Strategies for Combating Waterborne Diarrheal Diseases in the Developing World

Investigating Current Appropriate Technologies and their Effectiveness in Environmental Public Health

Katie Marie Peterson
Dr. Ernie Diedrich and Dr. Jean Lavigne
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Abstract: Over 5,000 people worldwide die every day due to waterborne diarrheal diseases associated with inadequate sanitation and clean water (Conant). However, unlike other public health epidemics with incurable prognoses and expensive treatment, waterborne diarrheal diseases can be tackled with local resources, small lifestyle changes, and straightforward education campaigns. These forms of solutions are often referred to as appropriate technologies due to their adaptable nature in various communities and environments. This project will compare and analyze appropriate technologies aimed at addressing sanitation and safe water resources in the developing world, and will suggest strategies for creating environmental health campaigns that are cost-effective, long-lasting, and beneficial to communities worldwide.

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Introduction

Over 3.4 million people worldwide die every year due to waterborne diarrheal diseases associated with inadequate sanitation and clean water (Conant). However, unlike many other public health epidemics with incurable prognoses or expensive prevention and treatment, waterborne diarrheal diseases can be tackled with local, inexpensive resources, small lifestyle changes, culturally sensitive solutions, and simple, straightforward awareness campaigns. These types of solutions are often referred to as "appropriate technologies" due to their ambiguity and varying appropriateness in different communities, environments, and duration. This project will investigate the various appropriate technologies currently used in the developing world to combat waterborne diarrheal diseases. Through comparison and analysis of unique programs aimed at solving sanitation and safe water resources, it will be possible to create effective environmental health campaigns that are cost-effective, long-lasting, and beneficial to communities worldwide.

Waterborne Diarrheal Disease Definition

In order to assess appropriate technologies implemented in the fight against waterborne diarrheal diseases, it is first essential to understand the gravity of diarrheal diseases in the developing world. Waterborne diarrheal diseases are transmitted to humans through various means, usually involving water, and can be fatal if left untreated or after multiple reoccurrences. Furthermore, while diarrheal diseases are prevalent in all ages, they are often the most severe and deadly among children due to their small body size

and rapid ability to become dehydrated. More than 2 million children die every year from such diseases, more than the combined number of child deaths annually from AIDS and malaria (PATH). While diarrhea-related deaths occur globally, the number of deaths is disproportionately skewed towards the developing world. Due to environmental

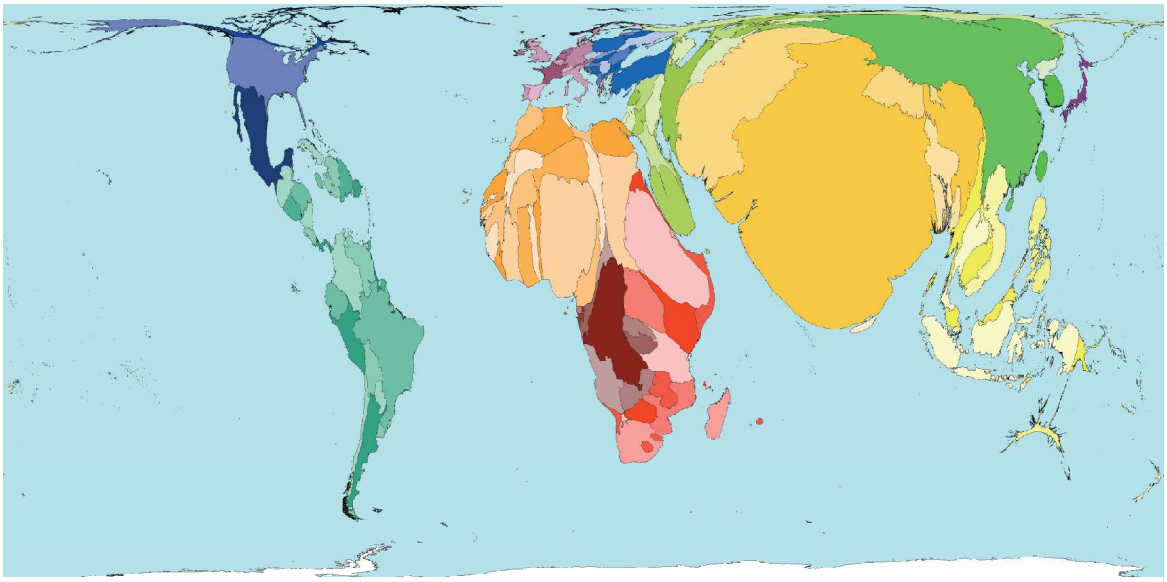


Figure 1: This map illustrates the proportional rates of childhood diarrheal cases in territories worldwide. The largest countries projected on this map are those with the highest rates of childhood diarrhea, and are largely located in the developing world (Childhood Diarrhea).

conditions and cultural tendencies, the number of diarrheal episodes in children in the developing world is ten times greater than that of children in developed countries (Acute Diarrheal Illness Backgrounder).

While diarrhea is a common illness in every country for children between the ages of six months and two years, it is the most common in areas with poor environmental health conditions. Diarrhea causes the body to become dehydrated through the loss of an abnormally large amount of water and electrolytes, and its effects are most greatly felt by children. This occurs because their small bodies are not able to store large amounts of fluid, and therefore they struggle more to stay hydrated. In addition to the loss of water and

electrolytes, individuals lose a significant amount of nutrients during a diarrheal episode. These nutrients are especially essential for the health and growth of children (Guidelines for New Diarrhea Treatment Protocols for Community-Based Healthcare Workers). While one episode of diarrhea is unlikely to cause great harm to an individual, repeated reoccurrences can have long-lasting impacts. Multiple episodes of diarrhea have been shown to result in malnutrition and in "permanent shortfalls in physical and cognitive development, with decrements of up to 8 cm in growth, 10 intelligent quotient points, and 12 months of schooling" (Steiner, Samie and Guerrant). While worldwide diarrheal death rates are known, the number of educational and financial opportunities missed due to diarrheal episodes is immeasurable, and these impacts are significant enough alone to warrant solutions. Unfortunately, many parents do not recognize the connections between their child's diarrheal disease, the long-term harm that it has on both their child's body and mind, and how their daily lifestyle choices could prevent diarrheal disease transmission in their child.

Multiple forms of waterborne diarrheal diseases exist worldwide with different methods of transmission, severity, and duration. Viral infections, from the rotavirus in particular, are the leading causes of acute diarrheal illnesses worldwide. The rotavirus is such a widespread virus that it has infected nearly every child by the age of five on a global scale, and kills over half a million people annually (Hirsch). Escherichia coli (E. coli), Salmonella, Cholera, and Shigella are all bacteria found in the human digestive tract that also cause a significant amount of diarrheal illnesses (Diarrhea prevention and treatment; Curtis). In addition to viral and bacterial infections that cause diarrheal symptoms, there are numerous parasites such as giardia and cryptosporidium present in water sources that

often result in diarrhea. Unfortunately, due to the lack of diagnostic tools available in many developing communities, "researchers do not know the causes of up to half of diarrheal infections that lead to death" (Acute Diarrheal Illness Backgrounder). Although the causes of infection are not always known or measureable, the methods of waterborne diarrheal disease transmission are largely known and therefore can be prevented through education and proper appropriate technologies.

