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Accessibility to Safe Drinking Water and Diarrheal Diseases: A Quasi-Experiment on a Case of Water Well Drilling in the Village of Kassouala, Municipality of Tchaourou, Benin, January 2018-July 2019

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Abstract

Background: In 2017, 900 million people in the world did not have sustainable access to safe drinking water (SDW). In addition, between 2016 and 2020, the global population with safely managed drinking water at home increased from 70 percent to 74 percent. Drinking water insecurity is the daily situation of people in developing countries. The lack of SDW supply is at the root of many diseases, including diarrheal diseases. Kassouala is a village in the municipality of Tchaourou without access to SDW, but having benefited from the drilling of a well in September 2018. The objective of this study was to study the effect of access to safe drinking water on the frequency of diarrheal diseases in Kassouala between January 2018 and July 2019. **Methods:** We conducted a quasi-experimental study in Kassouala using the natural experiments of the village of Bérétou as a control group for estimating the effect of a causal nature. There were double temporal (January 2018-July 2019) and geographical (Kassouala-Bérétou) comparisons based on data collected from health care registers. A population-based comparability survey of the two villages was conducted among 170 households in each village (experimental village, control village). A two-stage cluster sampling procedure was used to select the survey participants. Data were collected from heads of household by semi-structured questionnaire. We used Pearson or Mantel-Haenszel chi-square tests, as appropriate, and the "difference-in-difference" method to assess the effect. **Results:** In Kassouala, the proportion of households with access to safe

drinking water had increased to 78.88%, whereas it was nil in 2018 before the well drilling, and the frequency of diarrheal diseases decreased significantly from January 2018 before drilling to July 2019 after drilling (57.11% to 44.64%; $p < 0.0001$). In Bétérou, on the other hand, a control village, used as counterfactual village, a significant increase was noted (31.48% vs. 50%; $p < 0.0001$). The difference-in-difference was estimated at −30.99% with a degree of statistical significance estimated at $p < 0.0001$ accounting for the decrease in the frequency of diarrhea in Kassoula relates to SDW accessibility to the population due to the drilling of the well. **Conclusion:** Access to safe drinking water in Kassouala has a causal effect on the reduction of diarrheal diseases. However, for the supply of drinking water to be integrated into the community development plan of Tchaourou, it is necessary to support the scaling up of this intervention, which would be considered as a pilot, of a community participation program.

Keywords

Diarrheal Diseases, Water Supply, Drinking Water, Community Participation, Benin

1. Introduction

Water is life, and its availability in poor quality in a community is a reflection of poor quality of human life in that community. Access to safe drinking water (SDW) is then a challenge in health promotion and the World Health Organization (WHO) in its Guidelines for drinking-water quality-2017 reported that "Access to SDW is essential to health, a basic human right and a component of effective policy for health protection" [1]. The United Nations International Children's Emergency Fund (UNICEF) reported that in 2017, 900 million people worldwide do not have sustainable access to safe drinking water; 2.4 billion have no access to adequate sanitation and indulge in open defecation [2]. Between 2016 and 2020, the global population with safely managed drinking water at home increased from 70% to 74%; safely managed sanitation services grew from 47% to 54%. In 2020, around 1 in 4 people lacked safely managed drinking water in their homes and nearly half the world's population lacked safely managed sanitation. The majority of the people (8 out of 10) without basic water services lived in rural areas [3].

Drinking water insecurity is the daily life of people in developing countries. However, everyone agrees on the evidence that without access to safe drinking water, sanitation and hygiene (WASH), there can be no health, no survival, no growth, and no development [4]. And the 6th sustainable development goal states to ensure access to water and sanitation for all, and the first target is to achieve universal and equitable access to safe and affordable drinking water for all by 2030 [5]. This SDW supply situation is critical in sub-Saharan Africa where

