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Assessing the impact of water, sanitation and hygiene (WaSH) on diarrhoeal disease and malnutrition among children under 5 in Chad

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Abstract

Background: Chad has the second highest under-5 mortality rate in the world, as well as the highest rate of under-5 mortality due to diarrhoea at the time of this study.

Objective: This study assessed the relationship between household WaSH sources, diarrhoeal disease prevalence, and malnutrition among children under 5 in Chad.

Methods: The samples used in this study consisted of 5,192 and 11,842 children under 5, respectively, from the 2004 and 2014 Chad Demographic and Health Surveys. Logistic regression analysis was employed to assess the relationship between improved versus unimproved household WaSH sources and diarrhoeal and malnutrition prevalence among children under the age of five in Chad.

Results: Analysis of the overall category of improved household WaSH sources versus the overall category of unimproved WaSH sources showed no evidence for the effects of using improved WaSH sources on the prevalence of diarrhoea. However, analysis of the individual WaSH sources within each category revealed that in 2014, specific types of water sources led to increased prevalence of diarrhoea, whereas specific sanitation facilities led to decreased prevalence of diarrhoea; also, having access to improved water sources and sanitation facilities significantly reduced malnutrition prevalence.

Conclusion: A better understanding of which household WaSH sources aid in decreasing the prevalence of the disease is consequential to global health professionals who operate developmental efforts so that funding can properly be allocated to making those resources available for intervention.

Keywords: WaSH, infectious disease, children under five, malnutrition, sub-Saharan Africa

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INTRODUCTION

A high proportion of preventable morbidity and mortality throughout developing countries are attributable to poor water, sanitation, and hygiene (WaSH) conditions, and research has shown that lack of clean water and proper sanitation are causal factors of disease transmission [1]. For instance, more than 25 diseases are caused by poor and inadequate WaSH conditions, killing more than two million people each year, including more children than acquired immune deficiency syndrome (AIDS), tuberculosis, and malaria combined [2,3]. Worldwide, poor WaSH conditions are the primary reason for diarrhoeal disease, which results in morbidity and mortality among children under 5 [4-10]. Across countries, 64.2 million disability-adjusted life years (DALYs) are attributed to unsafe water and poor sanitation and hygiene practices, of which 52.5 million DALYs (82%) are in low-income countries. The burden of disease resulting from these conditions lies heavily upon sub-Saharan Africa (46% of global DALYs) [1], where there is a dearth of clean or safe water sources in many communities. Over 25% of the population of many African countries lack portable drinking water, while more than 50% lack adequate sanitation and hygiene facilities, which gives rise to the

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spread of viruses and bacteria that cause diarrhoeal disease [11]. At the time of this study, Chad was the fifth largest country in Africa and the seventh poorest country in the world, according to the United Nations Human Development Index ranks [12,13]. In addition, Chad had the second highest under-5 mortality rate in the world at approximately 123.20 deaths per 1,000 live births [13]. A 2018 study reported that the highest rate of diarrhoea mortality among children under 5 occurred in Chad (499 deaths per 100,000) [12]. In 2002, two years after the Millennium Development Goals (MDGs) were developed and published, the World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF) categorised sources of WaSH as either being improved or unimproved.

Improved water sources are those that are protected from outside contamination, particularly from faeces, via active intervention or by the nature of how the source was constructed [14]. Improved water sources include technologies such as piped household water connections, public taps, standpipes, protected dug wells, and springs or rainwater collection [15]. Unimproved water sources do not protect from outside contamination; they include non-piped supplies such as unprotected wells and springs [15,16]. Improved sanitation facilities hygienically separate human waste from human contact; they include flush/pour toilets to a confined system, improved latrines (e.g., ventilated, with slab), or composting toilets [14,15]. Unimproved sanitation facilities do not assure hygienic separation of human excreta from human contact and include on-site sanitation: pit latrines without slabs, hanging latrines, and bucket latrines [16]. As of 2010, approximately 87% of the world's population had access to improved water sources; however, 39% of the world's population did not have access to improved sanitation facilities [14,15]. Studies have shown that globally, 780 million individuals do not have access to improved drinking water, and 2.5 billion individuals do not have improved sanitation [8,17]. Lack of proper WaSH resources mainly occurs in developing countries in which more than a billion people must resort to open defecation and where, on average, handwashing with soap is practised only after 19% of toilet use [14,15,18-20].

Few researchers and program implementers have considered WaSH in terms of WHO and UNICEF's categorisation, much less examined this categorisation at the household level. It is important to closely examine WaSH sources being utilised at home and understand if improved WaSH sources actually reduce the prevalence of diarrhoea and malnutrition among children. Therefore, the purpose of this study was to assess the relationship between household WaSH sources (improved versus unimproved), diarrhoeal disease prevalence, and malnutrition prevalence among children under 5 in Chad. The following research questions were examined in this study:

- How did the use of improved versus unimproved household WaSH sources affect the prevalence of diarrhoeal disease among children under 5 in Chad in 2004 and 2014?
- What was the relationship between each improved and unimproved household WaSH source and diarrhoeal disease prevalence among children under 5 in Chad in 2004 and 2014?
- What was the relationship between improved and unimproved household WaSH sources and the prevalence of malnutrition among children under 5 in Chad in 2004 and 2014?

