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Cumulative effects of environmental factors on household childhood diarrhoea in Ghana

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Abstract

Many children under five years still die from diarrhoeal diseases globally even though much progress has been made. The threat to public health posed by diarrhoeal diseases warrants the need to understand the interaction of the disease determinants from a spatio-temporal perspective to inform policy and intervention design. In this study, a pooled regression analysis was carried out using the Ghana Demographic and Health Survey data on 15,808 children under five years, to assess the combined effect of environmental factors on childhood diarrhoea prevalence and morbidity over a 21-year period. Childhood diarrhoea prevalence declined steadily from 20% to 16% from 1993 to 2003 but increased to 20% in 2008 and finally decreased significantly to 12% in 2014. The strength of the association between diarrhoea prevalence and each of the predictors presented in decreasing order of magnitude were as follows: current age of child, geographical region, religion, mother's highest educational level, ethnicity, source of drinking water and toilet facility, residential wellbeing, birth order, age of mother, and sex of child. Regional and temporal heterogeneities in prevalence, rate and distribution of diarrhoea were observed, indicating the need for context-specific interventions and policies.

Key words: childhood, diarrhoea, environment, Ghana, interaction, morbidity

Highlights

- Steady progress has been made towards reducing childhood diarrhoea prevalence in Ghana between 1993 and 2014.
- Children in urban poor households are the most vulnerable to diarrhoea.
- There is spatio-temporal heterogeneity in childhood diarrhoea prevalence in Ghana.

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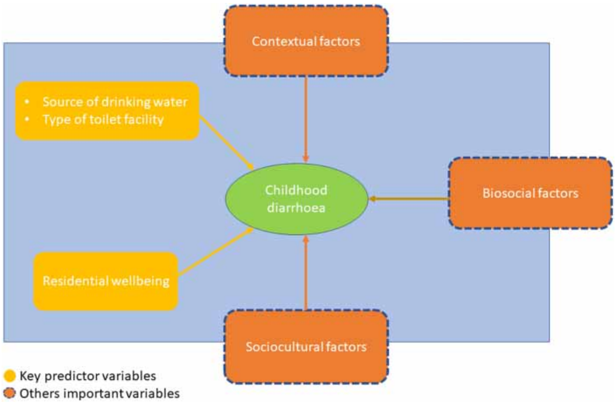
Graphical Abstract



INTRODUCTION

Since 1990, considerable progress has been made in reducing child mortality worldwide, yet about 525,000 children under the age of five die annually from diarrhoea mainly in developing countries (World Health Organization & UNICEF 2017). Contaminated water and unimproved toilet facilities have been associated with diarrhoea prevalence (Acharya *et al.* 2018; Wolf *et al.* 2018). The Joint Monitoring Programme for Water Supply and Sanitation 2015 report estimates that globally, about 663 million people live without improved drinking water sources and 2.4 billion people have no access to improved sanitation facilities (WHO & UNICEF 2017). In 2000, about 1.3 million children in developing countries were estimated to have died from diarrhoeal diseases as a result of contaminated food and water sources, poor sanitation and hygiene (WHO 2002).

In developing countries, children under five years of age experience on average three episodes of diarrhoea every year (Bandyopadhyay *et al.* 2012; Mengistie *et al.* 2013; Mihrete *et al.* 2014). In spite of the progress made in health, water and sanitation, sub-Saharan Africa continue to record high levels of childhood mortality with diarrhoea as one of the leading causes (Boadi & Kuitunen 2005; Beyene *et al.* 2018). Besides mortality, childhood diarrhoea has long-term effects on children's growth impairment (Null *et al.* 2018; Troeger *et al.* 2018). This compelled most developing countries to put in place policy interventions and research to understand the etiology of the disease (Platts-Mills *et al.* 2018). Several studies have reported that diarrhoea prevalence is linked to a heterogeneity of environmental factors in households, particularly drinking water sources and toilet facilities (Mokomane *et al.* 2018; Wolf *et al.* 2018), household behavioral practices, place of residence, socio-economic factors and housing conditions of households (Boadi & Kuitunen 2005; Osumanu 2007; Bandyopadhyay *et al.* 2012; Kumi-Kyereme & Amo-Adjei 2016).

In Ghana, it is estimated that about 14,000 children under five years die annually from diarrhoea (Asamoah *et al.* 2016). Studies have reported a positive association between childhood diarrhoea prevalence and access to improved drinking water sources as well as toilet facilities (Gyimah 2003; Boadi & Kuitunen 2005; Kumi-Kyereme & Amo-Adjei 2016). Though these studies brought to bear the importance of environmental factors in childhood diarrhoea prevalence, the combined effect of drinking water source and type of toilet facility, taking into consideration residential well-being, has not been explored. In addition, little is known about the spatio-temporal nuances of childhood diarhoea prevalence in Ghana. A comprehensive study that assesses the contribution of environmental, compositional and contextual factors to diarrhoea prevalence among children in Ghana is necessary to reveal commonalities at the national and sub-national scales in order to inform policy and intervention design. The present study assessed the combined effect of source of drinking

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water and type of toilet facility and residential wellbeing on childhood diarrhoea morbidity prevalence over a 21-year period in Ghana while accounting for relevant compositional and contextual factors. The major research questions addressed in this study include: general trend of childhood diarrhoea morbidity among children under five years in Ghana between 1993 and 2014; the cumulative effect of source of drinking water and toilet facility and residential wellbeing on childhood diarrhoea prevalence; and the order of magnitude of compositional and contextual factors' influence on childhood diarrhoea prevalence.

