The importance of safe drinking water at the point of consumption
Impact on diarrhoeal diseases for children under 5
and school absence rates for children between 6 to 12
According to the United Nations, good progress has been made against Objective 7c of its Millennium Development Goals (MDGs). This objective to halve by 2015 the proportion of the population with no access to a supply of safe drinking water and to basic sanitation has been met. In 2010, 89% of the world’s population had access to improved drinking water compared to 76% in 1990. But does this represent real progress for public health?

The NGO 1001fontaines has conducted two studies on the impact of safe drinking water on school absenteeism and on the incidence of diarrhoeal diseases for children. Both of these impact studies were carried out in Cambodia in 2012.

The first study, published in the American magazine PLOS ONE, concerned the measurement of absenteeism in primary schools (children from 6 to 12 years old). The rate of absenteeism in schools benefiting from the daily supply of 1001fontaines’ safe drinking water was compared to schools which did not have this service. It was shown that, during the dry season, when this safe water was properly supplied, the rate of absenteeism was reduced by...75%.

The second study, published on the English site Biomedcentral, consisted of following a group of children under 5 years old for a period of six months at their family homes. The number of diarrhoeal episodes was measured and correlated to the type of water consumed. We were able to show that the children who drank surface water had 33% higher risk of diarrhoeal episodes compared to those consuming 1001fontaines water, or harvested rainwater. With protected groundwater, the percentage risk increased to...62%.

Both of these studies raise two crucial questions in terms of public health and development aid:

- Would the simple fact of providing children under 5 years old with 1 to 2 litres of clean drinking water of indisputable quality be sufficient to make a significant reduction in infant mortality for a relatively low cost?
- Given that 2 litres of safe drinking water per person per day has a critical impact on health, would it not be more effective to allocate a portion of the billions of dollars of aid that are spent every year on providing access to 50 litres per person per day of water for all purposes to the specific goal of providing 2 litres per person per day of safe drinking water?

In the words of Louis Pasteur: « we drink 90% of our diseases ». Given this, wouldn’t a focus on guaranteeing the quality of safe drinking water be one of the best ways to prevent vulnerable populations from contracting 90 % of their diseases?

1001fontaines is convinced that safe drinking water of guaranteed quality can be the most economic and most effective way to decrease significantly one of the major causes of infant mortality. Today, we call on public health organisations, as well as on major funders (institutions and foundations) to initiate a new field of research specifically focused on the access to safe drinking water to complement other actions targeting larger quantities of “improved” water.

The 1001fontaines model shows that, in Cambodia today, it would be economically feasible to supply every child under 5 years old, with 2 litres of safe drinking water per day for a cost of less than US $ 10 per child per year. And, how much is the life of a child worth?

François Jaquenoud
Cofounder and Executive Director,
1001fontaines
Impact of the Provision of Safe Drinking Water on School Absence Rates in Cambodia: a Quasi-Experimental Study, in PLOS ONE
Impact of the Provision of Safe Drinking Water on School Absence Rates in Cambodia: A Quasi-Experimental Study

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Abstract

Background: Education is one of the most important drivers behind helping people in developing countries lift themselves out of poverty. However, even when schooling is available absenteeism rates can be high. Recently interest has focussed on whether or not WASH interventions can help reduce absenteeism in developing countries. However, none has focused exclusively on the role of drinking water provision. We report a study of the association between absenteeism and provision of treated water in containers into schools.

Methods and Findings: We undertook a quasi-experimental longitudinal study of absenteeism rates in 8 schools, 4 of which received one 20 L container of treated drinking water per day. The water had been treated by filtration and ultraviolet disinfection. Weekly absenteeism rates were compared across all schools using negative binomial model in generalized estimating equations. There was a strong association with provision of free water and reduced absenteeism (Incidence rate ratio = 0.39 (95% Confidence Intervals 0.27–0.56)). However there was also a strong association with season (wet versus dry) and a significant interaction between receiving free water and season. In one of the intervention schools it was discovered that the water supplier was not fulfilling his contract and was not delivering sufficient water each week. In this school we showed a significant association between the number of water containers delivered each week and absenteeism (IRR = 0.98 95%CI 0.96–1.00).

Conclusion: There appears to be a strong association between providing free safe drinking water and reduced absenteeism, though only in the dry season. The mechanism for this association is not clear but may in part be due to improved hydration leading to improved school experience for the children.


Introduction

The receipt of a good quality education is one of the most important factors in enabling children to fulfil potential in later life and reduce poverty [1]. Increased educational attainment is also associated with substantial health gains especially on child health in future generations including reduction in child mortality [2,3]. Important gains in child health may be associated even with future mothers improved access to primary education alone [3]. The importance of access to education is reflected within the Millennium Development Goals of the commitment to ensure that all children can complete a course of primary education [4]. In an earlier review of studies from developing countries, the authors pointed out that time spent learning being linked to educational achievement is one of the most consistent findings [5]. However, as pointed out by Abadzi [1], instructional time available to children in many developing countries is often markedly reduced. Indeed Abadzi concluded that “assumptions about the pro-poor poverty alleviation effect of education may be unrealistic", and that additional public investment may fail to mitigate poverty, unless it improves instructional delivery [1]. There are many reasons for this reduced educational contact time in low income countries, some of which are institutional such as teacher absenteeism, frequent school closures, etc [1]. However, even when schools are open, pupil absenteeism can be high [1]. Clearly reducing student absenteeism is important to improving educational attainment and consequent poverty alleviation.

Recent interest has turned towards the potential role of improving water and sanitation provision in schools as a tool towards improving children’s health and educational achievements. In a recent systematic review, the authors identified 41 studies that reported on the impact of water, hygiene and sanitation interventions on health and educational outcomes of which 8 were concerned with absenteeism [6]. Most of these studies were from developed nations. Although there was some indication of links between water and sanitation provision and
Methods

This study was approved by the University of East Anglia Faculty of Health ethical committee and the Cambodian National Ethics Committee for Health Research. Given that we did not introduce any intervention, only summaries of routinely collected data were obtained and no person specific data was collected, there was no requirement for informed consent to be obtained.

The intervention being investigated was delivery of treated water in containers to schools. These water containers were provided free of charge to schools and funded by “1001 fontaines pour demain” (1001F), a non-governmental and not-for-profit organization based in Caluire, France. 1001F has been working in Cambodia since 2005. The basic model is to identify local entrepreneurs and financially support them to build a local plant to bottle filtered and ultraviolet disinfected water in cleaned and disinfected 20 L containers. Most of these containers are then sold to local customers. During and after start-up 1001F technical staff provide training and an ongoing quality assurance scheme. Funding for 1001F is mainly from private donors, though it has also received financial support from French Embassies in the countries where it works. A video highlighting 1001F’s work can be seen at the following link: http://fr.youtube.com/watch?v=8ybkVECYrE. In some of the villages, 1001F paid the entrepreneur to provide free water to the village school. Each participating school was provided with 1001F water in containers to be placed in the classroom so that each child could take water whenever they wished. For those schools participating in the scheme one 20 L bottle of water was delivered to each class each day. Given that the average class size was 38 children, this equates to approximately 0.53 L per child per day. The overall cost of the scheme was US$1.4 per child per year.

In this study, we obtained absenteeism data from the four schools where 1001F were providing free water. In addition we obtained this same data from four schools not in receipt of free water. In a related community study of childhood diarrhoea we were conducting a longitudinal study of childhood diarrhoea and water use in 25 villages. These villages had been chosen at random from all villages with an established 1001F presence or through a process of propensity score matching, the details of which is described elsewhere [10]. Four schools from these 25 villages were in receipt of the free school water scheme and willing and able to provide absenteeism data. Four control schools were chosen from the other 25 villages based on number of registered students present and the proportion of students under 14 years closest to those values of the intervention schools. The head teacher was then approached and invited to participate.

