Assessment of drinking water access and household water insecurity: A cross sectional study in three rural communities of the Menoua division, West Cameroon

Carole Debora Nounkeu1*, Yvan Dymas Metapi2*, Florent Kamkumo Ouabo3, Agnes Suzanne Toguem Kamguem4, Bertin Nono5, Nicholas Azza6, Patrice Leumeni7, Georges Nguefack-Tsague8, David Todem9, Jigna Morarji Dharod10‡, Dieudonne Kuate2‡*

1 Regional Hospital Limbe, Limbe, Cameroon, 2 Department of Biochemistry, University of Dschang, Dschang, Cameroon, 3 Department of Mathematics, BTU Cottbus-Senftenberg, Senftenberg, Germany, 4 Department of Biochemistry, University of Yaoundé I, Yaoundé, Cameroon, 5 Delta Air Lines, Atlanta, GA, United States of America, 6 Independent Researcher, Kampala, Uganda, 7 The African Ministers’ Council on Water (AMCOW), Abuja, Nigeria, 8 Faculty of Medicine and Biomedical Sciences, University of Yaoundé I, Yaoundé, Cameroon, 9 Department of Epidemiology and Biostatistics, Michigan State University, East Lansing, MI, United States of America, 10 Department of Nutrition, University of North Carolina at Greensboro, Greensboro, NC, United States of America

*These authors contributed equally to this work.
‡ JMD and DK also contributed equally to this work.
*dieudonne.kuate@univ-dschang.org

Abstract

Water is a physiological need, key for survival. In limited water access situations, health, well-being, and productivity of households are negatively affected. Water insecurity refers to when access to adequate amount of clean water does not occur all the times for household members to lead a healthy and active life. A cross sectional study was conducted with 121 women from three rural communities in the West-Cameroon, to assess water insecurity experience and its correlation with related indicators. Specifically, this study aimed to: examine drinking water access by time spent on collection and distance to the water source, determine the prevalence of household water insecurity, and examine the relationship between water insecurity and diarrhea as well as drinking water access-related indicators. The main sources of drinking water included boreholes (69%), wells (13%), and rivers (12%). Each household spent an average total amount of 3 hours on water fetching. The mean duration of the drinking water stored was 4 days, after which the process was repeated. The majority of households (94.2%) were water insecure (total WATINE-17 score ≥1). About 61% reported drinking less water than they felt they should and 32% of them, said they had to drink dirty water. Water insecurity mean score was higher in households who reported diarrhea among their 0–5 years old children than their counterparts (p = 0.008). This study highlights the problem that good access to improved water source still represents in low-resource households of rural areas, with the subsequent complex interactions on women and children’s health. Future research on water management and storage is warranted to understand the sources of cross-contamination and to identify the potential
points of intervention to ensure safe drinking water for rural households. Policies should be
designed in order to incorporate systematic household water insecurity measurement in
monitoring advancement towards 2030 SDG.

Introduction

Water is a natural resource, critical for humans, animals, and plants’ life to thrive and being
sustained. Despite the total volume of water on earth is estimated at 1.4 billion km$^3$, approxi-
mately 97.5% of it is saltwater [1]. Of about 35 million km$^3$ of water that represents freshwater,
only 1% is easily accessible for human use and principally comes from water that runs off after
precipitation (lakes, rivers, shallow aquifers) [1]. Unfortunately, there is no statistical correla-
tion between specific country annual per capita water availability and its inhabitants’ access to
safe water. For instance, Egypt and Morocco, which are well-known water scarce countries,
have high level water and sanitation-related investments and disclose quasi universal water
access whereas many sub-Saharan countries have abundant physical resources, but they have
not invested enough in harnessing them for use. Cameroon, a country with sufficient freshwa-
ter availability (ranked 49$^{th}$ out of 182 countries in terms of abundant water supply), only
reported 47% of its rural population as having access to safe water in 2010 [2–4]. This disparity
in drinking water access can also be explained by challenges such as increasing population and
urbanization, poor water network coverage, high pressure on the demand for water, and pov-
erty and the inability to pay for a connection and water service. As a result, private water
sources are installed in households who can afford them whereas poorer households rely on
multiple alternative sources or depend on neighbors for free water [2, 5].

At the household level, water is critical in sustaining food production, ensuring food and
nutrition security [6]. Moreover, access to sufficient amount of clean water facilitates regular
and adapted hygiene practices, proper sanitation maintenance, and adequate food safety mea-
sures [7, 8]. In poor setting countries, multiple water sources are often selected based on their
pre-established use, with high-quality and generally distant water sources devoted to drinking
and cooking, whereas nearby shallow wells or surface water are used for bathing, laundry, and
cleaning. Hence, in water scarce contexts, assessing drinking water access reveals a more realistic
picture of efforts made by households to collect water from improved sources and all the
water uses are reduced at varying levels, negatively affecting health, well-being, and productiv-
ity of the households [9–11]. At the individual level, water represents approximately 60% of
the body weight and performs several physiological functions such as digestion, thermoregula-
tion, waste elimination, and lubrication of joints and organs [2]. But, because the human body
does not produce enough water from the metabolism, adequate water intake i.e., 3.7 liters/day
for men and 2.7 liters/day for women is critical in maintaining an ideal body hydration status
[2].

