Check for updates

Water-related factors and childhood diarrhoea in African informal settlements. A cross-sectional study in Ouagadougou (Burkina Faso)

Stéphanie Dos Santos, François de Charles Ouédraogo and Abdramane Bassiahi Soura

ABSTRACT

Improved access to water is a key factor in reducing diarrhoeal diseases, a leading cause of death among children in sub-Saharan Africa. In terms of water access, sub-Saharan African cities are some of the worst off in the world, with 20% of populations supplied by an unimproved water source. This situation is even worse in informal settlement areas. Using cross-sectional data on access to water from a survey implemented in three informal neighbourhoods of the Ouagadougou Health and Demographic Surveillance System, logistic regressions are modelled to test the effect of different modalities of access to water on childhood diarrhoea. Our results show that the prevalence of diarrhoea in children is high: one-third of households with a child under 10 experienced an episode of childhood diarrhoea during the 2 weeks preceding the survey, even though 91% of the households surveyed have access to an improved water source. The results show that efforts to reduce childhood morbidity would be greatly enhanced by strengthening piped water access in informal settlement areas in Africa. In addition, this study confirms that, beyond the single measure of the main access to water, accurate variables that assess the accessibility to water are needed.

Key words | Africa, childhood diarrhoea, informal settlements, water-related factors

Stéphanie Dos Santos (corresponding author)
Laboratoire Population-Environnement-Développement (AMU/IRD),
Institut de Recherche pour le Développement,
BP 182, Ouagadougou 01,
Ouagadougou,
Burkina Faso
E-mail: *stephanie.dossantos@ird.fr*

François de Charles Ouédraogo
Département de Géographie,
Université de Ouagadougou,
BP 7021, Ouagadougou 03,
Ouagadougou,
Burkina Faso

Abdramane Bassiahi Soura
Institut Supérieur des Sciences de la Population,
Université de Ouagadougou,
BP 7118, Ouagadougou 03,
Ouagadougou,
Burkina Faso

INTRODUCTION

In sub-Saharan Africa, urban dwellers are considered to have good access to water, in contrast to their rural counterparts. Figures from the Joint Monitoring Programme (WHO/UNICEF Joint Monitoring Programme (JMP) 2012) show that in 2010, 83% of urban populations had access to an improved source of water, compared to 49% in rural areas. Consequently, until recently, the majority of scientific work concerning the issue of access to water has focused primarily on rural areas (Gleitsmann *et al.* 2007). However, the current urban growth rate of African cities is leading to the development of informal settlements that do not have access to basic services, including water. Changes in both water supply (due to climatic changes) and demand (due to the increase in urban populations and economic growth) have caused many African urban dwellers to experience difficulties in meeting their daily water needs (Mitlin & Satterthwaite 2013).

The limitations of the current indicator of access to an improved source of water used by the JMP are widely known, particularly with respect to health implications (Lim *et al.* 2012). Firstly, intra-urban disparities are very important, especially in informal areas (Dagdeviren & Robertson 2009). These disparities, however, are totally masked when using a global indicator of water access in urban areas. Secondly, details on accessibility to water are required in order to be able to analyse the daily difficulty of accessing water in these contexts (Howard & Bartram 2003; Schaefer *et al.* 2007; Dos Santos 2012). Hunter *et al.* (2010) described six water supply determinants that play an effective role in maintaining good health: quality, quantity, access (physical

doi: 10.2166/wh.2014.115

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

distance or socioeconomic and cultural dimensions of access), reliability, cost, and ease of management. These factors have long been widely recognised in the literature as reducing waterborne disease in children (Esrey *et al.* 1991), notably by contributing to appropriate hygienic practices such as hand washing (Cairncross *et al.* 2010). Thirdly, taking a coarse indicator into account is an obvious reason for the lack of positive results with regard to access to water in some studies on child health in developing countries (Cairncross 1990; Fewtrell *et al.* 2005).

Finally, households may use more than one water source depending on opportunity and on the reliability of the water supply. Water cuts may therefore require households to switch temporarily from an improved source of water to an unimproved source, such as street water vendors, to mitigate the impact of the cuts (Dagdeviren & Robertson 2009). The use of an alternative source may also affect the quantities available, either negatively or positively. In this context, the use of rainwater harvesting has received particular attention. However, even though this source of water is considered to be improved, several studies have shown that the storage of rainwater often does not meet World Health Organization (WHO) guidelines for drinking water, especially with respect to bacteriological water quality, and it thus constitutes a potential source of human illness (Ahmed *et al.* 2011).

As noted by Hunter *et al.* (2010), 'many uncertainties remain about how to improve public health through improvements in the water supply'. In particular, few population-based studies in Sahelian cities have specifically investigated the relationship between accessibility to water – including different aspects of water access – hand washing practices, and childhood diarrhoeal diseases, using models that control for confounders, thus allowing for a complete study of water factors all things being equal. This article attempts to contribute to a deeper understanding of these relationships in Sahelian informal settlements, based on data from three informal settlements in Ouagadougou, the capital city of Burkina Faso.

CONTEXT

Burkina Faso is one of the poorest countries in the world, ranked 181 out of 186 by the United Nations Development Programme's (UNDP's) Human Development Index (UNDP 2013). Its capital, Ouagadougou, is part of the Sudano-Sahelian area and has a tropical savannah climate with two very distinct seasons: a rainy season, which lasts approximately 4 months, from May/June to September, and a dry season, during which the Harmattan blows a hot dry wind from the Sahara. Ouagadougou counts over 1.5 million inhabitants and has experienced significant population growth over the past few decades. Based on the latest census, the demographic growth rate is currently estimated at 7.6% per year (INSD 2009).

This growth has resulted in the rapid spread of urban space to the periphery, especially to informal settlements. One-third of households are settled in such informal areas, according to the latest estimation (Boyer & Delaunay 2009). These settlements are outside the municipal authority and typically have no access to basic urban services.

