THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF BIOMEDICAL ENGINEERING

Implementation of Hygienic Products and Medical Systems in Developing Countries

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SPRING 2023

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Biomedical Engineering
with honors in Biomedical Engineering

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ABSTRACT

Globally, one of the biggest barriers to gender equality and socioeconomic mobility is the lack of accessibility to menstrual hygiene products. Female academic success is impeded by insufficient hygienic systems for adolescents which impacts their occupational freedom, income potential, and ultimately societal status. These issues are felt disproportionately by refugees where poverty is very prominent. The Pennington School's Applied Science Program has worked in partnership with the Dzaleka Refugee Camp in Malawi, Africa to create a reusable menstrual product that disrupts the system of gender inequality in Dzaleka through their Women in STEM Solving Problems (WISSP) Program. This thesis examines how the WISSP reusable menstrual pad compares to United States pad products and Malawian menstrual alternative solutions in a wetback test and an absorbency test. This thesis also examines the social and economic implications that the WISSP menstrual pad would have on refugees when women could sew and sell the pads themselves with locally sourced materials. This thesis finds that the WISSP reusable menstrual pad provides a sustainable economic and hygienic solution for women in the Dzaleka refugee camps because of its comparable performance to alternative menstrual solutions, ability to make alternative menstrual solutions more suitable for long term usage, and its unique impact on societal barriers for women in refugee camps.

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ACKNOWLEDGEMENTS

I would like to dedicate this thesis to my parents. To my mom for how she inspired this thesis project and helped me cultivate my appreciation for how engineers can change the world. To my dad for supporting me through an engineering degree through endless encouragement and the occasional physics and math tutoring.

Chapter 1

Introduction

Menstrual health and equity have a huge impact on the success and opportunities of women. In communities across the world, women struggle to have consistent access to menstrual products, clean water, and private sanitation facilities. This aspect of gender inequality is attributed to poverty and the cultural and social stigmatization of menstruation. Urinary and reproductive infections, discomfort, social exclusion, embarrassment, and abandonment of education are all consequences women face because of menstrual inequity.

Momentum has built over the last decade to invest in research and resources for women's health and reproductive health, spearheaded by non-governmental organizations (NGOs), women's advocacy organizations, and the United Nations (UN). One of the groups that has worked to address this global issue is The Pennington School's Women in STEM Solving Problems (WISSP) team. WISSP has researched and designed solutions to intentionally address the challenges impoverished women experience including limited access to affordable products, accessible sanitation infrastructure, and economic negotiation power in the family. The group's research has been in partnership with Dzaleka Refugee Camp in Malawi, Africa. Serving over 50,000 primarily African refugees, Dzaleka is a refugee camp run by the United Nations High Commissioner for Refugees (UNHCR).

One of the solutions that has emerged from WISSP's research is a reusable menstrual product, known as the WISSP Pad Solution, that requires minimal water for washing and can be used for extended periods without needing to be changed. The WISSP Pad Solution is a hybrid

product that is integrated with existing menstrual solutions with the goal of increasing the time the existing menstrual solution can be used. By extending the time between product changes, women will face less disruptions throughout the day and spend less money on menstrual products. These disruptions can be so extensive to the point where girls will drop out of school, and women have no opportunity to make an income. Products are so inaccessible that women may rely on transactional sex to gain access, or they revert to unsafe and unsanitary menstrual solutions. Therefore, targeting longer lasting menstrual solutions is an investment that affect all aspects of women's success. This thesis will analyze two qualities of the WISSP Reusable Hybrid Menstrual Product, the wetback phenomenon and absorption capacity, to make informed recommendations for product design and future research to observe other aspects of a reusable menstrual solution's value to the community.

Chapter 2

Background and Literature Review

Global Women's Health and Reproductive Health

Women's health and reproductive health has been historically overlooked as important focus areas in medical research and education. A huge part of those practice areas is menstrual health. Globally, varying cultural and societal norms, socioeconomic differences, and diverse religious practices can lead to significant disparities in the ways girls and women are equipped to manage their menstrual cycle. The topic of menstruation has had a negative connotation over time, and in certain societies, women who menstruate have been considered impure or dirty, which has resulted in restrictions on their activities. In rural West Bengal, India, 85% of girls practiced restrictions in the realms of religion, marriage, school, playing, eating, and household work while menstruating (Dasgupta & Sarkar, *Menstrual hygiene: How hygienic is the adolescent girl?* 2008). Uninformed education and stigmatized information about menstruation has also led to some women not cleaning themselves in communal bathing sites or refusing to touch menstrual blood; these actions continue to contribute to a high rate of bacterial infections amongst women in low-income countries (Kirkegaard, *Left in the dark: How period taboos put women and girls at risk* 2022).

Until relatively recently, there was little discussion or research on menstrual health and hygiene, especially at the global level (Sommer et al., *Comfortably, safely, and without shame:*

Defining menstrual hygiene management as a public health issue 2015). Menstrual hygiene management and other women's health topics have developed momentum for public health research, especially as the United Nations (UN), non-governmental organizations (NGOs), health-focused foundations, and women's advocacy organizations have made it a priority (*Puberty education & menstrual hygiene management* 2014).

Accessibility of sanitary menstrual products and solutions have continued to be an essential conversation in menstrual hygiene management (MHM). Disposable menstrual pads were invented in the early 1900s when cellulose was discovered by war medical works to absorb blood, making it easier for women to manage their periods (Voxapod®, *The history of Menstrual Products* 2021). However, these products were not widely available in many parts of the world, particularly in low-income countries (Kaur et al., *Menstrual hygiene, management, and waste disposal: Practices and challenges faced by girls/women of developing countries* 2018). Even today in low-income communities of India, only 11.25% of girls use sanitary napkins during menstruation (Dasgupta & Sarkar, *Menstrual hygiene: How hygienic is the adolescent girl?* 2008). When women don't have access to menstrual products, they often take up alternative solutions such as a piece of fabric or cloth. Serious health conditions, such as reproductive tract infections (RTIs) and urinary tract infections (UTIs), can result from unsafe management. Hepatitis B and thrush can result from failure to wash hands between menstrual products. (World Bank Group, *Menstrual Health and hygiene* 2022)

Lack of access to sanitary menstrual products and hygiene infrastructure (running water and restrooms) don't only lead to bacterial infections or health problems. It can also lead to embarrassment and shame for women when they cannot conceal or privately deal with their menstrual cycles. The use of cloth as a menstrual solution may not provide adequate protection,

particularly for those with heavy menstrual flow. Leakage from menstrual solutions can be anxiety-inducing and uncomfortable. This shyness and stress prevent girls and women from attending school, work, and social events during menstruation, and this response is amplified when they don't have access to menstrual materials (World Bank Group, *Menstrual Health and hygiene* 2022). In two Kenyan schools, girls reported that 95% of them miss between 1-3 days in school while menstruating. Girls with access to disposable products reported significantly lower levels of fear and were less likely to see menstruation as a negative impact on their grades than girls who did not have access to products (Mucherah & Thomas, *Reducing barriers to primary school education for girls in rural Kenya: Reusable Pads' intervention* 2019). Beyond accessibility of products, many women and girls report that there were unaware of what menstruation was when they got their first period, also known as menarche (UNFPA, *First menstruation is often accompanied by fear, shame, lack of information, women and girls in Arab States reveal* 2021). Some girls will go as far keeping it a secret due to the immense amount of anxiety and shame they feel. When women and girls use reusable menstrual products that require washing and drying, there is another element of stigma associated with that process (Hennegan et al., *A qualitative understanding of the effects of reusable sanitary pads and puberty education: Implications for future research and Practice* 2017). It is a violation of privacy when women must wash menstrual products and hang them to dry in the sun, so some will turn to completing the process in enclosed areas which can result in the buildup of mold and mildew that causes reproductive infections (Venema, *The Indian Sanitary Pad Revolutionary* 2014). It is important that reusable products do not require frequent washing or long drying time frames.

Researchers have linked gender equality with women's health, particularly in low-income nations, which has illuminated the significance of menstruation hygiene and health for women's

health and wellbeing. Access to period products, menstrual education and, and cultural taboos and stigma associated with menstruation have been addressed in efforts to promote menstrual health and cleanliness. There is still considerable work to be done to guarantee that all women and girls have access to the tools and assistance they need to manage their periods with dignity and comfort.

Defining Period Poverty

The term "period poverty" pertains to the inadequate provision of menstrual hygiene products, education, and facilities, along with the social stigma that comes with menstruation. This issue impacts a vast number of individuals globally, especially those residing in impoverished areas. Historically, menstruating individuals were marginalized, leading to misunderstandings and societal taboos that continue to persist. These cultural attitudes lead to shame, embarrassment, and social exclusion.

