Assessing the impacts of a water, sanitation, and hygiene (WASH) intervention on changing behavior in Bihar, India

Emily R. Wilcox

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Luke Juran, Chair

Alasdair Cohen

Venkataramana Sridhar

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ABSTRACT

Access to safe water, sanitation, and hygiene (WASH) is a fundamental human right and a critical component of public and environmental health. Inadequate access to WASH facilities and practices can give rise to preventable diarrheal and waterborne diseases, which can have severe consequences on individuals' health and well-being. This is especially true in low- and middle-income countries such as India. To address these issues, the S.M. Sehgal Foundation identified water quality and hygiene needs in Bihar, India, and thus launched a behavior change intervention called "WASH for Healthy Homes." The intervention aimed to promote the use of silver-ceramic pot filters and safe handwashing practices in five communities of the Vaishali District. While behavior change is a common approach to address WASH issues, evaluating the outcomes of such interventions is crucial for determining the most effective strategies and conditions under which they can be successful. Therefore, this study assessed the effectiveness of the WASH for Healthy Homes intervention and identified factors that influenced its success. A mixed methods approach was utilized that combined statistical analyses of pre- and post-intervention survey data with a thematic analysis of interview and focus group discussion data. Results demonstrated that the intervention was successful in increasing the adoption of the silver-ceramic pot filter and overall safe handwashing practices within the study communities. Success of the WASH for Health Homes intervention was facilitated by participants' health concerns, trust in the field coordinator and social peers, the aesthetic appeal of the treated water, and repeated intervention messaging. However, adoption of intervention behaviors was hindered by several factors, including economic barriers, gender roles in decision-making, the effects of children and elderly in the household, and low attendance during intervention sessions. The research findings provide valuable insights that can help nonprofits better design and execute behavior change interventions, especially in the face of increasing WASH challenges.

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GENERAL AUDIENCE ABSTRACT

Access to safe water, sanitation, and hygiene is a basic human right and critical for human health. Unfortunately, many people, especially those in low- and middle-income countries like India, lack adequate access to these facilities, leading to waterborne diseases and other health problems. To address this issue, the S.M. Sehgal Foundation launched a behavior change program called "WASH for Healthy Homes" to promote the use of water filters and safe handwashing practices in rural Bihar, India. To determine the success of the intervention and identify factors that influenced its effectiveness, this study used a variety of methods including statistics, interviews, and focus group discussions. Results showed that the program was successful in increasing the adoption of the filter and safe handwashing practices. Success was due to participants' health concerns, trust in the field coordinator and their peers, the aesthetic appeal of the filtered water, and repeated messaging. However, there were also barriers to adoption, such as economic barriers, gender roles, and low attendance during intervention sessions. These findings are important for nonprofits to better design and execute behavior change interventions in the face of growing WASH challenges.

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Chapter I: Problem Statement

Ensuring access to safe water, sanitation, and hygiene (WASH) is essential for the health and well-being of both humans and the environment. A large number of individuals, particularly in low- and middle-income countries (LMICs), depend on water sources that are susceptible to biological and chemical contaminants, lack access to proper sanitation facilities, and have inadequate hygiene practices. Studies have demonstrated a considerable relationship between inadequate WASH practices and diseases such as soil-transmitted helminthiases, arsenicosis, and malaria (Mara, 2017; Ngatu et al., 2019). Furthermore, diarrheal diseases associated with unsafe WASH conditions contribute to more than 800,000 deaths yearly, with 700 children under the age of five dying every day, as well as cognitive impairment and growth stunting (UNICEF, 2021; World Health Organization, 2022).

To address these WASH issues and other global challenges, the United Nations expanded upon the Millennium Development Goals (MGDs) of 2000 by introducing the Sustainable Development Goals (SDGs) in 2015. Specifically, SDG-6 aims to "ensure the availability and sustainable management of water and sanitation for all" by 2030 (United Nations, 2019, pp.9). As the previous MDGs did not account for the relationship between hygiene and health, SDG-6 also has a special focus on attaining equitable hygiene by 2030. While there has been progress in increasing the proportion of the population with access to safely managed WASH services since the adoption of the SDGs, a significant number remain underserved. Approximately 74% of the global population have access to safely managed drinking water, 54% have safe sanitation facilities, and 71% have access to basic handwashing facilities with soap and water (World Health Organization & United Nations Children's Fund, 2021).

Given this need for improvement in global WASH standards, interventions have played an essential role in achieving the availability and sustainable management of water and sanitation. WASH interventions have contributed to reduced morbidity and mortality rates, improved the quality of life for many, and stimulated economic growth (Wolf et al., 2022). Promoting affordable WASH technologies and education at the individual and community levels has been a strategy used by nonprofits, governments, and aid agencies and organizations to reduce WASH-related illnesses in rural areas and LMICs (Dreibelbis et al., 2013). For example, proper and consistent implementation of household water treatment can be an effective approach to mitigate health hazards associated with the consumption of contaminated drinking water. Research has indicated that interventions emphasizing point-of-use (POU) water treatment can decrease the risk of diarrhea by approximately 50% (Wolf et al., 2022). The impact of water quality on reported cases of diarrhea is not consistent, however, which underscores the significance of appropriate sanitation and hygiene practices in addition to clean water (Bartram & Cairncross, 2010). Studies have reported that interventions focusing on handwashing can decrease the risk of diarrhea by as much as 47% by preventing the transmission of diseases through the fecal-oral route (UNICEF, 2013).

Despite intervention programs, countries such as India continue to suffer from poor WASH conditions. For example, in rural India, less than 60% of residents have access to improved water sources, only 46% use safely managed sanitation, and 68% practice safe handwashing (World Health Organization & United Nations Children's Fund, 2021). Moreover, diarrheal diseases associated with poor WASH practices account for 13% of child deaths each year (Kundu et al., 2018; Wagner & Pramling Samuelsson, 2019). Efforts to address these challenges have become more urgent with the onset of the COVID-19 pandemic and the emergence of increased climate variability, which are large threats to WASH security throughout the country. Although there have been positive intentions behind WASH interventions, they frequently fail to achieve success and long-term sustainability due to inadequate attention paid to program design, community engagement, beneficiary preferences, and a host of other variables (Taylor, 2013). Evaluating whether WASH interventions achieved their intended outcomes can help to determine the most effective intervention strategies and the conditions under which they are successful. Additionally, identifying intervention barriers fosters strategies to overcome challenges that hinder success, which can be incorporated into future interventions to further improve effectiveness.

Various organizations have been instrumental in establishing interventions to enhance infrastructure and raise WASH awareness. For example, in the Vaishali District of Bihar, the S.M. Sehgal Foundation (SMSF) identified several communities that faced extreme water quality issues and lacked safe WASH practices. SMSF is a non-governmental organization (NGO) based in India that oversees projects relating to water management, sanitation, and hygiene. To help improve health and quality of life in these rural communities, SMSF partnered with CAWST, a Canadian non-profit, to develop a behavior change intervention called WASH For Healthy Homes. The aims of the intervention were to improve human health and well-being by educating communities on household water treatment and safe storage (HWTS) and proper handwashing practices.

This study seeks to expand on the existing knowledge of WASH interventions by evaluating the effectiveness the WASH For Healthy Homes intervention had on promoting behavioral change in rural Bihar, India. The research questions are:

1. Based on the stated goals of the WASH For Healthy Homes intervention, did the project achieve “success”?

2. What barriers and facilitators impacted the success of the WASH For Healthy Homes intervention?

Chapter II: Review of Literature

2.1 Water

After completion of the Millennium Development Goals (MDG) in 2015, the world has moved to complete the Sustainable Development Goals (SDG) by 2030. Goal 6 of the SDG's is to "ensure availability and sustainable management of water and sanitation for all" (United Nations, 2019, pp.9). Drinking water sources are often grouped into two categories: improved and unimproved sources. Although these definitions have varied and been debated, the World Health Organization (2017) defines improved water sources as "those that are potentially capable of delivering safe water by nature of their design and construction" (p.13). Examples of improved water sources include piped water, protected springs, and protected wells. Conversely, unimproved water sources are those that have a higher risk of becoming contaminated with fecal matter and include surface water, unprotected springs, and tanker trucks.

The Joint Monitoring Program (JMP) uses a ladder system to track the progress of SDG 6. The ladder categorizes improved water sources into several groups, ranging from "safely managed" (ideal conditions) to "surface water" (poorest conditions). To be classified as safely managed, water sources need to meet three criteria: accessibility on premises, availability when needed, and free from contamination (World Health Organization, 2017). Factors such as water collection time are also taken into consideration when determining ladder positions. For example, if the time it takes to collect water from the source is greater than 30 minutes, it can be downgraded from safely managed to "limited".

While a water source may qualify as improved, there can be significant variations in its quality (Bain et al., 2014). In many countries, handpump water can contain naturally occurring chemicals like arsenic and fluoride that are proven to have negative health impacts (Wright et al., 2004). Furthermore, the complexities of household environments and water handling practices pose challenges to accurately determining water use and consumption (Gross & Elshiewy, 2019). On numerous occasions, water collected from improved sources can become contaminated by the time it is consumed due to poor collection methods, unmaintained storage containers, or dirty scooping utensils (Ferretti et al., 2010; Harris et al., 2013). A systematic review carried out by Bian et al. (2014) revealed that 38% of studies found more than a quarter of improved water sources had fecal contamination in low- and middle-income countries (LMICs). Rural areas also have less access to improved water sources compared to people in urban areas (Banerjee et al., 2020).

2.1.1 Groundwater

Being the largest groundwater user in the world, India uses this resource for industrial, agricultural, and drinking water purposes (Adimalla & Qian, 2019). Groundwater is commonly believed to be a safe source of drinking water, however, rural communities in India have faced challenges in ensuring groundwater is free from biological, chemical, and physical contaminants (Adimalla & Qian, 2019). In areas where open defecation and pit latrines are common, fecal pathogens including *E. coli*, helminths, and viruses can infiltrate through the ground into the water table (Islam et al., 2016; Yoshino et al., 2019). Ingesting this contaminated water is a significant contributor to diarrheal diseases, which are difficult health threats to address. Groundwater is also at risk from chemical contaminants such as arsenic and fluoride, which are naturally occurring substances found in bedrock that can permeate into aquifers (Hundal et al., 2007). Prolonged exposure to arsenic in drinking water is a recognized carcinogen (Smith et al., 1998), and fluorosis can lead to muscular deformities and dental problems (Srivastava & Flora, 2020). Additionally, because agriculture is a common land practice in rural parts of the country, nitrogenous fertilizer used for crops can percolate through the soil into the groundwater (Chen et al., 2016). Ingesting high levels of nitrate via water has been associated with an increased risk of "blue baby syndrome," multiple sclerosis, and gastrointestinal cancer (Suthar et al., 2009).

2.1.2 Wells and Handpumps

There are many different types of groundwater wells including hand dug/bored wells, driven wells, and drilled wells. In developing countries, hand dug wells are the most common method of collecting groundwater and can be constructed using simple hand tools such as shovels and pickaxes (Ibrahim et al., 2021). The soil and rocks are typically removed using a pulley system and are often lined with stones, bricks, or other hard materials. According to Ibrahim (2021), "hand-dug wells remain the most feasible and easiest way of providing water for domestic (drinking, cooking, washing) and agricultural purposes due to their simplicity and affordability in construction" (pp.1). However, hand dug wells tend to be shallow (10-30ft) and have a larger diameter that exposes more of the aquifer. This makes hand dug wells prone to going dry and can expose them to contamination from the surface if they are not properly lined or covered (Ibrahim et al., 2021). Driven wells and drilled wells are also commonly used around the world. Driven wells entail inserting a pipe into soft sand or gravel to extract water relatively close to the surface. Even though these wells are completely cased, they are similar to hand dug wells in their risk of contamination from surface pollutants due to their shallow nature (Water Science School, 2018).

Conversely, drilled wells have the capacity to reach depths of more than 1,000 feet and are at lower risk of surface contamination (Water Science School, 2018). Positive displacement pumps—more commonly known as handpumps—are widely utilized in developing countries because they can be easily installed into dug wells. Some advantages to hand pumps include that they are economical and can be located in rural areas that lack electricity (WellPumpCentre, 2022). Some of the disadvantages, however, are that handpumps require a lot of maintenance if used frequently and can deteriorate. Additionally, corrosive groundwater can ruin parts of the handpump, which changes the taste and appearance of the water (WellPumpCentre, 2022).

2.1.3 Bottled Water

One of the top ten bottled water consumers in the world is India and the demand for its production has been increasing throughout the country (Joseph et al., 2018). While it is true that bottled water can be a clean and reliable drinking water source, there have been multiple studies that show its quality to be variable (Ahmed et al., 2013; Kassenga, 2007; Warburton W., 2000; Williams et al., 2015). In India, microorganisms (e.g., *E. coli*, *staphylococcus*, etc.) and chemical contaminants (e.g., DDT and HCH) that can have serious health consequences for consumers have been detected in bottled water (Agrawal et al., 2010; Gangil et al., 2013). The quality of bottled water is dependent on multiple factors that range from the water source to treatment and handling practices. For example, it is commonly seen that sachet water manufacturers acquire their water from shallow wells or boreholes that often contain various contaminants (Gangil et al., 2013). In other cases, even if the source water is potable, the increase in bottled water demand has caused manufacturers to take shortcuts by using unsanitary bottles, equipment, or handling methods (Bedada et al., 2018). Furthermore, because bottled water is often a supplemental source of drinking water, it can be grouped into both the improved and unimproved water categories. Bottled water is only considered an improved source when used in combination with another improved source for basic needs. Otherwise, because of the wide variability and uncertainty of quality, bottled water is placed in the unimproved category (World Health Organization, 2017). With the rising misconception that bottled water is indefinitely a clean water source, it is clear that maintaining safe manufacturing and distribution processes are important for ensuring the health of the consumer.

2.1.4 Additional Water Sources

In addition to groundwater and bottled water, there is government provided water, rainwater, and surface water. Government provided water is considered to be an improved source and is water piped directly to the home. In many circumstances, government provided water is what people aim for because it is generally reliable, safe, and convenient. Clasen (2015) argues that government provided water can help with childhood survival, school attendance, and gender equity. Government provided water can also have contamination issues, however. In rural areas, water coming from government provided sources does not flow all day long, but instead maybe once or a couple times a day. Knowing this, in addition to the fact that many pipes are cracked or damaged, the negative pressure in the empty pipes can draw in outside contamination (Juran & MacDonald, 2014).

Rainwater capturing is another common method of collecting water and is considered an improved source. There are multiple ways to gather rainwater with one method being with a simple bucket and another being with a more complex catchment system. Generally, most people agree that rainwater is safe, but the collection method can lead to potential contamination (Sánchez et al., 2015). For example, if the catchment system is unmaintained, bacteria, fungal flora, and waterborne pathogens can get into the water. Additionally, if it is a roof rain catchment system, Sanchez et al., (2015) stated that heavy metals like zinc, copper, and sometimes lead are associated with corrosion of roofing materials.

Lastly, surface water can range anywhere from a large lake to a river or small stream and is considered an unimproved water source. Because these sources are often unmaintained, they are typically a last resort source of water collection. Runoff pesticides from agriculture, untreated waste, and waterborne pathogens are commonly found in surface waters that may cause serious health problems for the individuals consuming it (Sharma & Bhattacharya, 2017).