MATERIALS AND METHODS

The data analysed in this study were derived from both the 2004 and 2014 Chad Demographic and Health Surveys (CDHS). This cross-sectional survey was designed to provide data on population and health indicators at the state and national levels. The sampling frame for the CDHS was a list of Enumeration Areas (EAs) developed from a recent population census. The primary sampling units (PSU), known as clusters, were selected from the list of EAs. The sample survey was selected using a stratified two-stage cluster design made up of approximately 300 to 500 clusters. Details about the sampling are available elsewhere [21]. Data analysis was limited to children who lived with their mother and whose mother was a member of the surveyed household. In all, 6,085 women and girls aged 15-49 participated in the 2014 CDHS for 2004 and 17,719 for the 2014 CDHS. The sample of children under 5 was 5,192 for the 2004 survey and 11,842 for 2014. The independent variables in this study were the source of drinking water and sanitation facilities.

Multiple response options for both variables were presented in the survey. Therefore, both variables were dichotomised into improved sources (1) and non-improved sources (0) based on WHO and UNICEF's categorisation [22]. Because this study was also interested in understanding the impact of each type of water source and sanitation facility, the full range of responses for both independent variables was examined. Improved water sources included piped water into dwelling, yard or plot, public tap or standpipe, tubewell or borehole, protected dug well, protected spring and rainwater receptacles, harvested rainwater, tanker truck or cart with a small tank, and bottled or sachet water. Unimproved water sources included unprotected dug wells, unprotected springs, and surface water sources (i.e., rivers, ponds, and streams). Improved sanitation facilities included flush toilets, septic tanks, pit latrines with slabs, ventilated improved pits (VIP), and compost toilets, while unimproved facilities comprised of flush toilets not connected to a sewer, pit latrines without a slab, hanging latrine or toilet, bucket latrines, and open defecation in bush or field or no facility.

The dependent variables in this study include diarrhoeal disease and malnutrition; diarrhoeal disease was dichotomised as one if a woman reported that their children had diarrhoea in the last two weeks and 0 if the child was reported as not having diarrhoea in the last two weeks. To measure malnutrition, every child's weight (kg) and height (cm) were recorded. Weight and height are two well-linked anthropometric indicators and are traditionally used to measure malnutrition status in children [23-29]. Thus, height-for-age (HAZ), weight-for-age (WAZ), and weight-for-height (WHZ) scores were used in this study. Children in this study were classified as stunted, underweight, and wasted if their z-scores were < 2 SD from the population [23-25,30]. HAZ, WAZ, and WHZ were converted into binary variables. HAZ was converted to stunted, which was one if HAZ < -200 and 0 otherwise (but considered missing if HAZ was 70 > 600). Similarly, underweight was coded as one if WAZ is 71 < -200 (or 0 if missing) and wasted was coded as one if WHZ is 72 < -200 (or 0 if missing). For both dependent and independent variables, "I don't know", and other responses were recoded as missing. Control variables included the respondent's current age, highest educational level, sex of child, type of place of residence, and wealth quintile. All data were analysed using IBM SPSS Statistics for Windows, Version 25.0 Armonk NY: IBM Corp.

RESULTS

The mean age of the respondents was 28 ± 6.9 years for both samples. Most respondents reported having no education in both the 2004 (n = 4,023; 74.30%) and 2014 (n = 13,058; 72.40%) datasets. The biological sex of the respondents' children was almost equally distributed between males and females in both datasets. In the 2004 sample, residence type was somewhat equally divided between urban and rural, while in the 2014 dataset, rural was more represented (n = 14,250; 79.00%). For the wealth index, all categories were somewhat equally represented, except for the category of 'richest' in 2004, which was slightly more present (n = 1,975; 36.50%) than in 2014 (n = 3,114; 17.30%) (Table 1). Descriptive statistics of the dependent and independent variables for the two time periods are presented in Table 2. For the first research question, the binary logistic regression model was statistically significant in 2004 and 2014; $\chi2$ (12) = 43.162, p < 0.000 and $\chi2(12)$ = 136.701, p < 0.000, respectively (Table 3). The results showed that having access to an improved household source of drinking water did not significantly affect the odds of experiencing diarrhoeal disease in 2004 or 2014. Likewise, having access to an improved household sanitation facility did not influence the odds of experiencing diarrhoea in 2004 or 2014. As such, the improvement of household water sources and sanitation facilities had no statistically significant difference in terms of diarrhoea prevalence among children under five in Chad during both time periods.

However, some effects were found for the control variables. Mothers with primary and secondary education were significantly more likely to have a child who experienced diarrhoea compared to mothers with no education. Also, in 2014, living in a rural area decreased the odds of developing diarrhoea compared to living in an urban area. In 2004, having any level of wealth beyond the poorest significantly increased the prevalence of the diarrhoea effect, which reverted in 2014, where having any level of wealth beyond the poorest (except for the middle) significantly decreased the prevalence of diarrhoea. Finally, the odds of experiencing diarrhoea decreased with age, both in 2004 and 2014. For research question 2, the logistic regression model was statistically significant in 2004 and 2014; $\chi2$ (15) = 40.290, p < .000 and $\chi2(24)$ = 171.236, p < .000 respectively (Table 5). The effects of the source of drinking water were systematically evaluated, where piped water was used as the reference category for comparison. In 2014, several sources of water led to a significantly higher prevalence of diarrhoea when compared to piped water, notably surface water, unprotected dug wells, protected springs, tubewells, and public taps.