In higher income countries like the United States, period poverty can be seen through the “pink tax” which refers to the tax on and general cost of menstrual products. In the United States, many states exempt necessities such as groceries and clothing from taxes (Legendre & Figueroa, *States That Still Impose Sales Taxes on Groceries Should Consider Reducing or Eliminating Them* 2020), but 22 states still charge a sales tax on period products (*Tampon Tax*). Because there is a minimum amount necessary for every person to spend on their basic needs, lower income families spend a much higher percentage of their income on food, housing, and hygienic necessities. Therefore, sales taxes and high costs of basic needs, like menstrual products, disproportionately affect low-income families. Many companies and schools have adopted

practices such as making free products available in all bathrooms to lower the impact of inaccessibility on a woman's performance in the classroom or the workplace. Several countries including Scotland and New Zealand provide free menstrual products in all schools; Scotland even provides free pads and tampons to anyone who needs them (Rodriguez, *20 places around the world where governments provide free period products* 2021).

People in low-income nations suffer from period poverty even more than poor families in wealthy nations. In these impoverished nations, the barriers surrounding the high cost of menstrual products are amplified, and many families are forced to make tough decisions on whether they have the money to purchase menstrual products at all. In Malawi, a pack of menstrual products can cost more than a family's daily income (*Reusable sanitary pads and Sustainability* 2023). This can drive women to go to extreme measures to acquire menstrual products; a study in Kenya found that many women will engage in transactional sex to get access to products, which is much more normalized in these areas (Phillips-Howard et al., *Menstrual needs and associations with sexual and reproductive risks in rural Kenyan females: A cross-sectional behavioral survey linked with HIV prevalence* 2015). Because women rarely have the opportunity to make an income in impoverished families, they must negotiate with their partners to make menstrual products a purchasing priority. Without economic power in the family's social dynamic, it is very difficult to advocate for products only women need. In Dzaleka Refugee Camp in Malawi, women consistently speak how they must advocate for themselves to their husbands to protect themselves from malnutrition, disease, and period poverty (Ramier, *Life for Women in a Refugee Camp in Malawi: Understanding perceptions of security and insecurity* 2016).

Low-income communities also lack adequate infrastructure to provide safe, private, and sanitary places for women to change menstrual products. These communities often have not been able to invest in clean water or sanitation facilities. When girls know they won't have access to the right infrastructure to change their menstrual products at the rate necessary to remain clean and confident, they will skip school and isolate themselves (Sommer et al., *Comfortably, safely, and without shame: Defining menstrual hygiene management as a public health issue* 2015).

Refugee Health and Resource Equity

Refugees are people who have been displaced from their homes due to war, poverty, persecution, or unlivable environmental catastrophes (UNHCR, *What is a Refugee?*). Following World War II, the United Nations High Commissioner for Refugees (UNHCR) was established to address the displacement of Europeans who were forcefully uprooted from their homes. This marked the inception of the contemporary refugee system. The 1960's decolonization of Africa led to the UNHCR having a higher presence throughout the continent that still lasts today (United Nations High Commissioner for Refugees, *History of UNHCR*).

Refugees generally face exacerbated effects of poverty. When they enter foreign refugee camps, they are met with language barriers, different dietary accommodations, significant financial limitations, cultural changes, overcrowded living quarters, and generally poor sanitary conditions. All these disruptions can lead to unhealthy lifestyles for refugees, and there is often a lack of healthcare services in refugee camps.

These challenges for refugees greatly affect women's, reproductive, and menstrual health. Violent conditions in one's home country can cause individuals to experience post-

traumatic stress disorder (PTSD), anxiety, or depression (Meaza et al., *Tuberculosis among refugees and migrant populations: Systematic review* 2022); these people are less likely to seek help regarding stigmatized topics such as menstruation. Because of overcrowding and poor living conditions in camps, refugees may be more susceptible to infectious diseases like tuberculosis and hepatitis (Meaza et al., *Tuberculosis among refugees and migrant populations: Systematic review* 2022). As stated earlier, infections like hepatitis affect women who don't wash their hands when changing menstrual products, so these conditions disproportionately affect them. There are also increased rates of violence in refugee camps, and 99% of women in a Cameroon refugee camp indicated that they "do not feel safe enough to use sanitation facilities at night" (Gassama Mbaye & Aidara, *The Palgrave Handbook of Critical Menstruation Studies* 2020). Current efforts to alleviate period poverty in refugee camps includes distribution of disposable and reusable menstrual products and investing in pipes for running water. The distribution of free disposable menstrual products in refugee camps is not the best solution because men will trade menstrual products and other basic necessities at the market in exchange for other goods (Whitaker, *Changing opportunities: refugees and host communities in western Tanzania* 1999).

Menstruation can have a significant impact on the education and retention of female refugees in school. Lack of menstrual products or nearby sanitary facilities leads to many girls missing school during their period and ultimately gaps in their education. Due to shame, stigma, and discomfort, many girls drop out of school entirely once they begin to menstruate. In Africa, 1 in 10 girls will miss classes or drop out entirely once they begin to menstruate; these numbers are higher in low income and refugee communities (Thomson, *1 in 10 girls in Africa will drop out of school for this reason* 2015).

Retention of women in school is a pressing social matter across the globe. Child marriages could decrease by two-thirds if all women were educated to at least a secondary level (*About child marriage*). Educated women tend to be treated with greater respect and are more likely to receive support for their career aspirations. This is particularly vital for female refugees, as remaining in school can lead to social mobility opportunities and the ability to overcome poverty (United Nations High Commissioner for Refugees, *The Struggle for Equality - Why girls lose out*). For every additional year a girl spends in primary school, her expected income rises between 10-20%, and for every additional year in secondary school, this raises her expected income between 15-20% (UNICEF, *UNICEF says education for women and girls a lifeline to development* 2011).

Reusable, locally sourced menstrual solutions can help address these issues by providing a sustainable and affordable alternative to disposable products, which are limited resources in refugee camps. Some reusable menstrual solutions can also extend the lifetime of disposable products or cloth, decreasing the number of times that women must change menstrual products throughout the day, which is extremely valuable in refugee camps that lack sanitary and safe facilities (*Reusable sanitary pads and Sustainability*). Products that are handmade and/or sewn are very valuable for refugees because women can find a source of income by manufacturing and distributing these products. Income-generating women are better able to meet their own needs and the needs of their families because they are more financially independent from their husband's income to gain access to basic needs. These women are less likely to feel trapped in sexually and domestically violent relationships, which is extremely common in refugee camps (Lugova et al., *Sexual and Gender-Based Violence Among Refugees and Internally Displaced Persons in the Democratic Republic of the Congo: Post-Conflict Scenario* 2020).

In summary, societal barriers such as gender norms, limited education, and lack of resources can create significant challenges for women in refugee camps, including limited access to menstrual hygiene products. Sustainable, locally sourced menstrual solutions can provide an affordable and environmentally friendly alternative, while also providing job opportunities for women in refugee camps and promoting their economic empowerment. Reusable products help alleviate the impact of unsanitary infrastructure by extending the lifespan of accessible menstrual solutions.

Women in STEM Solving Problems (WISSP) Mission

In 2020, the Applied Science Program at The Pennington School acquired a $40,000 grant from the MasterCard Foundation to conduct research on the barriers and enables for youth in refugee camps (Wirsig & Gibbard, *Barriers to and Enablers of Economic Opportunities for Youth in Dzaleka Refugee Camp* 2020). The research was centered around Dzaleka Refugee Camp, a Malawian refugee camp sponsored by the United Nations High Commissioner for Refugees (UNHCR). Although originally intended to host a maximum of 12,000 individuals, Dzaleka is now home to over 52,000 refugees, primarily hailing from the Democratic Republic of the Congo (DRC), Burundi, and Rwanda (*UNHCR - Malawi*). A relationship was developed between The Pennington School and Dzaleka via Jesuit Refugee Services (JRS), a global refugee advocacy and education-based non-governmental organization (NGO). JRS facilitated on-the-ground communication and focus groups to gather data for the purpose of this research. Although the purpose of the research uncovered gaps in technology and outside world

communication, many conversations with refugees illuminated the glaring struggles of women in the camps.

The Pennington School spearheaded the Women in STEM Solving Problems (WISSP or WIS^{2}P) team, which is an Applied Science team who put engineering and human-centered design principles to work. The team invented a reusable, locally sourced, patent-pending product known as the WISSP Pad Solution in 2022. The WISSP Pad Solution is a hybrid (part reusable, part disposable) sanitary napkin designed to target many of the barriers women face in refugee camps. It relies on locally sourced fabrics to ensure accessibility of materials to create the product. The product aims to extend the lifespan of commonly used menstrual solutions such as the free, disposable pads distributed in the camp and of cloth alternatives that women utilize when they don't have access to other products. The product is also handsewn, and its inventors have developed step-by-step instructions for women in Dzaleka to sew products themselves to make an income. The WISSP Pad Solution aims to utilize very little water for washing which is important in a refugee camp with limited sanitary services (Kambala et al., *Acceptability of menstrual products interventions for menstrual hygiene management among women and girls in Malawi - Reproductive Health* 2020).