Waterborne Diarrheal Disease Transmission

In order to create and employ solutions for the global public health epidemic of waterborne diarrheal diseases, it is imperative to promote awareness and understanding of the various methods of disease transmission. Many public health educators discuss germ transmission in terms of the five F's: fingers, flies, fields, foods, and fluids. Diarrheal diseases are largely spread through contaminated water and food supplies. This contamination occurs mainly from inadequate hygiene and sanitation. According to "The Handwashing Handbook" by the World Bank, adequate sanitation, which can be defined as a clean and safe toilet or latrine, is inaccessible to 2.6 billion people worldwide (2005). Therefore, over one quarter of the world's population is forced to defecate in fields, behind buildings, and close to community water sources. When fecal matter is not disposed of properly, there is a huge risk of disease transmission. Accidental contact with feces by humans or other organisms such as pets or flies may lead to infection and illness. Additionally, the intentional use of untreated human

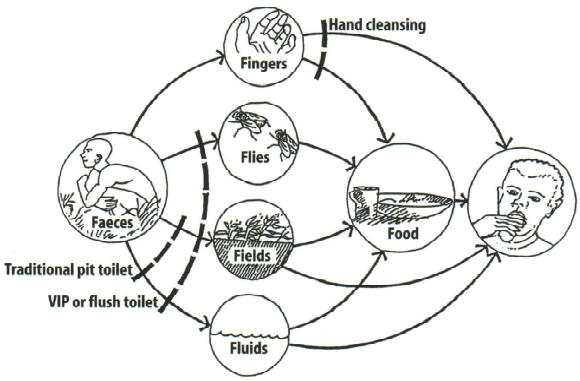


Figure 2: The five F's for transmitting waterborne diarrheal diseases (Conant).

feces as a fertilizer in agricultural practices often leads to infection and illness. Furthermore, contamination of local water sources from the fecal matter of both domesticated and wild animals is a very large issue, and is one that is often more difficult to address due to the lack of control in the movement and habitation of most animals.

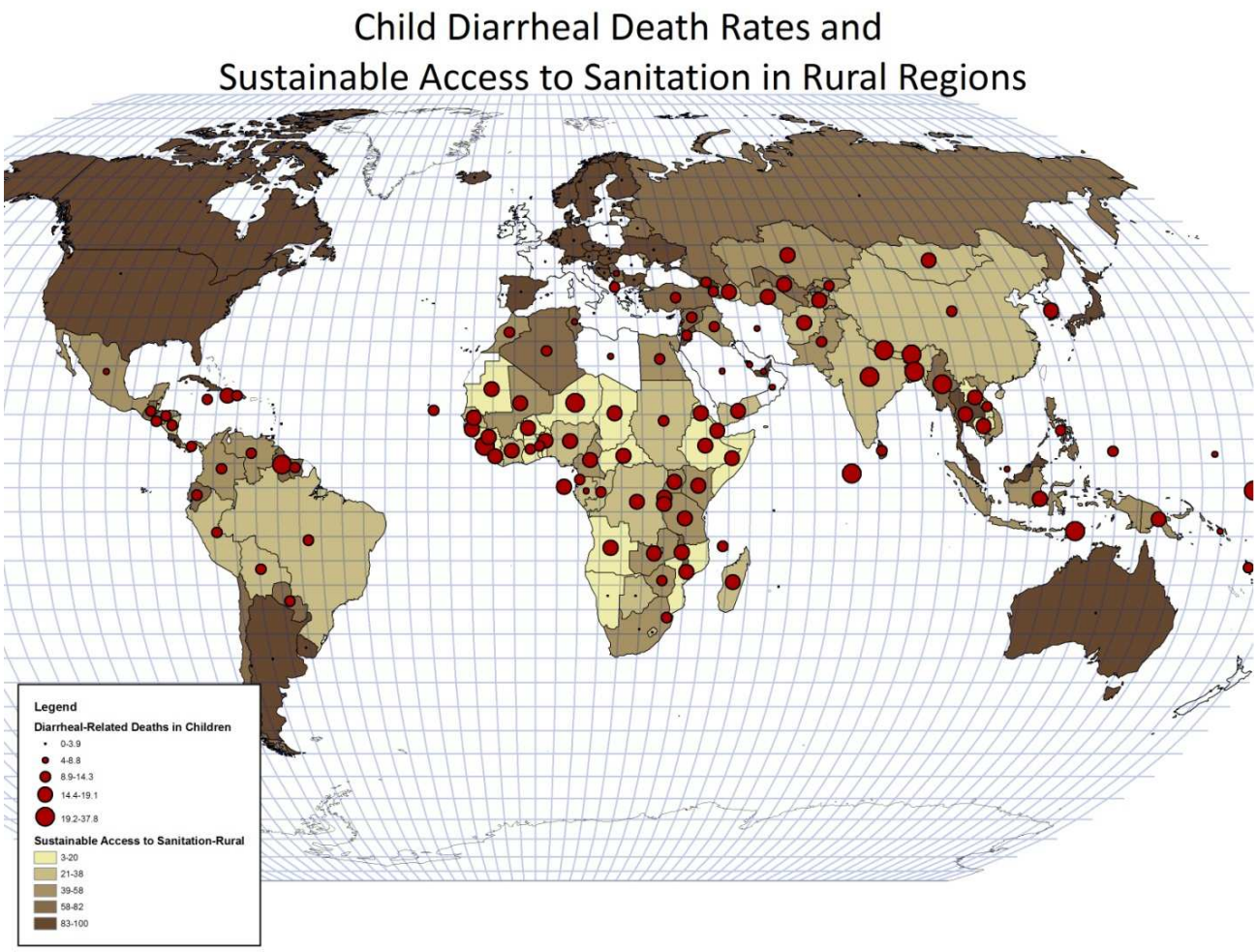


Figure 3: This figure demonstrates the strong relationship between diarrheal death rates and a lack of sustainable access to sanitation measures.

While germs are transmitted through a variety of means, the most common method of diarrheal disease transmission is through polluted drinking water supplies resulting from inadequate sanitation. Every day over 1.2 billion people lack sustainable access to a safe drinking water source (Powder). Millions of people spend multiple hours every day to

the collection of water. There is often the need to travel long distances to and from water sources collecting back-breaking amounts of water in order to stay hydrated and prepare meals for families. Even in communities where wells and boreholes have been installed, they are often in a state of disrepair or provide access to unclean water that requires significant filtration or disinfection in order to be drinkable (Peterson).