Data collection was based on routinely collected absenteeism data provided to the study team by the head teacher. Data was provided from the week beginning 4th December 2011 to 31st May 2012. This period spread over two school terms one of which was in the dry season and the other the wet season.

Data analysis was done using STATATA version 11. Absenteeism rates per week were calculated as the number of days absent/ (5 x children registered). Random effects negative binomial regression analyses were done using a generalized linear model with a random intercept for school. The outcome variable was the number of days lost in each week from absenteeism and the number of children enrolled in the school was the exposure variable. The predictor variables were whether or not the school received water and season. Interaction terms were included for intervention and season.

In one school it was discovered that the number of water containers delivered fell short of the contracted amount. A further regression analysis was done for this school with days missed in the week being the dependent variable. The actual number of water containers delivered in the week and days missed at all the other schools combined were predictor variables. The analysis was restricted to the dry season and excluded holiday weeks.

Results

Table 1 shows certain key characteristics of to the villages where each of the eight schools were based. It can be seen that across most characteristics the intervention and control schools were generally very similar. The main exception is that very few people in intervention villages have access to improved water or sanitation compared to the control villages. This is not too surprising as the 1001F had primarily targeted its intervention at schools in areas where it was known that the local community had poor access to improved drinking water. Also of note was that rather more of the populations of the intervention villages were reported as being migrants. The predominant source of drinking water in the control schools was whatever the children brought in from their home. In one control school (C2) children also had access to a hand pump and jar in a pagoda about 100 m from the school and in another (C3) there was a rainwater harvesting tank for which children were reported to have some use.

Data was collected for 26 consecutive weeks. Three schools were closed during week 18, all schools were closed during week 19, and all but one in week 20. The dry season was taken to include all the weeks before the break in week 19 and the wet season in weeks subsequent to this holiday. Across all eight schools this represented 60,194 child weeks of follow-up. The overall absenteeism rate was 5.57%. Figure 1 shows the absenteeism rate for each school by week. The most obvious finding was the dramatic increase in absenteeism during the wet season, towards the end of the study period. This was not surprising given the fact that in many villages, children would be kept off school at this time to help in the fields.

Table 2 shows the results of the negative binomial regression analysis comparing absenteeism rates using whether or not the...
school received free 1001F water and season as predictor variables. In addition we investigated the interaction between season and receipt of 1001F water. It can be seen that absenteeism was less than half in the intervention schools compared to those who did not receive 1001F water. Given the significant interaction term the association between having 1001F water and reduced absenteeism was restricted to the dry season with no such association in the wet season (as was also clear in figure 1).

At the end of the study period it became clear that one of the suppliers was not fully fulfilling their contract as they did not have sufficient capacity to provide water to the school and their paying customers. Although container water was provided this fell short of the contracted amount. The remaining three schools received all their assigned supplies. Table 3 shows the results of the regression analysis of absenteeism in the school with incomplete water delivery adjusted for within week absenteeism in other participating schools. There was a significant association between the number of containers of water delivered in the week and reported absenteeism. For every extra container delivered there was a 2.9% reduction in absenteeism (95% confidence intervals (CI) 0.5 to 5.1%). The association was also tested between absenteeism and delivery in the previous week. Absenteeism was not associated with the number of containers delivered in the previous week.

Discussion

In this study we have shown lower absenteeism in schools receiving free containers of 1001F water. However, this association was only seen in the dry season and not in the wet season. There were also strong seasonal effects as absenteeism in several of the schools increased dramatically during the wet season, irrespective of water delivery. We were informed that this increase in absenteeism during the early wet season was partly because children were frequently kept off school to help in the fields. We have, furthermore, shown that in one school where delivery of water containers fell short of the contracted amount, absenteeism rates were associated with the number of containers delivered in the week. As far as we are aware this is the first study to show that provision of adequate safe drinking water in school can affect attendance in a developing country.

Clearly one has to be cautious when interpreting the results of an observational study like this. Nevertheless, taking both analyses together, this gives a fairly strong indication that provision of safe palatable drinking water is indeed associated with reduced absenteeism. Firstly although this study was not blinded and so potentially open to some form of reporting bias, school absenteeism rates are not subjective and so our results should not be as at risk of reporting bias that has affected many other studies of water and health in low income countries [8]. We cannot, of course, exclude bias in the way the classroom teacher records the daily attendance register or in how the school compiles absenteeism data from the class registers. However, any such bias is far less likely when based on register records than may be expected by asking children to recall their absence history during interview as was done in the only other study of school absence and WASH [7]. Secondly, although it is plausible that selection of schools for the intervention may have led to a degree of bias, it is difficult to see how this would have affected the association found between number of containers delivered and absenteeism in the school with incomplete contract fulfilment. Of particular note here was that the intervention schools were generally in areas with poor domestic access to improved drinking water supplies and sanitation. If inadequate drinking water and sanitation does

<table>
<thead>
<tr>
<th>School code</th>
<th>Number of children in school</th>
<th>Number of households in village</th>
<th>Population</th>
<th>% population male</th>
<th>% population 5 yrs old</th>
<th>% population 5 to 14 yrs old</th>
<th>% population with lower secondary education or greater</th>
<th>% adult female literacy rate</th>
<th>% working in primary sector</th>
<th>% with access to improved water</th>
<th>% with access to sanitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>370</td>
<td>405</td>
<td>1634</td>
<td>49</td>
<td>8</td>
<td>20</td>
<td>96</td>
<td>84</td>
<td>68</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>401</td>
<td>395</td>
<td>1706</td>
<td>50</td>
<td>10</td>
<td>27</td>
<td>96</td>
<td>58</td>
<td>96</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>335</td>
<td>340</td>
<td>1951</td>
<td>48</td>
<td>11</td>
<td>25</td>
<td>95</td>
<td>72</td>
<td>94</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>450</td>
<td>455</td>
<td>942</td>
<td>51</td>
<td>13</td>
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<td>98</td>
<td>67</td>
<td>94</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>I1</td>
<td>587</td>
<td>585</td>
<td>1378</td>
<td>50</td>
<td>8</td>
<td>19</td>
<td>93</td>
<td>66</td>
<td>94</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>I2</td>
<td>271</td>
<td>267</td>
<td>1126</td>
<td>50</td>
<td>12</td>
<td>19</td>
<td>99</td>
<td>50</td>
<td>94</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>I3</td>
<td>954</td>
<td>954</td>
<td>1075</td>
<td>49</td>
<td>12</td>
<td>19</td>
<td>98</td>
<td>73</td>
<td>94</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>I4</td>
<td>174</td>
<td>174</td>
<td>873</td>
<td>49</td>
<td>10</td>
<td>19</td>
<td>98</td>
<td>64</td>
<td>94</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Characteristics of the villages in which the schools were based.

impact of school absenteeism, then if anything this source of bias would be expected to increase absenteeism in the intervention schools rather than reduce it. It is not clear what effect if any the greater number of migrants in some villages would have on absenteeism in school. We would however suggest that further randomised studies are required before a more definitive conclusion can be made.

This leaves the question of what was the mechanism between water supply provision and absenteeism. In this study we were not able to collect any data on the reasons for the absenteeism. Given the fact that the association was between absenteeism rates and water delivery in the same week and not the previous week, we are not suggesting that this association was primarily due to a reduction in waterborne infectious disease. A possible explanation in our view may be that by providing readily available palatable and safe water in the classroom, children are more likely to drink during the school day and so not become dehydrated. Even mild dehydration in vulnerable groups such as young children has been suggested as being associated with various adverse health effects [11]. Furthermore, in a recent study from a hot dry region of Italy, the authors showed that supplementary drinking water was associated with improved cognition and an improved subjective sense of vigour [12]. This Italian study is in line with similar findings from several previous researchers [13,14]. What this suggests therefore is that provision of supplementary water sufficiently improves the child’s general wellbeing as well as the learning and experience of the school day as he/she is better hydrated. Consequently they are more likely to attend school the following day if they had felt good at school the previous day.

