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Drinking water infrastructure in the Ashanti Region of Ghana: developing a model for sustainable interventions by non-governmental organizations

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ABSTRACT

Access to clean water plays a critical role in advancing health in low- and middle-income countries. Over the past decade, Ghana has met United Nations targets for expanding access to clean water. Non-governmental organizations (NGOs) have taken part in this achievement; however, they have done so with varying success. In 2013, researchers from the University of Chicago, accompanied by local partners, visited seven villages in the Ashanti Region in which a Ghanaian NGO had installed boreholes for drinking water access. Household and leader questionnaires were administered to examine the impact of the project on each community. Four additional villages, which utilize surface water, were visited to establish baseline health and sanitation characteristics. Water samples were collected from primary drinking water sources and tested for coliforms. Two out of seven NGO wells were non-functional and over 35% of respondents cited broken pipes as common problems. Nonetheless, over 60% of respondents reported that a borehole had reduced their water collection time by a median of 30 minutes daily. Coliform counts were lower in samples taken from boreholes relative to samples taken from communities using surface water. Finally, we found redundant water services in many communities and no formalized approach to borehole maintenance.

Key words | Ashanti Region, borehole, drinking water, Ghana, non-profit organization, well

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INTRODUCTION

Basic water and sanitation services are still unmet needs in many low- and middle-income countries (Awuah *et al.* 2009). The use of untreated surface water for drinking and cooking can have negative effects on health and human development. The impact of improving sanitation and

providing access to clean water is established by evidence that such interventions have decreased childhood mortality by 55% on average (Esrey *et al.* 1991). Recognizing the importance of water and sanitation services, Target 7C of the Millennium Development Goals (MDGs) sets out to

halve the number of people with limited access to clean drinking water and basic sanitation services (UNDP & NDPC/GOG 2012). To achieve this target, international non-profits and public-private partnerships often implement programs that are supplementary to those directed by national and municipal governments.

Ghana has surpassed its MDG for water delivery and has provided more than 10 million Ghanaians with access to drinking water from improved sources between 1995 and 2011 (WHO 2012). Improved drinking water sources include household connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collection. In 1990, 56% of the Ghanaian population used improved drinking water sources or delivery points; in 2011, this number increased to 86% (UNDP & NDPC/GOG 2012; WHO & UNICEF 2013). Greater access to improved water sources has occurred in both rural and urban populations (WHO & UNICEF 2013). Access in rural areas is considerably less, however, with only 52.8% of rural areas having access to improved drinking water at the end of 2006 (GOG & DANIDA 2007). This overall success has largely been attributed to strong and sustainable government policies, the work of Ghana's Water and Sanitation Agency, the Ghana Water Company Limited (GWCL), and the actions of international non-governmental organizations (NGOs) (WHO 2012).

Although access to improved water sources has greatly increased over the past two decades, microbial contaminants of domestic drinking water still remain a problem (Bastable & Clusen 2003; Gundry *et al.* 2004; Arnold *et al.* 2013). As such, families often rely on vendors, creating unnecessary expenses for already impoverished families.

In the Ashanti Region of Ghana, chieftaincy is one of the most enduring traditional institutions, dating back to pre-colonial times. Chiefs are still the central authority within communities. They control a community's land, provide cultural leadership, maintain peace, and support community development in concert with the central and municipal government (Aurhur 2006). They are also responsible for working with development agencies.

Within this context, a Ghanaian NGO, supported by US-based philanthropists, has sought to provide clean water, schools, and sanitary facilities to rural communities in the Ashanti Region outside of Kumasi, Ghana for over 10 years. Desiring to continue their projects in a more

sustainable manner, the NGO's funders approached the Center for Global Health (CGH) at the University of Chicago for recommendations. Working alongside the NGO and a locally based research team, a pilot project was devised to evaluate the status and impact of the projects on the communities served. In addition, CGH was tasked with developing a framework to guide future project implementation in the region.

