Sand Dam Assessment for Water Quality

MCC Kenya, August 2016-May 2017

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Acronyms and Definitions

CFGB	Canadian Foodgrains Bank
cfu	Colony forming units; on bacterial test cards, these are the number of colonies which have grown up. Since each colony comes from one bacterium, it is simply the number of bacteria in the sample.
FC	Fecal coliforms; fecal coliforms are E. coli bacteria that indicate fecal contamination, and are the basis of standard health guidelines.
GC	General coliforms; non-fecal coliforms which are generally not in themselves pathogens. There are not usually health guidelines for general coliforms (although that is starting to change; some places now are setting standards not to have general coliforms in water). Excessive numbers of general coliforms can indicate a larger probability that pathogens are present.
LOD	Limit of detection; a statistical analytical definition, indicating the lowest concentration or amount that can be determined by the method used.
MCC	Mennonite Central Committee
ppm	Parts per million; a common unit of concentration, for instance mg per kg (or in the case of salts in water, mg per liter)
SASOL	Sahelian Solutions Foundation
SODIS	Solar disinfection, a method of water purification
TDS	Total dissolved solids; effectively equivalent to salt content in water samples that were tested
UDO	Utooni Development Organization

Summary and Key Findings

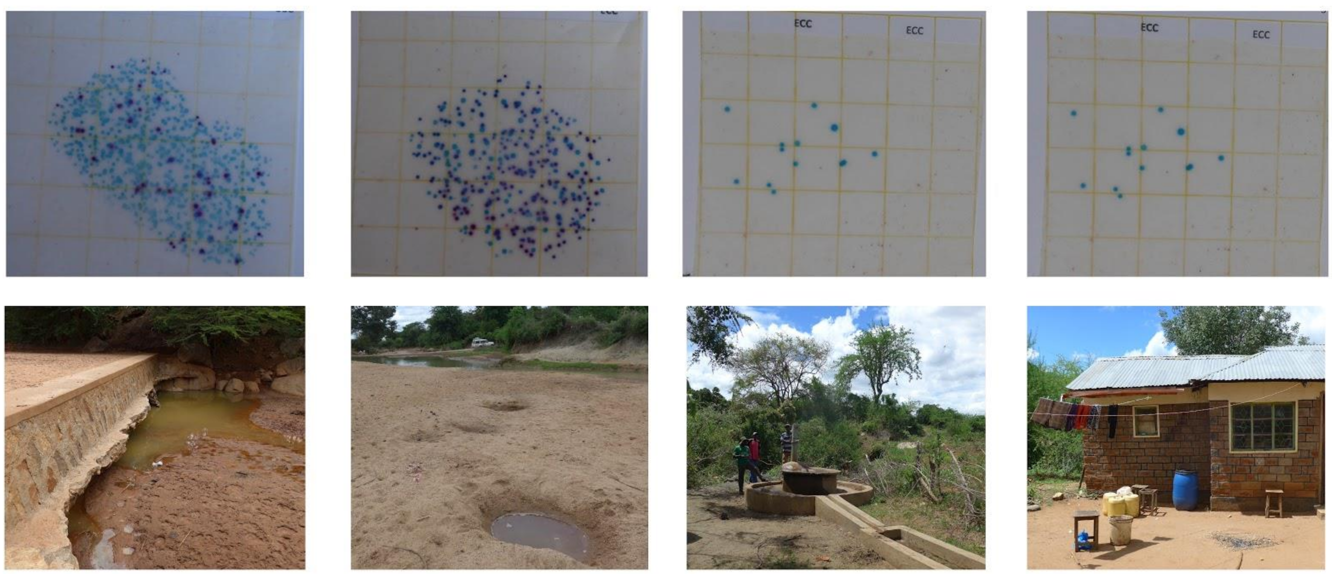
MCC and CFGB have supported sand dams in the Ukambani region of Kenya for some two decades through two partners, Sahelian Solutions Foundation (SASOL) and Utooni Development Organization (UDO). Along with funding from other sources, these partners have worked with communities to construct several thousand sand dams in the region. Taken together with other organizations and government activities in the region since colonial times, there are estimates of up to 5000 sand dams in Ukambani. These structures therefore represent a major water harvesting technology in the region.

Despite their prevalence, and obvious importance to many communities as a water source, there is little information available concerning water quality, and in particular the potential contamination of water with pathogens that would compromise its effectiveness as a drinking water source. This study was undertaken to assess bacterial levels (fecal and general coliforms), salinity and pH, in water associated with sand dams, including roof rainwater collected at households. In addition, water use patterns and perception of water quality was surveyed for communities at 97 randomly selected sand dams.

Key Findings

- Bacteria, salinity and pH were measured in water samples during dry season visits to 97 sand dams, and wet season visits to 36 sand dams. Survey data was collected during the dry season on the use of water from sand dams, including perceptions of water quality.
- **Bacteria contamination is present in all categories of water sources**, although specific levels vary widely. In large part, sand dams don't appear to act has "large sand filters".
    - **Fecal coliforms (as *E. coli*) were present at high to very high risk levels (>100 cfu/100 ml)** in 84% of samples from sand dam scoop holes in the dry season. All samples from scoop holes had general coliforms. Scoop hole water was not cleaner than surface water in fecal coliform levels.
    - **Pump well and roof rainwater collection are the least contaminated sources.** 75% of water samples from both pump wells and roof water were clear of fecal coliforms. Roof water had high levels of general coliforms.
- **Practices employed to prevent contamination of scoop holes (fencing, deep holes, clearing water from holes) did not reduce water contamination**.
- **Salinity is often at levels considered less desirable for human consumption**. About ¼ of users reported issues with salty water. Water in the dry season was above 900 ppm (a cutoff for "poor" water with respect to saltiness) in 28% of scoop holes and 71% of pump wells. Salinity was less during the wet season, and was not an issue in harvested rainwater.
- Water pH is near neutral and not an issue in the region.
- Survey (questionnaire) data indicates **some awareness of potential water quality issues**, but general **misperceptions of water cleanliness**, and a **lack of practices ensuring clean water consumption**.
    - **Most communities at sand dams (74%) report that all or most users believe water is clean**. Most commonly this assumption is based on appearance (the water looks clean).
    - Consistent with these beliefs, **most communities at sand dams (71%) report that all or most users do not treat the water before consumption**.

    - **When treated, users almost exclusively used waterguard (commercial chlorine additive) and/or boiling**. There were no instances of SODIS or filtration.
    - Despite stating beliefs that water at dams is general clean, and a widespread lack of water treatment, these same users frequently reported **nuanced understandings of water risks**. For instance, users sometimes reported selectively treating water for their children, and some measures (fencing holes, clearing old water from scoop holes) were taken with the belief that they provided cleaner water.
- While the improved provision of water for household consumption by sand dams has obvious benefits which are to be appreciated (e.g. reduced distances for collection, increased amount of water), there is an opportunity to improve health benefits by promoting practices that improve the quality of water consumed by users. While source management could limit exposure to contamination (especially if pump well or rainwater harvesting were promoted), cleanliness is best ensured with point-of-use water treatment. Many users have some understanding of water risks, which provides an opening for improved WaSH practices in these communities.



Surface water average: 900 fecal coliform / 100 ml

Scoop hole average: 1800 fecal coliform / 100 ml

Pump well average: 11 fecal coliform / 100 ml

Roof rainwater average: 45 fecal coliform / 100 ml

Above: Examples of bacterial tests at 4 types of water sources, results are from the specific sources shown. Cards show fecal coliforms as purple dots (general coliforms as blue dots).

Introduction

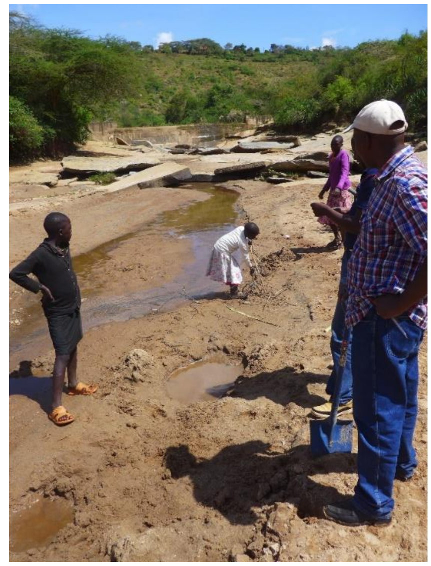


Fig. 1 Scoop hole next to surface water. The assumption has been that the water filtering through the sand to a scoop hole such as this is cleaned.

Water quality was investigated at sand dams as part of a larger sand dam assessment in cooperation with UDO and SASOL. Sand dams have a long history of providing water to communities in the Ukambani region (Machakos, Kitui and Makueni), but very little work has been done analyzing the quality of this water, and potential health risks associated with consumption of that water. To our knowledge, there is no published data on the level of pathogens in water from sand dams.[1] This is of particular relevance since the assumption by promoters and users alike has been that the water is relatively clean. While this is a logical assumption based on the known ability of sand filtration to provide clean water in some situations (such as biosand filters), this assumption has not been thoroughly tested. The widespread presence of livestock manure on sand dams (often close to scoop wells), and the open nature of the water source, raise concerns that these assumptions of water purity from sand dams may not reflect the reality of the situation.

The sand dam assessment visited 89 randomly selected dams from UDO and SASOL records (constructed by these organizations), plus 8 colonial era sand dams selected by SASOL, during the dry season (Aug-Oct 2016). Wet season (November 2016 and April 2017) visits were made to 37 sand dam sites (chosen by proximity to UDO and SASOL) in order to measure water quality parameters only. Bacteria (general and fecal coliforms), salinity, and pH were measured, with a focus on scoop holes, but included surface water (e.g. pools or flowing water), dug wells, pump wells, and household samples (such as roof water during the wet season). Interviews with users provided information on water use and perceptions of water quality.

