The Effect of Infrastructure on Water-Related Diseases in Rural African Communities

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Water-related diseases are still a leading cause of death in developing countries. Though the relationship between water-related disease mortality rates and water sanitation and hygiene measures is well documented, the means to provide proper water and sanitation treatment remain elusive. This paper examines the effect of hard infrastructure on water-related disease rates and proposes that building infrastructure is the best way to reduce the prevalence of water-related disease in rural African villages. It examines the history of sanitation infrastructure in developed countries as well as why similar measures are difficult to implement in sub-Saharan Africa. This paper analyzes three rural African countries' sanitation infrastructure systems (Botswana, Rwanda, Swaziland) to recommend best practices in rural African villages. Recommendations for future infrastructure systems are given as well as how governments can best implement those systems to reduce water-related disease mortality rates.

Objective

The relationship between water hygiene and sanitation and water-related diseases has been well documented and established for years, yet water-related diseases continue to plague developing countries. The means to provide proper water and sanitation treatment facilities remain elusive. For the purpose of this paper, the term 'water-related diseases' includes waterborne, water-washed, water-based, and water-related vector diseases. Many governments and organizations have tried different approaches to lower the prevalence of these diseases but have not delivered due to lack of feasibility and sustainability. The best way to approach Millennium Development Goal 7C of halving the proportion of people without access to safe drinking water and basic sanitation by 2015 is to invest in public infrastructure that will support existing systems, expand available options, add value to basic functions of society, and protect the integrity of water systems.

Infrastructure at its most basic level supports the fundamental systems that make up societies. It brings added value to the necessary functions it supports (Mostert, 2006). This examination of the effects of infrastructure will only include hard infrastructure (physical works needed for the operation of society) because it must be firmly in place before soft infrastructure (people and institutions that maintain society) can be considered (Rinaldi, Peerenboom, & Kelly, 2001). Although many types of infrastructure are appropriate for different locations and needs, water-systems infrastructure and transportation infrastructure are most relevant to water-related diseases. With only these two types of infrastructure it is possible to intervene on almost every level of water-human contact as well as to provide support for the medical systems that treat water-related diseases. This discussion will primarily focus on water-systems infrastructure but the importance of transportation infrastructure in preventing and reducing water-related diseases should not be discounted or undervalued. Water-systems infrastructure includes components to access, pump, transport, store, treat, deliver, and collect water. The ultimate goal of water-systems infrastructure is piped water for domestic and agricultural use and sanitation facilities to treat waste.

The world has seen the drastic differences between the "haves" and "have-nots" of infrastructure along the developed/developing border of societies. Hard infrastructure can springboard countries into development by providing a framework for a healthy, productive society. This paper will show how building public infrastructure is the best way to prevent and increase access to treatment of water-related diseases in rural communities in Africa. It will evaluate several current methods of providing infrastructure systems and recommend general guidelines for the future. By itself, building infrastructure will not solve all water-related problems but, if managed correctly, it can serve as an effective barrier to the transmission and prevalence of water-related diseases.

Introduction

Water-related diseases are almost entirely preventable but they continue to cause over five million deaths per year in developing countries (United Nations, 2010). Toepfer (2002) calculated that 80% of morbidity and mortality in the developing world is due to water-related diseases and that half of the world's hospital beds are filled by patients afflicted with water-related diseases. Diarrhea and malaria are the two largest killers of children under five years old in sub-Saharan Africa. The United Nations 2010 Millennium Development Goals Report states that only 47% of population in rural sub-Saharan Africa has access to a source of clean drinking water. Within the same population, only 24% have access to an improved sanitation facility. Civilizations in the early Greek and Roman empires were able to harness control of water hygiene and sanitation yet today almost one billion people worldwide do not have access to clean water and three billion do not have access to proper waste management (Batterman et al., 2009). The need for water treatment and basic sanitation is demonstrated in the overwhelming incidence and prevalence of water-related diseases in developing countries. The World Health Organization (2002) estimates that water-related diseases account for 4-8% of the total disease burden in developing countries and 90% of all diarrheal diseases. The effectiveness of prevention is demonstrated in extremely low incidence and prevalence of water-related diseases in developed countries. Public infrastructure is one way of bridging the gap between areas of high and low prevalence.