The value of the WISSP product is two-fold. It focuses on addressing the most pressing barriers for women to have sanitary, affordable, and low-maintenance menstrual solutions, and the product also financially empowers women by providing an income-generating opportunity for them. The goal of WISSP's work is to have women sew WISSP Pad Solutions with locally sourced materials that have been supplied by a camp manager. These women will profit from this work through: grants received to fund WISSP's work, local NGOs who have purchased pads to distribute in their communities, and any revenue earned at local markets from selling the pads.

This study will be focused on quantifying the extension of life the WISSP Pad Solution offers when used in combination with current menstrual solutions in Dzaleka refugee camp. It will also make design recommendations to maximize the life of the WISSP Pad Solution.

Chapter 3

Methods

Product Testing

To determine the effectiveness of the pad solution and the value it created for women refugees in Dzaleka, Malawi, it was important to conduct product testing that compared the Women in STEM Solving Problems (WISSP) Pad Solution against other scientifically proven standards of care. Because the nature of the WISSP Pad Solution is not to serve as an alternative product itself but rather is designed to enhance existing standards of care in Dzaleka, the research must also study how the WISSP Pad Solution performs when combined with the usage of commonly used menstrual solutions.

The product testing performed in this research does not evaluate all the value this product intends to offer. The scope of this testing is to determine one aspect of comfort that menstrual pad products are measured on with a ***wetback test*** and to quantify the capability of the pad solutions with an ***absorbency test***.

The wetback test measures the amount of fluid that comes back on a filter paper after pressure is applied to the paper onto the fluid-filled menstrual pad solution to mimic the comfort and experience of a woman wearing the menstrual pad. The upwards pressure that one's underwear puts onto the pad causes a "wetback" phenomenon of the user experiencing fluid coming back onto their skin. Especially in unsanitary environments with limited access to washing and cleansing systems, this is important to evaluate because sitting blood on skin in

humid conditions can lead to infections and extreme discomfort (World Bank Group, *Menstrual Health and hygiene* 2022).

Although various tests are used across medical device companies to quantify the absorption of their product before leakage, or "retention of fluid", the absorbency test used for this product testing was an absorbency capacity test. Menstrual fluid solution was deposited on each pad solution until the product leaked, and the number of mL retained by each product was compared.

There were seven pad solutions compared in this research's product testing: Pad Solution #1: United States Premium Pad Option, Pad Solution #2: United States Economy Pad Option, Pad Solution #3: Malawian Disposable Pad, Pad Solution #4: Reusable WISSP Pad, Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad, Pad Solution #6: Washcloth, and Pad Solution #7: Washcloth + Reusable WISSP Pad.

Pad Solution #1 was a US Premium Product. This product was an "Always Maxi Feminine Pad for Women, Size 1 Regular Absorbency, with Wings, Unscented" (*Always Maxi Feminine Pads for Women, Size 1 Regular Absorbency, with Wings, Unscented, 45 Count*). A US Premium standard of care product was used in this testing because it shows how well the WISSP Product performs when used in combination with accessible products in Dzaleka. Because the American regulatory testing requirements for medical devices are generally standardized, my research utilized their groundwork and metrics to develop a Standard Operating Procedure (SOP) and visualize the WISP Product's effectiveness relative to other menstrual solutions. Pad Solution #2 was a US Economy Product. This product was an "Always Ultra Thin Feminine Pad For Women, Size 1 Regular with Wings, Unscented" (*Always Ultra Thin Feminine Pads For Women, Size 1 Regular Absorbency, Multipack, With Wings, Unscented, 36 Count x 2 Packs (72*

Count total)). An economy product was important to include because it helped develop a calibration relationship between accessibility (in this case cost) of product and its performance. Both Pad Solution #1 and Pad Solution #2 were disposable products.

Pad Solution #3 was the Malawian Disposable Pad that is distributed in the Dzaleka Refugee Camp. This product was a "Purity Maxi Pad, Cotton-Scented, with Wings". Pad Solution #4 was the Reusable WISSP Pad by itself to determine whether it could act as an alternative pad solution in replace of other options. Pad Solution #5 was the Reusable WISSP Pad and Malawian Disposable Pad combined. The WISSP Pad was designed to strap the Malawian Disposable Pad to it with the goal of extending its estimated time range of usage. The Malawian Disposable Pad Solution is a disposable product, but the WISP Pad is a reusable product.

Although the research did not originally include Pad Solution #6, a Washcloth, in its scope, it became important to demonstrate that the WISP Pad enhanced the variety of pad solutions that women have access to in Dzaleka Refugee Camp, not just the Malawian Disposable Pads. A washcloth, piece of fabric, or scarf-like material is a commonly used menstrual solution option in Dzaleka, similarly to how the Malawian Disposable Pads are (Nkhoma, *Reach and Save refugee girls in Malawi from sexual violence* 2020). As done for Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad, Pad Solution #7 combined the Reusable WISSP Pad and the Washcloth. The Washcloth is a reusable menstrual solution after washing. For the Pad Solutions that combined the products, the research doesn't just evaluate how that solution compares to the US Premium and Economy Products, but it also evaluates how the combination compares to the commonly used menstrual solutions by themselves.

Figure 1. Pad Solution #1: United States Premium Pad Option

Figure 2. Pad Solution #2: United States Economy Option

Figure 3. Pad Solution #3: Malawian Disposable Pad

Figure 4. Pad Solution #4: Reusable WISSP Pad

Figure 5. Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad

Figure 6. Pad Solution #6: Washcloth

Figure 7. Pad Solution #7: Reusable WISSP Pad + Washcloth

Based on the claims and goals the WISSP Team had for the barriers the product would overcome, the study hypothesized that the WISP Pad was combined with the currently accessible menstrual solutions (a Washcloth or Malawian Disposable Pad) would statistically significantly increase the absorption capacity of the accessible menstrual solutions if they were used by themselves. It also hypothesized that when the WISP Pad was combined with the currently accessible menstrual solutions (a Washcloth or Malawian Disposable Pad), the product would either have a statistically similar or greater absorption capacity of the US Premium Product. It was predicted that the US Premium Product would have a greater absorption capacity than the Washcloth or Malawian Disposable Pad did when used by themselves. It was hypothesized that both Pad Solutions that included the Malawian Disposable Pad would have a greater wetback value than the United States Premium Product.

The purpose of this testing is to make WISSP Pad design recommendations based on both qualitative and quantitative observations, develop evidence for marketing claims that can be used to secure funding and corporate support for WISSP Pad implementation, and provide the

Dzaleka community of women and Malawian Non-Governmental Organizations (NGOs) with data to inform users about this product before usage.

Wetback

The wetback testing was extremely important to evaluate one important aspect of the pad solutions' comfort. Comfort in menstrual products can be evaluated many ways, mostly by user testing, but this research was able to utilize laboratory testing. The purpose of the wetback test was to mimic the phenomenon of menstrual fluid coming back onto a user's skin due to the upwards pressure applied by that user's underwear. Menstrual pad products actually leverage this upwards force from the underwear to stay in place as the user is mobile throughout the day, but the drawback of this applied pressure is that the menstrual fluid wetback is uncomfortable and can cause infection.

The Women in STEM Solving Problems (WISSP) Pad was not designed to decrease the amount of wetback fluid because the WISSP Pad is focused on decreasing the need to replace and purchase Malawian Disposable Pads and/or Washcloths, which are the existing menstrual solutions for women in Dzaleka. This mission of decreasing the need to replace and purchase menstrual solutions is best solved by increasing the absorption capacity of those products. The combination of the WISSP Pad and the accessible Dzaleka menstrual solutions does not alter the surface of the menstrual product that is in contact with the user's skin, so the addition of the WISSP Pad should not impact the wetback results.

Despite the WISSP Pad not being designed to improve the wetback experience for users, it was important to perform this testing to confirm there is no impact from the WISSP Pad and

that there isn't a need for the WISSP Pad to address this comfort metric for existing menstrual solutions in Dzaleka.

If the combination of the Reusable WISSP Pad and Malawian Disposable Pad or the combination of the Reusable WISSP Pad and Washcloth statistically significantly increases the amount of wetback fluid measured compared to the Malawian Disposable Pad or Washcloth solutions by themselves, the Reusable WISSP Pad should make design considerations that address this. If the Malawian Disposable Pad and/or Washcloth deposit a statistically significantly greater amount of menstrual fluid in wetback compared to the United States Premium and Economy products, then the WISSP Pad should consider a modification that decreases wetback fluid.

The Standard Operating Procedure (SOP) and decision to utilize wetback testing was inspired by the European Disposables and Nonwovens Association (EDANA)'s suggested performance testing standards for hygiene absorbent products. EDANA is committed to uniting all parts of the menstrual product value chain to inform testing procedures. In their "Guidelines for Testing Feminine Hygiene Products", one of the recommended tests is wetback testing to evaluate comfort and potential for bacterial infection based on wetback fluid (*EDANA Guidelines for Testing Feminine Hygiene Products* 2018). Many other scholarly articles utilize wetback testing (Shibly et al., *Development of biopolymer-based menstrual pad and quality analysis against commercial merchandise - bulletin of the National Research Centre* 2021) (Barman et al., *An Overview On Sanitary Napkins*).