access to safe drinking water and a healthy living environment is a challenge for health and development [6]. Until 2017, in Benin, the issue of WASH was more relevant than ever in rural and urban areas [2]. In 2015, in Benin, the safe drinking water supply rate stood at 67.6% in rural areas; which enabled Benin to achieve the target of Millennium Development Goals (MDGs) no. 7 in the water sub-sector in rural and semi-urban areas. However, this rate hides disparities from one region to another and within municipalities [6]. Until 2014, the municipality of Tchaourou, the largest municipality in Benin with a landmass representing 6.5% of the national territory, experienced challenges including the insufficiency of SDW points, the lack of maintenance of SDW point equipment, the problems related to the management of SDW points and the time devoted to SDW supply by the populations [4]. Unimproved water remains among the top 12 risk factors in most of sub-Saharan Africa where diarrhea remains a leading killer [7]. From Systematic Review in 2014, it is widely reported by several researchers that inadequate water has long been associated with diarrhea [8]. Kassouala is a village in the municipality of Tchaourou bordering the municipality of Parakou, the university town of the North of Benin. In a practical work approach for community diagnosis, a group of students at the end of their undergraduate studies in epidemiology was sent to this village of Kassoula in April 2018. With a well-conducted strategy for this community diagnosis approach, it emerged that the population of this village consumed, for the most part, water used for drinking from the backwater and diarrhea was their priority health problem [9]. Counts of health care registers in the health center serving this village reported that during the period from January 2018 to July 2018, among the 422 people who consulted, 241 had diarrheal diseases, a frequency of 57.11% [9]. It is in this context that in September 2018, and in accordance with the program of the Beninese government (PAG-2016-2021) which aims to ensure access to safe drinking water for all the populations of Benin by 2021, the Non-Governmental Organization Global Aid Network (NGO GAIN Benin) has drilled the drinking water well in Kassouala with the support of the university internship group. The realization of the borehole was a scientific opportunity to better appreciate the effects of such a realization on the reduction of diarrheal diseases for adequate suggestions for the benefit of the health of this community. It is in this context that we were interested in studying the effects of safe drinking water accessibility in the village of Kassouala on the incidence of diarrheal diseases.

2. Methods

2.1. Study Settings

The intervention site of our study is Kassouala village that is a very large village in the municipality of Tchaourou, bordering Nigeria.

The village of Kassouala is located 29 kilometers (Km) from Saint Martin de Papané Hospital, the Tchaourou Zone Hospital and 19 km from the town of

Tchaourou. It has 1398 inhabitants in 2018 and includes four (4) hamlets, which are Okessawa, Albarika, Sogho and Djarahondo. A fifth of this population is under the age of five.

It has a health center to serve approximately 25,000 inhabitants for primary health care.

It was in this village that the community diagnosis was carried out in April 2018, the population prioritizing their problems prioritized the inaccessibility of safe drinking water as a health problem and which obviously caused, among other things, frequent diarrhea.

2.2. Study Design

We conducted a quasi-experimental study in Kassouala exploiting the natural experiments of the village of Bérétou as a control group for estimating the effect of a causal nature. There was a double comparison: temporal (January-July 2018; January-July 2019) and geographical (Kassouala-Bétérou); Kassouala being the experimental village (factual) and Bétérou the control village (counterfactual). This is the estimation of the causal effect by the "difference-in-difference" (DD) method.

For the comparison of the frequencies of diarrhea to be used for the DD method, the data from the curative care registers were collected by tally sheets for this purpose.

Household survey data in 2018 was used for comparability of sites in the DD method.

2.3. Sampling, Recruitment and Data Collection

For the choice of the best comparable village to that of Kassouala (factual), out of the 86 other villages and city areas that make up the municipality of Tchaourou, the village of Bétérou was chosen as the control village that can best reflect the counterfactual effect from the experimental one (Kassouala).

A two-stage cluster sampling procedure was used to select 170 households in each village. The minimized sample size was calculated using the formula of Schwartz with allowable margin error of ±4%. The calculated minimized sample size was 157 households. That minimized sample size increased by 10% for preserving statistical power because of refusal to participate in the study. These samples were taken respectively in the study population consisting of all the inhabitants of the village of Kassouala in 2018 and in the control village of Bétérou comparable to Kasouala from the point of view of accessibility to safe drinking water, sanitation and hygiene, before drilling of the well.

