Water quality risks of "improved" water sources: evidence from Cambodia

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ABSTRACT

Objectives: To investigate the quality of on-plot piped water and rainwater at the point of consumption in an area with rapidly expanding coverage of “improved” water sources.

Methods: We conducted a cross-sectional study of 914 peri-urban households in Kandal Province, Cambodia, between July-August 2011. We collected data from all households on water management, drinking-water quality, and factors potentially related to post-collection water contamination. We took drinking-water samples directly from a subsample of household taps (n=143), stored tap water (n=124), other stored water (n=92), and treated stored water (n=79) for basic water quality analysis for *E. coli*, and other parameters.

Results: Household drinking-water management was complex and dynamic, with different sources used at any given time and across seasons. Rainwater was the most commonly used drinking-water source. Households regularly mixed different water sources in storage containers, including “improved” with “unimproved” sources. Piped water from taps deteriorated during storage ($p<0.0005$), from 520 cfu/100 ml (CV: 5.7) *E. coli* to 1100 cfu/100 ml (CV: 3.4). Stored non-piped water (primarily rainwater) had a mean *E. coli* count of 1500 cfu/100ml (CV: 4.1), not significantly different from stored piped water ($p=0.20$). Microbial contamination of stored water was significantly correlated to observed storage and handling practices, including dipping hands or receptacles in water ($p<0.005$), and having an uncovered storage container ($p=0.052$).

Conclusions: The quality of “improved” water sources in our study area was not maintained at the point-of-consumption. These results have implications for refining international targets for safe drinking-water access as well as the assumptions underlying global burden of disease estimates, which posit that “improved” sources pose minimal risks of diarrhoeal diseases.

INTRODUCTION

The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP) tracks global coverage of water and sanitation, dividing water and sanitation access into "improved" and "unimproved" categories, with "improved" sources defined as those assumed to pose a lower risk to health (Table 1). In its *2012 Update*, the JMP indicated that the global Millennium Development Goal (MDG) to "halve, by 2015, the proportion of people without sustainable access to safe drinking-water" [from 1990 levels] had been met in 2010, with global coverage of "improved" water sources at 89% (WHO/UNICEF 2012). The definition of "improved" does not, however, include any measure of the consistency of access or the microbiological or chemical quality of water delivered. These definitions have wider implications: a 2012 global burden of disease comparative risk assessment used the JMP definition, considering "improved sources" as having very low attributable health risks (Lim *et al.* 2012). Even so, there is a growing body of evidence suggesting that there are health and other advantages offered by consistently treated on-plot water access over other "improved" sources that may be less safe (Brown *et al.* 2013; Bartram & Cairncross 2010; Cairncross & Valdmanis 2006). Conflicting viewpoints reflect the lack of global data on the relative safety and sustainability of different "improved" sources, and underline the need, as noted by the JMP, for improvements to current indicators in post-2015 monitoring (WHO/UNICEF 2012).

Cambodia has seen "improved" water access rise from 48% in 1990 to 63% in 2000 and 87% in 2010, with piped, on-plot access rising from 15% to 63% between 1990 and 2010 (WHO/UNICEF 2012). At the national level, Cambodia has handily met the MDG water access target. Rapid expansion there has followed national decentralization policies encouraging construction of public and private water supply systems, with particularly rapid growth of privately operated supplies (UNDP/UNICEF 2009; ADB 2007). Many small water supplies remain within the informal sector, however, possibly due to complex registration and licensing procedures, limited monitoring and regulation, and associated formal and informal charges (ADB 2007). Anecdotal evidence suggests that there is considerable variability in terms of service reliability and management, treatment effectiveness, water quality, and quantity available to connected households (ADB 2007; JICA 2010; Feldman *et al.* 2007), though these attributes have not been systematically assessed and no formalized monitoring system is in place. Many piped-to-plot supplies – counted as "improved" – are intermittently operated and use minimally treated or untreated surface water.