METHODS

Source of data

Data for this study were drawn from the Ghana Demographic and Health Surveys (GDHS), which are nationally representative population-based morbidity data covering a 21-year period (1993–2014) for five different surveys (1993/1994, 1998/1999, 2003, 2008, and 2014). The GDHS is a cross-sectional study conducted by ICF International in collaboration with Ghana Statistical Service (GSS), the Ghana Health Service (GHS), and the National Public Health Reference Laboratory (NPHRL). The GDHS provide data for monitoring and impact evaluation indicators in the areas of population, health, and nutrition. DHS data on diarhoea is limited to children under five years as they are known to be most likely to experience diarrhoea (Bandyopadhyay *et al.* 2012). The GDHS collected demographic, birth history, household and health information from a representative sample of 15,808 children from 16,944 women between the five survey periods such that maternal and household characteristics inform us about current existing conditions.

Definitions of improved and unimproved drinking water sources and type of toilet facilities

This study adopted the WHO/UNICEF Joint Monitoring Programme (JMP) (2017), definitions for improved and unimproved drinking water source and type of toilet facilities (see Table 1). The WHO/UNICEF JMP 2017 report established new criteria in categorizing drinking water sources and type of toilet facility into 'improved' and 'unimproved' (Armah *et al.* 2018).

For drinking water, improved sources are those that deliver safe water by the nature of their design and construction. An improved source should meet these three main criteria: accessibility on premises, availability when needed and not being polluted by contaminants. With respect to type of toilet facility, improved facilities are facilities that hygienically separate excreta from human contact. Three main criteria were taken into account in defining a safe and improved toilet facility: (i) treated and disposed of *in situ*; (ii) stored temporarily and then emptied, transported and treated off-site; (iii) transported through a sewer with wastewater and then treated off-site.

MEASURES

Response variable

The response/outcome variable was childhood diarrhoea prevalence, which was based on mothers' response ('yes' or 'no') to the question on whether a particular child had experienced diarrhoea within two weeks before the survey. In this context, a child is defined as having diarrhoea if he or she consistently passes watery stools at least three times per day. The response was restricted to the two week period of the survey to avoid recall bias and ensure the validity of the measure of diarrhoea prevalence. The outcome variable which had three observations (yes, last one week, yes, last

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Table 1 | Classification of improved and unimproved facilities under WHO/UNICEF joint water supply and sanitation monitoring programme, (2017)

Service	Improved	Unimproved
Drinking water sources	Piped water, boreholes or tubewells, protected dug wells, protected springs, rainwater, and packaged or delivered water.	Unprotected dug well, unprotected spring, river, dam, lake, pond, stream, canal and irrigation canal
Type of toilet facilities	Flush/pour flush to piped sewer systems, septic tanks or pit latrines; ventilated improved pit latrines, composting toilets or pit latrines with slabs.	Pit latrines without a slab or platform, hanging latrines or bucket latrines and open defecation.

two weeks and no) was then represented as a dichotomous variable where all yes responses (yes, last one week and yes, last two weeks) were combined and recoded as '1' representing 'yes'. The 'no' responses were recoded as '0'.

Key predictor variable

The choice of the key predictor variables was informed by literature review, parsimony, theoretical relevance and practical significance. The main independent variables were a combined variable of household source of drinking water and type of toilet facility and residential wellbeing (a combined variable of place of residence and wealth index). Observations under the variables; source of drinking water and type of toilet facility, were categorized into 'improved' and 'unimproved' based on WHO/UNICEF JMP 2017 report. Observations under improved were recoded as '1' and unimproved as '0'. These variables were combined to produce the predictor variable 'source of drinking water and toilet facility' with four mutually exclusive observations, unimproved unimproved (households with unimproved source of drinking water and unimproved type of toilet facility), unimproved improved (households with unimproved source of drinking water and improved type of toilet facility), improved unimproved (households with improved source of drinking water and unimproved type of toilet facility), and improved improved (households with improved source of drinking water and improved type of toilet facility). Figure 1 illustrates source of drinking water and toilet facility and the prevalence of childhood diarrhoea.

Residential wellbeing was generated from place of residence (rural and urban) and wealth index. DHS groups households into five wealth quintiles (richer, rich, middle, poor, and poorer). For parsimony, observations under richer were combined with those under rich and recoded as 'rich', and observations under poorer and poor were combined and recoded as 'poor' The wealth index is a

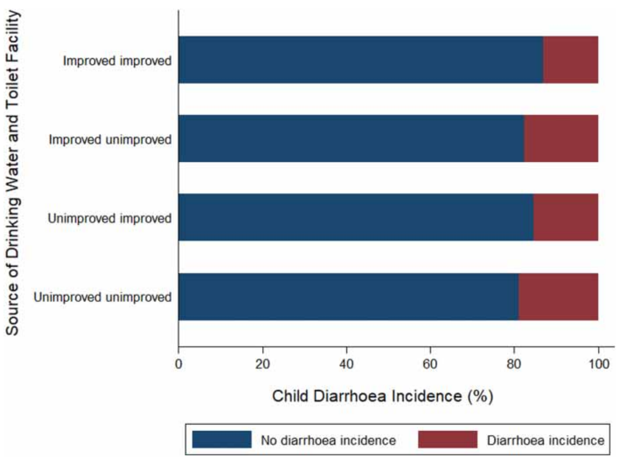

Figure 1 | Source of drinking water and toilet facility and the prevalence of childhood diarrhoea.

