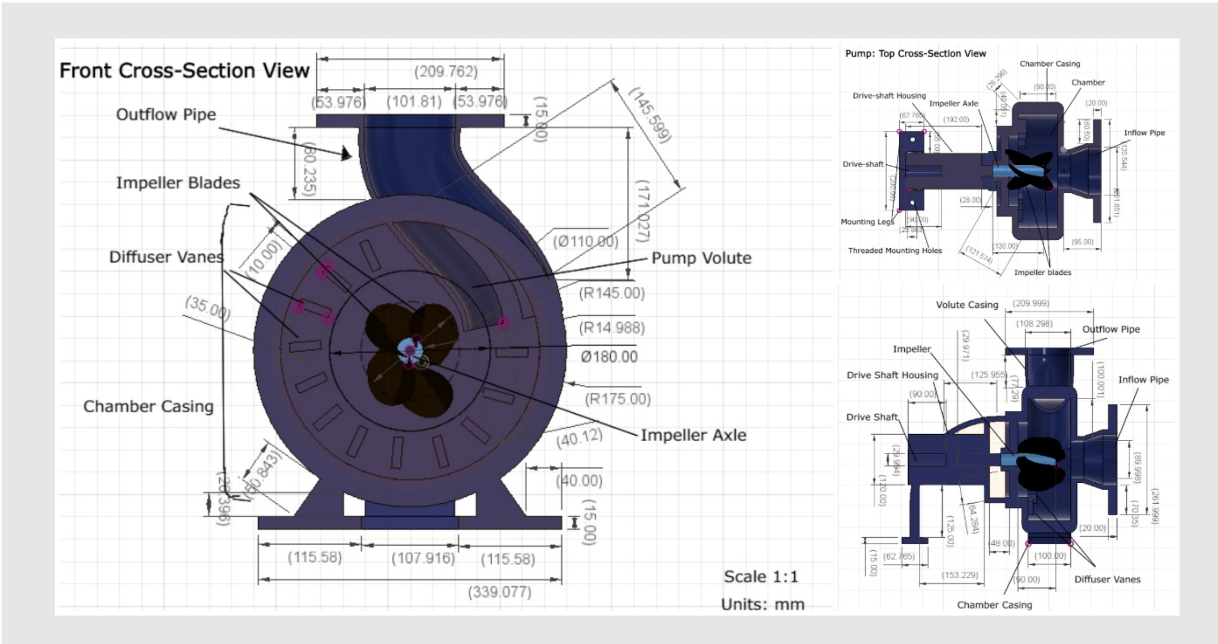

Fig. 9: Cross-sectional CAD drawing of the CDC's modified centrifugal diffuser pump.

After making these modifications, we were left with a completed pump (see Fig. 10) and, ultimately, a completed collection system (see Fig. 11).