Communities that do not have large-scale public infrastructure are significantly more likely to have high rates of poverty and high rates of water-related disease (Manase, Nkuna, & Ngorima, 2009). It may be unfair to ascertain that overall poor health outcomes are a direct result of the absence of public infrastructure but infrastructure is definitely a contributing factor. There is a direct link from lack of infrastructure to prevalence of water-related diseases (Gasana, Morin, Ndikuyeze, & Kamoso, 2002). Infrastructure has the potential to touch every part of the water-human interaction system and cut out pathogenic agents while protecting the human population and the integrity of the water. Infrastructure can positively intervene in the sourcing of water as well as storage, distribution, collection, sanitation, and reintegration with the environment (Batterman et al., 2009). Other benefits of infrastructure include spurred economic growth, increased employment, better medical utilization because of roads that also transport medical supplies, easier staffing of clinics, lack of vector-bearing standing water, improved safety in developed areas with roads, and other tangential gains. Infrastructure also contributes to gender equality because access to piped water frees girls to go to school by cutting down on time spent retrieving water (Fay, 2005). It can improve educational outcomes as well by promoting overall health. Infrastructure focuses on the needs of populations instead of relying on individual behavior change, which has proven unsuccessful (Batterman et al., 2009). Where behavior change only shows temporary and insignificant results, infrastructure has the potential to impact entire communities without the high cost burden of educating and training individuals.

The extreme alternative to water and sanitation infrastructure is individual water collection and open defecation (United Nations, 2010). The absence of an integrated system forces families to secure their own water. As a result, families often go without a clean, adequate water supply because of the work required to collect and store water for domestic and agricultural use. Many places in rural sub-Saharan Africa rely on seasonal rains but are left with almost nothing during dry periods (Van Koppen, 2003). Lack of waste management is arguably a much more pressing issue than even access to clean water. The pathogens and coliforms found in excreta cause many diseases—the majority of water-related diseases stem from fecal-oral transmission through direct or indirect contact (Batterman et al., 2009). Indirect contact can come from open defecation that allows fecal matter to seep into groundwater or from using contaminated excreta as fertilizer or from improperly channeled water runoff. Because there is no way to totally avoid contact with human and animal excreta (especially in rural Africa), neutralizing pathogens with waste treatment is the only realistic way to cut out the fecal-oral disease transmission route. Isolating excreta to a consolidated area is a positive step but is minimally effective in lowering water-related disease rates (Bolaane & Ikgopoleng, 2011). Batterman et al. (2009) notes that isolated pit latrines in Africa, which technically indicate "access to sanitation," often serve over 200 people and frequently overflow during rainy season. Integrated sanitation infrastructure is the most promising hope for sustainable waste management.

Successful development is not generated spontaneously. All countries must build from the ground up both figuratively and literally. Developed countries have had to lay infrastructural foundations and can serve as models for developing countries looking to improve public health through water reform and infrastructure. Perhaps the best example with which to compare rural Africa is the United States. Other western European nations experienced similar growth in infrastructure but had a much longer history of development with which to work. Cutler and Miller (2005) calculate that clean water technologies (delivered by public infrastructure) account for half the reduction in mortality in the United States over the course of the 19th century, in which mortality rates fell almost 45%. Within that mortality drop, clean water technologies were responsible for 75% of the decrease in infant mortality and 63% of child mortality. The average life expectancy in the United States rose 15 years from 1900-1945. The integration of water purification and waste treatment was a major factor in that change. At the beginning of the 20th century, water-related diseases accounted for almost a quarter of all infectious diseases due to urbanization, over-crowding, and upstream sewage disposal (Cutler & Miller, 2005). Water reform spurred by developments in early germ theory and Dr. John Snow's work in London changed the demography of the United States as well as day-to-day life for citizens. It was made possible by large-scale public infrastructure (Cutler & Miller, 2005).

The history of water reform in the United States has great bearing on modern developing countries. Cutler and Miller (2005) analyze how the United States faced similar common obstacles to water reform as developing countries do today. But the United States differed in several important ways. Cutler and Miller conclude that American citizens deeply valued water reform as they began to grasp the link between water, sanitation, and pathogenic agents during the transition between the miasma theory of disease and germ theory. City governments struggled to pay for infrastructure and reform just like today but they financed it by starting with basic services like filtration and chlorination. There were initial cost delays, but by 1928 almost all major American cities had instituted water hygiene and sanitation systems. Although the systems and delivery infrastructure were expensive the United States eventually experienced a twenty-three to one rate of return on clean water technologies (Cutler & Miller, 2005).