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measure of a household's cumulative living standard and was calculated from data collected on ownership of durable assets, housing characteristics and access to services (Howe *et al.* 2009). Indicator weights were then assigned using the Principal components analysis (PCA). The wealth index places individual households on a continuous scale of relative wealth (Armah *et al.* 2018). (Figure 2).

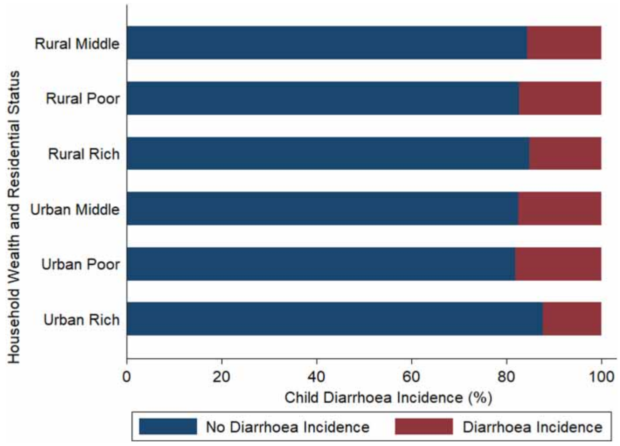

Figure 2 | Household wealth and residential status and the prevalence of childhood diarrhoea.

After combining place of residence and wealth index to form residential wellbeing variable, six groups were obtained; urban poor (poor households in urban areas), rural poor (poor households in rural areas), urban middle (middle quintile households in urban areas), rural middle (middle quintile households in rural areas), urban rich (rich households in urban areas), and rural rich (rich households in rural areas).

Compositional and contextual factors

Compositional and contextual factors have often been shown to be associated with childhood diarrhoea prevalence (Bauza *et al.* 2018; Luby *et al.* 2018; Null *et al.* 2018). Compositional factors are socio-demographic characteristics of individuals (Collins *et al.* 2017). They are subdivided into biosocial and socio-cultural factors. Biosocial factors refer to the underlying biological or physical characteristics present at birth and remain unchangeable (Pol & Thomas 2000). Socio-cultural factors generally comprise beliefs, lifestyles, customs, and values. The compositional factors included age of mother in years (15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49), ethnic group (Akan, Ga/Dangme, Ewe, Guan, Mole-Dagbani, Grussi, Gruma), gender of child (male, female), current age of child (0, 1, 2, 3, 4), Highest educational level of mother (no education, primary, secondary, higher), religion (no religion, Christian, Muslim, Traditional), birth order number (1, 2–3, 4–5, 6 and above).

Contextual factors are physical and social opportunities present in a defined geographical space or period of time such as availability of and access to services (Collins *et al.* 2017). The contextual factors considered in the study are geographical region (Western, Central, Greater Accra, Volta, Eastern, Ashanti, Brong Ahafo, Northern, Upper East, and Upper West) and year (1993/1994, 1998/1999, 2003, 2008, and 2014).

Data analysis

All statistical analyses were carried out using STATA 13 MP (StataCorp, College Station, TX, USA). Descriptive analyses were performed to describe the status and trend of childhood diarhoea prevalence in Ghana over the 21-year period. Inferential and multivariate analyses were carried out to

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assess associations between childhood diarhoea prevalence and the key predictor while controlling for the compositional and contextual factors.

Univariate analysis

Univariate analysis of the predictors of childhood diarrhoea prevalence was operationalized via Pearson's Chi-square and Cramer's V statistics. Pearson chi-square statistics was used to assess associations between the outcome variables and the predictors whilst Cramer's V statistics was used to estimate the strength of the associations.

Multiple regression

A negative log-log regression model was fitted to the data at the multivariate level and outputs reported as exponentiated coefficients or odds ratios (OR) where an OR equal to 1 means that the predictor does not affect odds of diarrhoea prevalence. OR greater than 1 indicates the predicator has higher odds of childhood diarrhoea prevalence and OR less than 1 means the predictor has lower odds of childhood diarrhoea prevalence. In modelling asymmetrical binary outcomes with proportion of the 'no' responses far greater than the 'yes' responses, negative log-log regression model is preferred (Fahrmeir & Tutz 2013).

The regression models built in this study were under the assumption of independence of subjects, but the cross sectional survey of respondents has a hierarchical structure with respondents nested in clusters, this however could potentially bias the standard errors (Armah *et al.* 2019). Clustering of observations was therefore accounted for by using robust estimates of variance including any other statistical outliers in the estimation of standard errors. Confidence interval of 95% was used with level of statistical significance set at 0.05 in the study. The models took into account some compositional (age of mother, ethnic group, sex of child, current age of child, highest educational level of mother, religion, birth order) and contextual variables (year, region) that are known in literature to affect diarrhoea prevalence. Four models were run in the multivariate analyses. The first model considered the key predictors (source of drinking water and toilet facility, residential wellbeing); biosocial factors were added to the key predictors in the second model. Socio-cultural and contextual factors were controlled for in models three and four respectively.