Results

Bacteria levels in water sources

Four types of water sources are typically associated directly with sand dams (Fig. 2): surface water as standing or flowing water, scoop holes of varying depths which are dug in the sand, dug wells as permanent structures which usually are not covered, and pump wells which are sealed, often deeper,

[1] Avis recently measured bacteria at sand dams and determined that their samples were generally clean (unpublished work; http://www.excellentdevelopment.com/site-assets/files/articles/excellent-news/the-evidence-sand-dam-water-is-clean/a-microbial-analysis-of-water-stored-by-sand-dams_web.pdf). The reason for differences with results from this study is not clear; the most obvious difference is that samples from that study were taken from test holes excavated in the sand, whereas samples in this study are from existing water sources currently being used by the community. In addition, SASOL in cooperation with Dutch colleagues measured bacteria levels in water sources, but focused on general water sources in Kitui rather than on sand dams.

and often more closely controlled in their usage. All water sources tested were in the near vicinity of sand dams and were those used by the sand dam communities. It is was not possible to know to what extent the sources were actually “sand dam water” (for instance, pump wells may have tapped into deeper aquifer water, or scoop holes downstream from the dam structure may have been sourcing groundwater seeping into the sand).

Fig. 2 Sand dam water sources

The levels of fecal coliforms in surface water, scoop holes, and dug wells were in the high to very high risk range (>100 per 100ml; Fig. 3)[2]. Fecal coliform levels were quite variable within these categories, with some samples quite clean (zero fecal coliforms), or very dirty (tens of thousands of fecal coliforms per 100 ml). Scoop holes had levels of both fecal and general coliforms that were not statistically different from that found in surface water or dug wells. [3]

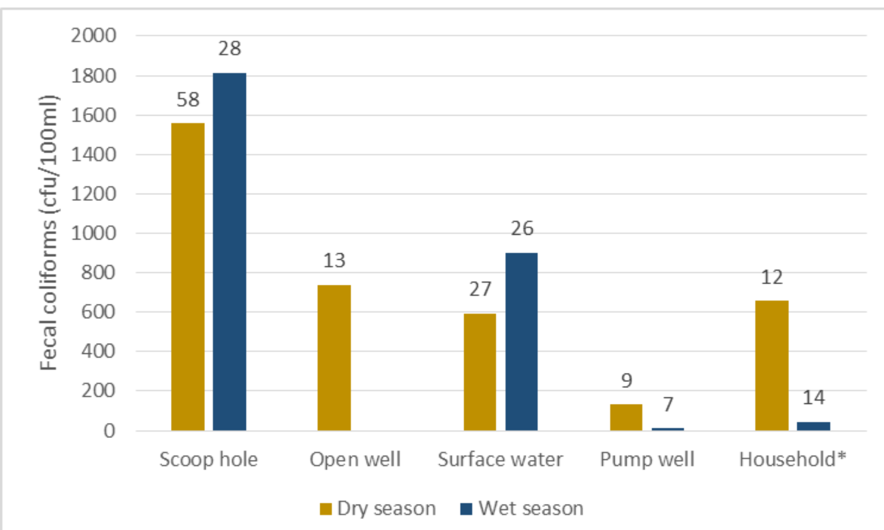


*Fig. 3. Geometric means of fecal coliform levels by water source. Numbers represent sample sizes. *Water in the household was from storage containers at the house used for drinking (from scoop holes in the dry season, and roof rainwater in the wet season).*

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[2] The official WHO standard for fecal coliforms is “no fecal coliforms per 100 ml”. Relative risk here uses a common categorical rating system, considering anything above 100 fecal coliforms per 100 ml as high to very high risk. 1-10 fecal coliforms per 100 ml is considered low risk, and 10-100 fecal coliforms per 100 ml is considered intermediate risk. Organization, W. H. (1996). Guidelines for drinking-water quality, 2nd edition, Geneva: world health organization.

[3] See addendum for all statistical analyses. Bacteria levels in water are generally shown and analyzed on a logarithmic basis, and data is often expressed as the “log10 concentrations”. Because the log10 concentration is less intuitive for most people when visualized graphically, we show most data in graphs on a standard scale. However, differences which appear relatively large on a standard scale are often not statistically different, because of the log10 basis of the data.

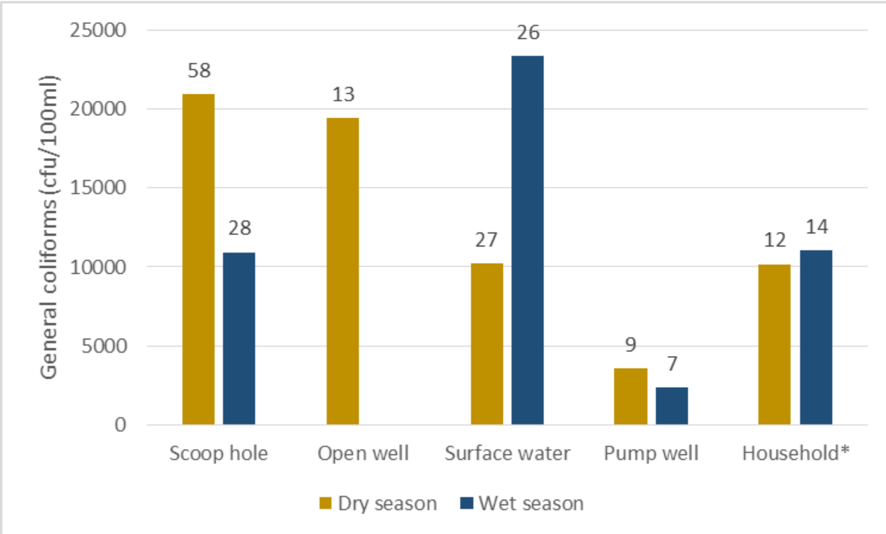

Fig. 4. Geometric means for general coliform levels by water source. Numbers represent sample sizes. General coliforms are not considered harmful in themselves, but high levels are generally considered as an indication that other contamination (such as viruses, parasites, non-fecal coliforms, etc) are likely present. There are no established values representing health standards for general coliforms, although there are recent moves in some countries to set "no general coliforms per 100 ml" as a health standard.

Water from pump wells and roof rainwater collection ("household" during the wet season; Fig. 3, 4) was statistically less contaminated with fecal coliforms compared to the other categories. 75% of samples were clear of fecal coliforms in both bases (12/16 in pump wells, and 9/12 in roof rainwater). General coliforms were high in the roof rainwater (Fig 4), apparently bacterial contamination occurs easily, but was selective for non-fecal coliforms. Our test could not detect the lower risk levels of fecal coliforms (1-100 cfu/100 ml), so there was possibly still some low levels of contamination. However, these water sources were obviously cleaner than scoop holes, dug wells and surface water.

Fig. 5 Rainwater collection system typical of that used during rainy season.

There were not dramatic differences in contamination between dry and wet season (Figs. 3, 4), although the dynamics of bacterial contamination likely change during the seasons to some degree. For instance, there is an obvious decrease in manure piles on sand dams during the wet season, as they were apparently washed away during rain events (which theoretically this also could mobilize manure contamination). Aquatic contamination in other situations (e.g. stream contamination in North America) sometimes show an initial increase in bacteria during rains ("first flush") and then decrease as they are flushed out of the system. Whatever seasonal changes occur at sand dams, they are not dramatic, and bacteria levels still largely exceed what is considered acceptable for health standards. The one exception is in the water consumed at the household level; ***fecal coliform levels are much lower during the wet season as the water source shifts from scoop holes to rainwater***.

In scoop holes, fecal coliforms were present at high to very high risk levels in 84% of samples (Fig. 6). The remaining 16% of samples had very low to medium risk - we could not distinguish between absence and presence of fecal coliforms (per 100 ml) at these lower levels. General coliforms were present in all samples, usually in the thousands to hundreds of thousands per 100 ml.

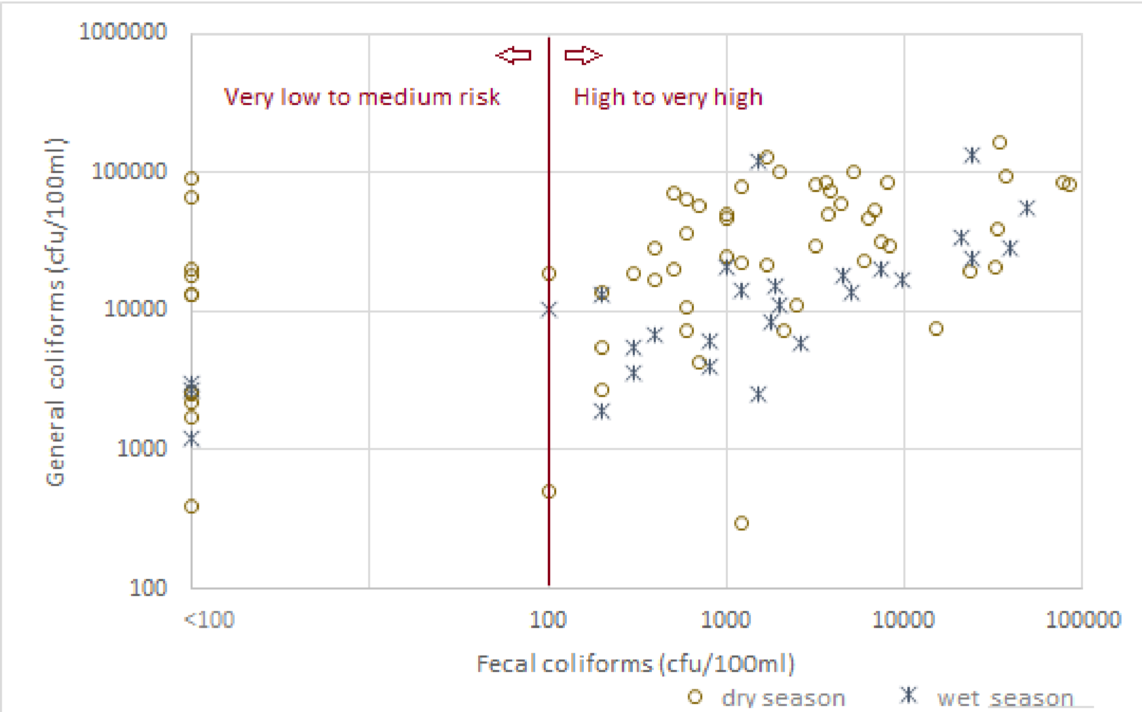

Fig. 6. Fecal and general coliform levels in individual scoop holes. Note that values are plotted on log axes. Samples where no fecal coliforms were observed are indicated as “<100”, since the small water sample volume tested meant the effective detection limit 100 cfu/100 ml.