The United Nations (UN) in 2010 declared access to water a human right [12]. The volume
of 50 liters of water was set as the minimum amount per capita per day to lead a healthy and
active life [13]. Nevertheless, for around 30% of people worldwide, access to clean drinking
water remains a daily struggle; especially for those living in developing countries. Currently,
approximately 435 million people worldwide rely on unimproved drinking water sources and
144 million people use surface water, with about half of these people living in sub-Saharan
Africa [13]. Additionally, eight out of ten people who lack access to basic drinking water ser-
vices (water collection time from improved sources exceeding 30 minutes for a round trip,
including queuing) live in rural areas [13]. This low and inconsistent access to safe and sufficient water promotes the occurrence of water-related diseases in rural communities in sub-Saharan Africa [14]. For instance, approximately 1,400 children die every day due to diarrhea resulting from water-borne and water-washed infections [15]. Consequently, WHO reported that half of all undernutrition cases in children occur secondary to inadequate food/nutrients utilization by the body, consecutive to multiple episodes of diarrhea and worm infections [15, 16]. Therefore, ensuring that water security is crucial to improve children’s nutritional status and prevent faltering growth.

In contrast to water security, insecurity refers to when access to adequate amount of safe and clean water does not occur all the times for the entirety of household members to lead a healthy and active life [17]. To measure water insecurity, the UN developed standards based on per capita water availability and translating equitable and sufficient access to water: (1) per capita daily water use ≥ 50 liters; (2) total water collection time ≤ 30 minutes; (3) water source ≤ 1,000 meters of home, and; (4) water cost ≤ 5% of the household income [18]. However, these indicators are not able to capture the various ways that water access can be problematic, mask intra-population disparities, and cannot quantify health, economic, and psychosocial burden of water problems that occur at the individual level [19]. Thus, acknowledging this experiential nature of household water insecurity and related psychosocial distress as well as coping strategies occurring due to it, multiple experiential water insecurity scales have been developed [20, 21]. The Household Water Insecurity Experience (HWISE) scale was constructed and validated as a cross cultural household water insecurity scale using data collected between 2017 and 2018, from 22 countries. The HWISE has been presented as a revolutionary tool in monitoring and evaluating water-related interventions as an adjunct to the UN standard metrics [22]. However, one of the most recent scales, the Water Insecurity Experience Scale (WATINE-17), was shown to be able to capture all the key dimensions of household water insecurity, including its positive correlation with food insecurity, and was validated in Cameroon [17]. To further examine water insecurity experience and its correlation with related indicators, a cross-sectional study was conducted to: (1) examine drinking water access by time spent on water collection and distance to the water source, (2) determine the prevalence of household water insecurity, and (3) examine the relationship between water insecurity and diarrhea as well as drinking water access-related indicators, in three rural communities in the Western region of Cameroon.

**Methodology**

**Study zone**

The study took place in Cameroon, Central Africa, specifically in the Menoua Division, located in the West Region. Menoua is divided into six subdivisions (Dschang, Nkong-Ni, Santchou, Fongo-Tongo, Penka Michel and Fokoue) that are further subdivided into 22 villages, including Bafou (Fig 1). Bafou has a surface area of 178 km$^2$, is located at 12km of the urban center of the Menoua division, Dschang, and is irrigated by a dense network of rivers [23, 24]. The climate there is characterized by a rainy season from mid-March to mid-November and dry season from mid-November to mid-March. The average annual temperature is 22.5˚C and average annual rainfall is 1364.4mm [23, 24]. This climate coupled to its volcanic soil renders this village a very productive agricultural area [24, 25].

The Menoua division has been characterized by previous studies as a rural setting of Central Africa where economic water scarcity prevails despite the physical availability of freshwater [17]. In fact, notwithstanding its enormously supplied aquifer, access to safe drinking water remains scarce and expensive in this area where the average income for households with a
Fig 1. Study site and location of Bafou within the Menoua division, West Cameroon [30].

https://doi.org/10.1371/journal.pwat.0000029.g001
mean size of 8 members is less than US$79.94 [26]. In fact, public water supply in Cameroon is managed by a state water agency, Cameroon Water Utilities Corporation (CAMWATER), which presents a very low coverage due to rapidly growing population. In Dschang, the chief of the Menoua division and urban center, CAMWATER covers 27% (36 km) of land and serves 32.5% of households [4, 26]. The price of network connection includes US$63.42 for a pipe of 15mm diameter and less than 5m length, an additional US$3.542 for each additional meter, US$7.25 of expenses for installation of the water meter, as well as a long waiting period between request and effective connection [26, 27].

Because of this poor access to public infrastructure coupled to the high incidence of poverty in rural areas of Cameroon in general and of the Menoua division in particular, access to water on premises has become a luxury and households rely on inappropriate water distribution systems such as spring water, surface water, or wells for domestic water supply [28, 29].

Data collection

From March to June 2021, a cross-sectional study took place in three neighborhoods of the Bafou village. Using a door-to-door approach and with the help of community health workers familiar with the village population, adult women living in households with no access to water on premises i.e. water source not located inside the participant’s dwelling, plot or yard, were recruited. Women who were interested and met the criteria to participate in the study were given details about the research, their written consents were obtained, and they underwent face-to-face one-on-one interviews. All the interviews were conducted at the participant’s houses in either French or the local dialect (Yemba) by the research assistant. The study was approved by the Cameroon National Committee of Ethics for Human Research and no incentive was given to the respondents for taking part to the research.

