ISSN: 2753-7919
British Journal of Healthcare and Medical Research; Vol. 13 No. 01 (2026) (232-248)
https://doi.org/10.14738/bjhr.1301.19915

Hand-Dug Well Water and Waterborne Diseases in Lubumbashi, DR Congo

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Abstract: This cross-sectional investigation was conducted in the Savio health Area, within Tabacongo Neighbourhood, a peri-urban area of Lubumbashi City in the Democratic Republic of the Congo. The researchers carried out face-to-face interviews with heads of 121 households utilizing a structured questionnaire. The study examined variables such as the use of well water, hygiene practices related to containers and hand-dug wells, and the proximity of the well from sanitation facilities in relation to the incidence of waterborne diseases. Among the participants, 56% were women; the average age was 46 years, and 42% had attained secondary education or higher. Trading emerged as the predominant occupation, accounting for 46% of respondents. The results indicated that 64% of households reported instances of diarrhoea, 62% noted cases of typhoid fever, and 19% experienced cholera. The analysis identified a relationship between well water usage and diarrhoea, typhoid fever and intestinal parasitosis, mediated through multiple factors, including the well proximity to potential sources of contamination, and user practices in handling the water. The utilization of hand-dug well water combined with inadequate cleanliness standards for both containers and wells significantly increases the risk of illness from these diseases. This research underscores the urgent need to enhance hygiene practices and improve management of water sources to reduce disease incidence. Further investigations incorporating bacteriological testing are essential for a more comprehensive understanding of contamination pathways.

Keywords: Hygiene, hand-dug wells, waterborne diseases, risk factors, peri-urban, Lubumbashi, Democratic Republic of the Congo

INTRODUCTION

The availability of safe drinking water is a significant public health issue in sub-Saharan Africa (SSA). Although advancements have been made in pursuit of Sustainable Development Goal 6, which aims to ensure clean water and sanitation for everyone, millions within the region still depend on unimproved water sources, notably hand-dug wells [1].

In the Democratic Republic of the Congo (DRC), research on hand-dug well water and waterborne diseases has emerged as a critical area of inquiry due to the widespread reliance on groundwater sources, amid inadequate sanitation infrastructure, and the high burden of waterborne illnesses. With a population exceeding 100 million, the DRC faces persistent challenges in providing safe drinking water, particularly in suburban and rural areas where hand-dug wells are common [2-3]. While these traditional sources are crucial for accessing groundwater in regions without formal infrastructure, they often act as conduits for waterborne diseases. This contamination can result from human and animal waste, substandard construction methods, and insufficient maintenance practices [4].

Hand-dug wells are manually excavated shallow groundwater sources. In contrast to boreholes, which are created using machinery, hand-dug wells possess a broader diameter and are less deep, making them more vulnerable to contamination from surface water.

On the other hand, waterborne diseases, which are illnesses caused by harmful germs found in polluted water, pose a significant problem for people living in SSA. Diarrhoeal diseases, in particular, are a major cause of illness and death, especially among children under five years old. In 2021, around 1.2 million people died from diarrheal diseases. That was equivalent to all violent deaths combined. The World Health Organization estimates that around 829,000 people die from diarrhoea each year due to unsafe drinking water, lack of sanitation facilities, and poor hygiene practices, with low-income countries being hit the hardest[5]. Although the connection between contaminated water sources and disease propagation has been extensively documented, communities with limited options continue to depend on hand-dug wells. Regional disparities in infection rates have also been reported [6-8].

Existing research reveals the role of hand-dug wells as vulnerable water sources, and the influence of environmental and behavioural factors on contamination and disease prevalence [9-12]. Understanding this connection is essential for developing effective strategies that protect public health while maintaining access to vital water resources in resource-constrained regions. Moreover, factors influencing contamination, including hygiene practices, water storage, and environmental conditions, remain underexplored in DRC [13-15]. This knowledge gap impedes the development of targeted interventions and policies, potentially perpetuating disease transmission and undermining public health efforts [16-17].

This study aims to identify the factors that facilitate the emergence of these diseases and to evaluate how dependence on water from hand-dug wells affects the prevalence of such illnesses in households located in a peri-urban area in the DRC.

MATERIALS AND METHODS

Sampling Method

To ensure the randomness of the selection process, a three-step sampling methodology was implemented to identify the households for the survey. The initial step involved the random selection of some streets from a comprehensive list encompassing all streets in the Savio Locality. In the subsequent stage, dwelling plots were randomly chosen within each street selected during the first step, following a thorough census. This selection considered the sampling fraction derived by dividing the number of surveyed plots by the allocated sample size for that particular street. It is important to note that only those dwelling plots equipped with hand-dug wells were included in this study. Finally, in the third stage, one household within each selected dwelling plot from the previous stage was randomly chosen for interviews using a mobile application.

Study Area

The study took place in September 2022 within the Savio Health Area, depicted in Figure 1, which has a total population of 26,412 individuals. This region is part of the Tabacongo

neighbourhood, located within the Kampemba Health District of the Kampemba Municipality in Lubumbashi, Democratic Republic of the Congo (DRC). Furthermore, the Tabacongo neighbourhood is in proximity to both the industrial district and the BRASIMBA brewery.

Figure 1: The map of the study area adapted from OpenStreetMap data

https://rues-rd-congo.openalfa.com/taba-congo

Data Collection Technique

The data were collected at the home of the participants by a face-to-face interview using a pre-established, structured questionnaire. The questionnaire was administered to either the household head or his/her representative who gave an oral consent to participate in the study.