For the comparisons of household sanitation facilities, the reference category was flush toilets. In 2014, several types of sanitation facilities led to reduced rates of diarrhoea when compared to flush toilets. Reduced rates of diarrhoea occurred when the sanitation facility was no facility, hanging toilet, pit latrine, and pit latrine with a slab. The control variables behaved much in the same manner as in the previous analysis. Educational level was statistically significant in 2014. As before, when compared to mothers with no education, mothers with primary and secondary education had children who were significantly more likely to have experienced diarrhoea. Also, in 2014, living in a rural area decreased the chances of developing diarrhoea compared to living in an urban area. Additionally, in 2004, having any level of wealth beyond the poorest (except for the rich) significantly increased the prevalence of diarrhoea,

Table I: Descriptive Statistics of the Control Variables

	2004		2014	
	Years	SD	Years	SD
Age of respondent M/SD	28	6.9	28	6.8
Highest educational level	N	%	N	%
No education	4,023	74.30%	13,058	72.40%
Primary	1,017	18.80%	3,507	19.40%
Secondary	345	6.40%	1,410	7.80%
Higher	29	0.50%	71	0.40%
Sex of child				
Male	2,734	50.50%	9,173	50.80%
Female	2,680	49.50%	8,873	49.20%
Type of place of residence				
Urban	2,375	43.90%	3,796	21.00%
Rural	3,039	56.10%	14,250	79.00%
Wealth index				
Poorest	892	16.50%	3,449	19.10%
Poorer	836	15.40%	3,684	20.40%
Middle	731	13.50%	3,814	21.10%
Richer	980	18.10%	3,985	22.10%
Richest	1,975	36.50%	3,114	17.30%

an effect which was again reverted in 2014, where having any level of wealth beyond the poorest significantly decreased the prevalence of diarrhoea. Finally, as before, the risk of experiencing diarrhoea decreased with mothers' age, both in 2004 and 2014. For research question 3, the logistic regression model was statistically significant in 2004 $\chi2\ (12) = 45.1015$, $p < .000$ (stunted); $\chi2(12) = 59.426$, $p < 0.000$ (underweight); $\chi2(12) = 41.063$, $p < 0.000$ (wasted). The model was also statistically significant in 2014, $\chi2\ (12) = 101.048$, $p < 0.000$ (stunted); $\chi2(12) = 94.290$, $p < 0.000$ (underweight); $\chi2(12) = 93.100$, $p < 0.000$ (wasted). The results of the analysis are presented in Table 4 and Table 6. In 2014, when controlling for demographic characteristics, having access to an improved source of household drinking water significantly decreased the chances of a child being underweight, stunted, or wasted. Similarly, when controlling for demographic characteristics, having access to an improved household toilet facility significantly reduced the odds of being underweight, stunted, or wasted. Control variables behaved similarly to previous analyses with minor differences. In both samples, a mother with primary education (but not higher education) reduced the likelihood of a child being classified as wasted or underweight when compared to mothers with no education and when other variables were controlled. Being a female child significantly increased the odds of being underweight, stunted, and wasted compared to being a male child in both 2004 and 2014, although this effect was slightly less apparent in 2014.

Compared to living in an urban area, living in a rural area in 2004 significantly reduced the likelihood of being

Table 2. Weighted descriptive statistics for the dependent and independent variables

	2004		2014	
Independent Variables	N	%	N	%
Source of drinking water				
Unimproved	655	12.40%	8,113	45.00%
Improved	4,642	87.60%	9,915	55.00%
Type of toilet facility				
Unimproved	3,008	55.60%	15,899	88.50%
Improved	2,402	44.40%	2,066	11.50%
Source of drinking water				
Piped Water	1,237	26.60%	1,030	5.70%
Public tap, standpipe	0	0.00%	1,685	9.30%
Tubewell, borehole, dugwell, protected well	3,192	68.80%	7,020	38.90%
Protected spring	37	0.80%	52	0.30%
Rainwater	176	3.80%	5	0.00%
Tanker truck, cart with small tank	0	0.00%	112	0.60%
Bottled, sachet water	0	0.00%	11	0.10%
Unprotected dug well	0	0.00%	5,941	33.00%
Surface water, River, dam, lake, ponds, stream, canal, irrigation channel	0	0.00%	1,577	8.70%
Type of toilet facility				
Flush toilet, to pour, to piped sewer system, to septic tank, to pit latrine, to somewhere else	2,116	39.10%	224	1.20%
Pit latrine with slab	286	5.30%	1,842	10.30%
Composting toilet	0	0.00%	0	0.00%
Flush/pour flush not to sewer, septic tank, pit latrine	0	0.00%	0	0.00%
Pit latrine without slab, open pit	0	0.00%	2,871	16.00%
Bucket	0	0.00%	19	0.10%
Hanging toilet/hanging latrine	0	0.00%	151	0.80%
No facility/bush/field/open defecation	3,008	55.60%	12,858	71.60%
Dependent Variables				
Had diarrhoea recently				
No	3,455	74.90%	12,963	80.20%
Yes	1,156	25.10%	3,208	19.80%
Stunted				
No	851	17.50%	7,715	45.30%
Yes	4,013	82.50%	9,298	54.70%
Underweight				
No	723	14.90%	7435	43.70%
Yes	4,141	85.10%	9,578	56.30%
Wasted				
No	829	17.00%	7,561	44.40%
Yes	4,035	83.00%	9,452	55.60%