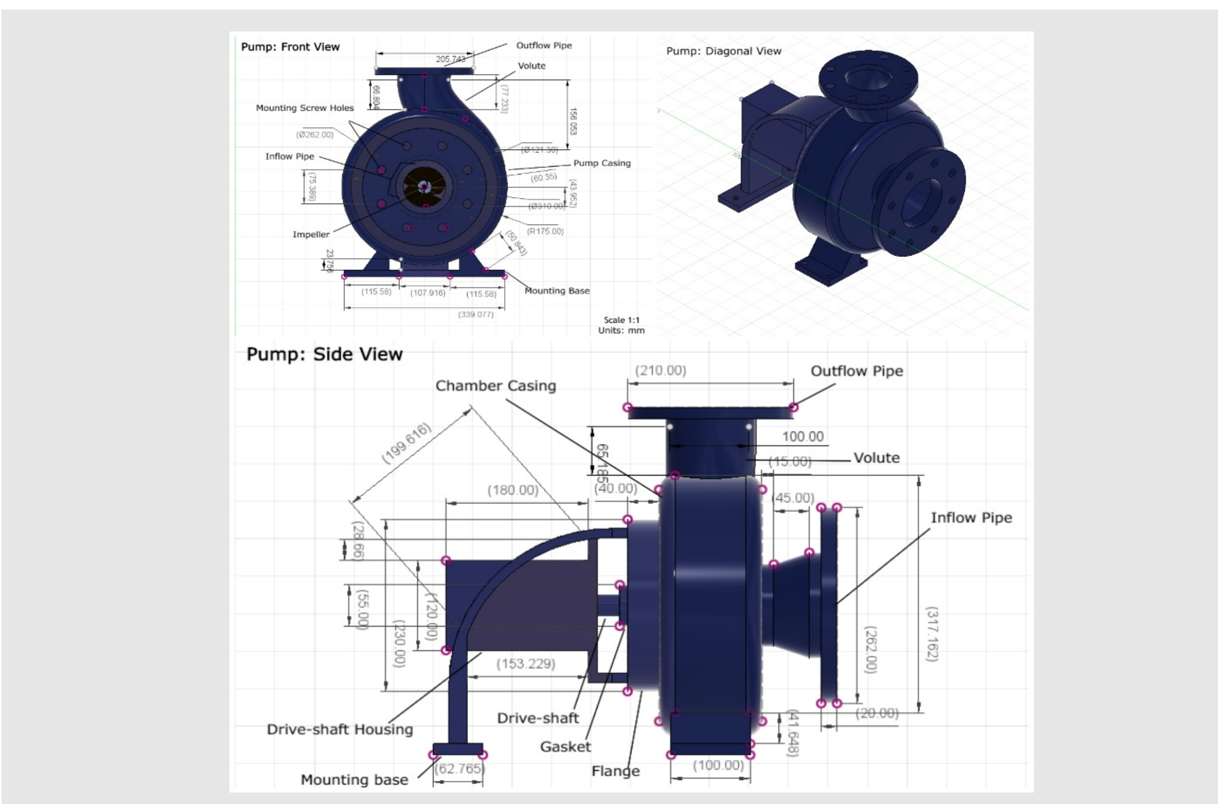

Fig. 10: CDC's modified centrifugal diffuser pump drawn using CAD and dimensioned in mm.

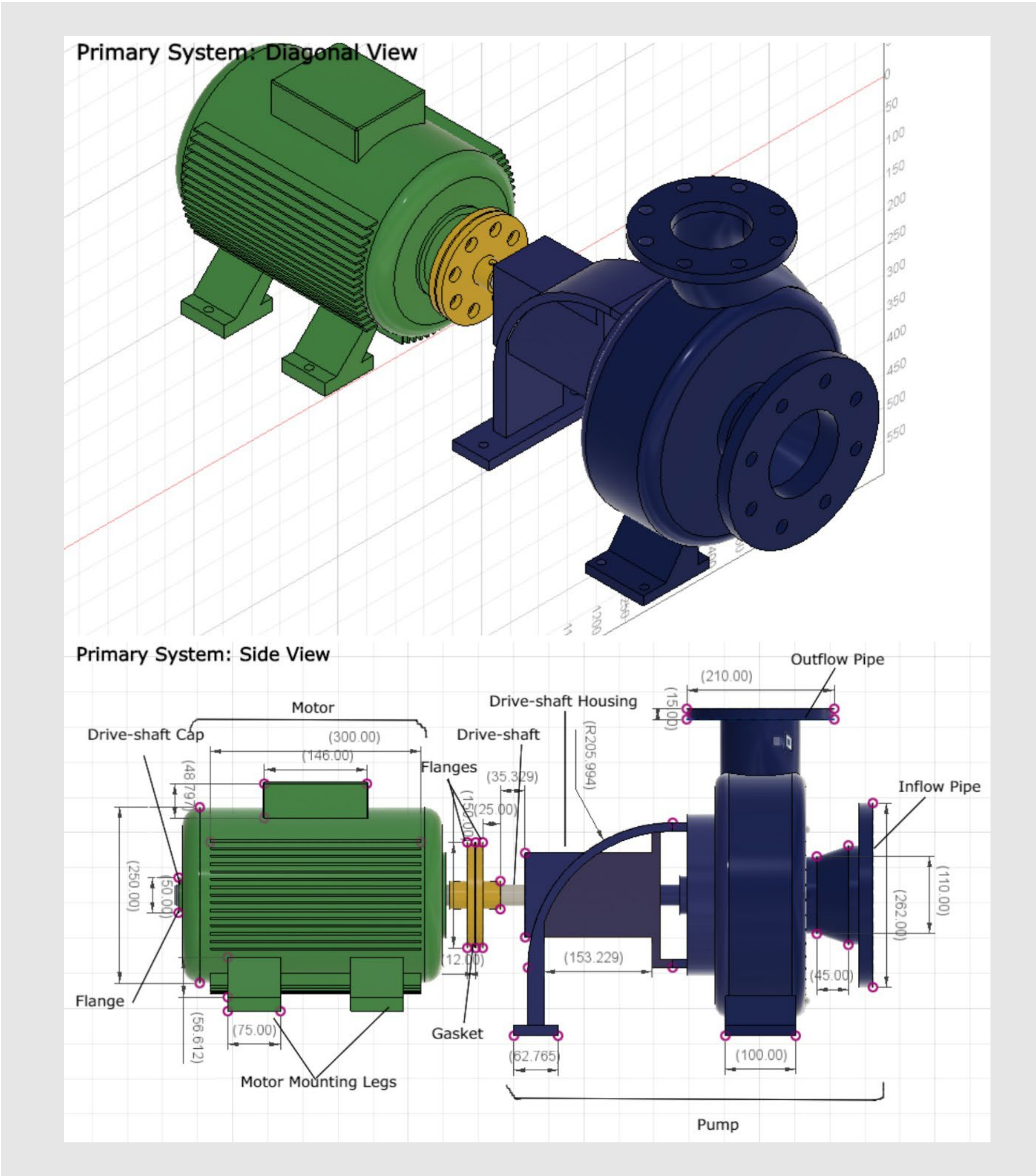

Fig. 11: CDC's complete water collection system - the motor and the centrifugal diffuser pump - drawn using CAD and dimensioned in mm.