Effect of location and design of scoop holes

Scoop holes differ in ways which might impact the amount of contamination present. We recorded whether scoop holes were: 1) fenced to exclude livestock (see Fig 10 below), 2) shallow, medium or deep (<0.5 m, 0.5-2 m, or <2 m, respectively), and 3) on the dam surface or downstream from the dam (water downstream of the dam is often designated for nondrinking purposes by communities). There was no statistical effect of these characteristics on fecal coliforms (Fig. 7; see addendum for more details). ***Thus, neither protective enclosures, nor the position and depth of the scoop hole, had any discernable effect on keeping water clean.***

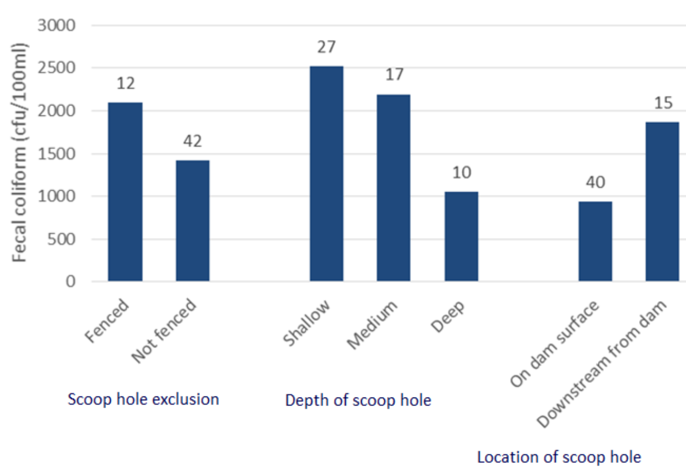

Fig. 7 Geometric means of fecal coliforms in scoop holes, broken down by characteristic. Because fecal coliform levels are highly variable in scoop holes, the differences in averages here are not statistically different.

Effect of emptying scoop holes prior to water collection

Scoop hole users often will empty water out from a scoop hole and then let it refill prior to collecting water for use, if nobody has obviously taken water from the hole for some hours. This represents some understanding that scoop hole water is not always clean, probably based on its visual appearance. The hole refills from water "filtering" out of the sand, and the practice is thus likely also grounded in a belief that water held in the sand is effectively filtered.

In 12 scoop holes during the wet season, we tested whether emptying the hole and letting it refill had an impact on bacterial counts (Fig 8, 9). ***General and fecal coliforms were not statistically different (paired t-test) after scooping the hole***. Freshly dug scoop holes in sand dams also had high levels of fecal bacteria (581 cfu/100 ml; N=7). Thus, scooping out water may change the appearance of the water (e.g. removing algae or other visible elements in the water), but it does not seem to reduce the risk of pathogen ingestion. Fecal coliform bacteria was apparently present in the water held in the sand.

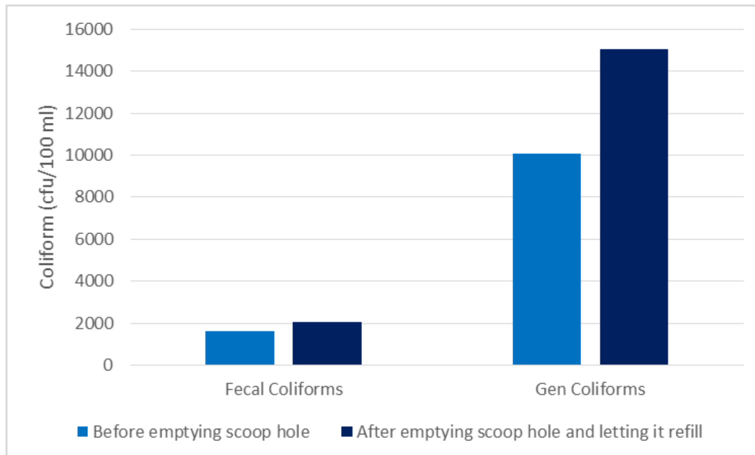

Fig. 8 Geometric means of fecal coliform counts in wet season scoop holes before and after being cleared of water.

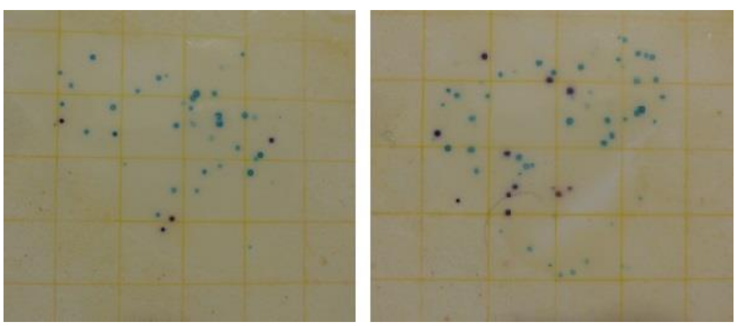

Fig. 9. Example of bacteria tests in wet season before (left) and after (right) clearing water from the scoop hole.

Does the sand in sand dams help to clean the water?

Although water taken directly from scoop holes was clearly contaminated, there may still be some benefit to water quality as it percolates through the sand. Indeed, on theoretical grounds, there is good reason to believe this should happen, as there is clear evidence that water can be cleaned by moving through sand beds (such as biosand filters; (Lea 2008)). Filtration is sediment beds in general is an established step in cleaning water. The notably lower fecal coliform levels in pump wells of this study, for instance, are consistent with this. However, the assumption that water in general in sand dams is clean seems overstated in sand dams for several reasons:

1. As elaborated above, when scoop holes were cleared of water, it did not obviously clean out the bacteria from the water. In some locations, very deep (4 meters or more) scoop holes were constructed by communities to access the deep water. Even this water, which presumably spent more time filtering through sand, was not free of bacteria (Fig. 7, 10, 11). Water therefore either was constantly recontaminated at the scoop hole site, or effectively carried bacteria as it percolated into the scoop hole from the sand.

Fig. 10. Deep scoop hole (~5 meters) protected with fencing to keep out livestock.

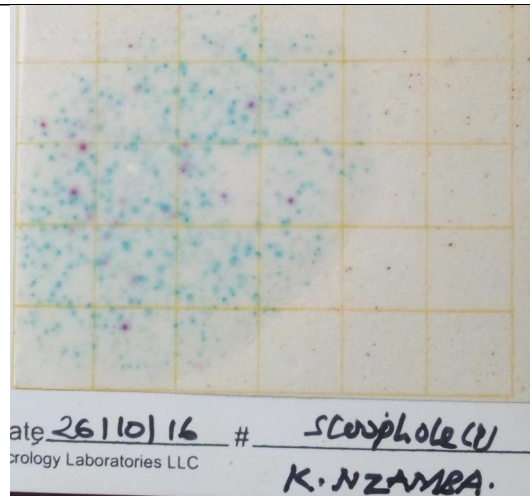

Fig. 11. Water sample from the scoop hole at left. Fecal coliforms were 1500 per 100 ml, well within the high risk zone (>100), despite being fenced and deeply dug.

2. Despite some suggestions by community members that livestock are restricted in access to sand dams (in order to keep manure buildup), or are only allowed downstream of scoop holes, in an overwhelming number of cases sand dams had abundant manure across the dam surface and livestock were often observed on dams (Fig. 12, 13). In most cases, manure was observed within a few meters of scoop holes. This clearly represents a high quantity source, and effective filtering would need to be very robust to handle this bacterial load.[4]

Fig. 12. Typical dry season scene on sand dam, with abundant manure.

Fig. 13. Scoop wells simultaneously being used for collection of drinking water, and for watering cattle.

[4] We estimated the number of manure piles within a 5m radius of scoop holes for over ½ of samples. There was a weak correlation of this "manure load" with scoop hole contamination. See addendum for data.

3. Experience in other situations, such as effective protection of pump wells, indicates that consistent contamination easily occurs where fast water flow can happen due to the presence of water channeling, such as along the outside of well pipes. The high permeability of coarse sand, which is desired for optimal water provision in sand dams, might provide easy passage for bacteria as water rapidly moves through these channels.

However, there remains the possibility that "deeply protected" water in sand dams is largely clean. The only other study (unpublished[5]) of which we are aware did not find significant contamination of sand dam water. It's unclear what accounts for the difference from this study, but samples from that study were from freshly excavated test holes which could represent a better protected pool of water. We also note that in the three cases where pipes were present at the base of the dam face (Fig. 13), water was free of any bacteria. Possibly this is because the water had filtered through a large volume of sand, as the pipe would have been draining water from the deepest part of the dam. However, the water in all of these cases also obviously carried a large amount of iron (the outflow was strongly stained red); chemical toxicity may therefore be responsible for the lack of bacteria rather than filtering per se. People reported not using the water from these pipes due to the taste, or fear of the coloration associated with the water. It is not clear, therefore, whether a strategy of harvesting deep water (e.g. with a pipe) would help.