2.*1.5 Household Water Treatment*

Household water treatment methods such as boiling and filtering have been proven to be effective in limiting microbiological contaminants in drinking water (Clasen, 2015). The World Health Organization (WHO) has taken steps to standardize water treatment methods by developing household water treatment guidelines. They have introduced three recommendation levels based on log reduction values that include, “most protective,” “protected,” and “interim” (World Health Organization, 2011). While this system has helped in laboratory settings, it has created uncertainty among policymakers regarding the acceptable levels of microbiological contamination in drinking water (Clasen, 2015). In a paper by Clasen (2015), it is noted that “The intervention can be optimized when the intervention (1) is microbiologically effective; (2) is made accessible to a population at risk; and (3) is used correctly, consistently, and over the long term” (pp.71). Moreover, a study by Wright et al., (2004) noted the significance of not only concentrating on the water source, but also on the point of use (POU), as appropriate water storage can reduce the likelihood of recontamination.

Boiling water is one of the most common methods of household water treatment and is used by an estimated 1.2 billion people around the world (Rosa & Clasen, 2010). Multiple studies have shown that boiling water can be an effective and simple household treatment method to help reduce biological contamination that causes diarrheal diseases (Cohen & Colford, 2017; Juran & MacDonald, 2014). In order to eliminate a significant number of waterborne pathogens, however, the water needs to be boiled at the correct temperature and duration of time. In a systematic review conducted by Cohen and Colford (2017), they found that the effectiveness of boiling depended on the type of pathogen and organism group. Although boiling water at 100°C is supposed to eliminate pathogenic organisms, many people fail to bring their water to a rolling boil and may simply just heat up the water (Juran & MacDonald, 2014). As seen in McLennan (1998), some caregivers only boil water for their young children; when the children reach a certain age, caregivers stop boiling because they think the children are old enough to drink untreated water. In a study by Nichter (1985), individuals in Sri Lanka found boiled water to be "tasteless" and said that untreated water was able to satisfy their thirst more than boiled water.

Another method of household water treatment is a ceramic pot filter (CPF). A CPF is typically constructed using a mixture of clay, sawdust, and water that is pressed into the shape of a pot with a mold. The pot is then solidified in a fired kiln that combusts the sawdust resulting in a porous pot (van Halem et al., 2009). The CPF is typically placed into a plastic receptacle that collects the water as it filters through the pot. CPF's are widely used in developing countries and are considered a promising POU drinking water treatment method (van Halem et al., 2009). Ceramic pots can also be lined with a layer of colloid silver, which is applied either by either brushing it on or dipping the pot in it. The combination of the porous filter and disinfection properties of the silver helps to remove both *E. coli* and protozoa oocysts from contaminated water (Oyanedel-Craver & Smith, 2008; van Halem et al., 2009). In a study conducted by Oyanedel-Craver & Smith (2008), they found that the type of soil can impact the filtration of bacteria. Specifically, soil with uniform, fine-grained particle sizes will produce filters that are more efficient in filtering bacteria. One significant advantage to CPF's is that they are typically locally manufactured and straightforward for people who are uneducated (van Halem et al., 2009). A drawback, however, is that the water flow rate can be slow, and the filter tends to clog over time, which requires maintenance to unclog (van Halem et al., 2009).

2.2 Sanitation

Similar to how WHO uses ladders for water monitoring, there are also ladders for sanitation. By definition, improved sanitation facilities are "those designed to hygienically separate excreta from human contact" (United Nations Children's Fund & World Health Organization, 2019, pp.62). Safe sanitation services range from "safely managed" (ideal conditions) to "open defecation" (poorest conditions). Sanitation services are considered safely managed if excreta are treated and disposed of in situ, stored temporarily and treated off-site, and transported through a sewer with wastewater and then treated off-site (United Nations Children's Fund & World Health Organization, 2019). Sanitation services decrease from safely managed when they are shared with other households.

2.2.1 Toilets and Latrines

It is widely understood that poor sanitation and minimal access to toilet facilities are linked to various human health issues. Water resources are often contaminated with feces from open defecation due to a lack of toilets (Jeyakumar et al., 2021). In many situations, it is not always evident how defecating in the open, even if it occurs far from a water source, can get into water supplies. In countries like India where 15% of the population openly defecates (World Health Organization & United Nations Children's Fund, 2021), diarrheal diseases caused by the contamination of water resources is a rising concern. Open defecation increases the exposure of soil transmitted helminthiases (hookworm, ascariasis, etc.) and giardiasis (*G. duodenalis*), which are known to have long-term health consequences such as impaired cognition, irritable bowel syndrome, and anemia (Mara, 2017). Furthermore, multiple studies have suggested a correlation between high areas of open defecation and childhood stunting (Wagner & Pramling Samuelsson, 2019), and 28.5% of stunted children live in India (Spears et al., 2013). Because of the many health consequences linked to open defecation, it is imperative that the Indian government, and other non-governmental organizations, determine an effective and enduring solution to poor sanitation dispersed throughout the country.

In India, there have been multiple governmental policies enacted with the aim to reduce the amount of open defecation (Central Rural Sanitation Program, Total Sanitation Campaign), but many have been recognized as failures (Gautam, 2019). The Swachh Bharat Mission (SMB), which had goals to eliminate open defecation by providing toilets to every household in India by 2019, was one of the more recent policies passed in 2014. According to the guidelines for the SBM (Department of Drinking Water and Sanitation Ministry of Jal Shakti, 2023), the proposed methods of eliminating open defecation were to provide households with upfront payments for toilet construction (if eligible), promote collective behavior change, and ensure community engagement. While the mission contributed to a 72% increase in toilet use overall, the policy did not consider the social and cultural barriers associated with toilet use (Gautam, 2019).

There is a common misconception that the reason people choose to openly defecate is due to a lack of access to toilet facilities, however, multiple studies have argued that there are many social and cultural barriers that have prevented a wide acceptance of toilet use (Gautam, 2019; Mara, 2017). In some cases, people prefer open defecation, even if toilet facilities are available, because it is viewed as a sign of strength and purity (Tiwari et al., 2022), and people associate toilet cleaning with the "untouchable" caste (Coffey et al., 2017). In other situations, however, fears of sexual violence towards women and children at public toilets (Doron & Jeffrey, 2014), poor toilet construction (Routray et al., 2015) and the view that pit latrines are impure have hindered a wide acceptance of toilet adoption (Coffey et al., 2017). In a study focusing on open defecation in rural India (Coffey et al., 2014) it was found that older adults are more likely to open defecate compared to younger women. This was presumed because older people were more likely to have practiced open defecation for the majority of their lives, and younger women preferred toilet use due to privacy and menstrual hygiene concerns. These findings indicate that the individuals who use toilet facilities may have limited decision-making ability in the household, implying a power dynamic.

Furthermore, a lack of access to toilet facilities disproportionately affects women and children. Without a toilet, women are forced to publicly defecate in the daytime, which lacks privacy, or if they wait until night, they risk being attacked (Wagner & Pramling Samuelsson, 2019). In an educational setting, young girls (62%) have a greater need for toilets than young boys (38%) (Muralidharan et al., 2015). When there are no toilet facilities available in the classroom, girls tend to go home rather than open defecate like the boys, which negatively impacts girls' education (Vashisht et al., 2018). Even when there are toilets present, however, they may not be in the best condition, which can increase the risk of abuse. This can be mitigated by providing simple improvements like locks on latrine doors, gender separation, and proper lighting (Sphere Association, 2018).

A key finding in the study by Coffey et al. (2014), was that "people who live in households with a latrine that was built with government support are more than twice as likely to defecate in the open as people who live in households whose latrine was privately constructed" (pp.51). This is thought to be because of two main reasons: first, the quality of government provided toilets can be poor and might not be a design that individuals in the household desire, and second, when the latrine is constructed by the household, the people are more likely to have a higher level of education, be wealthier, and to be educated on the benefits of proper sanitation (Coffey et al., 2014). These findings highlight why it is important for government organizations to perform a thorough evaluation of the communities they provide latrines for; not every community is the same, and each has their individualized preferences.

In a study on open defecation in rural Bihar (Jain et al., 2020), multiple participants expressed disgust and unwillingness to maintain their household's latrine pit. The problem also arose of individuals not knowing what to do with their solid and liquid waste; even if they cleaned out the latrine, there was not a safe location to discard their waste and they would ultimately have to dump it on the land threatening health safety. The authors determined that one of the key obstacles in ensuring adequate sanitation is the absence of proper waste management, and this lack of waste removal and poor organization plays an important role in the reluctance of many people to use latrines (Routray et al., 2015).

2.2.2 Waste Removal and Drainage

It is well known that India has struggled to find affordable, long-lasting waste management systems, and disposing of raw sewage into the environment can contaminate water supplies and expose people via drinking water, bathing, or soil (Eisenberg et al., 2007). Untreated sewage often seeps into the environment through poorly built soakaways that are constructed for septic tanks (Wankhade, 2015). Additionally, groundwater contamination from pit latrines is a rising concern because many latrines are found in close proximity to tube wells and can leach excreta that filtrates through the ground into the water table (Islam et al., 2016). When looking at rural versus urban communities, there has been more overall access to wastewater and sanitation systems in the urban areas (National Sample Survey Office, 2016). However, even in cities that do have underground management access, the piping systems are often inadequate and in poor condition (Narain, 2012).

2.3 Hygiene

Hygiene can be defined as the set of conditions and practices that promote good health and prevent the transmission of diseases (United Nations Children's Fund & World Health Organization, 2019). Hygiene encompasses a range of practices such as handwashing, menstrual hygiene, and food hygiene. Hygiene was not included in any of the MDGs even though it is well known to have a significant impact on human health. However, in the SDGs aimed for 2030, hygiene and its importance towards health is recognized along with its relationship with sanitation. Unlike the water and sanitation ladders, hygiene ranges from "basic" (ideal conditions) to "no facility" (poorest conditions). The main determinant of a facility is the presence of soap and water on the premises. Classification may get challenging when other hand washing materials such as ash, soil, or sand are used to wash hands.

The pathogens that cause diarrheal diseases are frequently transmitted to humans through the fecal-oral route, with contaminated hands being a common source of infection (Sircar et al., 1987). Taking care of nail hygiene is especially important because of the large prevalence of agriculture for livelihood and the handling of children's feces in India (Jeyakumar et al., 2021). In a study in rural Bangladesh (Alam et al., 1989), diarrheal diseases in children increased when their mother's personal hygiene was poor. A solution to reduce the spread of infections, and therefore reduce illness and death in children, is to wash hands with soap (Aiello et al., 2008). A previous study on hand hygiene has found that washing hands with soap and water has reduced the rates of diarrheal diseases in children ages 5-9 years old by a range of 47-73% (Shahid et al., 1996).

The act of providing sanitation facilities alone does not have as much of an effect on health compared to introducing education on proper hygiene behavior (Fewtrell et al., 2005). Because of this, hygiene education interventions in developing countries are often used in conjunction with water and sanitation programs (Cairncross et al., 2005). Typically, when people understand why it is important to wash hands and how to do so properly, more people are likely to do it. Specifically, introducing handwashing in schools can be an effective, low-cost solution for promoting proper hygiene among children. Younger kids tend to be easily impressionable, so familiarization with proper hand hygiene increases the likelihood that kids will take this behavior outside of the classroom (Chittleborough et al., 2012). A problem with this, however, is that children generally have a very low social status in the household making behaviors learned at school unimpactful at a bigger level (Lewis et al., 2018).

There are many successful hygiene promotion techniques that have decreased the spread of disease. For example, frightening people with the health consequences from dirty hands is not as effective as promoting good feelings such as to smell and feel clean (Fewtrell et al., 2005). These emotional motivations, which also include happiness and inclusiveness, have been more successful in initiating lasting behavior change compared to interventions that only focus on the health benefits from handwashing (Biran et al., 2014). A benefit from hygiene promotion found in Stanton et al. (1988) is that even after an intervention ends, healthy behavior can endure from a simple educational message. However, studies have faced bias in their analyses of hygiene behavior interventions because participants may only display the proper behavior when being observed and not otherwise (Ram et al., 2010).

Even when people have the knowledge on how to perform proper hygiene practices, difficulties arise when there is a lack of physical infrastructure (i.e. accessibility, time, resources) (Fewtrell et al., 2005). Structural factors can play a vital role in determining whether good hygiene is practiced or is long-lasting (Chittleborough et al., 2012). When there is a favorable environment present, including group handwashing, for example, hand hygiene tends to increase (Rosen et al., 2011). Another large limitation to achieving proper hygiene is when women have to manage menstrual hygiene. Due to a lack of sanitation facilities or hygiene products, women and girls have an increased risk for reproductive tract infections and gender-based violence (Muralidharan et al., 2015).

2.4 WASH Interventions

Defined in Jeyakumar et al. (2021), “water, sanitation and hygiene (WASH) interventions aim to increase access to basic necessities, including clean water, safe stool disposal and food sources free from contamination, and in doing so decrease the diarrheal diseases” (pp.183). While it is true that community intervention studies have varied greatly in methodology, it is common to see WASH programs with goals to change perceptions and behavior (Ginja et al., 2019). According to Gizaw & Addisu (2020), behavioral change is a crucial determinant in ensuring the development of better-quality sanitation and hygiene practices. Some common outreach strategies for promoting proper WASH behaviors have included mass media and the spread of awareness within communities (Devine & Koita, 2010). Specifically, schools have played a major role in the implementation of behavior change interventions because it is thought that children's habits and actions are shaped in an educational setting (Lewis et al., 2018). WASH education in schools has been linked to advancements in the health of the student (Bowen et al., 2007) and has contributed to a decrease in diarrheal disease occurrences (Dreibelbis et al., 2013). However, it is important to have a good balance between education techniques and physical infrastructure. You can educate students on safe WASH practices, but if there is a lack of materials required to implement these behaviors (e.g., soap, handwashing stations), there will not be widespread health benefits (Tidwell et al., 2019). Conversely, if there is only physical infrastructure with no education, the increase of safe behaviors will not be adequate for long-term sustainability (Dreibelbis et al., 2016).

As stated in McKenzie-Mohr & Schultz (2014), "incentives have been widely used as a behavior change tool and in fact, individuals often point to incentives as the primary reason for engaging in the behavior" (pp. 41). When a project lacks any physical infrastructure, there are many alternatives that have been proven to be impactful with one example being a social approach. People are more likely to participate in a new action or change in behavior if there is positive reinforcement from others in their community (Ginja et al., 2019). An example of this in Ginja et al. (2019) includes a "public pledge," in which members of the community openly pledge that they will accept and act on proper WASH behaviors. There is typically widespread approval when people meet the promise, whereas when the promise is not kept, there is community disapproval. Another example of a social approach is to make interventions fun and pleasurable. Introducing simple board games with key information to lessen tension (Devine & Koita, 2010), or encouraging singing and dancing (Waterkeyn & Cairncross, 2005) can be the motivation for people to want to attend intervention sessions. Finally, introducing religious teachings of hygiene and individual cleanliness can set a positive inspiration that gets translated into improved WASH behaviors (Qazi & Anwar, 2021).