A collection of household population survey data was conducted in July 2018 in the two villages just before the drilling of the well in September 2018 using a semi-structured questionnaire taking into account our variables of interest for access to sanitation, hygiene and safe drinking water which has been pre-tested in Tchatchou, another village of the municipality of Tchaourou.

As part of the monitoring, a one-time data collection on the sources of water supply and the reason for not using the well was carried out in the population of Kassouala in July 2019 using the same sampling technique.

The collection of data within the framework of the DD approach was carried out from the primary care registers of the health centers that respectively served the villages of Kasouala and that of Bétérou. A case report sheet has been prepared for this sake.

The dependent variable is the diarrheal disease which was treated in binary with the two modalities (Yes, No) and the independent variable of interest accessibility to safe drinking water also treated in binary (Yes, No). The "Yes" modality of the diarrheal disease corresponded to its diagnosis recorded in the primary care register during the period of January-July 2018 or January-July 2019. As for the accessibility of drinking water, its "Yes" modality corresponded to the accessibility of a safe drinking water supply point to a study participant during the period under consideration.

2.4. Eligibility Criteria

As for the population survey, the study included households settled in the villages since at least September 2017 and whose household head or representative gave free and informed verbal consent to participate in the study. No household was excluded after consent. However, in the event of the household head's inability to complete the questionnaire, a valid substitute is selected purposefully in the household.

As for the collection of data from curative care registers, only patients with exhaustive registration data including diagnosis and origin are included in the study.

2.5. Statistical Analyses

At the end of the survey, the questionnaires were analyzed manually to check the completeness and consistency of the data. The processing sheets of the primary care logs were also checked for their completeness and consistency.

Then, data entry was done using Epi-Data 3.1 French version software.

Data were analyzed with Epi-Info version 7.2. Measures of Central Tendency and Dispersion Measures were used to describe the quantitative variables and the proportions for the qualitative variables. The statistical tests used to compare our results were the Pearson or Mantel-Haenszel chi-square tests (depending on the case) and the difference-in-difference (DD) [10] [11] [12] [13] for the assessment of effect. The tests were considered statistically significant when their degree of significance estimated in the study was below the chosen statistical significance threshold of 5%. The difference-in-difference method, a quasi-experimental approach compares the changes in outcomes over time between a population enrolled in a program (Kassouala village) and a control population (Bétérou village).

3. Ethical Considerations

The study protocol was approved by an ad hoc committee convened by the School of Public Health and Epidemiology, University of Parakou in Benin. Informed verbal consent was obtained from each head of household or representative before participation in the study. It should be noted that data collection in the study complied with the ethical principles contained in the Declaration of Helsinki of the World Medical Association [14]. The subjects surveyed were then reassured about the anonymity and confidentiality of the information collected. The collection of data in the primary care logs was carried out on the basis of counting sheets with numbers that could in no way be linked to the individuals concerned.

4. Results

- Comparability of the study site with the counterfactual

Kassouala is a village northwest of Tchaourou and Bétérou in the center-east of the commune of Tchaourou (**Figure 1**).

From a socio-demographic point of view, the two villages have the same average age of 30.93 ± 13.57 years and 30.87 ± 10.53 years respectively, and the distributions of education levels, profession and religion are similar in the two villages. Except at the level of income in Bétérou where those with an income ≥ 35,000.00 CFA francs were in higher proportion (15.29% vs 3.53%). Nevertheless, in terms of access to safe drinking water, hygiene and sanitation, the two villages were similar (**Table 1**).

- Frequency of occurrence of diarrhea in Kassouala

The analysis of the primary care logs of the health structures serving the village (Kassoula health center and Tchaourou communal health center), from January to July 2018, noted that of the 422 visits by patients from the village, 241 complained about diarrhea without organic diagnosis as the cause of water insalubrity, a frequency of 57.11%. From the analysis of the data from January to July 2019 after the drilling of the well, in September 2018, a statistically significant decrease in this frequency was already noted (57.11% to 44.64%; $p < 0.0001$) (**Table 2**). In this period, 78.82% of the inhabitants of the village already consumed this well water, and for those who did not consume it, it was in particular because of long waiting times at the borehole before having access to water (**Table 3**).

