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The Effect of Seasonal Climate on Bottled Water Distribution in Rural Cambodia

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Abstract The rural population of Cambodia currently has limited access to improved water sources, with monthly access significantly varying between the wet and dry seasons. This poses difficulties for many households across the country, especially in the dry season when stored rainwater – a common source for many – becomes difficult to obtain, necessitating a switch to sources unsafe for consumption. This study evaluates the effect of seasonal climate on bottled water as an alternative solution to accessing safe drinking water. A study of 240 households in the Battambang province, Cambodia correlated seasonal uptake of bottled water with household wealth, quality of road access and access to alternatives. This was supported by historical data on bottled water uptake from three communities. The results suggest that substantial seasonal change in uptake occurs in rural Cambodia; most noticeably in households of low wealth. As one of the first studies on bottled water in Cambodia, these are important findings; particularly given the recent increase in rural bottled water distribution. The study finds bottled water is not an appropriate means for Non-Governmental Organisations targeting the poorest strata of the community; however there is potential for the private sector to supply more affluent households.
Keywords Seasonal access; bottled water; Cambodia

INTRODUCTION

Sustainable access to safe drinking water has been defined as a water source that is secure, reliable, and available for use on demand by users on a long-term basis. In addition, it is a water source that is free of pathogens, provides sufficient quantities and is affordable and reliable (Clasen, 2012). In 2012, the United Nations announced that "*the goal of reducing by half the number of people without access to safe drinking water has been achieved*" (UN, 2012). However, the data from national household-level surveys was collected by minimally trained survey administrators (Clasen, 2012). The householder reports on its primary source of drinking water as 'improved' when it consists of piped water, public tap, borehole, protected dug well, springs or rainwater. Water that is classed as 'unimproved' consists of bottled water, tanker trunks, unprotected dug wells and springs, surface water or similar) and this information is used as an indicator for water coverage (instead of water quality, quantity and access; WHO and UNICEF, 2012). This suggests that the number of people using safe water supplies has likely been over-estimated. As of 2010, 58% of the rural population in Cambodia had access to improved water sources (WHO and UNICEF, 2012). According to the 2010 Cambodian Millennium Development Goal (MDG) Report (UNDP, 2012) the 2015 target of 50% of the rural population with access to an improved water source is on-track, but further efforts to meet the challenging 2025 target that aims for 100% coverage are still required.

The capacity for Cambodian communities to provide their own safe water solutions is severely impaired by the nation's financial situation (Irvine *et al*., 2006). Nearly half of the population earn less than US$1.25 per day, which is defined as the international poverty line (Ravallion *et al*., 2009). This has resulted in widespread poverty in many rural areas around the country, and the lack of capital prevents villages from maintaining even current levels of service for water and sanitation (UNDP and UNCF, 2007). The situation is made more difficult to solve by the patterns of community distribution across the country. In Cambodia, 82% of the population live in low-density rural areas (ADB, 2007), where the emphasis has been on accessing drinking water through ground water sources such as tube wells and surface water sources such as rivers and shallow ponds. It is now evident that not all these sources meet drinking water standards and not all areas have enough water to meet even basic needs. Problems range from arsenic and iron contamination in groundwater through to faecal contamination and pesticide residues collecting and concentrating in open ponds.

Due to these issues considerable effort has been directed into treatment methods that provide point-of-use (POU) treatment for drinking water. In particular household filters such as bio-sand filtration or ceramic filters have been developed along with approaches such as solar disinfection, chlorination and boiling (Brown and Sobsey, 2012; Hansen *et al*., 2011; Luoto *et al*., 2012; McGuigan *et al*., 2011). These methods have proven effective in dealing with faecal contamination and some other pathogens. Unfortunately they cannot cost effectively address heavy metal contamination or remove agricultural waste products; they are also of limited benefit where insufficient water exists in the first place. Piped water from small scale water treatment plants are now being developed for larger villages - typically 300 plus families, but it is estimated that only 2.5% of the population of the country can access piped water (WEPA, 2012). Many people throughout Cambodia already practice rain water harvesting on an ad-hoc basis collecting run off in rain water tanks, typically of about 500 litres in capacity (Barrie, 2012).