Perhaps the biggest differences between the United States in the 19th century and developing African countries today is that water reform is not communally valued in rural Africa as it was in American cities. The United States government was also much more centralized and efficient than many African governments. In the United States the major obstacle was passing legislation (Cutler & Miller, 2005). Once the legislation passed, it was taken for granted that it would be implemented. Many African countries and regions have had water legislation for decades but have yet to implement anything because of corruption, lack of funds, and political turnover and uprising (Van Koppen, 2003). The major lesson that can be learned from water reform in the United States is the multiplier effect of public health interventions. The concept is that increasing the benefits to private health behaviors through public health interventions induces an increase in those behaviors. Such interventions, like large-scale infrastructure and water reform, must be a personal health behavior multiplier instead of a substitute. Otherwise, public health suffers and water-related disease rates remain the same or increase (Cutler & Miller, 2005).

Many of the issues surrounding water-related diseases in sub-Saharan Africa stem from previously mentioned obstacles. Government interventions have been minimal and have not engaged communities. Many large-scale projects have failed because they were not designed to meet the users' real or perceived needs and did not align with their values (Mostert, 2006). In cases in which governments built public infrastructure, the issue has not been that the infrastructure was deficient but that the surrounding education, promotion, and unfeasible costs were deficient. Current trends and practices will be discussed in depth under 'Literature Review,' but it is essential to note that existing practices (or lack thereof) have led to poor health outcomes and high rates of water-related diseases. Ruling parties must change their methods in order cut down on preventable maladies and unnecessary deaths due to water-related diseases.

Literature Review

Current trends in infrastructure development in rural Africa reveal good intentions paired with instability and inadequate financing. "Normal practice" until the 1970s meant no practice whatsoever. However, there have been many efforts since the 1980s to improve water and sanitation infrastructure (Van Koppen, 2003). The World Health Organization defines improved sanitation as access to a pit latrine, but multiple studies have shown even a pit latrine (without waste treatment) is inadequate to prevent water-related diseases (Batterman et al., 2009). Many African countries responded to the International Drinking Water and Sanitation Decade (1981-1990) with isolated policy efforts but found that policy by itself was not enough to ensure change (Bolaane & Ikgopoleng, 2011). The Africa Water Task Force attempted the process of integrating fragmented legislation and designing national water systems in 2002 (Van Koppen, 2003). They also set out to specify the role of the government and private sector while making access to clean water and sanitation more equitable for all. The reform they envisioned was very similar to early water reform efforts in Europe, the United States, Latin America, and Asia (Van Koppen, 2003). Despite the task force's efforts, early attempts were largely ineffective.

So the question remains: why have the majority of African countries been so unsuccessful in their efforts to change? What sets apart Africa from other regions that have attempted water reform in a similar fashion? Van Koppen (2003) argues that sub-Saharan Africa is different for three reasons that keep them stagnant in their efforts. First, sub-Saharan Africa has a fairly adequate water supply but its power remains unharnessed due to a lack of economic means. Second, current sub-Saharan African water systems preserve the backbone of society (agriculture) but lack any margin or room for change. Agriculture is the biggest indicator of economic growth in the region and is extremely important to development and everyday life. Wealth is developed bottom-up through farming rather than top-down through industries like mining and tourism. The combination of these factors results in poor farmers who depend on their existing water systems daily. If they attempt to change anything about their system, they will inevitable lose money or crops in the adjustment period—a risk almost no one can afford to take. Finally, there are very few large stakeholders of water in Africa. The use of water is mainly scattered between small stakeholders, which makes it extremely difficult for governments to collect taxes because individuals already finance their own independent water systems. African governments have proven incapable of regulating water systems because the existing systems are independently owned and operated.

Van Koppen concludes that Africa's real problem is not lack of water or knowledge but improper channeling of funds. Human development and agricultural growth depend on the ability to access clean water, which depends on delivery systems. Governments trying to build delivery systems through public infrastructure must first convince their citizens that they can provide a better service than the existing system of independent procurement. Based on Van Koppen's research, it appears as though Africa's water policy reform efforts will flounder until governments are capable of providing water systems with almost no initial cost to their beneficiaries. It is in this narrow space that infrastructure enters as a viable option.