- Frequency of occurrence of diarrhea in Bétérou

The counting of cases in the curative care registers of the health structures that served this village (communal health center of Tchaourou and the departmental university hospital center of Borgou), from January to July 2018 reported a frequency of diarrhea of 31.48% and contrary to the decrease in frequency between 2018 and 2019 in Kassouala, we have rather a statistically significant increase (31.48% to 50%; $p < 0.0001$) (**Table 4**). Thus, while the frequency of diarrhea increased significantly from 31.48% to 50% in Bétérou (like a counterfactual group), there have had rather a significant decrease in the frequency in the

Table 1. Sociodemographic characteristics, drinking water, hygiene and sanitation in the villages of Kassuala and Bétérou, Municipality of Tachaourou, Benin, 2018.

Kassouala (N = 170) n %			Bétourou (N = 170) n %		
Age			**Age**		
Mean age ± SD*	30.93 ± 13.57		30.87 ± 10.53		
Education			**Education**		
Illiterate	89	52.35	Illiterate	81	47.65
Primary education	37	21.76	Primary education	41	24.12
Secondary or university education	44	25.88	Secondary or University education	48	28.23
Profession			**Profession**		
Trader	14	8.24	Trader	26	15.29
Farmer	73	42.94	Farmer	65	38.24
Retailer	12	7.06	Retailer	21	12.35
Craftman/MTD**	71	41.76	Craftman/MTD**	58	34.12
Religion			**Religion**		
Animistic	2	1.18	Animistic	5	2.94
Christian	141	82.94	Christian	109	64.12
Muslim	13	7.65	Muslim	47	27.65
Atheistic	14	8.24	Atheistic	9	5.29
Income			**Income**		
<35,000 f	164	96.47	<35,000 f	144	84.71
≥35,000 f CFA	6	3.53	≥35,000 f CFA	26	15.29
Water for consumption			**Water consumption**		
Water from backwater	120	70.59	Water from backwater	123	72.35
Runoff water	50	29.41	Runoff water	42	27.65
Purification of water for consumption			**Purification of water for consumption**		
Yes	5	2.94	Yes	7	4.12
No	165	97.06	No	163	95.88
Availability of latrines			**Availability of latrines**		
Yes	1	0.59	Yes	1	0.59
No	169	99.41	No	169	99.41

*Standard deviation; **motorcycle taxi drivers.

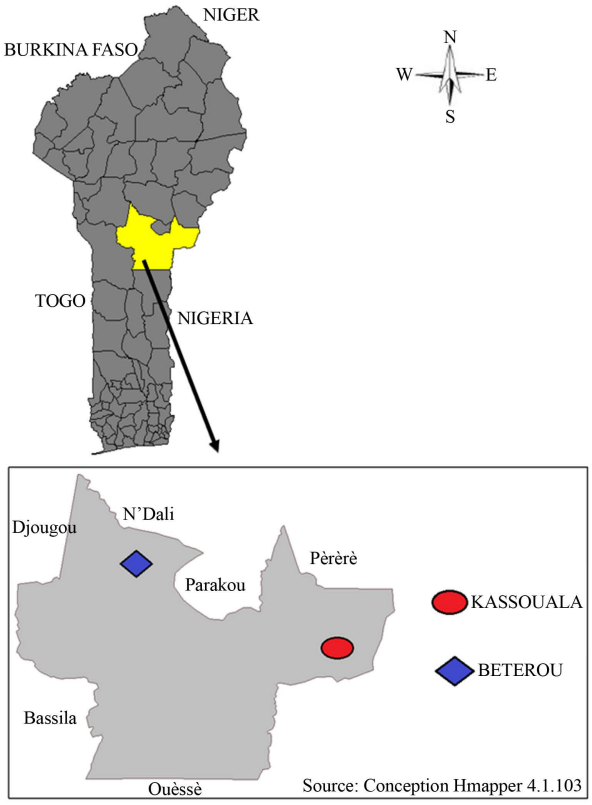

Figure 1. Geographical location of the municipality of Tchaourou in Benin and the villages of Kassouala and Bétérou in the municipality, Benin, 2018.