Next, the filtration and storage unit had to be modeled. It features a removable filter that slides in and out of the tank itself (see Fig. 12). This way, community residents can easily clean out the sediment filter on a regular basis to ensure long-lasting purification.

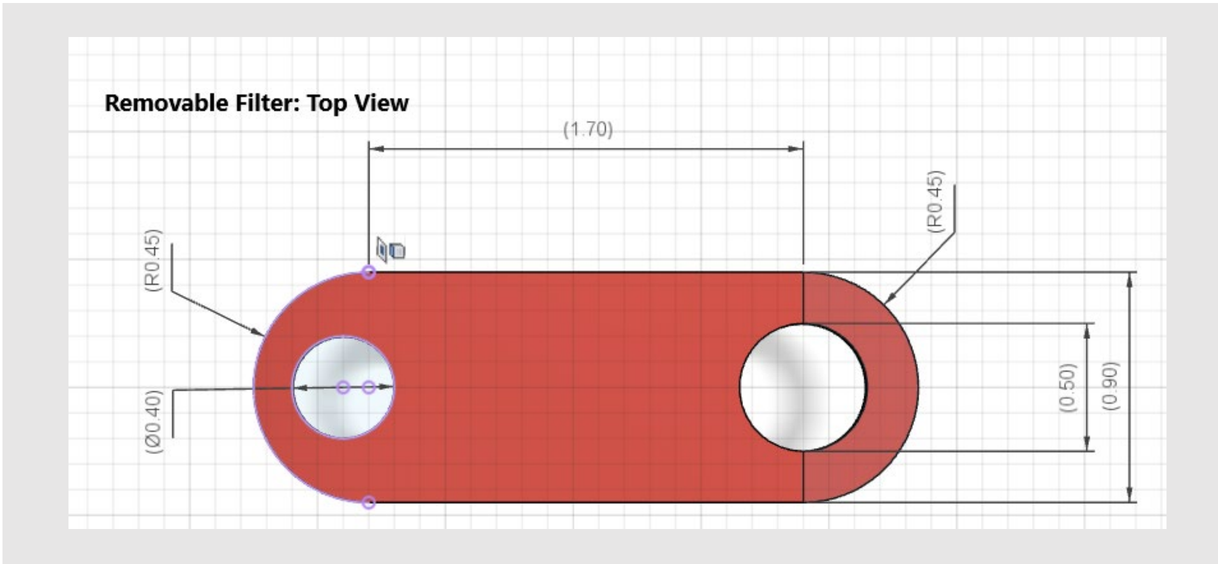

Fig. 12: Dimensioned CAD drawing of the CDC's removable sediment filter.

The tank itself rests on a flat platform, held up by an octagonal arrangement of diagonal supports. The legs under the platform are meant to be driven into the ground in order to ground the entire unit. We modeled and designed the tank using CAD (see Fig. 13) and used a funnel-shaped design that directs the water through the removable filter.