The meteorological climate in South East Asia provides its own challenges, as Cambodia experiences a monsoon season for approximately 6 months of the year (Irvine *et al.*, 2006). Between May and October the country experiences approximately 88% of its annual rainfall (Kummu, 2003). This necessitates a bi-annual change in water source for many rural families, switching from rainwater harvesting in the wet season to collecting surface- or ground-water during the drier months (ADB, 2007; PATH, 2011). A recent survey carried out by the Ministry of Rural Development found over 60% of respondents accessing water from unimproved sources during the dry season, with this statistic almost halving during the wet season to 34% (MRD, 2010).

The introduction of bottled water distribution in the provision of safe water to communities in the developing world is a relatively new and rapidly growing sector (Hystra, 2011). Few studies on bottled water in the developing world exist, with only a number commenting on the cost of bottled water (Hutchens *et al.*, 2012; Hystra, 2011). The largest Non-Governmental Organisation (NGO) currently distributing bottled water in Cambodia is Teuk Saat 1001 (TS1001). In operation since 2004, TS1001 has created a network of over 50 operational treatment and distribution stations, and has ambitious plans for expansion (1001 Fontaines, 2010).

The aim of this study was to assess bottled water as a means of providing rural communities with access to safe drinking water throughout the year. This was achieved by: (i) investigating the seasonal variation in uptake and (ii) identifying factors influencing the continuation of TS1001 customers across the year.

METHODOLOGY

Ethics

The research study, implemented in households in Cambodia, was carried out given the prior consent of the individual and with the knowledge that private information would be collected in confidence. Individuals were made aware they were in a position to withhold any information they wished.

Sample group

The study focused on three rural communities in the Battambang province, Cambodia, where TS1001 treatment and distribution stations are in operation (Figure 1): Kamping Pouy (Station A), Prek Loung (Station B) and Cheng Mean Chey (Station C). Battambang province is located in the far northwest of Cambodia and has a strong agricultural economy with rice as its primary crop. Battambang province was selected for the purpose of this study as the percentage of households not having access to safe drinking water is much higher than the national average (CDHS, 2010), while it is considered a prosperous province with 13 business producing bottled water (USAID, 2010).The communities selected for this study were situated at least 10 km from the city of Battambang, and had between 1,000-3,000 households. All three stations had been in operation for over 1 year, to allow the community to become familiar with the TS model. This also ensured that the station had successfully distributed water to families during both the wet and dry seasons. Through stratified random sampling 240 households were studied between the 26th December 2011 and 13th January 2012. A control group of 120 households, 40 in each village was compared against TS1001 current users, 40 in each community. The selection method used in the study is shown in Figure 2, and is in agreement with methods previously used to understand the use of biosand filters in Cambodia (WSP, 2010).

(a)

(b)

Figure 1 (a) Location of surveyed stations; (b) bottled water distributed in Cambodia.

Data collection

Data was collected from two sources: (i) data monitoring the volume (in litres) of water distributed each day over the lifetime of the three stations, supplied by TS1001 and (ii) a survey comprising of formal questions and surveyor observations to investigate the household's seasonal drinking water habits and the possible limitations to delivery due to road quality and distance to the station. As the survey was conducted during the dry season, interviewees were questioned on their alternative water source and treatment method in the wet season.

Data analysis

Data investigating the daily volume (in litres) of water sold at each station was plotted over the lifetime of the station to identify if a pattern of seasonal variation existed. An average trend line was plotted to reduce anomalies in the data, and give an average representation on a day-to-day basis.

An odds ratio analysis was applied to the survey data to identify links between seasonal variation and uptake. This method, used in other systematic studies (En and Gan, 2010), identifies whether the factor has a positive or negative correlation on the uptake of TS1001 bottled water and provides a confidence interval showing if the factor is statistically significant or merely a trend. The odds ratio is a measure of the odds of an event occurring in one group to the odds of it occurring in another. An odds ratio result of >1 suggests a positive correlation to the factor and the probability of uptake of bottled water. Similarly, an odds ratio of <1 suggests a negative correlation. The factors were statistically significant if the 95% confidence intervals were consistently above or below zero. A factor was considered to be positively significant if both confidence intervals were >1 and negatively significant if both confidence intervals were <1. The odds ratio is calculated given the response from the respective group, the answer being identified as either an 'event' or a 'non-event'. The odds of the event are calculated using the formula stated in Equation 1.

$$\textit{Odds Ratio (OR)} = (G1\ E \times G2\ NE) / (G2\ E \times G2\ NE)$$

Equation 1 Odds Ratio

where, G1 E refers to TS1001 Event, G1 NE refers to TS1001 Non Event, G2 E refers to Control Event, and G2 NE refers to Control Non Event.