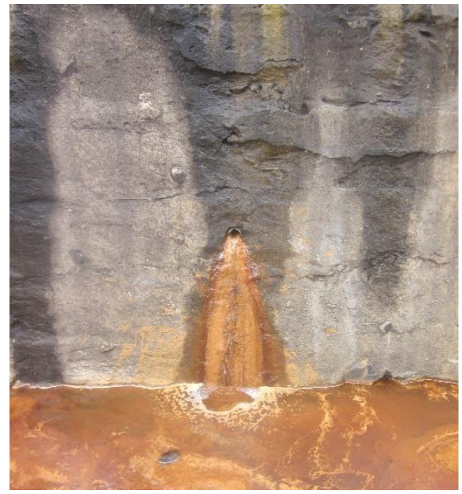

Fig 14. Pipe in face of dam structure draining water from deep sand, showing red color of water presumably from iron.

Conductivity

Conductivity is a measure of "saltiness" of water, which although not generally a health risk, does become unpalatable. "Saltiness" is often reported in different ways[6], as conductivity itself (the directly measured parameter in μS/cm, as we did), salinity (ppm) or total dissolved solids (TDS, ppm). Salinity and TDS are calculated from conductivity using a conversion factor, we used a standard conversion of 0.65. For drinking water purposes, concern about salts begins in the 500-1000ppm range. The WHO states "The palatability of water with a total dissolved solids (TDS) level of less than about 600 mg/l is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l. The presence of high levels of TDS may also be objectionable to consumers, owing to excessive scaling in water pipes, heaters, boilers and household appliances. No health-based guideline value for TDS has been proposed."[7]

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[5] http://www.excellentdevelopment.com/site-assets/files/articles/excellent-news/the-evidence-sand-dam-water-is-clean/a-microbial-analysis-of-water-stored-by-sand-dams_web.pdf

[6] Fondriest Environmental, Inc. "Conductivity, Salinity and Total Dissolved Solids." Fundamentals of Environmental Measurements. 3 Mar 2014. Web. < http://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/ >

[7] http://www.who.int/water_sanitation_health/publications/2011/9789241548151_ch10.pdf?ua=1

For convenience, we have used the following categories[8] to rate drinking water based on TDS concentrations.

- <600 ppm - good
- 600 to 900 ppm - fair
- 900 to 1200 ppm - poor
- >1200 ppm - unacceptable

This does not represent community assessments, but rather a standard rating scheme. Therefore "unacceptable" here may represent acceptable water for communities in water-stressed contexts of Ukambani (although it would unlikely be seen as desirable).[9]

Water from drinking water sources in the dry season often has high salinity levels that can make it less desirable. The salinity in dry season water samples from scoop holes and dug wells was classified as poor or unacceptable in 28% and 40% of the time, respectively. Salinity dropped in scoop holes and dug wells in the wet season, with none classified as poor or unacceptable (Fig. 15). Pump wells were consistently more saline in both dry and wet seasons, classified as poor or unacceptable in 71% and 50% of samples, respectively. Rainwater had a much lower salinity, usually less than 50 ppm. The finding that higher salinity sometimes compromises the usefulness of water is consistent with an unpublished study that included salinity measurements at sand dams.[10]

pH

pH is not considered an issue of concern in the region. pH was slightly less than neutral in all instances (pH around 6.3-6.9), with rainwater predictably being slightly more acidic (pH 5.5)[11]. There are no set health standards for pH[12], although a common desirable range is 6.5-8.5[13]; values in Ukambani are at or just below the lower end of this range. Although communities are aware of the concept of pH (perhaps in the context of soils) and therefore interested in pH, the findings are consistent with previous reports that pH is not a problem.

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[8] from the South Australia standards - http://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/protecting+public+health/water+quality/salinity+and+drinking+water

[9] Users reporting of salty water did not correlate well with the measured salinity at dams. Salinity of water from dams where members reported problems with salty water did not differ significantly from those where there were no reported problems with salty water (average salinity 1072 and 724 ppm, respectively).

[10] Wayne S. Teel. The Impact of Sand Dams on Community Development in Semi-Arid Agricultural Areas in Kenya. http://www.sasolfoundation.co.ke/2013/wp-content/uploads/2013/08/Sand-Dams-in-Ukambani.pdf

[11] see addendum for data

[12] http://www.who.int/water_sanitation_health/dwq/chemicals/ph_revised_2007_clean_version.pdf. pH itself is generally not considered a health hazard, although acidic water is more corrosive and can cause issues with toxic metals leaking from metal delivery systems.

[13] Such as the EPA secondary water standards: https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals.

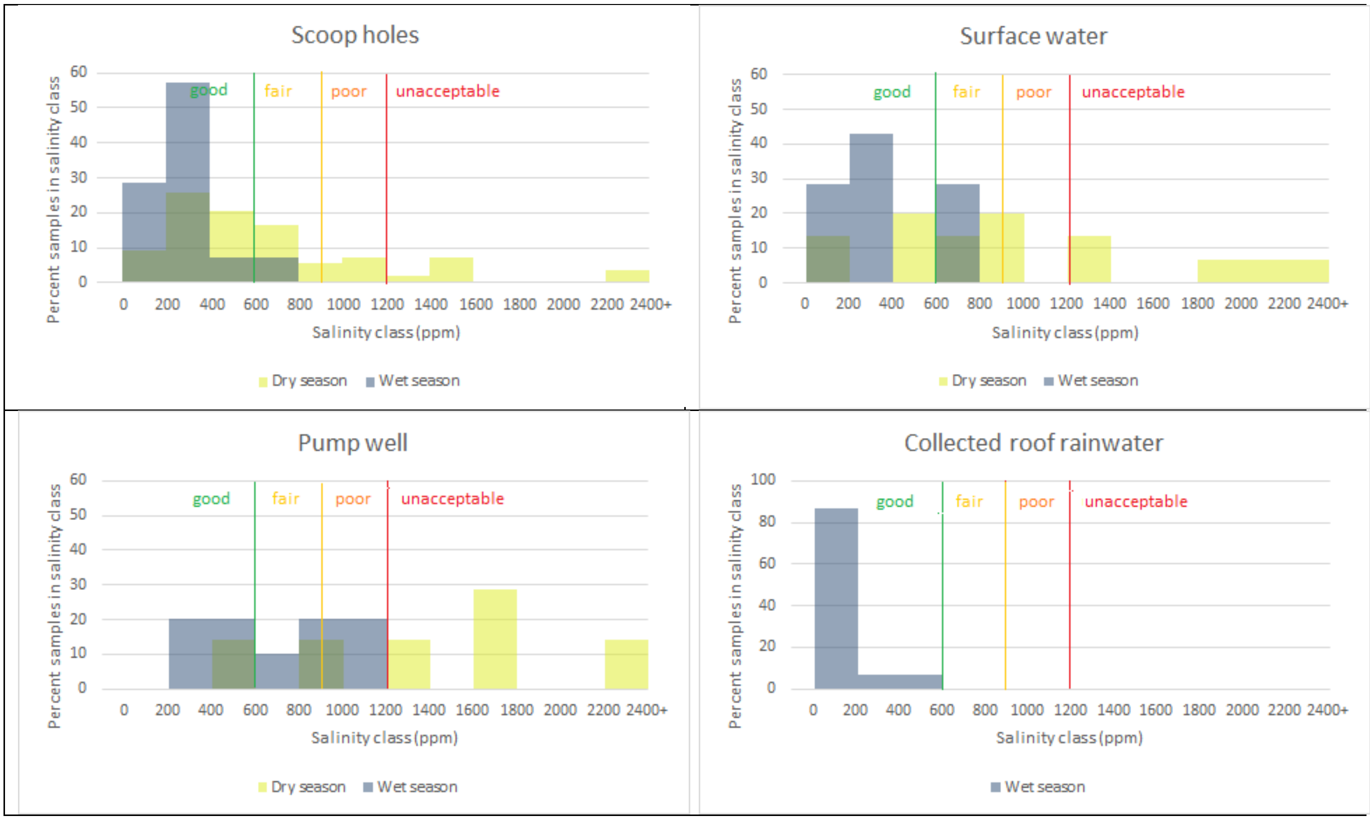

Fig. 15. Salinity (ppm) in dry and wet season from water sources.

Questionnaire data on water use and perceptions.

Visits to 97 selected sand dams included interviews with 1 or (usually) more sand dam users, who reported on perceptions of water quality, and their knowledge of water sources and usage at that site. Responses here are for sites visited in the dry season, and include dams without water. As sand dam selection was based on a random selection design, the questionnaire responses are considered representative (at a 10% confidence interval; see methods) for sand dam communities in general in Ukambani.

Perceptions

When asked what sand dam users think of water from the source, ***about ¾ of interviewees responded that users of the dam generally believed water was clean to drink*** (Fig. 16). For those who believed it was clean to drink, the most common reason was its appearance – the water looked clear (Fig. 17). For those who believed it was not clean to drink, answers were more diverse (Fig. 18). Some reasons had to do with physical characteristics (color or taste), while other reasons related to assumptions about how the management of water affected risks.

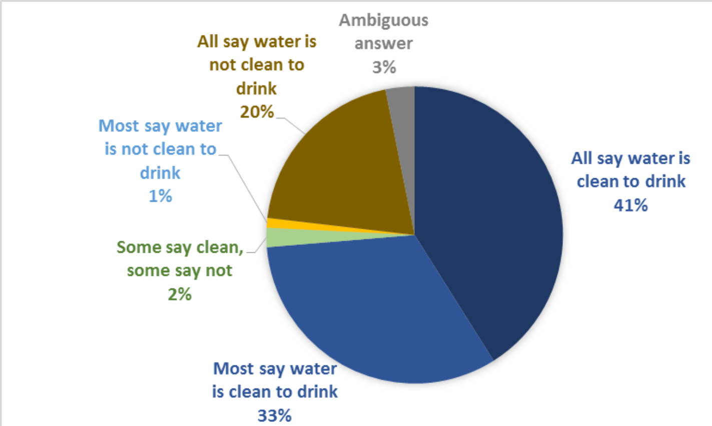

Fig. 16. Interviewee answers about how sand dam users perceive water cleanliness. Interviewees are reporting on their understanding of how that community of sand dam users perceive the water. Answers were in reference to the water source at the sand dam, whether scoop hole, dug well, or pump well.