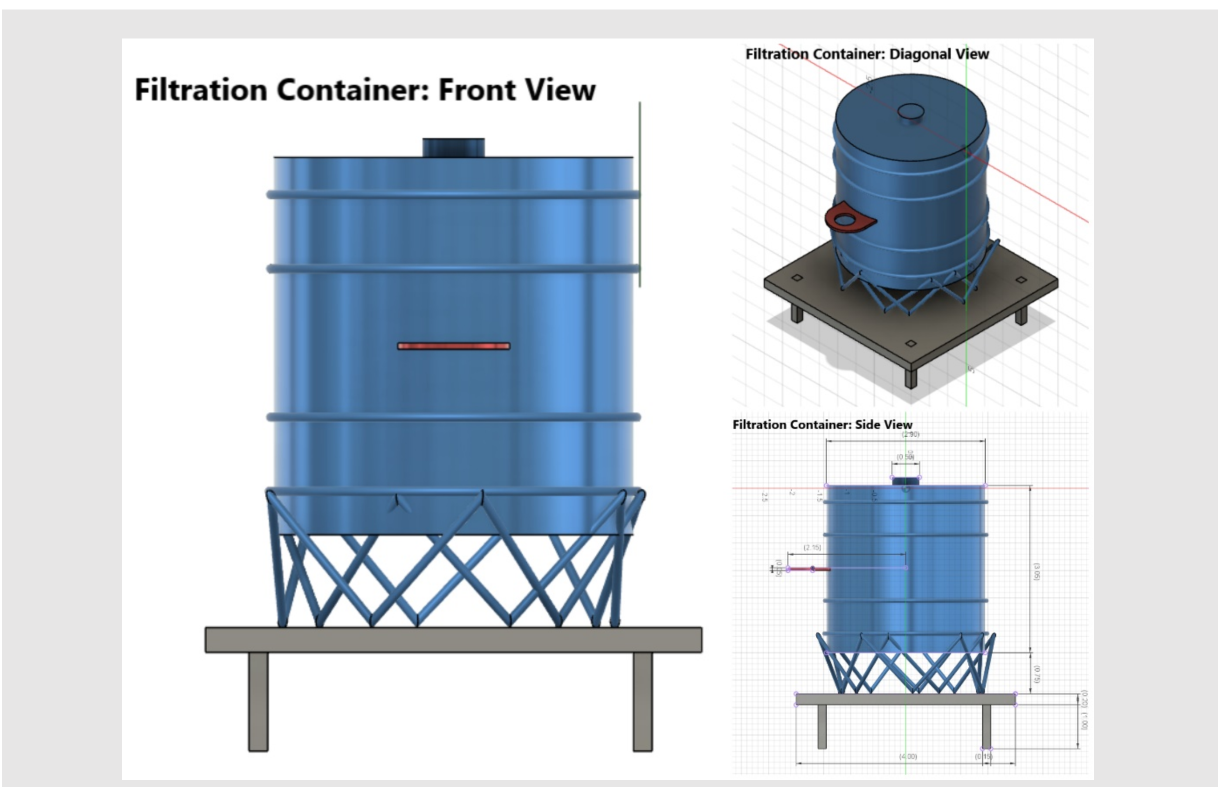

Fig. 13: CAD drawing of the CDC's water storage and filtration system – a filtering water tank.

SUMMARY OF ITERATION PROCESS

I. Means of Testing Solution

To evaluate the solution, three main areas need to be tested: the efficacy of the filter, effectiveness of the pump, and integrity of the tank and its supports. The first – that of the effectiveness of the filtration – is most easily tested. The procedure would be as follows:

Materials:

- Scaled down recreation of proposed filters
  - 500g filtration pebbles/gravel
  - Fabric layer
- 1 gallon of water
- 1 open - top rectangular plexiglass container with dimensions 50cm x 50cm x 5cm (Container A)
- 1 open-top bottom less plexiglass container with dimensions 50cm x 50cm x 5cm (Container B)
- Water-proof adhesive
- Stopwatch
- Scale

Procedure:

1) Attach the opening of Container A to the bottom of the filter.
2) Attach the bottom edge of Container B to the top of the filter.
3) Mix 5kg of dry dirt into the gallon water.
4) Pour water into top container and measure the time for the gallon to completely be filtered to measure water flow.
5) Detach the bottom container and apply flocculant to the water sample and wait for the sediments to settle.
6) Pour as much water out as possible without disturbing the particles and wait to dry.
7) Gather the dry sediments and measure its mass.

**The goal of this procedure is to see what percentage of sediments was successfully filtered. This could be ascertained by subtracting the resulting mass of sediments from 5 kg, then dividing the result by 5 kg.*

To test the effectiveness of the pumping mechanism, a simulated river environment would be best. We can quantify the efficacy of the pump thusly:

Materials:

- Water tank sloped at 15 degrees with dimensions 5 meters x 2 meters (Tank A)
- Water tank (open-topped) with dimensions 20cm x 20cm x 25cm (Tank B)
- Water
- Stopwatch
- Water piping
- Water pressure gauge
- Scaled prototype model of pumping mechanism

Procedure:

1) Secure model halfway down the slope of Tank A
2) Attach piping from model to Tank B and attach pressure gauge
3) Make a mark on an edge of Tank B 19cm from the bottom
4) Pour water from the higher edge of the tank
5) When the model activates, measure the time required to for water pumped to Tank B to reach the mark (this is how long it will take for the mechanism to pump 1 gallon of water)
6) Record highest instance of water pressure from water pressure gauge

By measuring the time necessary for the pump to transport 1 gallon, we can determine whether the design will provide adequate water flow. The water pressure reading will enable better understanding on the integrity of the system, and whether potential damage to pipping can occur due to high pressure, or whether the system will be able to transport water over longer distances.