In order to gain perspective on the rapid growth of "improved" water access in Cambodia, we examined water quality and household-level water management in two communities with high (97%) coverage of "improved" water, including on-plot connections to a piped supply (25%) and rainwater harvesting (95%). The goal was to understand whether these “improved” drinking-water sources could also be characterized as low-risk sources. Our choice of sources allowed us to observe the quality dynamics of two particular “improved” water sources, available in adequate quantity and present on-site. By contrast, the majority of papers on this topic have examined sources outside the household.

METHODOLOGY

We conducted a cross-sectional survey in two peri-urban sites (sites “A” and “B”) between July and August 2011. We used a census-derived list of approximately 1000 community water sources in Kandal province, which, in consultation with local government officials was used to identify private piped systems. We identified twelve candidate sites meeting selection criteria of (i) high access to improved water, including piped water, (ii) peri-urban or urbanizing area, and (iii) proximity to the water quality laboratory. As the province surrounding the capital city of Phnom Penh, Kandal is the most rapidly urbanizing area of Cambodia (6), with rapid expansion of piped water networks. Sites A and B were selected from eligible areas based on interest in water quality issues among the village leadership and system operators, and after consultation with local government authorities. Many households in both villages had private piped water connections, although the reliability and quality of water delivered was highly variable and a number of households only relied on piped connections in the dry season. Piped water at site A was subjected to basic but inconsistent treatment (occasional chlorine pre-treatment, followed by flocculation and sedimentation); piped water at site B was untreated. Both piped systems abstracted surface water and were operated intermittently. We selected households at random from within village boundaries and presented an adult member of the household with informed consent information. We then enrolled consenting households, who agreed to respond to a questionnaire covering a range of issues related to water use, water safety, health, and related knowledge, attitudes, practices, and beliefs. A subset of households also supplied water samples.

We collected water samples from households with functional piped connections on the premises (either inside the living area or in the yard), which accounted for at least part of their drinking-water. Approximately 80% of such sources were randomly sampled, with sampling limited by laboratory sample processing throughput. Samples included piped water at tap, stored piped water, non-piped stored water (usually rainwater), and treated (usually boiled) water. We tested water samples for *E. coli* and basic physical-chemical measures (pH, temperature, turbidity, free and total chlorine at the point of sampling). For microbial samples, we used sterile Whirl-Pak™ sample collection bags (Nasco Corp., FA, USA) and transported samples on ice after collection for processing within 24 hours at our laboratory. Chlorine residuals were tested at the point of collection from the single site where piped water was treated with chlorine (site A) at the point-of-entry and at-tap in a random selection of households.

We used membrane filtration for processing microbial indicator samples. Following filtration through sterile 47 mm, 0.45 µm pore size cellulose membranes (Millipore, Bedford MA, USA), we placed membranes on 60 mm plates of selective agar medium (Bio-Rad Rapid *E.coli* 2™), and incubated at 35°C for 18 - 24 hours. We processed all water samples in duplicate, with three dilutions each. We measured pH and temperature using a Hach pH meter and turbidity using a Hach nephelometer (Hach, Loveland, CO USA). We tested free and total chlorine using a Hach chlorine test kit (Hach, Loveland, CO USA).

Following double entry and verification of all data in EpiData (EpiData Association, Odense, Denmark), we performed data analysis in both Excel and in STATA 11.1 (Statacorp, TX, USA). For assessing trends and differences between covariate groups, we used non-parametric statistical tests of heterogeneity, including Kruskal-Wallis and Wilcoxon rank-sum tests. For microbial quality measures, we used arithmetic means as indicators of risk (Haas 1996), Williams means as potentially more accurate indicators of central tendency (Alexander 2012), and geometric means for comparability with other published findings that report this measure. We used negative binomial analyses to investigate predictive factors for water quality at various household water points (Alexander 2012). We used raw mean counts of *E. coli* in negative binomial regression, with outcomes expressed as risk ratios (RRs), estimating the change in the relative mean number of events between categories (McElduff *et al.* 2010). As these data were drawn from a larger study powered for other indicators, water quality data were not powered for full multivariate analysis. We report possible correlation where our findings showed statistical significance in both our regression analyses and non-parametric tests of homogeneity.

