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RESEARCH PROTOCOL

The Use of Water Filters to Prevent Contagious Skin Infections Amidst Refugee Camps: A Research Protocol

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Abstract

Introduction: Global refugee crises have caused a surge in contagious skin infections among refugees, which can be attributed to the lack of clean water and overcrowded conditions within refugee camps that allow infections to spread easily. This research protocol presents a comprehensive approach to addressing skin infections in refugee camps through the Hygiene for Health (HFH) initiative. HFH consists of a Slow Sand Filtration (SSF) system utilizing graphite oxide-coated sand and a team of volunteers for education and monitoring.

Methods: The study evaluates the viability and efficacy of HFH in refugee camps. The slow sand filtration system utilizing graphite oxide (GO) coated sand is a novel approach to water purification. The unique properties of GO-coated sand make it highly effective in removing contaminants. The study will implement 10 GO SSF systems in refugee camps where skin infection is a concern, to evaluate their effectiveness in improving water quality and reducing skin infections. Volunteers will play a crucial role in the study, with one group focused on education and community empowerment while the other monitors the impact of the initiative.

Anticipated Results: Projected results expect GO SSF systems to reduce bacterial skin infections among refugees by improving water quality.

Discussion: The HFH approach is specific and practical, making it suitable for addressing the refugee health crisis. Moreover, cost analysis demonstrates that despite initial expenses, GO SSF systems offer long-term benefits compared to traditional SSF systems.

Conclusion: Previous research and evidence indicate that HFH will successfully reduce the number of skin infections among refugees by implementing GO SSF.

Keywords: refugee crisis; water filtration; skin infections; graphite oxide-coated sand

Introduction

Global refugee crises have precipitated a dire public health concern: a surge in contagious skin infections among refugees. This phenomenon can be attributed to inadequate access to clean water and severe overcrowding that facilitates the rapid transmission of infections [1, 2]. Several contaminants, including fecal matter and chemicals, make the water in refugee camps extremely dangerous for hygiene [3].

The escalating incidence of leprosy, a bacterial skin infection with an increased rate of "1.6 new cases per year" since 2012, is of particular concern [4]. A 2020 study proved that poor water, sanitation and hygiene (WASH) factors are associated with higher odds of leprosy [5]. Furthermore, other studies have detected potentially viable *M. leprae*, the bacteria responsible for leprosy, in water samples [5, 6]. This research suggests that water used by infected individuals may inadvertently serve as reservoirs for infection.

In addition to leprosy, other pathogenic microorganisms such as *Staphylococcus aureus*, *Streptococcus pyogenes*, and *Pseudomonas aeruginosa* have been identified in water sources and may lead to severe skin infections such as impetigo [7, 8]. This disease, which is highly contagious and characterized by red sores on the face, has a mortality rate of over 50% in adults without treatment [9]. Skin infections pose an imminent threat to individuals of all ages, underscoring the need for more effective sanitation infrastructure.

This research protocol outlines a solution to address the pressing issue of skin infections in refugee camps. Such a solution requires a comprehensive approach focusing on disease prevention, improving sanitation, and providing health-centred education. The proposed solution, Hygiene for Health (HFH), aims to reduce the incidence of skin infections by introducing effective sanitation infrastructure. HFH comprises two components: (1) a slow sand filtration system that features GO-coated sand and utilizes sustainable natural resources, and (2) a team of volunteers that spread awareness about skin infections and monitor the effectiveness of the solution. The HFH initiative aims to empower refugee communities with the tools and skills to be self-sustaining in the long term. Its cost-effectiveness is paramount, ensuring accessibility, affordability, scalability, and reach of this innovative solution.

Slow Sand Filtration

Slow sand filtration (SSF) is a water purification method typically used to address water needs in rural and remote areas [10]. A conventional SSF passes raw water through a bed of fine sand to produce clean, potable water. A vital component of a traditional SSF is the schmutzdecke, a biologically active layer composed of organic matter that forms on the surface of the sand [11]. The schmutzdecke layer becomes viable after a maturation period of several weeks, before which all filtered water must be discarded [11]. It plays a crucial role in removing bacterial contaminants, trapping and consuming particulate matter and pathogens with an effectiveness between 90-99% [11].