Several countries have attempted to decrease the prevalence of water-related diseases through building public water infrastructure. Bolaane and Ikgopoleng (2011) completed a case study on Botswana's attempts to improve public health in rural areas through large-scale infrastructure and found that after seven years the majority of the public never embraced the idea. The government-built sanitation facilities have gone largely unused and citizens have not paid to connect their homes to the system. Based on Bolaane's analysis, the problem in Botswana was not the infrastructure but that it did not meet the needs of the users. Botswana experienced the same detrimental rates of water-related diseases as other sub-Saharan African countries before the government attempted intervention. Theoretically, communities should have latched onto the idea of infrastructure to prevent water-related disease and allow greater access to medical treatment. But Bolaane and Ikgopoleng found that most citizens did not use the infrastructure because of the initial cost. In order to install water delivery and sanitation in a home (bathroom, kitchen, and toilet), an average Botswanan family had to save half their income for a year—an unfeasible feat for most citizens. The Botswanan government financed the project on the basis of cost recovery, which assumed that the government would make money back from the beneficiaries of the system. But the citizens were unable or unwilling to pay, and so the government has not recovered the cost of building the infrastructure. Other reasons that citizens did not connect to the system included satisfaction with existing pit latrines and a sense of entitlement to free sanitation and water from the government. Some simply did not feel that clean water was a priority (Bolaane & Ikgopoleng, 2011). The results in Botswana show the importance of community involvement as well as economic accessibility.

Botswana's attempt to use infrastructure to decrease water-related diseases highlights a few important lessons, mainly that systems only succeed if they are affordable and if the public is engaged and values the need. Bolaane and Ikgopoleng also conclude that water and sanitation systems must meet the following requirements to be sustainable: they must protect human health, not deplete the environment, be technically and institutionally appropriate, be economically feasible and culturally acceptable, they must have social, environmental, technical, institutional, and financial dimensions, and they must be based on the users. Sometimes infrastructure alone is not enough to improve public health. It must fit within the context of affordability, public attitude, and perceived need. The Botswana case study's final suggestions for infrastructure systems were having multiple stakeholders to spread the cost burden and increase utilization, and engaging the community so individuals understand the value of infrastructure (Bolaane & Ikgopoleng, 2011). These lessons in ineffective water reform support the notion that successful systems must be a true partnership between the provider and beneficiary, something that Africa lacks in many areas of foreign and domestic aid.

A study on water-related diseases and infrastructure in Rwanda by Gasana et al. (2002) shows more promising results as a payoff of better public utilization. Diarrheal diseases are the most prevalent water-related diseases in Rwanda and often lead to malnutrition, measles, and malaria. Infants under 24 months suffer an average of 6-8 acute diarrheal episodes per year. The main causes of Rwanda's diarrheal diseases are pathogenic microorganisms from untreated human and animal feces. Gasana's study found that good personal hygiene practices were not enough to ward off diarrheal diseases. The source water needed to be protected, the surface water needed to be properly drained, and contaminates needed to be controlled (Gasana et al., 2002). None of these things could be done by any individual but necessitated action on a larger scale. The situation screamed for public infrastructure.

Gasana's team built water hygiene and sanitation infrastructure in several rural areas in Rwanda to monitor and analyze water contamination and its effect on diarrheal morbidity in children. The study found that piped water greatly reduces the number of coliforms in water, which are responsible for many water-related diseases. Before the intervention household water had an average of 1100 coliforms/100mL because of unclean transportation and storage methods (deduced by analyzing coliforms through the delivery process) (Gasana et al., 2002). After installing a piped water and filtration system, there were only 3-5 coliforms/100mL of household water. Building infrastructure provided a safe and clean method of delivery that immensely cut down on coliforms picked up in transportation and storage. The infrastructure both protected and improved the drinking water and waste management. The study concluded that improved water and sanitation infrastructure paired with hygiene education and expanded primary care services have the potential to greatly reduce water-related diseases and diarrheal morbidity and mortality. The authors acknowledged that infrastructure must be complemented by efforts to decrease population density and nutritional deficits in order to maximize potential (Gasana et al., 2002). Health education was also integral to creating demand for the piped water and sanitation system.

