Loop 1
Recycling of water for environmental and economic sustainability

FILTER FOREVER

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Innovation Pilot Spring 2022 Lab 5:
Engineers Without Borders

Group 11

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Executive Summary

This project is about the people of *Grafton* in *Sierra Leone* and the insufficient amount of water. Only 19% of the inhabitants are getting the water they need during their everyday life. The request for creation of this project is by *Engineers Without Borders* in collaboration with *Water4*. Two interviews physical interviews with students from Sierra Leone has been conducted while analyzing the case. Likewise, there has been some email correspondence regarding essential questions we need answers for. The purpose of the project was to develop an innovative solution to the scarce water supply. The innovate solution we developed was a mobile and cheap water filter consisting of several natural resources. This water filter can in theory contribute to the non-existing recycling of water in *Grafton*. Thus, theoretically resulting in 40-45% of all water being recycled which means that the current water supply will be able to support additional residents of *Grafton*. The cost of the device was calculated to be 1.00 USD. Thereby, being quite affordable. The device is also quite adaptable. This could mean that even more water could be reused e.g., by attaching the device to a sink, a drain, or any other place where water else would be wasted.

Introduction

Grafton is a village in Sierra Leone with 21.000 occupants. The village was originally meant to be a temporary refugee camp. Yet, the inhabitants ended up settling there permanently even though there were serious lacking infrastructure and clean water. The company *Water4* have however created a partial solution by pumping water up from the underground water reservoirs. This can unfortunately only supply 4.000 of the 21.000 inhabitants.
The goal of this report is to investigate this problem and come up with new solutions aiding in achieving clean water for everyone. This will be done with focus on the SDG 6; clean water & sanitation, and with a focus on the solution being sustainable to some degree.
The innovative product will be developed through qualitive interviews with relevant professionals; *Water4* and *Engineers Without Borders,* and through thorough analysis and design.

Problem owner

The problem is provided by *Engineers Without Borders*, *EWB*, in collaboration with *Water4*. *EWB* is an NGO aiding in the needs of disadvantaged communities and people throughout the world. This is done through innovative solutions to difficult problems. Furthermore, *Water4* is a company aiming at providing clean and affordable water for everyone.

Introduction to problem

In the developing world there is, at the moment a shortage to get clean and safe water. For the people living in Grafton Water4ever have built a lot of water infrastructure and some kiosk that sells water. The system that are running right now can serve 4000 people and the area have a population of 21000 people.

The problem that are facing the community and Water4ever is to guarantee the water supply for the next ten years. Some of the issues that are facing the water situation is the uncertainty of the groundwater level. This is because there is not enough research to clarify how fast the groundwater is regenerated. On the other hand, there is the issue of water supply. The water that are sold now are just used once and are not recycled. If the water is recycled it will help to secure more water to the 21000 people and help to secure the water consumption in the next ten years.

Proposal

Problem definition

To secure the water supply for longer time and optimize the water consumption, we will investigate the potential of recycling water in the households.

We see a potential to collect and reuse water from each household's consumption, to use for other purpose than drinking, as for example laundry or cleaning.

Based on knowledge from the engineer student Alfred, who is working on the project, we know that the minimum water consumption per person is 7 liters per day and the distribution of water consumption is divided into 5 primary groups: Drinking water, cooking, bath, cleaning, and laundry.

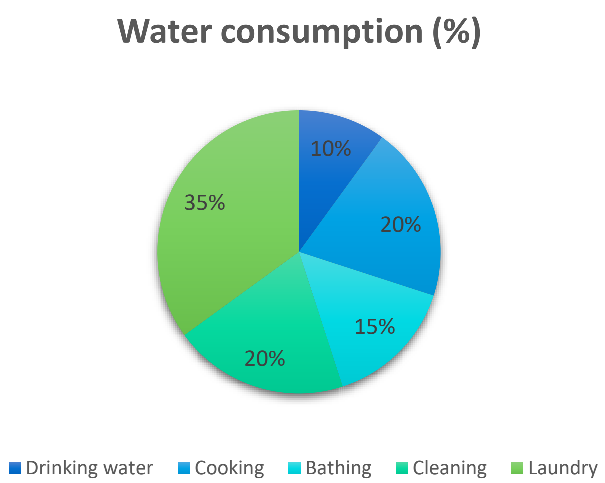
From the distribution of water, we assume that about 45% of the water can be recycled, primary from the consumption for laundry, cleaning, and bathing.

We assume that bath, laundry, and cleaning will be done from a bucket placed on the floor. Naturally there will be some evaporation and water waste from doing these activities, but we do also assume that it will be quite easy to recycle the water from these buckets.

We cannot guarantee that the water is clean enough to drink or use for cooking, but we are secure that it is clean enough to use for other purpose such as laundry and cleaning.