Data Management

Data were entered using a standardized data structure created in *IBM SPSS* [18], cleaned, converted into csv format and then transferred to R [19] for analysis.

Variables

Information About the Household Head

Gender (male or female); Age in years, Professional occupation of the household head, Education attained which entails the last certificate obtained if any; and household size given by the number of household members.

Information About the Water Used by the Household Members

The participant was asked about the drinking water source and any method used to treat the hand-dug well water. The fieldworker assessed the bucket and rope used to retrieve water from the well and the well maintenance then noted each as clean or unclean.

Dependent Variables

Participants reported any occurrence of four waterborne infections (diarrhoea, typhoid fever, cholera and intestinal worms) in their households within the 2 weeks preceding the interview.

Data Analysis

Data were summarized by employing counts (n) and percentages (%) for categorical variables, while numerical data were represented using mean values and standard deviations (SD). The four categorical response variables were cross-tabulated with each of the influencing factors, followed by the application of a chi-square (χ^2) test for independence to assess their univariate associations. Additionally, a logistic regression model was constructed with each waterborne disease serving as the response variable. All socio-demographic factors and characteristics of hand-dug wells were included in the model to identify which variables exhibited independent association with the studied waterborne diseases. The anti-log of the estimates along with 95% confidence intervals (CI) were computed to derive the Odds Ratios (OR).

RESULTS

Socio-demographic Characteristics

A total of 121 households participated in this study. The socio-demographic and occupational profiles of the heads of these households are detailed in Table 1. A notable 56% of these households were led by females. The average age of the household heads was 46 years (SD=16), with ages spanning from 21 to 88 years. Among the participants, 42% had attained a higher level of education, specifically at least secondary education. Furthermore, 18 out of the 121 participants were classified as unemployed, housewives, or lacking formal employment. Additionally, 32 household heads, constituting 27%, reported being employed as civil servants. On average, each household comprised 5.7 members, with a standard deviation of 2.55. Household sizes varied from a single individual to as many as 12 members; interestingly, the median number of individuals per household was found to be 5.

Characteristics of Hand-dug Well and Water Handling Hygiene

Table 1 presents a summary of the attributes associated with hand-dug wells and the hygienic practices linked to water management.

- *Primary source of drinking water:* A significant proportion of households, specifically 78 (65%), obtain their drinking water from boreholes. In contrast, only 26 out of 121

households (21%) utilize water from hand-dug wells, while the remaining 17 households (14%) rely on piped or bottled water.

- *Proximity to sanitation facilities:* Slightly more than one-quarter of households, totalling 31 (26%), have constructed their wells at least six meters away from sanitation facilities, a distance that is generally considered safe from faecal contamination.
- *Household Water Treatment:* Point-of-use water treatment techniques serve as a protective measure against waterborne pathogens, even in instances where the source water is compromised. In this study, 20 participants (17%) indicated that they employed chlorination, while the majority, comprising 73 households (60%), reported boiling their water. Additionally, 28 participants (23%) utilized purification methods that included filtration.
- *Hygiene of the Water Retrieval Container and Well Maintenance:* Approximately half of the surveyed individuals used clean buckets and ropes for drawing water from the well. Furthermore, 43 participants (36%) ensured proper maintenance of their wells.

Table 1: Summary of sample characteristics

Characteristic	**N = 121**
Gender, n (%)	
Female	68 (56%)
Male	53 (44%)
Age (yrs), Mean (SD)	46 (16)
Age (yrs), n (%)	
20-29	23 (19%)
30-39	38 (31%)
40-54	33 (27%)
55+	27 (22%)
Household size, Mean (SD)	5.69 (2.53)
Household Size, n (%)	
1-4	40 (33%)
5-7	48 (40%)
8+	33 (27%)
Education attained, n (%)	
Lower	70 (58%)
Upper	51 (42%)
Occupation, n (%)	
None	18 (15%)

Independent	70 (58%)
Official	32 (27%)
Unknown	1
Drinking water source, n (%)	
Piped or Bottled	17 (14%)
Borehole water	78 (64%)
Well water	26 (21%)
Distance to toilets, n (%)	
< 6m	90 (74%)
>= 6m	31 (26%)
Water treatment, n (%)	
Chlore	20 (17%)
Boiling	73 (60%)
Purification	28 (23%)
Retrieval container, n (%)	
Unclean	60 (50%)
Clean	60 (50%)
Unknown	1
Well maintenance, n (%)	
Unclean	78 (64%)
Clean	43 (36%)

Waterborne Diseases

- *Diarrhoea:* Among the 121 household heads surveyed, 77 individuals (64%) indicated that at least one member of their household experienced an episode of diarrhoea within the two weeks preceding the interview.
- *Typhoid fever:* During the same timeframe, typhoid fever was reported in 75 households (62%).
- *Other diseases:* Additionally, a smaller number of cases were noted, with 23 households (19%) reporting instances of cholera and 26 households (19%) citing occurrences of intestinal worms.