METHODS

In March 2013, the University of Chicago research team visited drinking water boreholes installed by a Ghanaian NGO. In addition to the personnel from Chicago, the team was made up of partners from Komfo Anokye Teaching Hospital (KATH), based in Kumasi, Ghana and representatives of the NGO.

Questionnaires were administered to households in 11 rural communities, ranging in size from 15 to 75 households, in the Ashanti Region of Ghana. Households were selected randomly with consideration of the accessibility of the dwelling and availability of resident(s). When possible, all available members of small communities were approached and administered the questionnaire with an average of 10 participants per community. Seven of these communities had boreholes provided by the NGO (Abesua, Krapa, Asawasi, Manhyia, Nkyerpoaso, Prophet Emmanuel, and Asawasi). An additional four communities (Domeabra, Krobo, Kubease, and Ofoase) that utilized unimproved, surface drinking water sources were chosen in order to gather data in communities that had yet to receive any intervention. Household questionnaires assessed family history, socioeconomic status, education level, respiratory health, history of diarrhea, history of waterborne disease and skin conditions, malaria, chronic health conditions, status of drinking water systems, land ownership and agricultural production, irrigation systems, cooking practices, school attendance, and community activities.

Interviews were also conducted with community chiefs and leaders from all but three communities to identify those in charge of water delivery and to gather information regarding their responsibilities, the presence or absence of a water committee, well maintenance, and fee collection.

In addition, the researchers collected water samples from each working borehole within the community along with any other community identified source of drinking water. These sources included: government-constructed boreholes, community-constructed boreholes, hand-dug wells, springs, and streams. The samples were tested for fecal coliform counts using Coliscan EasyGel (Micrology Laboratories, LLC, Goshen, IN, USA). Coliscan provides a simple and quantitative way to identify and differentiate *Escherichia coli* and coliforms from other bacteria in water. To identify the presence and numbers of *E. coli* and coliforms, a 5 ml sample of test water was added to the medium, poured into a petri dish, and incubated at room temperature for approximately 48 hours. After incubation, all purple colonies on the Coliscan dish were counted and reported as fecal coliforms (*E. coli*) per milliliter of water.

The location of boreholes identified by the research team was mapped using global positioning system technology. Stata/SE version 12.1 statistical software was used for data analysis. Exemption was obtained from the University of Chicago human subjects review board prior to initiating fieldwork.

Information taken from the questionnaires also guided the research team in developing a set of recommendations for the NGO, as requested. These recommendations may be found in the conclusions section of this paper.

RESULTS

Sociodemographic characteristics

In the 11 communities, there were a total of 102 respondents, 87% of whom were female. The average age was 42.2 ± 14.8 years and the average number of children per household was 4.7 ± 2.1 . Of the households surveyed, 73.6% reported having access to electricity, and 87.1% of households used traditional cookstoves for their cooking needs. Other sociodemographic data that have been disaggregated by the type of water source used can be found in Table 1.

Status of projects/water testing results

Of the seven communities visited that had boreholes constructed by the NGO, two were not functional, one

Table 1 | Sociodemographic characteristics of study population

Demographic measurements	Villages with borehole	Villages without borehole
Number of respondents	71	31
Age (mean \pm SD)	41.94 \pm 14.71	42.72 \pm 15.32
Female <i>n</i> (%)	62 (87.3)	27 (87.1)
Number of children (mean \pm SD)	3.45 \pm 1.02	3.70 \pm 1.19
Child death in family <i>n</i> (%)	28 (47.5)	5 (20.0)
Child vaccinated <i>n</i> (%)	58 (96.7)	22 (95.7)
Marital status <i>n</i> (%)	–	–
Single	6 (8.5)	3 (9.7)
Married	50 (70.4)	24 (77.4)
Divorced	6 (8.5)	0 (0.0)
Separated	3 (4.2)	2 (6.4)
Widowed	6 (8.5)	1 (3.2)
No response	0 (0.0)	1 (3.2)
Education level <i>n</i> (%)	–	–
None	8 (11.3)	9 (29.0)
Primary/elementary	27 (38.0)	5 (16.1)
Junior secondary	29 (40.8)	13 (41.9)
Senior secondary	4 (5.6)	2 (6.5)
High school	1 (1.4)	0 (0.0)
Polytechnic	1 (1.4)	0 (0.0)
University	1 (1.4)	2 (6.5)
No response	0 (0.0)	0 (0.0)
Monthly income, Ghanaian cedi (GHS) (0.31 USD) (mean \pm SD)	314 \pm 528	166 \pm 317
Use toilet <i>n</i> (%)	63 (88.7)	25 (89.3)
Have electricity <i>n</i> (%)	57 (85.0)	10 (41.7)