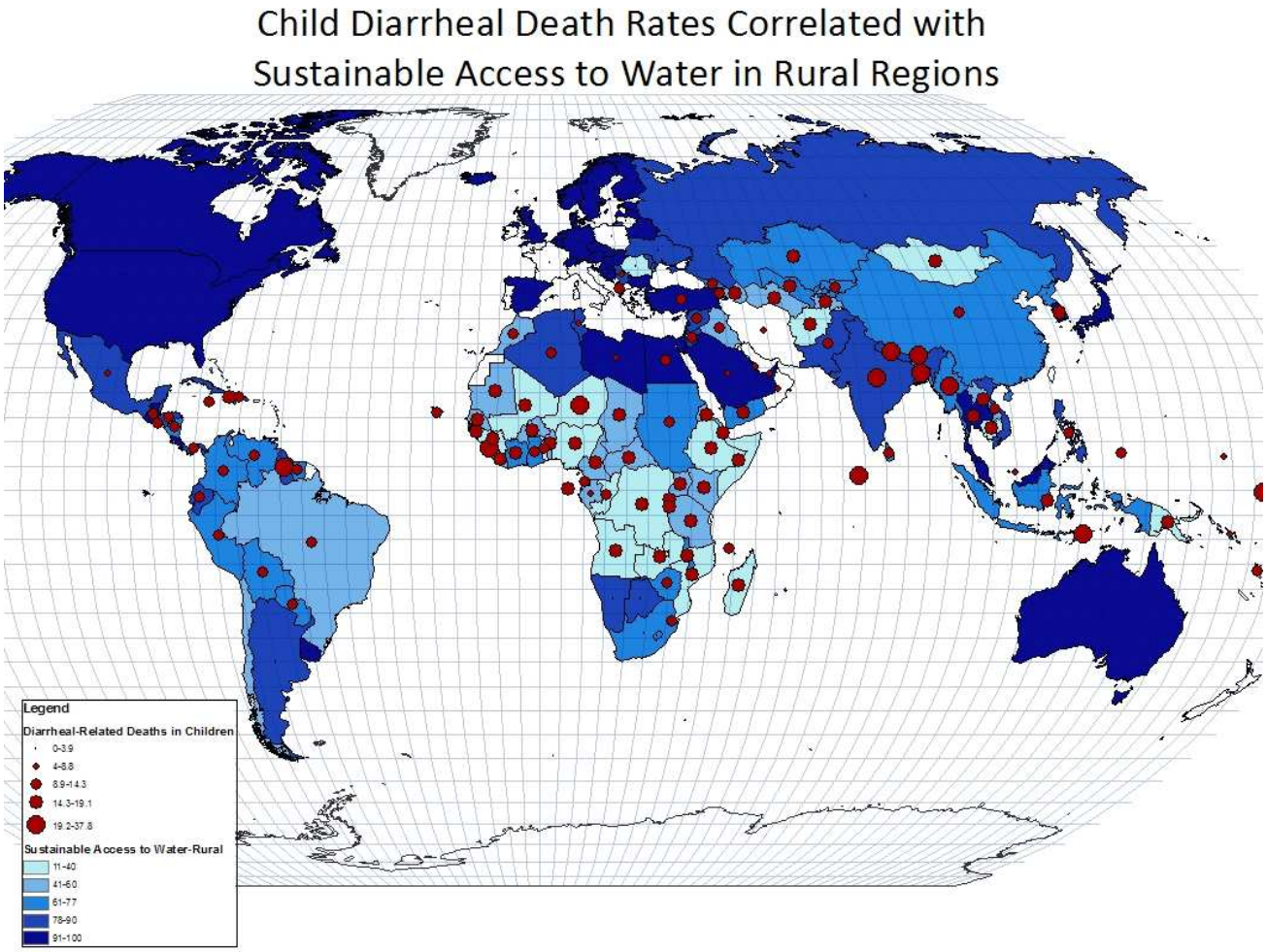


Figure 4: This figure demonstrates the strong relationship between diarrheal death rates and a lack of sustainable access to drinking water sources.

The countless hours devoted to the collection of unsafe drinking water and firewood in order to boil such water hinder educational opportunities for millions of children, and economic opportunities for millions of women every day. Unfortunately, the strain of water collection alone is often so great that millions of individuals are unable to devote the time

to filter or disinfect their water, an honest error which results annually in the death of millions.

Challenges in Combating Waterborne Diarrheal Diseases

While the public health, educational, and economic implications of waterborne diarrheal diseases are enormous, particularly in the developing world, there are viable possibilities for solutions. Many of the roadblocks faced by other epidemiological issues do not apply to waterborne diarrheal diseases: disease transmission is understood, treatments are simple and inexpensive, and preventative measures are non-invasive and non-controversial. Unfortunately, diarrheal-related deaths continue to kill millions every year. Clean water filters, sanitation systems, and vaccinations *do* exist, but they are rarely implemented or publicized in a manner that is effective in the long-term for preventing waterborne diarrheal disease transmission. As with many environmental issues, there is no silver bullet or magical solution to the issue of waterborne diseases. Different countries face different water and sanitation issues, but appropriate technologies that are sensitive to particular cultures, environmental regions, and waterborne diseases have terrific potential for success.

Appropriate Technology Definition

Many different waterborne diarrheal disease awareness campaigns exist, but they must be tailored specifically to individual communities. Additionally, there are dozens of appropriate technologies that could be tailored to the environmental and cultural needs of a community. The definition of appropriate technologies differs in various contexts, but the ultimate goals include: environmental consciousness, inclusivity of the specific culture of a

community, cost-effectiveness, the use of local resources, and creation by community members versus an outside organization so as to empower individuals and create a sense of responsibility. The Appropriate Technology Sourcebook, a compilation of successful appropriate technology solutions applied in communities worldwide, states that appropriate technologies should:

1. require only small amounts of capital;
2. emphasize the use of locally available materials, in order to lower costs and reduce supply problems;
3. be relatively labor-intensive [so as to provide employment opportunities], but more productive than many traditional technologies;
4. be small enough in scale to be affordable to individual families or small groups of families;
5. be understood, controlled and maintained by villagers whenever possible, without a high level of specific training;
6. be produced in villages or small workshops;
7. suppose that people can and will work together to bring improvements to communities;
8. offer opportunities for local people to become involved in the modification and innovation process;
9. be flexible, can be adapted to different places and changing circumstances;
10. be used in productive ways without doing harm to the environment. (Darrow and Saxenian).

According to Dr. Thomas Clasen, a specialist in household water management at the London School of Hygiene and Tropical Medicine, "Simple, affordable technologies … can reduce diarrheal disease among all ages and children under 5 years of age by about 40%" (Sylvester). It has been demonstrated that basic solutions that employ the values of appropriate technology can be successful. Therefore, such technologies need to be created, employed, introduced and marketed in a way that allows them to be effective in individual communities over a long period of time.

Scales of Cleanliness

There are three geographic scales of cleanliness that need to be addressed in order to tackle the issue of diarrheal disease transmission: personal cleanliness, household cleanliness, and public cleanliness. Personal cleanliness is often referred to as hygiene, and involves handwashing, bathing, and wearing clean clothing (Conant). Cleanliness at this scales is *the* most effective way to combat waterborne diarrheal diseases, but due to cultural norms and traditions, it is often the most difficult to address and change. Household cleanliness involves safe food preparation, the storage of safe drinking water, and providing access to clean water, a task that is most effective for individuals versus communities, due to the lack of basic infrastructure in most rural villages in the developing world. Public cleanliness is often referred to as sanitation, and involves the use of clean and safe toilets or latrines as well as ensuring clean water sources on a community level (Conant).

Personal Cleanliness

One of the most straightforward methods of addressing waterborne diarrheal disease mortality and morbidity is through the use of appropriate technologies for personal cleanliness or hygiene. While personal cleanliness technologies encompass overall hygiene as well as laundry and dish washing, handwashing is the main focus for multiple reasons. In order to be one of the most effective methods of disease prevention, handwashing is necessary before preparing food, after using a toilet or defecating, and after cleaning up a child (Curtis). Handwashing is extremely cost-effective due to the small amount of soap necessary, and requires only a few minutes out of each day in order to be successful. In spite of this, current rates of handwashing are extremely low worldwide. Therefore, the

possible impact of handwashing campaigns that utilize the principles of appropriate technologies could be enormous (Curtis). According to a review of multiple studies, handwashing could reduce the risk of diarrhea transmission by 47%, which would decrease the number of diarrhea-related deaths by over one million annually (Curtis). Unfortunately, most examples of handwashing campaigns have proven to be ineffective over the long-term, because regular handwashing is not a common practice in many regions. A current Peace Corps Volunteer in Uganda, Megan Peterson stated:

> Ugandans always wash their hands before meals—it's seen as very dirty and bad manners to not do so, mostly because Ugandans typically eat with their hands. They are less likely, however, to wash their hands before preparing a meal, after using the latrine, or changing a diaper (Peterson).