Reference groups for independent variables were chosen based on parsimony and literature. The reference groups for the key predictor variables (source of drinking water and toilet facility, residential wellbeing) were 'unimproved unimproved' and 'urban poor' respectively. Studies have shown that people who rely on unimproved sources of drinking water and toilet facilities are more prone to diarrhoea (Acharya *et al.* 2018). Urban poor are the marginalized group that mainly lives in slums with no access to improved essential services such as source of drinking and toilet facilities (Hawkins *et al.* 2013; Armah *et al.* 2018). Regarding age group, mothers between 15 and 19 years were chosen as the reference group because they are not in a good position to provide better services in terms of improved water and toilet facilities because in Ghana, it is the school going age group and usually unemployed (Baah-Boateng 2015). The reference group selected for the ethnic group was 'Akan'. The reference group selected for sex of child was 'male' as literature supports that males are more prone to childhood diarrhoea than females (Luby *et al.* 2018). The 'no education' group was chosen as the reference group for mother's highest educational level as studies have indicated that lack of education has a direct influence on diarrhoea morbidity (Gyimah 2003). 'No religion' was chosen as the reference group for religion. The reference group selected for birth order was '1'. The reference group selected for region was 'Western'. 1993/1994 was chosen as the reference group to serve as a baseline for temporal assessment of diarrhoea prevalence.

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Ethical statement

The DHS data uses procedures and questionnaires that have been reviewed and approved by the ICF International Review Board (IRB). The surveys under DHS adhere to ethical standards and comply with US Government health and services regulations to research and Ghana laws.

RESULTS

Descriptive analysis

Figure 3 presents the trend of child diarrhoea prevalence in Ghanaian households over the 21-year period (1993–2014). Diarrhoea prevalence progressively decreased from 1993 (20%) to 2003 (16%); however, it increased in 2008 (20%) and decreased substantially in 2014 (12%). The prevalence in rural households was always higher than that of the urban households except 2014, where both urban and rural households recorded same magnitude of prevalence.

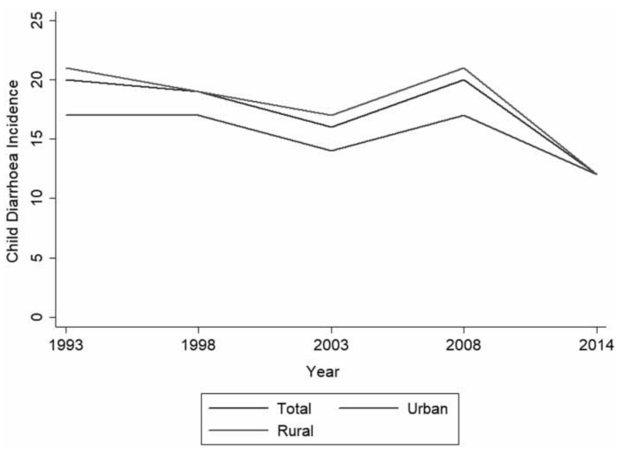

Figure 3 | Trend of childhood diarrhoea prevalence from 1993 to 2014.

Figure 4 provides information on diarrhoea prevalence across the ten regions over the study period. The results show that among all the regions, Greater Accra experienced continuous decrease in prevalence of the study period. Northern Region had the highest prevalence (38%) in 1993 but in 2014 Brong Ahafo became the region with the highest prevalence (18%). The region with least prevalence in 1993 was Upper West (14%) but in 2014, Volta recorded the lowest prevalence (6%).

Univariate analysis

Non-parametric Pearson's Chi-Square and Cramer's V statistics were adopted in evaluating the association between the diarrhoea prevalence and the predictors (see Table 2). The results show that the key predictors, joint effect of source of drinking water and type of toilet facility and residential wellbeing, were associated with diarrhoea prevalence ($P < 0.0001$ and $P < 0.0001$ respectively). The hypothesis that the joint effect of source of drinking water and type of toilet facility and residential wellbeing was independent of childhood diarrhoea prevalence was rejected. However, the Cramer's V results indicate that the observed association was weak.

It was also observed that all compositional and contextual variables were associated with diarrhoea prevalence with varied strength of associations. The strength of the associations presented in

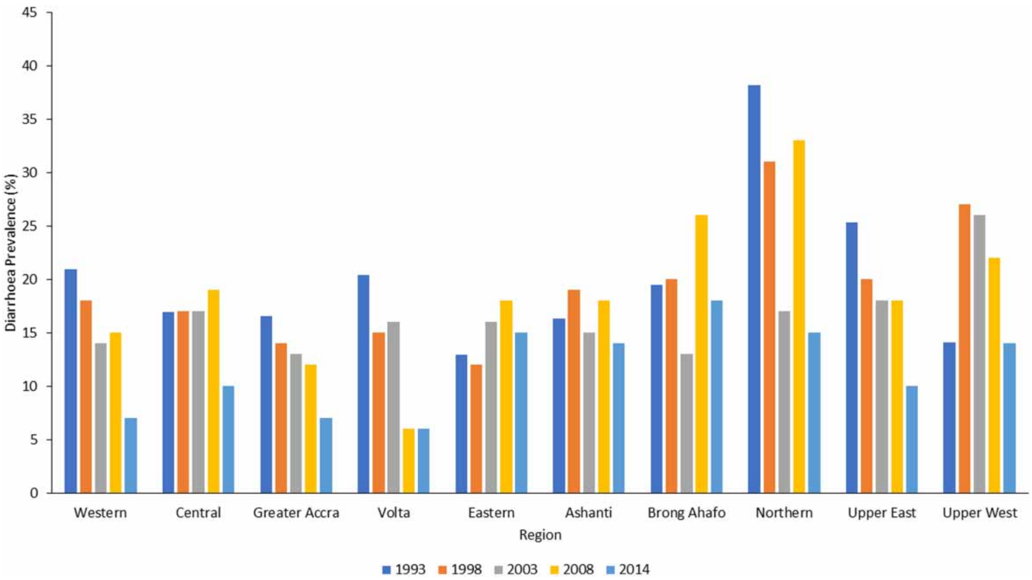

Figure 4 | Childhood diarrhoea prevalence across regions.