Table 2. Comparison of the frequency of diarrhea between 2018 and 2019 in the village of Kassouala, Tchaourou, Benin.

	2018		2019		p-value*
	n	%	n	%	
Had diarrhea	241	57.11	462	44.64	
Had not diarrhea	181	42.89	573	55.36	<0.0001
Total	422	100.00	1035	100.00	

*Mantel-Haenszel p-value.

Table 3. Distribution of inhabitants according to their source of safe drinking water supply after the water well drilling in the village of Kassouala, Tchaourou, Benin, 2019.

	n	Frequency (N = 170)%
Drinking water supply source		
Borehole water	134	78.82
Backwater water	36	21.18
Reason for consuming backwater water		
Distance to the borehole	7	19.44
Waiting time at the borehole	29	80.56

experimental village of Kassuala (as factual group) from 57.11% to 44.64%.

➢ Comparison of diarrhea frequency between the two villages in 2018 and 2019

In 2018, at baseline, the frequency of diarrhea was significantly higher in Kassouala than in Bétérou (57.11% Vs 31.48%; $p < 0.0001$) (Table 5).

➢ Difference-in-difference method

The difference in frequencies in Kassouala between 2018 and 2019 was significantly negative at −12.47% (difference in the frequency of diarrhea, after versus before the drilling well) with a degree of statistical significance estimated in the study at $p < 0.0001$. On the other hand, that in Bétérou, the control village was significantly positive at +18.52% (difference in the frequency of diarrhea, after versus before the date of the drilling well in Kassuala, the experimental village) with a degree of statistical significance estimated in the study at $p < 0.0001$. The difference-in-difference was then estimated at −30.99% (−12.47 - 18.52) with a degree of statistical significance estimated in the study at $p < 0.0001$ (Figure 2).

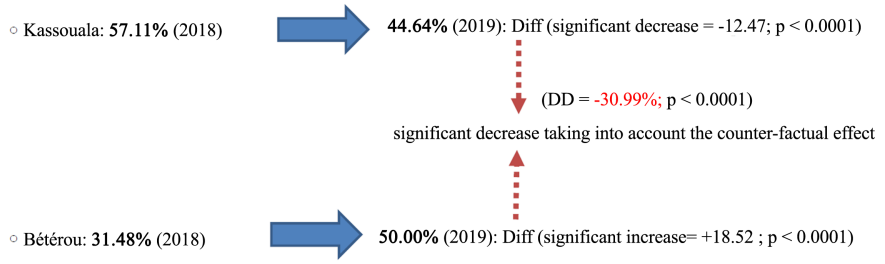

Figure 2. DD giving the causal effect of water well drilling on the decrease in the frequency of diarrhea in Kassouala using the counterfactual model based on Betérou, Tchaourou, Benin, 2018-2019.

Table 4. Comparison of the frequency of diarrhea between 2018 and 2019 in the village of Bétérou, Tchaourou, Benin.

	2018		2019		p-value*
	n	%	n	%	
Had diarrhea	68	31.48	106	50.00	<0.0001
Had not diarrhea	148	68.52	106	50.00	
Total	216	100.00	212	100.00	

*Mantel-Haenszel p-value.

Table 5. Comparison of the frequency of diarrhea in 2018 between Kassouala and Bétérou, Tchaourou, Benin.

	Kassouala		Bétérou		p-value*
	n	%	n	%	
Had diarrhea	241	57.11	68	31.48	<0.0001
Had not diarrhea	181	42.89	148	68.52	
Total	422	100.00	216	100.00	

*p-value from pearson chi-square.