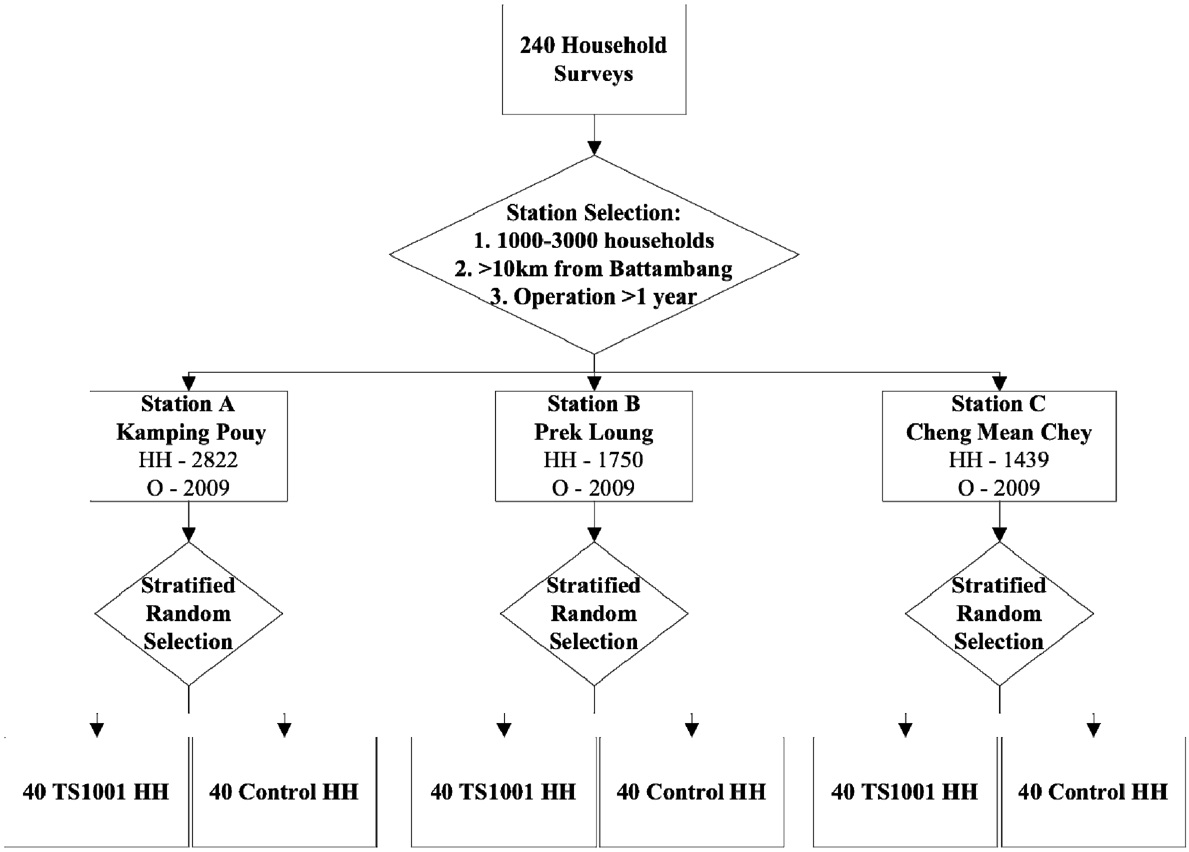

Figure 2 Sample selection method flowchart (HH - Household; O - Year of station opening)

RESULTS

Seasonal variation in TS1001 uptake

Data on the quantity of bottled water sold over the lifetime of each station was collected from TS1001 (Figure 3). The three TS1001 stations researched follow the same pattern over the two years, with average distribution peaking at approximately 2,000 litres per day during March and falling to less than 1,000 litres per day in September. There are an insufficient number of yearly cycles to draw definitive conclusions on the seasonal variation in bottled water uptake, although the initial trend suggests a drop-off rate of greater than 50% in the dry season.