A total of 121 caretakers were interviewed during the study in three neighborhoods of the Bafou group (Fig 1). The selection of these different neighborhoods was based on previous collaboration with the communities of this area and geographical access to the different places with bikes, which represent the most common transportation mean. Data collection was conducted sequentially: within each neighborhood, interviews were conducted until redundancy in answers provided by participants was observed. The questionnaire used for the interview included the following sections:

1. Socio-economic and demographic characteristics such as participant’s age, education, household size, possession of livestock, or farming garden;
2. Water in/security status assessment using the WATINE-17 scale [17].
3. Drinking water access-related questions were asked specifically for the main drinking water source and led to collecting information on:
   i. type of drinking water source: the proposed options were taps, boreholes, wells, rivers, and others;
   ii. distance to a drinking water source: participants were asked to estimate the length (in meters) between their homes and the main drinking water source,
   iii. time spent to collect drinking water in one way trip plus queuing: the participants were asked to report the time in minutes they spent from the moment they left home with their container to the moment they reached the water source. In addition to that, the approximate queuing time was reported for a usual trip. Time spent to reach the water source + queuing time represented the “time spent to collect water (one way)” as it did
not include returning time, which we assumed could be longer due to the container being heavier.

iv. number of trips generally done by the fetchers on days drinking water is collected,
v. number of people involved in drinking water fetching in each household.

4. Questions on water use were also asked to collect information on the duration in days of drinking water storage before replenishment, the different drinking water treatment means, the total amount of drinking water used in each household per day, and whether any money was spent by the household to get the drinking water.

Of the 121 households, 85 had 0–5 years old children. To this sub-sample, additional questions on the incidence of diarrhea (having three or more stools of a soft or watery consistency in 24 hours) were asked. The timeframe used was the past two weeks.

Data analyses. Data entry and analyses were carried out using SPSS 26 (IBM Corporation, Somers, NY, USA) and Microsoft Excel 2013 and the threshold for statistical significance set at 0.05. Descriptive statistics were conducted to examine the socio-demographic characteristics of participants, water insecurity prevalence, and water access and water use-related behaviors. All continuous data were reported as mean and 95% confidence interval or standard deviation and categorical variables were summarized as percentages. Details about the WATINE-17 scale is provided in a previous paper [17], but specifically, this scale with 17 statements comprised two options: Yes = 1, No = 0. The total WATINE-17 score for each household hence ranged from 0 to 17, where higher scores indicated greater water insecurity. Based on the score, and according to the scale description [17], a cut-point for distinguishing subcategories with predicted differences in water insecurity has not been defined yet and participants should be grouped into the following two categories: a score of 0 = water secure; ≥1 score = water insecure.

For continuous variables such as amount of drinking water used by the household in 24 hours, distance to the water source, and time spent to collect water on one hand and the WATINE-17 score on the other hand, Pearson correlation was used. Bivariate tests such as one-way ANOVA were conducted to detect statistically significant differences in the WATINE-17 score means depending on whether the children presented diarrhea within the last two weeks or not as well as the nature of the water source.

Ethical considerations. Ethical clearance was obtained from the Cameroon National Committee for Ethics and Human Research. Written consent was obtained from each participant prior to the beginning of the data collection. Anonymity of participants and confidentiality of data gathered were assured. For additional information about ethical, cultural, and scientific considerations specific to inclusivity in global research refer to Supporting Information (S1 Text).

Results
Socio-demographic characteristics of participants
As shown in Table 1, the average age of the 121 women who participated in this study was 41 years. More than half of the participants (55%) had a secondary or higher level of education. The average size of the households visited was six and about two-third of them (70%) included children of less than 5 years old. About 74% of households owned at least one animal in their compound and 73% of households were surrounded by a farming garden. All the participants reported having sanitation facilities within their compound.
Table 1. Socio-demographic characteristics of participants living in rural communities in the Western Region of Cameroon (n = 121).

| Socio-demographic characteristics                              | Mean ± Standard Deviation |
|----------------------------------------------------------------|---------------------------|
| Age of women (years)                                           | 41.48 ± 14.56             |
| Household size                                                 | 6.98 ± 4.8                |
| Number (%)                                                     |                           |
| Mbeng                                                          | 40 (33.1)                 |
| Mbih                                                           | 41 (33.9)                 |
| Ntsingbeu                                                      | 40 (33.1)                 |
| Education                                                      |                           |
| Primary or less                                                | 55 (45.5)                 |
| Secondary or higher                                            | 66 (54.5)                 |
| Households with a farming garden                               | 88 (72.7)                 |
| Households raising livestock                                   | 90 (74.4)                 |
| Number of children living in households (< 5 years)            | 85 (70.2)                 |
| Children who have had diarrhea during the last 2 weeks*        | 26 (30.6)                 |

*Sample size of household with children n = 85

https://doi.org/10.1371/journal.pwat.0000029.t001

Description of household-level drinking water access

Water fetching process. Drinking water source. The majority of households (69%) obtained their drinking water from boreholes followed by wells (13%) and rivers (12%) (Table 2). When asking the reasons why participants chose to use a specific drinking water source, the main issues reported by women as negatively impacting household' choice to a drinking water source included long queuing (24%), long distance to the drinking water source (7%), low water output at the source (3%), and high cost to pay for water (4%).