In this context and until recently, the Office National de l'Eau et de l'Assainissement (ONEA – National Office for Water and Sanitation) developed an unusual water management system called 'shared water management' (Jaglin 1995), a pragmatic approach that prioritised the provision of clean water to the greatest number of people via public standpipes located in formal neighbourhoods, rather than through shared or fully private water connections at home. As a consequence, Ouagadougou had one of the lowest rates of access to piped water on premises in the region (Dos Santos 2006). Since 2006, considerable efforts have been made to enhance piped water connections at home (Dos Santos & Le Grand 2013). Currently, according to the definition used by the JMP, 99% of households in Ouagadougou have access to an improved source of water (INSD & ICF International 2012). This situation is a real counter-example, given the national level of poverty (Hunter *et al.* 2010). This is particularly noticeable when comparisons are made with the capital cities of neighbouring countries (Table 1). In this context, Ouagadougou presents an intriguing profile to undertake this study.

Ouagadougou is also faced with a number of environmental and socioeconomic issues that could be responsible for childhood diarrhoeal morbidity. In 2010, diarrhoeal morbidity in Ouagadougou (18.2%) was higher than in other cities in the country (15.0%) and than in rural areas (14.4%) (INSD & ICF International 2012). Finally, the

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

Table 1 | Distribution of households by access to water in some sub-Saharan African capital cities

	Improved access				
	Piped on the premises	Other improved	Total	Unimproved	Total
Ouagadougou[a]	47	52	99	1	100
Bamako[b]	41	54	95	5	100
Cotonou[c]	48	51	99	1	100
Dakar[d]	76	16	92	8	100
Niamey[e]	42	52	94	6	100

[a]Demographic and Health Survey (DHS) 2010.
[b]DHS 2006.
[c]DHS 2006.
[d]DHS 2005.
[e]DHS 2006.

focus on the outskirts is highly relevant because Ouagadougou is a city surrounded by children: the percentage of young children in the population hovers around 10% in the central areas, but doubles for the outlying neighbourhoods (INSD 2009).

METHODS

Data

The study was conducted in the Ouagadougou – Health and Demographic Surveillance System (Ouaga-HDSS) (Rossier *et al.* 2012) field site in August 2012. The Ouaga-HDSS is a research platform devised to design and test innovative programmes that promote the wellbeing of vulnerable urban populations (the Ouaga-HDSS is part of the INDEPTH network). Since 2008, the Ouaga-HDSS has periodically collected health and demographic information in five neighbourhoods in the northern outskirts of the capital city: three unincorporated neighbourhoods (Nioko 2, Nonghin, and Polesgo) and two incorporated neighbourhoods (Kilwin and Tanghin). The three informal sites were selected so as to target the most vulnerable populations of the city. In addition, information given by the municipalities helped to select the three informal areas as devoid of formal zoning plans.

In 2012, a multidisciplinary project was implemented in the three informal neighbourhoods followed by the Ouaga-HDSS (Figure 1) that aimed to monitor the variability and the diversity of access and use of water in households. At this time, the total population of these three informal settlements was estimated at 45,371 individuals, most of whom were illiterate and living in very rudimentary economic conditions and housing (Rossier *et al.* 2012). Within each study site, the selection of households for the study was done using a simple random sampling method. Socioeconomic and demographic characteristics of the selected households, such as the standard of living or the gender of the head of the household, were then compared to ensure the representativeness of the sample. In total, the sample comprised 702 households with at least one child under 10 years: 232 households in Nonghin, 233 in Nioko 2, and 237 in Polesgo.

The person responsible for the household (most often the wife of the head of the household, who is most likely to be the person responsible for water collection and storage and thus best placed to provide reliable answers) replied to a standard, pre-coded questionnaire. The nature and purpose of the study was explained to participants. The household questionnaire consisted of seven modules addressing issues as varied as the types of water supply (main and alternative type), the conditions of collection and storage of water, and the cost of water, as well as various domestic water uses. In addition, a health section on water-related diseases was administered for each child under the age of 10 living in the household.

While studies on childhood diarrhoea largely target children under five because diarrhoea is primarily a concern for children in this age group, it could be helpful to obtain a more detailed picture of the burden of childhood diarrhoeal disease in households. We therefore focused on children under the age of 10. It was possible to restrict the analysis to children aged 0–5 years old, but as we had information from a larger sample, we chose to do the analysis on children aged 0–10 years old, in order to gain robustness in the modelling.

Statistical analysis

Descriptive statistics were used to summarise the study variables. We then estimated multivariate logit models to assess the effects of different factors relating to access to water on the probability that a household would have reported at