Materials

The materials necessary for the wetback testing included all pad solutions: Pad Solution #1: United States Premium Pad Option, Pad Solution #2: United States Economy Pad Option, Pad Solution #3: Malawian Disposable Pad, Pad Solution #4: Reusable WISSP Pad, Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad, Pad Solution #6: Washcloth, and Pad Solution #7: Washcloth + Reusable WISSP Pad.

In order to produce a menstrual solution with similar viscosity and color to real menstrual blood, the study required Lab Alley Glycerin 99.5% Reagent Grade (*Glycerin 99.5% reagent grade*), Happy Belly Red Food Coloring (*Amazon Brand - Happy Belly Red Food Color 1 fl oz*), and distilled water (Larsson et al., *Studies on blood viscosity during the menstrual cycle and in the postmenopausal period in healthy women* 1989). “Eisco Labs Premium Qualitative Filter Paper – 7.28" (18.5cm)” (*Premium Qualitative Filter Paper, 100 Pack - 7.28" (18.5cm) - Eisco Labs*) was used to absorb menstrual fluid from the pad solutions. The study also required a mass as wide as the width of your pad solutions to mimic the underwear’s applied pressure. The mass should be at least 100 grams in order to effectively demonstrate a force felt by the pad, distributed evenly throughout the mass, and it should be larger in area than the filter paper. The mass used in this study was 118.18 grams. A Fuzion Digital Kitchen Scale, 500g/0.01g Digital Weight Gram and Oz Scale (*Fuzion Digital Kitchen Scale, 500g/ 0.01g Small Jewelry Scale, Food Scales Digital Weight Gram and Oz*) was used to weigh the mass of the filter paper before and after absorbing menstrual fluid. A timer is used to standardize and control the variable of time which has an impact on absorption rate from the surface of the menstrual option. The

experiment requires the following glassware: five 50 mL beakers, a 500 mL beaker, a 100 mL beaker, a 250 mL beaker, a 10 mL graduated cylinder, and a 50 mL graduated cylinder.

Procedure

The entire Standard Operating Procedure for wetback testing can be found in [APPENDIX A]. The controls of the test included Pad Solution #1: United States Premium Pad Option, Pad Solution #2: United States Economy Pad Option, Pad Solution #3: Malawian Disposable Pad, Pad Solution #4: Reusable WISSP Pad, and Pad Solution #6: Washcloth. The experimental situations were Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad and Pad Solution #7: Washcloth + Reusable WISSP Pad.

To prepare the menstrual blood analog solution, the solution should achieve a 79.1% (v/v) distilled water and 20.9% (v/v) glycerol solution (Anastasiou et al., *Experimental investigation of the flow of a blood analogue fluid in a replica of a bifurcated small artery* 2011) because it will mimic the properties of human blood with 45% hematocrit (Larsson et al., *Studies on blood viscosity during the menstrual cycle and in the postmenopausal period in healthy women* 1989).

$$\frac{300 \text{ mL solution}}{1} \times \frac{79.1\% \text{ distilled water}}{\text{solution}} = 237.3 \text{ mL distilled water}$$

$$\frac{300 \text{ mL solution}}{1} \times \frac{20.9\% \text{ distilled water}}{\text{solution}} = 62.7 \text{ mL distilled water}$$

This test requires 300 mL of blood analog solution in a 500 mL beaker. 62.7 mL of glycerol solution is measured in a 100 mL beaker utilizing a 10 mL and 50 mL graduated cylinder. 237.3 mL of distilled water is measured in a 250 mL beaker utilizing a 10 mL and 50

mL graduated cylinder. Then, the glycerol solution and distilled water are mixed in a beaker. Once the solution is mixed, 15 drops of red food coloring dye is added to the beaker to increase visibility of the solution against a white background. The solution is mixed again.

All five 50 mL beakers are labeled with the numbers 1-7, and the mass is recorded of each utilizing the balance. 50 mL of the menstrual blood analog solution is poured into each 50 mL beaker, and the beakers 1-7 are weighed again. From there, you can determine the mass of menstrual blood analog solution in each beaker by subtracting the two recorded masses. Five pieces of filter paper are labeled with the numbers 1-7, and the mass is recorded of each utilizing the balance.

Beaker #1 is poured in the motion demonstrated below over Pad Solution #1: United States Premium Pad Option over the span of ten seconds. The area the fluid should be poured onto is no more than 2 inches in height and 1 inch in width. This motion of fluid distribution centralizes fluid in the center of the pad which mimics the way a user would deposit menstrual fluid on a pad.

Without touching or moving the pad, the fluid is allowed to settle into Pad Solution #1 for two minutes. This process of settling accounts for the fact that the fluid was deposited onto the pad at a much faster rate than a user would deposit fluid from their body; the settling allows the fluid to soak into the pad, so the wetback results are more similar to a real life wetback situation than if the filter paper was allowed to soak up fluid immediately after a large amount was deposited at a fast rate.

Quickly, Filter Paper #1 was placed very gently on the center of fluid-filled Pad Solution #1. The mass was applied evenly on top of the filter paper, ensuring that all parts of the filter paper that overlaid the Pad Solution were covered by the mass. The filter paper and mass were

allowed to sit on the Pad Solution for two minutes; they apply a force downwards that is similar to the pressure applied upwards by one's underwear. After the two minutes is up, the mass is quickly removed, and the filter paper is moved quickly to the balance to record its new mass. It is important this step is done quickly so the fluid does not evaporate from the filter paper before it is massed. The change in mass of the filter paper represents the amount of wetback fluid.

The process of depositing fluid, settling, applying a mass, and weighing is repeated for all seven pad solutions with corresponding beaker numbers, filter paper numbers, and pad solution numbers. It was repeated three times for each pad solution so there were multiple trials.

Absorbency

The absorbency capacity of a menstrual product is one of the number one indicators of an effective product. By increasing the absorbency capacity of a product, a user does not have to replace a product as frequently. This decreases the number of products a user has to buy and saves them the time and inconvenience of having to change products. For Dzaleka refugees, these two outcomes have a huge impact on their quality of life.

In the United States, the average percent of one's income spent on menstrual products is much smaller than a refugee's income (*Reusable sanitary pads and Sustainability*), so a decrease in the number of necessary products has much less of an income on their access to other basic necessities. But because menstrual products are rare and valuable in the refugee camp, especially relative to their income, a decrease in the number of products a user has to buy or trade for is very impactful.

Another difference in the quality of life between most Americans and Dzaleka refugees is access to private sanitary services. Especially in the workplace and in classrooms, there are usually restrooms nearby with clean water, toilet paper, and private areas. In Dzaleka, collecting water, typically a women's tasks, during the dusty season is extremely time-consuming and strenuous; wait-times at boreholes can be 2 to 3 hours on average (Ramier, *Life for Women in a Refugee Camp in Malawi: Understanding perceptions of security and insecurity* 2016). Schools don't always have nearby private restrooms. Because of this, decreasing the number of times a refugee has to change their menstrual product has a bigger impact on their lifestyle than many Americans can conceptualize.

These outcomes show how valuable it is to invest in menstrual products with longer lifetimes. The purpose of the absorbency test is to assess the fluid retention capacity of all pad solutions. The quantitative and qualitative results will be used for design recommendations for the WISSP Pad so that it increases the fluid retention of available menstrual products in Dzaleka, and the results will be used as evidence for any marketing claims the team would like to make to secure funding for implementation of this product.

The Standard Operating Procedure (SOP) and decision to utilize absorbency testing was inspired, again, by the European Disposables and Nonwovens Association (EDANA)'s suggested performance testing standards for hygiene absorbent products. EDANA is committed to uniting all parts of the menstrual product value chain to inform testing procedures. In their "Guidelines for Testing Feminine Hygiene Products", one of the recommended tests is absorbency testing to measure fluid retention capacity (*EDANA Guidelines for Testing Feminine Hygiene Products* 2018). Specific procedures and metrics were found in other scholarly articles

(Shibly et al., *Development of biopolymer-based menstrual pad and quality analysis against commercial merchandise - bulletin of the National Research Centre* 2021).

Materials

The materials necessary for the wetback testing included all pad solutions: Pad Solution #1: United States Premium Pad Option, Pad Solution #2: United States Economy Pad Option, Pad Solution #3: Malawian Disposable Pad, Pad Solution #4: Reusable WISSP Pad, Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad, Pad Solution #6: Washcloth, and Pad Solution #7: Washcloth + Reusable WISSP Pad.

In order to produce a menstrual solution with similar viscosity and color to real menstrual blood, the study required Lab Alley Glycerin 99.5% Reagent Grade (*Glycerin 99.5% reagent grade*), Happy Belly Red Food Coloring (*Amazon Brand - Happy Belly Red Food Color 1 fl oz*), and distilled water (Larsson et al., *Studies on blood viscosity during the menstrual cycle and in the postmenopausal period in healthy women* 1989). A timer is used to standardize and control the variable of time which has an impact on absorption rate from the surface of the menstrual option. Paper towels were used to identify leakages as soon as they occurred from a pad. This experiment utilized Brawny Tear-A-Square Paper towels (11 in x 5.5 in) (27.9 cm x 13.9 cm). The experiment requires the following glassware and equipment: a 1000 mL beaker, a 500 mL beaker, a 250 mL beaker, a 100 mL graduated cylinder, and a 60 mL syringe.