Water fetching time. The participants reported making on average about 36 minutes one way (multiplied by 2 for round trip) to reach the drinking water source; plus 19 minutes queuing time. And per households, generally two trips were made to collect adequate amount of drinking water considering the usual household consumption and storage time. All these contributed to spending about 3 hours, on a day drinking water is fetched for the households. This water fetching process was repeated after all the storage was used.

Water fetchers. As for water fetchers, within the households, mainly adults (64%) and children (57%) were involved in collecting drinking water. About 10% of households reported paying cash to get drinking water in the form of asking someone to fetch water for pay or buying bottled water.

Water storage and use. The participants reported using cans (85%), buckets (6%), or both (9%) to collect drinking water and 84% of these containers were covered by a lid (Table 2). In 65% of households, these drinking water containers were washed and cleaned before each filling. The water fetched was generally kept and stored in the fetching container but, 22% of participants reported that they transferred it in cleaner or easier-to-handle (bottles or buckets) containers for direct use. For approximately 30% of households, the water fetched underwent a treatment (chlorination, filtration) prior to be suitable for drinking.

The participants reported storing drinking water on average for 4 days and the replenishment was done following that cycle. Nevertheless, the total amount of drinking water used in 24 hours as reported by the participants exceeded 20 liters in only 21% of households. Based...
on that, each household consumed a mean amount of 10.94 (95% CI [9.62, 12.26]) liters of water for drinking in a day.

Prevalence of household water insecurity in the study population

Only 5.8% of households in the study area were water secure following the WATINE 17 interpretation guidelines [17] i.e. their WATINE-17 score = 0 to all the statements, compared to 94.2% who were water insecure (total WATINE score ≥1). The mean household WATINE-17 score was 5.98 ± 4.82. As for individual WATINE-17 statements, about 61% of participants reported drinking less water than they felt they should and 32% of participants said they had to drink dirty or muddy water (Fig 2).

Table 2. Description of sources, time, distance and other water access-related behaviors practiced among households living in three neighborhoods of Bafou group (n = 121).

| Description of source, time, distance and other water access-related behaviors | Mean [95% CI] |
|---|---|
| Time taken to reach the drinking water source (minutes)* | 36.02 [31.29 ; 40.74] |
| Number of trips to the water source | 1.84 [1.63 ; 2.06] |
| Maximum duration before replenishment of water stores (days) | 4.08 [3.52 ; 4.64] |
| Queuing time at the drinking water source (minutes)* | 19.34 [15.85 ; 22.85] |
| Total amount of drinking water consumed in 24 hours (liters) | 10.94 [9.62 ; 12.26] |
| Source of drinking water supply | n (%) |
| Taps | 7 (5.8%) |
| Boreholes | 83 (68.6%) |
| Wells | 16 (13.2%) |
| Rivers | 15(12.4%) |
| Distance between household and drinking water supply source |  |
| ≤1000 m | 112 (92.6%) |
| >1000 m | 9 (7.4%) |
| Queuing time |  |
| < 5 minutes | 50 (41.3%) |
| 5–15 minutes | 28 (23.1%) |
| > 15 minutes | 41 (33.9%) |
| Person responsible for drawing the drinking water |  |
| Children | 69 (57%) |
| Teenager | 55 (45%) |
| Adults | 78 (64%) |
| Types of containers used to collect drinking water |  |
| Cans | 103 (85.1%) |
| Bucket | 7 (5.8%) |
| Quantity of drinking water used in 24 hours |  |
| <20 L | 96 (79.3%) |
| 20–40 L | 22 (18.2%) |
| >40 L | 3 (2.5%) |
| Frequency of cleaning of storage containers |  |
| Before each filling | 79 (65.3%) |
| 1 time per week | 35 (28.9%) |
| 1 time per month | 7 (5.8%) |

*a n = 109 due to missing values

*b n = 91 due to not applicable/missing responses
Household water insecurity, under 5 years’ children health status, and measures of good water access

Among the households with young children, 30.6% reported their children were experiencing diarrhea during the last 2 weeks preceding the survey (Table 1). In examining the association, it was found that water insecurity mean score was higher among the households who reported diarrhea than their counterparts (WATINE-17 score in diarrhea group: 8.50 ± 5.32 vs. no diarrhea group: 5.36 ± 4.78; F(1, 83) = 7.273; p = 0.008). Further, correlation analyses indicated that the water insecurity score was related to the total amount of drinking water consumed in 24h, in households with children less than 5 years old (r = 0.266; p = 0.015). Among all the participants, lower water insecurity scores were likely to be associated with satisfaction in the quantity of drinking water or use of improved water sources, and the difference was statistically significant (Table 3).

Discussion and conclusions

The result of this study shows that access to drinking water is limited in rural areas by the availability of improved water source and distance to these sources. In our study, the use of unimproved source, such as unprotected wells, was common. Furthermore, water fetching required extensive time commitment characterized by multiple trips to the water source and huge amount of time spent there. Similar to our finding, a study presenting a synthesis of the data on water fetching from households in 23 countries revealed that a round trip to a water source involved considerable amount of time averaging as much as 3 hours [31]. Paralleling this, Sorrenson et al. (2011), summarizing data about water access and carrying from 44 countries,
reported that women and children did multiple trips lasting each for more than one hour to collect daily water for their households [32]. A recent study published by Agesa & Agesa (2019) used an econometric methodology to demonstrate that time lost in water collection could explain higher dropout rate for females in school [33]. Mirroring the time availability theory [34], women in the rural areas might end up compromising on either work or water. For instance, higher time demands at job might force women to reduce their investments in daily household chores including water fetching [35]. Since women are primary person responsible for securing water for their households [32], water fetching demanding an average of 3 hours of time might divert them from engaging in farming and related income generating activities including childcare.