decreasing order of magnitude based on Cramer' V statistics (Table 2) is: current age of child > geographical region > religion > mother's highest educational level > ethnic group > source of drinking water and toilet facility > residential wellbeing status > birth order number > age of mother > sex of child.

Multivariate analysis

Disaggregated and pooled data analyses were carried out at the multivariate level. Four models were established in the pooled regression analysis encompassing source of drinking water and toilet facility and residential wellbeing (model 1), biosocial (model 2), sociocultural (model 3), and contextual (model 4) to assess their relationships with childhood diarrhoea prevalence (Table 3).

The model output (Table 3) indicates that households with unimproved source of drinking water and improved toilet facility ($OR = 0.895$, $P < 0.05$), improved source of drinking water and toilet facility ($OR = 0.873$, $P < 0.001$) were less likely to experience diarrhoea compared with those with unimproved source of drinking water and toilet facility. This relationship between improved source of drinking water and toilet facility and diarrhoea prevalence persists after accounting for biosocial and socio-cultural factors. Urban rich households are less likely (approximately 14.3%) to experience diarrhoea than the urban poor households.

The output in model 2, which controlled for biosocial factors, revealed that households with improved source of drinking water and toilet facility are 10.9% less likely to experience diarrhoea than those with unimproved source of drinking water and toilet facility. This percentage indicates a slight decrease in the odds of diarrhoea prevalence (1.8%) of households with improved source of drinking water and toilet facility in model 1. Urban rich households were approximately 12.9% less likely to experience diarrhoea compared with the reference group (urban poor). This also shows a slight decrease in the odds of diarrhoea in urban rich households (1.4%) in model 1. Also, Ewe ethnic group households ($OR = 0.873$, $P < 0.0001$) were less likely to experience diarrhoea prevalence than the Akan households. However, the Mole-Dagbani ($OR = 1.114$, $P < 0.0001$), households were more likely to experience diarrhoea than their counterparts (Akan households). Model 2 output similarly showed that female children under five years old were less likely ($OR = 0.930$, $P < 0.0001$) to experience diarrhoea compared with their male counterparts. Children that are 1 year and 2 years old were 31.3% and 10.6% more likely to experience diarrhoea compared

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Table 2 | Percentage distribution of childhood diarrhoea prevalence by predictor variables

	Had diarrhoea recently		
Variable	**No (%)**	**Yes (%)**	**Inferential statistics**
Source of drinking water and type of toilet facility			
Unimproved Unimproved	81	19	Pearson $chi^2 = 70.1863$ (Pr = 0.000; Cramér's V = 0.0666)
Unimproved Improved	85	15	
Improved Unimproved	82	18	
Improved Improved	87	13	
Residential wellbeing			
Urban poor	82	18	Pearson $chi^2 = 48.7782$ (Pr = 0.000; Cramér's V = 0.0568)
Rural poor	83	17	
Urban middle	83	17	
Rural middle	84	16	
Urban rich	88	12	
Rural rich	85	15	
Sex of child			
Male	83	17	Pearson $chi^2 = 10.2301$ (Pr = 0.001; Cramér's V = −0.0254)
Female	85	15	
Current age of child (years)			
0	84	16	Pearson $chi^2 = 333.8502$ (Pr = 0.000; Cramér's V = 0.1453)
1	76	24	
2	82	18	
3	89	11	
4	91	9	
Mother's highest educational level			
No education	81	19	Pearson $chi^2 = 97.4883$ (Pr = 0.000; Cramér's V = 0.0785)
Primary	83	17	
Secondary	87	13	
Higher	94	6	
Ethnicity			
Akan	85	15	Pearson $chi^2 = 79.0084$ (Pr = 0.000; Cramér's V = 0.0708)
Ga/Dangme	85	15	
Ewe	88	12	
Guan	85	15	
Mole-Dagbani	80	20	
Grussi	80	20	
Gruma	81	19	
Age of mother (years)			
15–19	79	21	Pearson $chi^2 = 12.6842$ (Pr = 0.048; Cramér's V = 0.0283)
20–24	83	17	
25–29	84	16	
30–34	84	16	
35–39	84	16	
40–44	84	16	
45–49	85	15	
Religion			

(*Continued.*)