Even if, as we suspect, the main reason for the reduced absenteeism in the intervention group is due to improved hydration rather than a reduction in waterborne disease, this should not be taken as an indication that the provision of water of any quality would be acceptable. The link between contaminated

Figure 1. Absenteeism rate by school and week. Solid line shows rates for intervention schools and broken line for control schools. doi:10.1371/journal.pone.0091847.g001

Table 2. Risk factors for absenteeism rates in schools.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Incidence Rate Ratio</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receives 1001F Water</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Yes</td>
<td>0.386</td>
<td>0.266</td>
<td>0.560</td>
<td></td>
</tr>
<tr>
<td>Season</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td>1</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Wet</td>
<td>2.618</td>
<td>2.279</td>
<td>3.008</td>
<td></td>
</tr>
<tr>
<td>Season × 1001F water interaction</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Yes-Wet</td>
<td>1.991</td>
<td>1.603</td>
<td>2.472</td>
<td></td>
</tr>
</tbody>
</table>

doi:10.1371/journal.pone.0091847.t002
drinking water and disease risk is well accepted and it is clear that the main risk falls on young children [13]. Any scheme to increase drinking water provision in the classroom that does not ensure that water is safe to drink is likely to put the children at risk of waterborne disease. However, providing safe water in the school environment does not necessarily mean children will drink it. Indeed taste appears to be a major determinant affecting whether or not people continue to use safe drinking water sources [16,17]. Chlorination of drinking water is associated with poorer taste for many people [18,19]. On the other hand filtration can be associated with improved taste [20]. The fact that 1001F water uses filtration and Ultraviolet disinfection but not chlorination would mean that it would have better taste qualities than other safe water sources and so may be more likely to be used by children.

In conclusion, we have shown a significant association between provision of supplementary water in the classroom and reduced absenteeism rates. With the delivery mechanism in this study the cost per child is modest, but the potential benefit to children’s education and subsequent life potential could be extremely large. There is a great need for further research in this area, especially randomised control trials and studies aimed at determining the biological mechanisms behind this reduction in absenteeism.

Acknowledgments

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Author Contributions

Conceived and designed the experiments: PRH HR FJ HL MY PH C. Longuet. Performed the experiments: MY HL C. Lo. Analyzed the data: PRH FJ. Wrote the paper: PRH HR MY HL C. Longuet PH C. Lo FJ.

Table 3. Risk factors for absenteeism in school with incomplete delivery of water containers during the dry season.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Incidence Rate Ratio</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water delivered in week/container</td>
<td>0.971</td>
<td>0.949</td>
<td>0.995</td>
<td>0.016</td>
</tr>
<tr>
<td>Absenteeism days in other schools/days missed in week</td>
<td>1.000</td>
<td>0.992</td>
<td>1.007</td>
<td>0.976</td>
</tr>
</tbody>
</table>

References

Water source and diarrhoeal disease risk in children under 5 years old in Cambodia: a prospective diary based study, in BioMedical Central
Water source and diarrhoeal disease risk in children under 5 years old in Cambodia: a prospective diary based study

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Abstract

Background: Despite claims that the Millennium Development Goals (MDG) targets on access to safe drinking water have been met, many 100 s of millions of people still have no access. The challenge remains how to provide these people and especially young children with safe drinking water.

Method: We report a longitudinal study designed to assess the effectiveness of an intervention based on provided treated drinking water in containers on self-reported diarrhoea in children. The intervention was "1001 fontaines pour demain" (1001 F) is a non-governmental not for profit organization (created in 2004 and based in Caluire, France) that helps local entrepreneurs treat package, and sell safe drinking water. Cases and controls were chosen at village and household level by propensity score matching Participants were visited twice a month over six months and asked to complete a diarrhoea health diary.

Results: In total 4275 follow-up visits were completed on 376 participants from 309 homes. Diarrhoea was reported in 20.4% of children on each visit, equating to an incidence rate estimate of 5.32 episodes per child per year (95% confidence interval = 4.97 to 5.69). Compared to those drinking 1001 F water, children drinking surface water were 33% (95% CI −1 to 17%), those drinking protected ground water were 62% (95% CI 19 to 120%) and those drinking other bottled water 57% (95% CI 15 to 114%) more likely to report diarrhoea. Children drinking harvested rainwater had similar rates of diarrhoea to Children drinking 1001 F water.

Conclusion: Our study suggests that 1001 F water provides a safer alternative to groundwater or surface water. Furthermore, our study raises serious concerns about the validity of assuming protected groundwater to be safe water for the purposes of assessing the MDG targets. By contrast our study provides additional evidence of the relative safety of rainwater harvesting.

Keywords: Water, Diarrhoea, Latrines, Cambodia, Child health, Bottled water, Disinfection

Background

Diarrhoeal disease is one of the most important causes of disease burden and mortality in children under 5 years old [1]. Most of this disease burden falls on those children growing up in the world’s poorest countries and is largely associated with inadequate drinking water and sanitation [2]. In recognition of this, improved access to safe drinking water and sanitation has been one of the key aspects of the millennium development goals (MDG) [3]. Although recent statements from the United Nations and World Health Organization have claimed that the MDG on water access has been met ahead of target [4], there have been cogent arguments that these claims are exaggerated [5]. In any event, even if the MDG targets have been met in full there still remains many 100 s of millions of people without access to sustainable safe water supplies. In this regard the issue of whether improved water quantity (access) or quality is most important for protecting
child health is central to policy on improving water supplies. The quantity versus quality debate has continued since the late 1980s [6]. However, at least in the view of the authors of this article, there is sufficient evidence to support the conclusion that both quality and quantity are important [6-9]. Once one accepts the importance of good quality drinking water, then the question becomes how can people access a sufficient, reliable and sustainable source of safe drinking water? Whilst the preferred option must always be properly managed community mains drinking water treatment and distribution networks, this is not possible for many communities because of either financial or geographical considerations. In such communities the options for obtaining safe drinking water are limited to accessing other sources of “improved” drinking water. According to the WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation “An improved drinking-water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with faecal matter” (WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation http://www.wssinfo.org/definitions-methods/introduction/). Under JMP definitions, improved drinking water sources include piped water into dwelling or yard, public taps or standpipes, tubewells or boreholes, protected dug wells, protected springs and rainwater sources. Unimproved water sources include unprotected springs, unprotected dug wells, carts with small tanks or drums, tanker-trucks, surface waters and bottled waters.

For people without access to improved drinking water supplies the options are much more limited. Household Water Treatment is being heavily promoted in many parts of the world despite the generally poor evidence that these technologies are effective in reducing self-reported diarrhoeal disease. In particular, double blinded trials of household chlorination have not found any impact on diarrhoeal disease [10]. The evidence in favour of other technologies such as solar disinfection (SODIS) is also weak with independent studies suggesting poor compliance and little if any strong evidence of impact on health with support only coming from unblinded trials [11]. By contrast the evidence in favour of ceramic filters being effective in reducing self-reported diarrhoea is somewhat stronger [11]. The reasons for the lack of effect of Household Water Treatment probably includes poor effectiveness against some pathogens (especially chlorination and Cryptosporidium) and poor compliance [12,13].

In the JMP classification, bottled/packaged waters are deemed to be an unimproved water supply and are, therefore, considered to be at risk of contamination (WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation http://www.wssinfo.org/definitions-methods/introduction/). This classification is almost certainly correct as the quality of bottled water can be variable [14-17]. However, the question remains whether or not bottle water can be produced to an acceptable quality that would be associated with improved health impacts at a price that would make it an economically acceptable choice for the primary source of drinking water. In this paper we report a longitudinal study of diarrhoeal disease in children under five in communities where a particular type of packaged water, 1001Fontaines, was sold and in communities where this water was not available.