There is substantial evidence that unsafe water increases the risk for diarrhea among children. However, limited childcare, secondary to reduced water access (increased time spent in water fetching) and subsequent poor childhood nutrition has also been incriminated as a contributor to high diarrhea rates among children under 5 years old [36]. Huge water fetching burden, marked by time spent and multiple trips to collect drinking water, might limit caretakers’ ability to provide optimal care, involving young children left unattended or given the responsibility to older siblings. Past research has shown that children playing unattended in the compound can also be associated with high cross-contamination and incidence of diarrhea due to the ingestion of dirt or inadequate hygiene practice [37, 38]. In the recent DHS-Camer-oon study, poor water services were associated with limited diet diversity among children, highlighting that nutrition care might also be affected due to high water fetching burden for caretakers [39].

Results of our study show that water insecurity is common among rural households in Central Africa-Cameroon. Even though marginally statistically significant, similar to other findings [8, 40, 41] water insecurity was higher among those who spent larger amount of time in fetching water for drinking i.e., water insecurity score increased with increase in number of hours spent in fetching drinking water. Additionally, the incidence of diarrhea was higher in households experiencing water insecurity and the difference was statistically significant. Our study specifically focused on drinking water access, but other previous studies have shown that water insecurity has been associated with domestic violence [42]; food insecurity [10, 43]; depression and anxiety [44, 45] and limited social capital [46].

Table 3. Assessment of the correlation between the Water Insecurity Experiential Scale (WATINE) against diarrhea and water access-related indicators in households with children under 5 years old (n = 85).

| Indicators                          | Mean ± Standard Deviation | Measure of association (or correlation) | Statistical significance |
|------------------------------------|---------------------------|----------------------------------------|--------------------------|
| Satisfaction in the quantity of drinking water* |                           |                                        |                          |
| No                                 | 8.08±5.40                 | F(1,119) = 11.34                       | P = 0.001                |
| Yes                                | 5.02±4.23                 |                                        |                          |
| Incidence of diarrhea in children under 5 years age* |                           |                                        |                          |
| No                                 | 5.36 ±4.78                | F (1, 83) = 7.273                      | P = 0.008                |
| Yes                                | 8.50 ± 5.32               |                                        |                          |
| Drinking water sources             |                           |                                        | P = 0.023                |
| Improved                           | 5.40 ±4.52                | F (1, 119) = 5.321                    |                          |
| Unimproved                         | 7.68 ±5.33                |                                        |                          |
| Amount of drinking water used in 24 hours|                           |                                        |                          |
| No                                 | R = 0.266                 |                                        | p = 0.015                |
| Yes                                | 8.50 ± 5.32               |                                        |                          |
| Time spent to collect water (one way)|                           |                                        |                          |
| No                                 | R = 0.211                 |                                        | p = 0.067                |
| Yes                                | 8.50 ± 5.32               |                                        |                          |

*a = 121

https://doi.org/10.1371/journal.pwat.0000029.t003
An experience of water insecurity involving range of coping mechanisms such as severe level of limiting water intake and/or drinking unsafe water is directly related to health and well-being of households. In fact, improving water security or allowing consistent access to safe and sufficient amount of water will not only help to achieve clean water and sanitation goal (SDG# 6) but, it will also ensure achievement of SDG# 5 (gender equity), SDG#3 (good health and well-being), and SDG#4 on quality education. In addition to the WATINE-17 development study results [17], this study demonstrates a strong predictive ability of the scale i.e., the water insecurity score was significantly higher in the households with children experiencing diarrhea; hence highlighting the need to integrate water insecurity measurement in SDG monitoring.

The WASH + nutrition clinical trials in rural setting in Kenya, Bangladesh, and Zimbabwe focused specifically on the sanitation and hygiene aspects of WASH, with limited interventions in improving “W” or access to drinking water. However, the results showed that WASH was not directly related to improved growth among young children. This is not surprising, since this and previous studies [47, 48] showed that to begin with, water access was a huge issue and integration of improvement of water infrastructure was critical in advancing health in rural areas. Additionally, measurement of water insecurity in WASH and other integrated trials is critical, since like food insecurity, water insecurity is experiential in nature and might not be captured by environmental indicators such as distance and time to water source. A recent systematic review of 27 randomized and non-randomized trials and interventions revealed the importance of food security and WASH approaches when trying to improve nutritional status of both young children and pregnant women [49]. In fact, adequate WASH practices might lead to better food hygiene measures at the household level, with subsequent reduction in children exposure to fecal pathogens [50].