Procedure

The entire Standard Operating Procedure for absorbency testing can be found in [APPENDIX B]. The controls of the test included Pad Solution #1: United States Premium Pad Option, Pad Solution #2: United States Economy Pad Option, Pad Solution #3: Malawian Disposable Pad, Pad Solution #4: Reusable WISSP Pad, and Pad Solution #6: Washcloth. The experimental situations were Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad and Pad Solution #7: Washcloth + Reusable WISSP Pad.

To prepare the menstrual blood analog solution, the solution should achieve a 79.1% (v/v) distilled water and 20.9% (v/v) glycerol solution (Anastasiou et al., *Experimental investigation of the flow of a blood analogue fluid in a replica of a bifurcated small artery* 2011) because it will mimic the properties of human blood with 45% hematocrit (Larsson et al., *Studies on blood viscosity during the menstrual cycle and in the postmenopausal period in healthy women* 1989).

$$\frac{1000\text{ mL solution}}{1} \times \frac{79.1\%\text{ distilled water}}{\text{solution}} = 791\text{ mL distilled water}$$

$$\frac{1000\text{ mL solution}}{1} \times \frac{20.9\%\text{ distilled water}}{\text{solution}} = 209\text{ mL distilled water}$$

This test requires 1000 mL of blood analog solution in a 1000 mL beaker. 209 mL of glycerol solution is measured in a 250 mL beaker utilizing a 100 mL graduated cylinder. 791 mL of distilled water is measured in a 1000 mL beaker utilizing a 100 mL graduated cylinder. Then, the glycerol solution and distilled water are mixed in a beaker. Once the solution is mixed, 15 drops of red food coloring dye is added to the beaker to increase visibility of the solution against a white background. The solution is mixed again.

Pad Solution #1 is placed facing upwards on two half sheets of paper towels. A 60 mL syringe is held two inches above the center of the pad, and it begins to deposit the menstrual analog solution onto the pad in a motion demonstrated below. Utilizing a syringe and a timer, the fluid is deposited onto the pad at a constant rate of 10 mL every thirty seconds. The area the fluid should be poured onto is no more than 2 inches in height and 1 inch in width. This motion of fluid distribution centralizes fluid in the center of the pad which mimics the way a user would deposit menstrual fluid on a pad.

For as long as the menstrual product does not leak onto its surrounding paper towel, every three minutes the syringe will run out of fluid. Without touching or moving the pad, the fluid is allowed to settle into Pad Solution #1 for fifteen seconds while the syringe is refilled with 60 mL of fluid. This process of settling accounts for the fact that the fluid was deposited onto the pad at a much faster rate than a user would deposit fluid from their body; the settling allows the fluid to soak into the pad, so the wetback results are more similar to a real life wetback situation than if the filter paper was allowed to soak up fluid immediately after a large amount was deposited at a fast rate.

As soon as the first drop of blood is discovered on the paper towel, the fluid deposition is halted, and the number of mL deposited is recorded. The process of depositing fluid, settling, noticing leakage, and weighing is repeated for all seven pad solutions with corresponding pad solution numbers.

Chapter 4

Findings and Results

Wetback Test

Data was collected for the wetback test in the form of qualitative observations and quantitative metrics (grams of fluid that wetback onto a filter paper pressed against a menstrual fluid-soaked pad). A greater number of grams of fluid indicated that more fluid was coming back on filter paper after a force was applied to the filter paper onto the pad. This test was designed to mimic the wetback of a pad due to the pressure from one's underwear. The fluid was poured onto each Pad Solution at the same rate, deposited within the same square area, and distributed in the same motion to eliminate any impact those processes could have on differences in absorption until leakage for each Pad Solution. Three trials were conducted on different filter papers (labeled with a number indicating the Pad Solution and a letter indicated the trial) for each of the following Pad Solutions: Pad Solution #1: United States Premium Pad Option, Pad Solution #2: United States Economy Pad Option, Pad Solution #3: Malawian Disposable Pad, Pad Solution #4: Reusable WISSP Pad, Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad, Pad Solution #6: Washcloth, and Pad Solution #7: Washcloth + Reusable WISSP Pad, and the data and average data is depicted in Table 1 and Table 2 below.

Table 1. Raw Filter Paper Wetback Fluid Mass Data Based on Pad Solution

Filter Paper	Mass (g) when dry	Mass (g) when wet	Wetback Fluid Mass (g)

Filter Paper #1a	2.32	3.26	0.94
Filter Paper #1b	2.37	3.34	0.97
Filter Paper #1c	2.1	3.29	1.19
Filter Paper #2a	2.26	3.52	1.26
Filter Paper #2b	2.3	3.43	1.13
Filter Paper #2c	2.23	3.66	1.43
Filter Paper #3a	2.18	2.2	0.02
Filter Paper #3b	2.13	2.13	0
Filter Paper #3c	2.33	2.35	0.02
Filter Paper #4a	2.3	3.8	1.5
Filter Paper #4b	2.2	3.56	1.36
Filter Paper #4c	2.24	3.88	1.64
Filter Paper #5a	2.21	2.21	0
Filter Paper #5b	2.14	2.15	0.01
Filter Paper #5c	2.28	2.28	0
Filter Paper #6a	2.27	5.02	2.75
Filter Paper #6b	2.32	4.78	2.46
Filter Paper #6c	2.19	4.91	2.72
Filter Paper #7a	2.3	4.96	2.66
Filter Paper #7b	2.15	4.82	2.67
Filter Paper #7c	2.29	4.54	2.25

Table 2. Pad Solution Mass and Average Wetback Fluid Mass Data

Pad Solution	**Mass (g)**	**Average Wetback Fluid Mass (g)**
Pad Solution #1: United States Premium Pad Option	8.83	1.033
Pad Solution #2: United States Economy Pad Option	4.17	1.273
Pad Solution #3: Malawian Disposable Pad	8.78	0.013
Pad Solution #4: Reusable WISSP Pad	20.28	1.500

Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad	28.62	0.003
Pad Solution #6: Washcloth		2.643
Pad Solution #7: Washcloth + Reusable WISSP Pad		2.527

Multiple two-tailed, Type 1 T-Tests were performed between data sets for different Pad Solutions to demonstrate how United States Premium Pad Options differentiate from comparable Pad Solutions in Malawi, Africa and to demonstrate how Pad Solutions changed in absorption capacity when they were combined with the Reusable Women in STEM Solving Problems (WISSP) Pad seen in Table 3 and Table 4.

Table 3. Comparing United States Premium Pad Wetback versus Comparable Pad Solutions Wetback

Comparing Comparable Solutions:	**T-Test P-Value**	**Percent Difference in Mean**
Comparing #1 and #3:	0.0056	-98.71%
Comparing #1 and #5:	0.0060	-99.68%
Comparing #1 and #7:	0.0204	144.52%

Table 4. Comparing Pad Solutions Wetbacks by Themselves versus Pad Solutions Combined with Reusable WISSP Pad Wetbacks

Comparing Solutions Made Better by WISSP Pad:	**T-Test P-Value**	**Percent Difference in Mean**
Comparing #3 and #5:	0.4226	-75.00%
Comparing #6 and #7:	0.6133	-4.41%

The null hypothesis states that the two Pad Solutions being compared are not statistically significantly different. A p-value less than 0.05 indicates that there is a less than 5% chance the null hypothesis is correct, and the Pad Solutions are likely statistically significantly similar.

Based on the T-Test, Pad Solution #3: Malawian Disposable Pad wetback statistically significantly less grams of menstrual fluid than Pad Solution #1: United States Premium Pad Option did (p-value: 0.0056 < 0.05, % change: -98.71%). Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad wetback statistically significantly less grams of menstrual fluid than Pad Solution #1: United States Premium Pad Option did (p-value: 0.0060 < 0.05, % change: -99.68%). Pad Solution #7: Washcloth + Reusable WISSP Pad wetback statistically significantly more grams of menstrual fluid than Pad Solution #1: United States Premium Pad Option did (p-value: 0.0204 < 0.05, % change: 144.52%). Pad Solution #3: Malawian Disposable Pad did not wetback statistically significantly different grams of menstrual fluid than Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad absorbed (p-value: 0.4226 > 0.05, % change: -75.00%). Pad Solution #6: Washcloth did not wetback statistically significantly different grams of menstrual fluid than Pad Solution #7: Washcloth + Reusable WISSP Pad (p-value: 0.613 > 0.05, % change: -4.41%).

