Prospectus

Electrolytic Disinfection of Water Through Silver Ion Release

(Technical Report)

Current Methodologies and Improvements for Waste Classification in Foreign Countries

(STS Research Paper)

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I. Introduction

The rapid globalization and technological advancement have brought many improvements for human civilization. However, these improvements come with a significant consequence: global waste. Until early 2018, the United States, Japan, Germany, and many other developed countries have dodged the blame for the generation and treatment of waste by exporting waste, including hard-to-recycle plastics, to China and other eastern Asian countries. Thus, ever since the import ban on waste by the Chinese government in 2018, the problems of global waste management were revealed to the world. (Brooks, Wang, & Jambeck, 2018) Global waste is expected to increase to 3.4 billion tonnes by 2050, which is greater than double the population growth over the same period of time. Moreover, at least 33 percent of the annual 2.01 billion tonnes of municipal solid waste (i.e. trash) is not managed in an environmentally friendly manner. ("Trends in Solid Waste Management," n.d.) Waste treated in such manner will inevitably pollute the environment, contaminating the earth and water that we depend on.

The solution to the fundamental issues of global waste requires more than just a few regulations or laws. It requires strong and trusted governments and the awareness and willingness to change by the people who generate the waste. However, when looking on a smaller scale, solutions to help alleviate the environmental consequences can be achieved through the introduction of technology. One important environmental consequence due to global waste is drinkable, clean water. Unmanaged urban municipal solid waste can end up in the streams and sewer systems, contaminated the water supplies. While sewer and water contamination treatment systems are common in more developed countries, a severe lack of basic water services exist in many lower-income countries such as South Africa. The Limpopo province of South Africa is a prime example of these problems. It has one of the lowest rates for drinkable water access at only 44 percent. (Majuru, Jagals, & Hunter, 2012a) The residents receive piped water from the South African municipal government but at an infrequent and unreliable rate and, therefore, have to rely on nearby river systems that lack any filtering facilities. Water tests done in 2009 indicated that all the available water sources, including the municipal water supply from the government, contain higher counts of E.coli bacteria than the World Health Organization (WHO) standards. ("Challenges," 2011)

The technical capstone aims to reduce and alleviate the drinkable water shortage in low-income rural areas such as the Limpopo province by developing a point-of-use (POU) water treatment device. There are several POU methods for treating water such as chlorine-based methods, silver-embedded ceramic water filters, and biosand filters. (*Guide_smallsystems_pou-poe_june6-2006.pdf*, n.d.) The final capstone deliverable aims to provide a durable and effective POU treatment device that improves upon currently available silver ion treatment methods by controlling the exact amount of silver ions into the water to be treated through a microcontroller.

While it is essential to correctly implement the technical aspects of the final technical deliverable, it is also equally important to understand the social and ethical backgrounds of the final user base. We must always consider what the final user base truly needs and the surrounding social and political narrative throughout the development process to ensure that the final product successfully achieves our objective.

II. Technical Report

Lack of access to an improved water source leaves communities vulnerable to the effects of water-borne diseases such as typhoid and cholera. These diseases are especially dangerous to children as they often cause severe diarrhea which kills around 2.2 million people annually; 90% of these deaths are children. ("The United Nations world water development report 2019: Leaving no one behind—UNESCO Digital Library," n.d.)

Point of use water treatment technologies are an effective way to combat water-borne illnesses because they allow for households to treat water in their own home shortly before consumption. The ability to treat water within a home is especially important for areas with rudimentary water systems which require households to collect water from taps in a variety of containers and carry these home for domestic use where the sitting water will be vulnerable to further contamination. (Majuru, Jagals, & Hunter, 2012b Ionic silver has been known to have antimicrobial properties since Roman times, and recent studies have reaffirmed the efficacy of using ionic silver for disinfection of potable water. (*Silver.pdf*, n.d.) Currently, ionic silver is employed in several point of use water treatment technologies, including the Folia Water paper filter and the MadiDrop. (*The Madidrop: Product Information*, 2017)

The MadiDrop is a micro porous, water permeable ceramic tablet infused with microscopic silver clusters and can treat up to 20 liters daily. Once it has been placed in water, the Madidrop continuously releases low levels of silver ions; however, this approach is flawed because there is no control over how much silver is released into the water. Additionally, another flaw of the Madidrop is that it was designed to be placed in a container and forgotten about. Due to this layer of abstraction, its end users may not allow recently added water to sit for the required contact time needed for the silver particles to kill the microbes in the water.

The Madidrop and other silver-based point of use water filtration systems do not control the amount of silver released into water and do not effectively oxidize the silver for disinfection. As a result, the water is not properly sterilized and does not abide by the EPA secondary drinking water safety standard of 100 µg/L. (De France, 2018) Therefore, my team is designing an electronic point of use water treatment device that will control the number of silver ions released using an MSP430 microcontroller. The target concentration of ions delivered for the prototype is 50 µg/L, which is half of the EPA guidelines. The device will be limited to operate twice per day so that the amount of silver released stays within the 100 µg/L standard. We will produce thirty prototypes, which will be field tested in rural South African homes in the town of Thohoyandou.