The Rwanda study avoided some of the larger problems presented in the Botswana study by taking a different approach to funding. The authors of the study in Rwanda provided the infrastructure to people in order to monitor diarrheal diseases. Private funding cut out the issues of affordability and government trust that presented themselves as major obstacles in Botswana. Also, the majority of people at the beginning of the Rwandan study agreed on a questionnaire that water provision is the most fundamental means of survival, showing that water issues were already highly valued in Rwanda (Gasana et al., 2002). The Botswanan government assumed that everyone would use infrastructure if it was provided, but clean water and sanitation were never a priority to the majority of Botswanan citizens (Bolaane & Ikgopoleng, 2011). The Rwandan study also meticulously estimated their water usage and contracted out with participants before they built the infrastructure.

One of the best success stories of infrastructure's effect on water-related disease is in rural Swaziland. Swaziland is on track to achieve 100% water and sanitation services coverage by 2022 (Mwendera, 2006). It will exceed regional and national goals as well as the MDGs. It has already seen a decrease in water-related diseases and is projected to see more throughout the completion of coverage. Swaziland is different from Botswana or Rwanda in that it is a lower-middle income country and is admittedly better able to finance the project (though Botswana is technically an upper-middle income country, most of their rural population is poor) (Mwendera, 2006; Bolaane & Ikgopoleng, 2011). The government of Swaziland realized that financing and maintaining water systems would cost a great deal of money and time so they designed a scheme based on community contribution and engagement.

Under the government water reform plan, communities in Swaziland are responsible for electing a Water Supply and Sanitation Committee whose members commit to plan, manage, and maintain the proposed water supply and sanitation system. Before any infrastructure is built, the government sends people to train the entire community on health and hygiene, the operation of the water system, and important management skills like bookkeeping (Mwendera, 2006). This ensures that the community understands the need for clean water and sanitation as well as provides citizens with the skills to maintain the government's investment. Individual communities must pay for at least 25% of the cost of infrastructure through unskilled labor or cash. The government finances the rest. At the end of construction, communities own the system and are responsible for half the cost of future repairs. Swaziland utilizes micro-infrastructure, consisting of boreholes drilled to access groundwater, and macro-infrastructure like submersible pumps. Piped water in rural areas is either driven by gravity systems or electric or solar power. Requiring an elected committee as well as labor and financial contribution builds demand and sustainability through long-term commitment. Swaziland's success in reducing water-related diseases shows that different types of infrastructure are effective in lowering disease rates. It demonstrates how community engagement can aid existing infrastructure in creating demand and underscoring value.

The findings from Swaziland's success support Manase, Nkuna, and Ngorima's study (2009) on water and sanitation infrastructure acting as an entry point for HIV intervention. They found that the civil contributions made by improvements to water and sanitation go much further than providing clean water and waste treatment (Manase et al., 2009). They quote the UN Water Supply and Sanitation Collaborative Council (WSSCC) statement that water and sanitation interventions are entry points for poverty alleviation. Swaziland has some of the highest rates of HIV/AIDS in the world, yet they maintain a relatively high per capita income largely due to water and sanitation infrastructure (Mwendera, 2006; Manase et al., 2009). Infrastructure cuts down on water-related co-infection and saves money, time, and strength for those connected to the delivery system. Manase et al. (2009) studied how communities with high HIV rates benefitted from water and sanitation infrastructure in rural South Africa. Yet another example of innovative financing, the communities ensured food security and created jobs by investing in a community garden. The money made from the crops paid for the creation of sanitation facilities, the maintenance of pipes, and school fees for orphans (Manase et al., 2009). As a result, water-related disease rates have decreased. This program serves as an example of creative partnership with benefits spread across a host of contributors, users, and community members.

Future and Recommendations

At the current pace, the world is on track to meet or exceed MDG 7C to halve the proportion of people without access to clean drinking water by 2015 (United Nations, 2010). Unfortunately the same is not true of sanitation. If current trends continue, the absolute number of people without basic sanitation services will increase before 2015 and half the population in developing countries will still lack proper waste management (United Nations, 2010). Water-related disease rates will never decrease if water hygiene and sanitation services do not improve. Medical treatment for water-related diseases will fail to keep up with increasing demand (Batterman et al., 2009). The only way to reverse the trend, to decrease disease rates, is to prevent them before they occur.