Absorbency Test

Data was collected for the absorbency test in the form of qualitative observations and quantitative metrics (mL until the product leaked red menstrual solution onto the surrounding white paper towel). A greater number of mL indicated that the product retained more fluid than a product that recorded a lesser number of mL until leakage. The fluid was poured onto each Pad Solution at the same rate, deposited within the same square area, and distributed in the same motion to eliminate any impact those processes could have on differences in absorption until leakage for each Pad Solution. Three trials were conducted for each of the following Pad

Solutions: Pad Solution #1: United States Premium Pad Option, Pad Solution #2: United States Economy Pad Option, Pad Solution #3: Malawian Disposable Pad, Pad Solution #4: Reusable WISSP Pad, Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad, Pad Solution #6: Washcloth, and Pad Solution #7: Washcloth + Reusable WISSP Pad. Data collected about each Pad Solution can be found in Table 5.

Table 5. Individual Trial and Average Number of mL Until Leakage Based on Pad Solution

Pad Solution	**Trial 1: Number of mL Until Leakage**	**Trial 2: Number of mL Until Leakage**	**Trial 3: Number of mL Until Leakage**	**Average Number of mL Until Leakage**	**Std Deviation**
Pad Solution #1: United States Premium Pad Option	92	88	98	92.67	5.033
Pad Solution #2: United States Economy Pad Option	22	24	27	24.33	2.516
Pad Solution #3: Malawian Disposable Pad	155	172	158	161.67	9.073
Pad Solution #4: Reusable WISSP Pad	10	7	8	8.33	1.527
Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad	186	181	168	178.33	9.291
Pad Solution #6: Washcloth	25	32	26	27.67	3.785
Pad Solution #7: Washcloth + Reusable WISSP Pad	153	132	142	142.33	10.503

Multiple two-tailed, Type 1 T-Tests were performed between data sets for different Pad Solutions to demonstrate how United States Premium Pad Options differentiate from comparable Pad Solutions in Malawi, Africa and to demonstrate how Pad Solutions changed in absorption capacity when they were combined with the Reusable Women in STEM Solving Problems (WISSP) Pad seen in Table 6 and Table 7.

Table 6. Comparing United States Premium Pad Absorbency versus Comparable Pad Solutions Absorbency

Comparing Comparable Solutions:	**T-Test P-Value**	**Percent Difference in Mean**
Comparing #1 and #3 Malawian Disposable Pad:	0.0117	74.46%
Comparing #1 and #5 Reusable WISSP Pad + Malawian Disposable Pad:	0.0082	92.45%
Comparing #1 and #7 Washcloth + Reusable WISSP Pad:	0.0127	53.60%

Table 7. Comparing Pad Solutions Absorbencies by Themselves versus Pad Solutions Combined with Reusable WISSP Pad Absorbencies

Comparing Solutions Made Better by WISSP Pad:	**T-Test P-Value**	**Percent Difference in Mean**
Comparing #3 and #5 Reusable WISSP Pad + Malawian Disposable Pad:	0.1457	10.31%
Comparing #6 and #7 Washcloth + Reusable WISSP Pad:	0.0050	414.46%

The null hypothesis states that the two Pad Solutions being compared are not statistically significantly different. A p-value less than 0.05 indicates that there is a less than 5% chance the null hypothesis is correct, and the Pad Solutions are likely statistically significantly similar.

Based on the T-Test, Pad Solution #3: Malawian Disposable Pad absorbed statistically significantly more mL of menstrual solution than Pad Solution #1: United States Premium Pad Option did (p-value: 0.0117 < 0.05, % change: 74.46%). Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad absorbed statistically significantly more mL of menstrual solution than Pad Solution #1: United States Premium Pad Option did (p-value: 0.0082 < 0.05, % change: 92.45%). Pad Solution #7: Washcloth + Reusable WISSP Pad absorbed statistically significantly more mL of menstrual solution than Pad Solution #1: United States Premium Pad Option did (p-value: 0.0127 < 0.05, % change: 53.60%). Pad Solution #3: Malawian Disposable Pad did not absorb statistically significantly different mL of menstrual solution than Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad absorbed (p-value: 0.1457 > 0.05, % change: 10.31%). Pad Solution #6: Washcloth absorbed statistically significantly less mL of menstrual solution than Pad Solution #7: Washcloth + Reusable WISSP Pad (p-value: 0.0050 < 0.05, % change: 413.46%).

Qualitatively, the study revealed that leakages almost always occurred at the front and back end of the pads or on the immediate sides surrounding the area of fluid distribution first. Only for Pad Solution #6: Washcloth did the leakage occur through the center of the pad. Despite the Washcloth leaking through the center, the WISSP Pad was relatively dry underneath the cloth as seen in Figure 8.

Figure 8. WISSP Pad Remains Relatively Dry Underneath Cloth Soaked in Menstrual Fluid

The felt material of Pad Solution #4: Reusable WISSP Pad actually repelled fluid instead of absorbing it, as seen in Figure 9.

Figure 9. WISSP Pad by Itself Repels Menstrual Fluid

Finally, the WISSP Pad slightly “scrunched” the Malawian pad which caused a “convex” formation of the center of the pad being more raised than the sides and fluid would drain more quickly to the sides. The WISSP Pad also “scrunched” the washcloth in Pad Solution #7 as seen in Figure 10.

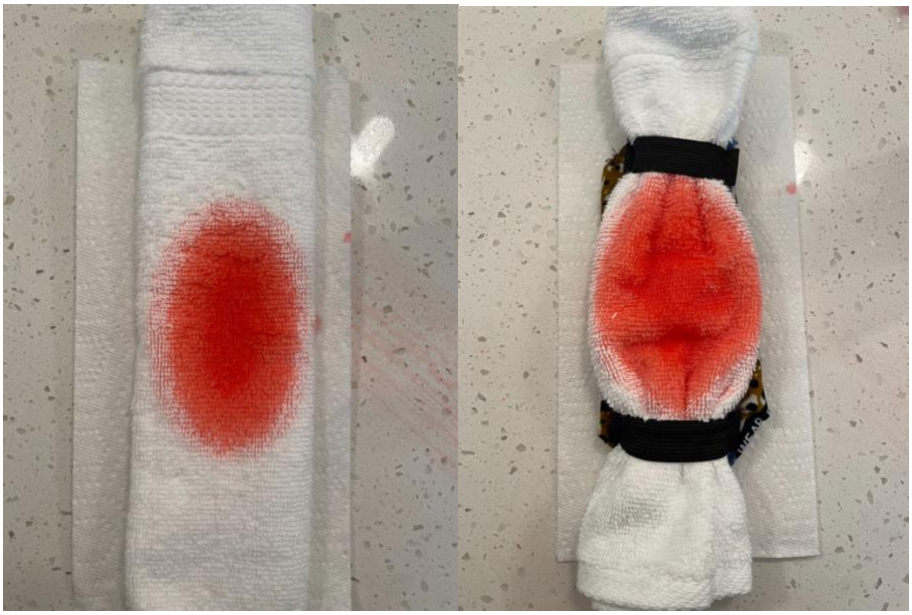

Figure 10. Comparison of Cloth by Itself with Cloth + WISSP Pad to Demonstrate Scrunching Phenomenon

Chapter 5

Discussion

Goals and Limitations

The original goal of this study was to test whether a pre-designed product, the Women in STEM Solving Problems (WISSP) Pad Solution, is a comparable or better menstrual product on the basis of wetback testing and absorbency capacity testing to United States standards. The study also aimed to observe whether the WISSP Pad Solution increased the absorbency capacity of commonly accessible menstrual solutions, a washcloth or a Purity disposable pad, when used in combination. Wetback testing was an important test because it evaluates comfort of a product and can even give us insight into the potential for infection from sitting menstrual fluid. Absorbency capacity was another important test because a greater amount of fluid that could be retained by a product indicated that product had a larger "lifespan" between changing products. In communities where sanitary and private infrastructure is limited, lifespan of a product strongly impacts quality of life and ability to continue normal activities with dignity.

The WISSP Team specifically designed the WISSP Pad to better existing menstrual solutions, so it was hypothesized that when the WISSP Pad was combined with a Washcloth or Malawian Disposable Pad, the absorption capacity of the accessible menstrual solutions would increase compared to if they were used by themselves. It was also hypothesized that the product would either have a statistically similar or greater absorption capacity of the US Premium Product when the WISP Pad was combined with a Washcloth or Malawian Disposable Pad. Based on my understanding of United States healthcare products versus Malawian healthcare

products, I predicted that the US Premium Product would have a greater absorption capacity than the Washcloth or Malawian Disposable Pad did when used by themselves. For the same reasons, I hypothesized that both Pad Solutions that included the Malawian Disposable Pad would have a greater wetback value than the United States Premium Product.

Significance of Wetback Tests

Based on the T-Test, Pad Solution #3: Malawian Disposable Pad and Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad both wetback statistically significantly less grams of menstrual fluid than Pad Solution #1: United States Premium Pad Option did. This disproves the hypothesis that the Malawian Disposable Pad would wetback a greater amount of fluid than the US Premium Pad, whether or not the WISSP Pad was present. One possible reason for this was that the Malawian Disposable Pad's "valley seams" within its structure collected and "irrigated" menstrual fluid to other parts of the pad.

With this difference, we noted that Pad Solution #3: Malawian Disposable Pad did not wetback statistically significantly different grams of menstrual fluid than Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad absorbed. Therefore, the WISSP Pad had virtually no impact on the amount of wetback fluid recorded for the Malawian Disposable Pad.