Lastly, the best way to test whether the designed container would be able to hold the volume of water and the structural integrity of the supports would be through a scaled prototype. Once the prototype is created, simply bring fill the container to its maximum capacity with water before observing whether defects occur. The strength of the container itself as well as the integrity of its supports can be assessed through the following procedure:

Materials:

- Scaled prototype of water tank
- Water
- Stopwatch

Procedure:

1) Fill the tank up towards 50% capacity
2) Measure one (1) hour after Step #1
3) Observe and record all structural deficiencies.
4) Repeat steps 1-3 by filling the tank up to 80% and 100% capacity

*The goal of this procedure is to pinpoint vulnerabilities within the water tank itself and its supports

II. Reflection of Possible Refinements Based on Testing

Given that the apparatus can only be limitedly tested under the given circumstances, we will only be physically testing the filtration segment of the solution. However, there are a number of means by which we can improve upon all aspects of our solution. We can consider pre-existing drawbacks of both the materials and design, then assess the plausibility and effectiveness of modifications.

a. Hypothetical Testing and Refinements

The purification component of the Centrifugal Distributor and Cleanser relies on a gravity-based filtration system. While this is largely effective at separating and removing sediments from the water, it falls short in the lack of a way to filter bacteria, viruses, and heavy chemicals from the water. Because of this, many common water-borne diseases such as cholera and typhoid may continue to spread through the water. To remedy this, adding an automated system to dispense a small amount of chlorine proportional to the amount of water would help remove any remaining bacteria and viruses from the water and make it suitable for consumption. This system would function as part of the collection tank in communities, so pre-packaged chlorine would have to be added to a compartment and dispensed automatically based on the quantity of water contained in the tank - this could be accomplished using a simple water level activator, sensor, or manual release mechanism. An alternative to this would be to have chlorine coatings on the ends of the PEX pipes, though the amount of chlorine for this requires close monitoring to ensure that lethal levels are not reached, and that the water does not become toxic.

Despite the potential presence of bacteria in river water, our solution will not implement a release mechanism for chemical filtering agents to cut costs and material use. This is because, in the case of the DRC's Congo River, surface water has a "high dilution capacity" due to "vast areas having low population densities and human activities generally being of a low-input subsistence type" (United Nations Environment Programme, UNEP 2011). This means that river water from the Congo is naturally safe to drink when sediments are removed. However, if CDC were to be used as a solution to other nations' water crises, one of the aforementioned chlorine purification release mechanisms could easily be employed.

Another component of CDC that could be refined through rigorous testing is the centrifugal water pump. If our testing reveals underwhelming percentages of water intake, we must make refinements to the pump's design. We will enlarge the centrifuge and impeller of the pump, and naturally this will impel a larger volume of water at a greater rate. Additionally, adding diffusers, or stationary vanes around the pump's impeller reduces internal turbulence by evenly distributing water around the pump's chamber, ultimately increasing efficiency and minimizing mechanical strain on the pump. These diffusers also allow multiple paths for water to travel to the pump's outlet, allowing more axial symmetry than other pump types to evenly distribute pressure, a process that mitigates radial loads on the pump. Although this may require additional expenses, it is much more cost-efficient than simply installing more pumps along a given channel. Furthermore, the addition of an auxiliary control system could improve efficiency. Weights can be placed at the top of the central pipe– one at the top of the pump, and the other on the bottom – to gauge the water pressure. A small array of solar cells can be present at the surface to supply electrical energy to the pumps. If the water pressure is insufficient, the weight would drop, which would signal to the system to increase the kinetic energy of the pump to maintain water flow. The auxiliary control system will help to regulate this, water intake, and potential systemic maintenance using a computer program and water level and pressure gauges.

Finally, testing our solution may reveal a lack robustness in the water tank and its support structure, which we could refine. Our means of testing involves pinpointing structural deficiencies. Currently, our support system is comprised of diagonal support beams arranged in an octagonal fashion. Although this network of beams meets industry standards for architectural support, in the case it fails during the test described above, there is a simple method of refining it. First, we must observe the problematic joint or point at which the vulnerability exists. We can add more beams, employ a different geometric arrangement, or in the case of extreme failure, use a different, more robust metal.

b. Implemented Testing and Refinements

To test the effectiveness of the filtration, a modified version of the procedure listed under section I was used. We used simplified containers instead of the customized plexiglass containers, and two pints of water instead of one gallon. We also scaled down the volumes of filters by 1/5. All other aspects of the model were made to resemble those listed under the procedure. We performed five trials under this model, the results of which are shown in Table 1.

Trial Number	Percentage of Sediment Filtered (Only filtration pebbles)	Percentage of Sediment Filtered (w/ sediment layers)
1	51.3	78.3
2	48.4	91.6
3	46.9	79.1
4	49.7	67.9
5	48.3	78.7
Avg.	48.92	79.12

Table 1

Initially, we were not satisfied by the then effectiveness of the filtration. We decided to add several more layers of sediment comprising of washed sand and charcoal below the layer of filtration gravel. These layers served to physically obstruct more pollutants. This led to far more optimistic results (see rightmost column).