We obtained ethical approval for this study from Duke University's Institutional Review Board, the London School of Hygiene & Tropical Medicine's Research Ethics Committee, and the Cambodian National Ethics Committee for Health Research.

RESULTS

Table 2 summarizes key descriptive data. We visited a total of 914 households, with an average of 5.3 members per household. We did not detect free or total chlorine in any sample from site A's distribution network (n=50, detection limit: 0.10 mg/l). More than 95% of households in these two communities had access to an "improved" water source at the household level. All households practiced domestic water storage.

Household water management and perceptions

Our questionnaire revealed heterogeneity in water use behaviours among households in the sample, within and across seasons. Approximately 77% of study households used different quantities and/or sources between seasons, often using a primary source supplemented by one or more secondary sources. Rainwater was the most commonly used source. It was the primary source for 82% of households in the rainy season, and stored rainwater was the most widely used secondary source in the dry season. After rainwater, three other sources were commonly used: raw surface water, water vendors, and piped water (Figure 1).

Households stored water from a number of different sources, and consumed certain types directly without treatment. We divided household storage containers into three main categories: those primarily storing piped water (usually large concrete jars connected to the piped water tap); those primarily storing non-piped water (concrete jars either connected to rainwater drainage pipes or open to any source), and those storing water treated at the household (usually a smaller container kept in the household). Approximately 94% of all households had stored, non-piped water, 30% had stored, on-plot piped water, and 63% had stored treated water available during our visits. Approximately 56% of households reported drinking untreated water directly from household storage containers, most commonly using the major primary and secondary sources listed above (Table 2). Direct consumption without treatment differed significantly across different sources (p=0.0001) with stored rainwater consumed the most frequently, followed by bottled water, raw water, vended water, and piped water. In the dry season, households also supplemented their water by purchasing it from vendors providing untreated surface water. Households commonly mixed water from various sources together, including from “improved” and “unimproved” sources. Three quarters of containers storing piped water also contained water from other sources, and all storage container types were at least 20% composed of mixed – including unimproved – sources (Table 2).

We also asked households about the perceived safety of different sources. Approximately 72% of households reported no aesthetic or health concerns related to water in the rainy season, compared with 57% in the dry season. Rainwater was perceived to be of the highest quality, with over 90% of users reporting “no concerns” in either season. By contrast, only 55% of piped water users had no concerns across both seasons, and reported the major issues as being that it “looked bad” (approximately 20%), and was “bad for health” (approximately 7%). Responses were similar for raw water and vended water where 50-60% reported no issues, and the major ones mentioned were physical appearance and health concerns. Water quality perceptions are further explored in another publication from this dataset (Orgill *et al.* 2013).

Water quality

We investigated *E. coli* counts in four water sample types: 1) piped at-tap (n=143); 2) piped and stored (n=124); 3) non-piped and stored (n=92); and 4) treated and stored (n=79). We only investigated microbial quality across sources in households that also had running piped water, to observe the difference between the tap and point-of-use. Microbial levels were found to be significantly different across all four sources (p=0.0001). *E. coli* counts in piped water at tap were far lower than those of stored piped water (p<0.0005) , suggesting household-level recontamination or growth of *E. coli* in storage. The arithmetic mean of tap water was 520 cfu/100 ml (CV (coefficient of variation): 5.7), rising to 1100 cfu/100ml (CV: 3.4) during storage (Table 3). Williams's means increased from 11 cfu/100 ml to 68 cfu/100 ml.

Water quality at tap was the only source found to differ significantly between sites A and B (p=0.001). Williams' means of *E. coli* were lower at site A (6.9 cfu /100ml, n=95)), where there was rudimentary water treatment, than in site B (34 cfu/100ml (n=48)). We detected no difference in counts in piped water that was stored between sites, however (p=0.77).

We found no significant difference between *E. coli* counts in piped and non-piped stored sources (p=0.203), though mean stored non-piped water was more contaminated than stored piped water, with an arithmetic mean of 1500 cfu/100ml (CV: 4.1) and a Williams' mean of 40 cfu/100ml (Table 3). Many households had stored, treated (usually, boiled) water on hand which was of significantly lower risk compared to all other household sources of drinking-water (p<0.0005). Stored treated water had a Williams' mean of 3 cfu *E.coli* /100ml, and an arithmetic mean of 350 cfu/100ml (CV: 5.4).