Factors Associated to Waterborne Diseases

Diarrhoeal Disease

Table 2 presents a summary of the bivariate analysis conducted to explore the relationship between several factors and the incidence of diarrhoea within households. The analysis

identified five specific factors that were statistically associated with the occurrence of diarrhoea:

- *Occupation of the household head:* It was observed that 94% of individuals without formal employment reported experiencing diarrhoea in their household, in contrast to only 59% from other occupational categories (p=0.015).
- *Proximity to sanitation facilities:* The analysis revealed that households with hand-dug well located within 6 meters of sanitation facilities experienced a diarrhoea rate of 72%, compared to a significantly lower rate of 39% for those with toilets situated at least 6 meters away from hand-dug wells (p<0.001).
- *Source of Drinking Water:* Among households utilizing well water, 88% reported instances of diarrhoea, in contrast to 65% of those consuming piped or bottled water and 55% of households relying on borehole water (p=0.009).
- *Hygiene of Retrieval Container:* Of the households using unclean retrieval buckets, 82% experienced occurrences of diarrhoea, compared to only 45% among those employing clean buckets (p<0.001).
- *Well Maintenance:* In households with properly maintained wells, 51% reported cases of diarrhoea, while this figure rose to 71% for those with poorly maintained wells (p=0.034).

Table 2: Summary of the household characteristics by Diarrhea Occurrence

	Diarrhoea			
Characteristic	**No** N = 44	**Yes** N = 77	**Overall** N = 121	**p-value**[1]
Gender, n (%)				0.78
Female	24 (35)	44 (65)	68 (100)	
Male	20 (38)	33 (62)	53 (100)	
Age (yrs), n (%)				0.20
20-29	10 (43)	13 (57)	23 (100)	
30-39	15 (39)	23 (61)	38 (100)	
40-54	7 (21)	26 (79)	33 (100)	
55+	12 (44)	15 (56)	27 (100)	
Household Size, n (%)				0.090
1-4	11 (28)	29 (73)	40 (100)	
5-7	16 (33)	32 (67)	48 (100)	
8+	17 (52)	16 (48)	33 (100)	
Education attained, n (%)				0.83
Lower	26 (37)	44 (63)	70 (100)	
Upper	18 (35)	33 (65)	51 (100)	

Occupation, n (%)				0.015
None	1 (5.6)	17 (94)	18 (100)	
Independent	29 (41)	41 (59)	70 (100)	
Official	13 (41)	19 (59)	32 (100)	
Unknown	1	0	1	
Drinking water source, n (%)				0.009
Piped or Bottled	6 (35)	11 (65)	17 (100)	
Borehole water	35 (45)	43 (55)	78 (100)	
Well water	3 (12)	23 (88)	26 (100)	
Distance to toilets, n (%)				<0.001
< 6m	25 (28)	65 (72)	90 (100)	
>= 6m	19 (61)	12 (39)	31 (100)	
Water treatment, n (%)				0.93
Chlore	7 (35)	13 (65)	20 (100)	
Boiling	26 (36)	47 (64)	73 (100)	
Purification	11 (39)	17 (61)	28 (100)	
Retrieval container, n (%)				<0.001
Unclean	11 (18)	49 (82)	60 (100)	
Clean	33 (55)	27 (45)	60 (100)	
Unknown	0	1	1	
Well maintenance, n (%)				0.034
Unclean	23 (29)	55 (71)	78 (100)	
Clean	21 (49)	22 (51)	43 (100)	
[1]Pearson's Chi-squared test				

Given the interconnectedness of the various factors analysed, we utilized a comprehensive multivariate analysis model that encompassed all collected variables to evaluate their independent effects. Among the five identified factors, only proximity to sanitation facilities and the cleanliness of the retrieval container showed a significant correlation with the occurrence of diarrhoea in households. The results from this analysis are depicted in Figure 2.

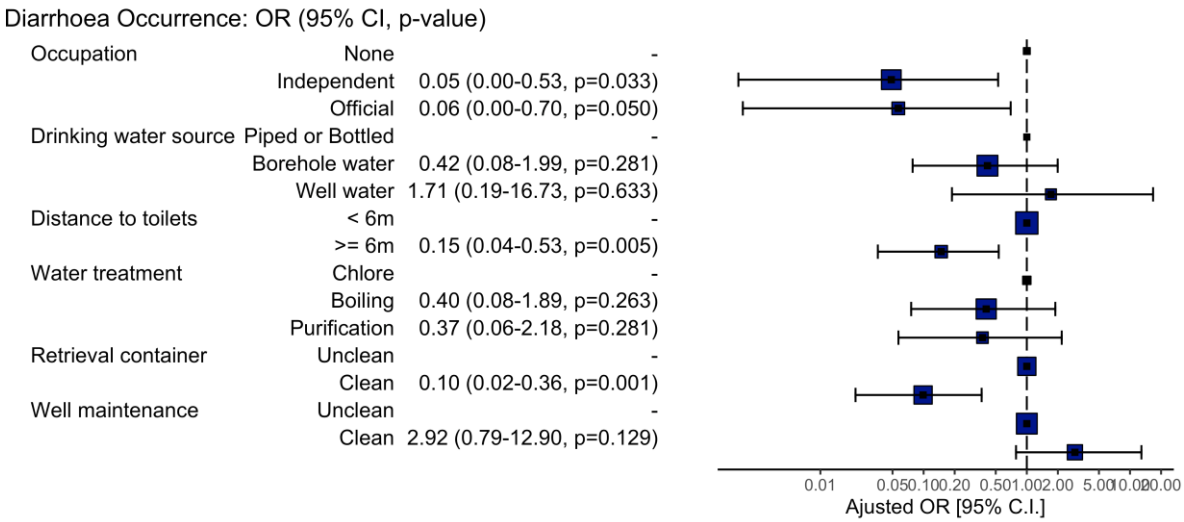

Figure 2: Factors associated to Diarrhea Occurrence

Participants whose wells were located at least 6 meters away from sanitation facilities reported significantly lower odds of experiencing diarrhoea compared to those with wells situated nearer to these facilities, with an odds ratio (OR) of 0.15 [95% C.I.: 0.04 to 0.53]. In a similar vein, households using clean retrieval containers had significantly reduced odds of experiencing diarrhoea compared to those utilizing unclean containers, with an OR of 0.10 [95% C.I.: 0.02 to 0.36].