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

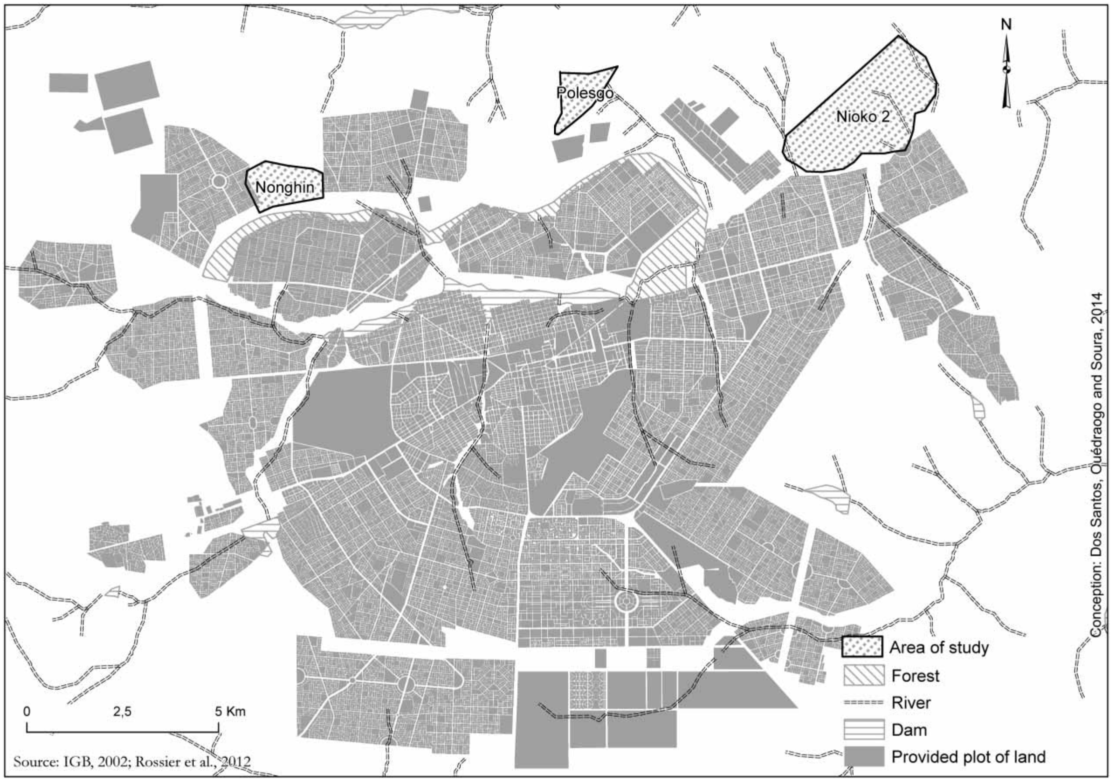

Figure 1 | Location of study sites, Ouagadougou Health and Demographic Surveillance System.

least one episode of childhood diarrhoea in the 2 weeks preceding the survey, after controlling for demographic and socioeconomic variables. Self-reported diarrhoea was used as an outcome measure in this study. An episode of diarrhoea was defined according to the most widely accepted definition – that is to say the onset of three or more loose or watery stools within a 24-h period (Wright *et al.* 2006).

The model can be expressed as:

$$\ln\,(q_i/1 - q_i) = \beta_0 + \beta_i x_i$$

where q is the probability of at least one occurrence of childhood diarrhoea in the ith household, β_0 is the baseline constant, β_i is a series of unknown coefficients, and x_i is an array of independent variables. The estimated coefficients (β_i), when exponentiated, are interpreted as the odds of at least one occurrence of childhood diarrhoea ($q_i/1 - q_i$) for households with certain characteristics relative to the odds of diarrhoea in a reference (or baseline) group of households: in other words, relative odds or odds ratios (OR).

To better understand the effects of water factors net of other key covariates, variables were introduced separately into the models, thus allowing for a comparison of coefficients across the different equations. Model 1 presented the estimated effects of the main source of drinking water. Model 2 showed the estimated effects of the time needed to collect water outside the house. Model 3 included both the variable tested in Model 1 and the variable tested in Model 2. This three-step process was used to highlight the relative role and importance of each of the two first factors relating to water. Finally, Model 4 expressed the completed model integrating all water factors, including the first two and four other water factors: type of water storage, quantity available per capita per day, use (or not) of rain water as an alternative source of water, and hand washing before eating. In all models, the socioeconomic variables of the household were introduced in order to provide a more accurate assessment of the effect of water factors all things being equal. Presumably, adding these controlling variables to the equation also

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

proxies the effects of some omitted variables (e.g. cultural beliefs and practices, breastfeeding, etc.), thus allowing for a more precise assessment of the effects of water factors. All data were analysed using Stata v.11 statistical software. Finally, we used the cluster option to calculate robust standard errors to account for the fact that the observations are clustered into neighbourhoods and that the observations may be correlated within neighbourhoods, but would be independent between neighbourhoods. In theory, our analytical model counts for two levels: the household level and the neighbourhood level. However, the relatively small sample size and the limited number of neighbourhoods surveyed make it impossible to use a multilevel analytical approach.

Independent variables

For the purpose of this study, the key covariates were factors related to water supply and availability of water at home. Control variables included were related to the head of household (age, gender, and type of activity), the economic status of the household, and the number of children under 10 living in the household. A list, together with descriptive statistics of all the covariates used in the present analysis, is given in Table 2. A brief description of each of these covariates is given below.

Factors related to water

Six factors related to water were considered in this analysis. Main access to drinking water was divided into three categories: (1) piped water at the premises or at standpipe; (2) hand pumps located in the neighbourhood; and (3) unimproved sources (mainly buying water from door-to-door vendors). The time taken to fetch water was preferred to the distance to the water point because the Euclidean distance does not reflect the actual difficulty of collecting water outside the home, especially in informal settlements where there are no paved roads or drainage systems. In these areas, streets of any kind are largely absent, save for the sandy tracks created by the inhabitants. These tracks are characterised by bumps and gaps and become streams during the rainy season, making the collection of water on foot or with carts or bicycles very difficult.

Table 2 | Socioeconomic and demographic characteristics and water factors of the sample

Characteristics	Frequency ($n = 702$)	%
Main source of drinking water		
Piped water on the premises	27	3.8
Standpipe	395	56.3
Pump	181	25.8
Street vendors	99	14.1
Time spent to collect water		
Not concerned	126	17.9
< 5 minutes	82	11.7
5–30 minutes	396	56.4
> 30 minutes	98	14.0
Quantity available – per capita per day		
< 10 L	92	13.1
10–19 L	253	36.1
20–50 L	316	45.0
> 50 L	41	5.8
Water storage		
Covered	676	96.3
Not covered	26	3.7
Use of rain water as an alternative source		
Yes	485	69.1
No	217	30.9
Hand washing before eating		
Yes	699	99.6
No	3	0.4
Sex of head of household		
Female	50	7.1
Male	652	92.9
Level of education of head of household		
None	280	40.1
Primary and over	418	59.9
Activity of head of household		
Wage earners – formal sector	214	30.5
Informal sector	437	62.2
No professional activity	51	7.3
Economic status of the household		
Low	275	39.2
Medium	422	60.1
High	5	0.7