Graphite Oxide-Coated Sand

Graphite oxide (GO) coated sand was developed initially at Rice University [12]. By binding graphite oxide to sand, this composite material harnesses the attributes of both constituents, resulting in a filtration medium that surpasses conventional alternatives [12]. After wrapping around the sand, the hydrophilic components of GO are exposed [12]. These regions exhibit an affinity for water-soluble contaminants—including heavy metals and various acids—and bacteria [12]. Due to these unique properties, GO-coated sand is an excellent medium for filtration, excelling at attracting and removing contaminants. When combined with the SSF mechanism, GO-coated sand proves to be highly effective at filtering out contaminants.

Objective

This research protocol aims to evaluate the viability and efficacy of implementing the HFH solution within refugee camps.

Methods

This study will be split into two components: the slow sand filtration system and the on-field volunteers. The latter component is primarily intended to monitor the efficacy of the former component.

Slow Sand Filtration (SSF)

In this study, 10 SSF systems will be implemented within refugee camps where skin infection is a concern, for approximately a year. This study defines a concerning frequency of skin infections as 1 in every 3 individuals presenting symptoms related to dermatologic conditions. Each SSF will be located within a refugee community to ensure that clean water is easily and equally accessible. These conditions will provide an area to evaluate the efficacy of GO-coated sand in slow sand filters and its potential to alleviate the skin infection crisis. All SSF systems in this study will adopt GO-coated sand as the filtration medium, supplanting conventional sand.

This substitution proves extremely advantageous; using GO-coated sand will circumvent the schmutzdecke incubation process and construct an SSF with enhanced filtration capabilities, according to existing studies [13]. A study by Vu and Wu (2022) compared the efficacy of using the GO-coated sand with and without the schmutzdecke layer for removing micropollutants. Results revealed that the enhanced ability of the sand to remove contaminants was primarily attributed to the GO, not the schmutzdecke [13]. The study concluded that this was likely due to the high affinity between GO and organic contaminants, a property inherent to GO coated sand. As such, the schmutzdecke incubation process may no longer be needed when using a GO sand filter [13]. This circumvention of the schmutzdecke incubation process provides a great advantage over traditional SSF as a GO SSF can be used immediately without waiting for the schmutzdecke to become viable.

Creating GO-coated sand entails the dispersion of GO into water and mixing this slurry with fine sand [12]. Following this, the mixture will be heated to 105ºC to evaporate the water, leaving behind GO-coated sand with five times the filtration capacity of regular sand [12]. Within the GO SSF, raw water will first pass through the schmutzdecke layer to eliminate various pathogens before travelling through the GO-coated sand, whose hydrophilic tendencies will adsorb contaminants, allowing clean, filtered water to flow out (Figure 1). Vu and Wu concluded that the GO coating "changed the surface reflection and elemental composition, and reduced the surface area, pore size, and pore volume of the sand" [13]. As mentioned above, the filtration capacity of the sand was heightened, owing to the affinity between GO and organic compounds [13].