If the water should be used for drinking or cooking, it needs to be boiled, to remove enough bacteria. We do not expect the citizens to boil the water as it will require additional resources from every household, so our recommendation is only to use the water for cleaning, bathing, and laundry.

Figure 1: Distribution of water consumption



Bathing, cleaning, and laundry will probably be done in some kind of bucket or container. The recycling of water will support a financial saving on the purchase of water for the households and furthermore it will probably give a saving in the water consumption, so we reduce the risk to run out of water by night at the water kiosks and will make a saving of water from the.

Besides the financial saving, it will make the water more accessible for the citizens, when they do not need to transport the water from the water kiosk.

Prototype

Figure 2: Illustration of prototype

The idea behind this prototype is to be useful for every household and not be too expensive. This is a way to combat the problem with the water waste and to minimize water consumption. To do this we have invented a new and basic filter that can filtrated some of the water from bathing, cleaning, and laundry.

The issue now is that there is no way to recycle this water that can be useful again instead of letting it out on the ground.

The concept is to use available raw materials that are cheap and plenty in the local area, so the transportation cost is not so high. This filter will have five different layers and a colander on top to catch large debris. The layers are as follows:

1) Sieve
2) Gravel
3) Sand
4) Activated Carbon (GAC-A)
5) Sand
6) Cotton

Each material being used in the filter has unique and important abilities towards filtration of the water. The gravel and sand are being used for filtering away protozoans, several bacteria, and E. coli. [1] The activated carbon is used for filtering particular and potentially harmful chemicals from the water as well as odors or tastes like hydrogen sulfide.[2] The reason for using the GAC-A is that it is the one achieving the lowest TSS-score[3] and thereby the best for this use.[4] The cotton layer is however mostly for keeping the other parts from falling out. In general, the reason for the different materials in the filter is that they are easily replaceable and filter the water for bigger and dirtier particles. Therefore, it is also important to stress that it is not going to be drinking water, but water that can be used for washing cloth and water plant.

User test

To test our prototype, we have come up with the idea to use a plastic water bottle to test if the different layers filtrate the water. To test the water, we have used food coloring to see if the filter, filtrates the water.

There is a disclaimer for this prototype and that if we used normal charcoal and not activated charcoal. The big difference between these two are that activated charcoal can absorb a lot more bacteria and have a longer lifetime, because the activated charcoal has a much higher absorbency.

Figure 3: The filter before and after filtration of water

[1] CDC Center for Disease, Control and Prevention
[2] Minnesota Department of Health (August 2018)
[3] Total Suspended Solids. The lower the score the less solids in the water.
[4] Siong, Y. K., Idris, J., & Mazar Atabaki, M. (January 2013)

Visuals

As well as building a prototype, a conceptual design has been made using CAD. The model matches the dimensions of the materials which are listed in Materials Calculations, so it can be seen as an accurate representation of the formfactor of the filter. We see that it's small enough to fit in any home or business and can easily be carried when it's due for replacement.

Figure 4: Filter Forever filtration system and labeled jerrycan.

During Water4Ever's project in Grafton, they have encountered some resistance from the local population regarding the transition from using surface water sources to purchasing filtered groundwater. Even if all locals can afford to purchase water, they may believe that there is no benefit in doing so.

That's why information is an important part of this project. If we want locals to adopt the filter system, we need them to believe that it is safe and cheap to use recycled water. We intend to do this by utilizing clear and concise infographics, which even illiterate persons can understand[5].

There are 4 places in which we would like to provide this information:

On jerry cans for recycled water:

A sticker for labeling these designated cans is both a practical way of preventing cross-contamination and provide information about what recycled water can be used for. We deemed this infographic to be the most critical to this project, so a graphic design has been made:

Figure 5: Educational sticker placed on jerrycans with recycled water.

On the filter itself:

This sticker provides information about how to keep the filter clean, how to spot signs it may be due for a replacement, where it should be placed (cool, shaded area), and how to collect rainwater.

On jerrycans for purchased water:

Even though this is outside the scope of our project, we took note of the issue of locals bringing dirty jerry cans to the kiosk. Therefore, we'd like to integrate our solution with an important role in Grafton water hygiene: the kiosk owners, who educate locals in safe water management. This label would remind users to clean their cans before bringing them to the kiosk, and further prevent mix-ups of water grades.

On the kiosk:

A poster or board can be placed on the kiosk which contains lots of information about water hygiene and water recycling, also in text. This serves as an "advertisement" for recycling.