Pad Solution #7: Washcloth + Reusable WISSP Pad wetback statistically significantly more grams of menstrual fluid than Pad Solution #1: United States Premium Pad Option did. This solution is not surprising because US menstrual products sold on the market undergo significant material testing to retain fluid underneath the layer that touches the skin. This quality is important because it limits the possibility of urinary tract or reproductive infections. Similar to

the results seen for the Malawian Disposable Pad, Pad Solution #6: Washcloth did not wetback statistically significantly different grams of menstrual fluid than Pad Solution #7: Washcloth + Reusable WISSP Pad. Once again, the WISSP Pad had virtually no impact on the amount of wetback fluid recorded for the Washcloth solution. This is an important discovery because we recognize that the WISSP Pad is not doing anything to worsen or better the wetback nature of commonly used menstrual solutions.

Significance of Absorbency Tests

As far as the absorbency testing data, Pad Solution #7: Washcloth + Reusable WISSP Pad absorbed statistically significantly more mL of menstrual solution than Pad Solution #1: United States Premium Pad Option did. It was not expected that the Washcloth + WISSP Pad combination would outperform the US Premium Pad. In this case, the WISP Pad took the Washcloth from being one of the least reliant commonly used menstrual solutions to being even more competitive than the US Premium Pad Option.

Pad Solution #3: Malawian Disposable Pad and Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad absorbed statistically significantly more mL of menstrual solution than Pad Solution #1: United States Premium Pad Option did. This discovery was very surprising because of the assumption that US Premium Products would absorb more fluid than the Malawian Disposable Pad. Because the Malawian Disposable Pad already absorbed more fluid than the US Premium product, it becomes even more important to evaluate whether the addition of the Reusable WISSP Pad adds enough value that it is worth investing monetary, time, and labor resources in.

Value for the Reusable WISSP Pad is measured in two ways: the amount it extends the lifespan of currently accessible products and the economic empowerment it establishes for women in refugee camps. This study is only examining the first quality by measuring absorption capacity. The absorbency data showed that the Pad Solution #3: Malawian Disposable Pad did not absorb statistically significantly different mL of menstrual solution than Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad absorbed. Despite this, the data did show that the Pad Solution #6: Washcloth absorbed statistically significantly less mL of menstrual solution than Pad Solution #7: Washcloth + Reusable WISSP Pad. On average, the washcloth would hold 414% less menstrual fluid than when it was combined with the WISSP Pad. This indicates that the WISSP Pad is still performing well at taking commonly used menstrual solutions and extending their lifespan to limit the number of required menstrual product changes.

Another qualitative takeaway from the absorbency data was that the WISP Pad, when used by itself, actually repelled fluid because its first layer is felt. This meant that the WISSP Pad cannot be used by itself as an alternative menstrual solution. Although this initially appeared as a drawback, it became clear in the Washcloth qualitative data that the cloth would reabsorb the menstrual fluid that was repelled by the felt layer of the WISP Pad. This is extremely valuable because one of the biggest barriers for usage of reusable, washable menstrual products is the stigma associated with washing and drying of products. For the WISP Pad to show resistance to fluid absorption while simultaneously increasing the absorption capacity of a product, it has found the balance of two crucial metrics to make this a successful product in Dzaleka Refugee Camp.

Another qualitative observation was that the first leakages from the Washcloth by itself always were straight underneath the center point of the fluid dripping, whereas the first leakages

from the Washcloth when it utilized the WISP Pad occurred on the sides. This is likely due to the scrunching effect from the elastic placeholders and width of the WISP Pad. Because the sides of the WISP Pad are made of fabric that absorb fluid, it is recommended that the WISP Pad is widened to incentivize more fluid to leak through the center because it will be repelled and re-absorbed by the Washcloth. The goal of this recommendation is to simultaneously increase the amount of leaked fluid that is re-uptaken by the Washcloth and decrease the amount of leaked fluid absorbed by the WISP Pad which can create discomfort on the upper thighs.

Chapter 6

Conclusion

The Women in STEM Solving Problems (WISSP) Pad intentionally serves the challenges that the women in the community of the Dzaleka Refugee Camp face by preserving comfort and not increasing the potential of bacterial infection as observed in the wetback testing. The WISSP Product showed immense value in increasing the absorbency of some commonly used menstrual solutions, such as Washcloth, which indicates that the WISSP Pad extends the amount of time required between changing of menstrual products. Less frequent trips to sanitation facilities are extremely valuable for the women in Dzaleka because the time it can take to locate nearby sanitation services that are private can take away from school or work obligations, and women experience high levels of fear when walking alone in the camp at night because of the prevalence of sexual abuse. Less frequent changing of menstrual products also means that women can use less menstrual products overall. This is especially valuable in the Dzaleka Refugee Camp because impoverished communities like Dzaleka view disposable menstrual products as so rare that they are often used as currency in exchange for other basic needs such as food. Women in Dzaleka speak of the lack of negotiating power they have with their husbands to advocate for menstrual products as a purchasing necessity for the family because men make the income in the family.

As mentioned before, there are limitations of the scope of this product testing. User testing is an essential next step to evaluate all aspects of comfort and performance in the real-world conditions of Dzaleka. More pad performance tests that are essential to confidently review

and compare pad solutions include how well the product stays in place in the average Dzaleka environment of mobility, how well the product holds structure as it fills with menstrual blood, how much water and time the reusable product requires for cleaning, stigma that may surround the reusable product's cleaning process, accessibility of material used for the product, and more. Slight modifications can be made to the WISSP Product to make it more affordable and easier to source local materials.

The value the WISP Pad offers to the women in Dzaleka is measured in two ways: the amount it extends the lifespan of currently accessible products and the economic empowerment it establishes for women in refugee camps. This study evaluated the WISSP Pad's material performance through wetback and absorbency testing, but it did not quantify the opportunity for becoming an income-generating product.

It is important in future work to collect data on the potential for economic empowerment the WISSP Pad presents by studying the possible revenue sources from either individual market buyers or non-governmental organizations (NGOs) willing to purchase bulk products to serve their community. The data will help solidify how implementable this solution is. It will be essential to develop value charts between the two aspects of value that the WISSP Pad introduces to the community: the amount it extends the lifespan of currently accessible products and the economic empowerment it establishes for women in refugee camps.

A final future consideration for this future is to measure the opportunity for scale this product has. This study was focused primarily on serving the needs of refugees in Dzaleka Refugee Camps in Malawi, Africa, but the challenges faced by women in Dzaleka are shared by women in refugee camps or poverty across the world. Because Dzaleka Refugee Camp is a large refugee camp and has interactions with the surrounding Malawian community, it has great

potential to be a good community to pilot the success of the entire lifecycle of this product from locally-sourcing materials to putting the product in the hands of buyers.

Appendix A: Wetback Testing Standard Operating Procedure

Purpose

Wetback (or rewet) is a measure of the amount of liquid released by the product to the skin after absorption when pressure is applied to the product. “Performance of sanitary pads can be evaluated on the amount of fluid sustained after applying pressure.” (Barman et al., *An Overview On Sanitary Napkins*)

This is important because it mimics the comfort and experience of one wearing the menstrual pad. The upwards pressure that one’s underwear puts onto the pad causes a “wetback” phenomenon of the user experiencing fluid coming back onto their skin. Especially in unsanitary environments with limited access to washing and cleansing materials, this is important to evaluate because sitting blood on skin in humid conditions can lead to infections.

Scope

The document will detail all steps and procedures needed to determine the wetback measure of each product we can gather. Safety should always be the first priority, and it may be necessary to deviate from the listed steps in order to ensure safe and efficient lab usage.

Materials

- Pad Solution #1: United States Premium Pad Option “Always Maxi Feminine Pad for Women, Size 1 Regular Absorbency, with Wings, Unscented”
- Pad Solution #2: United States Economy Pad Option “Always Ultra Thin Feminine Pad For Women, Size 1 Regular with Wings, Unscented”
- Pad Solution #3: Malawian Disposable Pad “Purity Maxi Pad, Cotton-Scented, with Wings”
- Pad Solution #4: Reusable WISSP Pad
- Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad
- Lab Alley Glycerin 99.5% Reagent Grade
- Happy Belly Red Food Coloring
- Distilled water
- Brawny Tear-A-Square Paper towels (11 in x 5.5 in) (27.9 cm x 13.9 cm)
- Flat 100 g mass to apply pressure
- Eisco Labs Premium Qualitative Filter Paper – 7.28" (18.5cm)
- Fuzion Digital Kitchen Scale, 500g/0.01g Digital Weight Gram and Oz Scale

Safety and Hazard Review

None

Procedure

Control: Pad Solution #1: United States Premium Pad Option, Pad Solution #2: United States Economy Pad Option, Pad Solution #3: Malawian Disposable Pad, Pad Solution #4: Reusable WISSP Pad

Experimental: Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad

Preparing the Menstrual Blood Solution - a 20.9% v/v aqueous solution of glycerol will be made for the blood analog solution (Anastasiou et al., *Experimental investigation of the flow of a blood analogue fluid in a replica of a bifurcated small artery* 2011)