Even with these successful WASH behavior intervention strategies, research has shown that WASH interventions that have focused on changing and maintaining WASH behavior have produced less success than expected (Ginja et al., 2019). A reason for this may be due to the challenges of creating an effective behavior change impact that endures after the intervention project ends and into the longer future. Habit has been proven to be an important component in shaping WASH behavior (Dreibelbis et al., 2013), and repetition in an educational setting or motivational messaging can induce lasting behavior change (Dreibelbis et al., 2016). Furthermore, concentrating on a small number of behavior changes is an effective technique to avoid lessening intervention importance (Loevinsohn, 1990).

An additional barrier to achieving community-wide intervention success is gender. Specifically, in interventions that target the overall community, it has been found that some husbands will not allow their wives to attend scheduled sessions (Waterkeyn & Cairncross, 2005). Other intervention programs involve household surveys to get a sense of the WASH environment, but in some cases, the men do not allow the women to participate. This can be problematic because women are traditionally responsible for collecting and handling water, and typically understand the household dynamic (Fisher et al., 2017). Because of this, many WASH interventions have focused on targeting women rather than men. However, it has been found that men are in charge of buying soap and other hygiene products in about half of households (Devine & Koita, 2010). On the other hand, gender roles can actually encourage women in participating in WASH interventions. Women have claimed that participating in community programs has resulted in increased respect and admiration from their husbands (Waterkeyn & Cairncross, 2005).

It is important to determine how different types of unpredictable circumstances can affect WASH interventions. One example of this was mentioned in a study by Tidwell et al., (2019), when teacher strikes and droughts disrupted a WASH intervention rollout in schools. Because of these events, teachers and students did not attend the initial training sessions, which delayed program delivery and evaluation. In a study by Waterkeyn & Cairncross (2005), political unrest was on the rise, and because of the fear of physical intimidation, a lot of the intervention enumerators were men, which impacted the gender environment. This resulted in fewer women taking part in the program and led to smaller control groups, which altered the initial goals of the study. There has also been the problem of malfunctioning technology during the implementation of WASH interventions. In a study by Ramos et al. (2007), frequent power outages, slow internet, and poor graphics caused intervention sessions to be rescheduled to a later date. This caused multiple participants to be unable to complete the tasks. In conclusion, these examples highlight the importance of program designers to anticipate potential disruptions and plan accordingly to ensure successful implementation of WASH interventions.

Chapter III: Evaluating the implications of a water, sanitation, and hygiene (WASH) intervention on behavior change in Bihar, India

3.1 Introduction

Access to safe water, sanitation, and hygiene (WASH) is essential for promoting human health and environmental well-being. However, a significant portion of the global population lacks access to basic WASH services. According to the World Health Organization (2021), 2 billion people lack access to safe drinking water, 3.6 billion lack safe sanitation services, and 2.3 billion lack basic handwashing facilities. Poor WASH practices have been linked to the transmission of various diseases, including soil-transmitted helminthiases, arsenicosis, and malaria (Mara, 2017; Ngatu et al., 2019). Moreover, inadequate WASH conditions contribute to more than 800,000 deaths yearly, with 700 children under the age of five dying every day due to diarrheal diseases (UNICEF, 2021; World Health Organization, 2022).

To address these WASH issues and other global challenges, the United Nations built on the Millennium Development Goals (MDGs) of 2000 by introducing the Sustainable Development Goals (SDGs) in 2015. Among the SDGs, SDG-6 has the specific goal to “ensure the availability and sustainable management of water and sanitation for all” by 2030 (United Nations, 2019, pp.9). Although progress has been made in increasing access to safely managed WASH services, many low- and middle-income countries (LMICs) still struggle with poor WASH conditions. In rural areas of India, for example, less than 60% of the population has access to improved water sources, only 46% use safely managed sanitation, and 68% practice safe handwashing (World Health Organization & United Nations Children's Fund, 2021). As a result, diarrheal diseases associated with poor WASH practices account for 13% of child deaths in India every year (Kundu et al., 2018; Wagner & Pramling Samuelsson, 2019). Therefore, urgent action is required to address these challenges and achieve SDG-6 targets, including improving access to safe water and sanitation for all.

Bihar, one of India's poorest states, is a region that faces extreme biological and chemical water quality issues coupled with inadequate hygiene practices. Groundwater is the primary drinking water source for 80% of the population, and it has been found that rural areas of Bihar are more likely to have unsafe drinking water sources (A. Kumar et al., 2021). Additionally, open defecation is prevalent in Bihar and India as a whole, contributing to the further contamination of water resources and an increased risk of diarrheal diseases. Soil-transmitted helminthiases (hookworm, ascariasis, etc.) and giardias (G. duodenalis), which are known to have long-term health consequences such as impaired cognition, irritable bowel syndrome, and anemia (Mara, 2017), are among the risks associated with open defecation. However, providing sanitation facilities alone has limited impacts on health, highlighting the critical role of promoting education on proper hygiene behavior (Fewtrell et al., 2005). For example, handwashing with soap is an effective method to mitigate the spread of infections and decrease morbidity and mortality rates in children (Aiello et al., 2008). Thus, to address WASH issues in Bihar and other regions of India, ensuring access to safe water and sanitation facilities must be combined with education and behavior change surrounding proper hygiene.

Institutions aiming to reduce WASH-related illnesses have employed the strategy of promoting affordable WASH technologies and education at both the individual and community levels (Dreibelbis et al., 2013). Implementation of household water treatment technologies has been proven to be an effective approach to mitigate health hazards associated with consuming contaminated drinking water, as noted by Wright et al. (2004), who also emphasize the importance of addressing point-of-use strategies to minimize recontamination. Despite best intentions, WASH interventions often fail to achieve success and long-term sustainability due to inadequate attention afforded to program design, community engagement, and beneficiary preferences (Taylor, 2013).

The Indian government and various international and domestic organizations have played a vital role in deploying interventions to improve WASH conditions in the country. For instance, in the Vaishali District of Bihar, the S.M. Sehgal Foundation (SMSF), an Indian NGO, identified several communities that struggle with issues related to water quality and safe WASH practices. To improve health and quality of life in these rural communities, SMSF collaborated with CAWST, a Canadian charity, to develop a behavior change intervention named WASH For Healthy Homes. The intervention aimed to change behavior via community education on household water treatment and safe storage (HWTS) with a focus on promoting silver-ceramic pot filters and proper handwashing practices. Assessing whether WASH interventions achieve their intended outcomes can help determine the conditions under which they are most (un)successful and ultimately foster the development and implementation of more effective intervention strategies. By evaluating the impact of the WASH For Healthy Homes intervention in rural Bihar, this study seeks to provide nuanced understandings of both the program and WASH interventions more broadly. The specific research questions are:

1. Based on the stated goals of the WASH For Healthy Homes intervention, did the project achieve “success”?

2. What barriers and facilitators impacted the success of the WASH For Healthy Homes Intervention?

3.2 Literature Review

The availability of safe water, sanitation, and hygiene (WASH) services has increased throughout the world. Even with improvement, rural communities in LMICs lag behind with less infrastructure and fewer WASH resources (World Health Organization & UNICEF, 2021). Studies have shown that there is a considerable relationship between unsafe WASH practices and the transmission of diseases such as soil transmitted helminthiases, arsenicosis, and malaria (Mara, 2017; Ngatu et al., 2019). Morbidity and mortality from diarrheal diseases associated with WASH-related factors are more prevalent in LMICs (Troeger et al., 2018). In India, diarrheal diseases account for 13% of child deaths each year with children under the age of five being at an increased risk (Kundu et al., 2018; Wagner & Pramling Samuelsson, 2019).

3.2.1 Water

Improved water sources are defined as those that, by design, reduce or eliminate potential outside contamination (World Health Organization, 2017). However, studies have shown that improved water sources have considerable variability in quality with more than a quarter of sources in LMICs being contaminated with fecal matter (Bain et al., 2014). Furthermore, water collected from improved sources are often contaminated by the time it is consumed due to poor collection methods, unmaintained storage containers, or dirty scooping utensils (Ferretti et al., 2010; Harris et al., 2013). Examples of improved sources include boreholes or protected dug wells, a piped water connection to the household (HH), and bottled water (under the right criteria).

India is the largest groundwater user in the world (Adimalla & Qian, 2019; Mukherjee et al., 2015). However, studies have shown that one-third of India’s districts have unsafe groundwater for drinking due to high levels of contamination (Joseph et al., 2018). In Bihar, many groundwater sources contain naturally occurring chemicals that permeate from bedrock such as arsenic and fluoride (Hundal et al., 2007). Arsenic in drinking water is a carcinogen (Smith et al., 1998), and fluorosis can lead to muscular deformities and dental problems (Krishnan & Indu, 2006). Additionally, because agriculture is a common land practice in rural parts of the country, nitrogenous fertilizers can percolate through the soil into the groundwater (Chen et al., 2016). Ingesting high levels of nitrate via water has been associated with an increased risk of "blue baby syndrome," multiple sclerosis, and gastrointestinal cancer (Suthar et al., 2009).

Additional water sources used in rural India include piped water provided by local governments and bottled water. Government provided water is often referred to as the "gold standard" because it is generally considered safe and convenient. However, in rural areas, water is often intermittent and may be transported through damaged or cracked pipes (Juran & MacDonald, 2014). The negative pressure created by the empty pipes can draw in outside contamination. Furthermore, India is one of the top ten bottled water consumers in the world and demand has been increasing throughout the country (Joseph et al., 2018). While it is true that bottled water can be a safe and reliable drinking water source, multiple studies have shown its quality to be variable (Ahmed et al., 2013; Kassenga, 2007; Williams et al., 2015). Studies on bottled water in India have found microorganisms (e.g., *E. coli* and *staphylococcus*) and chemical contaminants (e.g., DDT and HCH) that pose serious health consequences for consumers (Agrawal et al., 2010; Gangil et al., 2013).

3.2.2 *Ceramic Pot Filters*

Ceramic pot filters (CPF) are a point-of-use drinking water technology widely used in LMICs to reduce microbial contaminants in drinking water (Clasen, 2015; van Halem et al., 2009). CPFs are typically constructed using a mixture of clay, sawdust, and water that is pressed into the shape of a pot with molds, and they are often lined with a layer of colloidal silver. The combination of the porous ceramic and disinfection properties of the silver helps to remove 99% of pathogenic bacteria and filter out large microbial cysts (Oyanedel-Craver & Smith, 2008; Woodard, 2019). CPFs are also efficient in effectively removing sediments and turbidity that can cause aesthetic issues with drinking water. The CPF developed by the S.M. Sehgal Foundation (SMSF), called MatiKalp, produces 1-3 liters of filtered water per hour and has a lifespan of 2-5 years (Sharma et al., 2022).

3.2.3. Sanitation and Hygiene

It is widely understood that minimal access to toilet facilities and poor hand hygiene are linked to various human health issues. In countries like India, where 15% of the population openly defecates (World Health Organization & UNICEF, 2021), diarrheal diseases caused by the contamination of water resources is a rising concern. Multiple studies have suggested a correlation between high areas of open defecation and childhood stunting (Wagner & Pramling Samuelsson, 2019), and 28.5% of stunted children live in India (Spears et al., 2013). Some studies have argued that there are many social and cultural barriers that have prevented a wide acceptance of toilet use (Juran et al., 2019). Even if toilet facilities are available, some people prefer open defecation because they do not want the bad odor in their HH (Coffey et al., 2017). In other situations, however, fears of sexual violence towards women and children at public toilets (Doron & Jeffrey, 2014), poor toilet construction (Routray et al., 2015), and the view that pit latrines are impure have hindered a wide acceptance of toilet adoption (Coffey et al., 2017).

Providing sanitation facilities alone does not have as much of an effect on health compared to introducing education on proper hygiene behavior (Fewtrell et al., 2005). This is why hygiene education interventions in developing countries are often used in conjunction with water and sanitation programs (Cairncross et al., 2005). Pathogens from dirty hands (a common transmitter of infection) can infect humans via the fecal-oral route (Davis et al., 2018). Taking care of nail hygiene is especially important in India because of the large prevalence of agriculture (e.g., livestock) for livelihood, the handling of children's and bovine feces, and the prevalence of eating food without utensils (Jeyakumar et al., 2021). A significant solution to reducing the spread of infections, especially illness and death among children, is to wash hands with soap (Aiello et al., 2008). For example, a study on hand hygiene found that washing hands with soap and water reduced the rates of diarrheal diseases in children ages 5-9 by a range of 47-73% (Shahid et al., 1996).

3.2.4 WASH Interventions

Behavioral change is a crucial determinant in ensuring the development of improved WASH practices (Gizaw & Addisu, 2020). Common outreach strategies for promoting proper WASH behavior include mass media, songs and theater, and the spreading of awareness within communities (Devine & Koita, 2010). Individuals are more likely to participate in a new action or change in behavior if there is positive reinforcement from others in the community (Ginja et al., 2019). A barrier to behavior change success, however, is the challenge of creating habits that endure after the intervention ends. Habit has been proven to be an important component in shaping WASH behavior (Dreibelbis et al., 2013; MacDonald et al., 2018), and repetition in an educational setting or motivational messaging can help facilitate lasting behavior change (Dreibelbis et al., 2016). Another barrier to achieving community-wide intervention success is gender. In India, women are traditionally responsible for the collection and handling of water, and they typically understand the HH dynamic (World Health Organization, 2017). Because of this, many WASH interventions have focused on targeting women rather than men; however, it has been found that men are in charge of buying soap and other hygiene products in about half of HHs (Devine & Koita, 2010).

The Theory of Change (TOC) partially utilized in the WASH For Healthy Homes intervention is called Behavior Centered Design (BCD). Established by Aunger & Curtis (2016), the goals of BCD are to use emotional levers to create demand and a change in behavior. Specifically, the framework offers a theory of behavior change in addition to a process for designing and evaluating interventions (Aunger & Curtis, 2016). In other words, BCD helps to design interventions that cause changes to an environment, which in turn changes perceptions of the target audience and ultimately leads to changes in behavior. The design uses a five-step approach (access, build, create, deliver, and evaluate) (Aunger & Curtis, 2016), allowing for the incorporation of formative research and design thinking in order to evaluate intervention impact (Morton et al., 2020). Numerous studies have utilized BCD—including studies on handwashing, food hygiene, and oral rehydration (Biran et al., 2014; Doyle, 2016)—and techniques from disciplines such as cognitive psychology and behavioral economics have been integrated (Aunger & Curtis, 2016).

3.3 Background on the WASH For Healthy Homes Intervention

In the Vaishali District of Bihar, India, SMSF identified many people who lack safe WASH practices and environments. To help improve the health and quality of life in these rural communities, SMSF partnered with CAWST to develop and fund a behavior change intervention called WASH For Healthy Homes. The project was designed as a pilot study that, if successful, would be implemented on a larger scale.

Three villages, comprising five communities, were selected for project implementation totaling 317 families across 235 HHs (**Table 1**). The villages were targeted based on formative research and community members being Dalits, the most oppressed class in the Hindu caste system, and/or living below the poverty line. Formative research techniques included gathering information from people who held positions in the community (e.g., nurses, teachers) and conducting interviews with community members. Additionally, water samples were collected and tested from 88 water sources to determine microbial and chemical quality.

Table 1: Survey size by village

Gram Panchayat	Village	Community	Baseline households surveyed	Baseline families surveyed	Endline households surveyed
Jafrabad	Khoksa Kalyan	C1 C2	60 45	111 52	57 34
	Mohamadpur Lakhanpur	C	49	57	48
	Lakhanpur Lal	C1 C2	38 43	45 52	37 42
Total	**3**	**5**	**235**	**317**	**218**

Note: The endline dataset only included responses from the head of household and not all families living inside that household, so one household represents one family.

