

## **Introduction**

Waste management in Monrovia, Liberia is a complex systemic problem that is caused by several factors. First, Monrovia lacks the networks to give everyone access to clean drinking water. Especially with the increased population, this becomes a larger issue of water accessibility. The alternative ways to avoid water-borne illnesses from drinking polluted water is to use plastic water sachets to store drinkable water. However, these plastic sachets are disposed mainly by littering into the environment or burning because Monrovia lacks a robust waste management system. Therefore, the main objective of this project is to explore methods of reducing the amount of plastic waste in Monrovia, Liberia.

## **Background**

There are three main categories of waste that exist in Monrovia, Liberia: organic, electronic, and inorganic. Organic waste includes food scraps, papers, cardboard, and wood. This makes up most of the waste in Liberia. Electronic waste is primarily metals which makes up less than 10% of waste in Liberia. The last type of waste is inorganic waste which includes plastics, cans, and bottles. This makes up the rest of the waste in Liberia and is non-biodegradable unlike organic wastes.

Of the inorganic waste, plastic water sachets play the biggest role. The current distribution process for plastic water sachets begins in the factories at which sachet water is sourced directly from a pipe, borehole, or storage tank and filtered. This water is then sealed in sachets. From there, the sachet water is distributed to be sold in street shops. However, once used and empty, these sachet water bags pose as a detriment to the environment.

Plastic water sachets are made of non-biodegradable synthetic polyethylene. This material can remain intact for 1000 years. In Liberia, people resort to using plastic water sachets for three main reasons: affordability, availability, and safety. These plastic water sachets are cheap and are distributed conveniently across the nation to store drinkable water that is not widely available, especially due to their polluted river water. At least six bags are used per individual daily amounting to 29.1 million empty bags generated daily and these empty bags are usually disposed of through ground littering or burning, both of which are harmful to the environment. However, there lacks a robust waste management system. The Monrovia City Corporation and the Liberia Water and Sewage Corporation are constrained in terms of finance and logistics. They typically have two functioning waste collection trucks in Monrovia with six vehicles remaining dysfunctional. Due to reconstruction following the war, research and funding in the area of environmental sustainability is limited.

There are several immediate and long-term negative effects to this disposal method of plastic water sachets. In terms of the immediate effects, these plastic sachets serve as a detriment to the environment by polluting the land, air, and water, causing flooding, and acting as the main source of soil infertility. They also are harmful to the terrestrial and aquatic animals. In the long term, plastic water sachets will pose as a detriment to public health. Whether the plastics are broken down into microplastics in water, thrown away in a garbage pile or littered and buried deep within agricultural soil, they can end up in the food

chain. The microplastics themselves and the toxic chemicals they carry can end up in the human body and build up to block filtration systems and increase the risk of certain cancers, hormonal issues, and even infertility and birth defects.

## **Identifying the Problem**

The plastic water sachet problem can be divided into three main spaces based on the event chain described in the introduction. The first is the network of drinkable or piped water for which the main objective would be to reduce the amount of plastic water sachets used by giving more people or areas access to piped drinkable water. The second is waste generation for which the goal is to reduce the amount of plastic waste generated from the beginning stages from plastic water sachets. Finally, the last problem space is waste management for which the goal is to reduce the amount of plastic currently in the environment.

After further exploring these problem spaces, several solutions were identified. For the network of drinkable or piped water, the main solution would be to create a larger network of water distribution pipes throughout the city, and eventually, the entire country. For waste generation, solutions such as having biodegradable water sachets, water sachet liners that can be disposed safely, or recyclable aluminum cans/bottles will replace plastic water sachets. Lastly, in terms of waste management, the best solutions would be to enact policy changes, particularly in giving incentives to people to collect waste and punishments for littering, or through educating the community about the implications of plastic pollution, especially in schools and encouraging school clubs to organize cleaning efforts to raise awareness. This project aims at designing a solution for waste generation because there are numerous solution concepts and attacking this problem space would dually address waste management as it would eliminate the constant generation of plastic water sachet waste.