Notably, households that employed a maintained hand-dug well exhibited odds of experiencing diarrhoea that were 2.92 times higher than those using an unmaintained well; however, this observation did not attain statistical significance.

Typhoid Fever

Similar patterns, resembling those observed in diarrheal diseases, were detected in relation to Typhoid fever, as detailed in Table 3.

- *Proximity to Sanitation Facilities:* A comparative assessment indicates that the distance from hand-dug wells to sanitation facilities—specifically toilets located within 6 meters—correlates with an increased incidence of Typhoid fever, reported at 68%. Conversely, the prevalence of Typhoid fever significantly decreases to 45% when toilets are positioned at least 6 meters away from the well ($p<0.001$).
- *Source of Drinking Water:* Among households relying on well water, 81% reported cases of Typhoid fever, compared to 71% of households using piped or bottled water and 54% of those depending on borehole water ($p=0.037$).
- *Hygiene of Retrieval Containers:* In households utilizing unclean retrieval buckets, 85% indicated occurrences of Typhoid fever, whereas only 40% of households with clean buckets reported such instances ($p<0.001$).
- *Well Maintenance:* Of the households that described their wells as clean, 33% experienced cases of Typhoid fever; this is contrasted by a staggering 78% among those with poorly maintained wells ($p<0.001$).

The multivariate logistic regression model demonstrated a significant relationship between the incidence of Typhoid fever and both the cleanliness of retrieval containers and the maintenance status of the wells. The results from this model are presented in Figure 3.

Table 3: Summary of the household characteristics by Typhoid Fever Occurrence

	Typhoid Fever			
Characteristic	**No** N = 46	**Yes** N = 75	**Overall** N = 121	**p-value**[1]
Gender, n (%)				0.96
Female	26 (38)	42 (62)	68 (100)	
Male	20 (38)	33 (62)	53 (100)	
Age (yrs), n (%)				0.38
20-29	12 (52)	11 (48)	23 (100)	
30-39	15 (39)	23 (61)	38 (100)	
40-54	10 (30)	23 (70)	33 (100)	
55+	9 (33)	18 (67)	27 (100)	
Household Size, n (%)				0.41
1-4	16 (40)	24 (60)	40 (100)	
5-7	15 (31)	33 (69)	48 (100)	
8+	15 (45)	18 (55)	33 (100)	
Education attained, n (%)				0.60
Lower	28 (40)	42 (60)	70 (100)	
Upper	18 (35)	33 (65)	51 (100)	
Occupation, n (%)				0.32
None	4 (22)	14 (78)	18 (100)	
Independent	29 (41)	41 (59)	70 (100)	
Official	12 (38)	20 (63)	32 (100)	
Unknown	1	0	1	
Drinking water source, n (%)				0.037
Piped or Bottled	5 (29)	12 (71)	17 (100)	
Borehole water	36 (46)	42 (54)	78 (100)	
Well water	5 (19)	21 (81)	26 (100)	
Distance to toilets, n (%)				0.025
< 6m	29 (32)	61 (68)	90 (100)	
>= 6m	17 (55)	14 (45)	31 (100)	

Water treatment, n (%)				0.77
Chlore	9 (45)	11 (55)	20 (100)	
Boiling	27 (37)	46 (63)	73 (100)	
Purification	10 (36)	18 (64)	28 (100)	
Retrieval container, n (%)				<0.001
Unclean	9 (15)	51 (85)	60 (100)	
Clean	36 (60)	24 (40)	60 (100)	
Unknown	1	0	1	
Well maintenance, n (%)				<0.001
Unclean	17 (22)	61 (78)	78 (100)	
Clean	29 (67)	14 (33)	43 (100)	
[1]Pearson's Chi-squared test				