With the villages identified, a household-level survey (baseline) was conducted via in-person interviews to gain a better understanding of WASH knowledge and habits. The interviews were delivered in Hindi by a male SMSF field coordinator who has been trained to facilitate community mobilizations related to behavior change techniques. Survey respondents were primarily a woman from each family. Prior to the start of data collection, participants were informed of the purpose of the study and were required to sign a consent form agreeing to participate. The survey data probed topics related to demographics, health, water sources, point-of-use treatment, sanitation services, and hygiene practices.

An analysis of the baseline survey determined that the greatest needs across the villages were safe drinking water and proper hygiene behaviors. Based on this result, SMSF and CAWST decided to promote silver-impregnated ceramic pot filters and educate on safe handwashing procedures (including construction of a handwashing station) as the foundations of the intervention. The filter is a point-of-use water treatment technology that is considered to be culturally acceptable and relatively affordable (350 INR) to village members. Furthermore, the filters were produced by local potters, which helped to provide livelihood opportunities.

The two main goals of the WASH For Healthy Homes intervention were to achieve a 50% increase in HH water treatment and safe storage (HWTS) with the ceramic pot filters, and a 50% increase in safe handwashing practices. In order to achieve these goals, a behavior change communication (BCC) campaign and community training sessions centered around HWTS and hygiene were implemented. The BCC exposed members of the community to messages that targeted positive WASH behaviors by introducing murals, posters, brochures, and social events. Examples of BCC messaging can be seen in **Figure 1**. The community training sessions were drawn upon and partly formulated around the Behavior Centered Design (BCD) theory. Using this approach, the training sessions educated the villages on HWTS while providing needed skills to adopt the silver-impregnated ceramic pot filter, handwashing station, and safer sanitary behaviors.

Figure 1: Murals painted in the study communities stating, “If you drink clean water, you will live a healthy life” (left) and “Did you wash your hands with soap before eating?” (right).

There were a total of 14 training sessions developed by SMSF and CAWST that occurred two times per month at local community centers. Example session plans included pathways for water contamination, transmission of disease-causing pathogens, building a handwashing station, safe water storage handling, and ceramic pot filter use and maintenance. The sessions were conducted by the SMSF field coordinator, and the 317 families were divided into 10 groups of about 30 women who attended the meetings. Session activities included games, Q&A, and other interactive activities that were appropriate for members who may have low literacy and/or lack knowledge on WASH. A volunteer group leader (female) in each community was assigned to inform community members of the sessions and encourage attendance. Prior to the start of the sessions, participants were informed that there would be no monetary compensation for participation in the project. These conditions were approved by the participants, and they were aware that it was their responsibility to purchase and maintain the filters and handwashing station if they chose to adopt.

An endline survey was conducted shortly after completion of the WASH training sessions and includes 218 HHs (**Table 1**). The endline survey was used to determine whether goals of the WASH For Healthy Homes intervention were reached. Due to time and money constraints, the endline survey only contains interviews with the female head of HH (primarily female) rather than each family living within a HH. To determine whether intervention technologies were being used as reported, the field coordinator made undisclosed observations of behaviors during the endline data collection. For example, when making observations on the use of handwashing stations, staff looked for water in the container and soap at the sink that was being used.

3.4 Study Area

This research was conducted in the Vaishali District (Desri Block) of the Indian state of Bihar (**Figure 2**). Bihar is the third most populous state and is recognized as one of poorest in the country (Dayal et al., 2017). According to the National Multidimensional Poverty Index Baseline Report, 51.9% of persons living in Bihar fall below the poverty level and 50.6% reside in HHs with unimproved or no sanitation facilities (R. Kumar et al., 2021). A majority of the population of Bihar (nearly 89%) reside in rural areas, where male and female literacy rates are 57.1% and 29.6% respectively–the lowest in the country (Census of India, 2011). The most widely spoken languages are Hindi (77%) followed by Urdu and Bihari (Census of India, 2011). Additionally, there have been 726,000 COVID-19 cases and 9,664 deaths in Bihar with only 80,280 residents fully vaccinated (Mathieu et al., 2020).

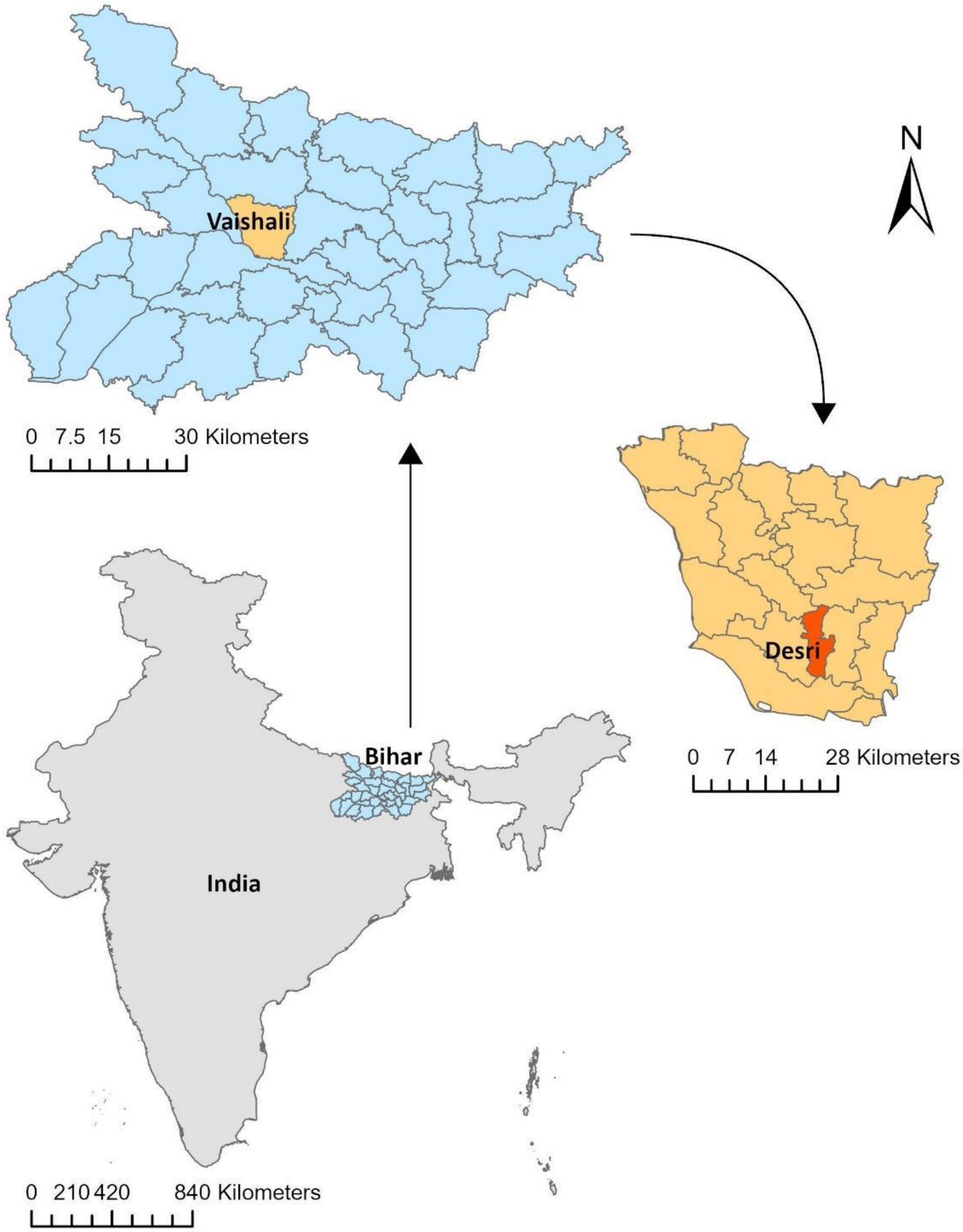

Figure 2: Broader study area map of Vaishali District

Bihar contains deciduous forest as its primary vegetation, yet only a small amount of the land is forested (7.1%) (Department of Agriculture, 2014). The remaining cultivated plains are home to a vast majority of the population who live in compact or clustered villages. Bihar is the third largest producer of vegetables in India (Department of Agriculture, 2014) and dominant crops produced are rice, wheat, and corn (Dayal et al., 2017). Around 76% of the population is employed through agriculture, but low production rates result in rural poverty and low nutrition with 51.9% of the population being malnourished (highest in the country) (R. Kumar et al., 2021). In the Vaishali District, specifically, 45% of families face food shortages for one or more months in a year and 10% for more than six months (Bhatta et al., 2013).

Bihar is situated in the Gangetic Valley that extends from the Himalayas to south of the Ganges River and primarily consists of fertile alluvial soils (Shah, 2008). The Ganges runs west to east through Bihar, which naturally separates the state into the northern Bihar plains (53,300 km^2) and southern Bihar plains (40,900 km^2) (Department of Agriculture, 2014). Bihar is one of the most flood-prone states in India, which threatens the safety and livelihoods of millions of residents each year (Zakwan & Ara, 2019). Flooding is a result of the many river systems flowing from Nepal into the lowlands during the monsoon rains. Monsoon season produces 87% of the annual rainfall and can result in breaches of artificial river embankments and waterlogging (Mishra, 2009). For example, the Kosi River, a major tributary of the Ganges, has been given the nickname "Sorrow of Bihar" due to its frequent and devastating floods (Dayal et al., 2017). During periods of flooding, drinking water sources are often contaminated by the introduction of fecal matter and other pathogens present in the flood waters (Mishra, 2009).

Groundwater is the main drinking water source for 80% of the population of Bihar and it has been found that rural areas are more likely to have unsafe drinking water sources (A. Kumar et al., 2021). Specifically, 31 of the 38 rural districts in the state have groundwater that is contaminated with arsenic, iron, and fluoride (Prasad et al., 2022). Arsenic in drinking water has been shown to have adverse health effects such as gastrointestinal diseases and various cancers

(A. Kumar et al., 2021). When there is excess pumping of the groundwater, the water table gets depleted and chemical contaminants such as arsenic and fluoride that are naturally found in the bedrock emerge (Mishra, 2009). Furthermore, because iron is the second most abundant element in Earth's crust, it is a very common contaminant in drinking water as it frequently leaches from the underlying geology into groundwater (Haldar et al., 2020). With continuous exposure to high levels of iron, people may suffer from eye disorders, heart disease, and joint pain (Alimohammadi et al., 2017; Haldar et al., 2020).

The dominant religion in Bihar is Hinduism, practiced by 86.3% of the population, followed by Islam (Census of India, 2011). Hinduism is well known for its caste system, and Hindus are divided into four main caste categories (*varnas*) which include Brahmins (most esteemed caste), Kshatriyas, Vaishyas, and Shudras (Pruthi, 2004). An additional caste called Dalits or "Untouchables," are conceptualized as so degraded that members are not even considered part of the system (Rawat, 2011). These main castes are then divided into around 3,000 sub-castes (*jatis*), which often determine occupation/livelihood. Hindus believe that these groups are based on *karma* (ethical consequences) and *dharma* (duty), and originated from Brahma, the Hindu deity of creation (Pruthi, 2004). Furthermore, it is traditionally considered forbidden to marry outside of one's caste, and upper and lower castes often live in separate or segregated areas. In this study, project participants are members of multiple sub-castes including Paswan, Harijan, Kumhar, and Saha. Both Paswans and Harijans are part of the Dalit caste, and in rural Bihar they are one of the most discriminated groups who are well known to be landless agricultural laborers (Mendelsohn, 1998). Kumhars are historically potters, while Sahas are traditionally shopkeepers and grocers (Baidyanath, 1979).

3.5 Methodology and Analysis

This mixed methods study utilized original survey, interview, and focus group data. The household-level survey—which provided useful data on WASH practices, demographics, reported health, and related variables—was analyzed statistically. However, statistics alone did not capture the entire picture; statistics informed *what* the results were, but they did not explain *why*. In order to answer the question of 'why,' this study adopted qualitative methods of key informant interviews, participant interviews, and participant focus group discussions (FGDs). This qualitative approach assisted in better understanding the capacity, perceptions, and needs of the community while also facilitating community engagement and rapport (Hennik, 2014). Furthermore, a strengths, weaknesses, opportunities, and threats (SWOT) analysis for the WASH For Health Homes project was performed focusing on water, sanitation, and hygiene. This analysis assisted with the identification of interview and focus group discussion questions and enabled the contextualization of quantitative and qualitative findings. Collectively, the mixed methods approach helped to explain, support, and refute study outcomes through a more holistic, grounded, and triangulated analysis of the WASH intervention program.

3.5.1 Survey Data

The baseline survey was deployed from December 2020 through February 2021, and the endline data were collected in January 2023. The baseline dataset included responses from 317 families across the study area where one member of the family (predominantly a woman) was interviewed. The endline survey had 218 responses from the same families, but only included an interview with the (often female) head of the HH rather than each family living in the home. This was done due to time and financial constraints and was based on the assumption that families living in the same HH exhibit similar behaviors. A correlation analysis was done between datasets using the HH identification number and identified 171 eligible HHs that could be used for survey comparison.

Evaluating success of the WASH For Healthy Homes intervention was determined through an analysis of performance indicators (silver-ceramic pot filter purchases and handwashing practices) in the baseline and endline surveys. Success for the WASH For Healthy Homes project was defined as achieving (1) a 50% increase in the uptake of HWTS, focusing on locally produced ceramic pot filters, and (2) a 50% increase in the adoption of safe handwashing practices. The 50% increase was achieved when a minimum of one additional family in the endline for every two families in the baseline either purchased a filter or practiced safe handwashing compared to the baseline. Since safe handwashing practices were not explicitly defined in the project proposal, this study defined safe handwashing as washing hands with soap at critical times.

To further establish a clear definition of safe handwashing practices, only those who exclusively used soap (not a combination of soap, ash, or soil) were considered, as HHs that used various materials may not have used soap every time they washed their hands. Washing hands at critical times refers to specific moments when washing with soap can prevent illness and promote better overall health. Washing hands with soap before cooking meals, before eating meals, after using the toilet, and after handling the feces of a child were the critical times used in this study. Additionally, the WASH For Healthy Homes project promoted the construction of designated handwashing stations. This research will assess the success of the project in terms of achieving a 50% increase in the construction of handwashing stations.

3.5.2 SWOT Data and Analysis

Prior to the start of the study, a SWOT analysis was conducted. The analysis was used as a qualitative tool to help determine and anticipate which features of the WASH For Healthy Homes project might be adopted quickly or easily as well as which features may be missing or present limitations. Elements of the SWOT analysis were determined using formative research on the study area, baseline survey data, a consideration of the socio-geographical context, and consultations with SMSF. A separate analysis was conducted each for water, sanitation, and hygiene (Appendix A). In addition to viewing the WASH For Healthy Homes project more holistically, findings of the SWOT analysis assisted in identifying key informant and participant interview questions, focus group questions, as well as *a priori* themes for the thematic analysis.