Methods
We undertook a prospective longitudinal survey of parent-reported diarrhoeal disease in children under 5 years old in rural communities in Cambodia. Participating households were visited every 2 weeks and a short questionnaire administered to determine, amongst other things, the incidence of acute diarrhoea in children and drinking water sources.

The 1001 F model
“1001 fontaines pour demain” (1001 F) is a non-governmental not for profit organization (created in 2004 and based in Caluire, France) whose primary goal is to improve access to safe drinking water. This initiative is specifically orientated towards small rural communities, which generally fall outside of the remit of water access projects. Between 2005 and 2011, 1001 F has implemented several pilot projects in Cambodia, enabling by the end of 2012, approximately 65,000 people in 58 villages to have access to safe water. 1001 F does this by supporting water entrepreneurs in communities to build water treatment and distribution businesses.

The basic business model is to support local entrepreneurs to build a water treatment system, based on filtration and ultraviolet disinfection of source water with bottling in cleaned and disinfected 20 L containers for subsequent distribution and sale. A continuing quality assurance programme is implemented with support from 1001 F technical staff. The entrepreneurs are supported and trained over an initial apprenticeship year by the end of which the business is financially self-sustaining. After that first year ongoing support is provided by a team of technicians which gives technical assistance and carries out quality control tasks for 50 to 60 sites. Water treatment plants are powered by solar energy. The cost to consumers is less than US$0.01 per litre.

Funding for 1001 F comes mainly from private donors (private companies, foundations), although it has also received financial support from the French Embassies in Cambodia and Madagascar. A video showing more information can be found at the following link: http://fr.youtube.com/watch?v=8bykbVECVrE.
Participant selection and recruitment
Participant selection was a two phase process; firstly selection of villages and secondly selection of households within villages. For village selection, data concerning 56 villages were obtained from The National Institute of Statistics, Ministry of Planning, Royal Government of Cambodia (http://www.nis.gov.kh/index.php/online-statistics/resultonline). This data included the number of homes in the village, the population, % male, % children <14, % children <5, % of population >25 years with no, some, completed primary and completed secondary education, % migrants, % with access to improved water supplies, % with no toilet facility, % adult female literacy and % employed in primary, secondary and tertiary sectors. Of the 56 villages, 27 had access to 1001 F water. With this data, propensity scores (the probability of being an intervention village) were calculated using logistic regression analysis as has been done in previous studies [18,19]. The most closely matched 1001 F and control village pair was then chosen for inclusion, followed by the next most closely matched, etc.

All households within chosen villages were then visited and a recruitment questionnaire administered covering a range of demographic, socio-economic and environmental variables. This questionnaire also asked about whether or not 1001 F water was the primary source of drinking water. At this first visit, respondents were asked whether or not they would be prepared to participate in the prospective study. Using just the data from 1001 F villages a propensity score model was derived for whether or not the household consistently used 1001 F water using binary logistic regression. The same model was then applied to households in control village in order to identify those households who would most likely purchase 1001 F water should this become available. Frequency matching was then done across ranges of propensity scores between households using 1001 F water and those households with similar scores in control villages.

Data collection
The first visits in the prospective part of the study were done on the 8th December 2011. Each respondent was given a diary in which to record diarrhoea and or vomiting every day for each child. Households were then visited every two weeks for a total of 12 visits. At each visit the interviewer read the diarrhoea diary and asked about whether or not the drinking water source had changed since the previous visit and whether or not the child had been away from home.

The case definition for an episode of diarrhoea was 3 or more episodes of diarrhoea in a 24 period or any number plus vomiting.

Data analysis and sample size calculation
All analyses were done with SPSS version 18. To determine incidence rate ratios we used Generalized Estimating Equations for negative binomial family and log link. In order to account for repeat sampling of the same individual and possible within group correlation, person, household and village level were specified as subject variables. An autoregressive (1) working matrix was chosen because of a degree of autocorrelation between visits. As well as using propensity score matching to match people in villages without access to 1001 F to users in villages with such access, a range of potential confounding variables with tested in single predictor analyses. Those founders that were significantly associated with diarrhoea at the p < 0.2 level were included in a multiple predictor model. The least significant potential confounding variable was removed and the model re-run until all variables were significant at the p < 0.2 level.

Ethical approval
This study was reviewed and approved by the ethical review committee of the Faculty of Health, University of East Anglia and National Ethics Committee for Health Research of Cambodia. Informed consent was obtained from the parents or guardians of all children participating in this study.

Results
For several of the originally chosen intervention villages, only a small number of households using 1001 F water and with children living at home were recruited. Where this was the case the intervention village with the closest propensity score and not already included was also added to the study. Any recruited volunteers from the original village were still included in the study. Eventually households from 25 villages were included in the prospective study. Of these 25 villages, 15 were 1001 F villages and 10 control villages.

In total 4275 follow-up visits were completed on 376 participants from 309 homes. Of these 376 participants, 340 (90.4%) were included on all 12 occasions. Of the 36 that were not included in all visits 12 were recruited after the study start because they were born into families already recruited, leaving 24 (6.4%) who either died, moved away or decided not to participate further. Key demographic characteristics of the recruited population are shown in Table 1 for the intervention and non-intervention recruits. Figure 1 shows the distribution of ages on recruitment to the study. From the initial analysis it would appear that the populations using 1001 F water and not were very similar on all key variables including propensity score, household size, age at recruitment, anthropometry, family income and mother’s education (Table 1).
One of the key findings was that households’ choice of water often varied from one visit to the next. Indeed 98 (32%) households reported changing their main drinking water source from the previous visit at least once. It can be seen from Figure 1 that the main change was a reduction in use of 1001 F water an increase in use of rainwater during April and May (the rainy season). Also of note was an increased use of bottled water other than 1001 F water. Most times this water was described as “Pure water” which was a bottled water of unknown provenance and uncertain source/treatment.

Overall diarrhoea was reported in 20.4% of children on each visit. This equates to an incidence rate estimate of 5.32 episodes per child per year (95% confidence interval = 4.97 to 5.69). The risk factors associated with disease risk in a single variable analysis are listed in Table 2. Figure 2 shows the crude estimates of diarrhoea in people consuming water from different water sources.

Table 1 Demographics of the recruited populations in intervention and non-intervention communities

<table>
<thead>
<tr>
<th>Variable</th>
<th>1001 F user</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propensity score</td>
<td>N</td>
<td>165</td>
<td>0.46</td>
<td>0.21</td>
<td>0.707</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>211</td>
<td>0.47</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>Number of adults in home</td>
<td>N</td>
<td>165</td>
<td>2.70</td>
<td>1.16</td>
<td>0.653</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>211</td>
<td>2.76</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>Number of children in home</td>
<td>N</td>
<td>165</td>
<td>2.37</td>
<td>1.33</td>
<td>0.177</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>211</td>
<td>2.76</td>
<td>1.14</td>
<td></td>
</tr>
<tr>
<td>Age at recruitment</td>
<td>N</td>
<td>165</td>
<td>2.18</td>
<td>1.31</td>
<td>0.785</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>211</td>
<td>2.21</td>
<td>1.29</td>
<td></td>
</tr>
<tr>
<td>Height/cm at recruitment</td>
<td>N</td>
<td>165</td>
<td>78.0</td>
<td>13.7</td>
<td>0.285</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>209</td>
<td>79.4</td>
<td>12.4</td>
<td></td>
</tr>
<tr>
<td>Weight/Kg at recruitment</td>
<td>N</td>
<td>165</td>
<td>10.0</td>
<td>3.1</td>
<td>0.147</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>209</td>
<td>10.5</td>
<td>2.8</td>
<td></td>
</tr>
</tbody>
</table>

Proportion male

| Proportion male                  | N   | 165 | 0.47 | 0.603  |
|                                  | Y   | 211 | 0.50 |        |

Proportion mothers with secondary or higher education

| Proportion mothers with secondary or higher education | N   | 165 | 0.36 | 0.966  |
|                                                     | Y   | 211 | 0.36 |        |

Monthly income

<table>
<thead>
<tr>
<th>Monthly income</th>
<th>N</th>
<th>165</th>
<th>US$101-150</th>
<th>0.225</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y</td>
<td>211</td>
<td>US$101-150</td>
<td></td>
</tr>
</tbody>
</table>
Table 3 shows the final model after adjustment for the visit number, age, whether or not the child spent a night away from home in the previous two weeks, whether or not people use latrines or open defecation, water source, and whether or not the household recently changed their drinking water source were all associated with risk of illness. Whether or not there was a further case of diarrhoea in the home was not included in the final model as when there were more than one case it was not clear whether they were co-primaries or which was
Figure 2 Percentage of households (both intervention and control) reporting main source of drinking water at each visit.