[5] Sierra Leone Literacy Rate 2004-2022

Economic perspective

In this section we will break down the cost of producing this product and the break-even point is for this product for the customer. There will also be some argumentation regarding materials cost and future impact. Investment budget

As we talked about in the prototype section, our product will be made out of 0,5-meter 5-inch diameter PVC pipe. In the PVC pipe there will be 5 layers with a mesh net on top to ensure that bigger waste product doesn't go into the filter. So, the product will be made with mesh net on top, then gravel, sand, activated charcoal, sand, and then cotton. We have made the decision that every layer will be 5 cm thick to ensure that the water must pass through enough of each layer to be cleaned. So, 5 layers with 5 cm each result in 25 cm of filter. Below is a breakdown of the prices for the different material for the filter.

Disclaimer: All the prices see below are found on Alibaba or the internet. The price for some of these materials will vary maybe be cheaper as they could be acquired in Sierra Leone instead of another country. But as no information could be found regarding these materials locally in Sierra Leone, we made the decision to go with prices mainly found on Alibaba.com.

Materials Calculations

As mentioned before is the filter divided up into 5 layers, 2 layers sand, 1 layer activated gravel, 1 layer gravel and 1 layer cotton balls. To find out how much we will need for each layer, it was necessary to figure out the volume used for each layer. And each layer is 5 inches (12,7cm) in diameter and 5 cm thick. This makes each layer to be 0,000633 cubic meter, we used this to calculate how much of activated charcoal, sand gravel we needed. A list of references on conversion on the materials and prices is available in appendix.

Silica Sand[6] = 0,000633 m3 x 1538 kg/m3 =0,97

Activated Charcoal[7] = 0,000633 m3 x 1480 kg/m3 = 0,93 kg = 1 kg

Gravel[8] = 0,000633 m3 x 1680 kg/m3 = 1 kg

Table 1: Cost of materials[9].

Materials	Min. Quantity bought	Price pr unit	Quantity used pr filter	Price
PVC pipe	1000 meters 1 meter	0,20 $ pr meter	0,5 meter	0,10 $
Activated Charcoal	1 tons 1 kg	250 $ pr ton 0.25 $ pr kg	1 kg	0,25 $
Silica Sand	1 tons 1 kg	80 $ pr ton ,08 $ pr kg	2 kg	0,16 $
Gravel	1 tons 1 kg	50 $ pr ton 0,05 $ pr kg	1 kg	0,05 $
Cotton	1000 bags 500 gram	0,07 $ pr bag	250 gram	0,035 $

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Endcap plug	1000 pieces 1 plug	0,05 $ pr plug	1 plug	0,05 $
Mesh filter net/sieve	100 m2 1 m2	0,23 $ pr m2	0,015 m2	0,0035
Stickers for jerrycan	2000 pieces	0,01 $ pr sticker	0,01 $ sticker when you buy one jerrycan	0,01 $
Total for Materials				**0,65 $**
Transport for materials			20 %	**0,78 $**
Assembly and markup			30 %	**1 $**

Transport is set at 20 %, this is an assumption that 20 % will cover the cost of transport. This is just an estimate.

Assembly and markup price is set at 30 %, this is to cover the assembly cost of the women in the water kiosk and to add a profit margin from selling that the women in the kiosk will make. It is set at 30 % to be in the same range as the profit margin is from selling water. This should be enough to cover the labor of assembling the filters and make it lucrative for the women to assembly and sell these filters and maybe also educate people about the use of them.

Initial investment for the first filters

To get the project started there will need to be invested 800$ to give the kiosk and women the materials needed to start making the filters and sell them. The materials you get for 800$ is enough to make 1000 filters.

Table 2: Cost of materials to production of filters[10].

Materials	**Min. Quantity bought**	**Calculations**	**Cost**
PVC Pipe	500 meters	0,20 $ * 500 meters	100 $
Activated charcoal	1 ton	250 $ pr ton	250 $
Silica sand	2 ton	80 $ pr ton	160 $
Gravel	1 Ton	50 $ pr ton	50 $
Cotton	500 bags 500 g each	0,07 $ pr bag * 500 bags	35 $
Endcap Plug	1000 pieces	0,05 $ pr plug * 2000	50 $
Mesh net	50 m2	0,23 $ pr m2 * 100 m2	11,5 $
Stickers	1000 pieces	0,01 $ pr sticker * 1000	10 $
Total for materials			**666,5 $**
20 % for transport			**800 $**

Break-even point

69 liters of waters costs 1 cent. To reach the break-even point 6900 liters need to go through the filter. From the case description we got the information that a person each use 7 liters a day. A family of 5

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persons uses 35 liters of water per day, but only 45 % of that water is recyclable. Therefore, 35L x 0.45 % = 15.75 liters a day can go through the filter. 6900 liter/15.75 liters = 438 days to reach break-even. This can also allow each household to use more water if they recycle it 2 or 3 times before they go fetch some new drinking water. These calculations assume that 5 people live in a household. If they are more persons in a household or recycle more than 45 % of the water, the filter will break even for the consumers before the 438 days. If they use more water per person, then the breakeven point also will be sooner than the 438 days. But besides being saving money for the family, the filter also saves them for walking up to the water kiosk as often.