3.5.3 Model Construction and Analysis

Surveys were analyzed statistically using generalized linear mixed-effects models (GLMM) with a logistic link function to perform a logistic regression in a hierarchical format using R Studio. Variables used in the models were selected a priori and grouped based on the hypothesized impact each group would have on the outcome. The variables in each group that were thought to have the most impact on the outcome were entered into the model sequentially to identify which predictors were most important (Victora et al., 1997). Variables were eliminated from the model if they did not have a significant impact on the outcome (Cohen et al., 2017). The final models were determined by examining values from the Akaike Information Criterion (AIC), which is a statistical tool that selects the best model based on complexity and goodness of fit (Burnham et al., 2011). Specifically, the AIC score between each model was compared and the AIC weights showed the proportion of predictive power the final model had on the outcome.

Lower AIC scores and higher AIC weights compared to the other models in the set indicate the model best at explaining the data.

Prior to running the GLMM, assumptions of the logistic regression model such as linearity and the absence of multicollinearity were tested. Plots were created in R for each independent variable to test the assumption of linearity between the independent variables and the log odds of the dependent variables. This was done for both numerical and categorical variables and if the plots showed a clear linear relationship, then the linearity assumption was supported. A variance inflation factor (VIF) was calculated to test for multicollinearity (when two or more independent variables are highly correlated). A VIF of 1 means the variables are not correlated, a VIF between 1-5 is moderately correlated, and a VIF greater than 5 is highly correlated (Feldman, 2018). When the independent variables are highly correlated, it is harder to determine which variable is influencing the outcome (Potters & Lee, 2023). Variables were excluded in the analyses if the VIF was higher than 2.

Analyses were conducted at two scales: the study population level and HH level. The population level examined survey responses from all families as a total set (baseline), while the HH level examined data within each village (baseline and endline). The two scales enabled the analysis of various factors across different spatial contexts and assisted in comparing and contrasting outcomes across the participants. Furthermore, because the GLMM can account for correlation among observations within the same cluster, the model nested families (n=317) within HHs (n=235) in each community (n=5). Outputs for the GLMM were reported as log odds, which were then converted into odds ratios for interpretation. The GLMM was used to evaluate which variables contributed to behavior change or the absence of it. For example, socioeconomic status and education level were investigated as factors as to whether individuals adopted the silver impregnated pot filter or built a handwashing station. Other variables, such as family size, age/elderly, and diarrhea incidence were investigated to identify relationships with safe handwashing practices.

The model specified both random and mixed effects that were estimated simultaneously to provide a more accurate estimation of the effect each predictor variable had on the outcome variable. The random effect used in the baseline survey analysis included the nested families, HHs, and communities because it was assumed that unmeasured or unobserved factors specific to each community could have varying effects on the outcome. The random effects used in the endline comparison analysis was the communities. The fixed effects used in both analyses were the remaining predictor variables (e.g., education, socioeconomic status, family size) because the assumption is that they will have a constant effect on the outcome across all respondents.

3.5.4 Participant Interviews and Focus Group Discussions

A series of semi-structured participant interviews and focus group discussions (FGD) were conducted with project beneficiaries that each lasted 30-60 minutes. The goal was to garner contextual knowledge, experiences, perceptions, and explanations on what participants were/were not receptive to, why approaches worked/did not work, and how various barriers/facilitators manifested. Interview and FGD questions were guided by the Integrated Behavioral Model for Water, Sanitation, and Hygiene (IBM-WASH) (Dreibelbis et al., 2013). The theoretical framework emphasizes the importance of three sets of factors that influence WASH behaviors: contextual, technological, and psychosocial factors. The questioning route and definitions can be seen in Appendix B.

Participant recruitment was done by the SMSF field coordinator who had previously informed village members of the interviews via word of mouth or WhatsApp. Only women above the age of 18 were targeted with the exception of one male FGD in order to explore the connection between water and gender. Those who were interested in participating volunteered based on self-selection. Self-selection sampling (or volunteer sampling) is a type of non-probability sampling that does not use random criteria (Baltagi, 2001). More specifically, the main criterion for selection in this study was participant availability on the interview day. One benefit of this method is that it can provide useful information required to make generalizations about the sample set (Baltagi, 2001).

All participant interviews and FGDs occurred over an 8-day period in May 2022. Interview questions were asked in English by the female researcher and then repeated to participants in Hindi by a female SMSF translator. The male field coordinator was present for the FGDs but not for individual interviews. Responses were then translated back to English and carefully transcribed in a notebook citing exact quotations from participants.

3.5.5 Participant Interviews

There were a total of five participant interviews spanning all villages with the goal to qualitatively supplement, refute, and add human dimensions to the statistical data (**Table 2**). We remained neutral by not voicing our opinions and asked questions that explored both positive and negative aspects of the project. Studies have shown that remaining neutral is critical because interviewees may respond with answers they think the interviewer wants to hear (Hennik, 2014). Additionally, we took steps to help shift the balance of positionality and hierarchy by letting interviewees be in command (Chacko, 2004). For example, interviews were organized in the place/landscape that participants desired with some of these ‘mobile’ or ‘landscape’ interviews being in their home, the local community center, and throughout the waterscapes with which they interact. Interviewees showed us where they retrieve water, pointed out water features and hazards, demonstrated water collection and storage processes, and ultimately provided a more informed and dynamic understanding of how they interact with their local environment (Macpherson, 2016). This allowed us to take photographs of the waterscape, community taps, handwashing stations, and sanitation facilities to gain a user-centered understanding and visualization of the WASH environment.

Table 2: Qualitative data collection by village and community

Village	Community	Number of Focus Groups	Number of Individual Interviews	Total Number of Participants
Khoksa Kalyan	C1 C2	1 2	- 2	18 26
Mohamadpur Lakhanpur	C	1	1	27
Lakhanpur Lal	C1 C2	1 2	1 1	9 14
Total	**5**	**7**	**5**	**94**

3.5.6 Focus Group Discussions

There were a total of seven FGDs with project beneficiaries with at least one in each community. The goal was to capture a collective narrative that included a broad range of perspectives and lived experiences. The FGDs served as a mode of member checking and allowed for discerning major differences in deployment of the project, adoption of behaviors, and participant attitudes across the five communities. Interviews were organized in a way that built rapport and trust, which aimed to make participants feel comfortable when expressing their opinions without pressures of conformity. For example, interviews took place at local community centers, we sat on the ground alongside interviewees, and participants were informed that they are the experts on water in the area and that we were there to learn from them. All FGDs were with women except for one that was solely with men (n=4). The initial goal was to have 5-12 participants in each group as the optimal size (Halcomb et al., 2007), but many people were eager and excited to participate. Because of this, women's FGDs ranged from 7 to 26 participants with an average of 13 people per group.

One of the benefits of FGDs is that participants are able to express their views with spontaneity, which enables participants to openly share their thoughts, refine their viewpoints, and add to or contest others' viewpoints (Gundumogula, 2020). However, the technique also has limitations because some may feel pressure to agree or disagree with the views of other participants or may feel inhibited from participating due to group dynamics (Halcomb et al., 2007). This study limited these drawbacks by emphasizing that all experiences are valid and worthy of mentioning and that there are no 'right' or 'wrong' answers.

3.5.7 Participant Interview and Focus Group Discussion Analysis

A thematic analysis was conducted with participant interview and FGD responses to provide the requisite context, perceptions, and impacts of the intervention that cannot be obtained from statistical tests alone. Methodology for the thematic analysis was utilized from Braun and Clark (2006) by following a six-step process of: familiarization, generating codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. This method was chosen because it allowed for the benefit of flexibility and also provided a theoretically sound guide to thematic analysis (Braun & Clarke, 2006). Both participant interviews and FGDs were manually coded in Microsoft Excel and interview text of particular significance was cited using paraphrases to help support theme findings.

The initial generating of codes involved using a deductive (*a priori*) and inductive approach (Fereday & Muir-Cochrane, 2006). The deductive approach involved the testing of predetermined codes, whereas the inductive approach identified codes after the data were collected. The predetermined codes (e.g., economic barriers and health) were selected based on what was theoretically believed to have the greatest influence on behavior change and, therefore, the most impact on intervention outcomes. Codes using the inductive approach were introduced when project participants identified additional relevant points that were unforeseen or not considered. The codes were subsequently organized into sub-themes, which were then grouped into broader themes that encompassed the responses of individuals across the study area. All themes and subthemes were either directly related to project goals or reached a point at which a level of community consensus was identified.

3.5.8 Key-Informant Interviews

Key informant interviews were conducted to understand perceptions of individuals who contributed to the project design and deployment. The responses helped to identify, based on informants' firsthand and prior experiences, whether the project was successful and any barriers or facilitators that could have been attenuated or leveraged in this and future interventions. There were a total of four semi-structured interviews conducted with key-informants. The semi-structured format allowed key-informants to provide open-ended responses, and positive, negative, and hypothetical aspects (e.g., what would you have done differently) of the project were probed. Interviews included the field coordinators and project managers from SMSF and CAWST. Additionally, an interview was conducted with the Mukhiya (leader/president) of the panchayat (village) in which the five communities are located. Key-informants were recruited based on their role in the project and/or intricate knowledge of the study area. Interviews were conducted in-person except for those with officials at CAWST, which were organized using Zoom. All interviews were conducted in English with the exception of the Mukhiya of the panchayat in which staff translated the questions to Hindi. The interviews lasted around 30 minutes and were manually transcribed into a notebook. Key-informant interview questions can be found in Appendix C.

3.5.9 Ethical Considerations and Positionality Statement

Ethical clearance was obtained prior to the start of the study through the Virginia Tech Institutional Review Board (#22-159). Letters from the local government were secured that gave permission to conduct research in the study area. Participants were informed that their participation was voluntary, and informed verbal consent was required before interviews began.

As a white woman from the United States, I acknowledge that my positionality could have affected my interactions with project beneficiaries. I am aware that my cultural background, English language, and education could have created obstacles to communication and comprehension during the interviews. To address these challenges, I closely collaborated with the Indian NGO that had established relationships with these vulnerable communities. I maintained ongoing communication with both the NGO and other project staff to ensure effective collaboration throughout the research. Furthermore, I conducted member checks to verify that my recording of data were correct and peer debriefings with experts who are familiar with both the WASH domain and Indian context. I attempted to mitigate any power imbalances between myself and the participants by building trust and rapport, respecting their time and input, and expressing my willingness to learn from them. I also approached the project with an open mind and committed to listening to the voices of the community members I interviewed. By taking this collaborative research approach, I recognized the importance of listening to and respecting the perspectives and experiences of the communities while working in partnership with them (Chacko, 2004).

3.6 Results and Discussion

This study sought to determine whether the WASH For Healthy Homes intervention achieved its stated goals and to identify the factors that hindered or facilitated its success. This was done with the use of both quantitative and qualitative data through statistical and thematic analyses. Seven hierarchical regression models were performed on the baseline survey (n=317) in order to identify demographic and WASH variables that had the greatest influence on WASH practices (**Table 3**). The outcomes of interest for the models included (1) the presence of a toilet in the household (HH), (2) anyone in the HH who experienced waterborne or gastrointestinal illnesses in the past six months, (3) anyone in the HH with diarrhea in the past four weeks, and (4) washing hands with soap at the four defined critical times. Of the seven models, washing hands at the four defined critical times did not show any significant results.

Six hierarchical regression models were performed on the comparison of the baseline and endline surveys (n=171) in order to determine key demographic and WASH variables that were associated with the adoption of HWTS following the intervention (**Table 4**). Outcomes for the models were whether HHs (1) purchased the ceramic pot filter, (2) constructed a handwashing station, and (3) washed their hands with soap at the defined critical times. Three of the six models (washing hands with soap before a meal, before cooking, and after handling the feces of a child) did not have any significant associations.

Table 3: Hierarchical regression models for baseline survey dataset

Model (n=317)	Odds Ratio (95% Confidence Interval) Toilet in the house			Anyone in HH with illness in past 6 months	Anyone in HH with diarrhea in past 4 weeks
	Model 1	**Model 2**	**Final Model**	**Final Model**	**Final Model[a]**
Step 1: Demographic Indicators					
Education *(Reference: below matric)*					
Graduate	13.92** (3.81 – 86.7)	8.42* (1.09 – 65.23)	7.37* (1.07 – 50.57)	1.69 (0.49 – 5.81)	0.85 (0.18 – 4.09)
Higher secondary	3.77* (0.8 – 13.77)	3.61 (0.82 – 15.83)	3.02 (0.77 – 11.87)	1.39 (0.57 – 3.42)	0.66 (0.18 – 2.43)
Secondary	5.78* (5.78 – 27.32)	6.15 (0.95 – 39.82)	5.73* (1.07 – 30.85)	0.59 (0.25 – 1.4)	1.66 (0.59 – 4.62)
Socioeconomic Status *(Reference: antyodaya)*					
Above poverty level		N/A	N/A	N/A	1.12 (0.26 – 4.86)
Below poverty level		N/A	N/A	N/A	1.94 (0.63 – 5.99)
Step 2: Family Structure Indicators					
Elderly >60 years		N/A	N/A	0.79 (0.49 – 1.27)	N/A
Family size		1.54* (1.07 – 2.21)	1.50* (1.07 – 2.1)	1.08 (0.84 – 1.38)	N/A
Children <18 years		0.56* (0.33 – 0.94)	0.58* (0.36 – 0.94)	0.95 (0.68 – 1.33)	1.36* (1.04 – 1.77)
Step 3: Health Indicators					
Diarrhea *(Reference: no)*[b]			0.76 (0.18 – 3.29)	10.59* (1.4 – 80.03)	N/A
Illness *(Reference: no)*[c]			1.87 (0.60 – 5.82)	N/A	11.24* (1.49 – 84.91)
Disabilities *(Reference: no)*			1.53 (0.41 – 5.72)	3.09* (1.02 – 9.37)	1.25 (0.46 – 3.36)
Model Indicators					
AIC Score	403.28	400.96	396.56	183.31	219.21
AIC Weight (%)	3%	10%	87%	74%	87%

Notes: AIC=Akaike Information Criterion; AIC weight represents the proportion of the total predictive power for each model compared to others in the set; * p<0.05; ** p<0.01; *** p<0.001; [a] Steps 1 and 2 were combined; AIC weight based on two models. [b] Diarrhea refers to anyone in the household who experienced diarrhea in the four weeks prior to the interview; [c] Illness refers to anyone in the household who experienced a range of waterborne illnesses and/or gastritis in the six months prior to the interview.