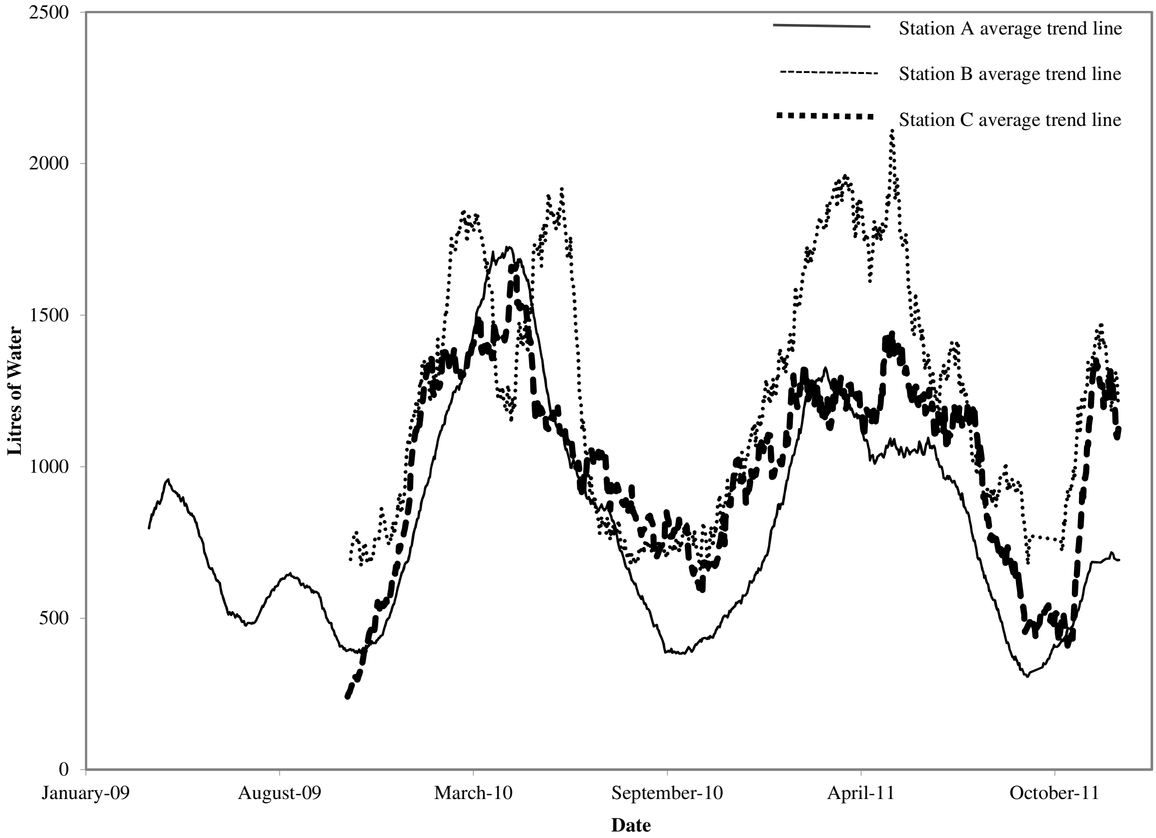

Figure 3 Teuk Saat 1001 daily uptake over the station lifetime

Seasonal factors controlling uptake of TS1001

Data on seasonal drinking water habits were collected for both study groups and compared using an odds ratio analysis to identify controlling factors. The results of the analysis are presented in Table 1; factors considered statistically significant are shown in bold.

The effect of seasonal variation has been noted by previous studies in other areas showing that up to 78% of households use rainwater when available, falling to only 10% in the dry season (ADB, 2007; PATH, 2011). The results of the analysis show a significant difference between the two survey groups in the wet season. The TS1001 group is evenly split between those that change to drinking rainwater in the wet season (47%) and those that continue to buy bottled water all year round (53%). The control group is more divided, with 67% of respondents reporting that they changed to rainwater compared to 33% that did not change. The odds ratio analysis shows that TS1001 users are statistically less likely to change to a different water source in the wet season than the control household group.