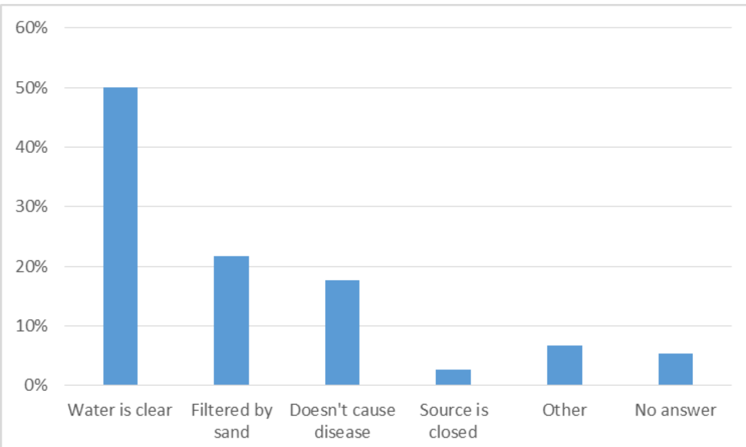

Fig. 17. Interviewees answers about why users think water is clean to drink. The question was open ended, and interviewees could mention multiple answers. Categories are the percent of interviewees whose answer was in that general category.

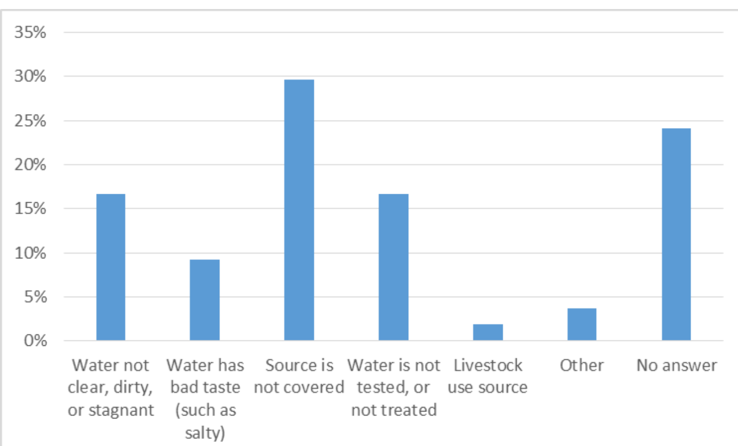

Fig. 18. Interviewees answers about why users think water is not clean to drink. The question was open ended, and Interviewees could mention multiple answers. Categories are the percent of interviewees whose answer was in that general category.

Behaviors

Most interviewees (nearly ¾) reported that no or few sand dam users treat their water (Fig. 19), consistent with the majority perception that water is clean to drink. However, although the percentages were similar in perception and behavior, 49% of those who thought water was clean to drink, still did treat the water at times. This suggests that users had a more nuanced view of water risks – perhaps they think it is "basically clean" but when given the opportunity would rather have treated water. Some users felt it was ok for them to drink, but thought it was too risky for their children. Others thought there was some risk, but apparently felt the risk was minimal relative to the effort or resources required to avoid that risk.

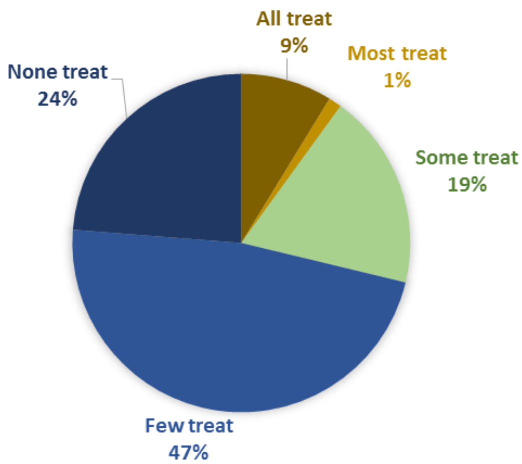

Fig. 19. Interviewees answers about whether sand dam users treat their water before drinking. Answers were in reference to the water source at the sand dam, whether scoop hole, dug well, or pump well.

When treated, waterguard and boiling were overwhelmingly the most common methods used (Fig. 20)***.*** The questionnaire did not probe on how thorough these methods were used (how long water was boiled, or how dosing was done), or on consistency of use – both issues which can significantly decrease benefits of the water treatment. We also note that all perception and behavior is "self" report ("self" being the group of sand dam users at a site, as reported by an individual or group), and thus potentially biased.

There was a significant shift during the rainy season to using harvested roof water (Fig. 21), a seasonal behavioral change with potential health impacts given the lower fecal coliform risk associated with roof water.

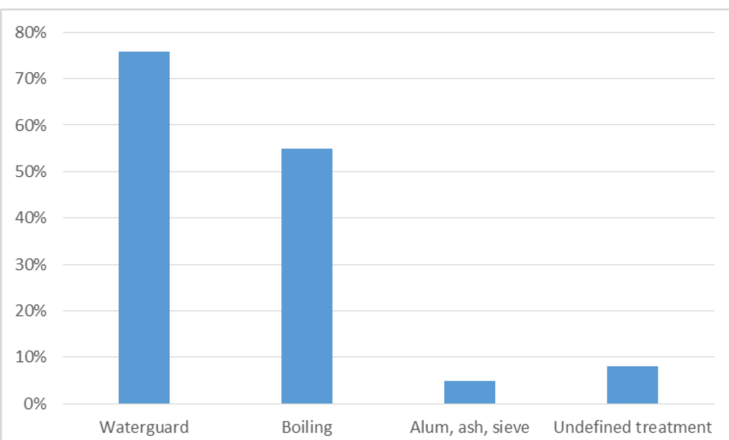

Fig. 20. Method of treatment used for those who do treat their water. Interviewees could give multiple answers, for instance when different users at a sand dam used different methods. Categories are the percent of interviewees whose answer was in that general category.

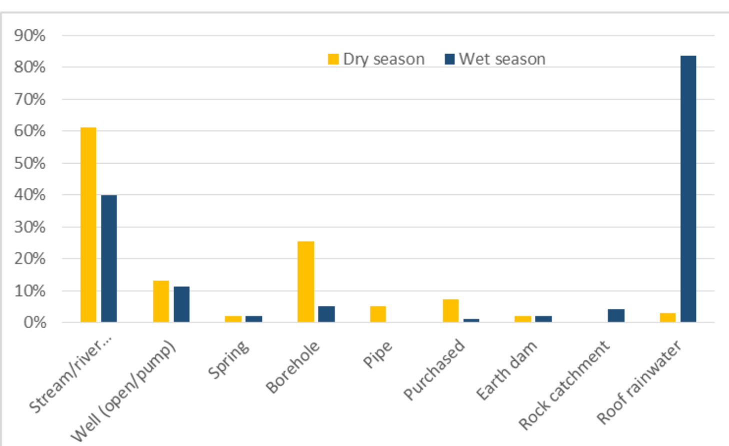

Fig. 21. Drinking water sources during dry and wet seasons. Interviewees could give multiple answers, for instance when different users at a sand dam used different sources. Categories are the percent of interviewees whose answer was in that general category.

Case Studies

Further specific examples of sand dam function, including water quality examples, are found as case studies at https://sites.google.com/site/mcckenyasanddams/case-studies.

Conclusions

Community members typically harvest water from sand dams by using scoop holes – simply holes dug in the sand which then fill with water from the surrounding sand. Water in the scoop holes is often noticeably clearer than water from adjacent surface water (standing or flowing water that is not restricted to a small scoop hole depression). The common assumption is that such water is therefore cleaner. This evaluation was meant to test that assumption, and to identify possible interventions if needed.

The results leave no doubt that there is a health risk associated with drinking water in the sand dam communities visited. In particular, the prevalent belief the water from sand dam scoop holes is cleaner than other water (and indeed, thought clean enough to drink) is not supported by these results. There were some differences in contamination levels, such as pump wells and rainwater that were significantly less contaminated. However, even in pump wells and rainwater, fecal coliforms were present in 25% of samples. Interventions meant to ensure clean water, such as the practice of clearing water out of the scoop hole prior to collecting water, or fencing off holes from livestock, did not ensure safe water. In fact, these practices had no impact on fecal coliform levels. Based on conventional standards (such as those of WHO), treating water from all sand dams sources would accrue health benefits.

Recommendations

Given that fecal coliforms are clearly present in water from sand dams, and that fecal coliforms are standard indicators of a health risk, some actions to ensure cleaner water would clearly lower that health risk. There are two general means of approaching water treatment: *treatment at source* or *treatment at point-of-use* (household water treatment and storage; HWTS). We consider each in turn here.

- Continue to encourage and explore actions which improve water quality at the source

There are several options for improving water quality *at the source*, in this case water harvesting points (scoop holes, dug wells, pump wells, and rainwater). Communities are aware of actions to exclude the source of contamination at the sand site, such as controlling livestock so that manure is not present on the dam, or to clear standing water out of scoop holes before taking water that is “freshly filtered” from the sand. These are clearly logical actions to take, and one can observe (for instance) that algae, foam, or other visual contaminants are removed by scooping out holes. Those actions should not be discouraged. However, they should not be mistaken as providing water clear of pathogens – they did not reduce fecal coliform levels in our tests.

Another option for providing clean water at the source is to move to more use of pump wells or rainwater harvesting. These sources clearly were less contaminated with fecal coliforms. We note, however, that from a public health perspective the presence of fecal coliforms in 25% of samples in both these sources is generally not considered acceptable. An additional concern with pump wells is ensuring their continued function. Although relatively uncomplicated, pump wells do require maintenance and are susceptible to damage, vandalism and breakage (Fig. 22). We did not systematically survey pump wells in the region, but estimate that around ½ of pump wells visited were not functioning. A robust arrangement is needed to ensure their sustainability if they are to be promoted. Maintaining functional water harvesting technologies is notoriously difficult, with an estimated 30-40% of handpumps in sub-Saharan Africa broken at any one time.[14] However, there are good lessons that can be drawn from programs on what factors correlate best with maintaining functional water harvesting technologies (Foster 2013).