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Table 2 | Continued

	Had diarrhoea recently		
Variable	No (%)	Yes (%)	Inferential statistics
No religion	83	17	Pearson chi^2 = 105.4699 (Pr = 0.000; Cramér's V = 0.0817)
Christian	86	14	
Muslim	78	22	
Traditional	79	21	
Birth order number			
1	85	15	Pearson chi^2 = 23.0567 (Pr = 0.000; Cramér's V = 0.0382)
2–3	85	15	
4–5	83	17	
6 and above	81	19	
Region			
Western	86	14	Pearson chi^2 = 135.8486 (Pr = 0.000; Cramér's V = 0.0927)
Central	86	14	
Greater Accra	88	12	
Volta	88	12	
Eastern	85	15	
Ashanti	84	16	
Brong Ahafo	81	19	
Northern	77	23	
Upper East	83	17	
Upper West	81	19	
Year			
1993/1994	80	20	Pearson chi^2 = 126.0166 (Pr = 0.000; Cramér's V = 0.0893)
1998/1999	81	19	
2003	84	16	
2008	80	20	
2014	88	12	
N	**15,808**		

to those that are less than 1 year. Nonetheless, those that are 3 years and 4 years (OR = 0.837, $P < 0.0001$, OR = 0.760, $P < 0.0001$ respectively) were less likely to experience diarrhoea compared to those under 1 year.

In model 3, socio-cultural factors were taken into account. The observed relationships in the previous models between improved source of drinking water and improved toilet facility, and diarrhoea prevalence still persisted even though the odds ratio further decreased by 3.4%. The relationship observed in the previous models between urban rich and diarrhoea prevalence disappeared. Mother's age categories (30–34, 35–39, and 45–49) became significant in the socio-cultural model, although they were not in the biosocial model, indicating that biosocial attributes suppressed this relationship.

Children of mothers 30–34 (OR = 0.875. $P < 0.05$), 35–39 (OR = 0.850, $P < 0.05$), 40–44 (OR = 0.817, $P < 0.05$) and 45–49 years old (OR = 0.772, $P < 0.05$) were less likely to report diarrhoea prevalence compared with mothers aged 15–19 years. The model output with respect to ethnic group revealed that the relationship between the Ewe ethnic group households and childhood diarrhoea prevalence persisted and the odds of diarrhoea prevalence remained approximately the same

Table 3 | Negative log-log regression model showing the relationship between diarrhoea prevalence and household characteristics

Variable	Source of drinking water + type of toilet facility					Biosocial factors					Socio-cultural factors					Contextual factors				
	OR	SE	P value	Conf. interval		OR	SE	P value	Conf. interval		OR	SE	P value	Conf. interval		OR	SE	P value	Conf. interval	
	Model 1					Model 2					Model 3					Model 4				
Source of drinking water and type of toilet facility (ref:Unimproved Unimproved)																				
Unimproved Improved	0.895	0.045	**0.032**	0.813	0.991	0.912	0.047	0.073	0.825	1.009	0.924	0.048	0.126	0.835	1.022	0.955	0.051	0.382	0.861	1.059
Improved Unimproved	0.979	0.027	0.431	0.928	1.032	0.959	0.027	0.137	0.908	1.013	0.971	0.027	0.306	0.919	1.027	0.993	0.029	0.804	0.937	1.052
Improved Improved	0.873	0.027	**0.000**	0.822	0.927	0.891	0.028	**0.000**	0.837	0.948	0.925	0.030	**0.017**	0.868	0.986	0.980	0.036	0.575	0.912	1.053
Residential wellbeing (ref:Urban poor)																				
Rural Poor	0.956	0.048	0.364	0.867	1.054	0.976	0.049	0.624	0.883	1.077	0.993	0.050	0.891	0.899	1.097	0.980	0.050	0.699	0.886	1.084
Urban Middle	1.019	0.066	0.772	0.898	1.157	1.038	0.068	0.567	0.914	1.179	1.057	0.069	0.396	0.930	1.202	1.055	0.070	0.421	0.927	1.200
Rural Middle	0.918	0.051	0.126	0.822	1.024	0.959	0.055	0.461	0.857	1.072	0.985	0.057	0.795	0.880	1.103	0.970	0.057	0.598	0.865	1.087
Urban Rich	0.857	0.046	**0.004**	0.772	0.951	0.871	0.048	**0.012**	0.783	0.970	0.923	0.051	0.148	0.828	1.029	0.898	0.051	0.061	0.803	1.005
Rural Rich	0.910	0.054	0.115	0.810	1.023	0.925	0.057	0.204	0.820	1.043	0.967	0.060	0.586	0.857	1.091	0.921	0.058	0.189	0.814	1.041
Age of mother (ref:15–19 years)																				
20–24						0.923	0.052	0.156	0.827	1.031	0.924	0.053	0.168	0.825	1.034	0.920	0.053	0.148	0.821	1.030
25–29						0.906	0.050	0.072	0.813	1.009	0.895	0.054	0.063	0.796	1.006	0.893	0.054	0.061	0.794	1.005
30–34						0.922	0.052	0.145	0.826	1.029	0.875	0.056	**0.038**	0.771	0.993	0.887	0.058	0.065	0.781	1.008
35–39						0.931	0.054	0.215	0.832	1.042	0.850	0.058	**0.018**	0.743	0.973	0.857	0.059	**0.026**	0.748	0.981
40–44						0.917	0.058	0.173	0.810	1.039	0.817	0.063	**0.008**	0.703	0.949	0.830	0.064	**0.016**	0.713	0.966
45–49						0.891	0.071	0.146	0.762	1.041	0.772	0.071	**0.005**	0.645	0.925	0.781	0.073	**0.008**	0.650	0.938
Ethnicity (ref: Akan)																				
Ga/Dangme						1.024	0.046	0.599	0.938	1.118	1.024	0.046	0.598	0.937	1.119	1.071	0.055	0.180	0.969	1.184
Ewe						0.873	0.029	**0.000**	0.818	0.932	0.875	0.029	**0.000**	0.819	0.935	0.963	0.043	0.394	0.882	1.051
Guan						0.946	0.065	0.423	0.827	1.083	0.886	0.063	0.088	0.770	1.018	0.883	0.067	0.101	0.762	1.025
Mole-Dagbani						1.114	0.031	**0.000**	1.054	1.177	1.007	0.035	0.837	0.942	1.077	1.010	0.047	0.828	0.922	1.107
Grussi						1.056	0.057	0.317	0.949	1.174	0.983	0.055	0.754	0.880	1.097	0.988	0.064	0.857	0.870	1.122