## **Solution Concepts**

### **Biodegradable Seaweed Water Pouches**

The first solution explored was the biodegradable seaweed water sachets. Notpla is a company that uses notpla, a revolutionary material made from seaweed and plants to package materials such as liquids. Their product, Ooho, features 100 percent edible and biodegradable packaging that can store 15 to 100 mL of liquid. The packaging is made from brown seaweed which grows up to one meter per day, does not need fresh water or fertilizer, and actively contributes to deacidifying the oceans.

However, there are several limitations to this product. The membrane is quite delicate so it can easily break or fall apart. Furthermore, since it is advertised as edible, it needs to be sold in another external packaging which negates the objective of eliminating the need for non-biodegradable packaging. Finally, it has a very limited shelf life.

### **Seaweed Takeaway Box**

Noting these limitations, Notpla developed a new product: the seaweed takeaway box. This features a recyclable, home compostable, naturally biodegradable packaging that can be disposed of in general garbage or a recycling bin. It is also made of 100 percent seaweed and other plants while being bigger and sturdier than Ooho.

The initial solution concept with this was to utilize this technology by partnering with Notpla to create a new mold specifically used to hold water and other liquids. Then this new mold would be adopted and manufactured in factories to replace plastic water sachets. Working with the Liberian government, this new alternative would be distributed as the new seaweed water bottles to the community.

However, this too has limitations. First, because the packaging is plant-based, there is a possibility of contaminating the seaweed packaging or allowing for water leakage. Furthermore, even though they are biodegradable, it would still take about four weeks to completely biodegrade, leaving the problem of clogging drains still unsolved. Lastly, there are various problems and questions in the plan to manufacture easy-to-use and functional water storage from this plant material.

### **Infinitely Recyclable Aluminum Bottles**

As an alternative to biodegradable packaging for water storage, this project looked to Open Water's infinitely recyclable aluminum cans and bottles. Open Water is a company that sells water contained in infinitely recyclable aluminum bottles. Aluminum containers are recycled more than twice as often as plastic, glass and carton containers and the recycling rate industry-wide is nearly 70 percent. The manufacturing process of this product is also a true closed loop in that it is infinitely recyclable. Lastly, the product and the operations are carbon neutral in that all emissions are offset.

Open Water advertises their aluminum containers as infinitely recyclable. This is due to the "true closed loop" in that material from one bottle can go right back into making another identical bottle. This does not happen with plastic and cartons. In terms of being carbon neutral, Open Water has partnered with Climate Neutral to become the first certified climate neutral bottled water company in the world. Their mission is to drive their carbon footprint to zero and this is done in three main steps. First, they measure emissions from manufacturing and production all the way through finished product delivery. Next, they reduce the impact by implementing changes in operation whether this may be in terms of transportation, energy, materials, or others. Lastly, they offset leftovers by using carbon offsets, such as investing in carbon reducing projects. Open Water specifically invests in projects that are independently certified and meet internationally-recognized standards. Examples of these are projects that support the preservation of nearly 500,000 acres of Amazonian rainforest, capture landfill-generated methane in Florida, and install electric vehicle charging stations.

### **System-Level Approach**

Working with the Liberian government, this new aluminum alternative will be adopted. The manufacturing facilities will partner with Open Water to manufacture aluminum cans/bottles which will then be distributed to the existing stores in Monrovia. These stores will sell the products while also acting as collectors. Additional collector sites will be set up to collect old containers for reuse and recycling.

The collecting system is proposed in two ways: in existing stores and through satellite collector sites. Stores will collect used aluminum bottles in exchange for a new aluminum

bottle of water at a cheaper price while also selling the aluminum bottles of water. Satellite collector sites simply collect used aluminum bottles and send them to manufacturing facilities to be reused/recycled. In exchange, they will give a monetary "reward" which will be the same value as the cheaper price offered at stores.

One of the main advantages of this system is its creation of job opportunities and its motivation to keep track of waste. In satellite collector sites, there will be employees to work the sites, collectors to go out and collect littered bottles/cans, and transporters to take received bottles and send them back to the manufacturing facilities. In the manufacturing facilities, there will be an additional team to get delivered used bottles and prepare them for recycling/repurposing. Lastly, in existing stores, there will be additional employees who will handle collection.