Predictors of water quality

Unhygienic water storage and handling practices were strongly correlated with microbial contamination in water samples. Households accessing water by dipping hands or using a receptacle (as observed during sample collection) had significantly increased *E. coli* counts compared to households that used pouring (*E. coli*: RR 10 95%CI 3.2-34, p<0.005) (Table 4). *E. coli* counts in samples from households having a covered storage container were approximately half of those in samples from households with uncovered containers (RR 0.49 95%CI 0.24-1.0, p=0.052).

DISCUSSION

Our results suggest that "improved" drinking-water sources, considered safe by the global monitoring framework and burden of disease analyses (WHO/UNICEF 2012; Lim *et al.* 2012), can be subject to recontamination once stored at the household level. Complex, variable household water storage and handling practices may be associated with poor drinking-water quality and increased risk. In our study, mean *E. coli* counts across all household sources tested exceeded the Government of Cambodia's limit of <1 cfu/100 ml for *E. coli* (MIME 2004). These levels of *E. coli* probably indicate a higher health risk than that recommended by the WHO's risk-based target for drinking-water quality (10^{-6} DALY per person per year) (WHO 2011c). International standards for drinking-water safety vary, but *E. coli* counts exceeding 100 cfu/100 ml are widely considered to be "high risk" (Brown *et al.* 2008).

There are at least three reasons why near-universal access to "improved" water sources in these study sites has not resulted in consistent access to low-risk water. First, intermittent access to rainwater and piped water has made water storage necessary, and water from all sources is subject to contamination from post-collection handling and storage. Our results are consistent with a number of studies reporting post-collection recontamination (Brown *et al.* 2013; Brick *et al.* 2004; Clasen & Bastable 2003; Copeland *et al.* 2009; Crampton 2005; Jensen *et al.* 2002; Levy *et al.* 2008; Levy *et al.* 2009; Oswald *et al.* 2007; Sodha *et al.* 2011; Trevett *et al.* 2005; Wright *et al.* 2004), although most previous studies have focused on recontamination after collection outside the household. Faecal contamination during water handling was highly plausible in our study setting given the high percentage of households lacking "improved" sanitation (45%), the low prevalence of self-reported hand-washing behaviours (21% after defecation, 10% after cleaning babies), and reported and observed unsafe water handling and storage practices (Table 4).

Second, households commonly mixed "improved" and "unimproved" sources, with the composition of mixed water depending on available sources (Table 2). Furthermore, respondents' reported perceptions of the relative safety of sources were not correlated with microbial contamination, a finding that is explored further in a separate paper from this study (Orgill *et al.* 2013). In contrast to findings from other studies that show higher risk of faecal-oral diseases in the rainy season (Chou *et al.* 2010; Cairncross & Feachem 1993), most households in this study perceived better water quality in the rainy season, and believed rainwater to be the safest source, although our results found it to be the most contaminated of all sources. Previous studies of rainwater harvesting have identified risk factors affecting rainwater quality, including contamination of rooftops or other collection surfaces, as well as unsafe storage and handling (Kahinda *et al.* 2007; Fewtrell & Kay 2007; Ahmed *et al.* 2010; Meera & Mansoor 2006).

Third, piped water supplies delivered surface water that was treated only partially and inconsistently (site A) or was untreated (site B). No chlorine residual was detected in any of the household taps. Both systems operated intermittently, a risk factor for microbial contamination through back-siphonage and infiltration when systems lose positive pressure (Lee & Schwab 2005). Arithmetic mean *E. coli* counts were 520 cfu/100 at the tap, with further microbial contamination during storage. The challenges of operation, maintenance, and management of piped water supplies have been reported in several other studies (Brown *et al.* 2013; Lee & Schwab 2005; Cotruvo & Trevant 2000; Agard *et al.* 2002; Basualdo *et al.* 2000). While microbiologically safe, piped water delivered directly and reliably to households is a good – perhaps the ultimate – end goal for water services provision (Cairncross & Valdmanis 2006), achieving this in practice presents a significant challenge, especially in resource-limited settings.