5. Discussion

Based on a community diagnosis carried out in the village of Kassouala in April 2018, diarrhea was reported to be their priority health problem in a context of lack of safe drinking water (SDW) and lack of latrines. As an alternative to a randomized community trial, and seizing the opportunity of the water well drilling, we then opted for a quasi-experimental study with two groups of comparisons [15]: factual group, which was our study site where there was the drilling of the well and a control group having received no intervention. We relied on the notion of counterfactual to estimate the specific causal effect [16] [17]. From the point of view of age, level of education, accessibility to water, hygiene and sanitation, which are factors that can directly influence the occurrence of diarrhea, the two villages are interchangeable. In the absence of randomization, it was this village of Bétérou that was as similar as possible in the municipality to our study site, which is the Kassouala village and which could be used to estimate the counterfactual effect. Between January-July 2008 and January-July 2019 on either side of the borehole in Kassouala in September 2018, we observed in Kassouala a statistically significant decrease in the frequency of diarrhea while nothing has changed in the village other than the drilling of the water well (57.11% to 44.64%; $p < 0.0001$). This is well interpreted as in several studies where there has been reported a significant association between the lack of safe drinking water and latrines and the increase in the incidence of diarrhea [8] [18]-[22]. In a systematic review with meta-regression by Wolf et al on the impact of safe drinking water and sanitation on diarrheal disease in low- and middle-income settings, the authors reported that improvements in drinking water and sanitation were associated with decreased risks of diarrheal disease [8]. But in our study population, apart from the water well drilling, there are almost no latrines. This could explain the lesser decrease in the frequency of diarrhea compared to what was expected. This situation in the villages of Tchaourou, in terms of sanitation, validates the UNICEF-Benin report on WASH, which notifies that in 2018, at the national level, more than one in two households (54%) did not use no toilets and still defecate in the open air (bush/field): 77% rural areas compared to 36% in urban areas [2].

The major national programs for access to drinking water (since 2016) for all populations have not taken into account small remote villages, so much so that PRACTICA Foundation, which deals with the Alliance WASH program, focuses on strengthening private water operators and manual drilling companies so that these villages have traditional drinking water wells [23]. This Alliance WASH program, which is set up to promote, as a priority, access to sanitation, hygiene and safe drinking water for marginalized groups in the four regions of Northern Benin, had not yet reached Kassouala and Bétérou villages in 2018; which allowed experimentation in Kassouala.

The statistically significant decrease in the frequency of diarrhea in Kassouala between January-July 2018 and January-July 2019 was not methodologically suf-

ficient to attribute this drop to the well drilled in September 2018. Because such a decline in frequency of diarrhea could be spontaneous evolution, this spontaneous evolution expected in Kassouala in the absence of water well drilling should be taken into account in the analysis of the results, to distinguish what is attributable, if any, to the drilling of the well [24]. In other words, other factors likely to influence such a significant decrease in the frequency of diarrhea, could even vary over time, and thus could make it difficult to isolate a specific effect of the drilling of the well: these are factors of confusion that had to be taken into account. However, the problem is that in a situation of open population thus with other possible interventions or specific factors which arise without our noticing it, it is difficult to adjust the effect found for all these factors of confusion. In the event of difficulty controlling confounding factors, the study and control groups comparison is used in addition to the pre-post exposure comparison described above in order to isolate the share of confounding factors in the total outcome generated. This study and control groups' comparison compared the differences obtained during the same period in Kassouala with Bétérou. The crux of the problem here remains the comparability of the two groups on many factors other than the intervention [24]. Such a search for the effect specific to the drilling of the well in Kassouala comes under causal inference, which is central to the analytical approach to causality in several disciplines, including epidemiology, and uses the model based on the notion of counterfactual to identify the effects of a causal nature as in our case of well drilling here [17] [25]. This process of isolating the specific causal effect defines the "difference-in-differences" method that we used in our present study. In general, the "difference-in-differences" (DD) method uses one or more control groups to approximate the trajectory of a counterfactual group (like Bétérou in our study) who did not receive an intervention that would be interchangeable with the group that received the intervention (Kassouala). The main assumption to consider in this type of approach is that, in the absence of the intervention, the trends of the control group are a good approximation of the trends of the group that will receive the intervention. In addition, in our present study, this means that if the intervention had not taken place, the trends in the frequency of diarrhea between Kassouala and Bétérou would have remained constant [17] [26]. The consequence here in our case is that at the time we noted a significant decrease in the frequency of diarrhea in Kassouala, we have on the contrary a significant increase in the frequency of diarrhea in the control group of Bétérou (31, 48% to 50%; $p < 0.0001$). Thus, the comparison pre-intervention and post-intervention noted a significant decrease in prevalence in the intervention village, while the upward trend was statistically significant in the control village of Bétérou. Thus, the factual group and the control group comparison reported an antagonistic evolution directly attributing the causal effect of the decrease in the frequency of diarrhea to the drilling of the well in Kassouala. Our study, to have the effect specific to the intervention by eliminating those generated by the potential confounding factors, associated the two comparisons: temporal (pre-exposure and post-exposure) and