Table 3 Final generalized estimating equation model of factors associated with risk of diarrhoea in children under 5 years old accounting for repeat measures within individual and possible clustering in home and village

<table>
<thead>
<tr>
<th>Variable</th>
<th>IRR</th>
<th>L95% CI</th>
<th>U95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age /y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.830</td>
<td>0.760</td>
<td>0.907</td>
<td>0.00004</td>
</tr>
<tr>
<td>2</td>
<td>1.909</td>
<td>1.44</td>
<td>2.529</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.662</td>
<td>1.259</td>
<td>2.194</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.592</td>
<td>1.193</td>
<td>2.125</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.637</td>
<td>1.22</td>
<td>2.196</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.265</td>
<td>0.928</td>
<td>1.726</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1.274</td>
<td>0.928</td>
<td>1.75</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.996</td>
<td>0.71</td>
<td>1.398</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.812</td>
<td>0.568</td>
<td>1.161</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.158</td>
<td>0.838</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>0.899</td>
<td>0.628</td>
<td>1.286</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any child spent night away from home in previous 2 weeks</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>1.289</td>
<td>1.09</td>
<td>1.524</td>
</tr>
<tr>
<td>Household monthly income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-500 income band</td>
<td>0.945</td>
<td>0.878</td>
<td>1.018</td>
<td>0.137</td>
</tr>
<tr>
<td>Sanitation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open defecation</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use latrine</td>
<td>0.782</td>
<td>0.621</td>
<td>0.984</td>
<td></td>
</tr>
<tr>
<td>Water source</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1001 F water</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piped supply</td>
<td>0.284</td>
<td>0.101</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>Rainwater</td>
<td>0.998</td>
<td>0.754</td>
<td>1.32</td>
<td></td>
</tr>
<tr>
<td>Protected groundwater</td>
<td>1.619</td>
<td>1.192</td>
<td>2.199</td>
<td></td>
</tr>
<tr>
<td>Other container water</td>
<td>1.569</td>
<td>1.149</td>
<td>2.141</td>
<td></td>
</tr>
<tr>
<td>Surface water</td>
<td>1.326</td>
<td>0.988</td>
<td>1.778</td>
<td></td>
</tr>
<tr>
<td>Unprotected groundwater</td>
<td>1.041</td>
<td>0.489</td>
<td>2.216</td>
<td></td>
</tr>
<tr>
<td>Recently changed water source</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1</td>
<td></td>
<td></td>
<td>0.014</td>
</tr>
<tr>
<td>Yes</td>
<td>1.295</td>
<td>1.054</td>
<td>1.591</td>
<td></td>
</tr>
</tbody>
</table>
the primary and which the secondary case. Of particular interest for this study was that compared to children drinking 1001 F water, children drinking surface water were 33% more likely to report diarrhoea (95% CI 1 to 17%), those drinking protected ground water were 62% (95% CI 19 to 120%) and those drinking other bottled water 57% (95% CI 15 to 114%) more likely to report diarrhoea. By contrast those using a piped supply were 72% (95% CI 20 to 90%) less likely to report diarrhoea. Also of interest were the findings that those drinking rainwater and unprotected ground water had very similar illness rates to those drinking 1001 F water. However very few people reported drinking from unprotected groundwater sources and the confidence intervals were very wide.

One of the findings in this study was the impact of recently changing water source on diarrhoeal risk. If the household source of drinking water had changed since the previous visit then there was an additional risk of diarrhoea of 30% (95% CI 5 to 59%). Although not the primary focus of this study we also found that use of latrines was associated with a 22% (95% CI 2 to 38%) reduction in diarrhoea compared to those using open defecation.

Discussion

This study was designed to investigate whether purchase of 1001 F water was associated with a reduced risk of diarrhoeal disease in children under five years old. We have shown that 1001 F as a drinking water source is associated with significantly reduced risk compared to many other widely used water sources in rural Cambodia, including surface water, protected groundwater and other bottled water. We would argue that the health benefits of consumption of 1001 F water over the alternatives are because of the design and management of the plants and processes, most importantly the use of UV disinfection that provides a wider kill spectrum against waterborne pathogens over alternatives [20]. However, probably the most important aspect is the initial training of entrepreneurs followed by the continued technical support and external quality control provided. In previous work we have shown that improved training of people managing water distribution in poor communities can be associated with health gains [21].

It should be stated that this was an observational and not an experimental study. As such participants were not blinded to their sources of drinking water and were clearly aware what water source they were using. Furthermore, the choice of whether or not to purchase water is governed by a range of other socio-economic factors. For both these reasons there is the potential for any findings to be affected by a range of biases and confounding [22]. For example, in one study of Household Water Treatment using Solar Disinfection (SODIS), the authors reported that people previously involved with the implementation were likely to over-estimate compliance compared to independent investigators [23].

To minimize the potential for reporting bias, we employed an independent survey company that had no prior involvement with 1001 F, and enumerators were trained on the importance of impartiality and not to suggest the value of one water source over another. To further minimize the potential for recall bias we provided participants with a daily diarrhoea diary so that they would not have to remember episodes of illness until the next visit. Also because this was an observational study rather than a randomised trial it was easier to prevent participants from being aware of our study hypotheses. To overcome the problem of confounding we used a two stage propensity score matching process. This process ensured that we were able to compare people in villages that had access to 1001 F water with people in villages that were as similar as possible. But perhaps more importantly, within those villages without access to 1001 F we were able to choose participants who were as similar as possible to people who were using 1001 F water in villages with access, i.e. people who would probably use 1001 F water if and when it became available. By these processes we have controlled for these sources of bias as best as we were able. However, even a process of propensity score matching is not a guarantee that all potential confounding variables are controlled for.

A particularly important finding was the observation that risk in people when drinking rainwater and 1001 F water was almost identical. Although harvested rainwater is classed as an improved drinking water source, a number of authors have expressed concerns about the safety of rainwater harvesting as a drinking water source based on microbiological examination [24,25]. However, in a recent systematic review and meta-analysis of epidemiological studies of diarrhoea and consumption of rainwater we showed that harvested rainwater was associated with a reduced risk compared to unimproved water sources and had similar risk as improved supplies such as mains water in most studies [26]. Our study provides further evidence for the relative safety of rainwater harvesting.

Of particular concern is the finding that protected groundwater sources were associated with the highest risk of illness. Protected groundwater sources are classified as improved water sources and so are considered to be protected from contamination with faecal matter (WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation http://www.wssinfo.org/definitions-methods/introduction/). Perhaps this should not be such a great surprise as microbiological studies of such groundwaters often report high rates of E. coli
indicating faecal contamination [27-29]. Because protected groundwater supplies are considered to be at low risk of contamination, communities reliant on these supplies are deemed to be provided with safe water under the requirements of the Millennium Development Goals (MDG). Many of those people now classed as having access to safe water would be so classed on the basis of access to protected groundwater. Our results cast serious doubt on the safety of protected ground waters and consequently further doubt on the validity of the claim that the MDG target on access to safe drinking water has been met.