(*continued*)

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

Table 2 | continued

Characteristics	Frequency ($n = 702$)	%
Number of children in the household		
1	210	29.9
2	308	43.9
3	136	19.4
4 and over	48	6.8
Type of sanitation		
Improved	681	97.0
Unimproved	21	3.0
Neighbourhood		
Nonghin	232	33.0
Nioko 2	233	33.2
Polesgo	237	33.8

Respondents were helped to evaluate the time taken to collect water with the use of a simplified diary that helped to situate the main events occurring in a typical day and trips to collect water in particular. Following a conventional categorisation of the time taken to collect water (Howard & Bartram 2003), this variable separated households into those that were more than 5 minutes' walk time from their source of water, those that were between 5 and 30 minutes' walk time to their source of water, and those that were more than 30 minutes' walk time to their source of water. A fourth category represented households that did not need to collect water outside. A third water factor distinguished households that covered the container used to store water at home from those that did not cover the container. This variable was used as a proxy of the attention given by the household to preventing the deterioration of the quality of water.

In addition, quantities of water available at home were expressed in litres per person per day. Water quantities were assessed through a detailed inventory of every trip to collect water according to the source of supply and the containers used for collection (usually cans of 20 or 50 L or barrels of 200 L). Fieldworkers were trained to recognise the volume of water held by various containers commonly used in these areas. Respondents were asked about quantities collected during each trip, and about the time period during which these quantities were consumed. These quantities were then confirmed by asking the price paid for water (prices depend on quantities). Given the generally low level of purchasing power, the person responsible for water collection usually has a good idea of how much he/she has paid.

These quantities were then tabulated and regrouped into four categories: less than 10, 10–20, 20–50, and more than 50 L per capita per day. The alternative source of water was measured by a dichotomous variable: the use or non-use of rainwater. Finally, we used the question addressed to the women responsible for children in the household (generally the mother), whether she generally washed her hands before eating, to capture hygiene behaviours. This variable was dichotomous (yes or no).

Control variables

Covariates also included a number of demographic, socioeconomic, and environmental factors at the household level. These control variables were the gender, level of education, and type of activity of the head of household; the wealth of the household; the number of children under 10 living in the household, and the type of sanitation. Given the generally low level of education in Burkina Faso, level of education was composed of only two categories: (1) no formal education and (2) primary and over. The professional activity variable distinguished between wage earners (or people working in the formal sector), heads of household working in the informal sector, and those with no professional activity (mainly housewife for some female heads of household or unemployed).

Owing to the lack of information on household income, the standard of living was measured by a proxy based on certain consumer durables owned by the household: radio, TV, refrigerator, bicycle, motorbike, and car. These six items were best regarded as proxy for general household wealth in Ouagadougou, given the general standard of living in such informal settlements. The statistical method used the principal component analysis (PCA) to create the index. Based on the scores of the first component of the PCA, which accounts for 50.4% of the variance, three categories of household were distinguished: the poorest, those in the middle, and the wealthiest. However, this study focused on informal settlements and given the very low standard of living in these areas, the variable grouped the middle and

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

the wealthiest households together. The variable used in this study therefore distinguished two modalities: (1) low economic status and (2) medium or high economic status.

The number of children under 10 living in the household was also included in the model. Households were divided into three categories: (1) one child; (2) two children; and (3) three children and over.

Finally, we included type of sanitation, since its role as a potential confounder of the relationship between water source and diarrhoeal diseases has been extensively studied (Esrey *et al.* 1991; Cairncross *et al.* 2010) – this variable was included in the models even though it did not discriminate much between households, as more than 97% of households used an improved type of sanitation. Households with improved toilet facilities (flush toilet, ventilated improved pit latrines, pit latrine with a slab) were distinguished from households with no toilet facilities of any kind.

RESULTS

Descriptive statistics

It was found that of the households included in this study, 32.6% ($n = 229$) of households with at least one child under the age of 10 had experienced at least one episode of childhood diarrhoea in the 2 weeks preceding the survey.

Concerning the characteristics of access to water (Table 2), the vast majority (91%) of the households surveyed used drinking water from an improved source according to the JMP definition. The main source of water was piped water from a standpipe located in a nearby formal neighbourhood (56%) or from their own private connection (4%). One household in four obtained water from a hand pump located in the neighbourhood and 14% bought water from a street vendor (in Ouagadougou, buying water from neighbours is extremely rare, contrary to some other African cities (Zuin *et al.* 2011)). However, these results hide a great heterogeneity among the three neighbourhoods in the study: most households in Polesgo (61%) reported that they used pumps as the major source of domestic water, whereas 28% said they used tap water from the municipal council via standpipes, and the rest (11%) obtained water from other sources, mainly from street vendors. In this neighbourhood, the low proportion of households that used piped water from a standpipe was understandable, because these households reported that the nearest water standpipe was far from their home (more than 2 km). Another indicator of the heterogeneity between neighbourhoods comes from the use of street vendors, which was 23% in Nonghin and only 8% in Nioko 2. We also noticed that nearly 4% of the households had access to piped water in their compounds. In fact, in Nioko 2, since 2011, a pilot project has been testing the feasibility of the extension of the water network in informal settlements by delegating the service to the private sector. Some households had the opportunity to connect their homes to the network; however, there were some concerns, especially regarding the quality and sustainability of the services provided, which have been highlighted in other informal settlements in developing countries (Dagdeviren & Robertson 2011).

In the sample, half of the households claimed to have spent between 5 and 30 minutes walking to fetch water, and one household in seven spent over 30 minutes walking to fetch water.