Water from pump wells was also more saline than other sources, which could hinder their usage. This is consistent with reports that boreholes in the area often suffer from salinization, especially after several years of operation. Despite these caveats, pump wells are desirable to communities due to their ease of use and their greater reliability in the dry season. Their use would reduce (but not eliminate) the likelihood of consuming contaminated water. Well sited and well managed pump wells would increase the benefit of sand dams to communities.

Fig. 22. Examples of pump wells. Pump well at left is functional, those to the right are broken from vandalism, floods, and general breakage.

Rainwater harvesting is a convenient method of providing water for households with the necessary infrastructure (tanks, effective roof surface). Almost everyone does this to some extent during the wet season, with some communities having large tanks to collect water for continued use into the dry season. Promotion of rainwater harvesting could alleviate some water stress, but should keep in mind several challenges: 1) lifetime cost per m^3 water is higher for rainwater collection (sand dams are the lowest; (Lasage and Verburg 2015)) and 2) the slightly lower pH and lack of minerals (lower salinity) of rainwater is a concern in situations where diets are mineral-deficient, or where leaching of metals could occur from tanks[15]. Finally, other strategies exist for water provision that are less used, such as rock

[14] RWSN (2009) Handpump Data 2009. Selected Countries in Sub-Saharan Africa, RWSN, St Gallen, Switzerland
[15] WHO rainwater harvesting standards

catchments, or exploring the possibility of more effectively tapping water deep in the sand with pipes embedded in the dam structure.

To reiterate, actions which increase the quality of water (either with respect to fecal coliforms or otherwise) *at the source* are worthwhile. From a multi-stage approach to providing clean water (where water quality improvements are encouraged at each step along the chain of provision), these are good steps to reduce health risks.

- Emphasize the effectiveness of point-of-use treatment

Recent reviews have emphasized the greater effectiveness of the second approach to providing clean water – using a point-of-use treatment strategy. Household water treatment and storage (HWTS) is considered particularly important in situations of limited resources. For instance, a recent review (Haller 2008) judged HWTS as the most cost effective means of garnering health benefits from improvements in water and sanitation. Promoting a home treatment option would be the most effective way to reduce the health risk associated with untreated water. Any of the common treatment options (chlorination, solar disinfection, filtration, boiling) could be effective options for treatment. Safe storage options are equally important, and should be emphasized along with treatment options (Shaheed, Orgill et al. 2014). Differences in ease of use, cost effectiveness and social desirability are the main considerations in choosing the best option for the local context of a community. Encouragingly, there are signs that communities are open to activities that would improve water quality. Although generally not treating water, communities have some nascent understanding of water contamination in their sources, and appear open to ideas on how to improve this.

- Raise expectations for providing clean water and encourage a holistic WaSH approach to thinking about water provision.

The reality of resource constraints or other factors can lead to a “clean enough” philosophy regarding clean water provision. While a graded approach to providing clean water can be a helpful strategy in *the process* of moving towards is often appropriate, it should not be the *end point*.[16] We should not be too quick to settle for water which is clearly not up to the established standards which are linked to health outcomes. As a strategy for larger general goals of improving livelihoods or food security (however those are defined), efforts should be made to link water provision with larger food and health goals (e.g. WaSH, nutrition). SASOL and UDO have worked with sand dams for many years and are now involved in a concerted effort to work with communities on food production, income generation, etc. They are therefore in a position to think about how water quality could integrate with their other activities.

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[16] Table 5.2 in Organization, W. H. (2011). Guidelines for drinking-water quality, Geneva: world health organization. as WHO example of rating system as a way to work towards cleaner water

Limitations of the evaluation

Methodological limitations of bacteria tests. Although the method of testing for coliforms is a standard and accepted way to assess water contamination, it does have the inherent limitation of not directly measuring all pathogens. Rather it an indicator test – the higher the levels of fecal coliforms, the more pathogens in general are likely present.

A further limitation in our testing approach is the inability to precisely assess contamination at lower levels. We used a 0.5 ml sample size in testing the water, and data was extrapolated from this to the standard expression of bacteria per 100 ml. When contamination is at lower levels, a 0.5 ml sample may not detect contamination. Supposing for instance, that actual contamination were 10 bacteria per 100 ml, a 0.5 ml sample size would only have a 5% chance of actually detecting any of the bacteria. In effect, this simply meant that we could have underestimated the number of samples with contamination – samples where there were no bacteria detected could have had contamination at lower levels than we could detect. The overall conclusion of consistent contamination is not affected by this limitation.

Sample sizes. Sample sizes for some of the categories (for instance, pump wells and rainwater harvesting) was lower than optimal, and values may not be exactly representative. However, in the context of public health actions, obtaining an exact value is perhaps less important than observing that there are cases where bacterial contamination is unacceptable. Thus, while only 12 rainwater sources were tested, the fact that 3 of these had measurable fecal coliforms still raises concerns about significant potential health risks.

Limitations of survey questionnaire. Questionnaire data were self-reported for communities, which raises concerns about biased responses. For instance, some interviewees may have been biased in their responses to questions of whether water is treated; conceivably tilting answers towards what they perceive as the "right answer", or alternatively towards answers that might increase the possibility of receiving more "stuff" for the community. Although questionnaires were translated by native Kikamba speakers, there is always the possibility that some errors could have occurred in the translation step. In general in the larger sand dam evaluation we put less emphasis on interview data. While the specific results of the survey data may not precisely reflect the community, we believe they reflect the general trends.

Methods

Bacteria

Bacteria were tested on Easygel cards, a newer technology based on the traditional Easygel petri dish method. This method is able to distinguish general and fecal coliforms (GC and FC) based on colony color. Cards were transported at room temperature to Kenya, where they were stored in the freezer (-4^{o}C) until taken to the area of Kenya being studied. Cards were held in the dark at all times, sealed in plastic bags. In Kitui and Machakos, the cards were held at room temperature in a storage container to prevent temperature fluctuations and light exposure. Cards were then transported to the field for sampling, with care taken not to leave them in a hot vehicle.

We tested 0.5 ml for all water samples except control (bottled water) where 1 ml was used. Separate sterile plastic pipets were used for each sample. We took care to perform sampling in the shade to avoid strong sunlight exposure, and metal tweezers were used to lift the plastic cover of cards by the edge. Care was taken not to touch the card surface or the tip of the sampling pipet. After plating, cards were held horizontal until the water no longer ran, to prevent any sample from running off the card. Cards were then stored in a smaller cooler to provide a constant temperature environment. When possible, a water bottle with warm water was included in the cooler to raise the incubation temperature to around 37^{o}C (recommended incubation temperature). When not possible, the incubation was at room temperature. Card incubation therefore fluctuated between approximately 25^{o}C and 37^{o}C. After 1-2 days, depending on speed of colony growth, colony forming units (cfu) were counted and photos taken for all cards. All samples were performed in duplicate, average RPD (relative percent difference) between duplicate cards was 44% for fecal coliforms.

Average bacteria counts are expressed as geometric means, as per the convention for water bacteria data. Since geometric means calculations cannot handle zero values, all values were increased by 1, and then the calculated geometric means was subsequently decreased by 1. Standard deviations, and statistical analyses were based on log transformed data. Since water was taken as 0.5 ml samples, the effective limit of detection (LOD) was 200 cfu/100 ml for a single test. With duplicate samples per site, we assume an LOD for a site of 100 cfu/100 ml. Cards showing zero FC did not, therefore, imply that water was within the WHO limit of no FC per 100 ml. (For example, if a water source was even within the "medium" risk level of 10-100 FC/100ml, it is still likely that a 0.5 ml sample of the water would not have included an FC in the test). Although this did not allow for fine distinctions at low bacterial levels, most samples were above this LOD.

Negative control samples were tested on a regular basis. Negative controls were either purchased bottled water, or SODIS treated water. Of 25 negative controls tested, two controls had bacterial colonies (with only 1 GC colony on each of these tests); the remaining 22 controls had no bacteria.

pH

We used pH paper to estimate the pH of water samples. In most cases, fine scale paper was used giving a resolution of 0.2 pH units. When the supply of the fine scale paper was exhausted, coarse scale paper was used with a resolution of 1 pH unit. Paper was dipped in the water, shaken very briefly, and then compared with a color scale immediately.

Conductivity

Conductivity was measured with a Hanna Pocketester field instrument. The instrument was calibrated at the start of the day to 84μS. Normally the instrument was very stable, such that the morning conductivity value prior to calibration was not far from 84μS. Two consecutive measurements were made from each sample, and the average used as the final value. Salinity in ppm was calculated as 0.65 x conductivity in μS.

Questionnaire

Two project staff were selected as interviewers, one for Kitui and one for Machakos/Makueni. Community members were normally identified and contacted in advance. In some cases, individuals to interview were identified once at the site. A single interview session was conducted at each site, with the group size varying between a single individual and larger groups of around 10 individuals (the median number of people present was 3). The lead interviewees (primary contact for the group present, and the lead spokesperson in the interview) were female in 47% of interviews conducted; median age of the lead interviewee was 51. Normally in groups there was a lead individual who led responses to questions. Individuals and groups were those that used the dam, or were part of the groups that made and managed the dam. All interviews were conducted in the local language, Kikamba, by native Kikamba speakers. Interviewees were requested to answer based on what they know of perceptions and behaviors of the community as a whole, not just their own perceptions and behaviors. Answers were recorded in English, and interviews normally lasted approximately 30 minutes. Interviews therefore largely represented single group (or in a few cases single individual) perspectives on the sand dam; we did not perform multiple interviews at each dam. The interview questions and data sheet are included in the addendum.