Although this study was not primarily concerned with sanitation other than as a potential confounder of water supply on disease risk, we have shown an important impact of latrine use in reducing disease risk. Despite the fact that improved sanitation is widely accepted as being one of the most important public health interventions in recent history [30], there is relatively little firm evidence of its value in development settings [31]. Our study would add important further support for the importance of sanitation improvements.

A final comment about the 1001 F programme is because of the focus on helping local entrepreneurs develop sustainable locally based businesses; this intervention supports economic development in a way that retains funds within the communities themselves. As we have shown previously in a very different setting, education and training around water supply can have an impact beyond water quality and support people in climbing out of poverty [21].

Conclusions
In conclusion this study has suggested that consumption of 1001 F water is associated with a reduction in acute diarrhoeal disease in young children. We have argued that the care taken in participant selection, the use of diaries rather than relying on memory and using an independent survey company would reduce biases and improve confidence in our conclusions. In addition our study has provided further evidence in support of the safety of rainwater harvesting. However, our work also suggests that protected groundwater sources may not actually provide safe drinking water casting further doubt on claims that the MDG on drinking water has been met.

Competing interests
PRH was until 2010 a member of the science advisory council of Suez Environment, a water utility. He also received an honorarium to attend a workshop held by Danone Group. Otherwise the authors declare no competing interests.

Authors’ contributions
PRH, HR, MY, HL, PH, CL and FJ were responsible for study design. MY, HL, CL and FJ were responsible for data collection, PRH undertook the analysis and wrote the first draft of the manuscript; all authors were involved in preparation and approval of the final draft of the manuscript.

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References
Impact studies summary
Cambodia 2012
1. Executive Summary

1.1. Project summary

1001fontaines, a non-profit organisation created in 2004, contributes to the global effort of international solidarity improving access to safe drinking water in small rural communities. It aims to improve the health of these populations by enabling them to meet their needs for safe drinking water in a sustainable manner and without any specific infrastructure or expertise.

The major objective of these studies was to measure to what extent the health of the beneficiaries of the 1001fontaines services were improved by such services. More specifically, two populations were observed:

- **Children between 6 and 12**, where attendance at school (School study) was measured;
- **Children under 5**, within their families (Cohort study), for whom episodes of diarrhoeal diseases were reported and correlated to the water source used by the family.

For the School study, attendance rates were extracted from the attendance reports of each school. These groups were observed during a 6 month period, during which each family of the Cohort study was visited twice a month in order to record potential diarrhoeal diseases.

1.2. School study findings

The comparisons of attendance statistics were made between two groups of schools, one where safe water was made available every school day to the children, while the children of the other group used their usual water sources. The results showed that absenteeism, during the dry season, was reduced by 55 to 75% for the children of the first group, depending on the adequacy of the delivery of the water by our entrepreneurs. Although we do not suggest that a similar reduction might be automatically expected in the waterborne diseases preventing them from attending school, we do believe that this suggests that this provision of safe water sufficiently improves the child’s general wellbeing, as well as the experience of the school day, as he/she is better hydrated. Consequently the child is more likely to attend school the following day.

1.3. Cohort study findings

The study clearly shows that, as an alternative to piped systems (which appear as the safest water source but obviously cannot be deployed widely in rural areas for investment cost reasons), two water sources (rainwater harvesting and 1001fontaines water) can be associated with reduced childhood diarrhoea while other alternatives cannot. Other water sources (groundwater, as well as surface water) show a probability of getting ill that is 33 to 62% higher than for harvested rainwater or 1001fontaines water. This higher risk is most likely to be associated with the conditions of transportation or storage of such water (leading to its contamination before its consumption), as well as to poor hygiene practices.
2. The 1001fontaines initiative

2.1. Description

1001fontaines is a non-profit organisation (created in 2004) contributing to the global effort of international solidarity and, more specifically, improving access to safe drinking water. This initiative is specifically orientated towards small rural communities, which generally fall outside of the remit of water access projects. It aims to improve the health of these populations by allowing them to meet their needs for safe drinking water in a sustainable manner and without any specific infrastructure or expertise.

As you will see by visiting our website www.1001fontaines.com or by watching a short video (link at the end of this section), 1001fontaines has implemented several pilot projects in Cambodia between 2005 and 2013, enabling today roughly 172,000 beneficiaries in more than 100 villages to drink safe water.

We started similar projects in Madagascar in 2008 (10 operating sites running at present and 16 more to be launched in 2014 and 2015), and a first pilot project is currently undertaken in India (West Bengal).

Furthermore a specific Sponsorship Programme was started in 2008, whereby safe water is provided free of charge to schools in the villages where a 1001fontaines station exists. As of today 56,000 children benefit from the service. We recognise that children are the most vulnerable to water-borne diseases, and we are convinced that targeting children is an effective means of raising not only their own, but also their parents’ awareness of Water and Sanitation for Health (WASH) issues.

1001fontaines has received a number of awards, notably the « 2006 Award for International Solidarity», an annual award granted by the French « High Council for International Cooperation » (a service of the office of the Prime Minister). In 2011, the title of “Asian Social Entrepreneur of the year” was awarded to the Cambodian co-founder, M.Chay Lo, by the Schwab Foundation.

1001fontaines’ funding comes from private donors (companies, foundations), as well as institutional donors such as the French Embassies in Cambodia and Madagascar and the French Development Agency (AFD).

1001fontaines’ long-term strategy is to provide totally safe water to millions of villagers in many countries:

- at an affordable price – currently around US $ 0.01 per litre,
- in a sustainable manner; our economic model relies on social enterprise principles with each operating site, as well as the supporting infrastructure, being self-financing through water sales,
- for a very low one-time investment cost – currently US $ 10 per beneficiary.

The following link will help you grasp the core principles guiding our actions, as well as the positive impact that they generate on health.

1001fontaines video (6 minutes): http://fr.youtube.com/watch?v=8bykbVECvRE
2.2. Operating principles

Over the first six years (2005-2011), the work of 1001fontaines has focused on addressing three major issues:

- **Water quality**: The water sold in each village by local 1001fontaines entrepreneurs is produced and distributed in 20 litre bottles according to a process, which was designed with the help of two world-wide leaders in drinking water distribution, namely Veolia and Danone. Quality requirements correspond to the highest World Health Organization (WHO) standards and water quality is controlled on a frequent basis according to procedures designed for us by the Fondation Mérieux (France).

- **Accessibility**: This starts with offering safe drinking water at an affordable price for poor people (i.e. ability to pay). We meet this condition with a selling price of around US $ 0.01 per litre. Accessibility also requires undertaking significant training and social marketing actions, in order to foster changes in behavior related to hygiene and safe water consumption (i.e. willingness to pay). Over a 6 to 8 year period our objective for each production site (in each village) is to convert at least 40% of the population from drinking contaminated water to drink safe water every day.

- **Sustainability**: After a one-year apprenticeship period, each production site becomes financially self-sustainable, i.e. the operator generates enough revenues to make a living and finance all operating and maintenance expenses, as well as growth investments.

Operational sustainability is also guaranteed by a technical support platform, i.e. a team of skilled technicians supervising 50 to 60 operating sites. The platform gives technical assistance to operators and carries out quality control tasks. In exchange for these services the platform receives monthly assistance fees from each site according to a micro-franchise operating model.

Thus, water sales enable the achievement of financial sustainability for both the support platform and the operating sites, despite a very low selling price.

From 2012 onwards, since the viability of its safe water provision model had been demonstrated, 1001fontaines has been pursuing two new constituents of its vision, namely scalability and replicability.