Scientific studies have demonstrated that handwashing campaigns *do* increase the rates of handwashing in communities, but only for an average of six months, a time period that often correlates with a non-governmental organization (NGO) worker's employment in a community (Curtis). Therefore, while effective in the short run, it is obvious that the benefits of handwashing have yet to be demonstrated in a truly persuasive method that is long-lasting and able to break through cultural barriers in most regions.

It has been argued that handwashing is not the best method of diarrheal disease prevention because of limited access to soap. This argument, however, is unfounded. Soap is accessible in nearly all parts of the developing world (with the exception of extremely remote locations), but it is often used solely for laundry and bathing. Any soap, not only antibacterial soap, combined with water is able to remove dirt that contains microbes, as long as hands are fully covered with soap and thoroughly rinsed (World Bank). Even in locations where soap is not accessible, clean sand or ash may be employed instead due to the emulsifying properties which they possess (Conant). In a study conducted by the World

Bank, neighborhoods were either given handwashing promotions or not given handwashing promotions, with dramatic results: "Children under 15 years living in households that received handwashing promotion and soap had half the diarrheal rates of children living in control neighborhoods" (2005). While this study is most certainly unethical, it boldly proves the point that simple measures can have huge impacts. If the benefits of handwashing could be promoted successfully, diarrheal disease infection rates would decrease significantly and human energy could be expended on greater issues such as education, poverty reduction, and environmental conservation.

One method of handwashing promotion is through the use of appropriate technologies. A great example of an appropriate technology for personal cleanliness is the tippy-tap. A tippy-tap is a simple piece of equipment that can be easily made by an individual from resources that are available in most developing communities. In addition, one of its greatest assets is a minimal use of water to efficiently wash hands. The resources necessary to create a tippy-tap are inexpensive and available in most regions worldwide: a plastic bottle with a screw top (such as a soda pop bottle), a stiff, hollow tube (such as the inside tube from a ball-point pen), and string or rope. This equipment is built by burning a small hole towards the bottom of the bottle, where the small tube is then placed. The tippy-tap operates by releasing a small amount of water through the small tube when the

Figure 4: This figure demonstrates the high correlation between diarrheal death rates and a lack of sustainable access to drinking water sources.

screw top is opened slightly (Conant). The bottle can be hung by a string and kept near a cooking area or latrine in order to remind an individual to wash his or her hands.

The exclusive Breastfeeding of infants, rather than using infant formula, is another appropriate strategy on the personal cleanliness scale that can be used to prevent diarrhea episodes among infants. By choosing to nourish a child exclusively with breast milk instead of formula mixed with water, a mother is able to ensure that the nourishment she is giving her child is safe and clean. Unfortunately, exclusive breastfeeding is a controversial option for mothers who are HIV positive and do not want to spread the virus to their infants through breast milk. According to the Johns Hopkins Bloomberg School of Public Health, "Breastfeeding causes nearly 40 percent of all pediatric HIV infections, yet also prevents millions of child deaths every year by protecting infants from diarrhea and other infections" (Iliff, Piwoz and Tavengwa). Oftentimes an HIV positive mother must choose between potentially transmitting HIV to her infant, or feeding her child with cow's milk or formula that are both more expensive and could potentially infect the infant with a waterborne diarrheal disease. Peace Corps Volunteer Megan Peterson commented on this issue:

> Antenatal services in Uganda recommend that HIV+ mothers feed their babies breast milk but ONLY breast milk for the first six months. Feeding exclusively breast milk has been shown to reduce the rate of mother-to-child transmission. When a mother feeds breast milk and other foods or drinks, the infant's stomach and intestinal tissues weaken and are more susceptible to absorbing the virus (Peterson).

Because safe and nutritious formula options do not exist in Peterson's region of Uganda and in many regions of Africa, experts believe that it is safer overall to promote exclusive breastfeeding. Mothers living in regions where HIV is prevalent, and who are either HIV positive or are uncertain of their HIV status, are told to breastfeed exclusively instead of

feeding a combination of breast milk and formula to their infants in order to protect their child's health (Iliff, Piwoz and Tavengwa). While transmission of HIV is possible, it is much more likely for infants to become ill and die from dehydration related to diarrhea rather than from HIV, and therefore breastfeeding remains an appropriate strategy for combating waterborne diarrheal diseases. This example illustrates the complexity of appropriate technologies and how a solution that may be 100 percent effective in a specific region may not be the best solution in another region due to environmental, physical, or cultural reasons.

Household Cleanliness

While proper sanitation and personal hygiene are incredibly important to stopping the spread of waterborne diarrheal diseases, oftentimes the most effective measure is providing clean drinking water. Water that is both affordable and acceptable for drinking and cooking can be made available throughout the world using various appropriate technologies, which vary between regions, climates, and cultures. Providing safe drinking water at a community-wide scale is possible, but is oftentimes extremely difficult in rural areas that lack access to large wells and water piping systems. Measures can be taken to prevent fecal contamination in water such as fencing off livestock from drinking water sources and use of latrines or toilets on a community-wide scale, but these methods rely on 1oo percent participation of every individual in a village, which is very difficult to achieve over a long period of time. Therefore, point-of-use water treatment has been shown to be the most effective way to provide clean drinking water to individuals (Lenton, Wright and Lewis). There are many point-of-use drinking water treatments which vary in labor intensity, environmental friendliness and sustainability, and duration for completion.

One of the easiest ways to attain safe drinking water is through rain water collection. This can be easily completed using large buckets and troughs, but this system relies completely on the local weather, and therefore often leads to problems when a community is in a period of drought (Peterson, Mailander). Rainwater is easily collected using the corrugated metal roof of a home with gutters that are connected to, or can easily be drained into large buckets, but this type of water often still needs to be treated in some way. Rainwater is best used for laundry, handwashing, and cleaning, as it is not immediately suitable for drinking (Rainwater Collection). However, rainwater collection is one of the fastest and simplest ways to gain access to relatively clean water in the developing world, and should be utilized at a much higher rate.

Although unsustainable and often harmful to the environment, boiling of water is one of the most common methods of preparing drinking water in the developing world, and is done using firewood, charcoal, kerosene, and other similar fossil fuel sources. While the boiling of water is a viable option in nearly every region in the world using local resources and simple methods, it does not come without both environmental and health drawbacks.