Table 3. Logistic regression predicting incidence of diarrhoea by WASH sources and controls

Variable (2004)	β	SE	Wald	*p*	*OR*	95% CI
Source of drinking water (Improved)	0.090	0.11	0.70	0.404	1.09	[0.89, 1.35]
Type of toilet facility (Improved)	0.018	0.12	0.02	0.878	1.02	[0.81, 1.28]
Highest education level (Higher)	0.288	0.65	0.20	0.658	1.33	[0.37, 4.77]
Highest education level (Secondary)	0.114	0.18	0.43	0.514	1.12	[0.80, 1.58]
Highest education level (Primary)	-0.020	0.09	0.06	0.812	0.98	[0.83, 1.16]
Sex of child (Female)	-0.057	0.07	0.76	0.383	0.95	[0.83, 1.07]
Type of place of residence (Rural)	0.248	0.13	3.73	0.053	1.28	[1.00, 1.65]
Wealth index (Richest)	0.540	0.19	8.49	0.004	1.72	[1.19, 2.47]
Wealth index (Richer)	0.362	0.13	7.92	0.005	1.44	[1.12, 1.85]
Wealth index (Middle)	0.434	0.12	13.03	0.000	1.54	[1.22, 1.96]
Wealth index (Poorer)	0.561	0.11	23.98	0.000	1.75	[1.40, 2.19]
Current age-Respondent	-0.010	0.00	4.18	0.041	0.99	[0.98, 1.00]
Variable (2014)	β	SE	Wald	*p*	*OR*	95% CI
Source of drinking water (Improved)	-0.021	0.04	0.26	0.609	0.98	[0.90,1.06]
Type of toilet facility (Improved)	-0.061	0.07	0.68	0.409	0.94	[0.81, 1.09]
Highest education level (Higher)	0.093	0.27	0.12	0.734	1.10	[0.64, 1.88]
Highest education level (Secondary)	0.349	0.07	27.14	0.000	1.42	[1.24, 1.62]
Highest education level (Primary)	0.385	0.04	76.52	0.000	1.47	[1.35, 1.60]
Sex of child (Female)	-0.04	0.04	1.10	0.294	0.96	[0.89, 1.04]
Type of place of residence (Rural)	-0.283	0.08	12.48	0.000	0.75	[0.64, 0.88]
Wealth index (Richest)	-0.413	0.10	17.18	0.000	0.66	[0.54, 0.80]
Wealth index (Richer)	-0.246	0.06	16.30	0.000	0.78	[0.69, 0.88]
Wealth index (Middle)	-0.114	0.06	3.72	0.054	0.89	[0.80, 1.00]
Wealth index (Poorer)	-0.149	0.06	6.60	0.010	0.86	[0.77, 0.97]
Current age-Respondent	-0.007	0.00	5.37	0.021	0.99	[0.99, 1.00]

Note: CI = confidence interval for odds ratio (OR). The weighted population was $N = 4,611$ in 2004; $N = 16,171$ in 2014.

Table 4. Logistic regression results of WASH sources and controls on malnutrition (stunted)

Variable (2004)	β	SE	Wald	*p*	*OR*	95% CI
Source of drinking water (Improved)	-0.221	0.12	3.37	0.067	0.80	[0.63, 1.02]
Type of toilet facility (Improved)	-0.175	0.12	2.01	0.157	0.84	[0.66, 1.07]
Highest education level (Higher)	-0.120	0.82	0.02	0.884	0.89	[0.18, 4.44]
Highest education level (Secondary)	0.261	0.22	1.44	0.230	1.30	[0.85, 1.99]
Highest education level (Primary)	-0.105	0.09	1.37	0.241	0.90	[0.76, 1.07]
Sex of child (Female)	0.208	0.07	8.40	0.004	1.23	[1.07, 1.42]
Type of place of residence (Rural)	-0.421	0.15	8.33	0.004	0.66	[0.49, 0.87]
Wealth index (Richest)	-0.217	0.20	1.17	0.280	0.81	[0.54, 1.19]
Wealth index (Richer)	-0.173	0.14	1.56	0.212	0.84	[0.64, 1.10]
Wealth index (Middle)	0.000	0.13	0.00	0.998	1.00	[0.77, 1.30]
Wealth index (Poorer)	-0.284	0.12	5.27	0.022	0.75	[0.59, 0.96]
Current age-Respondent	0.012	0.00	5.16	0.023	1.01	[1.00, 1.02]
Variable (2014)	β	SE	Wald	*p*	*OR*	95% CI
Source of drinking water (Improved)	-0.145	0.03	18.15	0.000	0.87	[0.81, 0.93]
Type of toilet facility (Improved)	-0.354	0.06	35.94	0.000	0.70	[0.63, 0.79]
Highest education level (Higher)	0.078	0.23	0.12	0.734	1.08	[0.69, 1.70]
Highest education level (Secondary)	-0.028	0.06	0.24	0.623	0.97	[0.87, 1.09]
Highest education level (Primary)	-0.039	0.04	1.12	0.291	0.96	[0.90, 1.03]
Sex of child (Female)	0.082	0.03	7.07	0.008	1.09	[1.02, 1.15]
Type of place of residence (Rural)	-0.085	0.07	1.61	0.205	0.92	[0.81, 1.05]
Wealth index (Richest)	0.070	0.08	0.75	0.387	1.07	[0.92, 1.26]
Wealth index (Richer)	0.139	0.05	7.76	0.005	1.15	[1.04, 1.27]
Wealth index (Middle)	-0.034	0.05	0.49	0.485	0.97	[0.88, 1.06]
Wealth index (Poorer)	-0.065	0.05	1.89	0.169	0.94	[0.85, 1.03]
Current age-Respondent	-0.008	0.00	13.21	0.000	0.99	[0.99, 1.00]