- **Scalability**: By mid-2012, 58 operating sites were running in northwest Cambodia, serving up to 100,000 beneficiaries on a regular basis. The next step (2012-2017), which has the operational support of the Cambodian Ministry of Rural Development, is to scale up the model by opening 3 new support platforms throughout Cambodia and creating 200 new operating sites connected to these platforms, ultimately to serve 1 million customers. (Today 7 million Cambodian people living in rural areas do not have any access to safe drinking water). This programme will create approximately 1,000 income-generating full-time jobs.

- **Replicability**: Given its successful achievements in Cambodia, 1001fontaines intends to replicate it in other countries, where the demand for safe water needs to be fulfilled.

Pilot projects are currently underway in Madagascar and in India.
2.3. Achievements

At the end of 2013, 1001fontaines safe water production units served, through 100 production sites, approximately 172,000 beneficiaries in Cambodia, 116,000 being villagers paying around US $ 0.01 per litre of safe water, and 56,000 being children under 12 who take advantage of a daily free delivery of safe water in their schools.

2.4. School programme

In conjunction with the launch of production sites for safe drinking water in the largest possible number of villages, the charity 1001fontaines initiated a programme in early 2008, called “Water in school” aimed at providing a supply of clean drinking water to the most vulnerable people, especially children.

This programme finances the daily supply of safe drinking water to the primary schools, children’s homes and health care centres in the villages, where we operate. This supply is provided by social enterprises launched by 1001fontaines in the respective villages. If the volumes required justify it, a water purification unit may actually be installed on the premises.

To date, 118 sponsorship programmes have been established in Cambodia:
- 114 “Water in school” programmes, providing the daily supply of drinking water for the primary schools of the villages concerned, whereby a quantity of 20 litre containers of safe water (one for each classroom) is delivered every morning,
- 4 “fontaines” sponsoring programmes, which consist of the installation on site of the complete water production unit enabling the school or care centre to satisfy, by themselves, the needs for drinking water of all the children whom they support. This solution is preferred to the “Water in school” programme, where there is a large number of children in attendance each day at the site.

As 1001fontaines continues to deploy its solution to additional villages during 2013-2014, the objective is to expand the sponsorship programme to provide clean drinking water to more than 60,000 children, with an annual budget of US $ 100,000.

Less than US $ 2 supplies safe drinking water for 1 child at school for 1 year.

In addition to the direct impact on the health of the children, who benefit from safe drinking water, the provision of this water is an opportunity for educating the children on the importance of safe drinking water and improved hygiene.

The children in the sponsorship programme are then very effective in educating other members of their families and motivating them to adopt new hygiene habits to the benefit of the whole family.
3. Impact study description

3.1. Objectives

The major objective of this study was to measure to what extent the health of the beneficiaries of 1001fontaines safe drinking water was improved.

More specifically, two populations were observed:
- **Children between 6 and 12** (School study), where attendance at school was measured;
- **Children under 5**, within their families (Cohort study), for whom episodes of diarrhoeal diseases were reported and correlated to the water source used by the family.

These groups were observed during a 6 month period.
For the School study, attendance rates were extracted from the attendance reports of each school.
For the Cohort study, each family was visited twice a month in order to record potential diarrhoeal diseases.
The observation period was Dec 1st 2011 to May 31st 2012. Most of this period corresponded to the “dry season” (Dec 1st to mid-April) - the rain started to fall in mid-April 2012.

3.2. School study

The School study was conducted in the primary schools of 8 different villages:
- 4 villages where a 1001fontaines safe water production facility had been established (for at least 2 years) and where the local 1001fontaines producer delivers, every school day, free of charge, a 20 litre bottle of safe water in each classroom (under the 1001fontaines “Water in School” programme). This “Intervention Group” comprised 1,986 children.
- 4 villages where no 1001fontaines project had ever been implemented, and where children, at school, had to rely on the usual sources of water they brought from home or found in the neighbourhood of their school. This “Control Group” comprised 1,534 children.
The next chart explains what was measured, week after week, over this 6 month period.

<table>
<thead>
<tr>
<th>Class</th>
<th>Sex</th>
<th>CS</th>
<th>4-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-school</td>
<td>M</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>33</td>
<td>3</td>
</tr>
</tbody>
</table>

Potential schooldays = Nb of children x 5 days/week

Absenteeism = \( \frac{\text{Nb of absences}}{\text{Potential schooldays}} \)
3.3. Cohort study

This study focused on children under 5 at their family homes and tried to correlate their incidences of diarrhoeal diseases with the types of drinking water that they consumed. The following chart shows the key figures regarding the Cohort study participants:

<table>
<thead>
<tr>
<th>Basic demographics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 4275 completed follow-up visits on</td>
</tr>
<tr>
<td>• 376 participants</td>
</tr>
<tr>
<td>• 310 homes</td>
</tr>
<tr>
<td>• 15 villages</td>
</tr>
<tr>
<td>• 340 participants were interviewed on all 12 occasions</td>
</tr>
<tr>
<td>• 48.4% Male and 51.6% Female</td>
</tr>
</tbody>
</table>

3.4. Budget / Duration

These studies were conducted between January 1st, 2011 and October 31st, 2012. Their cost amounted to US $ 208,000. Many experts contributed to ensure that the studies were conducted according to the best practices of epidemiology.

A Scientific Committee oversaw the studies and included the following people:
- Professor Paul Hunter (University of East Anglia)
- Professor Philippe Hartemann (Faculté de Médecine de Nancy)
- Doctor Christophe Longuet (Fondation Mérieux)
- Doctor Hassan (WHO Cambodia).

The research protocols were established by Professor’s Hunter department at the University of East Anglia. All data collection was subcontracted to an independent institute, namely the Indochina Research Ltd, based in Cambodia.

These studies were conducted according to the following schedule:
- January 1st – March 31st, 2011: Preparation of the research protocols
- April 1st – November 30th, 2011: Recruitment of the families (Cohort Study) and selection of the schools (School study)
- December 1st, 2011 – May 31st, 2012: Field data collection
- June 1st – October 31st, 2012: Data Analysis.

This study was made possible financially thanks to the following contributors:
- Fondation Ensemble,
- Véolia Fondation,
- Danone Group,
- AFD (The French Development Agency),
- Fondation Mérieux.
4. School study findings

4.1. Major findings

The comparison of the absenteeism rates between the primary schools of the Control and Intervention groups are shown hereunder.

This table shows a reduction of 55% of absenteeism between these two groups, during the dry season. The reduction is extremely consistent for the detailed results, school by school and grade by grade.

The results shown for the rainy season are difficult to interpret, since other factors may significantly contribute to raising this absenteeism:

- Rainfall, in rural areas, has a major impact on the roads and may prevent a significant number of families from sending their children to school;
- Cultivation of the rice field, which is the major economic activity of these families, restarts with the rainy season (only one harvest per year in Cambodia), which may lead some families to keep some children at home, in order to compensate for the parents’ presence in the rice fields.

4.2. Additional findings

When reviewing the detailed absenteeism numbers, school by school, a marked consistency appeared, week after week, school by school and grade by grade, except for one school (Hum Sen Svay Leu Primary School) belonging to the Intervention Group.

After a field investigation, it appeared that the 1001fontaines entrepreneur, in charge of supplying the Hun Sen Svay Leu Primary School with safe water every morning, did not actually serve that school as planned. Due to a lack of enough containers (20 litre bottles) to satisfy both the villagers demand and the school demand, the entrepreneur preferred first to serve his paying customers (the villagers). This limited the quantity of water delivered to the primary school to the number of remaining available containers.