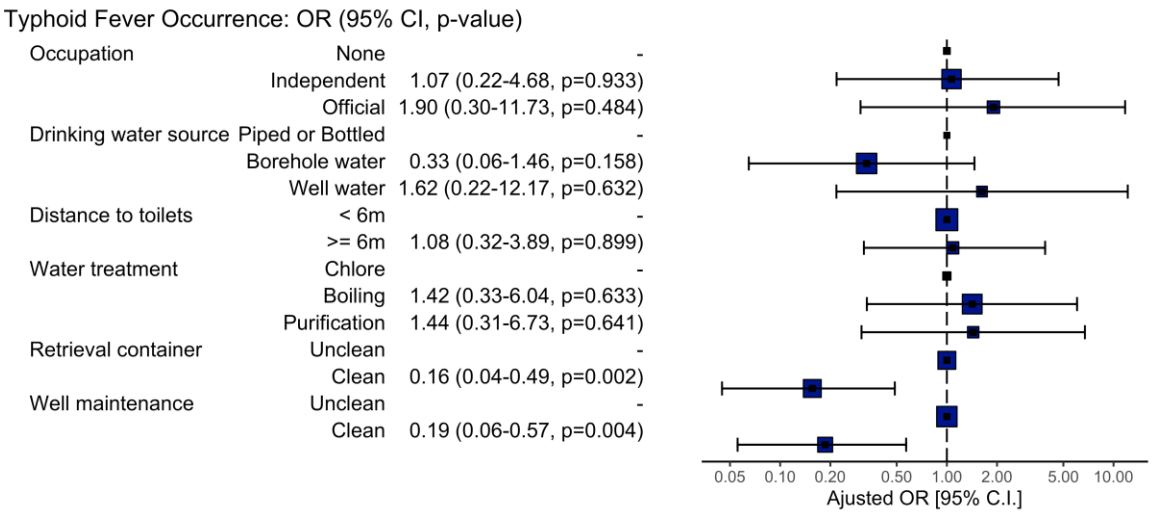

Figure 3: Factors associated to Typhoid Fever Occurrence

Cholera

Our research found no relationship between the occurrence of cholera and any household attributes or practices related to the upkeep of hand-dug wells or methods for water treatment.

Intestinal worms

- *Proximity to Sanitation Facilities:* The analysis indicates that households with hand-dug wells located within a 6-meter radius of sanitation facilities exhibit a substantial increase in the prevalence of intestinal worms, rising to 27%. In contrast, when toilets are situated at least 6 meters away from the well, the incidence of intestinal worms significantly decreases to just 6.5% ($p<0.018$). This finding emphasizes the

urgent necessity for maintaining an adequate distance between water sources and sanitation facilities to reduce health risks.

- *Source of Drinking Water:* The research revealed that 54% of households dependent on hand-dug well water reported cases of intestinal worms, whereas only 12% of those utilizing piped or bottled water and 13% of those sourcing water from boreholes experienced similar occurrences ($p<0.001$).
- *Hygiene of Retrieval Containers:* Among households using unclean retrieval buckets, 30% reported the presence of intestinal worms. In comparison, only 13% of those who kept their buckets clean encountered equivalent issues ($p<0.027$). This underscores the considerable influence that hygiene practices can have on health outcomes.

The multivariate logistic regression analysis indicated that no individual factor was found to be independently associated with the presence of intestinal worms.

DISCUSSIONS

The research revealed a significant prevalence of diarrhoea, typhoid fever, cholera, and intestinal parasitosis among households that utilize water from hand-dug wells in a peri-urban area of Lubumbashi, DRC. This observation is supported by various studies that have established a connection between the consumption of contaminated water from hand-dug wells and the heightened incidence and prevalence of waterborne diseases in SSA [6-7,20-23]. In recent decades, research conducted in the DRC has highlighted frequent occurrences of cholera, typhoid fever, and diarrhoeal diseases associated with water sources that are contaminated [24-25].

We employed self-reported health outcomes in our study. This approach is known to potentially introduce biases related to recall and reporting, which could result in the misclassification of disease status and weaken the associations observed with water and sanitation variables[7,26-29]. However, we argue that these biases are likely to have only a minimal impact on the indicators without undermining the validity and reliability of the data obtained. Self-reporting emerged as the most practical and economical method for swiftly collecting responses to the closed-ended questions presented.

In the DRC, the relationship between contamination of hand-dug well water and the incidence of waterborne diseases is shaped by various factors. These include the construction techniques employed for the wells, their proximity to potential contamination sources, and user practices regarding water handling.

The proximity of hand-dug wells to pit latrines is a critical factor influencing the risk of waterborne diseases. This observation underscores the pressing need to maintain an adequate distance between water sources and sanitation facilities to mitigate health risks. The recommended separation distance is typically between 15 to 30 meters; however, our research indicates that risks can be discerned even at a reduced threshold of 6 meters. Given that many residential areas face spatial constraints, leading to shorter distances between hand-dug wells and sanitation facilities, our findings are consistent with those of other scholars who have shown that decreased distances are associated with heightened microbial contamination [9,15,20, 30-37].

A further set of factors identified as significant in the correlation between the use of hand-dug water sources and the incidence of waterborne diseases includes behavioural determinants, such as hygiene practices and methods of water handling. These factors serve as essential mediators of both contamination and disease risk. Our research indicates that maintaining adequate cleanliness of hand-dug wells, as well as the buckets and ropes utilized for drawing water, serves to mitigate disease risk.

Our results underscore the importance of the proximity of pit latrines and inadequate sanitation practices in facilitating microbial contamination of hand-dug wells. This supports existing theories regarding faecal-oral transmission pathways associated with groundwater sources. Evidence has been found indicating that wells situated within unsafe distances from sanitation facilities are at a heightened risk for disease, thereby confirming the susceptibility of shallow groundwater to contamination from onsite sanitation systems [30-31,37].