These results also revealed even more problematic situations in terms of potential health impacts: one in two households are not able to meet their basic water needs for domestic use. The study showed that the quantity of water available for 49% of the households is less than 20 L per capita per day. In contrast, very few of the people responsible for children did not wash their hands before eating – although this variable was not discriminating; we included it in the models as it is more accurate than others available in the database, such as hand washing with soap, which is more vague. In terms of water storage, almost all households covered the container used to store water. Finally, one-third of households used rainwater for domestic use as an alternative source of water during the rainy season.

Explicative results

The estimated OR from the different models are presented in Table 3, according to the water and socioeconomic factors described earlier. Examination of the results revealed that, as expected, access to piped water on the premises or at

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

Table 3 | Factors associated with under-10 diarrheal morbidity (Logit Model, $\exp(X_i\beta_i)$), taking into account the fact that the data are clustered by neighbourhood

Variables[a]	Model 1[b]	Model 2[b]	Model 3[b]	Model 4[b]
Main source of drinking water (pump)				
Piped water – at home or at standpipe	0.85***		0.82***	0.85***
Unimproved – mainly vendors	0.49*		0.78	0.79
Time spent to collect water (5–30 minutes)				
Not concerned		0.56•	0.62**	0.57*
< 5 minutes		0.94	0.87	0.83
> 30 minutes		1.19*	1.25***	1.29***
Quantity available – per capita per day (<10 L)				
10–20 L				0.75
20–50 L				0.70***
> 50 L				0.81
Water storage (covered)				
Not covered				1.84**
Use of rain water as an alternative source (no)				
Yes				1.17•
Hand washing before eating (no)				
Yes				0.62
Sex of head of household (male)				
Female	0.94	0.94	0.95	0.99
Level of education of head of household (none)				
Primary and over	0.84**	0.83***	0.83**	0.82***
Activity of head of household (informal sector)				
Wage earners – formal sector	0.89	0.92	0.91	0.92
No professional activity	0.84	0.86	0.88	0.91
Economic status of household (low)				
Medium and high	0.76***	0.77***	0.78***	0.79***
Number of children in the household (1)				
2	1.27	1.27	1.26	1.27
3 and over	1.92**	1.91**	1.90**	1.91**
Type of sanitation (unimproved)				
Improved	0.58**	0.61**	0.60**	0.59***

[a]Reference category in parenthesis.
[b]Odd ratios.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.10$.
•$p < 0.15$.

standpipes had a significant effect on the occurrence of childhood diarrhoea, even after controlling for socioeconomic variables and taking into account the fact that the data are clustered by neighbourhood. In the final model (Model 4), the risk of diarrhoea was 15% ($p < 0.01$) lower in households with access to water delivered by ONEA than among households who obtained water at a pump located in the neighbourhood. The effect of purchasing water from a vendor was more difficult to interpret: this source of water seemed to have a positive effect on the

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

lower occurrence of childhood diarrhoea when compared with fetching water from a collective pump, but the level of significance was relatively high (OR = 0.79, $p < 0.20$). However, in a single predictor model (Model 2), this effect was very strong and significant (OR = 0.49, $p < 0.10$).

As expected, the time taken to collect water also had an effect: households that did not need to fetch water outside their compounds were at a significantly lower risk of having a child suffering from an episode of diarrhoea than households that were between 5 and 30 minutes from a source of water (a standpipe or a pump) (OR = 0.57, $p < 0.10$). Remarkably, there was no difference between households that were less than 5 minutes' walk time from a water source and households that were between 5 and 30 minutes' walk time. On the contrary and as was expected, a walk time of over 30 minutes was significantly associated with a higher risk of diarrhoeal diseases (OR = 1.29, $p < 0.01$).

In addition, the quantity of water available at home was associated with the risk of diarrhoea. Notably, the risk of diarrhoea was 30% ($p < 0.01$) lower in households where between 20 and 50 L of water per capita per day was available when compared with households where less than 10 L per capita per day was available.

The results also showed that storing water safely had a significant impact on incidence of childhood diarrhoea: households who stored water in a container that was not covered had nearly twice the risk ($p < 0.05$) of childhood diarrhoea of those who stored water in a covered container.

Using rainwater as an alternative source of drinking water also constituted a factor influencing childhood diarrhoea: households that used rainwater were more likely (OR = 1.17, $p < 0.15$) to have an occurrence of childhood diarrhoea than households that did not use rainwater as an alternative source of drinking water.

Finally, although the effect of washing hands before eating was not statistically significant, the gradient followed the expected direction of reducing diarrhoeal diseases in children.

Household socioeconomic status differentials were also observed. Firstly, educated heads of household and wealthier households experienced the lowest occurrence of childhood diarrhoea. These variables may partly act as a proxy for proximate variables like adequate nutrition or health care services.

Secondly, the number of children in the household played a role in the risk of the occurrence of diarrhoea in the 2 weeks preceding the survey. In particular, having at least three children significantly doubled (OR = 1.91, $p < 0.05$) the risk of a household experiencing childhood diarrhoea. Mathematically speaking, this result was to be expected, because the probability that there was at least one child morbid episode in the household increases with the number of children under the age of 10 living in the household. This result was also expected due to contagion risk.

Finally and as expected, households with improved sanitation facilities were significantly 0.59 times less likely to have experienced an episode of childhood diarrhoea compared to those with unimproved sanitation facilities.

DISCUSSION

Firstly, we found that the occurrence of childhood diarrhoea during the rainy season in the informal settlements of Ouaga-HDSS was very high: one-third of households with at least one child under the age of 10 experienced an episode of childhood diarrhoea. This is despite the fact that 91% of these households surveyed have access to an improved source of water, according to standard measures. Such a high occurrence of diarrhoeal morbidity indicates the need for careful attention to be paid to these irregular neighbourhoods.