The results of this study also provide a synopsis on drinking water management. In fact, participants reported storing drinking water for an average of four days. Such a long storage of drinking water generally leads to greater opportunities for pathogen contamination via repeated sampling of water from containers with dirty utensils and/or hands, further endangering the consumer health [51, 52]. Future research on water management and storage is warranted to highlight sources of cross-contamination and points of potential intervention in ensuring safe drinking water for rural households. Some limitations of this study include the use of convenience sampling and the exclusion of households, even though not many, which had water on premises. Also, the study area represents economic water scarcity vs. physical water scarcity, causing a limited external validity. These negatively impact representativeness and generalization of the results of the study to other settings. However, the use of a validated scale and local community workers are strengths of the study allowing participation of hard to reach population of caretakers living in remote areas in rural region of Central Africa. This study highlights issue that the availability of improved water source and time spent to fetch water still represent in low-resource households of rural areas; where having water on premises remains a luxury with subsequent complex interactions on women and children’s health. Policies should be designed in order to incorporate systematic household water insecurity measurement in monitoring advancement towards 2030 SDG in order to efficiently flag communities where substantial number of households experience water insecurity and track the evolution over time of household water insecurity.

Supporting information
S1 Text. Inclusivity in global research.
(DOCX)
S1 Data.
(CSV)

Acknowledgments
The authors are thankful to the community health workers and participants in the study.

Author Contributions

Conceptualization: Carole Debora Nounkeu, Yvan Dymas Metapi, Dieudonne Kuate.

Data curation: Carole Debora Nounkeu, Yvan Dymas Metapi, Agnes Suzanne Toguem Kamguem.

Formal analysis: Carole Debora Nounkeu, Yvan Dymas Metapi, Florent Kamkumo Ouabo, Bertin Nono, Georges Nguefack-Tsague.

Methodology: Florent Kamkumo Ouabo, Nicholas Azza, Patrice Leumeni, David Todem, Jigna Morarji Dharod, Dieudonne Kuate.

Resources: Agnes Suzanne Toguem Kamguem, Nicholas Azza, Patrice Leumeni, Georges Nguefack-Tsague, Dieudonne Kuate.

Software: Florent Kamkumo Ouabo, Bertin Nono, Georges Nguefack-Tsague.

Supervision: Carole Debora Nounkeu, Jigna Morarji Dharod, Dieudonne Kuate.

Writing – original draft: Carole Debora Nounkeu, Yvan Dymas Metapi, Florent Kamkumo Ouabo, Jigna Morarji Dharod.

Writing – review & editing: Carole Debora Nounkeu, Yvan Dymas Metapi, Florent Kamkumo Ouabo, Agnes Suzanne Toguem Kamguem, Bertin Nono, Nicholas Azza, Patrice Leumeni, Georges Nguefack-Tsague, David Todem, Jigna Morarji Dharod, Dieudonne Kuate.

References

1. Boberg J. Liquid assets: how demographic changes and water management policies affect freshwater resources. Santa Monica, Calif.: Rand; 2005. 124 p.

2. Jequier E, Constant F. Water as an essential nutrient: the physiological basis of hydration. Eur J Clin Nutr. 2010; 64(2):115–123. https://doi.org/10.1038/ejcn.2009.111 PMID: 19724292

3. Damkjaer S, Taylor R. The measurement of water scarcity: Defining a meaningful indicator. Ambio. 2017; 46(5):513–31. https://doi.org/10.1007/s13280-017-0912-z PMID: 28299747

4. Nkamedjie P, Ekukole S, Mabvouna Biguioh R, Bita AIG, Ateudjieu J. Access to Potable water in Dschang Health District, West Cameroon: A Cross Sectional Descriptive study. Int J Res. 2016; 3:1346–61.

5. Oyerinde AO, Jacobs HE. The complex nature of household water supply: an evidence-based assessment of urban water access in Southwest Nigeria. J Water Sanit Hyg Dev. 2022; 12(3):237–47. https://doi.org/10.2166/washdev.2022.176

6. Chen B, Han MY, Peng K, Zhou SL, Shao L, Wu XF, et al. Global land-water nexus: Agricultural land and freshwater use embodied in worldwide supply chains. Sci Total Environ. 2018; 613–614:391–43. https://doi.org/10.1016/j.scitotenv.2017.09.138 PMID: 28946381

7. Howard G, Bartram J, World Health Organization. Water S and HT. Domestic water quantity, service level and health. 2003 [cited 2020 Mar 16]; Available from: https://apps.who.int/iris/handle/10665/67884

8. Nounkeu CD, Kamgno J, Dharod J. Assessment of the relationship between water insecurity, hygiene practices, and incidence of diarrhea among children from rural households of the Menoua Division, West Cameroon. J Public Health Afr. 2019; 10(1).
9. Elliott M, Foster T, MacDonald MC, Harris AR, Schwab KJ, Hadwen WL. Addressing how multiple household water sources and uses build water resilience and support sustainable development. Npj Clean Water. 2019; 2(1):1–5.

10. Nounkeu CD, Dharod JM. A Qualitative Examination of Water Access and Related Coping Behaviors to Understand Its Link to Food Insecurity among Rural Households in the West Region in Cameroon. Int J Environ Res Public Health. 2020; 17(13). https://doi.org/10.3390/ijerph17134848 PMID: 32640517

11. Kithinji FK. Factors Influencing Households’ Access to Drinking Water: the Case of Communities in Imenti South, Kenya. PhD dissertation, University of Nairobi. 2015.

12. The UN-Water Task Force on Water Security. Water security and the global water agenda: a UN-water analytical brief [Internet]. Hamilton, Ont.: United Nations University—Institute for Water, Environment and Health; 2013 [cited 2020 Mar 15]. Available from: http://www.deslibris.ca/ID/237295

13. World Health Organization (WHO), United Nations International Children Emergency Fund (UNICEF). In: Progress on household drinking water, sanitation and hygiene 2000–2020: five years into the SDGs. World Health Organization; 2021. 162 p.