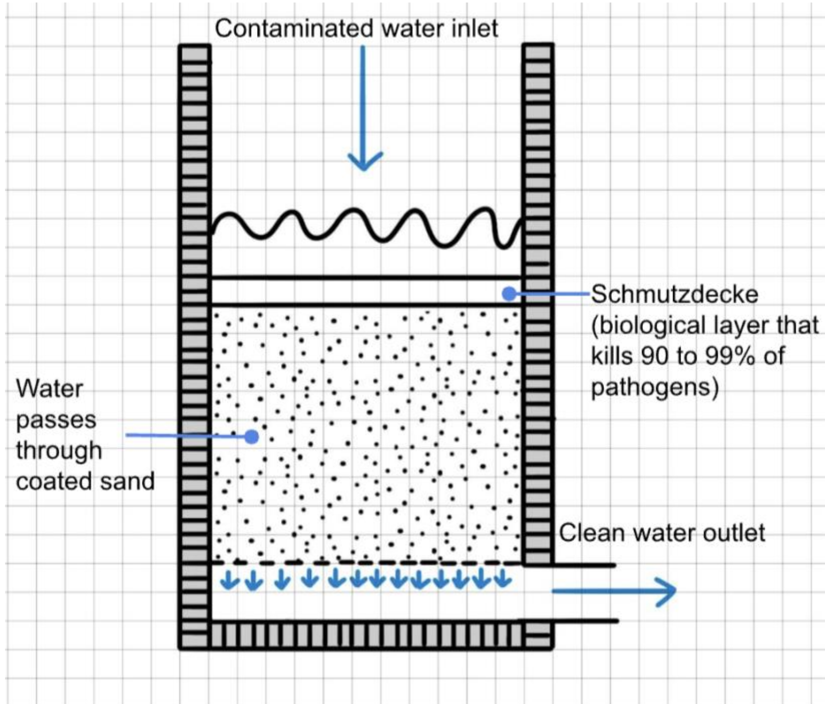

Figure 1. The slow sand filtration system was used in the study protocol. Raw water will enter through the top of the filter before travelling through the schmutzdecke layer before passing through the GO-coated sand. The clean water will then flow through the bottom of the filter, which will then be transferred to a reservoir available to refugees. This figure was created using Notability and Google Drawings.

According to the design recommendations by the American Water Works Association, a community-level SSF is recommended to possess a surface area of 100 m^2 and a depth of 0.9 m [13]. Each of the 10 SSFs utilized in this study will adhere to these measurements to ensure optimal clean water output.

The implementation of the HFH SSF system is strategically poised to harness sustainable natural resources. Sand for the SSF can be readily sourced from local rivers [15]. Furthermore, if possible, glass bottles residing in surrounding landfills can undergo a crushing process to be turned into medium and fine sand, offering not only a method to gather plentiful amounts of sand, but also an environmental benefit [16]. While the prospect of utilizing crushed glass coated with GO presents a compelling resource, its current viability remains subject to inconclusive empirical data; more research must be conducted on the properties of crushed glass coated with GO. As such, this component will not be a part of this study and instead stands as a forward-looking approach.

Volunteer Engagement and Responsibilities

In the execution of this study, a pivotal facet resides in the engagement of two volunteer cohorts, each of which shall be deployed across the 10 study sites. These volunteer groups will be composed of individuals drawn from the local populace and the international community, fostering a diverse and dynamic collective. Volunteers will be recruited via an online application form that assesses various criteria of the individual. Inclusion criteria includes commitment to community service, teamwork skills, open mindedness regarding different cultures and practices, familiarity with the local language, and availability for the 12-month study period. Volunteers will also undergo training where they will learn about skin disorders, how to recognize signs and symptoms of skin disease, mechanisms of a GO-SSF, research ethics where volunteers will learn to handle private health data, and specific cohort training. The first volunteer subgroup will explain the water filtration process, helping to initiate long-term autonomy within the refugee community. Group two will monitor the study throughout the 12 month period, including conducting a bi-monthly survey. This survey shall serve as the primary conduit for collecting empirical data, specifically in quantifying the projected decline in the prevalence of skin infections within the refugee community. The survey will be a self-report multiple-choice questionnaire which will allow volunteers to efficiently compile results at the end of each 2 month period. Surveys will be handed out by volunteers on Monday of the final week of the period, and collected by the following Sunday. This will allow patients ample time to complete the survey to the best of their abilities.

The questionnaire may ask for the demographic information of the individual, including sex and age; if the individual had experienced a skin infection within the last 2 months; the severity of the skin infection, if applicable; if the individual is aware of anyone who has suffered from a skin infection in the past two months; approximately how many times the individual has used the GO-SSF in the past 2 months; and the ease of access of the SSF for the individual. Evaluation criteria to assess severity of skin infections would include assessing the grade of edema (grade 1, 2, or 3); the stages of erythema (first, second, third, fourth, or fifth), the pain, tenderness, redness, and warmth of the area, as outlined by the Infectious Diseases Society of America diagnosis and treatment of skin and soft tissue infections 2014 updated guidelines [16]. These criteria will be outlined in plain wording on the survey to be easily understood by refugees who may not be knowledgeable on such medical terminology.

Results

The implementation of GO SSF systems in refugee camps holds considerable promise in significantly reducing the incidence of skin infections among refugees. This assertion is grounded in a comprehensive analysis of existing empirical data.