It is also noteworthy to mention that source-level contamination, which our piped-water data suggests is widespread, can pose a greater public health risk than solely household-level contamination. Risks from the latter are largely limited to household members, while those of the former can be spread through different mechanisms and affect a wider population of end-users. Despite documented risks associated with poor system operation and maintenance, there is a growing body of evidence on the relative health and non-health advantages offered by reliable treated on-plot water access over other “improved” sources (Brown *et al.* 2013; Cairncross & Cliff 1987; Churchill *et al.* 1987; Sorenson *et al.* 2011; Aiga & Umenai 2002; Devoto *et al.* 2011, Tomkins *et al.* 1978, White *et al.* 2002, Tumwine *et al.* 2002, Bartram & Cairncross 2010).

Decentralization, rapid development, inconsistent oversight and regulation, and increasing demand for water services have led to a growth in private water systems of variable quality in Cambodia (UNDP/UNICEF 2009; ADB 2007; JICA 2010). Our observations may apply to other regions as well given the rapid global increase in access to improved sources in areas where the infrastructure and human resources required to maintain and regulate supplies may need further development. Indeed, similar conclusions on the need for appropriate supporting infrastructure to make piped water safer and more sustainable were recently drawn in studies in India (Jalan & Ravaillon 2003), Brazil (Gamper-Rabindran *et al.* 2010) and Yemen (Lechtenfeld 2012).

In terms of protecting drinking-water quality, our study communities would benefit from safer and more consistently available piped water and support for managing household water safety. Adequate treatment, improvements in design (e.g., pressure regulation), and basic support for operation and maintenance is needed in informal systems, many of which are constructed by local entrepreneurs with limited access to resources or knowledge about engineering or safety aspects of water supply infrastructure (Lee and Schwab 2005). Locally viable mechanisms for providing this support are unclear, but optimization of existing systems that provide water at the point of consumption represent “low-hanging fruit” for rapidly expanding safe water access. Extension of local regulation and monitoring may help drive improvements where there is sufficient willingness to pay. Residents may also benefit from access to household-based water treatment and safe storage (HWTS) options and information about risks associated with unsafe water. Information about water safety and access to HWTS are intermediate, short-term levers that may deliver some benefits of improved water quality where infrastructure services are lacking. Rigorous studies of the effect of household-specific water quality information show that households, when informed about contamination, do adjust their water sourcing and/or treatment practices to utilize safer alternatives (Jalan & Somanathan 2008; Hamoudi *et al.* 2012). However, more research is needed on the content and delivery of such information to effect sustained behaviour change (Huber & Mosler 2012; Lucas *et al.* 2011), and on evidence based behaviour change interventions to more generally improve and sustain water, sanitation and hygiene practices (Mosler 2012; Fiebelkorn *et al.* 2012). While we acknowledge challenges to achieving high adherence to HWTS (Brown & Clasen 2012; Schmidt & Cairncross 2009), the near universal reliance on water storage and the quality disparity between “safe” and “improved” sources suggests that there is a role for targeted, context-specific, and effective HWTS methods as interim solutions. Although many households in our study practiced point-of-use treatment of stored water (boiling, in 80% of instances), with 72% of samples being low-risk (≤10 cfu/100 ml *E. coli*) after treatment, the relatively high arithmetic mean suggested that boiling may not always have been protective. Another study from peri-urban Cambodia found that boiling may not be consistently practiced by most households who report it (Brown & Sobsey 2012). Other options such as filtration and point-of-use or point-of-collection chlorination have shown promise in terms of improving water quality, but many challenges related to stimulating correct, consistent, and exclusive use of such technologies remain (Ahmed *et al.* 2011; Kremer *et al.* 2011; Whittington *et al.* 2012). More studies may be needed to identify appropriate and effective solutions with scale-able promise while concurrent efforts are underway to improve the safety and reliability of piped, treated water supplies.