constructed in 2002, and the other in 2012. In the community that had the borehole installed in 2002, the government had placed a newer borehole that was providing a sufficient amount of water to the community. The other community was relying on a hand-dug well, which was built before the installation of the NGO borehole. All communities that received an NGO borehole had at least one additional community borehole or hand-dug well.

Commonly reported issues associated with NGO borehole infrastructure included broken pipes (35%), unreliable water supply (35%), insufficient amounts of water (23%), and weak water pressure (23%). Respondents had similar complaints regarding non-NGO boreholes; however, a

greater proportion of respondents cited broken pipes (60%) and dirty water (33%) as issues and fewer reported issues with insufficient water pressure (0%) and unreliable water supply (10%) (Figure 1).

A minority of respondents (19%) reported paying a fee to have a well installed or maintained in their village. The most common form of payment reported was a fee per large bucket of water, with the median rate charged being 5 Ghanaian pesewas (approximately 0.02 USD) per bucket. Communities utilizing surface water did not report paying a fee for water collection.

Testing of water sources revealed that fecal coliform counts in water samples were higher in communities using surface sources, as compared to communities that relied primarily on a borehole. All of the communities that were dependent on spring water had fecal coliform counts greater than 100 colonies/ml, while communities with NGO boreholes had a median count of 2.8 colonies/ml (interquartile range 0.25–5.7).

Community impact

Overall, approximately half of the 102 respondents reported spending less than 30 minutes daily gathering water, although 7% of people reported needing to spend 2–3 hours daily to meet their needs for water. In communities that had received a borehole from the NGO, over 60% of people reported that their water collection time had been

shortened, with a median reduction of 30 minutes per day. In one community, a teacher noted that the children arrived at school earlier, because they no longer had to queue at the more distant hand-dug well or walk to the stream to collect water. Despite these reported time savings, we did not find a statistically significant difference in median water collection times between villages with and without a borehole. There was a significant correlation between reporting spending greater than 1 hour per day collecting water and broken pipes at the nearest well ($p = 0.03$).

Water was used almost universally for drinking, cooking, bathing, and washing clothes, and was rarely used for watering plants and irrigation. Hygiene practices, such as washing of water containers and use of improved sanitation facilities, were very common among the surveyed population. Respondents almost universally reported washing their water containers (98%), with a median frequency of once daily. Reported rates of washing water containers did not differ significantly between villages with or without a borehole. Essentially, all respondents (99%) reported having access to a toilet, which was most commonly a pit latrine. A majority (89%) of people reported using the toilet in their community, although in two communities, the pit latrines were locked and unused.

Among the communities that had received wells, close to 70% of respondents reported that they no longer worried about contracting a disease from their water. There was no statistically significant difference, however, between well

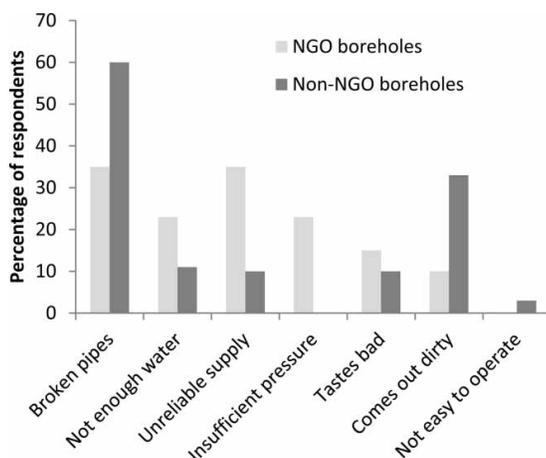


Figure 1 | Reported problems with water supply from boreholes installed by the NGO compared to boreholes installed by other entities including governmental.