Based on a 2022 study, the GO-coated sand used in the ten study sites is expected to be highly effective in removing organic contaminants [13]. The study—which examined the filtration efficacies of a traditional SSF compared to an SSF using GO-coated sand—confirmed the enhanced removal capacity and water-purification abilities of the coated sand compared to the plain sand, a difference attributed to the GO layer with a high affinity for organic contaminants [13]. The GO-coated sand outperformed the plain sand in all areas of study, including improving turbidity and removing micropollutants, total organic carbon, and iron [13]. Thus, it is reasonable to extrapolate from these findings that the GO-coated sand used in the ten HFH study sites will demonstrate similar results. Consequently, the application of this filtration technology is projected to prevent the introduction of new waterborne skin infections in refugee camps. Apart from the water-purification abilities of the GO sand, this claim is further supported by the relationship between contaminated water and increased infection rates. For example, it was seen that the application of contaminated ice, containing *Mycobacterium Chelonae*, to the skin led to an outbreak of cutaneous infections in patients receiving care for post-surgery wounds [17]. As such, the importance of clean water becomes apparent for reducing the risk of contracting a skin infection. Finally, the bimonthly survey data collected by the second volunteer cohort is expected to support these results, demonstrating a downward trend in both the incidence of skin infections and severity.

Utilizing the measurements referenced in the Methods section, one SSF is poised to treat approximately 240,000 litres of water per day [13]. The World Health Organization (WHO) stipulates that a minimum daily water allotment of 50 litres per person is necessary to satisfy basic needs and ameliorate health concerns [24]. Following this guideline, one SSF will be able to serve a maximum of 4800 people with clean water. The implementation of the first volunteer group is expected to ensure that the refugees will be able to confidently use this system by the end of the study period, giving them the ability to support themselves regarding hygiene.

The proven efficacy of GO-coated sand in removing organic contaminants, the ample water treatment capacity of the proposed SSF systems, and the effective utilization of the two volunteer groups underscores the potential for significant improvements in water quality and, consequently, the reduction of skin infections among the refugee population.

Discussion

Cost Analysis

With the ongoing global refugee crisis, it is critical to devise a solution to efficiently combat the spread of skin diseases while considering potential cost barriers in low-income areas. Projected SSF costs can be evaluated and analyzed using limited data from public facilities and engineering companies. Due to many confounding variables — such as design capacity, materials, local conditions, and filter area — exact labour, construction, and maintenance costs cannot be discussed as absolutes; instead, a range is provided to account for fluctuating market values and discrepancies between vendor pricing. The comprehensive cost analysis can be broken down into two sections: cost of GO-coated sand and construction, operation costs, and maintenance costs.

The price of GO is variable, with $10/kg to $100/kg representing the most popular lower and upper-cost bounds [13]. To produce 1 g of GO-coated sand, 6 mg of GO is required. With a 90% coating effectiveness, the price per kg of sand would be $0.07 and $0.67 for a GO price of $10/kg and $100/kg, respectively (Table 1) [13]. Moreover, slow sand filter systems are relatively inexpensive, as the design is tailored towards serving the needs of smaller communities, with the bulk of the cost associated with installing and constructing the system itself. Existing data shows that building an SSF system costs 100 to 300 USD per square meter [18]. To maintain the effectiveness of the filter and prevent clogging, an SSF must be cleaned every two months by replacing the filtration medium [11]. This increases costs by $0.34 and $3.25 per m^3 of GO-coated sand (Table 1) [13].

Table 1. A summary of the cost breakdown of a GO SSF

	$10/kg of GO	$100/kg of GO
Price to produce 1 kg of GO coated sand	$0.07	$0.67
Replacement cost per m^3 of sand	$0.34	$3.25

While a GO SSF is more expensive than a traditional SSF, the increased efficacy and the lack of a schmutzdecke maturation period offset the price. This means a GO SSF can be used effectively without lag time after installation or between routine bimonthly replacements, ensuring that communities continuously have clean water. Thus, the HFH initiative presents a cost-effective solution that efficiently serves low-income refugee communities.