As previously mentioned, individual communities require different methods of water-related disease prevention efforts through public infrastructure. The only way to adequately gauge the initial situation is to conduct a community survey to assess baseline health knowledge and cultural values. Infrastructure is not purely a technical issue because it interacts positively and negatively with foundational cultural tenets about human health and safety, equity, aesthetics, longitudinal equity, legitimacy and trust of government, the value of nature, sustainability, and economic efficiency (Mostert, 2006). In the future, governments must consider all of these communally agreed upon standards before haphazardly building systems. Public acceptance of the system depends on it. Mostert recommends conducting a values survey with evaluation criteria before implementing any physical intervention. The next step is then to develop alternative plans and assess the impact of both the blueprint and the alternatives (2006).

Batterman et al. (2009) recommends beginning at the distal causes of water-related diseases and approaching the issue with systems-level thinking. Some of the underlying causes of water and sanitation issues are population growth and density, few opportunities to protect water sources, growing demand for domestic and agricultural water, climate change that spurs feast and famine water sourcing, and human development projects that interfere with the natural water cycle (Batterman et al., 2009). If implemented correctly, hard infrastructure has the capability to affect and diminish most of the aforementioned causes of water-related diseases. Designing infrastructure to intervene in underlying causes (rather than immediate causes) helps achieve its maximum potential to reduce disease rates.

The major challenge to building infrastructure across rural Africa presented in research is the overwhelming financial burden of water reform. The studies in Botswana, Rwanda, and Swaziland demonstrate several methods of funding large-scale projects but a magic bullet has yet to be found. Though there are many ways of financing large-scale public infrastructure, there are several common traits that flag successful systems. Political and economic stability must precede implementation. Otherwise, isolated policy measures never seem to come to fruition (Van Koppen, 2003). Governments, as opposed to private organizations, must spearhead infrastructure and water reform efforts. NGOs simply do not have enough power or funds to implement a system on land they do not control. NGOs and humanitarian groups may be able to impact small communities with pit latrine and well projects but will never seriously impact water-related disease rates without providing the necessary water-systems infrastructure. Private organizations lend valuable skills and a potentially strong funding stream but can only operate after the government gives consent or abdicates leadership of the project to the private organization.

Even beyond financing, individual water and sanitation infrastructure systems must be unique. Based on evidence from the aforementioned studies, the best generic water-systems infrastructure employs a mix of methods to meet the various needs of all participants. The first priority in planning should always be disease prevention and increased access to water treatment. Feasibility must be at the forefront of all stages of design and implementation. Though possibly rather utilitarian, placing feasibility first is historically necessary to ensure completion of the project (Van Koppen, 2003). Many African countries have experienced "all or nothing" results based on how well governments estimated the total cost of the system.

After governments decide how much money they can allocate to infrastructure projects they begin to have options. The research suggests that governments should implement basic water and sanitation infrastructure in small communities first and then scale up as more people have access to essential services (Cutler & Miller, 2005). This creates a better chance of equity and allows opportunities for mid-project evaluation. Along the lines of equity, governments must decide which communities will receive infrastructure first and if they will be required to contribute time or money to the project. All the previously cited studies point out that communities best accept infrastructure when they feel connected to it through education, labor, and financial contribution. Having personal investment in the project creates value to the individual (Mostert, 2006). Other ideas for increasing public acceptance are to eventually decentralize responsibility of the system to the lowest possible level, organize public participation in upkeep, educate the users on health and hygiene best practice, promote the correlation between infrastructure and water-related diseases, have multiple stakeholders, and allow some management by the users (Mostert, 2006; Fay et al., 2005; Gasana et al., 2002; Manase et al., 2009).

Building infrastructure is a long-term investment and will require management and maintenance. There are many parties that can oversee these areas: government, contracted private organizations, community members, foreign investors and humanitarian agencies, etc. The dilemma for governments is deciding who should be given that authority. Whoever controls the water controls life. Corruption has the potential to destroy communities through the abuse of power. Governments must evaluate how much responsibility they can delegate to communities to maintain and manage their own systems. They must decide if it would be wiser to manage the systems internally or contract out to another organization(s). Delegating tasks and authority to community members encourages utilization and invested value but it is essential that the chosen people be objectively trustworthy as well as trusted within their communities. Communities might resist fully integrating with the system if the power-holder is seen as irresponsible or untrustworthy (regardless of actual merit). The best approach is to spread responsibility and keep the system transparent. Elected community members can be trained on management but must report to a government authority.