Table 2 | Effect of water source on health measures

Water/health results	Villages with borehole	Villages without borehole	p-value
Fecal coliform count (mean \pm SD)	5.92 \pm 5.72	> 100 \pm NA ^a	Significant (<0.05) ^a
Diarrhea in last month <i>n</i> (%)	35 (50.0)	14 (48.0)	Not significant
Family member with diarrhea in last month <i>n</i> (%)	28 (45.2)	13 (44.8)	Not significant
History of intestinal worms <i>n</i> (%)	35 (55.5)	21 (72.4)	0.17
History of typhoid <i>n</i> (%)	4 (5.8)	0 (0.0)	Not significant

^aColonies this numerous could not be precisely counted.

and non-well communities in terms of incidence of diarrheal disease within the past 30 days (Table 2).

DISCUSSION

This pilot fieldwork has begun the process of determining the locations of the 70+ boreholes constructed by the NGO, in addition to assessing the water quality, operational status, and community benefit of these boreholes. Data collected from 102 respondents show that, while the boreholes have generally had positive impacts on communities, there are several issues to be addressed in order to create a sustainable model for future community borehole projects.

For communities where a borehole had been constructed by the NGO, over 60% of people reported that the borehole had reduced their water collection time, with a median reduction of 30 minutes per day. The lack of difference in median collection times between communities with and without a borehole is likely due to the fact that all the non-well communities visited were situated directly adjacent to the streams or springs on which they relied. Those that had received NGO boreholes had more distant secondary water sources. Research suggests that women and children carry the burden of water collection (Montgomery & Elimiech 2007; Sorenson *et al.* 2011). Indeed, studies have shown that time spent in collecting water provides an indication of the effort and quantity of water that can be collected by a household (WSMP 2010), with households spending more than half an hour per round trip progressively collecting less water, eventually failing to meet their families' minimum daily drinking water needs (Hutton & Haller 2004).

All NGO-constructed boreholes had significantly lower fecal coliform counts than those communities that collected their water from unimproved water sources. The continuing presence of coliforms in boreholes tested, however, highlights the need for regular water quality and sanitary inspections, as recommended by WHO (2004). Although the use of an 'improved drinking water source' is used as a proxy indicator to assess safe drinking water, other studies have shown that improved water sources may provide unsafe water (Luby *et al.* 2008; Sorlini *et al.* 2013). Indeed, recently, Bain and colleagues (2012) showed that assessing

drinking water safety according to whether or not it comes from an improved source is likely to overestimate the number of people with access to safe drinking water. Diarrhea is the second largest cause of death in children under 5 years old in Ghana (Ogez & Rickard 2013). These deaths account for 244,000 years of life lost per year in Ghana (UNDP & NDPC/GOG 2012), of which, a significant proportion can be prevented through safe drinking water and adequate sanitation. There was a high level of self-reported water container washing, indicating that there is a general awareness of pre- and post-collection contamination.

Two out of seven NGO boreholes had unrepaired equipment failures. Three communities collected a fee for water; however, because of the small sample size, we are unable to determine if paying for water or maintenance is associated with longer-term functionality of the boreholes. There was also no monitoring and evaluation system in place to assure the quality or quantity of water provided by the boreholes or to understand the impact of these boreholes on the health and well-being of the recipient communities. Furthermore, it was observed that in some communities, there were additional boreholes provided by the government or other NGOs. While we did not assess how many boreholes were needed in each community, duplication of efforts could be the result of multiple entities working independently and without adequate communication. This observation highlights the need for a process, which catalogs existing boreholes within each community prior to intervention. Accurate record-keeping and reporting, which details each borehole's functionality, water quality, and water capacity, are essential for ongoing sustainability of the projects.