Factors positively associated with uptake of TS1001 were: (i) access to the property via a good dirt track; and (ii) in-house collection of drinking water, such as rainwater harvesting or a dug well. Factors negatively associated with uptake of TS1001 were: (i) access to the property via a poor dirt track or path; (ii) using a pond as the primary source of drinking water in the dry season; and (iii) collection of drinking water using a pump.

Table 1 Odds ratio comparison between TS1001 and control household groups

	TS User			Control Household			Odds Ratio (95% CI)
	No.	Sample	%	No.	Sample	%	
Household uses a different source in wet season:							
Change to rainwater	56	119	47%	80	119	67%	**0.43 (0.26 – 0.73)**
No change	63	119	53%	39	119	33%	**2.31 (1.36 – 3.90)**
Road type:							
Paved	32	120	27%	32	120	27%	1.00 (0.56 – 1.77)
Good dirt track	56	120	47%	38	120	32%	**1.89 (1.12 – 3.19)**
Poor dirt track	25	120	21%	39	120	33%	**0.55 (0.31 – 0.98)**
Path	4	120	3%	11	120	9%	**0.34 (0.11 – 1.11)**
Previous/current source of drinking water:							
River	50	120	42%	37	120	31%	1.60 (0.94 – 2.72)
Pond	12	120	10%	25	120	21%	**0.42 (0.20 – 0.88)**
Rainwater	51	120	42%	46	120	38%	1.19 (0.71 – 1.99)
Shallow well	17	120	14%	10	120	8%	1.82 (0.79 – 4.15)
Deep well	2	120	2%	1	120	1%	2.02 (0.18 – 22.5)
Other bottled	3	120	3%	8	120	7%	0.35 (0.09 – 1.39)
Piped	6	120	5%	12	120	10%	0.47 (0.17 – 1.31)
Previous/current method of collecting drinking water:							
Collect by hand	28	115	24%	31	118	26%	0.90 (0.50 – 1.63)
Cart vendor	25	115	22%	24	118	20%	1.08 (0.58 – 2.04)
In-house	53	115	46%	38	118	32%	**1.80 (1.06 – 3.07)**
Pump	13	115	11%	25	118	21%	**0.47 (0.23 – 0.98)**

Seasonal Factors Controlling Continuation of TS1001 during Wet Season

Data on income and geographic location were collected for the TS1001 group, and correlated with drinking water habit during the wet season. The results of the analysis are presented in Table 2; factors considered statistically significant are shown in bold.

The results display a statistically positive correlation between households that have a daily income in the US$2 – 5 bracket and households that change to rainwater during the wet season. This is enhanced by a trend in negative correlations displayed by households with a daily income of greater than US$5, although the confidence interval distribution reduces the significance of these findings. It is envisaged that cost limits water year round access to the poorest. This research suggests that where drinking water can be obtained at a lower cost and access to a drinking source is available, the use of bottled water is at risk of being unable to attract customers and may continue to lose customers throughout the year. However those reliant on and 'in house' supply such as rainwater harvesting, were statistically more likely to use bottled water due to the lack of storage into the dry-season. Irvine *et al.* (2006) identified this reason as a major limitation for rainwater harvesting in areas such as Cambodia.

No statistically significant results were observed when correlating distance to treatment station with change to rainwater during the wet season. The results display a general trend, with households closer than 3,000m to the station less likely to change their water source in the wet season than those situated further afield.