1. We will be preparing 300 mL of blood analog solution
2. Add 62.7 mL of glycerol to a beaker
3. Add 237.3 mL of distilled water to a beaker
4. Mix the solution
5. Add 12 drops of red food dye to the solution to increase visibility
6. Mix the solution again

Testing Each Pad Solution

1. Record the mass of all Pad Solutions
2. Label five 50 mL beakers 1-5, and record the mass of each beaker
3. Pour 50 mL of menstrual blood solution into each beaker
4. Record the mass of each 50 mL beaker once the fluid has been added to determine the mass of the menstrual blood solution in each beaker
5. Number five pieces of filter paper 1 through 5, and record the mass of each

6. Pour one full beaker on one Pad Solution in a circular spiral centered around the center of the pad.
    1. Use the numbered beaker solutions corresponding to the numbered Pad Solutions
    2. Centralize the fluid pouring into an area over 2 inches in height, 1 inch in width
7. Let the fluid settle into the Pad Solution for 2 minutes each; do not move or touch the Pad Solution during this time
8. Place filter paper gently and evenly (do not hold any part of the paper towel besides the outer borders) centered on top of the wet part of the Pad Solution
    1. Use the numbered filter paper piece corresponding to the numbered Pad Solutions
9. Allow the filter paper to sit for 120 seconds on the Pad Solution with a mass (118.18 grams) placed on top to mimic the pressure underwear would apply on the pad upwards
10. Remove the paper towel and immediately record the new mass with fluid to determine the mass of the fluid that came back up

Appendix B: Absorbency Testing Standard Operating Procedure

Purpose

Various methods have been developed to assess the retention capacity (absorption before leakage). These methods range from simple designs (dunk, fluid acquisition) to those that take the shape and the features to prevent leakages into consideration. “An absorbent capacity test is used to assess a material's ability to absorb a liquid and how quickly it does this, defined as its speed of absorption (ISO/IEC 17025). It is being used by companies that produce products such as sanitary napkins, baby diapers, wipes, paper towels, sponges and personal and feminine hygiene items.”

Scope

The document will detail all steps and procedures needed to determine the absorbency of each product we can gather. Safety should always be the first priority, and it may be necessary to deviate from the listed steps in order to ensure safe and efficient lab usage.

Materials

- Pad Solution #1: United States Premium Pad Option “Always Maxi Feminine Pad for Women, Size 1 Regular Absorbency, with Wings, Unscented”

- Pad Solution #2: United States Economy Pad Option “Always Ultra Thin Feminine Pad For Women, Size 1 Regular with Wings, Unscented”
- Pad Solution #3: Malawian Disposable Pad “Purity Maxi Pad, Cotton-Scented, with Wings”
- Pad Solution #4: Reusable WISSP Pad
- Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad
- Lab Alley Glycerin 99.5% Reagent Grade
- Happy Belly Red Food Coloring
- Distilled water
- Brawny Tear-A-Square Paper towels (11 in x 5.5 in) (27.9 cm x 13.9 cm)
- 50 mL syringe
- Metal clamps for syringe

Safety and Hazard Review

None

Procedure

Control: Pad Solution #1: United States Premium Pad Option, Pad Solution #2: United States Economy Pad Option, Pad Solution #3: Malawian Disposable Pad, Pad Solution #4: Reusable WISSP Pad

Experimental: Pad Solution #5: Reusable WISSP Pad + Malawian Disposable Pad

Preparing the Menstrual Blood Solution - a 20.9% v/v aqueous solution of glycerol will be made for the blood analog solution

1. We will be preparing 1000 mL of blood analog solution
2. Add 209 mL of glycerol to a beaker
3. Add 791 mL of distilled water to a beaker
4. Mix the solution
5. Add 12 drops of red food dye to the solution to increase visibility
6. Mix the solution again

Absorption before leakage

1. Place Pad Solution #1 on a paper towel with the skin-facing side facing upwards
2. Fix a 50 mL syringe directly centered, 2 inches above the pad with metal clamps
3. Drip 50 mL of menstrual solution at a rate of 20 mL/min in the center of the pad
4. Drip 5 mL of menstrual solution at a time until the menstrual solution leaks onto the surrounding paper towel (max out at 100 mL)
5. Record the number of mL the Pad Solution absorbed before leakage
6. Repeat steps 1-5 with all other pad solutions

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ACADEMIC VITA

SYDNEY ALEXANDRA WIRSIG GIBBARD

Education

The Pennsylvania State University **University Park, PA**
B.S. in Biomedical Engineering, Concentration in Biochemistry and Molecular Biology Graduation May 2023
College of Engineering | Schreyer Honors College

- Senior Honors Thesis in Humanitarian Engineering: Implementation of Hygienic Products and Medical Systems in Developing Countries

Work

Boston Consulting Group (BCG) **Philadelphia, PA**
Incoming Associate, Summer Associate June 2022 - Present

- Collaborated with consulting associate to design innovative solutions and plans for client by pulling on the intersectional nature of my engineering and healthcare knowledge
- Expanded skills in conveying findings from market research in clear presentations with actionable next steps

Johnson & Johnson, Ethicon Medical Devices **Somerville, NJ**
Biosurgery Research and Development Intern May 2021 – August 2021

- Prototyped a demo kit for global use in hospitals to demonstrate key differences between SURGICEL Topical Absorbable Hemostats and competitors by performing usability testing, in-hospital demo sessions, and cost analyses
- Developed a database of 50+ competitors of SURGICEL evaluated on 24 different chemical quantifications using multiple Microsoft applications
- Conducted testing to evaluate oxidized regenerated cellulose, particularly bactericidal properties and in-vitro clotting, to prepare persuasive sales demos
- Populated a claims database to inform cross-functional partners about evidence gaps and a need for new clinical studies based on global standards
- Generated technical memos based on usability, human factors, design verification, and validation studies to make recommendations to engineers about the need for new clinical data

Girls Code the World **Pennington, NJ**
Founder | www.girlscodetheworld.org March 2018 - Present

- Developed curriculum for the 501(c)(3) nonprofit organization I founded that provides opportunities, resources, and role models for young girls in STEM-related fields through a series of education programs and extended mentorships
- Acquired $50,000 in funding from Drexel University's College of Computing and Informatics, National Science Foundation, the Philadelphia Foundation, Johnson & Johnson, and more
- Built an internship program for 15 employees to grow technical teaching, curriculum development, and mentorship skills
- Oversaw a Board of Directors of six professionals by leading projects, assigning tangible tasks, creating a strategic plan with short-term goals, and scheduling meetings

MasterCard Malawi Refugee Crisis Researcher **Lilongwe, Malawi, Africa**
Student Spokesperson and Author of Research Report March 2019 – September 2020

- Co-authored a research paper evaluating the barriers and enablers to economic opportunities for youth in Dzaleka Refugee Camp after a $40,000 grant acquisition from MasterCard
- Designed engineering projects students can work on in future years to support the people of Dzaleka such as a desk design project, hygienic pad design for teenage girls, and technology implementation

Extracurriculars and Development

Penn State Student Government and Faculty Senate **University Park, PA**

Student Body President, Vice President, Speaker, College of Engineering Representative September 2019 - Present

- Spokesperson for over 45,000 students to administration including the Board of Trustees, University President, Provost, the University Faculty Senate, Alumni Association, and other members of President's Council
- Implement new academic policies/practices, advocate for marginalized voices, and develop institutional media campaigns while balancing the needs of several stakeholders with concept proposals, representation on task forces, and more
- Member of the Student Fee Board, an allocation board that manages over $26 million in student fees annually
- Oversaw one hundred members by developing their timelines and budgets for projects that address student-facing topics
- Elected by students as the sole representative for the College of Engineering at Penn State and internally elected by my peers to serve as the leader of the Legislative Branch and manage the use of our $170,000 annual budget

Penn State Hershey Medical School's Primary Care Scholars Program 2021 **State College, PA**

Student Shadow and Mentee May 2021 – June 2021

- Implemented medical knowledge to compete in a problem-based learning medical case study competition

Extracurriculars: THON Hospitality Committee, State of State Marketing Director, Club Swim, SHOTIME Orientation Mentor, Lion Ambassadors, Pi Beta Phi Sorority, Homecoming Photography Committee
Experiences: General Electric (GE) Leadership Development Program, St. Mary Hospital Volunteer: Breast Center and Labor & Delivery, Haiti Medical Mission Trip, Advanced Heart and Vascular Institute Internship
Awards: 2023 President Eric. A Walker Award, Engineering Design Course Project Award, Princeton University's Hubert Alyea Award, National Center for Women in Information Technology Regional Award, Penn Stater Magazine May-June 2022 Issue Feature, Student Leadership Scholar
Skills: MATLAB, SolidWorks CAD Software, Java, Chemical and Biological Lab Concepts, Grant Writing, Project Management, Microsoft Suite, Qualitative and Quantitative Research, Design Validation and Verification, Clinical Studies