Perspective

The current prototype is an initial, simplified version that has the potential of becoming more sustainable, available for scaling and boosting the local economy while acquiring an expanding workforce in the kiosks.

Potentially, the local assemblance of filters enables replacements of individual parts which can extend the life expectancy of the filter. Not only will it be possible to reuse parts, such as the bucket, but it also unlocks a branding potential for EWB, focusing on Sustainable Development Goal (SDG) no. 12, Responsible Consumption and Production.

On another note, this procedure will elevate the company's mission of achieving Gender Equality, SDG no. 5 through adding more women to the workforce to assemble filters in the kiosks.

From an economic perspective, two scenarios seem feasible. Firstly, a bigger workforce assembling filters enables the kiosks to offer two products instead of one, both water and filters. In this case, cross-selling as an economic concept has an obvious potential. Secondly, a standardization of filter-components – and maybe even adding a sink or at least amount for sinks to the concept – makes it possible for EWB to scale the suggested concept, streamlining the supply chain of individual components. This way, the final filters end up identical, whether assembled in Grafton or other towns. Both above-mentioned examples will help EWB get closer to SDG no. 8, Decent Work and Economic Growth.

Conclusion

Through thorough analyses we have designed a temporary cheap and sustainable solution to the issues stated by *Engineers Without Borders*. An innovative product consisting of low-cost materials and high reusability was designed. It has the potential to create jobs locally in the community of *Grafton* and thereby aiding in the *SDG 8, Decent Work and Economic Growth*. This also has the potential to aid in *SDG 5, Gender Equality*, depending on how *Water4* and *EWB* handles it. Likewise, it does to some extend help in the problem of water limitation in *Grafton* as it can recycle 40-45% of the water being used in *Grafton*, and letting it be used again for anything except drinking and cooking. Concluding the project seems to be a success. By recycling the water already being used it allows several more residents in the town to get clean water, and it has the potential for further development like installment under sink in the house and collecting rainwater from the drain.

Sources

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Siong, Y. K., Idris, J., & Mazar Atabaki, M. (January 2013). *Performance of Activated Carbon in Water Filters*. Hentet fra ResearchGate: https://www.researchgate.net/publication/234060484_Performance_of_activated_carbon_in_water_filters

Appendices

Appendix 1: Reference on prices and volumes for calculation of product price (table 1 and table 2).

Product	**Mesurement**	**Reference**
Silica sand	Volume	https://www.aqua-calc.com/calculate/gravel-volume-to-weight/substance/sand-coma-and-blank-silica
	Price	https://huabangmineral.en.made-in-china.com/product/DBLEpitPsOYg/China-Silica-Sand-Price-Per-Ton.html
Activated charcoal	Volume	https://www.aqua-calc.com/calculate/weight-to-volume/substance/activated-blank-carbon
Gravel	Volume	https://www.gigacalculator.com/calculators/gravel-calculator.php
	Price	https://www.alibaba.com/product-detail/Gravel-Gravel-Factory-Supply-Garden-Natural_62461905601.html?spm=a2700.galleryofferlist.normal_offer.d_title.679bb054lvadFk&s=p
PVC pipe	Price	https://www.alibaba.com/product-detail/High-quality-100-water-supply-and_1600162946478.html?spm=a2700.galleryofferlist.normal_offer.d_image.487e65cbnXUFM9
Cotton	Price	https://www.alibaba.com/product-detail/Cotton-Ball-Cotton-Balls-Manufacturing-Cotton_1600357792698.html?spm=a2700.galleryofferlist.normal_offer.d_title.3e627e1bE8LK2P&s=p
Endcap Plug	Price	https://m.alibaba.com/product/1600180170053/High-quality-UPCV-PIPE-20mm-to.html?spm=a2706.7843667.0.0.38a443276x79Pn&fbclid=IwAR1O_lZMxR_XyryFqRorfFizwJz1vGY1Y9YDB6x-6lsYQPWm0hR-oRdtTk8
Mesh filter	Price	https://www.alibaba.com/product-detail/aluminium-mosquito-net-for-windows-and_60786124706.html?spm=a2700.details.0.0.5b463c0em0mq4l
Stickers for jerrycan	Price	https://www.alibaba.com/product-detail/Stickers-Stickers-High-Quality-Printing-High_60035242629.html?spm=a2700.galleryofferlist.normal_offer.d_title.2a233a77GPrvfT&s=p