As with much of western Africa, Ghanaian chiefs play an important role in regional government and development initiatives (Owusu 1996; Ubink 2007); engagement with the community must begin with the chiefs and projects must have their support. In one village, when asked why the community did not charge for water to maintain the wells, the local chief stated that '[the NGO] did not discuss this with us. They came and gave it as a gift and then left. How can I charge my people for water, when [the NGO] gave it to us as a gift?' Upon further inquiry, the chief stated that he would like to charge for water to maintain the wells. This conversation and other similar instances revealed that there may have been insufficient planning and

communication with community leadership before implementing the boreholes.

Finally, at each village visited, the community leaders were uncertain of how to rectify maintenance problems with the borehole. Most communities were not trained to perform their own mechanical repairs and were dependent on the NGO project manager, who was often reported as difficult to reach, resulting in non-functional boreholes for extended periods of time. This inefficiency highlights the necessity for a detailed plan including training for community mechanics to perform regular well maintenance, standard operating procedures, community engagement, and protocols to guide the development and implementation of each project.

These challenges are not unique to this single NGO. Small NGOs often have limited staff and resources to dedicate to monitoring and evaluating their initiatives. In addition, many do not have a focused vision and strategy, as their continuance depends on donor demands (Abbey 2008). Dedicating resources to measuring outcomes and monitoring impact is important to ensure that philanthropic resources are spent effectively. Despite the challenges, there is an opportunity to strengthen the framework for monitoring and evaluation used by small NGOs in order to harness their insight into local circumstances while also ensuring that philanthropic and development goals are met.

In order for philanthropic organizations to enjoy success in the Ashanti Region, they must create a model that values sustainability. Sustainable, and thereby, successful projects rely chiefly on leadership from various social groups and encourage equal participation from local chiefs, community members, as well as outside parties (Bossert 1990; Israel *et al.* 1998; Morell 2005; Choffnes & Mack 2009). These organizations have established clearly-defined goals and build on existing strengths and leadership of the community, while garnering the support of local institutions (Bossert 1990; Israel *et al.* 1998). These efforts become fixtures in the community by including educational and training components and are able to provide meaningful and long-term aid to local communities (Mølbak *et al.* 1989).

Limitations of this study include the sample size due to the small populations of the rural communities visited. In addition, more women than men were questioned, as women were more likely to be present inside the household

during the day. Further research would have to be done to access water use, well access, and health of residents in rural communities elsewhere in Ghana, as this study was limited to the region outside of Kumasi.

CONCLUSIONS

Driven by our observations during this pilot study and the models of successful development projects, we have generated five key recommendations that will enable more sustainable, productive, and responsible future drinking water interventions by the Ghana NGO that may be applicable to similar organizations working on drinking water projects in the region. At the core of our series of recommendations lies a new model that can be applied to future projects. Under this system, responsibility for routine maintenance and care of the boreholes would be shared by community leaders and/or a water committee. The resources for performing these duties would come from a very nominal use fee for each person utilizing the system and a small stipend provided by the NGO that is earmarked for maintenance purposes. The NGO would be responsible for scheduled water quality testing, addressing any major technical issues, and periodically checking well functionality. With this model in mind, our recommendations include the following:

Coordinate activities with government initiatives that seek to provide similar services and conduct community pre-surveys to identify water needs prior to borehole placement

In Ghana, water supply delivery is the responsibility of the GWCL in urban areas and the Community Water and Sanitation Agency (CWSA) in rural areas. CWSA supports project interventions to provide improved water supply and sanitation facilities in small towns and rural areas (Nyarko *et al.* 2008). CWSA has a procedure for selecting beneficiary communities (CWSA 2014).