14. Water for Food Security and Nutrition. A report by The High Level Panel of Experts on Food Security and Nutrition. HLPE Report 9 [Policy Support and Governance] Food and Agriculture Organization of the United Nations [Internet]. [cited 2021 Dec 10]. Available from: https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/458451/

15. Diarrhoea [Internet]. UNICEF DATA. [cited 2021 Dec 10]. Available from: https://data.unicef.org/topic/child-health/diarrhoeal-disease/

16. Prüss-Üstün A, Bos R, Gore F, Bartram J, World Health Organization. Safer water, better health: costs, benefits and sustainability of interventions to protect and promote health. Geneva: World Health Organization; 2008.

17. Nounkeu CD, Gruber K, Kamgno J, Teta I, Dharod J. Development of Water Insecurity Scale for Rural Households in Cameroon-Central Africa. Glob Health Action. 2021; 14: 1927328. https://doi.org/10.1080/16549716.2021.1927328 PMID: 34165038

18. UNICEF, WHO. Progress on household drinking water, sanitation and hygiene 2000–2017. 2019 [cited 2020 Mar 16]. Available from: http://www.who.int/water_sanitation_health/publications/jmp-report-2019/en/

19. Food Security and Nutrition Network. User Guide: Household Water Insecurity Experiences. 2020. Available from: https://www.fsnnetwork.org/resource/user-guide-household-water-insecurity-experiences

20. Jepson WE, Wutich A, Collins SM, Boateng GO, Young SL. Progress in household water insecurity metrics: a cross-disciplinary approach. WIREs Water. 2017; 4:e1214.

21. Nounkeu CD, Dharod JM. Status on the Scale Development to Measure Water Insecurity Experiences at the Household Level: A Narrative Review. Adv Nutr. 2019; 10(5):685–75. https://doi.org/10.1093/advances/nmz008 PMID: 31046076

22. Stoler J, Miller JD, Adams EA, Ahmed F, Alexander M, Asiki G, et al. The Household Water Insecurity Experiences (HWISE) Scale: comparison scores from 27 sites in 22 countries. J Water Sanit Hyg Dev. 2021; 11(6):1102–10. https://doi.org/10.2166/washdev.2021.108

23. Dongmo JL, editor. Bafou, une grande chefferie de l’ouest, Cameroun. Yaounde: CEPER, 1990. 115 p.

24. Yemele MD, Telefo PB, Lienou LL, Tagne SR, Fodouop CSP, Goka CS, et al. Ethnobotanical survey of medicinal plants used for pregnant women’s health conditions in Menoua division-West Cameroon. J Ethnopharmacol. 2015; 160:14–31. https://doi.org/10.1016/j.jep.2014.11.017 PMID: 25449451

25. Seino RA, Ghogomu RT, Manjeli Y, Dongmo TI, Chifon RN. A faunal survey of the Oedipodinae (Acrididae: Orthoptera) of the Menoua Division in Cameroon. Int J Fauna Biol Stud. 2013; 1:15–9.

26. Temgoua E, Ngnikam E, Ndongs on B. Drinking water quality: stakes of control and sanitation in the town of Dschang—Cameroon. Int J Biol Chem Sci. 2009;3(3).

27. Oumar SB, Mbonigaba J. An Assessment Of The Performance Of The Cameroon Water Corporation For The Period 1967 To 2013. J Appl Bus Res JABR. 2014; 30(3):929.

28. Nounkeu CD, Dharod JM. Water insecurity among rural households of West Cameroon: lessons learned from the field. J Water Sanit Hyg Dev Lond. 2018; 8(3):S85–94.

29. Zacharie Tite Mbomba Jiatsa. Can Fog and Rain Harvesting Secure Safe Drinking Water in Rural Cameroon?—Case study of Bafou (mountainous) and Mora (low-lying) villages. PhD dissertation, University of Kristianstad, Sweden; 2010. Available from: https://www.diva-portal.org/smash/get/diva2:622066/ FULLTEXT01.pdf

PLOS Water | https://doi.org/10.1371/journal.pwat.0000029 August 18, 2022 13 / 15
30. Tchékoté H, Melachio MN, Siyapdje EC. Appropriation foncière, pratiques agricoles et enjeux environnementaux à Bafou-Nord dans les monts Bamboutos (Ouest Cameroun). Belg Rev Belge Géographie. 2018; (2). https://doi.org/10.4000/belgeo.21085

31. Geere JA, Cortobius M. Who carries the weight of water? Fetching water in rural and urban areas and the implications for water security. Water Alternatives. 2017; 10:513–40.

32. Sorensen SB, Morssink C, Campos PA. Safe access to safe water in low income countries: Water fetching in current times. Soc Sci Med. 2011; 72:1522–6. https://doi.org/10.1016/j.soscimed.2011.03.010 PMID: 21481508

33. Agesa RU, Agesa J. Time Spent On Household Chores (Fetching Water) And The Alternatives Forgotten For Women in Sub-Saharan Africa. J Dev Areas. 2019; 53:29–42.