Participants reported a relatively high incidence of cholera; however, the validity of this statistic is uncertain. This study was carried out during a period when no official cholera outbreak had been documented in the area. It is recognized that *Vibrio cholerae*, the bacterium responsible for cholera, has been detected in hand-dug wells in various investigations across SSA [38]. Current literature presents inconsistent results concerning the presence of pathogens such as *Vibrio cholerae* in well water, with some studies indicating significant levels of contamination while others show no detectable bacteria during outbreaks [25,39-40]. Cholera remains endemic in many regions within this area, with sporadic outbreaks causing substantial morbidity and mortality. Hand-dug wells may serve as both transmission vectors for cholera and reservoirs where *V. cholerae* can persist between epidemic events. However, the precise incidence of cholera reported in this research is unclear due to the lack of clinical assessments of household members or bacteriological testing of the hand-dug well water.

CONCLUSIONS

The results challenge the oversimplified perspective that enhancing water sources alone is adequate for reducing disease rates. They emphasize the importance of evaluating the quality of sanitation infrastructure, the state of clean wells, and consumer behaviours related to water usage when analysing the spread of waterborne diseases.

The reliance on hand-dug wells and insufficient hygiene practices concerning containers and wells correlate with higher instances of waterborne diseases in the studied area. The research underscores the critical need to enhance hygiene practices and manage water sources effectively to reduce disease prevalence. Additionally, further investigations that include bacteriological testing are crucial for a more thorough understanding of the contamination dynamics observed in this study.

Acknowledgments

We extend our gratitude to the participants of this study for their willingness to share essential information; the completion of this article would not have been possible without their valuable contributions.

Author Contributions

Manu F. Manun'Ebo: conceived the study, conducted the data analysis, and authored the initial draft of the manuscript.

Tsheko Manya: developed the study framework and provided a review and approval of the manuscript.

Amina Abedi: executed data collection and performed data cleaning, reviewed and approved the manuscript

Choudelle Nkulu-wa-Ngoie: managed data collection and cleaning, as well as reviewing and approving the manuscript.

Cathy Kona Mutelo: formulated the study design and reviewed and approved the manuscript.

Alex N'Kashama Bukasa: oversaw the data collection process, contributed to data analysis, and reviewed and approved the manuscript.

Conflicts of Interest

The authors state that they have no conflicts of interest to disclose.

REFERENCES

[1] Machado, A., Amorim,E. C. C., & Bordalo, A. A. (2022). Spatial and seasonal drinking water quality assessment in a sub-Saharan country (Guinea-Bissau). Water, 14(13), 1987. https://doi.org/10.3390/w14131987

[2] Kapembo, M. L., Mukeba, F. B., Mukeba, F. B., Sivalingam, P., Sivalingam, P., Mukoko, J. B., Mukoko, J. B., Bokolo, M. K., Bokolo, M. K., Mulaji, C. K., Mulaji, C. K., Mpiana, P. T., Mpiana, P. T., & Poté, J. (2022). Survey of water supply and assessment of groundwater quality in the suburban communes of Selembao and Kimbanseke, Kinshasa in Democratic Republic of the Congo. Sustainable Water Resources Management, 8 (1), . https://doi.org/10.1007/S40899-021-00592-Y

[3] Kapembo, M.L., Laffite, A., Bokolo, M.K., Mbanga, A. L., Maya-Vangua, M. M., Otamonga, J., Mulaji, C. K., Mpiana, P. T., Wildi, W., Poté, J., & Poté, J.l. Evaluation of Water Quality from Suburban Shallow Wells Under Tropical Conditions According to the Seasonal Variation, Bumbu, Kinshasa, Democratic Republic of the Congo. Expo Health 8, 487–496 (2016). https://doi.org/10.1007/s12403-016-0213-y

[4] Odeleye, F. O., & Idowu, A. O. (2015). Bacterial pathogens associated with hand-dug wells in Ibadan city, Nigeria. African Journal of Microbiology Research, 9(10), 695-701. https://doi.org/10.5897/AJMR2014.7329

[5] WHO Water and sanitation factsheet. [https://www.who.int/europe/news-room/fact-sheets/item/water-and-sanitation[Online](https://www.who.int/europe/news-room/fact-sheets/item/water-and-sanitation%5BOnline){.uri} Resource] accessed on 16/01/2026

[6] Yaya, S., Hudani, A., Udenigwe, O., Shah, V., Ekholuenetale, M., & Bishwajit, G. (2018). Improving water, sanitation and hygiene practices, and housing quality to prevent diarrhea among under-five children in nigeria.. Tropical Medicine and Infectious Disease, 3 (2), . https://doi.org/10.3390/TROPICALMED3020041

[7] Amadu, I., Seidu, A., Agyemang, K., Arthur-Holmes, F., Duku, E., Salifu, I., Bolarinwa, O. A., Hagan, J. E., & Ahinkorah, B. O. (2023). Joint effect of water and sanitation practices on childhood diarrhoea in sub-Saharan Africa. PLOS ONE, 18 (5), e0283826-e0283826. https://doi.org/10.1371/journal.pone.0283826

[8] Kemajou, D. N. (2022). Climate variability, water supply, sanitation and diarrhea among children under five in sub-Saharan Africa: A multilevel analysis.. Journal of Water and Health, 20 4 (4), 589-600. https://doi.org/10.2166/wh.2022.199

[9] Mumbumbu, A. M., Tsongo, Z. K., Shindano, E. A., Barhwamire, T. K., & Wembonyama, S. O. (2024). Environmental and chemical determinants of contamination and survival of vibrio cholerae in water sources in Bukavu in the Democratic Republic of the Congo. Health and environment, 5 (1), 246-255. https://doi.org/10.25082/he.2024.01.002