Our study suggests that the problem of poor water quality is much more complex than simple characterization of water supplies as “improved” and “unimproved” according to global current definitions (WHO/UNICEF 2012). It is notable that the words “safe” and “sustainable” are explicit in the wording of the MDG target (WHO/UNICEF 2012), although neither of these qualities is systematically monitored at the global level, partly because there are no international consensus definitions of “safety” or “sustainability” of water supplies. The JMP acknowledge the limitations of current global water metrics and have been leading efforts to overcome the significant challenges to using measures of safety and sustainability in the post-2015 targets for expanding access (WHO/UNICEF 2012). While Cambodia and the globe are on track for achieving the UN MDG water target, diarrhoeal morbidity still ranks as one of the top five causes of global DALYs (Lim *et al.* 2012). Furthermore, cholera cases, for which the main prevention measure is safe drinking-water, sanitation and hygiene, have increased dramatically in Cambodia, Southeast Asia, and the entire globe (WHO 2013). In addition to increasing access to basic infrastructure and services, a greater focus is needed on assuring the safety of such services, especially to those most at risk for diarrhoeal disease. Such efforts would contribute to MDG targets for poverty reduction, nutrition, childhood survival, school attendance, and gender equity and would contribute to fulfilling WHO and Member State obligations (WHO 2011a; WHO 2011b). While real progress has been made in global access to water, the estimated 780 million without “improved” water (WHO/UNICEF 2012) and the potentially much higher number lacking access to microbiologically or chemically safe drinking-water deserve sustained international attention and continued meaningful investment.

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TABLES AND FIGURES

Figure 1: Water sources by season

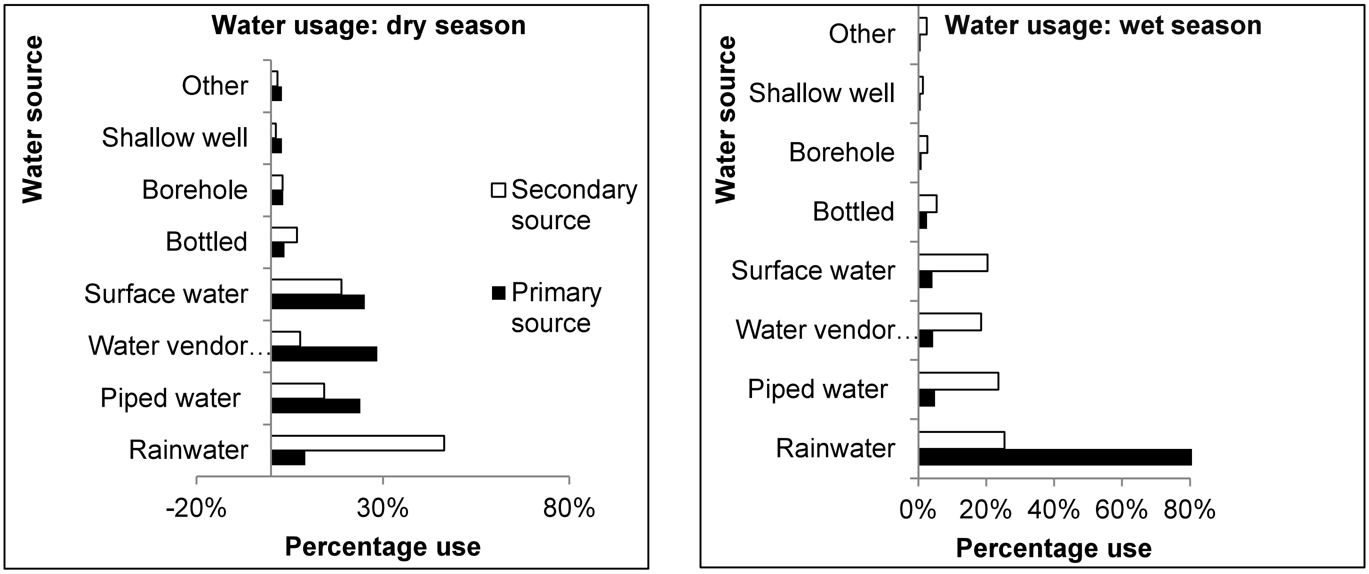

Table 1: Summary of the JMP definition for improved and unimproved drinking-water sources (WHO/UNICEF 2012)