Selection of sand dams

Questionnaire data was collected from dams as described below (from the accompanying full evaluation report for this study; see that report for more details on methods and limitations of dam selection). Water testing during the dry season was from the dams on this selection list which had water. Water testing in the wet season was not based on random selection; it included both return visits to some dams visited in the dry season, plus other dams that were chosen based on availability.

In order to avoid biases, and in an attempt to get a representative sample of the population of sand dams in Ukambani, sites were selected on a random basis. Initial sand dam sites were selected from lists of dams that SASOL (505 dams) and UDO (448 dams) had constructed. Because records of sand dams constructed from earlier (early 1990) were not kept, selected sites mostly represented dams that were not older than 20 years. The entire lists were randomly ordered using Excel, and the first 40-50 dams from each of the UDO and SASOL lists were taken as the initial selections. Several alternations were needed on those randomized lists. In particular, there were 12 cases dams could not be located or records were otherwise inaccurate. If in the field with community members, this normally involved searching a number of sites for the correct dam, which was not found. In those cases, we selected the last site searched, as a substitute for the original dam sought. In other cases, there was no clear information on where to search for a dam; these sites were dropped and the next on the list (for example, starting at the fifty-first on the randomized list) was added to the selection. Due to time constraints, we visited 49 UDO dams, and 40 SASOL dams. In addition, eight colonial-era sand dams (1950’s or early) were selected in Kitui. Eight colonial dams were selected, based on SASOL’s familiarity knowledge of their presence, their historical work with communities adjacent to these dams, and as a broad representation of the location of these dams.

Randomly selected dams were analyzed together with colonial-era dams. Estimates of sand dams in Ukambani are as high as 5000 [ref], and the total of 98 sites visited would also be at the 10% confidence interval[17] for this total number of dams in the region, although the dams visited are not a truly representative sample from that entire population (since there are not records for the earlier dams constructed in the region, and therefore no means of making a list from which to sample them).

[17] https://www.surveymonkey.com/mp/sample-size-calculator/

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Addendum

Statistical test for bacteria in water sources

Pairwise comparisons were made using the Tukey post-hoc test, p values for paired comparisons are shown in the tables below. Statistical significance is indicated at the $p<0.05$ (yellow) and $p<0.1$ (light yellow) levels.

Wet season, Fecal coliforms

	Surface	Scoop hole	Dug well	Pump well	Household
Surface					
Scoop hole	0.44				
Dug well	0.90	0.90			
Pump well	0.03	0.00	0.06		
Household	0.01	0.00	0.04	0.90	

Wet season, General coliforms

	Surface	Scoop hole	Dug well	Pump well	Household
Surface					
Scoop hole	0.22				
Dug well	0.90	0.59			
Pump well	0.00	0.06	0.02		
Household	0.43	0.90	0.66	0.11	

Dry season, Fecal coliforms

	Surface	Scoop hole	Dug well	Pump well	Household
Surface					
Scoop hole	0.15				
Dug well	0.19	0.90			
Pump well	0.64	0.03	0.04		
Household	0.90	0.32	0.25	0.85	

Dry season, General coliforms

	Surface	Scoop hole	Dug well	Pump well	Household
Surface					
Scoop hole	0.26				
Dug well	0.69	0.90			
Pump well	0.41	0.02	0.10		
Household	0.90	0.54	0.77	0.58	

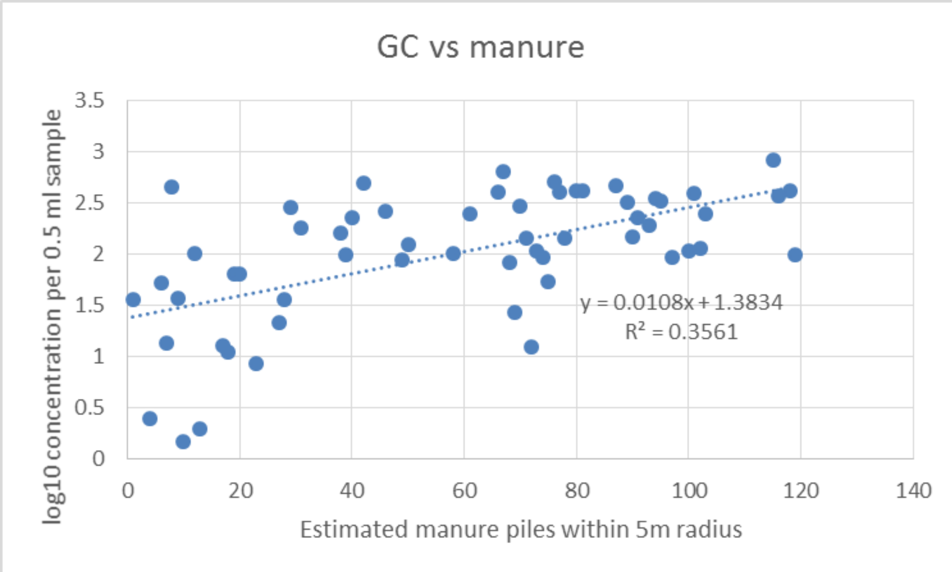
Statistical comparisons of scoop hole characteristics

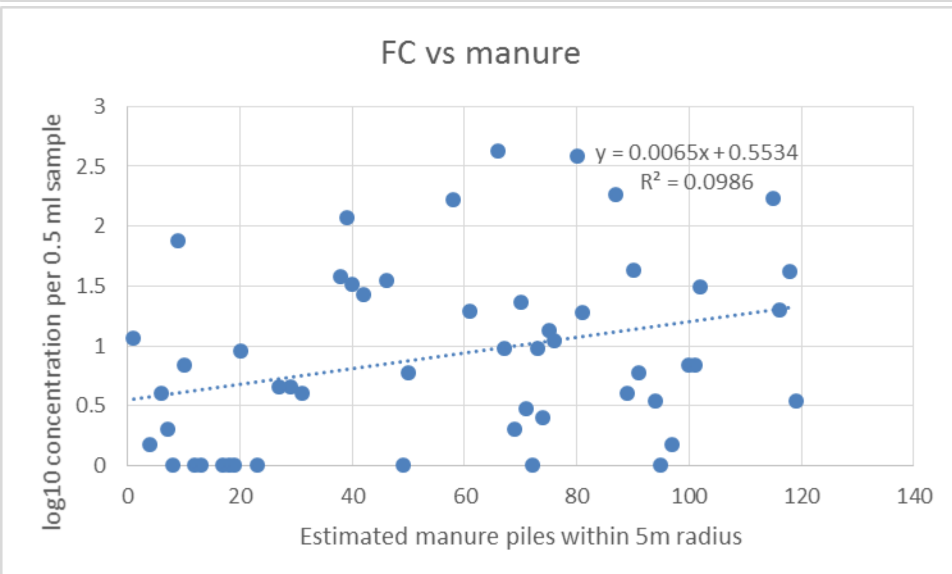
Data are as $\log_{10}$ concentrations (per 0.5 ml sample) and p values for paired t-test comparisons

	Fecal coliforms	**General coliforms**
Scoop hole exclusion		

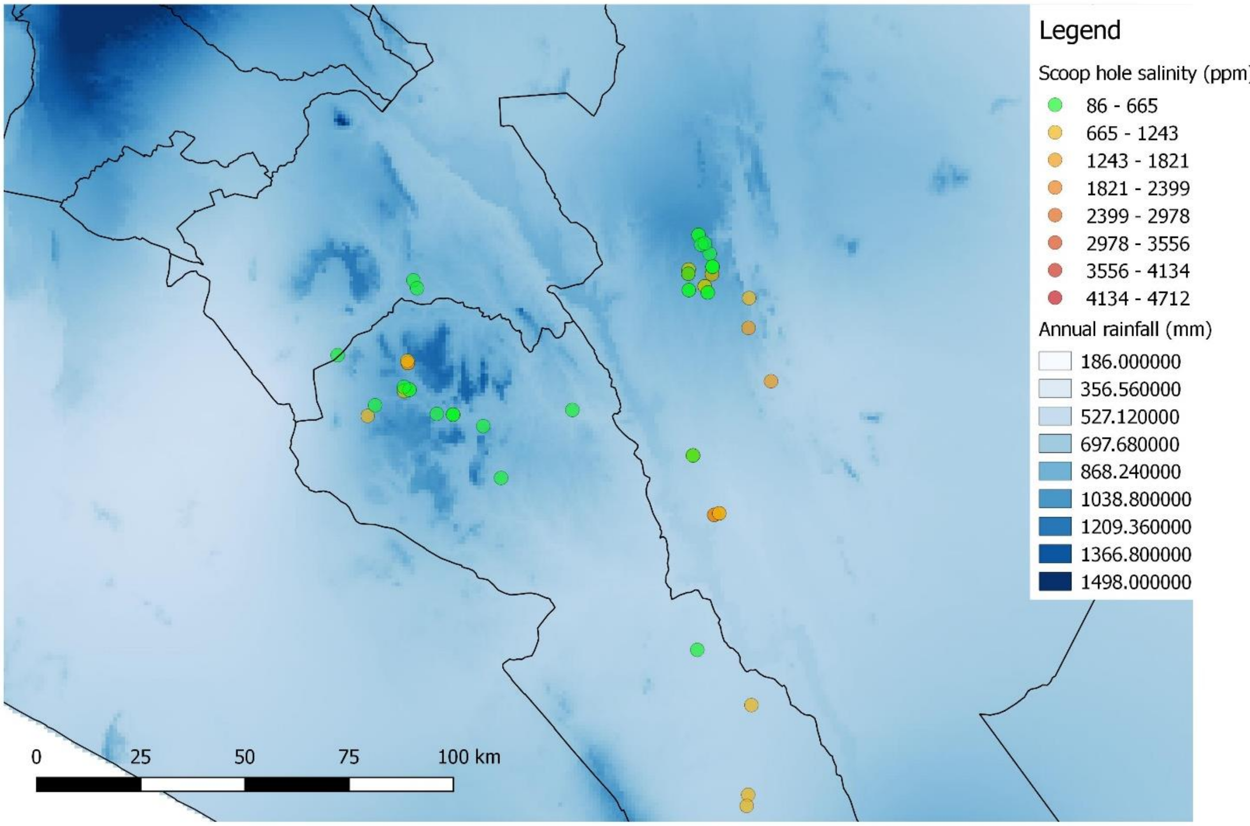
Fenced (N=12)	1.02 ± 0.79	2.14 ± 0.56
Not fenced (N=42)	0.85 ± 0.71	1.94 ± 0.67
	p=0.47	*p=0.35*
Scoop hole depth		
Shallow (<0.5m) (N=27)	1.10 ± 0.58	2.34 ± 0.33
Medium (0.5-2m) (N=17)	1.04 ± 0.83	2.23 ± 0.46
Deep (>2m) (N=10)	0.72 ± 0.68	1.71 ± 0.72
	p=0.22	*p=0.004*
Scoop hole location		
Dam surface (N=40)	0.67 ± 0.69	2.02 ± 0.62
Downstream from dam (N=15)	0.97 ± 0.70	2.00 ± 0.74
	p=0.16	*p=0.95*
Statistics of fencing and scoop hole location used t-test; Depth used ANOVA		