Although burning firewood as a method of water treatment is a tradition practiced worldwide, there are many drawbacks associated with it. Oftentimes women and children gather firewood in addition to gathering water, in order to build fires for food preparation and to boil water for

Figure 6: Deforestation, which can be attributed to firewood collection, forces women and children to travel far from the safety of their homes in order to obtain a free water treatment method (Deforestation: Easy Profits, Hard Problems).

disinfection purposes (see figure 6). The task of water and firewood collection forces children, especially young women, to spend a significant amount of time away from the safety of their home, and therefore reduces the amount of time available for homework, and forces many young people to drop out of school in order to support their families (Hangjie). Moreover, the collection of firewood and brush to be used for the boiling of water contributes greatly to the environmental degradation of local resources such as forests. Deforestation from firewood collection is a worldwide problem resulting in soil erosion, desertification, and the loss of thousands of species through habitat destruction, but is considered a necessary action in the daily lives of millions in the developing world. Once firewood has been collected, it is regularly burned in poorly ventilated cooking areas in order to prepare food and water, which leads to respiratory problems for those inhaling the fire's smoke. Deforestation, respiratory problems, and the loss of educational time for children certainly will not end worldwide simply by making alternative water treatments available, but these problems *could* be positively impacted by available appropriate technologies.

Fossil fuels such as kerosene and charcoal are also commonly used throughout the developing world due to their accessibility and relatively low cost. However, with the increasing shortage of fossil fuels, and greater awareness of green house gas emissions produced through the burning of fossil fuels, the prices for charcoal and kerosene will continue to rise until they will no longer be feasible fuel sources. Megan Peterson reflected on the situation of the use of fossil fuels as a water treatment option in her village, "Most people understand that they should be drinking boiled or treated water, but not all [people] have the means to treat their water. Boiling involves having a pan, a charcoal

stove, and charcoal—all of which cost money" (2008). Sadly, many in the developing world will continue to use these fuel sources only until they become slightly more expensive, at which point they may choose to stop investing in water treatment, and suffer the consequences of higher waterborne diarrheal disease rates.

Unlike the boiling of water, which requires a significant amount of time, energy, and resources, there are many other appropriate technologies which can provide safe drinking water in a more rapid and sustainable manner. A fast rate of purification or filtration of water is a specific requirement for all technologies because the large amount of time that is spent collecting water on a daily basis leaves individuals with little energy, resources, or motivation to make their water safe to consume . Therefore, it is essential for appropriate technologies related to the cleaning of water to be fast and efficient.

One of the fastest methods of water purification is the use of chlorine as a water treatment in many different water sources. Chlorination was first used successfully to combat waterborne diseases on a public scale in the early 1900s in cities throughout the United States and Europe and has continued to be implemented worldwide in water treatment plants when levels of bacteria dangerous to humans rise above a normal amount (Lantagne, Quick and Mintz, Household Water Treatment and Safe Storage Options in Developing Countries). Chlorination

Figure 7: A woman and her child in Zambia using chlorination treatment for drinking water.

was originally used on a large, public scale, but it is also functions on a small, individual scale through the utilization of sodium hypochlorite solution (bleach). A person wanting clean and safe water simply needs to add a small amount of the chlorination solution to a bottle of low turbidity water and shake the bottle (Lantagne, Quick and Mintz, Household Water Treatment and Safe Storage Options in Developing Countries). Turbidity can be defined as the level of clarity and transparency in water based on the amount of suspended particles, such as clay or silt. The cost of chlorination water treatment is extremely low, but it does require individuals to have access to the chlorination solution as well as to water bottles. According to the Population Services International, which has created a household water treatment entitled "Safe Water System", a bottle of dilute hypochlorite solution is able to treat 1,000 liters of water using refillable bottles for $.20, "a cost about 60 times less than the fuel necessary to boil an equivalent amount of water" (PSI). Like some other water treatments, chlorination inactivates bacteria and viruses, but it is not as effective at inactivating cryptosporidium and other parasites. Other drawbacks of chlorination include an off-taste for water consumers, its relatively unsustainable nature as a long-term practice, and the possible carcinogenic effects with long-term exposure to by-products of chlorination such as trihalomethanes and nitrogen trichloride (Toxicology and Carcinogenesis Studies of Chlorinated Water).

Unlike the use of chlorination as a form of water treatment, which requires that consumers rely on sodium hypochlorite solution on a regular basis, slow sand filtration water treatment simply requires the one-time purchase of inexpensive filtration equipment with little or no future costs. The concept of slow sand filtration is based on the success in rural communities over hundreds of years of utilizing porous stones as water filters, and

has been shown to be an effective method of combating waterborne diarrheal diseases, reducing bacteria by 81-100 percent on average (Lantagne, Quick and Mintz, Household Water Treatment and Safe Storage Options in Developing Countries). The most popular slow sand filtration system is the BioSand filter which is a concrete container filled three quarters full with sand from the region. Slow sand filters are often preferred over a similar technology; rapid sand filters, because they require less water, less labor, less maintenance, and employ a very unique and natural technology:

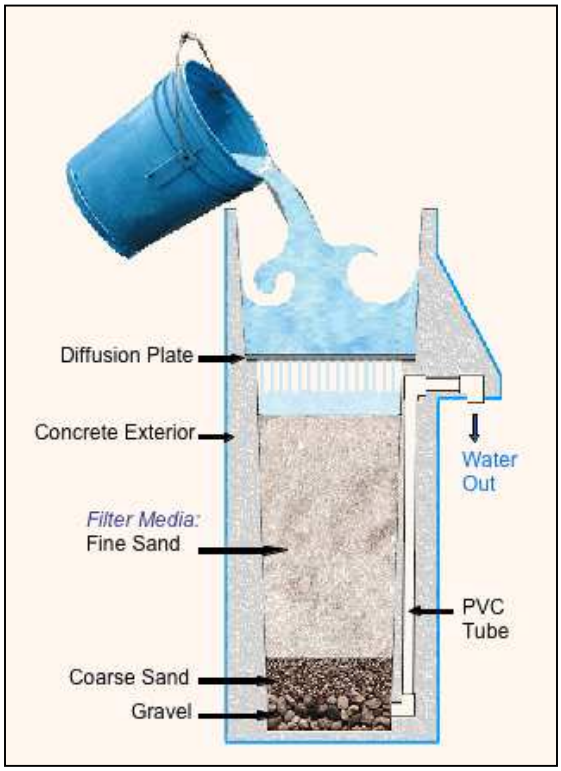


Figure 8: The water filtration process of a BioSand Filter (Duke, Nordin and Baker).

> A slow sand filter contains biological activity and is therefore often referred to as a bio-sand filter. As micro-organisms such as bacteria, viruses and parasites travel through the sand, they collide with and absorb onto sand particles. The organisms and particles collect in the greatest density in the top layers of the sand, gradually forming a biological zone. The biological zone is not really a distinct and cohesive layer, but rather a dense population that gradually develops within the top layer of the sand. The population of micro-organisms is part of an active food chain that consumes pathogens (disease-causing organisms) as they are trapped in and on the sand surface (Fewster and Mol, The Bio-Sand Filter).

Water needing filtration is poured onto a diffusion plate at the top of the filter, and is then filtered through layers of fine grain sand, medium grain sand, and gravel before it is clean enough to drink. While BioSand filters are very expensive for individuals in developing countries, their cost is often subsidized by local NGOs. In addition, a small number of NGOs

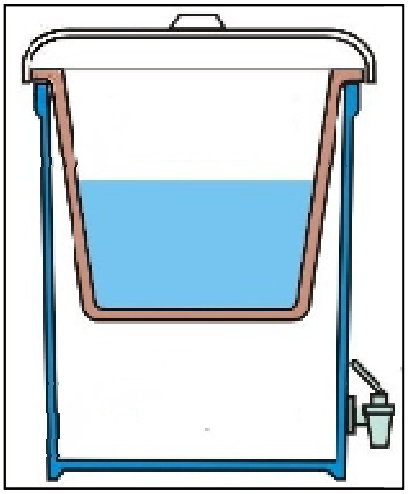
have developed training methods to teach local entrepreneurs efficient methods of constructing and selling slow sand filters in their community.