A few limitations appear in cost and disposal. First, Open Water sells 16-oz bottles for \$20.99 which is much more expensive than plastic water sachets. However, this product includes still ultra-purified water and electrolytes. Therefore, our solution is to sell these bottles with less expensive content as the focus is on the container and being able to store drinkable water. In terms of disposal, people can still litter containers. However, with additional collector sites, collector job opportunities, and incentives, our solution will reduce this risk.

## **Implementation**

This solution will be proposed to Open Water, the United States government, the Liberian government, as well as the United Nations. With approval, we will receive funding through three main methods: from the UN through the UNDEF project grant, grants from the respective governments, and angel investors. Next, while implementing the system-level solution as described above, we will work with the community to educate them on the implications of plastic pollution and encourage policy changes along with community efforts.

## **Process**

In the beginning of the process, I identified the problem to define this project as the following:

*The population increase in Liberia has impacted waste management which receives very little or no budget due to competing priorities in Liberia. According to a Monrovia City Corporation source, waste collection rate in the city of Monrovia is 800 tons of domestic solid waste per day, representing approximately 45% of the total waste generated in the city; the remainder goes in the environment. Common waste generated in Monrovia is single used plastics which accounts for more than 30% (USAID, 2008). Furthermore, a 2017 UNICEF report states that only 5% of Liberians have access to pipe-borne water. Therefore, to prevent diarrhea and other water borne diseases, most Liberians drink water stored in single used plastic sachet (Polyethylene PE/PET). This approach tends to solve the diarrhea problem but causes immense plastics pollution problems in the environment.*

The feedback I received helped me begin to narrow down this high-level, broad problem space. The problem could be seen from various angles. Waste management would be the issue for livability. It would also involve solutions that involve collecting waste that already exists in the environment. The water quality issue would involve the matter of public health. If people in Liberia can have access to piped or drinkable water, sachet water would not be used.

With the feedback, I began the process of necking down for milestone 3 after looking at the entire system as a whole and developing a roadmap to address all aspects of it. Using the event chain, I was able to divide up the problem into the three main subspaces as discussed previously. It was clear that there were unique ways to approach this problem and after conducting research, I had switched to focus on waste generation rather than waste management. From there, I received further feedback to expand my knowledge of the problem. Specifically, the background of Liberia and its community proved critical. What has the government tried so far to fix this problem? Are there no water piping projects, no recycling initiatives? What is stopping the simpler solutions? What does this country prioritize? What is its history and current state socioeconomically? These questions all needed to be answered to fully understand the problem and the root cause.

Moving into milestone 4 and 5, I began to investigate solution concepts and create a concrete system-level approach to implement this solution. Through further research, feedback, and guidance from my peers, I was able to have a few options to explore. Some of the main options included creating a completely new alternative to plastic water sachets. This included the idea of biodegradable water sachets that are plant-based and the idea of having liners in the current plastic water sachets that could be disposed of more safely or cleaned for reuse. The idea that came to fruition was the idea of the infinitely recyclable and carbon neutral aluminum cans/bottles from Open Water.

Once this idea was pitched, the next steps as suggested by my peers was to compare this solution to the existing system. Due to the poor waste management system in Monrovia, Liberia and the lack of access to drinkable water through pipe lines, plastic water sachets have been the dominant water distribution container material because it is very cheap to produce. The bigger problem is that they are not recycled and cause serious environment detriments. Even though this problem exists, the solution that I proposed needed to be viable and appealing to the Liberian demographic. In terms of the product itself, I elaborated on how the aluminum bottles are truly infinitely recyclable and carbon neutral. I also needed to understand the process of manufacturing, cleaning, and recycling these bottles to understand its true advantages. Furthermore, it was critical that I understand the cost comparison between the plastic water sachets and the aluminum bottle alternative. The plastic water sachet's main benefit is its affordability. However, as mentioned above, Open Water's aluminum bottles were quite expensive comparatively. Understanding this cost difference, a solution needed to be addressed in this area as well since cost is the biggest factor to the people in Liberia. The conclusion was to sell these bottles with less expensive content as the focus is on the container and being able to store drinkable water.

Concluding this project with much more thorough research in both the problem space and the solution space allowed me to develop a system-level solution to the plastic waste management problem in Monrovia, Liberia that introduces both a new alternative product, an implementation process, and a change in community awareness and attitude towards the environment.