(*Continued.*)

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Table 3 | Continued

Variable	Source of drinking water + type of toilet facility					Biosocial factors					Socio-cultural factors					Contextual factors				
	OR	SE	P value	Conf. interval		OR	SE	P value	Conf. interval		OR	SE	P value	Conf. interval		OR	SE	P value	Conf. interval	
	Model 1					Model 2					Model 3					Model 4				
Gruma						1.056	0.046	0.211	0.969	1.151	0.990	0.047	0.837	0.903	1.086	0.989	0.055	0.841	0.886	1.103
Sex of Child (ref: Male)																				
Female						0.930	0.019	**0.000**	0.893	0.969	0.929	0.019	**0.000**	0.891	0.967	0.924	0.019	**0.000**	0.887	0.963
Current age of child (ref:Less than 1 year)																				
1						1.313	0.040	**0.000**	1.237	1.393	1.319	0.040	**0.000**	1.243	1.400	1.319	0.040	**0.000**	1.242	1.400
2						1.106	0.034	**0.001**	1.041	1.175	1.111	0.035	**0.001**	1.045	1.181	1.119	0.035	**0.000**	1.052	1.190
3						0.837	0.028	**0.000**	0.784	0.895	0.850	0.029	**0.000**	0.795	0.910	0.852	0.030	**0.000**	0.795	0.912
4						0.760	0.027	**0.000**	0.710	0.814	0.773	0.027	**0.000**	0.721	0.828	0.772	0.028	**0.000**	0.719	0.829
Highest Educational Level (ref:No education																				
Primary											1.007	0.030	0.810	0.950	1.068	1.027	0.032	0.387	0.967	1.091
Secondary											0.944	0.030	0.071	0.887	1.005	0.963	0.032	0.247	0.903	1.027
Higher											0.699	0.062	**0.000**	0.587	0.832	0.736	0.067	**0.001**	0.616	0.879
Religion (ref: No religion)																				
Christian											0.990	0.042	0.812	0.911	1.075	1.001	0.043	0.984	0.921	1.088
Muslim											1.192	0.059	**0.000**	1.081	1.314	1.173	0.060	**0.002**	1.061	1.298
Traditional											1.140	0.068	**0.027**	1.015	1.281	1.111	0.067	0.080	0.987	1.250
Birth order number (ref:1)																				
2–3											0.992	0.032	0.808	0.932	1.057	0.995	0.032	0.867	0.933	1.060
4–5											1.075	0.045	0.080	0.991	1.167	1.074	0.045	0.088	0.989	1.165
6 and above											1.140	0.058	**0.009**	1.033	1.259	1.128	0.057	**0.018**	1.021	1.247
Region (ref: Western)																				
Central																1.032	0.049	0.504	0.941	1.132
Greater Accra																0.996	0.056	0.943	0.893	1.111
Volta																0.924	0.055	0.184	0.822	1.038

(*Continued.*)

Table 3 | Continued

Variable	Source of drinking water + type of toilet facility (Model 1)					Biosocial factors (Model 2)					Socio-cultural factors (Model 3)					Contextual factors (Model 4)				
	OR	SE	*P* value	Conf. interval		OR	SE	*P* value	Conf. interval		OR	SE	*P* value	Conf. interval		OR	SE	*P* value	Conf. interval	
Eastern																1.060	0.051	0.220	0.965	1.165
Ashanti																1.116	0.049	**0.011**	1.025	1.216
Brong Ahafo																1.191	0.055	**0.000**	1.087	1.305
Northern																1.192	0.067	**0.002**	1.068	1.330
Upper East																1.071	0.069	0.283	0.945	1.214
Upper West																1.109	0.071	0.106	0.978	1.258
Year (ref: 1993/1994)																				
1998/1999																1.078	0.047	0.082	0.991	1.173
2003																0.994	0.039	0.873	0.920	1.074
2008																1.118	0.047	**0.008**	1.029	1.215
2014																0.860	0.035	**0.000**	0.795	0.931
n	**15,108**					**15,076**					**15,072**					**15,072**				

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compared with the biosocial model (OR = 0.875, $P < 0.0001$). However, the relationship of the Mole-Dagbani ethnic group and childhood diarrhoea prevalence disappeared totally in model 3. The relationship between sex of child and the likelihood of experiencing diarrhoea in model 2 persisted and the odds ratio remained approximately the same (OR = 0.929, $P < 0.0001$). The observed relationships in model 2 for all categories of current age of child increased slightly in model 3 with respect to the likelihood of diarrhoea prevalence. Children less than 1 year old were 31.9% more likely to experience diarrhoea compared with their counterparts in the reference age group (less than a year). Those in age group 2 were also 11.1% more likely to experience diarrhoea compared with those that were less than a year old. Children under age groups 3 and 4 are 15% and 22.7% less likely to experience diarrhoea compared with their counterparts that are less than a year old. Mothers with higher education status had lower odds (OR = 0.699, $P < 0.0001$) compared with their counterparts with no education. Households of Muslim and Traditional religious background were 19.2 and 14% more likely to experience diarrhoea compared with their counterparts in homes without religion.