While these goals are a step in the right direction, the system we design must work outside the lab and be designed in such a way that it will be able to operate within its users' daily lives. Most of the people within the town of Thohoyandou, South Africa are illiterate. Accordingly, the user interface will need to be extremely simple and cannot require any written instructions. Additionally, in order to be a viable solution for providing clean water in rural communities, the device will need to be extremely durable. Its enclosure will be able to withstand accidental drops and total immersion in water. Further, the device will be simple to use, relatively cheap, and power efficient. Further, we have already received the functional requirement that the device should be able to operate for six months to one year on a replaceable 9 V battery.

III. STS Thesis

As a country becomes more urbanized and industrialized, the amount of municipal solid waste generated will inevitably increase as well. Therefore, it is no surprise that the United States and China, two of the most industrialized nations, generate the most municipal solid waste per day. However, this data may be misleading, since these two countries also happen to be two of the most populous countries as well. Thus, to account for this fact, we can look at the municipal solid waste per capita per day, where the United States is at 2.58 kg per capita per day, while China is only at 1.02 kg per capita per day. This is a staggering difference; moreover, the United States still prevails even when compared to other top GDP countries like Japan, Germany, France, the UK, India, etc. (AnnexJ.pdf, n.d.) While GDP is not a perfect measure of industrialization, this does not retract the fact that the United States generates a significant amount of municipal solid waste per capita compared to other developed countries.

So what could be causing this disparity? One significant component of waste management is waste classification or waste sorting, the sorting of waste into different elements. Waste could be sorted based on different categories, such as by materials, recyclability, organic/inorganic, and more. Despite these variations in sorting methods, they all improve the efficiency of waste management in general, thus reducing the cost and effort in recycling and waste classification. It is this area, waste classification, where the United States seems to be far behind compared to other countries.

One way to sort waste is by recyclability. The idea is simple, sort the waste by its ability to be recycled or not, preventing waste that can be recycled or reused to landfills, where the waste is buried away never to be seen again. To this day, the United States lacks a national law mandating recycling, and the recycling rate for municipal solid waste in the United States was only 34.6 percent. (US EPA, 2015) For a better perspective, this value is almost half compared to Germany at 56 percent, Austria at 54 percent, and South Korea at 54 percent. ("Recycling – Who Really Leads the World?," n.d.) While a small number of individual states have passed regulations related to recycling such as laws that establish deposits or refund values on recyclable beverage containers or banning recyclable materials in landfills, without a national regulation, the fundamental issues of recycling will not be solved. (US EPA, 2015) Then, what laws or regulations could the United States implement to combat this issue? We can look at examples from other countries with superior recycling rates.

While looking at countries with already significantly high rates of recycling may seem like the most intuitive route to take, it might be more effective to look at countries that have improved the most in recent years. Ever since the import ban of waste, China has done its best to improve its management of waste. In 2017, China saw an increase of 11 percent in metal and plastic recycling in a single year. In comparison, the United States only managed to increase of 6.8 percent in the most recent five-year period. (Halder, 2019) This rapid improvement could be attributed to the sudden involvement of the central government in recycling regulations. In recent years, the Chinese government has begun launching pilot recycling programs for its largest cities, such as Shanghai, Beijing, Guangzhou, Shenzhen, and Hangzho, enforcing the regulation on domestic waste management to make garbage classification compulsory instead of voluntary. ("The era of compulsory garbage sorting begins—Chinadaily.com.cn," n.d.) The final plan is to issue 46 cities to carry out mandatory garbage sorting by 2020. Under this plan, all public institutions, companies, and facilities are required to sort municipal solid waste by hazardous waste, kitchen waste and recyclable materials. In addition to mandated laws, the Chinese government offers incentives to increase the participation rate among regular residents, such as reward credits that can be used to purchase daily necessities. (“Yearender: China intensifies waste management—Xinhua | English.news.cn,” n.d.)

China is not the first country to nationally mandate trash sorting and recycling. Most of the countries with the highest recycling rates like Germany and South Korea have already had regulations to mandate trash sorting and recycling for years. (Fishbein, 1996) (“South Korea once recycled 2% of its food waste. Now it recycles 95%,” n.d.) Compared to such efforts, the United States severely lags behind. One commonality between the previously mentioned forgien countries is the effective involvement of the government in waste management policies. Thus, the inability to push a nation-wide enforcement on waste management could be attributed to the United States’ democratic and capitalistic foundation and historic distrust of the government. A national movement of such scale must involve the central government to achieve its goals efficiently, in addition to the willingness of the citizens to embrace the new mandates.

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