As was expected in the study hypothesis, a number of factors related to water access are associated with lower occurrence of childhood diarrhoea. Some of these were expected, while others were more surprising. The effect of access to pumps, usually defined as improved access to water, is noteworthy: households with access to water at a pump located in the neighbourhood were more likely to experience an episode of childhood diarrhoea than households with access to piped water at home or at standpipes. Even more surprisingly, it seems that there are no health benefits to obtaining water from a pump as opposed to from a street vendor, although the latter is defined as an unimproved source of water. In fact, access to water via a pump posed two major problems: the lack of chlorination of the water delivered by the pump and the time needed to

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf by guest

fetch water. Water delivered by ONEA through piped water at home or at standpipes (which is also the only source of water for street vendors) is treated with residual chlorine that helps to maintain a high quality of water after collection, as well as during handling and storage, in particular. On the other hand, water collected from protected boreholes is not treated, leading to potential risks of microbiological pollutions, an effect that has been recently studied (Ferguson *et al.* 2011). In a review of the debate about the potential health consequences of post-supply contamination, Trevett *et al.* (2005) concluded that re-contamination of clean water at the household level has a significant health impact, particularly on infants. The lack of residual chlorine in the water from protected hand pumps could therefore explain our results and specifically the lack of health benefits of water collected at pumps as opposed to water bought from street vendors.

Secondly, households with access to water via a pump spent time collecting water, which was not the case for households connected to piped water in their compounds or those buying water from street vendors. Furthermore, studies conducted in Burkina Faso and Malawi (Curtis *et al.* 1997; Masangwi *et al.* 2010) showed significantly lower diarrhoeal disease occurrence in households that had access to drinking water within their compounds when compared to households that had to collect water outside their compounds. Indeed, there is a well-known negative relationship between the distance or the time taken to collect water and the quantity of water available in the household: the shorter the distance, the greater the quantity available at home, allowing better hygiene practices such as hand washing at critical times (Howard & Bartram 2003).

Until recently, hand pumps at the neighbourhood level were the only solutions developed for improved drinking water supplies in the informal settlements in Ouagadougou, mainly by non-governmental organisations or private donors. However, the above evidence is proof that there is an urgent need to conceive strategies and policies 'outside the water box' (Dagdeviren & Robertson 2009). It is essential that steps are taken to increase efforts in these informal neighbourhoods, such as developing the utility network and, in particular, reinforcing progress in terms of water access in locations that fall beyond official city limits.

The results concerning access to water through street vendors also need attention. Firstly, and contrary to the latest DHS data, it is obvious that some households in this city have access to water via door-to-door vendors. Until now, there has been no estimate of this proportion, specifically in the informal periphery where those small-scale water providers are viewed by the population as an interim solution before utilities are built or completed. Secondly, despite popular opinion, a review found that there is no scientific evidence to prove that water delivered by vendors is of poor quality (Opryszko *et al.* 2009). Nevertheless, before redefining the standard categories and starting to consider vendors as improved access to water, it is possible to simply interpret these results as further proof of the positive effect of water being delivered at home. In the absence of regulation of this sector in Ouagadougou, and because the service delivered by street vendors comes at high prices for poorer households, our results should not be considered as promotion of the development of this private water sector in the long term. Since street vendors obtain chlorinated water from standpipes, buying water from them could be considered a short-term alternative and a response to the growing demand for clean water. The sector must be well monitored and regulated. Dagdeviren & Robertson (2011) reviewed the major limitations of developing small-scale private providers.

Our results also showed that the attention given to water storage at the household level has significant health benefits. A WHO research review of diarrhoeal disease control had already emphasised that keeping drinking water clean in the home in order to avoid re-contamination was identified as one of the key hygiene behaviours (WHO 1999).

A final interesting result came from the effect of using rainwater as drinking water, which is defined as an improved water source. Our results showed that rainwater collected from roofs during the rainy season seems to be a risky strategy for dealing with a lack of access to water, since it is associated with a non-negligible risk of diarrhoea in children. A recent review concluded that there is currently no evidence that rainwater carries increased risk of diarrhoea when compared to other improved sources of water (Dean & Hunter 2012). In fact, point-of-use water treatment was found to be highly effective (Fewtrell *et al.* 2005), and treatment of rainwater after harvesting in particular.

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

For example, boiling water is an effective way to purify water, even water of dubious quality, such as water provided by vendors (Thomas *et al.* 2013). However, in Ouagadougou, this practice is very rare: in our study, only three of 702 households boiled drinking water. The extreme poverty of households could be one of the reasons why water was rarely boiled. Although there is the possibility of misunderstanding the antimicrobial action of boiling water, people do not have enough resources to buy energy to boil water (wood, coal, or gas), particularly in informal areas where access to electricity is not available.

One of the strengths of this study is that it aimed to measure water factors as accurately as possible by the inclusion of information that was more detailed and more extensive than that used in the usual surveys (DHS, Multiple Indicator Cluster Survey (MICS), etc.). In particular, few studies based on data collected in informal settlements in Sahelian cities have formally evaluated six water-related factors in this type of analytical approach. In particular, the use of rainwater as an alternative water source during the rainy season is a variable often neglected in a semi-arid context. In addition, the fact that two of the co-authors spent considerable amounts of time working in the Ouaga-HDSS study sites has provided them with useful insights on how to interpret the findings.

Despite these advantages, some limitations should be noted. Water-related measured variables were self-reported by participants in the study. The information on the onset of diarrhoea also relied on the respondents' perceptions of diarrhoeal symptoms and was not medically verified. Among all of the limitations that this method entails, it is possible that some estimates were biased by systematic reporting errors. Multivariate models controlling for socioeconomic factors are likely to capture a large part of the self-selective nature of reporting, as, for example, better educated people are more likely to report health problems (Hobcraft 1993). Also, to optimise the accuracy of the data collection, investigators were trained to remind respondents not to forget any episode of diarrhoea or water collection trip. They were also asked to make some observations (e.g. the water storage variable was provided by direct observation). However, hand washing practices, which are very susceptible to perceptions of the 'right' answer, were not triangulated with observation. In this regard, and since the result was not significant, conclusions on this variable should be considered suggestive of health impact only. Equally, triangulation with health data or another source of current water data was not possible.