Table 4: Hierarchical regression models for baseline and endline dataset comparison

Model (n=171)	Odds Ratio (95% Confidence Interval) Purchase of a filter			Construction of handwashing station	Washing hands with soap after using the toilet
	Model 1	**Model 2**	**Final Model**	**Final Model**	**Final Model**
Step 1: Demographic Indicators					
Education *(Reference: below matric)*					
Graduate	1.29 (0.39 – 4.25)	0.49 (0.10 – 2.26)	0.27 (0.05 – 1.54)	N/A	N/A
Higher secondary	1.26 (0.43 – 3.71)	0.97 (0.31 – 3.04)	1.09 (0.31 – 3.81)	N/A	N/A
Secondary	1.41 (0.45 – 4.37)	0.97 (0.28 – 3.38)	0.76 (0.19 – 3.09)	N/A	N/A
Socioeconomic Status *(Reference: antyodaya)*					
Above poverty level	0.15* (0.04 – 0.64)	0.11** (0.02 – 0.52)	0.07** (0.01 – 0.37)	0.07** (0.01 – 0.45)	0.76 (0.18 – 3.14)
Below poverty level	0.64 (0.25 – 1.64)	0.55 (0.20 – 1.49)	0.61 (0.21 – 1.76)	0.20* (0.06 - 0.71)	0.93 (0.34 – 2.56)
Step 2: Family Structure Indicators					
Elderly >60 years		0.28*** (0.15 – 0.57)	0.28*** (0.13 – 0.60)	0.41** (0.21 – 0.80)	1.76* (1.00 – 3.07)
Family size		1.48* (1.04 – 2.09)	1.49* (1.02 – 2.19)	1.24 (0.90 – 1.70)	N/A
Children <18 years		0.52** (0.32 – 0.84)	0.49** (0.29 – 0.83)	0.70 (0.45 – 1.08)	N/A
Step 3: Health Indicators					
Diarrhea *(Reference: no)*[a]			0.67 (0.18 – 2.54)	1.12 (0.30 – 4.24)	0.77 (0.27 – 2.19)
Illness *(Reference: no)*[b]			7.28*** (2.55 – 20.78)	3.20* (1.19 – 8.61)	3.21* (1.29 -7.98)
Disabilities *(Reference: no)*			2.59 (0.77 – 8.72)	2.76 (0.77 – 9.94)	0.72 (0.26 – 2.01)
Model Indicators					
AIC Score	220.27	206.23	197.79	183.31	210.87
AIC Weight (%)	0%	1%	99%	75%	82%

Notes: AIC=Akaike Information Criterion; AIC weight represents the proportion of the total predictive power for each model compared to others in the set; * p<0.05; ** p<0.01; *** p<0.001; [a] Diarrhea refers to anyone in the household who experienced diarrhea in the four weeks prior to the interview; [b] Illness refers to anyone in the household who experienced a range of waterborne illnesses and/or gastritis in the six months prior to the interview.

A qualitative analysis of participant interviews and focus group discussions identified four major themes: (1) reasons behind intervention adoption, (2) barriers to intervention adoption, (3) WASH behaviors, and (4) program evaluation. Definitions for each theme and their associated sub-themes are provided in **Table 5**. The analysis process involved the use of multiple codes to generate each sub-theme, resulting in a total of 49 different codes.

Table 5: Summary of qualitative findings by theme and sub-theme

Theme	Definition	Sub-theme	Number of Mentions
Reasons behind intervention adoption	Statements that identify an explanation for intervention adoption	(1) Health	17
		(2) Diffusion of knowledge/trust	16
		(3) Aesthetics	8
		(4) Repetition	6
Barriers to intervention adoption	Statements that identify an explanation for barriers to intervention adoption	(1) Lack of session attendance	17
		(2) Economic barriers	6
		(3) Men as decision makers	5
		(4) Young children	2
WASH behaviors	Statements that reference WASH behaviors before and after the intervention	(1) Behaviors after intervention	34
		(2) Behaviors before intervention	10
Program evaluation	Statements that describe opinions about the WASH For Healthy Homes intervention	(1) Session frequency	12
		(2) Session meeting size	9
		(3) Session activities	9
		(4) Session meeting length	8
		(5) Session coordinator	5
		(6) Request for more information	4

Notes: Each sub-theme was comprised of various codes generated from the raw data. Number of mentions refers to the number of times a code was mentioned in that particular sub-theme.

3.6.1 Demographic and Baseline Survey Results

Tables 6 and **7** display the socio-demographics and WASH characteristics of the study population at baseline (n=317). The average family size is 5.53 members, and 90% of families have children under the age of 18, with 42% having children under age five. Only 47% of families in the study have a toilet within their HH. A statistical analysis of the baseline dataset revealed that family size and number of children in the family were significantly correlated with toilet adoption. Larger families were 1.5 times more likely to have a toilet compared to smaller families, which is consistent with findings from Rodgers et al. (2007). However, families with more children were less likely to have a toilet (OR=0.58) in the HH. This might be because families with larger numbers of children already face significant expenses, and the additional cost of maintaining a toilet only adds to their financial burden. Furthermore, this study found that the likelihood of having diarrhea increases by a factor of 1.36 for every child. Children are particularly susceptible to diarrhea (Mokomane et al., 2018)–due to inadequate personal hygiene and improper handwashing practices–highlighting the need for improved sanitation and hygiene practices in HHs with multiple children.

The baseline survey revealed that a majority of the study population (66%) had an education level below matriculation (tenth grade), while only 9% had a graduate-level education. In the statistical analysis of toilet adoption, families with at least one member educated at the graduate level were seven times more likely to possess a toilet than those with an education level below matriculation. Several studies have shown that toilet adoption increases with higher education levels, as individuals with greater education generally have a better understanding of the health risks associated with open defecation and the importance of improved sanitation (Ali & Khan, 2023; Coffey et al., 2017; Zeleke et al., 2019).

Table 6: Socio-demographic profile of the study population at baseline (n=317)

Demographic Variables	Value
Average family size (range, SD)	5.53 (1-17, 2.12)
Families with children <5 years (%)	42
Families with children <18 years (%)	90
Families with member with a disability (%)	14
Families with elderly members >60 years (%)	29
Family members with illness in last 6 months[a] (%)	78
Family members with diarrhea in last 4 weeks (%)	11
Socioeconomic Status (%)	
Above poverty line	17
Below poverty line	65
Antyodaya	18
Highest Education Attained by Any Family Member (%)	
Graduate	9
Higher secondary pass	13
Secondary pass	12
Below matriculation	66
Occupation (%)	
Daily wage labor + farming	48
Daily wage labor	43
Other	9

Table 7: WASH characteristics of the study population at baseline (n=317)

WASH Variable	Percent
Families that treat their water	2
Families that spend >30 minutes round-trip to fetch water	11
Households with a toilet	47
Families who wash hands with soap before meals	76
Families who wash hands with soap after using toilet	83
Families who wash hands with soap after handling child feces	89
Drinking Water Source	
Handpump	80
Govt. supply	10
Handpump + govt. supply	8
Other	2
Type of Water Storage Container	
None	46
Plastic bucket	32
Metal pot	21
Plastic bucket + metal pot	1

According to the baseline survey, 14% of families have at least one member with a disability. Furthermore, in the four weeks before the survey, 11% of families reported experiencing diarrhea, while 78% of families reported experiencing waterborne illnesses and/or gastritis within the last six months. The statistical analysis showed that families with disabled members were three times more likely to experience waterborne illnesses and/or gastritis compared to HHs without a disabled member. This is consistent with the findings of (Groce et al., 2011), who argue that persons with disabilities are more likely to confront sanitation and hygiene challenges due to physical and social barriers. Additionally, families reporting waterborne illnesses were 11 times more likely to have had diarrhea in the four weeks prior to the survey. This relationship is not surprising, as diarrhea is a common symptom of gastroenteritis and the presence of one can indicate the likelihood of the other. Improper WASH practices are often identified as the underlying cause of the prevalence of these diseases (Centers for Disease Control and Prevention., 2015), underscoring the critical role of education in promoting awareness about disease transmission.

3.6.2 Barriers to Intervention Adoption

A comprehensive understanding of the challenges that impeded success of the WASH For Healthy Homes intervention requires an examination of the diverse perspectives of participants on the barriers they encountered. Several key barriers were identified through statistical and thematic analyses, including economic constraints, male dominance in household decision-making, the needs of vulnerable groups such as children and the elderly, and low attendance at educational sessions.

3.6.2.1 Economic Barriers

Prior to the intervention, the baseline survey showed that only 2% of HHs treated their water (**Table 7**). However, in the endline survey (n=218), 61% of HHs adopted the silver-ceramic pot filters for water treatment (**Table 8**). Among those who did not adopt a water treatment method after the intervention (n=83), financial constraints were cited as the primary barrier. In fact, the sub-theme of economic barriers emerged through a qualitative analysis of the interviews and focus group discussions, which is not surprising given that the majority (65%) of the study population lives below the poverty line. Multiple participants indicated a desire to purchase the filter if they were able to afford it and recognized that, in the event of an illness, medical expenses would exceed the cost of the filter. One woman even shared that she gets filtered water from her neighbor, and expressed that she would have purchased the filter if it was more affordable. To help reduce the barrier of affordability, one potential solution could be to explore the possibility of subsidies or microfinance options for households living below the poverty line (Ojomo et al., 2015).

The economic barriers mentioned above are somewhat contradictory to the hierarchical model, however. The model indicates that individuals living above the poverty line were less likely (OR=0.07) to purchase a filter overall, and the same pattern was observed in the model analyzing the construction of a handwashing station, where individuals living above the poverty line were less likely to build a station. These findings contradict previous studies, which have found that the utilization of HWTS practices rises simultaneously with an increase in wealth among the population (Ojomo et al., 2015). One possible explanation is that–among those who did not purchase a filter or handwashing station–those with greater financial resources may have had other rationale for not purchasing while those with lesser finances were most impinged by economic barriers. Further, being above the poverty line does not necessarily imply financial security, particularly in cases of large families that must prioritize essential needs. Families above the poverty line in the study community are still relatively poor and must also allocate their scarce resources across numerous competing needs and wants.

Table 8: Endline survey responses regarding the adoption of HWTS

Household water treatment and storage	**Value**
Household water treatment method (n=218)	*Count (%)*
Silver-ceramic pot filters	132 (61)
No water treatment method	83 (38)
Other treatment methods	3 (1)
Who made the decision to purchase a filter (n=132)	*Count (%)*
Female head of household	99 (75)
Jointly	28 (21)
Male head of household	5 (4)
Reason for filter purchase (n=132)	*Count (%)*
Sensitization and awareness campaign	132 (100)
Reason for not having HWTS option (n=83)	*Number of mentions*
Cannot afford one	67
Like the taste of source water	39
Risk of breakage due to kids in the home	39
There is no space for one	17
Do not need one	14

3.6.2.2 Men as Decision-Makers

The adoption of a HWTS intervention can be influenced by household dynamics and the relative power dynamics among household members (Figueroa & Kincaid, 2015). During focus group discussions, several women reported having limited decision-making authority regarding financial matters. One female revealed that her husband gives higher priority to buying alcohol compared to the filter and noted that he consumes a liter of alcohol every day. Similarly, another female participant stated, “My husband drinks [alcohol] and it costs 100 INR a day. What can I do?” This can be attributed to the fact that men are typically the breadwinners in India–particularly in the study area–and therefore assume responsibility for financial decisions (Khanna & Das, 2016). Prevailing gender norms in the country can further restrict women’s ability to allocate WASH resources and advocate for improved WASH practices in the HH (Weber et al., 2019).

Bihar is one of the poorest states in India (Dayal et al., 2017), leading to an outmigration of males seeking employment opportunities. As a result, a large number of male heads of HH migrate to urban centers and other states for livelihood. This was identified as an obstacle for women acquiring the filter, as their husbands were hesitant to purchase because they were not convinced of the filter’s effectiveness and did not understand its purpose. During a focus group discussion, one woman stated, “I asked my husband to buy a filter, but he wouldn’t listen,” and then another woman contributed, “We don’t have the skills to build a handwashing station. Our husbands do, but they won’t listen.” This highlights the importance of involving men, in addition to women, in WASH intervention planning because their role is also fundamental to the uptake of program practices and technologies/infrastructure (Cairncross et al., 2005). Simply put, while WASH programs predominantly focus on women due to their roles in retrieving water, caretaking, and family health, the correlated male gender roles of being the breadwinner and making (economic) HH decisions should not be understated. While dissolving such androcentric roles remains a broad, longer-term societal goal, exploiting male gender roles as a method to bring them into WASH discussions may be a strategic leverage point in the meantime.

3.6.2.3 Children and the Elderly

The baseline survey reported that a majority of families (90%) have at least one child. In the thematic analysis, the sub-theme of having young children emerged as a barrier to intervention adoption. Specifically, interviewees cited concerns about their small children or grandchildren inadvertently breaking the ceramic filter during play as the reason for not purchasing it. This finding is similar to a study that identified the behavior of children as a potential barrier to the adoption of HWTS technologies (Bitew et al., 2020). The risk of filter breakage due to children in the home was also mentioned (n=39) in the endline survey as one of the top reasons for not having a HWTS option. Furthermore, the final hierarchical model for filter purchase demonstrated a statistically significant correlation, indicating that HHs became increasingly less likely to purchase a filter (OR=0.49) with each additional child.

The hierarchical model also revealed that families with an elderly member were associated with a lower likelihood of purchasing a filter (OR=0.28) and constructing a handwashing station (OR=0.41). The baseline survey highlighted that 29% of families in the study area have at least one individual 60 years or older. During focus group discussions, an elderly participant conveyed that she faced difficulty comprehending information presented during the sessions due to her age. The participant further added that she relied on her daughter's assistance to grasp the technical aspects of the sessions. Elderly individuals may face barriers in accessing or adhering to appropriate sanitation and hygiene practices, given their specific physical requirements (Ezbakhe et al., 2019). Moreover, they are more susceptible to complications arising from waterborne diseases due to their weakened immune systems (Pal et al., 2018). Because of these risks, it is crucial to design behavior change interventions that cater to the unique needs of vulnerable populations, particularly the elderly.

3.6.2.4 Lack of Session Attendance

A series of flooding events occurred that interrupted the WASH sessions. Thus, an interview question was designed to explore the extent to which the unexpected events may have influenced participants' ability or motivation to attend the sessions. The effectiveness of HWTS practices can be influenced by flooding, which may cause the intervention to be less effective and no longer work the same as it did under previous conditions (Mertens et al., 2019; MacDonald et al., 2016). A finding was that flooding negatively impacted livelihoods, which left community members unable to concentrate on learned messages since they were occupied with other pressing matters. For example, one woman shared that the flooding events filled her home with water, forcing her family to live in tents on the street. Others expressed family struggles with fuel shortages, limited food supplies, and a lack of fodder for their animals. One participant reported that her washroom had become fully submerged in water, rendering the toilet and handwashing station unusable. The participant expressed frustration over not being able to practice the behaviors she had learned in the sessions even though she desired to. In contrast, some participants mentioned that they had forgotten intervention messages, such as the proper steps for handwashing. Prior research has shown that flooding events can lead to a decline in living conditions, livelihoods, and access to WASH infrastructure (Fewster, 2015), and such disruptions also increase the risk of waterborne and mosquito-borne diseases (Eugene et al., 2020). Therefore, intervention planners should proactively plan for potential intervention disruptions by allocating time for make-up sessions / redundancy, providing informational materials, and fostering peer support within the community. These measures can help to prevent backsliding and sustain positive WASH behaviors through the intervention and beyond.

Another factor that contributed to low session attendance was the absence of physical incentives in the intervention. During a key-informant interview with the field coordinator, he noted that project beneficiaries did not like to attend the sessions at the beginning because they were not receiving any compensation. He noted that, despite participants providing consent at the beginning of the study knowing they would not be given anything for attending, they still expressed a desire for items such as snacks, samosas, or sweets. Furthermore, during an individual interview with a community group leader, she expressed that her community was particularly hard to motivate. She said, "They didn't care because they weren't giving them anything, so why would they go?" Studies have shown that offering some type of incentive for adopting WASH protocols can increase adoption and project success (Lewis et al., 2018; McKenzie-Mohr & Schultz, 2014). An alternative to providing physical infrastructure and other types of compensation or 'rewards' in WASH interventions can be with a social approach. For example, encouraging unity within a community and emphasizing social integration is shown to contribute to the success of WASH interventions (Waterkeyn & Cairncross, 2005). The use of a social approach was effective in the WASH For Healthy Homes study, as evidenced by responses in the focus group discussions. According to participants, their motivation to attend the sessions increased after the village fair. Women reported feeling a sense of peer pressure after seeing others attending, which prompted them to attend as well. Further, other focus group participants noted that the sessions drew them in because they also wanted to sit among their neighbors, listen to the others participate, and engage in small talk with their social peers.