Table 2 Odds ratio comparison between TS1001 users that discontinue service during wet season

	Change to rainwater			**No change**			**Odds Ratio (95% CI)**
	No.	Sample	%	No.	Sample	%	
Geodesic distance to station:							
< 1000m	13	56	23%	18	63	29%	0.76 (0.33 – 1.73)
1000 – 2000m	9	56	16%	14	63	22%	0.67 (0.26 – 1.70)
2000 – 3000m	16	56	29%	20	63	32%	0.86 (0.39 – 1.89)
3000 – 4000m	8	56	14%	6	63	10%	1.58 (0.51 – 4.88)
4000m +	10	56	18%	5	63	8%	2.52 (0.81 – 7.89)
Household daily income:							
US$0 – 2	7	55	13%	7	59	12%	1.08 (0.35 – 3.32)
US$2 – 5	23	55	42%	14	59	24%	**2.31 (1.03 – 5.16)**
US$5 – 10	12	55	22%	17	59	29%	0.69 (0.29 – 1.62)
US$10 +	13	55	24%	21	59	36%	0.56 (0.25 – 1.27)

DISCUSSION

Seasonal variation in bottled water uptake

Based on both the data supplied by TS1001 and the analysis of the survey results, it was observed that rural Cambodian communities display a significant variation in uptake of bottled water delivery between the dry and wet seasons. Trends identified (Fig. 2) suggest that the quantity of water distributed by TS1001 decreases by more than 50% between May and October, coinciding with the wet season. This is supported by the results of the household survey, where 47% of respondents reported a change from bottled water to rainwater harvesting during the months of heavy rainfall. A number of separate studies undertaken in Cambodia have reported a similar bi-annual change in drinking water source as rainwater becomes scarce in the dry season (ADB, 2007; MRD, 2010). PATH (2011) reported that as many as 78% of rural households use rainwater as a drinking water source when it is easily available, falling to around only 10% as precipitation decreases.

The TS1001 group and control household group were compared to identify any key differences in seasonal drinking water habits. Results from this study (Table 1) indicate that households were statistically unlikely to uptake TS1001 bottled water if they: (i) used a pond/small reservoir as the primary source of drinking water in the dry season ,and (ii) collected drinking water using a pump. In contrast, families that collected their drinking water ‘in-house’ – such as from a pump or rainwater harvesting scheme – were positively linked with adoption of the TS1001 bottled water scheme. This was likely to be related to the seasonal availability of a household's water source, as having access to a year-round source such as a pond negates the requirement for water delivery.

Bottled water as a safe drinking water source in rural communities

Bottled water is not classified as an 'improved' drinking water source by the World Health Organisation (WHO and UNICEF, 2012). This is not due to water quality, but instead is attributed to concerns over affordability and quantity. However, the 2011 Hybrid Strategies Consulting Report - which compares around 140 safe water access projects from across the world – suggests that bottled water could be an appropriate solution for up to 50 million people worldwide, 80% of whom are situated in Asia (Hystra, 2011). The findings of this study (Table 1) show a high proportion of TS1001 bottled water uptake during the dry season, when access to an improved source of drinking water is recognised as being low (ADB, 2007; MRD, 2010; PATH, 2011).

Hutchens *et al.* (2012) suggested that bottled water is financially suitable only for medium- and high-wealth rural families in Cambodia. This study indicates that it is primarily these groups who are prepared to continue paying for the service when rainwater is scarce, as demonstrated by the odds ratio analysis (Table 2). The results show a positive correlation between households earning between US$2 – 5 per day and households changing to drink rainwater during the wet season. Similarly, households earning greater than US$5 per day were observed to be more likely to continue to use the TS1001 bottled water throughout the entire year. This implies that households prefer to rely on bottled water delivery rather than collect their own rainwater, provided they can afford to.

Medium- and high- wealth families are more likely to continue receiving bottled water rather than transfer to rainwater collection than poorer households, emphasising the value of this service. This observation has consequences on the marketability of bottled water as a household amenity; demand from these wealth groups could be a strong incentive for increased private investment in bottled water. Further research is required to investigate the effect of this.

The findings of this research (Table 1) further show that 47% of TS1001 households switch to rainwater in the wet season. This is a popular source of drinking water in Cambodian households, due to its high levels of availability and ease of collection (ADB, 2007; PATH, 2011; Thomas and Martinson, 2007). Many families overcome the difficulties associated with low precipitation levels in the dry season by using large storage vessels to stockpile the rainwater until required (PATH, 2009; WSP, 2010). However, despite being classified as 'improved', rainwater collection is not without its own inherent challenges. Irvine *et al.* (2006) identifies a number of problems with existing rainwater harvesting systems in Cambodia, which include: (i) insufficient storage capacity; (ii) containers become breeding ground for mosquitoes; (iii) water is removed by a dipper, which is a source of pathogenic contamination and (iv) open top storage allowing dust and other contaminants to freely enter. Worldwide, the increased risk of stored drinking water is a major problem, and has been well documented (Tambrekar *et al.*, 2008). Evidence exists suggesting similar problems are endemic throughout Cambodia (Irvine *et al*., 2006; PATH, 2009; WSP, 2010). It is clear that safe storage remains one of the crucial factors in determining the success of rainwater harvesting as a means to meet the Cambodian government's development targets. In the absence of safe methods of storing and accessing rainwater during the dry season, bottled water could potentially be considered as an appropriate means of providing drinking water to rural households.