Infrastructure has the ability to influence many levels of water/human contact. The best water infrastructure system maximizes the number of potential interventions. In the normal water-related disease cycle, an infected person emits pathogens in excreta, the waste contaminates the water source, and other people interact with the untreated water. Water-related vector disease cycles begin differently but function in the same basic way. The best water-systems infrastructure design will intervene in each of those stages of the disease cycle, thus guaranteeing maximum efficiency and efficacy in the reduction of water-related disease rates.

Conclusions

Large-scale infrastructure has proved more successful in preventing water-related diseases and providing increased access to treatment than almost any other method of intervention. Many interventions have proved that individual education and changes in hygiene behavior are not reliable (Bolaane & Ikgopoleng, 2011). Pit latrines and well projects only provide isolated solutions and often do not improve overall water-related disease rates (Batterman et al., 2009). Privatization might seem like an ideal way to transfer responsibility for water-systems infrastructure from the government to an outside organization but any system (especially in rural Africa) will require infrastructure spearheaded by the government.

From the research, the most important thing a country can do to reduce water-related disease rates is to avoid metaphorical ostrichism in its responsibility to manage a national water system. Regardless of which implementation path a government chooses, doing nothing will ensure access disparity as well as high water-related disease rates. Skirting the issue because people will find independent ways to procure water is unacceptable in modern times. Not only does it allow the government to prey upon its citizens but it also proclaims to the rest of the world that the country has no interest in providing for its people. Water is the most basic need in life. To intentionally prioritize personal wealth and comfort without working to ensure water for everyone (as so many African government leaders have done) shows a high level of corruption. It insinuates that the leader is not responsible enough to hold the position (Fay et al., 2005). Though certainly not all African governments delay infrastructure because of corruption, any responsibility for deferment should fall on its shoulders because of the urgency of the situation and the abundance of aid and partnerships to implement water-systems infrastructure around the world. Regardless of what the government was accountable for in the past, governments of today must begin to invest in their communities by spearheading large-scale public infrastructure systems.

There is no way to improve systems [structural] problems without proposing systems [structural] solutions. Systems problems are the result of a set of entities that interact to create a final product/problem. Water-related diseases fall into this category because they are the end result of the human/water interaction chain and its numerous entities. Laying infrastructure is the most comprehensive way to deal with the majority of those entities at the same time. An infrastructure system has the ability to intervene in many pieces of the water-related disease cycle if implemented correctly. And because infrastructure is a system rather than an isolated solution, it affects a chain of people rather than a single family or village. Infrastructure lays groundwork for more integrated services and adds value to the existing community. It contributes to overall positive health, education, and economic outcomes (Fay et al., 2005).

Building infrastructure to decrease water-related disease rates is challenging and costly. Some might call into question if water-related diseases are important enough to invest so much in an indirect intervention. But over and over, building solid infrastructure proves successful in reducing disease rates and increasing access to treatment. It is expensive but is an investment in the future. Governments fool themselves if they believe they can successfully bring their countries into the 21st century without providing access to clean water and sanitation. The idea is unrealistic and shows a concerning lack of foresight on behalf of the government. The history of the United States shows how valuable infrastructure can be in bringing underdeveloped areas to par with the rest of the developed world (Cutler & Miller, 2005). Investing in infrastructure aids in achieving global health equity and is essential to the success of all small and large communities.

Currently, critical infrastructure (including water-systems infrastructure) is considered essential to the definition of functioning societies (Rinaldi et al., 2001). This framework presents a dilemma for developing countries without basic water-systems infrastructure. Are they not considered functional societies? Either the definition of a society or critical infrastructure must be reevaluated in order to align the incongruence.

Building large-scale public infrastructure will continue to prove important in the next century and beyond. Increased population density, climate change, and higher global health standards will force many underdeveloped areas to find ways to build their own infrastructure or call on others to do it for them. Water-related disease rates will increase as a result of mass urbanization, water scarcity, and crippling poverty if governments do not start to build public infrastructure. Rural African communities will eventually face issues surrounding population boom and climate change. Access to clean water and waste treatment will determine how water-related disease rates and overall health outcomes change. In looking to the future, water-systems infrastructure will ensure the sustainability of water supply and treatment on a season-to-season and year-to-year basis. Building large-scale public infrastructure will significantly affect health outcomes in rural African communities and will continue to be the best way to decrease water-related disease rates and allow increased access to medical treatment.

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