Given the volume of water that river sediments are dispersed across and nature of faster flowing rivers, we determined that this improved filter should be able to reduce sediments in water to a safe level for consumption.

Should the source of water in a particular area be from a slow-moving river or body of water, a chemical flocculant could be coated on the bottom-most layer of the filter to aid in further reducing the levels of suspended sediment in the water. An extra layer of anthracite charcoal could also be added below the layer of filtration gravel to further aid the process.

III. Reflection of Effectiveness of Solution and Testing Process

On its own, the Centrifugal Distributor and Cleanser is an effective system that leverages many different scientific principles, aspects of the Congo River, and advantages of specific materials. Although the aspects of the solution cannot be evaluated at this moment, our plan for testing will certainly reveal the standout issues.

Starting with the modified centrifugal diffuser pump, it takes advantage of the principle of centripetal force – their base efficiency of 80% is a relatively high figure in the water extraction industry. To further boost the efficiency rating, the pump features diffusers that minimize the mechanical strain on the pump by evenly distributing water around the chamber. Our testing process is meant to measure this improved efficiency rating in hyper-realistic conditions. We considered many factors when setting up a suitable river mock-environment. Not only can we monitor pressure conditions via a pressure gauge, but we can also model the sloping of the simulated environment with an open-topped, sloped water tank. Due to our broad range of situational considerations, we can safely declare the pump testing process to be valid, although relatively difficult to execute material-wise.

Moving onto the filtration test, we devised an experiment to quantify the efficiency of the gravity filter's ability to purify the water and rid it of all sediments. A prototype of the gravity filter is a realistic and reliable means of representing the filter's real-world efficiency. Simply dividing the weight of sediments filtered by the weight of sediments added yields an accurate figure of filtration efficiency. Refined filtration techniques were also measured the same way, and these tests' results was compared to those of the original filter to reveal the superior method of filtration. This test was fairly straightforward and thus accurate.

Finally, measuring the robustness of the container itself is, likewise, straightforward to execute. Simply testing the container's limits by careful adding water will certainly expose any structural flaws. Conveniently, the exact location of the structural flaw is found from this test, making it very easy to reinforce or reassess. Thus, this test is valid.

IV. Other Issues with Iteration Process

Due to financial concerns, we did not purchase chemical flocculant as stated in the procedure. Further, we were not able to procure custom plexiglass containers for the test and was forced to improvise. However, these issues should not interfere with the results given that the substitutions do not affect the mechanism of the filtration nor the measurement of the results.

Since we were limited in our capabilities, we weren't able to determine issues pertaining to other aspects of the system. However, these shortcomings should be detected and resolved through the proposed tests. An example potential issue may include bursts within the surface of the HDPE piping – although unlikely, this would force us to choose a different material such as PEX.

TECHNOLOGY STUDENT ASSOCIATION PLAN OF WORK LOG				
Date	**Task**	**Time involved**	**Team member responsible** (student initials)	**Comments**
11/29/2020 **1.**	Identify developing country on which to focus	0.75 hours	HZ, AI, DA	Met virtually as a team to brainstorm a set of developing countries with prominent issues regarding basic needs Options include: Uganda, Gabon, DRC, etc. Chose DRC due to their peculiar environmental and social status
11/08/2020 **2.**	Identify basic need to provide the DRC with	0.5 hour	HZ, AI, DA	Met virtually as a team to identify a specific human right to provide the DRC with Options include: electricity, water, air quality, roads, housing Chose to address water crisis due to DRC's severely high rates of thirst
11/21/2020 **3.**	Research geography of the DRC	2 hours	AI	Researched land, rivers, and topography of the DRC Compiled all information and sources into a shared Word document
11/21/2020 **4.**	Social and political research	2 hours	DA	Researched the gender-, ethnic-, and governmental-related issues in the DRC that have been hindering progress Compiled all information and sources into a shared Word document
11/21/2020 **5.**	Water crisis research	2 hours	HZ	Researched the history of the DRC water crisis and any past attempts to solve Created a rough timeline of solving efforts Compiled all information and sources into a shared Word document
11/29/2020 **6.**	Brainstorm solutions	1.5 hours	HZ, AI, DA	Met virtually as a team to brainstorm all possible solutions to the water crisis Good and bad ideas were shared Created a list of ten ideas to distribute clean water to rural places