Therefore, the level of service for the school was inadequate, especially in January and March.
4.3. Interpretation

The magnitude of the reduction of the absenteeism observed during the dry season between the Control and Intervention groups, its consistency over weeks and in detail, between the various schools and grades within the schools, leads us to conclude that the consumption, every day at school, of totally safe drinking water, has a significant impact on the ability and/or willingness for these children, aged between 6 and 12, to attend school.

This magnitude is emphasised in the following chart (where the Hun Sen Savy Leu primary School has been excluded from the Intervention Group), the reduction of absenteeism then consistently exceeds 75% during the dry season.

A subsequent question arises concerning the extent to which this reduction in absenteeism can be correlated with an impact on these children’s health.

Firstly, the observation of the absenteeism rates in the Control Group schools clearly shows the importance for these poor rural families of having their children attend school. For most of these families, they understand and believe that the major opportunity for their children to have a future life better than their own is to go to school. The low average rate of absenteeism, shown by this study (between 4 and 5%), confirms that attendance at school is a priority.

Besides health issues or lack of interest, the major reasons for not attending school are generally financial. In addition, there may be logistical difficulties in reaching the school or an obligation to devote time to income-generating activities rather than to school.

Regarding the first item (cost), it is likely that the financial issue did not interfere with the study. One reason for this is that, in Cambodia, education is a free public service, and the second reason is that the selected villages, through the selection technique used (Propensity Score Matching) are very similar with regard to the average income level.
With regard to logistical difficulties, this almost certainly contributes to absenteeism during the rainy season, but this is not very likely during the dry season.

Similarly, the priority potentially given to income-generating activities, while very likely during the rainy season, is probably minimal during the dry season. Most of the economic activity of these villages consists of rice production and this activity is performed (unfortunately for this population) only during the rainy season. Therefore, it can be assumed that the major reasons for absenteeism during the dry season are related to health issues, particularly diarrhoeal diseases, which are prevalent in the age group studied and/or with unwillingness to attend school.

The demonstrated reduction in absenteeism, resulting from just the consumption of safe water at school, has an important positive impact on the children’s access to education and, therefore, on their future.

This leaves the question of what is the causal relationship between the provision of clean drinking water and absenteeism. In this study we were not able to collect any data on the specific reasons for absenteeism. Given the fact that the association was between absenteeism rates and drinking water delivery in the same week and not the previous week, we are not suggesting that the drop in absenteeism was primarily due to a reduction in the incidence of waterborne infectious diseases. A probable explanation is that by providing readily available, palatable and safe drinking water in the classroom, children are more likely to drink during the school day and, so, not become dehydrated. Even mild dehydration in vulnerable groups, such as young children, has been suggested as being associated with adverse health effects.

What this study does suggest is that the provision of clean drinking water improves the child’s general wellbeing, as well as the experience of the school day, as he/she is better hydrated. Consequently, the child is more likely to attend school the following day.

4.4. Outlook

This study suggests that, just by regularly (each school day) providing safe high-quality drinking water at school to young children, a very significant impact can be achieved in terms of their general wellbeing and their willingness to attend school.

Furthermore, the 1001fontaines experience shows that this can be made possible for a cost not exceeding US $2 per child and per year.

Obviously, this depends on their being a 1001fontaines safe water production operation in their village.

By design, this study was made in villages offering to the families (through the existence of a 1001fontaines safe water producer) the ability also to consume at home (at night and over the week-ends) totally safe drinking water. Similarly, the fact that this facility exists and the education programmes which have been conducted in conjunction with its establishment may have contributed to improving the hygiene practices of these families, regardless of their consumption or not of safe drinking water.

However, the result seems significant enough to justify, on a wide scale, such programmes for safe drinking water delivery at school.
5. **Cohort study findings**

5.1. **Population surveyed**

As explained earlier, the study focused on children under 5 at their family homes and tried to correlate their incidences of diarrhoeal diseases with the types of drinking water that they consumed. 340 (out of an initial count of 376) such children were interviewed (via their parents) every 15 days, over a 6 month period. Most of the 36 cases that were dropped during the study resulted from the move of their family to another location, although a few of them were dropped because unfortunately they died during the study.

5.2. **Water sources**

The following chart indicates the water sources that each respondent claimed to have primarily used during the two weeks preceding each interview.

Since the study was focused on the impact of 1001fontaines projects, approximately 50% of the surveyed population were 1001fontaines consumers. The other 50% used other sources, such as rainwater (generally collected during the rainy season then stored at homes in large 1,000 litre jars), surface water or groundwater (protected or unprotected wells).

Some changes in water source may have been recorded from one interview period to another. Most of these changes occurred in April when rain started to fall again in Cambodia.
5.3. Definition of illness

For the purposes of the study, illness was defined as three or more episodes of diarrhoea in a 24 hour period or more plus vomiting. The study revealed an incidence rate of 5.32 episodes per child per year (95% confidence interval = 4.97 to 5.69).

5.4. Major findings and perspectives

The most valuable information resulting from this Cohort study is shown hereafter (Illness Incidence reported by water source).

<table>
<thead>
<tr>
<th>Water Source</th>
<th>Incidence Relative Ratio</th>
<th>Incidence Convidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piped water</td>
<td>0.284</td>
<td>0.101</td>
</tr>
<tr>
<td>Rain water</td>
<td>0.998</td>
<td>0.754</td>
</tr>
<tr>
<td>1001fontaines</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Unprotected Groundwater</td>
<td>1.041</td>
<td>0.489</td>
</tr>
<tr>
<td>Surface water</td>
<td>1.326</td>
<td>0.988</td>
</tr>
<tr>
<td>Other container</td>
<td>1.569</td>
<td>1.149</td>
</tr>
<tr>
<td>Protected Groundwater</td>
<td>1.619</td>
<td>1.192</td>
</tr>
</tbody>
</table>

This study clearly shows that, as an alternative to piped systems (which appears as the safest water source but obviously cannot be deployed for investment cost reasons widely in rural areas), two water sources (rainwater harvesting and 1001fontaines water) can be associated with reduced childhood diarrhoea while other alternatives cannot.

Other water sources (groundwater, as well as surface water) show a probability of getting ill that is 33 to 62% higher than for harvested rainwater or 1001fontaines water. This higher risk is most likely to be associated with the conditions of transportation or storage of such water (leading to its contamination before its consumption), as well as to some poor hygiene practices.

Surface water scored slightly better than groundwater. This may be related to boiling, which is a relatively common practice for surface water consumers but not for groundwater consumers.

Other containerised water suppliers do not seem to put the same priority on water quality as 1001fontaines.

Attention should be drawn to the poor score of protected groundwater, since most of the investments made by governments or international donors tend to be dedicated to such facilities.

This study raises the question as to whether the protected groundwater approach, by itself, can be considered as an access to “improved water” from the point of view of its impact on health. In addition, the current classification of the WHO/UNICEF Joint Monitoring Program (JMP) for Water Supply and Sanitation, which does not recognise bottled water as “improved water”, could be challenged. This study confirms that position for many suppliers of water in containers but questions it for suppliers, like 1001fontaines, which are committed to providing drinking water with a quality that meets high WHO standards.
The impact studies presented in this document were made possible thanks to the contribution of the following people, who shared their experience and insight in “Health and Water” to 1001fontaines:

1001fontaines
- François Jaquenoud  Co-founder
- Chay Lo  Co-founder
- Hélène Ferrer-Lefebvre  Development manager
- Marie Yen  Field project manager
- Sylvie Oursel  Volunteer

Scientific Committee
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- Helen Risbro  Univ. East Anglia (UK)
- Prof. Philippe Hartemann  Fac. Médecine Nancy
- Dr. Christophe Longuet  Fondation Mérieux

Participants
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- Lionel Goujon  AFD (Water Division)
- Stéphane Pamies  AFD (Evaluation Division)
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To all of them, our grateful thanks.
Improving the health of rural populations by enabling them to produce and distribute safe drinking water in a sustainable way

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