IMPROVED SOURCES	UNIMPROVED SOURCES
Piped water into dwelling, yard, or plot	Unprotected dug well
Public tap or standpipe	Unprotected spring
Tubewell or borehole	Cart with small tank or drum
Protected spring	Tanker drum
Protected dug well	Surface water (river, dam, lake, pond canal, irrigation channel)
Rainwater collection	Bottled water (considered improved when household uses drinking-water from an improved source for cooking and personal hygiene)

Table 2: Summary characteristics of the total study population

CHARACTERISTICS		POPULATION VALUES
SOCIODEMOGRAPHIC	Total number of HHs	914
	Total individuals	4842
	Mean people per HH	5.3
	Females	2547 (53%)
	HHs with children under 5	370 (41%)
	Illiterate HHs	43 (4.7%)
	Avg. years of adult education/HH	5.7
	Mean self reported HH income	125 USD
	Mean self reported HH expenditure	118 USD
WATER USAGE	HHs that change water source by season	77%
Major sources consumed untreated	Rainwater (n=869)	54%
	Water vendor (n=275)	35%
	Raw surface (n=269)	38%
	Bottled water (n=98)	43%
	Piped water (n=225)	20%
	Borehole private(n=73)	15%
	Neighbour (n=57)	14%
Composition of household stored water		
Stored piped water	Household pipe (n=160)	65%
	Rainwater (n=34)	14%
	Mixed (including unimproved sources) (n=49)	20%
	Other (n=4)	1%
Stored non-piped water	Surface water (n=13)	2%
	Rainwater (n=612)	72%
	Rainwater mixed with other sources (n=187)	22%
	Water vendor (n=15)	2%
	Other (n=20)	2%
Stored treated water	Household pipe (n=29)	5%
	Raw surface water (n=22)	4%
	Water vendor (n=25)	4%
	Rainwater (n=314)	55%
	Bottled (n=12)	2%
	Mixed (including unimproved sources) (n=157)	28%
	Other (n=13)	2%

SANITATION & HYGIENE	HHs with soap present during visit	732 (83%)
Access to sanitation	Improved	495 (55%)
	Unimproved	403 (45%)

Table 3: Overview of *E.coli* counts across four major household sources

E.coli cfu/100ml	Piped: tap	Piped: stored	Non-piped: stored	Treated: stored
n	143	124	92	79
<1	67 (47%)	22 (18%)	28 (30%)	57 (72%)
1-10	7 (5.0%)	12 (10%)	6 (7.0%)	6 (8.0%)
11-100	35 (24%)	33 (26%)	19 (21%)	5 (6.0%)
101-1000	27 (19%)	41 (33%)	24 (26%)	7 (9.0%)
1000+	7 (5.0%)	16 (13%)	15 (16%)	4 (5.0%)
Arithmetic mean (95%CI)	**520** (34-1000)	**1100** (430-1700)	**1500** (220-2700)	**350** (73-770)
Coefficient of variation (arithmetic mean)	5.7	3.4	4.1	5.4
Geometric mean (95%CI)	**120** (81-180)	**170** (120-250)	**200** (120-340)	**120** (45-330)
Williams' mean	11	68	40	3
Median	10	80	50	0

Table 4: Selected results from negative binomial regression of *E.coli* count data

SELECTED COVARIATES	RATE RATIO (RR)		
	RR	95% CI	P-VALUE
Water sources			
piped vs tap	2.1	1.1-4.0	0.03
boiled vs piped	0.57	0.37-0.87	0.008
boiled vs non piped	0.24	0.080-0.70	0.009
stored piped vs non-piped	1.4	0.70-2.6	0.37
Water storage			
dipping vs pouring (stored treated)	10	3.2-34	<0.005
covered vs uncov'd (stored piped)	0.49	0.24-1.0	0.052