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TECHNOLOGY STUDENT ASSOCIATION PLAN OF WORK LOG

Date	Task	Time involved	Team member responsible (student initials)	Comments
12/06/2020 1.	Finalize top three solutions	1 hour	HZ, AI, DA	Met virtually as a team to assess all solution options and chose top three Top three chosen: “Babylon”, “CDC”, Hermes
12/09/2020 2.	Information gathering and explanation of importance	2 hours	HZ	Wrote a rough draft of the information gathering and explanation of importance section in a shared word document Referenced the shared research documents to aid writing process
12/09/2020 3.	Definition of problem	2 hours	AI	Wrote a rough draft of the definition of problem and explanation of importance section in a shared word document Referenced the shared research documents to aid writing process
12/13/2020 4.	Edit and finalize information gathering and problem definition	2 hours	DA	Edited, fact-checked, and finalized the information gathering and problem definition sections
12/19/2020 5.	“Babylon” rough draft	2 hours	HZ	Wrote a rough draft of our first solution proposal: “Babylon” Compiled all information and sources into a shared Word document
12/19/2020 6.	“CDC” rough draft	2 hours	AI	Wrote a rough draft of our second solution proposal: “CDC” Compiled all information and sources into a shared Word document

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TECHNOLOGY STUDENT ASSOCIATION PLAN OF WORK LOG

Date	Task	Time involved	Team member responsible (student initials)	Comments
12/19/2020 **1.**	"Hermes" rough draft	2 hours	DA	Wrote a rough draft of our third solution proposal: "Hermes" Compiled all information and sources into a shared Word document
12/20/2020 **2.**	Chose top solution	1 hour	HZ, AI, DA	Met virtually as a team to assess top three solutions – plausibility, affordability, elegance, reliability After deliberation, we chose CDC as most plausible
12/21/2020 **3.**	Rough sketch of CDC	2 hours	HZ	Created a pencil and paper sketch of our system to help visualize the moving parts and aid the CAD process Used technical engineering drawing skills Uploaded image of drawing to shared folder
12/21/2020 **4.**	CAD design CDC	4 hours	AI, DA	Used Autodesk Fusion 360 and Rhinoceros to create 2-D and 3-D CAD models of CDC Took several images of CAD design to feature in portfolio
12/23/2020 **5.**	Create a means of testing each component	2 hours	HZ	Part H. (i): Devised tests for the components of CDC - one component is testable in reality, other two are hypothetical Compiled all information and sources into a shared Word document
12/24/2020 **6.**	Build model and test	3 hours	HZ, AI, DA	Safely met to carry out iteration process Wore masks and socially distanced Documented our testing via photos and recording data for trials

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TECHNOLOGY STUDENT ASSOCIATION PLAN OF WORK LOG

Date	Task	Time involved	Team member responsible (student initials)	Comments
12/25/2020 1.	Reflection on testing	2 hours	DA	Part H. (ii): Reflected on issues revealed by all tests Compiled all information and sources into a shared Word document
12/26/2020 2.	Reflected on accuracy and issues	2 hours	AI	Part H. (iii) and (iv): Reflected on the accuracy of tests and other issues revealed Compiled all information and sources into a shared Word document
1/1/2021 3.	Finalize and assemble portfolio	2 hours	HZ, AI, DA	Met virtually to fact-check, edit, and verify contents of portfolio Finalized citations Saved portfolio as a PDF
2/1/2021 4.	Plan display	1 hour	HZ, AI, DA	Met virtually to create a rough outline of the content of our display Decided to create a PDF infographic to summarize solution and testing Sketched out a rough layout of design
2/8/2021 5.	Create display	2 hours	HZ, DA	Used Canva to create the infographic display based on framework Saved as PDF files and assembled
3/18/2021 6.	Edit and submit project	1 hour	AI	Put final touches on portfolio and display, checked grammar and spelling Renamed files and submitted