3.6.3 Facilitators of Intervention Adoption

Several facilitators were identified that helped to increase adoption of the Wash For Healthy Homes intervention. Key facilitators include concerns for health, trust and knowledge sharing, aesthetic appeal, and repetition. To fully comprehend the facilitators, it is necessary to explore the perspectives and motivations of participants.

3.6.3.1 Health

The primary drinking water source for 80% of study participants at the baseline was a handpump (i.e., untreated groundwater). Government supply was the second most common source (10%) (**Table 6**). During the formative research prior to the intervention, 88 available water sources were tested for microbial and chemical quality. The findings indicated that all 88 had unacceptable levels of biological contamination, 86 had levels of arsenic beyond permissible limits, and 37 had high levels of iron. During the focus group discussions, some participants expressed that they were already aware of quality issues with handpump water, while others learned about them through the intervention. In a key informant interview with the *panchayat Mukhiya*, he acknowledged that both the groundwater and government provided water in his *panchayat* were contaminated. He described the water as pale yellow in color and mentioned that using it for bathing can cause skin problems. Towards the end of the interview, he said, "We want good water quality at everyone's doorstep."

The baseline survey showed that 78% of people in the study area reported having a gastrointestinal or waterborne illness in the six months preceding the survey (**Table 6**). After analyzing the hierarchical regression models that determined variables associated with intervention adoption, it was found that illness as a health indicator was significant across all three models (**Table 4**). Individuals that had a family member with a gastrointestinal or waterborne illness at baseline were seven times more likely to purchase the silver-ceramic pot filter. Additionally, those who suffered from these illnesses were three times more likely to construct a handwashing station and wash hands with soap after using the toilet.

In the thematic analysis, health was a sub-theme and driver behind the adoption of intervention messages among study participants (**Table 5**). In one discussion, a participant stated that when her family drank handpump water they suffered from stomach aches and diarrhea. In another discussion, women reported having to purchase a significant amount of medication to treat their stomach problems that they attributed to consuming handpump water. The silver-ceramic pot filter's ability to reduce water contamination and improve overall health was cited as a reason for its adoption by many participants. The willingness of the participants to adopt the technology to improve family health highlights the significance of adopting a family-centered approach to promote proper WASH behaviors. This trend is also observed in the statistical model that shows larger families were 1.49 times more likely to purchase a filter than smaller families. By better addressing the specific needs and concerns of families, interventions can be designed to meet their requirements effectively, ultimately facilitating a higher level of engagement and adoption (Starble et al., 2005).

3.6.3.2 Trust and Diffusion of Knowledge

During interviews and focus group discussions, participants expressed their initial skepticism towards the WASH intervention occurring in their community. For example, some women shared that their husbands did not want them to buy the filter because they believed the field coordinator was trying to cheat them. It is possible that the initial skepticism could have been influenced by the perceived credibility of the field coordinator–who is not a health professional–leading some to question his authoritativeness (Figueroa & Kincaid, 2015). However, once the field coordinator established a rapport and gained trust within the community, the participants became more receptive to the coordinator's messages and were convinced of his good intentions.

Additionally, the focus group discussions highlighted that the group leaders–who are study participants themselves–were typically among the first to purchase the filters. Other participants mentioned that although they were initially hesitant about the intentions of the field coordinator, they trusted the group leader, which increased their willingness to buy the filter. This demonstrates the importance of identifying and engaging trusted community leaders in WASH interventions because they are seen as role models and influential members in the community. Establishing trust in interventions can both rely on and enhance community relationships (Wall & Chéry, 2011), and these relationships may be essential to achieving success in WASH intervention adoption and behavior change that is sustainable.

To gauge comprehension and familiarity with session messaging, participants were asked whether they shared session information with their family and friends. The assumption is that participants who comprehended session information would have shared the learned concepts with their immediate family and close friends. Not only was this the case, interestingly, a trend surfaced in which participants even shared session information with individuals living outside of the study communities. For example, a male interviewee expressed that he told three of his family members who lived outside of the study community about the filter. All three of the participant's relatives made the external effort to purchase the filter and now all of their neighbors are interested in purchasing the filter. In other cases, however, individuals who were not part of the intervention wanted to purchase the filter, but they did not have access to the local potter or lacked the finances for purchase. In another case, a participant mentioned how she told her family outside of the study community, but they simply did not care about the filter. She then added that she feels the lack of motivation was due to not having access to the intervention program; if they were part of the program, she thinks they would purchase the filter. Children too were agents in the diffusion of information. Some children attended the sessions while others learned information from their family and murals painted in the villages. Some children even competed in the village fair, with one child winning a prize for constructing a small, improvised handwashing station. The child then went on to teach his school friends–who are not part of the intervention communities–about handwashing and how to make a handwashing station. Collectively, these cases highlight that knowledge from sessions was both being comprehended and conveyed to third parties both within and outside of the intervention communities.

3.6.3.3 Aesthetics

Studies have found that the appearance of water has an influence on perceptions of its quality (Wedgworth et al., 2014). Several members of the community mentioned the role of aesthetics in their decision to adopt the silver-ceramic pot filter. For example, focus group participants reported that their untreated water, when stored, acquired a pale-yellow color, leaving stains when used for washing clothes. Another individual reported a thin, yellow film that would form on the surface of her stored handpump water, which made her reluctant to consume it. The field coordinator was able to convince these individuals to purchase the pot filter by demonstrating the difference in water appearance before and after using the filter.

Additionally, HWTS products serve not only a functional purpose, but they also carry personal and cultural meaning for users (Gotzsch et al., 2006). A community member stated that he bought the filter because of its use of locally sourced materials. He explained that he appreciated the filter being made with local materials as he was familiar with them, citing his grandmother's use of earthen pots as a personal example. He further went on to express admiration for how the filter effectively keeps the stored water cool, which he found aesthetically pleasing. These findings demonstrate that aesthetics, as well as human perceptions and physical attributes of the water and treatment device, play significant roles in shaping users' perceptions of and experiences with the product.

3.6.3.4 Repetition

Program strategies such as repeated education, training, and promotional activities can serve as facilitators to encourage communities to adopt HWTS practices (Bitew et al., 2020; Rosenthal et al., 2020; Dreibelbis et al., 2016). Given that the WASH For Healthy Homes intervention was implemented during the COVID-19 pandemic, an interview question aimed to compare people's understanding of safe WASH practices from the intervention versus repeated COVID-19 messaging. The prevailing responses were that the intervention served to reinforce COVID-19 teachings and attributed to a greater impact on their overall behavior. Some participants cited that the intervention was more effective in educating them on proper hygiene, compared to general public health messaging on COVID-19, because of the repetitive nature of the sessions, which was particularly beneficial for slower learners. Furthermore, one focus group stated that they washed their hands before the intervention due to fears from COVID-19, but they were not aware of the proper techniques. They had used soil, ash, or water, but now they use soap and practice the correct steps for handwashing. These results highlight the importance of targeted and repeated intervention messaging in reinforcing proper hygiene practices over time.

3.6.4 WASH Behaviors Pre- and Post-Intervention

A goal of the interviews and focus group discussions was to understand key messages that project beneficiaries retained from the sessions. This was determined by asking what new information participants learned from the intervention. Most of the responses consisted of a reference to an old behavior practiced before the intervention followed by a new behavior after the intervention. For example, one woman mentioned that she used to wash her hands at the handpump after using the toilet, but now she uses a designated handwashing station instead. In another interview, a man shared that he was spending 600 INR monthly on bottled water due to contamination concerns in the handpump water. After purchasing the filter, he saves money and no longer buys bottled water.

In addition to stating changes in behavior, many interviewees highlighted the health effects that resulted from their changed behaviors. One woman stated that she used to suffer from frequent gastrointestinal illnesses when she drank water from the handpump, requiring 500-600 INR monthly for medication to manage the symptoms. However, after she started consuming the filtered water, she claimed she no longer needed any medicine, “not even one.” Another participant said that before using the filter, she experienced a sensation of “heaviness” in her stomach. After adopting the filtered water, she reported feeling “lighter” and happier. Some women in the focus groups also reported that their children began practicing proper handwashing techniques after the intervention. As a result, these mothers noticed a decrease in their children’s illness rates. Based on this feedback, it can be assumed that the intervention had, if anything, a positive impact on the health of study participants. It is important to note that this assessment is based on qualitative, self-reported health outcomes that may be biased (Singh et al., 2022). However, self-reported data remain critical for gauging insights into participants’ experiences with and perspectives on the program as these personal experiences are also drivers of motivation for behavior change (McKenna, 2011).

3.6.5 *WASH For Healthy Homes Program Evaluation*

3.6.5.1 Participant Perceptions of the Intervention

With the goal of enhancing the effectiveness of future WASH interventions, this study aimed to identify areas for improvement in the WASH For Healthy Homes intervention. To determine this, study participants were asked about their opinions on the intervention, including both positive and negative feedback, and any suggestions they had for improvement. One interesting finding among some female participants was their desire for a female coordinator. Even though many expressed admirations for the male coordinator, women also noted a preference for a female to discuss menstrual hygiene management. Another theme was a desire to learn even more information. Participants expressed a sense of empowerment and enjoyment in the sessions, leading to their strong desire to continue learning about WASH and related topics. Studies have found that empowering project beneficiaries, particularly marginalized groups, will increase access to proper WASH infrastructure (Leahy et al., 2017).

Regarding the structure of the sessions, several individuals conveyed satisfaction with the current format. The majority of participants preferred keeping the session frequency at twice a month because they felt that having additional sessions would be overwhelming, whereas having fewer sessions might result in forgetting important messages. Project beneficiaries also indicated their preference for the session meeting duration to remain unchanged at one hour long. The reason was that participants feared losing focus during longer sessions, but believed shorter sessions would not provide sufficient time for learning. Regarding session activities, the majority stated their preference for games/activities and the Q&A format. Individuals who favored games expressed they enjoyed having fun, which could serve as an incentive for them to participate in the sessions (Waterkeyn & Cairncross, 2005). Those who wanted more Q&A mentioned the enjoyment they gained from knowing the answers to the questions, as it was an informative experience for them.

Nonetheless, a few participants expressed their opinions about modifying the existing session format. An example of this was the size of the session meetings, where almost an equal number of participants expressed their desire for smaller meetings as those who preferred larger ones. Participants who favored smaller meetings wanted a more interactive learning environment and also complained that larger groups were more prone to "chit-chat" that could be distracting. Those who preferred the larger sessions said they enjoyed the sense of community and liked the more social environment.

3.6.5.2 Key-informant Perceptions of the Intervention

Interviews were conducted with key-informants to gain insight into the perspectives of those who played a role in designing and implementing the WASH For Healthy Homes project. While interviewing the field coordinator responsible for managing and executing the sessions, it was found that he held a general belief that the sessions were successful in conveying proper WASH practices to the participants. When asked about the challenges faced during the project's implementation, he mentioned that he would want more than one field coordinator and considered himself a "one-man army." Specifically, he mentioned that he would like to train a woman living in the villages, because she would live alongside the participants and be able to carry out daily monitoring and messaging. Having an additional team member would also enable them to broaden the study area and extend their reach to a larger audience. Adding another field staff member, particularly a female, was also mentioned during key-informant interviews with project managers. They indicated that if additional funding and resources were available, this would have been a priority.

3.6.5.3 Evaluation of Intervention Success

The first goal of the WASH For Healthy Homes project was to achieve a 50% increase in the uptake of HWTS, focusing on locally produced ceramic pot filters. During the project, there was a significant increase in the number of families who owned the pot filter, rising from only one at baseline to 191 at the endline. Therefore, it can be concluded that the WASH For Healthy Homes intervention successfully achieved its goal of increasing the uptake of HWTS. Interestingly, it was reported that an additional 199 filters were purchased from individuals living outside of the study area, indicating the potential for future scalability and wider adoption. Of the 218 respondents in the endline survey, 61% (n=132) reported purchasing a ceramic pot filter, with the decision to purchase the filter primarily being the woman head of HH (75%) (**Table 8**). Furthermore, 100% indicated that sensitization and the awareness campaign were the main factors influencing their decision to purchase the filter. These findings suggest that the project had the potential to bring about positive changes in behavior and increase the uptake of HWTS in the study area and beyond.

The second goal of the WASH For Healthy Homes study was to achieve a 50% increase in the adoption of safe handwashing practices. When looking at the 218 comparable families in the baseline survey, 72% reported washing their hands with soap before cooking, 77% before meals, 86% after using the toilet, and 89% after handling the feces of a child (**Table 9**). Of the 218 HHs in the endline survey, there was an overall increase in safe handwashing practices at three critical times compared to the baseline (the exception is for HHs who wash their hands with soap after handling the feces of a child, which decreased from 89% to 87%). While an overall marked increase in safe handwashing did occur, achieving a 50% increase in handwashing practices post-intervention would require a greater number of HHs to wash their hands with soap at critical times than was observed in the study sample. Therefore, it can be concluded that the intervention did not achieve its goal of a 50% increase in safe handwashing practices among the study population. However, it must be mentioned that, at the baseline, no HHs possessed a designated handwashing station–all HHs used the communal handpump to wash their hands. At the end of the intervention, a total of 164 handwashing stations were constructed, indicating that the WASH For Healthy Homes project successfully achieved its goal in this regard.

Table 9: Handwashing practices at baseline and endline

	Baseline	Endline
Handwashing practices	**% (count)**	**% (count)**
Washes hands with soap before cooking (n=218)	72 (156)	97 (211)
Washes hands with soap before meals (n=218)	77 (168)	98 (214)
Washes hands with soap after using toilet (n=218)	86 (188)	99 (215)
Washes hands with soap after handling the feces of a child (n=82)[a]	89 (73)	87 (71)
Household water treatment method	**% (count) n=317**	**% (count) n=218**
No water treatment method	98 (312)	38 (83)
Silver-ceramic pot filters	1 (1)	61 (132)
Other treatment methods	1 (4)	1 (3)

3.6.6 Limitations

3*.6.6.1 Limitations of the WASH For Healthy Homes Intervention*

While the WASH For Healthy Homes intervention improved safe WASH practices, there are some significant assumptions and limitations. First, it is assumed that individuals who purchased filters are actually using them (consistently), but this may not always be the case. During a focus group, it was revealed that at least one woman who had bought the filter was not using it due to her busy schedule and a preference for using handpump water directly. Similarly, it is assumed that those who constructed handwashing stations use them consistently. While walking around the villages, it was observed that some of the handwashing stations were broken and not in use. Additionally, in the baseline survey, participants were asked about handwashing practices during critical times, such as after using the toilet or before meals. For those who reported using soap, it is assumed that they use soap every time, whereas it may only be occasionally.