geographical (factual group: here, and control group: elsewhere) that account for the DD approach. The DD in our case here being at -30.99 is statistically significant at $p < 0.0001$. This validates the attribution of the causal effect to the drilling of the well. This causality found was well compatible with the distribution of the population of Kassouala in 2019 according to the type of water consumption. Indeed, the general population survey in July 2019 reported that 78.82% consumed water from the drilled well. In addition, for those who did not, the reason given was the long waiting time (80.56%) and the distance to reach the well (19.44%). The decreased risk of diarrhea was disproportional with this high adoption of drinking water consumption. This could be partly explained by water contamination at the source due to the high concentration of the population around the only drilled well and increasing rainfall during the period from March to August, which would hike the risk of water-and-feces-based diseases adding to the lack of hygiene and sanitation in the village [8], as we mentioned earlier. It is this context of growing increase in the risk of water-and-feces-based diseases that would explain the increased trend noted in Bétérou, which would have been the same situation in Kassouala in the absence of this well drilling intervention. As for the comparability of the two villages, the low frequency of diarrhea in January 2018 in Bétérou compared to Kassouala could be explained by the proportion of households with monthly income was higher in Bétérou than Kassouala (15.29% Vs 3.53%). This might cause these households to buy safe drinking water or fetch water from boreholes in Parakou (the bordering municipality endowed with water, hygiene and sanitation facilities) or in any other place. This would have reduced the risk of consuming non-drinkable water.

Our study has some limitations. The temporal and geographical comparisons have used data collected in the curative care logs of the health centers delivering the populations concerned. The majority of sick people in the rural areas do not seek for care in the health center. One could think of an underestimation on both sides, but in a comparability approach, such selection biases, if any, could only be non-differential and could not distort our found association. The interchangeability of Bétérou and Kassouala is limited in terms of monthly household income, but the effect of consistently reducing the incidence of diarrhea over time in a group would not interfere with the DD method. A population selection bias, if any in our study as it was conducted, would not be likely to deteriorate the causal imputability found. One could think of a community trial; but beyond the cost, it would not be ethically acceptable in the current context where the use of natural experiments is the most ethical and constitutes a good alternative in this case. One could think of collecting data on diarrhea during population surveys. Nevertheless, such data would only have generated differential information biases, because we could no longer have them for the year 2018.

Under our conditions, we could only think of residual confusion. However, if necessary, this absence of control in the difference-in-differences method would not be likely to confuse the causal imputability found, as approximately comparable in clinical trials.

In Benin, the Alliance WASH Benin program intends [23]:

- To strengthen local enterprises in the WASH sector to increase sustainable access to safe drinking water in remote areas.
- To identify improved water metering tools to strengthen the technical management of private water operators.
- To raise awareness on the potential of manual well drilling to provide safe drinking water to remote villages.
- To train local workshops and manual drilling enterprises.

This is a community participation approach for the sustainability of safe drinking water accessibility integrated into the community development of the municipality of Tchaourou.

Ultimately, this is a study providing evidence of the need for drinking water for all in order to achieve the sixth sustainable development goal.