Note: The weighted population was $N = 4,864$ in 2004; $N = 17,013$ in 2014.

Table 5. Logistic regression results of WASH source types and controls on diarrhoea incidence

Variable (2004)	β	SE	Wald	*p*	*OR*	95% CI
Source of drinking water (Surface water)	-	-	-	-	-	-
Source of drinking water (Unprotected spring)	-	-	-	-	-	-
Source of drinking (Unprotected dug well)	-	-	-	-	-	-
Source of drinking water (Bottled, sachet water)	-	-	-	-	-	-
Source of drinking water (Tanker truck)	-	-	-	-	-	-
Source of drinking water (Rainwater)	-0.139	0.23	0.37	0.542	0.87	[0.56,1.36]
Source of drinking water (Protected spring)	-0.992	0.58	2.94	0.086	0.37	[0.12, 1.15]
Source of drinking water (Tubewell)	0.206	0.13	2.41	0.121	1.23	[0.95, 1.60]
Source of drinking water (Public tap)	-	-	-	-	-	-
Type of toilet facility (No facility)	-0.010	0.12	0.01	0.936	0.99	[0.78, 1.26]
Type of toilet facility (Hanging toilet)	-	-	-	-	-	-
Type of toilet facility (Bucket)	-	-	-	-	-	-
Type of toilet facility (Pit Latrine)	-	-	-	-	-	-
Type of toilet facility (Pit Latrine with slab)	-0.160	0.24	0.47	0.495	0.85	[0.54, 1.35]
Highest educational level (Higher)	0.398	0.66	0.36	0.546	1.49	[0.41, 5.43]
Highest educational level (Secondary)	0.120	0.18	0.42	0.497	1.13	[0.80, 1.59]
Highest educational level (Primary)	-0.050	0.09	0.32	0.570	0.95	[0.80, 1.13]
Wealth index (Richest)	0.508	0.20	6.56	0.010	1.66	[1.13, 2.45]
Wealth index (Richer)	0.276	0.15	3.57	0.059	1.32	[0.99, 1.75]
Wealth index (Middle)	0.356	0.14	6.56	0.010	1.43	[1.09, 1.87]
Wealth index (Poorer)	0.498	0.14	13.37	0.000	1.65	[1.26, 2.15]
Type of place of residence (Rural)	0.159	0.14	1.39	0.239	1.17	[0.90, 1.53]
Sex of child (Female)	-0.090	0.07	1.65	0.199	0.91	[0.80, 1.05]
Respondent's current age	-0.014	0.01	7.57	0.006	0.99	[0.98, 1.00]
Variable (2014)	β	SE	Wald	*p*	*OR*	95% CI
Source of drinking water (Surface water)	0.270	0.13	4.22	0.040	1.31	[1.01, 1.69]
Source of drinking water (Unprotected spring)	0.104	0.16	0.43	0.514	1.11	[0.81, 1.52]
Source of drinking (Unprotected dug well)	0.369	0.12	10.25	0.001	1.45	[1.15, 1.81]
Source of drinking water (Bottled, sachet water)	0.897	0.75	1.44	0.231	2.45	[0.57, 10.65]
Source of drinking water (Tanker truck)	0.476	0.25	3.55	0.059	1.61	[0.98, 2.64]
Source of drinking water (Rainwater)	0.707	1.30	0.294	0.588	2.03	[0.16, 26.08]
Source of drinking water (Protected spring)	1.021	0.35	8.30	0.004	2.78	[1.39, 5.56]
Source of drinking water (Tubewell)	0.319	0.11	8.36	0.004	1.38	[1.11, 1.71]
Source of drinking water (Public tap)	0.276	0.12	5.67	0.017	1.32	[1.05, 1.66]
Type of toilet facility (No facility)	-0.623	0.17	12.95	0.000	0.54	[0.38, 0.75]
Type of toilet facility (Hanging toilet)	-0.533	0.26	4.31	0.038	0.59	[0.36, 0.97]
Type of toilet facility (Bucket)	-0.721	0.77	0.89	0.347	0.49	[0.11, 2.18]
Type of toilet facility (Pit Latrine)	-0.573	0.17	11.13	0.001	0.56	[0.40, 0.79]
Type of toilet facility (Pit Latrine with slab)	-0.683	0.17	16.11	0.000	0.51	[0.36, 0.71]
Highest educational level (Higher)	0.055	0.28	0.04	0.844	1.06	[0.61, 1.82]
Highest educational level (Secondary)	0.342	0.07	25.66	0.000	1.41	[1.23, 1.61]
Highest educational level (Primary)	0.372	0.04	70.20	0.000	1.45	[1.33, 1.58]
Wealth index (Richest)	-0.406	0.10	15.69	0.000	0.67	[0.55, 0.81]
Wealth index (Richer)	-0.261	0.06	17.86	0.000	0.77	[0.68, 0.87]
Wealth index (Middle)	-0.118	0.06	3.94	0.047	0.89	[0.79, 1.00]
Wealth index (Poorer)	-0.157	0.06	7.27	0.007	0.86	[0.76, 0.96]
Type of place of residence (Rural)	-0.295	0.08	13.09	0.000	0.75	[0.64, 0.87]
Sex of child (Female)	-0.039	0.04	1.04	0.308	0.96	[0.89, 1.04]
Respondent's current age	-0.007	0.00	5.68	0.017	0.99	[0.98, 1.00]