Weaknesses of this analysis also include the relatively small sample size and the limited number of neighbourhoods, which reduces the range of contextual and socioeconomic diversity. Firstly, this made it impossible to use a multilevel approach (Mohnen *et al.* 2011). We used the option included in Stata software that allows the fact that data are clustered to be accounted for. Standards errors are therefore more robust. In addition, since information on diarrhoea was collected at the household level, we controlled for the number of children in the household. However, the use of a multilevel analytical approach would have allowed us to estimate random effects at the neighbourhood level, in other words the amount of variance in outcome that is attributable to the context investigated. In models in which the neighbourhood of residence was included as a controlled variable (not shown), the risk of childhood diarrhoea differed significantly between neighbourhoods, without altering the effect of the other covariates. Households located in the neighbourhood of Polesgo were 47% less likely ($p < 0.05$) to experience an occurrence of childhood diarrhoea than households in Nonghin. Conversely, households in the Nioko 2 neighbourhood were 57% more likely ($p < 0.05$) to experience an occurrence of childhood diarrhoea than households located in Nonghin. Using data from the Ouaga-HDSS, studies on child environmental health also found persistent effects of area of residence (Peumi 2012; Bouba Djourdebbé *et al.* 2014). Therefore, we still have not captured geographical variation in terms of water supply or the effects of other omitted factors such as various types of environmental contamination at the neighbourhood level.

The relatively small household sample size also contributes to limit the extent of the impact and the discussion of some of the interesting factors due to the lack of power of the analysis. This is particularly true in the case of the effect of unimproved water sources, notably the use of water vendors.

While the results are only statistically representative of the three areas studied in this paper, we would argue that this case study sheds light on similar situations faced by a significant proportion of urban dwellers in Africa. In fact, the results depict an acute reality by highlighting the situation of water access in rapidly growing informal

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

settlements, and specifically the controversial use of water from pumps and rainwater, even though these are considered to be improved sources of water. This study also provides useful perspectives for future research. In particular, further sampling of households and neighbourhoods is recommended to confirm these results. The introduction of water quality would also be a key contribution in order to be able to conclude whether or not water from pumps or rainwater are more likely to be contaminated at point-of-use as compared with water chlorinated at the source.

CONCLUSION

As noted by Trevett *et al.* (2005), 'the case-specific routes that lead to diarrhoeal disease are extremely difficult to identify'. The conceptual framework is thus a complex one. In this paper, we tried to identify factors specifically related to access to water that can reduce childhood diarrhoea in informal African settlements. The present analysis addressed diarrhoea as a public health issue, without considering the aetiological diagnosis.

Our study shows that the management of some factors relating to access to water might be effective in preventing childhood diarrhoeal diseases. This is particularly the case in the context of the use of treated water delivered by the utility company, the attention given to the water storage, and the non-use of rainwater. As the issue of global water scarcity, combined with rapid urbanisation, worsens in the coming years, accurate water data at the household level will be increasingly necessary to support effective policy-making efforts. In particular, appropriate intervention programmes targeting the availability of piped water and the treatment of water, especially rainwater and water obtained from pumps during the rainy season, should be designed. There is also an urgent need for in-depth research into cost-effective ways that poorer households could treat their water.

ACKNOWLEDGEMENT

We gratefully acknowledge the support of the International Development Research Centre. Free and informed consent of the participants or their legal representatives was obtained and the study protocol was approved by the Ethics Committee of the Ministry of Health of Burkina Faso.

REFERENCES

Ahmed, W., Gardner, T. & Toze, S. 2011 Microbiological quality of roof-harvested rainwater and health risks: a review. *J. Environ. Qual.* **40**, 1–9.

Bouba Djourdebbé, F., Dos Santos, S., LeGrand, T. & Soura, A. 2014 Environmental factors and childhood fever in areas of the Ouagadougou – Health and Demographic Surveillance System – Burkina Faso. *J. Biosoc. Sci.* doi: 10.1017/S0021932014000479.

Boyer, F. & Delaunay, D. 2009 *Ouaga 2009 – Peuplement de Ouagadougou et Développement Urbain. Rapport Provisoire*. IRD – Ambassade de France au Burkina Faso, Ouagadougou, 250 pp.

Cairncross, S. 1990 Water supply and the urban poor. In: *The Poor Die Young* (J. Hardoy, S. Cairncross & D. Satterthwaite, eds). Earthscan Publications, London, pp. 109–126.

Cairncross, S., Hunt, C., Boisson, S., Curtis, V., Fung, C. I. & Schimdt, W.-P. 2010 Water, sanitation and hygiene for the prevention of diarrhoea. *Int. J. Epidemiol.* **39**, i193–i205.

Curtis, V. B., Kanki, B., Cousens, S., Sanou, A., Diallo, I. & Mertens, T. 1997 Dirt and diarrhoea: formative research in hygiene promotion programmes. *Health Policy Plan.* **12** (2), 122–131.

Dagdeviren, H. & Robertson, S. A. 2009 *Access to Water in the Slums of the Developing World*. in Working Paper. International Policy Centre for Inclusive Growth/UNDP, Brasilia.

Dagdeviren, H. & Robertson, S. A. 2011 Access to water in the slums of Sub-Saharan Africa. *Dev. Policy Rev.* **29** (4), 485–505.

Dean, J. & Hunter, P. R. 2012 Risk of gastrointestinal illness associated with the consumption of rainwater: a systematic review. *Environ. Sci. Technol.* **46**, 2501–2507.