We found that redundant services had been supplied to nearly all the communities in which the NGO constructed a borehole. In the future, proper coordination with CWSA and other NGOs could extend the impact of their work

and ultimately supply clean water to a greater number of Ghanaians. We found that the local government was not always aware of the resources at a community's disposal prior to placing a borehole. In addition, the NGO did not have knowledge of CWSA's detailed plans for borehole placement in the future. This method of project coordination and resource mapping would allow for an opportunity to conduct a pre-intervention assessment of community health. This data could be compared with the post-intervention health status of those impacted by the project. This would be a much more powerful way to collect evidence of a benefit to the community.

Establish a working relationship with community chiefs and leaders prior to community selection and project initiation

Ultimately, the success of a project will rely on the integrity of the leadership structure and the governance within each community. Indeed, good governance at the community level during a project has been positively correlated with a more sustained water supply (Dayal *et al.* 2000). Under the new model we propose, chiefs and water committees would be responsible for the routine maintenance and upkeep of NGO boreholes. To do so requires a level of organization that is not a universal feature of all communities. Establishing a relationship with these leaders will allow for upfront communication of eligibility criteria, goals, responsibilities, and expectations. In this way, potential problems can be seen before they occur allowing the NGO to focus its efforts on projects that have the most long-lasting impact. Potential communities could subsequently be vetted by the NGO and projects with the greatest potential for benefit selected.

Establish and train local water committees to operate and manage boreholes and address commonly encountered problems prior to the commencement of a project

Higher levels of participation in establishing community-managed water supply services are associated with better-sustained services (Dayal *et al.* 2000). This includes operation and maintenance of the boreholes by community

members. These water committees should be established and their fidelity tested for a fixed amount of time before a project begins. A standard charter that includes record-keeping, maintenance responsibilities, leadership structure, and membership should be constructed with opportunities for community input and election of committee members.

Develop a payment structure for operation and maintenance to ensure leaders and committees are able to address common borehole issues

According to our interviews with community leaders, charging a nominal fee to be used for the maintenance of a well is both feasible and desired. In coordination with ongoing small contributions from the NGO budget, a reserve could be built in order to protect against borehole malfunction. This, together with a trained and solvent water committee, could ensure both transparency and project longevity.

Create a monitoring arm of the NGO, which is responsible for verifying the continued and safe operation of installed and future wells

More specialized functions, such as water quality testing and advanced repairs of the borehole will require NGO assistance. Contracts between the community and NGO would be necessary to clearly define areas of support and expected community contribution. The NGO would also continue making periodic visits to project sites in order to document borehole status.

Moving forward, after completing a one-time survey of existing projects, a pilot program within which the above structure is applied is recommended. A continuing partnership with KATH, the local university, and the CGH could explore difficulties with the model and adapt accordingly. As new projects are started, pre- and post-implementation studies in each community could provide more powerful evidence of the impact of each project. This would be of great benefit, as the NGO would be better able to quantify their outstanding efforts and recruit additional funding.

Sustainable, successful projects rely on leadership from social groups and encourage the equal participation of stakeholders in the community. This proposed structure promotes community ownership and allows the NGO to

remain involved in a more supportive role. More rigorous methodology in the selection of communities, pre-project community engagement, and post-project monitoring will ultimately allow the NGO to complete a more broad and impactful scope of work.

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Authors' contributions

Donee Alexander: study concept and design, questionnaire design and construction, field management, data collection, and manuscript writing and review.

Nate Wilson: questionnaire construction, field management, data collection, database creation, and manuscript review.

Rebecca Gieseker: questionnaire construction, data collection, and manuscript review.

Emily Bartlett: database creation, statistical analysis, and manuscript review.

Natalie A. Rosseau: manuscript composition and review.

Evans Xorse Amuzu: questionnaire editing, manuscript review, and data collection.

Olofunmilayo Olopade and Daniel Ansong: project oversight and manuscript review.

Christopher Olopade: study concept, project oversight, mentorship, and manuscript review.

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