34. Blood RO, Wolfe DM. Husbands & wives: the dynamics of married living. Glencoe, Ill. New York, the Free Press; 1960. 293 p

35. Wong JD, Almeida DM. The Effects of Employment Status and Daily Stressors on Time Spent on Daily Household Chores in Middle-Aged and Older Adults. The Gerontologist. 2013; 53:81–91. https://doi.org/10.1093/geront/gns047 PMID: 22466418

36. Troeger CE, Khalil IA, Blacker BF, Biehl MH, Albertson SB, Zimsen SRM, et al. Quantifying risks and interventions that have affected the burden of diarrhoea among children younger than 5 years: an analysis of the Global Burden of Disease Study 2017. Lancet Infect Dis. 2020; 20:37–59. https://doi.org/10.1016/S1473-3099(19)30401-3 PMID: 31678029

37. Njue FM, Reid BM, Humphrey JH, Mtuya MN, Peito G, Stoltzfus RJ. Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links. Ann N Y Acad Sci. 2014; 1308(1):118–28.

38. Rosenbaum J, Tenaw E, Clemmer R, Israel M, Albert J. Exploring the Use and Appeal of Playpens to Protect Infants from Exposure to Animals, Animal Feces, and Dirt in Rural Ethiopia. Am J Trop Med Hyg. 2021; 104(1):346–56. https://doi.org/10.4269/ajtmh.20-0445 PMID: 33169663

39. Dharod JM, Nounkeu CD, Paynter L, Labban JD, Sastre LR. Examination of the Cameroon DHS data to investigate how water access and sanitation services are related to diarrhea and nutrition among infants and toddlers in rural households. J Water Health. 2021; 19(6):1030–8. https://doi.org/10.2166/wh.2021.123 PMID: 34874909

40. Boateng GO, Neilands TB, Frongillo EA, Melgar-Quiñonez HR, Young SL. Best practices for developing and validating scales for health, social, and behavioral research: a primer. Public Health Front. 2018; 6:149. https://doi.org/10.3389/fpubh.2018.00149

41. Stevenson EGJ, Greene LE, Maes KC, Ambelu A, Tesfaye YA, Rheingans R, et al. Water insecurity in 3 dimensions: An anthropological perspective on water and women’s psychosocial distress in Ethiopia. Soc Sci Med 1982. 2012; 75(2):392–400. https://doi.org/10.1016/j.soscimed.2012.03.022 PMID: 22575697

42. Choudhary N, Brewis A, Wutch A, Udas PB. Sub-optimal household water access is associated with greater risk of intimate partner violence against women: evidence from Nepal. J Water Health. 2020 Aug; 18(4):579–94. https://doi.org/10.2166/wh.2020.024 PMID: 32833684

43. Brewis A, Workman C, Wutch A, Jepson W, Young S. Household water insecurity is strongly associated with food insecurity: Evidence from 27 sites in low- and middle-income countries. Am J Hum Biol. 2020; 32:e23309. https://doi.org/10.1002/ajhb.23309 PMID: 31444940

44. Aihara Y, Shrestha S, Sharma J. Household water insecurity, depression and quality of life among postnatal women living in urban Nepal. J Water Health. 2016; 14(2):317–24. https://doi.org/10.2166/wh.2015.166 PMID: 27105416

45. Brewis A, Choudhary N, Wutch A. Household water insecurity may influence common mental disorders directly and indirectly through multiple pathways: Evidence from Haiti. Soc Sci Med 1982. 2019; 238:112520. https://doi.org/10.1016/j.soscimed.2019.112520 PMID: 31473576

46. Bukachi SA, Omia DO, Musyoka MM, Wambua FM, Peter MN, Korzenewicza M. Exploring water access in rural Kenya: narratives of social capital, gender inequalities and household water security in Kitui county. Water Int. 2021; 46:677–96.

47. Nounkeu CD, Dharod JM. Integrated approach in addressing undernutrition in developing countries: a scoping review of integrated water access, sanitation, and hygiene (WASH)+ nutrition interventions. Current developments in nutrition. 2021; 5:nzabo087. https://doi.org/10.1093/cdn/nzabo087 PMID: 34268466

48. Stevenson EGJ. Water access transformations: metrics, infrastructure, and inequities. Water Secur. 2019; 8:100047. https://doi.org/10.1016/j.wasec.2019.100047 PMID: 32864519

49. Urgell-Lahuerda C, Carrillo-Alvarez E, Salinas-Roca B. Interventions on Food Security and Water Uses for Improving Nutritional Status of Pregnant Women and Children Younger Than Five Years in Low-
Middle Income Countries: A Systematic Review. Int J Environ Res Public Health. 2021; 18(9):4799. https://doi.org/10.3390/ijerph18094799 PMID: 34063195

50. Freeman MC, Ellis AS, Ogutu EA, Caruso BA, Linabarger M, Micek K, et al. Impact of a demand-side integrated WASH and nutrition community-based care group intervention on behavioural change: a randomised controlled trial in western Kenya. BMJ Glob Health. 2020; 5(11):e002806. https://doi.org/10.1136/bmjgh-2020-002806 PMID: 33234528

51. Ngnikam E, Mougoue B, Tietche F. Eau, Assainissement et impact sur la santé: étude de cas d’un écosystème urbain à Yaoundé. Actes des JSIRAUF, Hanoi. 2007:6–9.

52. Pickering AJ, Davis J. Freshwater Availability and Water Fetching Distance Affect Child Health in Sub-Saharan Africa. Environ Sci Technol. 2012; 46:2391–7. https://doi.org/10.1021/es203177v PMID: 22242546