Dos Santos, S. 2006 Accès à l'eau et enjeux socio-sanitaires à Ouagadougou. *Espace Popul. Soc.* **2–3**, 271–285.

Dos Santos, S. 2012 L'accès à l'eau en Afrique subsaharienne: la mesure est-elle cohérente avec le risque sanitaire? *Environ. Risques Santé* **11** (4), 282–286.

Dos Santos, S. & Le Grand, T. K. 2013 Is the tap locked? An event history analysis of piped water access in Ouagadougou – Burkina Faso. *Urban Stud.* **50** (6), 1262–1280.

Esrey, S. A., Potash, J. B., Roberts, L. & Shiff, C. 1991 Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bull. WHO* **5** (69), 609–621.

Ferguson, A. S., Mailloux, B. J., Ahmed, K. M., van Geen, A., McKay, L. D. & Culligan, P. J. 2011 Hand-pumps as reservoirs for microbial contamination of well water. *J. Water Health* **9** (4), 708–717.

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest

Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L. & Colford, J. M. 2005 Water, sanitation and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *Lancet Infect. Dis.* **5**, 42–52.

Gleitsmann, B. A., Kroma, M. M. & Steenhuis, T. 2007 Analysis of a rural water supply project in three communities in Mali: participation and sustainability. *Nat. Resour. Forum* **31** (2), 142–150.

Hobcraft, J. 1993 Women's education, child welfare and child survival: a review of the evidence. *Health Transit. Rev.* **3** (2), 159–175.

Howard, G. & Bartram, J. 2003 *Domestic Water Quantity, Service Level and Health*. WHO, Geneva.

Hunter, P. R., MacDonald, A. M. & Carter, R. C. 2010 Water supply and health. *PLoS Med.* **7** (**11**), e1000361.

INSD 2009 *Analyse des résultats du Recensement Général de la Population et de l'Habitat de 2006*. Institut National de la Statistique et de la Démographie, Ministère de l'économie et des finances, Ouagadougou.

INSD & ICF International 2012 *Enquête Démographique et de Santé et à Indicateurs Multiples du Burkina Faso 2010*. Institut National de la Statistique et de la Démographie, ICF International, Calverton, Maryland, USA, 325 pp.

Jaglin, S. 1995 *Gestion Urbaine Partagée à Ouagadougou*. Karthala-ORSTOM, Paris.

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K. & Adair-Rohani, H. 2012 A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* **380**, 2224–2260.

Masangwi, S. J., Ferguson, N. S., Grimason, A. M., Morse, T. D., Zawdie, G. & Kazembe, L. N. 2010 Household and community variations and nested risk factors for diarrhoea prevalence in southern Malawi: a binary logistic multi-level analysis. *Int. J. Environ. Health Res.* **20** (2), 141–158.

Mitlin, D. & Satterthwaite, D. 2013 *Urban Poverty in the Global South: Scale and Nature*. Routledge, Oxon.

Mohnen, S. M., Groenewegen, P. P., Völker, B. & Flap, H. 2011 Neighbourhood, social capital and individual health. *Soc. Sci. Med.* **72** (5), 660–667.

Opryszko, M. C., Huang, H., Soderlund, K. & Schwab, K. J. 2009 Data gaps in evidence-based research on small water enterprises in developing countries. *J. Water Health* **7** (4), 609–622.

Peumi, J. P. 2012 *Facteurs environnementaux et symptômes des troubles oculaires et cutanés chez les enfants de moins de cinq ans: cas des zones de l'Observatoire de population de Ouagadougou*. Mémoire de Master (M.D.), Département de démographie, Université de Montréal, Montreal, Canada.

Rossier, C., Soura, A., Baya, B., Compaoré, G., Dabiré, B. & Dos Santos, S. 2012 The Ouagadougou Health and Demographic Surveillance System. *International Journal of Epidemiology* **41** (3), 658–666.

Schaefer, D., Werchota, R. & Dölle, K. 2007 *MDG Monitoring for Urban Water Supply and Sanitation – Catching up with Reality in Sub-Saharan Africa*. GTZ, Hochheim.

Thomas, K., McBean, E. & Murphy, H. M. 2013 Drinking water quality for peri-urban residents in Phnom Penh, Cambodia. *J. Water Sanit. Hyg. Dev.* **3** (4), 512–521.

Trevett, A. F., Carter, R. C. & Tyrrel, S. F. 2005 The importance of domestic water quality management in the context of faecal–oral disease transmission. *J. Water Health* **3**, 259–270.

UNDP 2013 *Human Development Report 2013. The Rise of the South: Human Progress in a Diverse World*. United Nations Development Programme, New York.

WHO 1999 *The Evolution of Diarrhoeal and Acute Respiratory Disease Control at WHO. Achievements 1980–1995 in Research, Development, and Implementation*. Department of Child and Adolescent Health and Development, World Health Organization, Geneva.

WHO/UNICEF 2012 *Progress on Drinking Water and Sanitation – 2012 Update*. WHO/UNICEF, Geneva.

Wright, J. A., Gundry, S. W., Conroy, R., Wood, D., Du Preez, M., Ferro-Luzzi, A., Genthe, B., Kirimi, M., Moyo, S., Mutisi, C., Ndamba, J. & Potgieter, N. 2006 Defining episodes of diarrhoea: results from a three-country study in Sub-Saharan Africa. *J. Health Popul. Nutr.* **24** (1), 8–16.

Zuin, V., Ortolano, L., Alvarinho, M., Russel, K., Thebo, A., Muximpua, O. & Davis, J. 2011 Water supply services for Africa's urban poor: the role of resale. *J. Water Health* **9** (4), 773–784.

First received 5 May 2014; accepted in revised form 19 October 2014. Available online 15 November 2014

Downloaded from http://iwaponline.com/jwh/article-pdf/13/2/562/394818/jwh0130562.pdf
by guest