Added value of our study: the difference-in-differences method is very rarely used in the estimation of causal effects in quasi-experimental studies in Benin. However, it is the most valid approach for estimating the causal effect of a community program in the absence of a community trial, which makes it possible to control for possible confounding biases. Our article is much more about methodological positioning, but it informs us that in marginalized areas like Kassouala, the drilling of a well for 1398 inhabitants could already have the initiation effect in achieving Sustainable Development Goal N06 related to ensuring availability and sustainable management of water for all by 2030. This will involve initiating the drilling of a well in a community in Bottom-up approaches emphasizing the participation of the local community in development initiatives so that they can select their own goals and the means of achieving scaling up to ensure universal and equitable access to safe drinking water at an affordable cost.

6. Conclusion

It appears from the study that Kassouala's access to safe drinking water has a causal effect in reducing the frequency of diarrheal disease. However, for the supply of drinking water to be integrated into the community development plan of Tchaourou, it is necessary to support the scaling up of this intervention, which would be considered as the pilot, of a community participation program that also takes into account the promotion of comprehensive hygiene and sanitation.

Conflicts of Interest

The authors have declared that no competing interests exist.

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Appendix

Semi-structured questionnaire for collecting data in the general population (used for two rounds of the population-based survey: each round had its suitable questions).

N°	Questionnaire item	Answer	Code
1	Questionnaire number	/_____/	-
2	Date of the survey	Day: /__//__/ Month: /__//__/ Year: /__//__//__//__/	
3	Name of the interviewer	/_____/ /_____/ /_____/	
4	What is the language of the interview?	/_____/	
	Socio-demographic factors		
5	How old are you?	Day: /__//__/ Month: /__//__/ Year: /__//__//__//__/	
6	what is your profession?	1) Trader /__/ 2) Farmer 3) Retailer 4) Housewife 5) Craftman/woman 6) Retired 7) Other (Specify)_____ 8) No Response	
7	Are you educated?	1) Yes /__/ 2) Literate only 3) Illiterate	
8	What is your highest level of education?	1) Primary /__/ 2) Secondary 1 3) Secondary 2 4) University	
9	What ethnic group are you from?	1) Dendi and related /__/ 2) Bariba and related 3) Fon and related 4) Yoruba and related 5) Nago and related 6) Peulh and related 7) Other (specify)_____ 8) Don't know 9) No response	
10	What is your religion?	1) Animistic /__/ 2) Christian 3) Muslim 4) Atheistic 5) Other (spify)_____ 6) No response	

Continued

11	Seniority in the village?	/__/ 1) Before January 2018 to present 2) From January 2018 to present 3) From 2019 to present
12	What is your marital status?	1) Single /__/ 2) Maried 3) Divorced 4) Widow (wer)
13	How many children?	/__//__/
14	What is your monthly income?	1) <35,000 f CFA 2) 35,000 f to 50,000 f (CFA) 3) >50,000 f CFA
	Behavioural Factors and Lifestyle	
15	What water do you drink?	1) Runoff water /__/ 2) Backwater 3) Borehole water
16	If water from backwater or runoff, do you treat it before consumption?	1) Yes /__/ 2) No
17	If yes, how do you treat water?	1) by Aquatab /__/ 2) by boiling 3) Other (Specify)_____:
18	Do you usually suffer from the following diseases?	1) stomach ache Yes /__/ No /__/ 2) diarrhea Yes /__/ No /__/ 3) vomiting Yes /__/ No /__/
19	If drilling water, do you still suffer from these diseases?	stomach ache /__/ 1) Yes 2) No Diarrhea /__/ 1) Yes 2) No Vomiting /__/ 1) Yes 2) No Other response (Specify)_____
20	Are you still going to the hospital for these diseases since the well drilling?	1) Yes /__/ 2) No
21	If so, do you have a health record?	1) Yes /__/ 2) No

Continued

	Environmental factors	
22	How far is your house from the well drilling?	1) Less than 1 km /__/ 2) 2 km 3) More than 2 km
23	What is the waiting time at the well?	1) Less than 1 h /__/ 2) 2 h 3) 3 h 4) 4 h 5) 5 h 6) More than 5 h
24	What water do you prefer to drink?	1) Borehole water /__/ 2) Backwater
25	If Marigot water, why?	/__/ 1) Distance to reach the drilling well 2) Waiting time at the borehole
26	Where do you defecate?	1) In the bush /__/ 2) Latrines