While BioSand filters do offer many benefits for individuals in areas with a lack of clean drinking water, there are obstacles, both physical and cultural that need to be addressed before they can implemented in a community. One drawback of BioSand Filters is their large size (they often weigh 350 pounds), which makes them difficult to both transport and install, especially for homes on stilts. In addition, the existence of sand in the region is essential for the creation of slow-sand filters. While sand may be imported, this would add great expense to the creation of filters, and may detract from the appropriateness of this specific technology in a location. In order for slow sand filters to be most effective, the water needing filtration must have low turbidity during most of the year. High turbidity water can be filtered for a short period of time, but will eventually clog the top "biological" layer of sand, and will slow down the filtration process incredibly. After the water is filtered, it needs to be stored in a clean container, in order to prevent recontamination of bacteria such as E. coli (Duke, Nordin and Baker).

One potential setback for the installation of BioSand filters is a lack of understanding of its necessity in a home or community. In areas with relatively low levels of water turbidity, the same areas where slow sand filters are most effective, individual are often unaware of a connection between clean drinking water and good health. This occurs because it is regularly not understood that relatively clear water does not necessarily signify clean water. It is not always possible to convince a community of this connection, but there are other, more superficial benefits to slow sand water filtration that contribute to their increased popularity. These benefits include an improved taste and a cooler

temperature over unfiltered water. Another strategy for increasing slow sand filtration popularity is to discuss the practice of digging small holes in sand alongside stream banks, in order to collect clean water. This is a very common practice in villages located near streams and rivers, and can illustrate the ability of a slow sand filter to produce cleaner, clearer water (Fewster and Mol, The Bio-Sand Filter). This example can then be utilized to demonstrate that BioSand filters work in the same manner except on a larger, more reliable basis, and in the convenience of a person's home.

Another method of drinking water filtration is ceramic water filtration. The organization called "Potters for Peace", a member of the World Health Organization's International Network to Promote Household Water Treatment and Safe Storage, began working in the 1980's with Guatemalan potters to create ceramic filters used to purify water (Rivera). The process of creating ceramic water filters begins by building an 8.2 liter ceramic pot using a mixture of local clay and other combustibles such as sawdust or rice husks. The pot is fired, which burns out the combustible matter and creates fine pores throughout, and then covered with colloidal silver which contain bactericidal properties. Water that is filtered through the finished piece is collected in a 20-30 liter plastic receptacle located below the pot (Lantagne, Quick and Mintz, Household Water Treatment and Safe Storage Options in Developing Countries). This type of drinking water filtration is very beneficial due to its low cost for construction and resources, its ease of use, the minimal maintenance that it requires, and



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its long life. Additionally, Potters for Peace states: "field experience and clinical test results have shown this filter to effectively eliminate approximately 99.88% of most water born disease agents" (Rivera). An outside organization conducted a study demonstrating that communities reduced the incidence of diarrhea by up to 50 percent when including the ceramic water filter into their rural health campaigns. While this strategy is simple, inexpensive, appropriate, and effective against bacteria, some critics argue that it is not effective against viruses, has a low flow rate, and that difficulties arise when educating users on its value and functions (Lantagne, Quick and Mintz, Household Water Treatment and Safe Storage Options in Developing Countries).

One of the most simple, inexpensive, and appropriate technologies in the treatment of water involves the use of solar radiation. Solar Water Disinfection, or SODIS, as it is known throughout the developing world, uses clear plastic water bottles and ultra-violet rays to effectively inactivate 99.9% bacteria and viruses effectively (Solar Water Disinfection-the method). It can be used in many regions, and is most effective in the latitudinal regions of 15-35 degrees above and below the equator (see Figure 10).

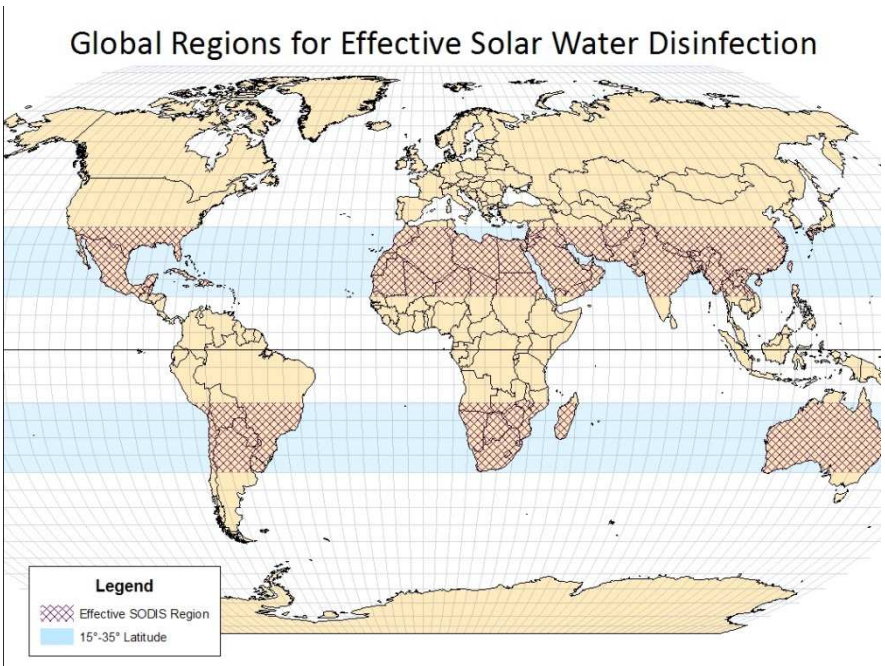

Figure 10: This map illustrates the latitudinal regions where SODIS is most effective due to the level of sunlight received daily.

Placing clear plastic bottles filled with low turbidity water in the sun for six hours on a sunny day will produce water that is safe for drinking. Water bottles can also be placed in the sun for two days if conditions are cloudy. SODIS is a very low-cost technology due to the abundance of water bottles available in even the most remote regions of the world, and requires relatively little labor to be effective. Unfortunately, it's not very well known, and even where it is known it is not highly trusted. Case studies of SODIS awareness and use show that the technology is most trusted, most effective and has the highest use rate over a long period of time when implemented by local community health workers instead of NGOs (Lantagne, Quick and Mintz, Household Water Treatment and Safe Storage Options in Developing Countries). Chris Lauer, a Peace Corps volunteer in Bolivia, stated that while he used SODIS effectively at his original placement, the community where he now lives does not understand or trust SODIS as a method of water treatment. Many Peace Corps volunteers surveyed throughout Latin America and Africa have either never heard of SODIS or have never seen it used in their community, a fact which is disheartening considering their ideal location for SODIS effectiveness. SODIS is a perfect example of an appropriate technology whose implementation could benefit the lives of millions, but because its simplicity of use and effectiveness has not been communicated successfully, it remains an untapped resource in the developing world.