Note: "-" denotes response categories which were absent in the 2004 dataset. The weighted population was N = 4,611 in 2004; N = 16,171 in 2014.

Table 6. Logistic regression results of WASH sources and controls on malnutrition (underweight and wasted)

Underweight						
Variable (2004)	β	SE	Wald	*p*	*OR*	95% CI
Source of drinking water (Improved)	-0.239	0.13	3.44	0.064	0.79	[0.61, 1.01]
Type of toilet facility (Improved)	-0.182	0.13	2.03	0.154	0.83	[0.65, 1.07]
Highest education level (Higher)	-0.366	0.82	0.20	0.657	0.69	[0.14, 3.48]
Highest education level (Secondary)	0.405	0.25	2.73	0.098	1.50	[0.927, 2.425]
Highest education level (Primary)	-0.170	0.09	3.28	0.070	0.84	[0.702, 1.014]
Sex of child (Female)	0.242	0.08	10.07	0.002	1.27	[1.097, 1.478]
Type of place of residence (Rural)	-0.496	0.15	10.31	0.001	0.61	[0.450, 0.824]
Wealth index (Richest)	-0.242	0.21	1.32	0.251	0.79	[0.519, 1.187]
Wealth index (Richer)	-0.297	0.15	4.13	0.042	0.74	[0.558, 0.990]
Wealth index (Middle)	0.028	0.14	0.04	0.847	1.03	[0.776, 1.362]
Wealth index (Poorer)	-0.255	0.13	3.68	0.055	0.78	[0.598, 1.006]
Current age-Respondent	0.013	0.01	5.15	0.023	1.01	[1.002, 1.024]
Variable (2014)	β	SE	Wald	*p*	*OR*	95% CI
Source of drinking water (Improved)	-0.142	0.03	17.44	0.000	0.87	[0.81, 0.93]
Type of toilet facility (Improved)	-0.312	0.06	27.84	0.000	0.73	[0.65, 0.82]
Highest education level (Higher)	-0.030	0.23	0.02	0.896	0.97	[0.62, 1.53]
Highest education level (Secondary)	-0.015	0.06	0.07	0.788	0.99	[0.88, 1.10]
Highest education level (Primary)	-0.075	0.04	4.14	0.042	0.93	[0.86, 1.00]
Sex of child (Female)	0.088	0.03	8.12	0.004	1.09	[0.82, 1.06]
Type of place of residence (Rural)	-0.071	0.07	1.11	0.292	0.93	[0.91, 1.26]
Wealth index (Richest)	0.069	0.08	0.71	0.400	1.07	[1.00, 1.22]
Wealth index (Richer)	0.098	0.05	3.86	0.050	1.10	[0.85, 1.03]
Wealth index (Middle)	-0.067	0.05	1.88	0.171	0.94	[0.84, 1.01]
Wealth index (Poorer)	-0.082	0.05	2.91	0.088	0.92	[1.03, 1.16]
Current age-Respondent	-0.009	0.00	17.09	0.000	0.99	[0.99, 1.00]
Wasted						
Variable (2004)	β	SE	Wald	*p*	*OR*	95% CI
Source of drinking water (Improved)	-0.064	0.12	0.29	0.587	0.94	[0.75, 1.18]
Type of toilet facility (Improved)	-0.140	0.12	1.30	0.254	0.87	[0.68, 1.11]
Highest education level (Higher)	-0.188	0.82	0.05	0.819	0.83	[0.17, 4.15]
Highest education level (Secondary)	0.275	0.22	1.52	0.218	1.32	[0.85, 2.04]
Highest education level (Primary)	-0.199	0.09	4.97	0.026	0.82	[0.69, 0.98]
Sex of child (Female)	0.189	0.07	6.87	0.009	1.21	[1.05, 1.39]
Type of place of residence (Rural)	-0.336	0.15	5.33	0.021	0.72	[0.54, 0.95]
Wealth index (Richest)	-0.139	0.20	0.48	0.490	0.87	[0.59, 1.29]
Wealth index (Richer)	-0.248	0.14	3.23	0.072	0.78	[0.60, 1.02]
Wealth index (Middle)	0.057	0.13	0.18	0.673	1.06	[0.81, 1.38]
Wealth index (Poorer)	-0.259	0.12	4.38	0.036	0.77	[0.61, 0.98]
Current age-Respondent	0.006	0.00	1.14	0.285	1.01	[1.00, 1.02]
Variable (2014)	β	SE	Wald	*p*	*OR*	95% CI
Source of drinking water (Improved)	-0.152	0.03	19.85	0.000	0.86	[0.80, 0.92]
Type of toilet facility (Improved)	-0.310	0.06	27.50	0.000	0.73	[0.65, 0.82]
Highest education level (Higher)	0.003	0.23	0.00	0.988	1.03	[0.64, 1.58]
Highest education level (Secondary)	-0.025	0.06	0.19	0.661	0.98	[0.87, 1.09]
Highest education level (Primary)	-0.073	0.04	3.97	0.046	0.93	[0.87, 1.00]
Sex of child (Female)	0.086	0.03	7.84	0.005	1.09	[1.01, 1.16]
Type of place of residence (Rural)	-0.105	0.07	2.47	0.117	0.90	[0.79, 1.03]
Wealth index (Richest)	0.054	0.08	0.45	0.504	1.06	[0.90, 1.24]
Wealth index (Richer)	0.097	0.05	3.77	0.052	1.10	[1.00, 1.22]
Wealth index (Middle)	-0.061	0.05	1.57	0.211	0.94	[0.86, 1.04]
Wealth index (Poorer)	-0.088	0.05	3.39	0.066	0.92	[0.83, 1.01]
Current age-Respondent	-0.009	0.00	14.59	0.000	0.99	[0.99, 1.00]