[10]Mbole, L. A., Otikeke, F. L., Zamba, C. N., & Lupiki, A. M. (2025). Déficit d'appropriation de l'assainissement et de l'hygiène dans la cité de Wanierukula en RDC. European scientific journal, 43 null, . https://doi.org/10.19044/esipreprint.7.2025.p119

[11]Mwanza, P. B., Katond, J., & Hanocq, P. (2019). Évaluation de la qualité physico-chimique et bactériologique des eaux de puits dans le quartier spontané de Luwowoshi (RD Congo). Tropiculturanull, . https://doi.org/10.25518/2295-8010.627

[12]Nathan, I. S., Lambert, I. S., Paul, L. T. J., Alice, B. M., & Sylvie, N. A. (2023). Physico-chemical and bacteriological quality of spring water in the commune of Kabondo in the city of Kisangani qualité physico-chimique et bacteriologique des eaux des sources de la commune de Kabondo dans la ville de Kisangani. JRDO-Journal of Applied Science, 9(7), 1-13.

[13]Malu, C. K. (2024). Étude des pratiques de prévention contre la recrudescence de cholera dans la zone de sante rurale/Ipamu (Province du Kwilu, République Démocratique du Congo. Journal Africain des Sciences, VOL. 1, 1 (2024) 144-155. https://doi.org/10.70237/jafrisci.2024.v1.i1.14

[14]Basandja, E. L., Mabela, G. K., Mulumba, Z. K., Kitronza, J. P. L., & Likwela, J. L. (2021). Quality of water adjusted sources and storage in the households of the sanitized villages in area of national program of sanitized schools and villages at Tshopo province in Republic Democratic of Congo. Journal of Biosciences and Medicines, 9 (6), 43-54. https://doi.org/10.4236/JBM.2021.96004

[15]Bisimwa, L., Endres, K., Williams, C. E., Thomas, E. D., Kuhl, J., Coglianese, N., Bauler, S., Masud, J., François, R., Saxton, R., Sanvura, P., Bisimwa, J., Mirindi, P., Mwishingo, A., Perin, J., & George, C. M. (2022). Diarrheal disease awareness is associated with caregiver handwashing with soap in the Democratic Republic of the Congo (reduce program). American Journal of Tropical Medicine and Hygiene, 106 (5), 1389-1394. https://doi.org/10.4269/ajtmh.21-0699

[16]Miller, J. D., Vonk, J., Staddon, C., & Young, S. L. (2020). Is household water insecurity a link between water governance and well-being? A multi-site analysis. Journal of Water Sanitation and Hygiene for Development, 10 (2), 320-334. https://doi.org/10.2166/WASHDEV.2020.165

[17]Endres, K., Mwishingo, A., Thomas, E., Boroto, R., Nyarukanyi, W. N., Bisimwa, J., Sanvura, P., Perin, J., Bengehya, J., Maheshe, G., Cikomola, C., & George, C. M. (2023). A quantitative and qualitative program evaluation of a case-area targeted intervention to reduce cholera in Eastern Democratic Republic of the Congo.. International Journal of Environmental Research and Public Health, 21 (1), . https://doi.org/10.3390/ijerph21010027

[18]IBM Corp. (2022). IBM SPSS Statistics, Version 29. Armonk, NY: IBM Corp..

[19]R Core Team (2025). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

[20]Olayinka, O. O., Adedeji, O. H., & Sanni, S. (2014). Water quality of hand-dug wells close to pit latrines: Implications for sanitation and health. IOSR Journal of Environmental Science, Toxicology and Food Technology, 8 (6), 56-64. https://doi.org/10.9790/2402-08625664

[21]Sohounou, M., Vissin, E. W., Atchade, G. A., & Edorh, P. A. (2016). Sanitation and risks of waterborne diseases in Aholouyèmè in the commune of Sèmè-kpodji (Benin, West Africa). Journal of Applied Biosciences, 100 (1), 9535-9544. https://doi.org/10.4314/JAB.V100I0.5

[22]Sm, S., E, T., Wr, G., Arienzo, A., Losito, F., Fokam, J., Jf, O., B, D., Nf, Z., Russo, G., Antonini, G., Panà, A., & Colizzi (2015). Water supply, sanitation and health risks in Douala 5 municipality, Cameroon. Igiene e sanità pubblica, 71 (1), 21-37.

[23]Usman, M. A., Gerber, N., & Braun, J. V. (2019). The impact of drinking water quality and sanitation on child health: Evidence from rural Ethiopia. Journal of Development Studies, 55 (10), 2193-2211. https://doi.org/10.1080/00220388.2018.1493193

[24]Brainard, J., D'hondt, R., Ali, E., Bergh, R. V. D., Weggheleire, A. D., Weggheleire, A. D., Baudot, Y., Patigny, F., Lambert, V., Zachariah, R., Maes, P., Kenge, D. K., & Hunter, P. R. (2018). Typhoid fever outbreak in the Democratic Republic of Congo: Case control and ecological study. PLOS Neglected Tropical Diseases, 12 (10), . https://doi.org/10.1371/JOURNAL.PNTD.0006795

[25]George, C. M., Sanvura, P., Namunesha, A., Bisimwa, J., Endres, K., Felicien, W., Williams, C., Trivedi, S., Davis, K., Perin, J., Sack, D. A., Bengehya, J., Balemba, G. M., Cikomola, C., Bisimwa, L., Leung, D. T., & Mwishingo, A. (2024). Epidemiology of vibrio cholerae infections in the households of cholera patients in the Democratic Republic of the Congo: Picha7 prospective cohort study. medRxiv 2024.12.16.24318937 https://doi.org/10.1101/2024.12.16.24318937