Public Cleanliness

Basic sanitation is essential to prevent the spread of waterborne diarrheal diseases, and also essential for the respect, dignity and safety of individuals. According to Jeff Conant, the author of Sanitation and Cleanliness for a Healthy Environment, toilets and latrines serve multiple purposes. They are a place to relieve oneself; a way to keep urine and feces

away from food and water; a safety measure for women who are otherwise forced to travel far from home during their menstrual cycle in order to meet their sanitation needs; a comfortable place protected from the elements that will promote the use of sanitation instead of outdoor defecation; a way to ensure school enrollment for adolescent girls who would otherwise be forced to leave school during their menstrual cycle to meet their sanitation needs; and a way to provide a sense of respect for its owners and users (Conant).

In addition to the various purposes that toilets and latrines serve, there are numerous toilet designs tailored to the environmental conditions of a region that can be created by community members using local materials and resources (Conant). Depending on groundwater levels, climatic conditions, frequency of floods, local cultural tradition, and the need for human waste as fertilizer, latrines and toilets are built using clay, bricks, concrete, or wood. Pit toilets are easily built, suitable in regions with deep groundwater and little risk of flooding, and their above-ground structural permanence is contingent on the use of human feces as fertilizer in the region. Urine-diverting dry toilets are constructed completely above ground, and have toilet bowls separating urine and feces with the purpose of using treated human waste as fertilizer. This style of toilet is best in regions with high ground water levels and a high frequency of flooding. Pour flush toilets contain one or two deep pits and are created in areas where anal washing after use of a toilet is the cultural norm. Besides the various toilet structures built to lessen the spread of waterborne diarrheal disease-causing bacteria, flytraps can be created and installed around toilets using simple tools and resources to further prevent the spread of germs (Conant).

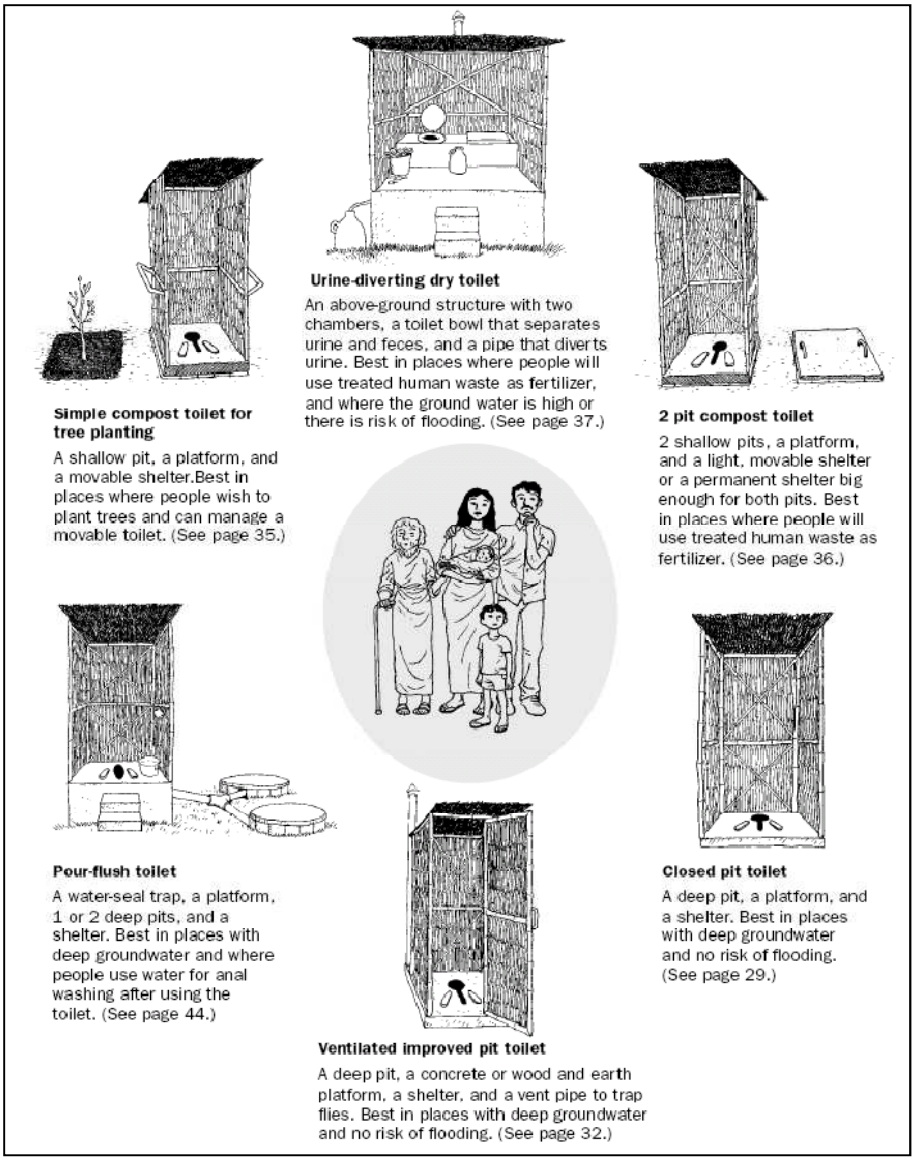

Figure 11: Various toilet designs which utilize the philosophy of appropriate technology (Conant) through their use of local resources, adaptability to local climatic conditions, cultural sensitivity, and simple design.

In addition to the creation of a latrine or toilet composed of local resources, it is imperative for a discussion to take place regarding the issue of household cleanliness with community leaders. Numerous personal experiences by Peace Corps volunteers, missionaries, medical expatriates, and NGO workers demonstrate that building a latrine or toilet in a community is not enough to stem the spread of waterborne diarrheal diseases.

Members of a village need to understand the connection between proper sanitation and waterborne diarrheal diseases before they can be motivated to make changes in their daily life. For example, Megan Peterson explained that while the majority of the people in her village use some sort of latrine or toilet, there is a lack of education regarding the importance of sanitation:

> The latrines used by most people are sometimes not in sanitary condition—they could be practically full, dirty, and/or the structure itself could be at risk or breaking. With toilets and latrines there are a number of myths surrounding their uses which lead to bad sanitation practices. Many people believe that the feces of children cannot contain harmful diseases or bacteria, so they allow toddlers and other young children to go in the bush or grass. Also some tribes and/or communities believe that pregnant women should not use latrines, which means they also use the bush or grass (2008).

When the original excitement over a latrine constructed by a foreign party wears off, it will often go into disarray from lack of cleaning, upkeep, and improper usage (Mailander). Instead of simply implementing a new sanitation system in a village, outside parties can be more effective by discussing the basic environmental and public health problems of a community, and providing tools and education to empower members of the community to create sustainable and appropriate sanitation systems on their own.

After an appropriate latrine style has been decided upon, community members need to take the initiative to build their new latrines. Allowing many local individuals to take part in the decision making process as well as assist in the physical building process creates a sense of pride that sometimes motivates people to take bigger steps. Providing information about health issues due to poor environmental conditions is not enough to convince communities to build and use latrines. People need to be encouraged to make the connection between their environmentally-friendly actions and the positive effects of them,

and they should also be given the basic tools and research to make changes on their own. Furthermore, communities need to create and assign the job of latrine maintenance, in order to ensure that latrines are kept in a safe, clean, and functioning condition. While this is not a glamorous job, it would be shared by all families who use the latrine, and therefore it creates a shared sense of responsibility within a community (Rudy).