Seasonal climate variation and rural road access

The results indicate a negative correlation between poor household road access and uptake of TS1001 bottled water (Table 1). This is important in the context of seasonal climate variation, as the rural road network in Cambodia is of a very low standard. Only 20% of the major roads and highways are covered in asphalt and are in passable condition all year round, and the problem is even more pronounced in the rural areas where 99.7% of rural roads remain unpaved (Sum, 2007). Improved roads create the conditions for better service access – such as transported water – to rural communities (Hettige, 2006). The results of the study (Table 2) confirm this. Households situated greater than 3km from the distribution station were less likely to continue using TS1001 bottled water during the wet season, compared to those that were closer. These combined findings suggest that the success of a bottled water distribution model is dependent on the reliability of transporting water between the source and the user. Poor road access is recognised as a barrier to reducing rural poverty (Hettige, 2006), and so this reliance on continual access fundamentally undermines the ability of bottled water to target those that most require safe water provision. Improvements in road quality to enhance the delivery of bottled water are likely to improve the uptake rates given the results; further research into this is required.

Sector involvement in bottled water provision

The results of the study indicate that bottled water does not target the poorest strata of the rural community, and is instead an amenity more appropriate for higher-income households. This makes bottled water potentially unsuitable for NGOs aiming to reduce rates of global poverty by providing safe water access to the poorest. Many failures of water supply projects have been attributed to weak, or a lack of, private sector involvement (Byars and Antizar-Ladislao, 2011); and the associated demand from wealthier households in Cambodia makes this an attractive area for private investment. The advantages of this include sector competition, leading to increased efficiency in service delivery (Kleemeier, 2010), although the considerable seasonal variation in uptake must be accounted for (Figure 3). There is a recognised lack of bottled water quality control in the region (Hystra, 2011), and so improved enforcement of standards are required from the National Government of Cambodia (NGC), who are recognised as being deficient in this area (NGC, 2010). NGOs who intend to implement change for the poorest should consider other, more affordable, water quality interventions.

Limitations

The main limitation of the work presented herein was the small number of stations and households studied; a larger number would have increased the extent to which our findings can be generalised. However, our study was restricted to three 'financially stable' communities as to minimize the possibility of local bias; communities of households of 1,500 or more (Hystra, 2011) where the TS model had been in operation for over 1 year. This study uses data provided by an external source over the lifetime of the distribution station, and relied on the operator providing accurate details of uptake. Data was not available on some dates; however the study only investigated trends over time. Households were identified for surveying using satellite imagery, and so some bias during selection may have occurred if a household was not visible. Mistranslation of answers during household surveys may be a further source of error.

CONCLUSION

Keeping cognisance of the limitation of the small sample size, a few findings are worth noting. The study finds that bottled water may be an appropriate means of providing safe drinking water to rural families during periods when rainwater is scarce. However, the quality of road access and the ease of collecting rainwater – itself an 'improved' water source – in the wet season results in a significant drop of 47% in bottled water uptake for a large proportion of the year. Additionally the research showed that the provision of bottled water as a year-round service is limited to medium- and high-wealth households, with the poor statistically more likely to revert to rainwater.

Bottled water is not an appropriate means for NGOs targeting the poorest strata of the community. Significant improvement in rainwater storage facilities, along with other water quality interventions by NGOs, may provide these families with the best possible access to safe drinking water during the dry season. This study recommends that the provision of bottled water is best suited to private operators distributing to affluent rural households, and the NGO must enable this by enforcing clear bottled water quality standards across the region.

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