Correlation of scoop hole contamination with manure piles in the scoop hole vicinity





Scoop hole salinity compared with annual average rainfall.



pH in water sources

	Dry season	Wet season
Scoop holes	6.27 ± 0.30, N=54	6.36 ± 0.46, N=25
Dug wells	6.36 ± 0.34, N=15	6.33 ± 0.60, N=6
Surface water	6.26 ± 0.27, N=26	6.21 ± 0.50, N=26
Pump wells	6.71 ± 0.27, N=7	6.90 ± 0.32, N=10
Household water	6.46 ± 0.46, N=7	5.58 ± 0.52, N=16

Survey questionnaire items relating to water perception and use

Full data sheets for the sand dam evaluation are shown below, including those sections not directly addressing water quality, perception or use. See sections 7&8 for water quality parameters, and section 11B for water perception and use.

Checklist of needed field items

- ☐ Survey sheet, pen
- ☐ GPS unit
- ☐ Camera
- ☐ Tape measures
- ☐ Laser distance finder
- ☐ Soil corer
- ☐ Soil sample bags, labels
- ☐ Permanent markers
- ☐ Shovel
- ☐ Conductivity meter
- ☐ Conductivity Standard
- ☐ pH paper
- ☐ Bacteria test cards
- ☐ Water sampling pipet
- ☐ Tweezers
- ☐ Dark container

Survey by: ____________________________________ Date: _________________

1. Coordinates at center of dam structure:

Name of Dam: ____

Latitude (Southing) in decimal degrees __________________

Longitude (Easting) in decimal degrees __________________

2. Photographic record (Record first picture number in series for this dam:_______)

a. View of entire dam site (from a vantage point up a bank from the dam)____________
b. Face of dam (from downstream, facing upstream)____________
c. Informational plaque ____________
d. Side view showing area immediately upstream of the dam (and including the dam)____________
e. View of drawback from the center of the dam structure (take from standing position)____________
f. Downstream view from dam structure, showing the stream downstream ____________
g. Proceed at least 1 dam length downstream, view of stream bed with banks (view from center of stream, plus view of the banks)_____________
h. View of the end point (drawback point) of the dam ________________

3. Indicate extent of:

a. Standing water downstream from dam:

b. Evidence of erosion at dam base:

c. Structural failure of dam:

d. Evidence of leakage from the dam:

4. Dam structure Sketch the dam face, include all relevant dimensions. Include total dam height (meters, to the nearest cm) for at least 5 places along the front of the dam.
Indicate right side on sketch. Right side is define as facing: ☐ upstream *or* ☐ downstream?

5. Estimated Drawback

Distance from dam along estimated thalweg (deepest part of the channel): ____________________

Latitude (Southing) in decimal degrees ___________________

Longitude (Easting) in decimal degrees ___________________

6. Width & Adjacent land use & characteristics

Sketch the surface of the dam site, including measured width (meters, to the nearest cm) at 30 m intervals (or a minimum of 4 locations) along the length of the dam. Sketch location of vegetation, animal waste, extraction/scoop holes, pump wells, etc. (any evidence of human usage). Along dam surface, record presence of animal waste or vegetation along transect line.

Record land cover/activities in transects away from dam site, at 20-50 meter intervals along each bank. Record distance from edge of bank for each location.

7. Sand/Soil Cores Soil cores to maximum depth of sampler at 3 locations (dividing width into quartiles): 2 meters behind dam (A), ¼ (B), ½ (C), and ¾ (D) distance to drawback. (see example in appendix). Record observations from the cores (such as layers of sand/silt). Indicate how deep the core was taken.

A - near dam

Right

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

Center

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

Left

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

B - 1/4 from dam

Right

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

Center

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

Left

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

C - 1/2 from dam

Right

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

Center

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

Left

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

D - 3/4 from dam

Right

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

Center

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

Left

Moisture	Sand	Silt	Clay	
				0.1
				0.2
				0.3
				0.4
				0.5
				0.6
				0.7
				0.8
				0.9
				1.0
				1.1
				1.2
				1.3
				1.4
				1.5

Pool 3 samples (for instance, the 3 from section A) from each location into a bag for later analysis

7. Water Sample – Conductivity (uS/cm) and pH

	Conductivity (duplicate samples)	Temperature	pH
Pump well			
Scoop well(s)			
Surface water			

8. Water Sample – Bacteria

<u>*At each selected site for bacteria measurements. Label cards, and indicate here the labels:*</u>

Approx. time of plating on cards: ______________________

	Label	Volume of water plated	Purple colonies, indicate time and date read	Blue colonies, indicate time and date read	Manure piles within 5 m radius of source
Negative Control [1; clean, filtered water]					
☐ Scoop Hole ☐ Pump Well ☐ Open Well ☐ Surface Water					
Describe location and appearance. Is it being used as a drinking source?					
☐ Scoop Hole ☐ Pump Well ☐ Open Well ☐ Surface Water					
Describe location and appearance. Is it being used as a drinking source?					

☐ Scoop Hole ☐ Pump Well ☐ Open Well ☐ Surface Water					
Describe location and appearance. Is it being used as a drinking source?					

9. Water Sample – Nutrients

10. Observations

Were there people utilizing the dam at the time of the survey? (describe number of people/animals and activities; indicate whether this was at scoop holes, pump wells, downstream etc)

Was there any water observed? (for example, pooled water, or wet sediment in dam cores) Indicate the number of scoop holes present with water. *We want a sense of whether water is currently stored in the dam.*

Double check:

- When leaving, is all equipment with you?!
- Are bacteria cards covered from the sun? Are they flat for 15-30 minutes after plating?
- Is all information recorded on the sheets?

11. Questionnaire **Date ________________________**

Name of Dam___________________________ **Name of interviewer______________________**

Identify at least two people in the region to interview. Preferably these are users of the dam, who have lived in the area for the duration of the dam.

> Hello! My name is _________________________, I am one of the researchers working with ________________________________. You were selected as a potential participant in this study because you are currently residing near this sand dam. We wish to understand the usefulness and limitations that sand dams pose in this region of Kenya. We will be asking some questions on sand dam function and usefulness. Participation in this interview is voluntary. The interview will take about 20 minutes. You can choose to stop the interview at any time or not to answer any question. If you decide not to participate in the interview or in answering questions, there will be no repercussions.

Name: ____ M/F Age__________

Were other people present during the interview? If so, how many?

Information about interviewee's relationship to the dam (such as: do they live near the dam? are they a group member?) ____________________

Does the respondent use the dam? Y / N How long has the respondent lived in the area? _________

Subcounty_____________ Ward________________

Sublocation ____________ Village________________

<u>A. Questions about the surveyed sand dam</u>

1. Does the dam run out of water? When? (how many months?)

2. Who uses the dam? (about how many households? Indicate if this number includes users of nearby dams)

3. Who is allowed to take water from the dam? How is water use managed? (if there is a management committee, what do they do?)

4. Is there (or has there been) any conflict over use of water? (or has conflict changed since building the sand dam?) What impact have you observed on **community relations** due to the sand dams? (positive or negative)

5. Is sand harvested from the dam? By whom and for what purpose? (Is there a policy on sand harvesting?)

B. Water Use

1. What are the main uses of water from the sand dam? (household, drinking, irrigation, cattle, etc.) Identify the use that requires the most water. (circle)

2. Is the water clean for drinking? (How clean is the water?) Why or why not?

3. Are there issues with color, taste, odor of the water?

4. Do you treat water before it is used for drinking? If so, how is it treated?

5. What is the main source of drinking water during the dry season?

6. What is the main source of drinking water during the wet season?

7. [for selected households, at dams where bacterial testing is performed]. "May we take a sample of water from your household that you use for drinking, in order to test for bacterial contamination?"

Time of plating on card: ______________________

	Label	Volume of water plated	Purple colonies, indicate time and date read	Blue colonies, indicate time and date read
Household water source [2]; duplicates				

C. Benefits and Costs

1. Briefly describe how this sand dam was built. What was the level of the community involvement in the construction process?

3. How is the sand dam impacting the surrounding communities? Which do you consider the most important impact? Has that impact changed over time?

4. Has the sand dam impacted women, men, boys, and girls differently? If so, how does it impact these groups differently?

5. What are the main challenges to adoption of sand dams by a community? Was there a cost to communities in adopting a sand dam? (either financial cost, or any other cost)

D. Nearby sand dams

1. Are there other sand dams in the region?

2. Where are they located? (Give a distance if possible) *If other sand dams are easily reached, take GPS coordinates for those sites.*

3. Is anything known about the history of the other dams (such as when it was built)?

4. Are the other sand dams being utilized? What for?