underweight (β = -0.496, $p < 0.001$, OR = 0.609 [0.450, 0.824]), stunted (β = -0.421, $p < 0.01$, OR = 0.656 [0.493, 0.874]), and wasted (β = -0.336, $p < 0.05$, OR = 0.715 [0.538, 0.951]), with no corresponding effect in 2014. Wealth and age behaved in the same way as reported for the previous research questions, with age associated with increased malnutrition rates in 2004 and lower in 2014, whereas wealth was associated with lower malnutrition rates in 2004 and higher malnutrition rates in 2014.

DISCUSSION

This study found no evidence for the effects of the usage of improved household water sources and sanitation facilities on the prevalence of diarrhoea among children under 5 in Chad, both in 2004 and 2014. When examining the relationship between each type of improved and unimproved household WaSH sources and diarrhoea prevalence, this study also found no effects in 2004. However, it was determined that in 2014, specific types of water sources led to an increased prevalence of diarrhoea, whereas specific sanitation facility types led to a decreased prevalence of diarrhoea among children under 5 in Chad. Regarding the relationship between improved and unimproved household WaSH sources and the prevalence of malnutrition among children under 5 in Chad, no relationship was identified in the 2004 sample. However, in the 2014 sample, this study determined that having access to improved water sources and sanitation facilities significantly reduced the prevalence of malnutrition by reducing the odds of being classified as stunted, underweight, and wasted.

The results of this study indicate that in 2014, more Chadians reported improved rather than unimproved household drinking water sources compared to Chadians in 2004. This study also found that when controlling for demographic variables, having access to an improved household source of drinking water did not significantly affect the odds of a child experiencing diarrhoeal disease in 2004 or 2014. Likewise, when controlling for demographic variables, having access to an improved household sanitation facility did not decrease the odds of a child experiencing diarrhoea in 2004 or 2014. In addition, when controlling for demographic variables, having an improved household water source or an improved household sanitation facility did not solely contribute to a lower prevalence of diarrhoea or malnutrition in 2004 or 2014. Conversely, the types of reported household sanitation sources in Chadian homes worsened in 2014 compared to 2004. Given the increased number of rural households compared to urban households over the 10-year period, this finding was expected because unimproved types of WaSH structures are typically associated with rural areas. An unexpected finding from this study was that living in a rural area in 2014 decreased the chances of a child having diarrhoeal disease compared to living in an urban area in the same year. This is surprising because household WaSH conditions were demonstrated to be worse in rural areas than in urban areas. This finding may reflect the deteriorating infrastructure in Chad. This study also found that reported diarrhoeal disease and all three levels of malnutrition (stunted, underweight, and wasted) decreased from 2004 to 2014. Compared to flush toilets, reduced rates of diarrhoea occurred when the type of sanitation facility was no facility, hanging toilet, and pit latrine. This finding was surprising given that these facilities are unimproved. Additionally, having any level of wealth beyond the poorest significantly increased the prevalence of diarrhoea in 2004. Therefore, children from the poorest families had a lower prevalence of diarrhoea compared to children from wealthier families. These observations may be endogenous effects (i.e., higher rates of diarrhoea might not necessarily be due to flush toilets or wealthier households but to another common denominator shared by those who are wealthier or have a flush toilet). For instance, this finding may be linked to the increase in health education about sanitation in rural or poorer communities, which are the areas mainly targeted for WaSH interventions [31].