As well as the creation of small scale sanitation systems in rural villages, steps need to be taken to ensure that livestock are kept away from food and community water sources. This should be done to prevent the spread of bacteria found in the fecal matter of livestock, which often results in community-wide diarrheal disease outbreaks (Rudy). According to Peterson:

> When people fetch water from swamps and open pools, contamination is definitely a problem. Livestock are allowed to graze just about anywhere and most definitely near water sources. Problems can also occur near constructed water sources if a fence is not built around the source to protect it from contamination (2008).

It is often difficult to control livestock without building fences. However, fences frequently create serious community and cultural issues relating to land ownership and care of livestock. Therefore, an appropriate technology strategy would involve informing a community of the implications of livestock fecal matter in and near water sources, and working with them to come up with livestock management solutions that may or may not include fencing.

Communication Methods

As the technology of SODIS has made evident, the problem with appropriate technologies is often not a lack of available resources or capital, but rather, inadequate and ineffective communication for a specific strategy. One of the greatest challenges facing the

movement to end fatalities from waterborne diarrheal diseases is an inability to effectively communicate either the gravity of the situation or the importance of appropriate

Figure 12: Examples of sanitation campaign posters in a Peace Corps volunteer's office in Uganda.

technologies in a community. Oftentimes solutions involving new technology or education are employed in communities by foreign organizations that lack an understanding of a local culture. As the authors of the Appropriate Technology Sourcebook explain,

> two of the most serious problems with this kind of approach are: 1) there is little room for "participation" by the beneficiaries except in the most minor sense— carrying out instructions; and 2) information flows almost entirely one way, from the central agency to the poor…Not surprisingly, most extension programs [have not] achieved the success rate (measured in numbers of people adopting the prescribed technologies) expected (Darrow and Saxenian).

According to Rick Fuentes, the media relations director of Fresh Energy, an environmental advocacy organization, effective communication methods are the key to implementing technologies that work. In order for a message to be understood and for practices to be executed in daily life, a story must be established that is relevant and interesting for a

community. Additionally, focusing the story on one character instead of multiple characters is the best way to humanize an issue. Instead of telling a story about the fifteen children who died from dehydration last year in a local village, it is more effective to focus on one the tale of one specific child. Finally, every effective message deserves a proper story teller. This may differ from community to community; some villages may respond well to a public health worker, whereas other villages may respond well to elders (Fuentes). Therefore, all individuals committed to the environmental public health issue of waterborne diarrheal disease transmission must be very mindful of their particular community and its culture when developing a communication strategy.

The communication strategies addressed above are useful, but are very general and could be applied to any community issue in any region of the world. Therefore, it is beneficial to elaborate on the possible ways to communicate solutions in a manner that is aligned specifically with appropriate technologies. In order for communication strategies to be effective in a community in the developing world, village members must have:

a. Access to information in a form in which it can be of practical use.
b. The ability to initiate communications in search of relevant experience and information from other communities, including information on the successful technologies that have been developed nearby, within the region, and around the world.
c. Support from those with more advanced scientific and technical skills, through technical assistance centers that respond to requests (Darrow and Saxenian).

By providing information about possible solutions in this manner, individuals have the ability to be educated and therefore feel empowered to act. The feeling of empowerment as a motivator to act is especially important in the WHO program entitled PHAST.

PHAST is a seven step process that demonstrates the connection between poor health and sanitation by utilizing participatory methods in community groups. Groups of interested individuals work together to discuss the environmental public health problems in their communities, create possible solutions, and figure out how to implement their solutions.

Figure 13: The seven step process of PHAST (PHAST).

According to PHAST, it is the job of a community health worker to encourage participation among villagers and allow them to make discoveries about possible solutions

regarding environmental issues, which will lead to greater self-confidence and empowerment:

> As a facilitator, you are not a leader who directs the group to where you think it should go. Instead you help the group to better understand its own situation and to make informed decisions about how to improve that situation.
> The only appropriate solution is the one that participants come up with. As an outsider, you cannot understand their situation in the way that they do, no matter how dedicated, interested or concerned you are. For this reason, the group's input is more important than what you think or feel. It is the group that will have to answer to the wider community and justify the decisions it makes (PHAST).

Field studies have demonstrated the success rates of participatory methods with the use of appropriate technologies, and they have proven to be more effective and longer-lasting than appropriate technologies introduced without participatory methods (PHAST). Although this style of communication requires more work and planning on the part of the health worker or volunteer, it is much more culturally sensitive. Furthermore, it allows villagers to become involved by encouraging them to provide input and make decisions, and therefore follows the philosophy of appropriate technologies.

Conclusion

Multiple strategies have been suggested to address the public health epidemic of waterborne diarrheal diseases. However, because of the adaptable nature of appropriate technologies, there is no *single* strategy that will eliminate all diarrheal disease-related deaths. In spite of this, certain steps can be taken in *every* region affected by waterborne diarrheal diseases in order to lessen their impact. According to experts in the field of water filtration:

> While the benefits of improved drinking water supply are evident, it is also true that the effects on health are multiplied several times if combined with improved sanitation and especially hygiene promotion. It is therefore highly recommended to plan and budget for the implementation of a sanitation component (for instance focusing on environmental sanitation or the safe disposal of excreta) and a hygiene promotion campaign. Recommended topics include washing hands with soap and handling drinking water in the house (Fewster and Mol, How to Start a Filter Project).

Although the optimal goal for every community in the developing world should include local, safe, and sustainable access to clean water and sanitation, as well as education concerning waterborne diarrheal disease transmission, this is not currently realistic due to the lack of infrastructure and resources in many developing countries. Consequently, it should be the goal of every household to ensure access to a latrine or toilet, in addition to ensuring a form of water filtration utilizing local resources. Unfortunately, even these basic goals are unlikely to be achieved by hundreds of millions of people due to poverty and a lack of education. While sanitation is essential to ensure the sustainability of a safe drinking water source at the community level, eventually it is the task of individuals to guarantee their own wellbeing. Therefore, the most critical recommendation that can be made based on time and resource constraints is the major promotion of handwashing coupled with a basic method to provide safe drinking water at the individual level. The only absolute way to avoid diarrheal diseases is to make certain that the water an individual drink is clean, and that an individual's hands, which are used to prepare, serve, and consume food are kept clean.

Like most environmental issues, no silver bullet exists in the fight for clean water and basic sanitation, and even with a multifaceted solution, the rates of death from diarrheal diseases are unlikely to ever reach zero. Nevertheless, the discussion should take

place about the environmental implications of the 5,000 people whose lives would continue if waterborne diarrheal disease deaths were eliminated. Current global food shortages, the rates of global warming that seem to be rising faster than current oil prices, the growth of the species endangerment and extinction lists, and the ever-increasing strain on natural capital such as rainforests and freshwater have all been attributed to human overpopulation. Some may argue that although diarrheal death rates are high, they serve as a form of population control for the world. However, this argument is completely groundless and immoral, and can be addressed by a few simple statements. The highest waterborne diarrheal death rates, especially among children, occur largely in the developing world. It is unjust to promote the growth and development of some children based on their geographic location while neglecting the health of other children simply based on their birth and upbringing in a less equitable location. Additionally, birth rates have been shown to drop significantly throughout the world as a population becomes more educated and has access to better health care resources. While it may be easy to disregard or even passively support the large number of deaths every day due to waterborne diarrheal diseases, this is not a stance that will benefit humanity or the environment. It needs to be emphasized that the health and well being of humanity is not mutually exclusive from the health and well being of the environment. All people deserve the right to dignity, a right which can be guaranteed by preserving both the health of the environment as well as the health of an individual.

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