[26]Nayebare, J., Owor, M., Kulabako, R., Campos, L. C., Fottrell, E., & Taylor, R. G. (2020). Wash conditions in a small town in uganda: How safe are on-site facilities?. Journal of Water Sanitation and Hygiene for Development, 10 (1), 96-110. https://doi.org/10.2166/WASHDEV.2019.070

[27]Gwimbi, P., George, M., & Ramphalile, M. (2019). Bacterial contamination of drinking water sources in rural villages of mohale basin, lesotho: Exposures through neighbourhood sanitation and hygiene practices. Environmental Health and Preventive Medicine, 24 (1), 33-33. https://doi.org/10.1186/S12199-019-0790-Z

[28]Levison, M. M., Elliott, S. J., Karanja, D. M. S., Schuster-Wallace, C. J., & Harrington, D. W. (2011). You cannot prevent a disease; you only treat diseases when they occur: Knowledge, attitudes and practices to water-health in a rural Kenyan community. East African journal of public health, 8 (2), 103-111. https://doi.org/10.4314/EAJPH.V8I2

[29]Hirai, M., Roess, A. A., Huang, C., & Graham, J. P. (2016). Exploring geographic distributions of high-risk water, sanitation, and hygiene practices and their association with child diarrhea in Uganda. Global Health Action, 9 (1), 32833-32833. https://doi.org/10.3402/GHA.V9.32833

[30]Stephen, E., Kithinji, D. K., & Mungai, G. N. (2025). Impact of pit latrines on enteric-pathogen contamination of groundwater in Tigania West sub-county, Kenya. International Journal of Current Science Research and Review, 08 (09), . https://doi.org/10.47191/ijcsrr/v8-i9-03

[31]Nyabayo, C. J., Chemoiwa, E. J., Mwamburi, L., Jepkogei, R. M., & Kimutai, A. (2016). The effects of vertical and horizontal separations between pit latrine and hand dug well on contamination water by human fecal matter in Bomachoge Borabu, Kenya. International Journal of Bioassays, 5 (09), 4782-4790. https://doi.org/10.21746/IJBIO.2016.09.001

[32]Othoo, C. O., Dulo, S., Olago, D., & Ayah, R. (2020). Proximity density assessment and characterization of water and sanitation facilities in the informal settlements of Kisumu City: Implications for public health planning. Journal of UOEH, 42 (3), 237-249. https://doi.org/10.7888/JUOEH.42.237

[33]Wright, J. S., Cronin, A., Okotto-Okotto, J., Yang, H., Pedley, S., & Gundry, S. W. (2013). A spatial analysis of pit latrine density and groundwater source contamination. Environmental Monitoring and Assessment, 185 (5), 4261-4272. https://doi.org/10.1007/S10661-012-2866-8

[34]Wright, J. S., Okotto, J., Yang, H., Pedley, S., & Gundry, S. W. (2011). Understanding the inter-relationship between millennium development goal targets: A spatial analysis of pit latrine density and groundwater. In American Association of Geographers Annual Meeting, Seattle, 12-16

[35]Jeandron, A., Saidi, J. M., Kapama, A., Burhole, M., Birembano, F., Vandevelde, T., Gasparrini, A., Armstrong, B., Cairncross, S., & Ensink, J. H. J. (2015). Water supply interruptions and suspected cholera incidence: A time-series regression in the Democratic Republic of the Congo.. PLOS Medicine, 12 (10), . https://doi.org/10.1371/JOURNAL.PMED.1001893

[36]Longembe, B. E., Jean, P. A., & Joris, L. L. (2024). Effectiveness of home water treatment for the control of diarrhea in children under five years: An intervention study in a rural health zone of Tshopo in the Democratic Republic of Congo. Journal of Water Sanitation and Hygiene for Development null, . https://doi.org/10.2166/washdev.2024.243

[37]Kimani-Murage, E. W., & Ngindu, A. M. (2007). Quality of water the slum dwellers use: The case of a Kenyan slum. Journal of Urban Health-bulletin of The New York Academy of Medicine, 84 (6), 829-838. https://doi.org/10.1007/S11524-007-9199-X

[38]Ibrahim, S., Bello, A., & Guadie, A. (2025). Assessing hygiene practices and microbial risks in groundwater sources: A case study of Kumbotso, Nigeria. PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-7376778/v1]

[39]Dimandja, A. O., & Al, E. (2024). Analyses physico-chimiques et bactériologiques des eaux domestiques pendant une épidémie de choléra à Lubumbashi, République Démocratique du Congo. Revue Malienne d'infectiologie et de microbiologie, 19 (2), 40-50. https://doi.org/10.53597/remim.v19i2.2834

[40]Bisangamo, C., Mulongo, P. M., Balegamire, J. B., Kayanga, L. W., Mitima, T. K., Kabyuma, C. W., Kavuvu, M., Malekezi, C., Mulinganya, B., Babone, L., & Munyuli, M. ©. (2012). Bacteriological pollution of artesian ground water sources used by local communities living in and around Bukavu Town (Democratic Republic of Congo) as sources of potable drinking water. https://doi.org/10.4172/2157-7587.S12-001.