Unlike in 2004, in 2014, Chadians who had any level of wealth beyond the poorest (except for the middle) significantly decreased the prevalence of diarrhoea. This finding is expected given that children who have access to higher levels of wealth are more likely to have exposure to education, more likely to go to school and learn about sanitary practices, live in areas with improved water sources and toilet facilities, and reside in households where the mother is able to afford soap for hand washing. In 2014, several sources of water led to a significantly higher prevalence of diarrhoea, notably surface water, unprotected dug wells, protected springs, tubewells, and public taps. This finding was expected because these sources are unimproved. However, because these particular sources of water are more prevalent in rural areas than in urban areas, more people resided in rural areas in 2014, and MDG-related WaSH efforts, the increased prevalence of diarrhoeal disease among children living in urban areas in 2014 was unexpected. More unimproved water sources were expected in the rural areas, which are traditionally less modernised in their infrastructure compared to urban areas [31-33]. Well-designed and conducted randomised trials regarding WaSH and clinical treatments for diarrhoeal disease (e.g., oral rehydration salts [ORS] and zinc supplements) could shed light on the unexpected results. Unfortunately, due to the country's history of war and socio-political strife [35–40], conducting these trials is not always possible; therefore, researchers must rely on observational analyses to fill such gaps.

This study also revealed that the Chadian population experienced a major population shift from urban areas to rural areas over the ten years included in the study. This population shift may be attributed to the country's volatility, civil unrest, and misuse of funds by Chad's government. Despite a tumultuous history [35-40], Chad's recent leaders have seemingly supported national and international global policies and programs to improve

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WaSH conditions and the nutritional status of children. At the national level, Chadian leaders adopted a National Inter-sectoral Plan for Nutrition and Food (2017 - 2021), a National Policy for Nutrition and Food (2014 - 2025), and a national vision plan called Vision 2030, The Chad We Want [29,30]. Study findings should be interpreted in light of some limitations. This research used secondary data, so the researcher did not directly collect data that may have provided additional input for analyses. Additionally, the data was collected in a multi-stage sampling protocol with cross-sectional samples. The present study could have been strengthened with longitudinal data to examine how participants' household WaSH sources, health behaviours, and health outcomes may have changed over time. Another limitation is that DHS respondents were limited to women and girls aged 15 - 49 years; therefore, data collection regarding children under the care of women aged 50 years and older was not collected. Finally, research findings are not generalisable to all of sub-Saharan Africa.

Nevertheless, this study also had some strengths. Data was used from the same country within a 10-year time span during which the MDGs were being implemented. In comparison to the extant literature, this study is better equipped to support relationships between WaSH interventions and diarrhoeal disease and malnutrition among children under five. Moreover, this study makes a unique contribution to the body of knowledge as no other study has examined the relationship between the distinct household WaSH sources and health outcomes with DHS data. Finally, this study closely examined the widely accepted pre-existing categorisation of the purported improved and unimproved household WaSH sources to learn if improved sources actually result in better health outcomes. The findings from this study are useful for practice and policy because they support the need for a multi-pronged approach to improving WaSH. A multi-pronged approach calls for several actions, including designing water sources and sanitation facilities that are proven effective in mitigating disease spread, ensuring access to improved household WaSH sources and facilities, health education and promotion, provision of supplies (e.g., soap, water containers), and water treatment to support the use of improved sources, implementation of health behaviour change (e.g., regular handwashing, use of safe water, proper water storage, and safe disposal of faeces); and implementation of effective policies that prioritise the improvement of WaSH. Multi-pronged interventions should emphasise health education so that children and households also have the knowledge to understand the importance of key health behaviours like regular hand washing with soap, particularly before eating and after using toilet facilities.

Finally, unlike existing studies [4-7,9,15,20-23,27,33,34], this study delved beyond the mere classification of improved or unimproved and deliberately investigated access within the various types of improved and unimproved WaSH sources.

Conclusion

The results of this study indicate that the use of improved versus unimproved household WaSH sources did not affect diarrhoeal prevalence among children under 5 in Chad. Additionally, diarrhoea and malnutrition decreased over the 10-year period covered in this study. Prior studies have found that improved WaSH sources are effective but not the only factor in improving outcomes, and they do not work in isolation when it comes to diarrhoeal occurrences and malnutrition. Rather, other factors such as health education and effective policies work in tandem with all elements of WaSH, including the amount of clean water when used for washing, cooking, and drinking. Specific household sanitation facilities were found to decrease the prevalence of diarrhoeal disease among children under 5. The types of household sanitation facilities associated with decreased diarrhoeal disease included no facility, hanging toilet, pit latrine, and pit latrine with the slab.

While most of the household sanitation facilities associated with decreased diarrheal disease compared to 'flush toilet' were unimproved, it is important to underscore that the use of flush toilets allows people to properly dispose of waste, ultimately preventing contamination of their environment and diminishing risk to themselves and others. A better understanding of which household sanitation facilities aid in decreasing diarrhoeal disease prevalence is of particular importance to global health professionals who operate developmental efforts with strict budgets requiring prioritisation. With findings from this study, future global health policy and practice in Chad should focus on bridging gaps in the provision of sanitation facilities that are proven to contribute to decreasing the prevalence of diarrhoeal disease and malnutrition among children.

DECLARATIONS

Ethical consideration

The Institutional Review Board (IRB) on Human Subjects at Texas Woman's University, Denton, Texas, approved this research. Additionally, procedures and questionnaires for standard DHS surveys have been reviewed and approved by ICF IRB.

Consent to publish

Not applicable.

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Competing Interest

Not applicable

Author contributions

Not applicable

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Availability of data

The data used in this study are publicly available on the DHS website (https://www.dhsprogram).

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