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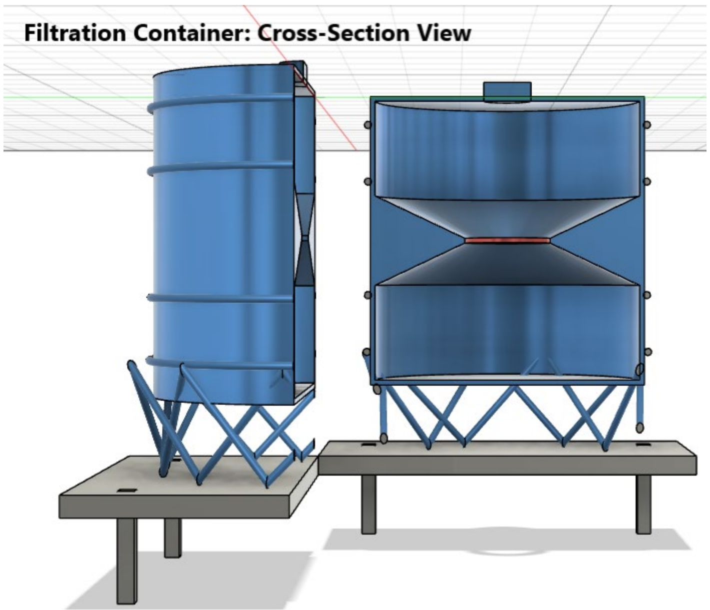
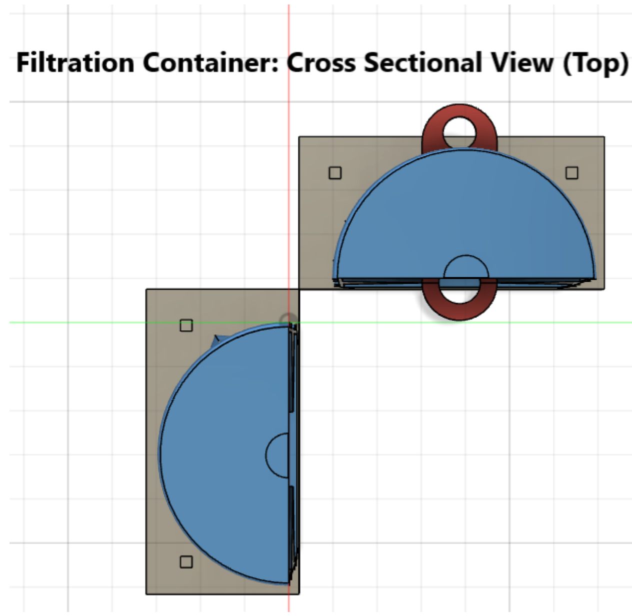
Cover Image:

https://c1.staticflickr.com/9/8518/8404847495_1445f1099c_b.jpg

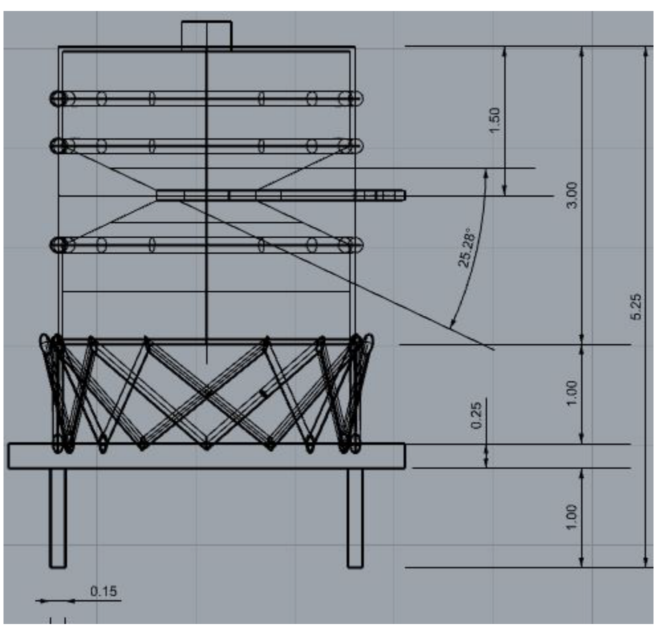
APPENDIX

Below is a gallery of additional images involving the Centrifugal Distributor and Cleanser.

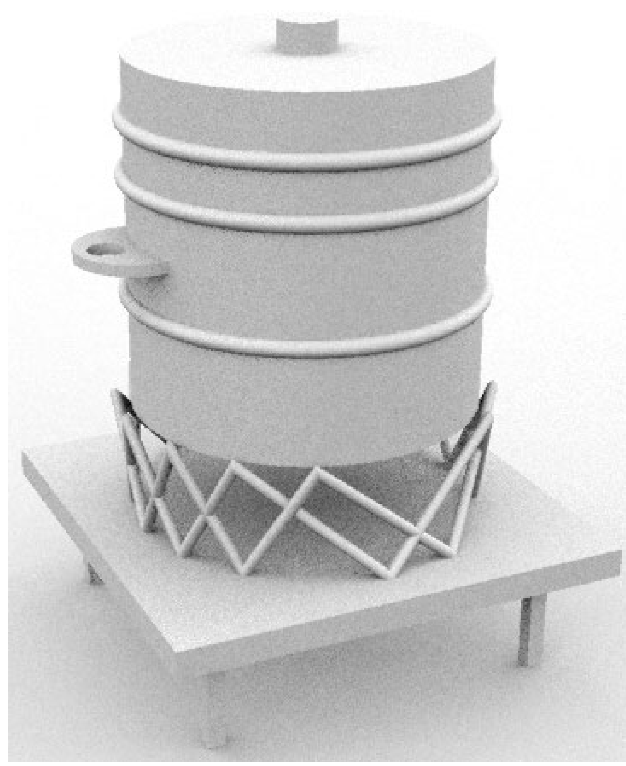




Cross sectional images of the water filtration tank



Dimensioned 2-D CAD drawing of the water filtration tank



3-D render of the water filtration tank