Strengths and Limitations

The proposed study exhibits several strengths. Namely, HFH provides an actionable 2-step solution that alleviates sanitation struggles in refugee camps, and also promotes autonomy to ensure that refugees will be self-sufficient in the long-run. In addition, HFH integrates innovative GO-coated sand technology into SSF systems, exploring an under-researched avenue that has demonstrated promise as a cost-effective method of sanitation. The unique properties of GO-coated sand, as referenced above, suggest enhanced filtration capabilities compared to traditional SSF systems. In addition, the absence of a schmutzdecke maturation period via GO-coated sand provides continuous clean water availability and contributes to the low cost of HFH. Finally, by the nature of SSF systems, the GO-SSF makes use of locally available materials and does not require close supervision.

Despite these strengths, the study faces limitations, including potential challenges in generalizing findings beyond the specific context of refugee camps. In addition, the study heavily depends on active volunteer participation for the collection of empirical data related to GO SSF performance. The study also acknowledges limited data on the viability of using GO-coated crushed glass and emphasizes the assumption of GO-coated sand effectiveness based on existing literature. While the study argues for the cost-effectiveness of GO-coated sand in the long run, the initial costs may still pose a short-term barrier to implementation in resource-constrained settings.

An additional element that must be discussed is the strengths and limitations of the self-report multiple-choice questionnaire in collecting patient data. By nature, this method of data collection is generally cost-effective and allows for real-time data collection, enabling adjustments to be made if necessary. In addition, the distribution of these surveys facilitate the efficient collection of data from a large number of participants across diverse and widespread populations, as in the case of the 10 study sites. Finally, the self-reported surveys capture both the subjective experience of individuals as well as objective demographic information. This provides volunteers with a holistic understanding of the situation and allows for a comprehensive analysis of how skin infections and the use of the GO-SSF may vary across different age groups, genders, or other relevant categories.

While this approach offers many benefits, it is not without limitations. Reliance on participant memory introduces potential recall bias, and social desirability bias may affect the accuracy of responses [19, 20]. Additionally, language and cultural barriers may still pose a challenge. Despite efforts to make the survey easily understandable, misinterpretation of questions or cultural nuances might affect the accuracy and reliability of responses. Finally, the subjective nature of self-reports may impact data reliability, especially regarding the severity of skin infections. Notwithstanding these challenges, the study aims to mitigate biases through clear survey design and training while recognizing the complementary role of data analysis in enhancing the overall findings.

Ethical Considerations

This study requires many ethical considerations, particularly during the data collection process. Considerations prior to, during, and following the process of data collection include:

- *Informing refugees of the objective of the initiative and reason for data collection*
- *Solely selecting refugees who volunteer to become involved in the study*
- *Informing refugees that data collection through the survey will remain confidential and de-identified unless there are any cases of harm to themselves and/or others*
- *Affirming that data collected is only accessible to HFH volunteers and members of the HFH data analysis team*

Conclusion

The study proposed in this paper presents a practical approach to tackle the causes of the increasing skin infections among refugees. Combining GO-sand with the schmutzdecke already found in SSF systems is a propitious solution to the various hygiene concerns within refugee camps due to the relatively low cost of the project and the filtration capabilities of the two substances. This system, coupled with the implementation of the two volunteer branches, promises long-term autonomy and the ability to evaluate the results of the GO SSF in real-time. An avenue to expand HFH includes sourcing glass bottles from landfills to be crushed and turned into sand for the SSF. Following the success of this study, the researchers are hopeful that the use of GO SSF will continue to increase throughout countries with a lack of access to clean water. The ability of the HFH plan to focus on affordable sanitation infrastructure, education, and community engagement will assist in creating a healthier and more resilient refugee population.

List of Abbreviations Used

WASH: water, sanitation, and hygiene
HFH: Hygiene for Health
SSF: slow sand filtration / slow sand filter
GO: graphite oxide
WHO: World Health Organization

Conflicts of Interest

The authors declare that they have no conflict of interests.

Ethics Approval and/or Participant Consent

Due to the nature of the proposal, this study did not require ethics approval and/or participant consent; it is an experimental proposal and analysis of existing research.

Authors' Contributions

All authors are to be held equally accountable for the aspects of manuscript production, including drafting the manuscript, critically examining it for its content, and collectively approving the final version to be submitted.

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