One significant limitation of the WASH For Healthy Homes intervention was the lack of a comparison group. Without a comparison group, it is difficult to determine whether any measured changes in behavior can be attributed to the intervention or other factors in the social or physical environment. Additionally, the baseline survey asked questions regarding health, including whether or not participants experienced diarrhea in the past four weeks or any illness in the past six months. The intervention's health data may have been influenced by several factors such as the lack of clinically tested data, a reliance on self-reported health indicators, and the potential for recall bias. Although the study conducted a baseline survey prior to the intervention and a follow-up survey post-intervention, there was a discrepancy between the two surveys. The baseline survey included all 317 participating families, including multiple families living in the same HH, while the follow-up survey only interviewed 218 HHs. The assumption was that all families within a HH would exhibit the same behaviors, but this cannot be assumed. Therefore, without a full one-to-one comparison between the pre- and post-intervention surveys, conclusions about the effectiveness of the intervention in bringing about behavior change are less robust than could have been due to survey design. Moreover, due to time, financial, and resource constraints, there are no plans to conduct a follow-up survey a few months or years after ending the intervention. This presents a challenge in assessing whether participants of the intervention sustained safe WASH practices over the long term.

3.6.6.2 Limitations of the Study and Future Research

It is important to note limitations of the study's methodology, particularly with regards to the interviews and focus group discussions. Participants were selected based on their willingness to volunteer, which opens up the possibility for self-selection bias. Given this potential, the study utilized a mixed methods approach that attempted to utilize several data types (baseline, statistical, interviews, observations) to triangulate arguments. That being said, it is important to note that the views or experiences of any one participant may not be representative of the broader study population. In addition, the study faced limitations related to language translation and potential social desirability bias. Responses of the participants were originally in Hindi and then translated to English, which could have led to miscommunication or changes in intended meaning. Moreover, participants may have experienced social desirability bias by providing responses they thought the researchers wanted to hear, especially since a field coordinator was present during the focus group discussions. The researchers attempted to mitigate these limitations by conducting peer debriefings, member checks, and going over quotations with the translator to ensure accuracy. Observations of the filter, checking that it is in use, and observing the handwashing station (with water in the tank and soap nearby) and nearby environments was also done to help cross-verify themes and interlocutor responses. The researchers attempted to mitigate social desirability bias by asking neutral, non-leading questions.

A next step in this research would be to explore the potential for expanding the intervention to other communities. Because the WASH For Healthy Homes was a pilot study, the end goal was to eventually scale up to cover a larger study area. Based on the results of this study, a future investigation could address the limitations identified and utilize the insights gained from both the quantitative and qualitative analyses to inform the study design.

3.7 Conclusion

This study employed a mixed methods approach to evaluate the effectiveness of the WASH For Healthy Homes intervention in rural Bihar, India. Surveys conducted at both baseline and endline stages provided valuable information on demographics, health, and WASH practices of the study communities, which were then analyzed using statistical methods. The findings helped determine whether the intervention achieved its intended goals of increasing safe WASH practices, with a focus on the adoption of silver-ceramic pot filters and safe handwashing practices. Moreover, this study went beyond quantitative data analysis by including key informant interviews, participant interviews, and FGDs to better understand community perceptions and needs. The thematic coding of interview data yielded valuable insights into factors that either facilitated or hindered success of the WASH For Healthy Homes intervention, providing a more comprehensive understanding of the intervention's impact.

Findings indicate that the WASH For Healthy Homes intervention was effective in increasing the adoption of HWTS. The study community, as well as neighboring areas, demonstrated a significant uptake and purchase of the filters. For the second goal, while there was an overall increase in safe handwashing practices, the intervention fell short of a 50% increase. This is because achieving the goal would require a greater number of households to consistently practice handwashing with soap at critical times than what was observed in the study sample. That being said, 164 dedicated handwashing stations were constructed by HHs in the study community, which is an outcome that was unexpected and not built into the original goals of the intervention.

This research reveals that adoption of behaviors promoted by the WASH For Healthy Homes intervention was hindered by several factors. Economic barriers, male dominance in decision-making, the unique role of children and the elderly, and low attendance during intervention sessions were identified as key hindrances. In addition to identifying barriers, this study also identified factors that facilitated adoption of the behaviors promoted by the WASH For Healthy Homes intervention. Participants' health concerns, trust in the field coordinator and peers, the aesthetic appeal of the water and pot, and repeated intervention messaging were identified as key facilitators. Finally, interviews with project beneficiaries provided valuable insights into the positive impact of the intervention on the health of the study participants, as well as their preferences and opinions about the intervention. Specifically, mothers reported a decrease in their children's illness rates, and participants expressed a preference for a female field coordinator.

Through an investigation of the WASH For Healthy Homes intervention, this study provides insight for similar interventions and communities facing similar WASH-related challenges. Incorporating the identified barriers and facilitators into program design may improve the effectiveness and sustainability of other interventions. By addressing these factors, public health organizations, NGOs, and other stakeholders can design WASH interventions to better meet the needs and preferences of target communities, contributing to the attainment of intervention goals and advancements towards SDG-6.

Chapter IV: Conclusion

This study aimed to enhance the existing knowledge on WASH interventions to contribute towards achieving program success and ultimately SDG-6. Access to safe and adequate WASH services is critical for human and environmental health. Unfortunately, a considerable number of people worldwide, especially those in LMICs, rely on water sources that are vulnerable to pollutants and lack access to adequate hygiene facilities. Although progress has been made in increasing access to safely managed WASH services through the implementation of interventions, poor WASH conditions still persist for many.

This study employed a mixed methods approach to evaluate the effectiveness the WASH For Healthy Homes intervention had on changing behavior in Bihar, India. Assessing the effectiveness of WASH interventions can aid in identifying the optimal intervention strategies and the circumstances that contribute to their success. Moreover, recognizing intervention barriers can provide valuable insights into overcoming the challenges that impede success.

Information on demographics, health, and WASH practices of the study communities was collected through household surveys at both baseline and endline stages. The data was analyzed using statistical methods to evaluate whether the intervention achieved its intended goals of increasing safe HWTS adoption, with a focus on promoting silver-ceramic pot filters and increasing safe handwashing practices by 50%. In addition, a qualitative approach was adopted, including key informant interviews, participant interviews, and FGDs, to gain a better understanding of the community's perceptions and needs and to promote community engagement. Thematic coding of interview data provided valuable insights into the factors that facilitated or hindered the success of the WASH For Healthy Homes intervention, offering a more comprehensive understanding of the intervention's impact.

The study found that several barriers hindered the adoption of the WASH For Healthy Homes intervention, including economic constraints, male dominance in decision-making, and low attendance during intervention sessions. However, the study also identified factors that facilitated adoption, such as participants' health concerns, trust in the field coordinator and peers, and the aesthetic appeal of the water. The study obtained valuable insights into the intervention's positive impact on participants' health, as well as their preferences and opinions. In light of these findings, it is important for future WASH interventions to consider these barriers and facilitators when designing and implementing programs. By addressing these issues, organizations can increase the likelihood of successful adoption and sustainment of WASH interventions in communities.

Future research could explore the feasibility of scaling up the WASH For Healthy Homes intervention to other communities beyond the pilot study area. This study's findings could inform the design of future investigations, addressing the limitations identified and utilizing insights gained from both quantitative and qualitative analyses. Such research could be valuable for public health organizations, NGOs, and other stakeholders interested in improving WASH practices in India and similar contexts. As access to safe WASH services is essential not only for preventing diarrheal diseases but also for promoting overall health and well-being, it is critical to continue strengthening these interventions.

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Appendices

Appendix A: Results of SWOT Analysis

WATER

Strengths	Weaknesses
• Most households obtain a sufficient quantity of water. • Communities are generally satisfied with the taste and smell of the water. • Most people walk a short distance (<30 mins/day) to retrieve water. • Some households have government water piped to or near the premises. • There are handpumps for supplemental quantity.	• Some households do not obtain a sufficient quantity of water. • Some walk a long distance (>30 mins/day) to retrieve water. • Handpump water is untreated. • Most households rely on water storage, even those with enough quantity. • Many storage containers are uncovered. • No/few water storage containers have a spigot to reduce contact during serving and storage. • Most households do not treat their water (e.g., boiling, filtration). • Some households pay for private drinking water (e.g., bottled water).
Opportunities	**Threats**
• Expanding government water supply piped to (or near) premises would increase drinking water access and decrease reliance on untreated groundwater. • A local potter produces silver impregnated pots to support household water treatment; the treated water is acceptable in terms of aesthetics. • Some households use biosand filters from past projects or other filtration methods. • Testing the quality of drinking water sources and sharing the results with the communities. • Introducing programs to educate the communities on water quality.	• Drinking water quality issues are present at the source. • Post-point contamination from travel, storage, and serving processes. • Water-borne diseases and public health issues. • Anything that changes the aesthetics of drinking water. • Costs (both economic and time) of household water treatment and capacity (liters/day) of the treatment device.

SANITATION

Strengths	Weaknesses
• Some have toilets in the household. • Households with toilets use them at near a 100% adoption rate.	• Most households do not have toilets or access to a toilet, resulting in open defecation. • Septic tanks or soak pits are in close proximity to groundwater sources (<30.5 meters). • Lack of drainage to manage grey water and sewerage from open defecation, and there are faulty sewerage systems. • State government programs that encourage construction of toilets are generally ineffective due to up-front costs, paperwork, and the amount of monetary assistance provided.
Opportunities	**Threats**
• More toilets would decrease open defecation, and data show that those with toilets use them consistently (high adoption rate). • Introducing drainage infrastructure, along with education on its benefits and how to take care of it, as a shared community system.	• Open defecation. • Some households dispose of wastewater on the road or in the open. • Solid waste and compost management. • Negative health outcomes from fecal-oral illnesses (from interactions with drinking water, grey waters, and open defecation) as well as from interactions with solid waste. • Lack of drainage infrastructure. • Community value for and ownership of what sustainable drainage management would entail. • Vector-borne diseases due to standing water.

HYGIENE

<table>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Most people wash their hands when cooking, eating, going to the bathroom, and handling the feces of a child.
Some wash their hands with soap when cooking, eating, going to the bathroom, and handling the feces of a child.</td><td>Most people do not wash their hands with soap, but instead use only water or a mixture of ash and soil
Water storage is done primarily in uncovered containers.
Water storage containers do not have spigots, so hands come in contact with water during serving processes.
Some water storage containers are visibly dirty and are not being washed (often) with soap.</td></tr>
<tr><th>Opportunities</th><th>Threats</th></tr>
<tr><td>Washing hands with soap (to capitalize on already high adoption of hand washing).
Education on the benefits of soap for handwashing and storage containers compared to other methods of washing for eliminating pathogens.
Obtaining storage containers that are covered and have spigots, along with education on the benefits of such storage.
Educating on menstrual hygiene management and evaluating the access to feminine hygiene products.</td><td>Many people have suffered from water-borne and WASH-related diseases in the past six months.
Potential for post-household water treatment contamination in cases of improper storage and serving.
The actual rate of long-term adoption of hygiene behavior change can be quite low.
Cost of soap and feminine hygiene products.
Cost of containers that are designed to store water more safely.
Cost of household water treatment devices to improve water quality and mitigate risks from improper household water management.
Cost in terms of gender and gender roles in any changes surrounding WASH.</td></tr>
</table>

Appendix B: The questioning route and definitions for interviews and FGDs

IBM-WASH Factor	Explanation of IBM-WASH Factor	Interview Theme Questions	Individual Interview Questions	Focus Group Discussion Questions
Contextual	Includes factors like social norms, the physical environment, and resource access that influence behavior	*WASH handling practices*	(1) From where do you retrieve your water? (2) How and where do you store water? For how long? (3) Do you treat your water? If so, how? (4) How do you dispose of your wastewater? (5) How do you wash your hands? (6) Have you built a handwashing station? Why or why not? (7) Have you noticed any changes in the occurrence of illness in the last month? (8) Have you purchased a silver-ceramic pot filter? Why or why not?	(1) Have you purchased a silver-ceramic pot filter? Why or why not?
Technological	Includes habits and cues that prompt people to engage in the WASH behavior	*Knowledge/awareness of sessions*	(9) What have you learned about water, sanitation, and hygiene from the group sessions versus general information from COVID-19? (10) Have you discussed the session information with family members or friends? If so, what did you share and why?	(2) Did the sessions introduce new ideas that you were previously unfamiliar with? If so, what ideas? (3) What have you learned about water, sanitation, and hygiene from the group sessions versus general information about COVID-19? (4) Have you observed advertising about WASH behaviors in your community? What do you recall from the advertising? (5) Have you discussed the session information with family members or friends? If so, what did you share and why?
Psychological	Includes attitudes and beliefs on the WASH behavior	*Opinion of sessions*	(11) Did you enjoy attending the group sessions? Why or why not? (12) What did you like about the sessions? How do you feel the group sessions can be improved? (13) What are related WASH issues that you are concerned about that were not addressed in the session meetings?	(6) What did you like about the sessions? How do you feel the group sessions could be improved? (7) Do you have any general feedback about the sessions?
		Barriers/facilitators of behavior change	(14) How have flooding events or other disruptions affected your motivation or ability to attend the group sessions?	(8) Did the sessions cause you to change any behavior(s)? If so, which behavior(s) and what was the rationale? (9) How have flooding events and other disruptions affected your motivation or ability to attend the group sessions?

Appendix C: Key-Informant interview questions

Questions for Elected Panchayat Head:

1. Official title and role in the communities.
2. What are the greatest water needs in your area?
3. What resources do you have (i.e. from district/state govt.) to address these water issues?
4. Given the water needs, do you welcome external assistance (such as this project) to address water issues in your community? Are there other similar projects that you have allowed to operate in your community?
5. Do you feel that the project focused on the greatest water needs of the community?
6. Have you noticed any changes in the community since the project has been deployed? What have community members shared with you about the project?
7. What problems in the community do you feel this project did not address or could have been addressed better? What would you like the project to address if there were more time and resources?

Questions for the Field Coordinator:

1. How long at Sehgal Foundation and role?
2. How many similar projects have you deployed or been a part of?
3. Do you feel that the project focused on the greatest water needs of the community?
4. What topics/information do you feel participants understood or adopted most easily?
5. What topics/information do you feel participants understood least or resisted the most?
6. Do you feel you had enough resources to deploy the project?
7. If you had more resources or time, how would the project have been different / what additional tasks would have been deployed?
8. How would you compare the success and outcomes of this project to other projects you were a part of?
9. Do you feel the sessions/technologies are appropriate for the culture and economy of the people?
10. What was the greatest challenge deploying the project? Follow-up flooding etc.
11. In what ways do you think the project could have been better or be improved?
12. How do you view the projects' success, impact, or failure? And why? I.e. Did he actually observe changes?
13. How were the attitudes of participants when attending the sessions? I.e. Did they seem excited to be there, not talkative etc.

Questions for CAWST Officials:

1. What is/was your involvement in the WASH For Healthy Homes Project?
    a. i.e., role, responsibilities/tasks, duration involved, etc.
2. In your experience, how does the project compare to similar projects you have worked on in terms of goals, deployment, timeline, outcomes, etc.?

3. The project had a protracted timeline due to several unpredictable events (e.g., COVID-19, floods)—how do you think these disruptions impacted the project?
4. Have you been involved in other projects with a protracted timeline due to interruptions?
    a. If so, how did it impact the project and its outcomes?
    b. Further, how have you managed these situations and attempted to leverage the challenges?
5. How do you view the project's success or impact, and why?
6. What limitations or constraints did the project face?
7. If you had additional resources, what could have been done differently?
8. Overall, in what ways do you think the project could have been better or improved?