Model 3 equally revealed that children born in birth order 6 and above (OR = 1.140, $P < 0.05$) were more likely to experience diarrhoea compared with their counterparts who are first born.

The relationship between diarrhoea prevalence and improved drinking water source and toilet facility disappeared in the final model (model 4), which took into account contextual factors. The relationship also disappeared for mothers aged 30–34 years; however, the relationship persisted for the age category 35–49 years. The relationship between ethnic group and childhood diarrhoea prevalence disappeared entirely. The relationship between sex of the child and diarrhoea prevalence persisted. Females (OR = 0.924, $P < 0.0001$) were still less likely to experience diarrhoea compared with their male counterparts. The relationship between current age of child and the prevalence of diarrhoea was persistent, just like that observed for mothers with higher educational status. The observed relationship between Muslim households and childhood diarrhoea prevalence decreased by 1.9% in model 4 compared with that observed in model 3. The relationship between Traditional households and childhood diarrhoea prevalence disappeared. Model 4 also revealed that children of birth order 6 and above (OR = 1.128, $P < 0.05$) were more likely to experience diarrhoea than their counterparts in the reference group. The model also indicates households in Ashanti (OR = 1.116, $P < 0.05$), Brong Ahafo (OR = 1.191, $P < 0.0001$), and Northern (OR = 1.192, $P < 0.05$) regions were all more likely to experience diarrhoea compared with households in the Western region. With respect to the years in which the surveys were carried out, households sampled in 2008 (OR = 1.118, $P < 0.05$) were more likely to experience childhood diarrhoea compared with the reference year 1993/1994. Also, households sampled in 2014 (OR = 0.860, $P < 0.001$) were less likely to experience childhood diarrhoea compared with the reference year 1993/1994.

DISCUSSION

The study assessed the cumulative effect of environmental determinants of childhood diarrhoea prevalence in Ghanaian households from 1993 to 2014. The findings of this study show that the national prevalence rate of childhood diarrhoea has declined. The increase in childhood diarrhoea prevalence in 2008, as found in this study, could be as a result of inadequate access to improved water and sanitation coupled with the increasing population of the country. Nonetheless, the national prevalence rate of childhood diarrhoea between 2008 and 2014 declined. This is consistent with Enweronu-Laryea *et al.* (2014), who reported a decline in severe diarrhoea hospitalization between 2008 and 2014 after the introduction of rotavirus vaccination in Southern Ghana. Additionally, the decline could equally be attributed to improvement made in water and sanitation resources at the individual and community levels in the country over the years, as found in Armah *et al.* (2018) and Millennium Development Goals Report (2015).

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Age of mother, sex of child, age of child, mother's highest educational level, religion, birth order number, region and year are important predictors of childhood diarrhoea prevalence while the source of drinking water and toilet facility, residential wellbeing and ethnicity does not predict childhood diarrhoea prevalence in the multivariate model.

The findings of the study show that children borne by older mothers had lower odds of diarrhoea prevalence compared to children borne by younger mothers. Young mothers do not have experience on issues relating to infant feeding and child care; their children become more vulnerable to diarrhoea disease. Besides, young mothers do not earn much that will enable them to live in a decent environment with improved water and sanitation facilities, given Ghanaian socio-economic conditions (Baah-Boateng 2015). This supports findings from Wolf *et al.* (2018) and contradicts the works of Dikassa *et al.* (1993) in Kinshasa, Zaire, who found that older mothers (40 years and above) were twice as likely to have reported their child had had diarrhoea.

Our findings suggest that female children have lower odds of diarrhoea prevalence compared to males. This finding is consistent with other studies (Ahmed *et al.* 2008; Luby *et al.* 2018), which found that male children are more vulnerable to diarrhoea. This might reflect gender-specific childcare practices in Ghanaian households. This is a grey area in literature and findings of other studies have been inconsistent. The study also found that younger children (0–3 years) were more likely to have diarrhoea compared to older children (4–5 years). These findings agree with other studies (Karambu *et al.* 2014; Mohammed & Tamiru 2014; Kumi-Kyereme & Amo-Adjei 2016). Between 0 and 3 years, children are in their developmental stage where they start to crawl and walk and easily get filth or put other contaminated objects into the mouth if not properly cared for. Also, children in these age groups are subjected to weaning practices during which the infant food can easily become contaminated, and immunity probably falls during weaning period. Nonetheless, higher age groups (3 and 4 years) with lower odds could be ascribed to better adaptation to the environment and development in their immunological systems makes them less vulnerable than their counterparts in the other categories, those as exemplified by Ahmed *et al.* (2008).

Children borne by mothers with higher educational level showed lower odds of diarrhoea prevalence compared to those borne by uneducated mothers. Mothers who are educated are more likely to exhibit better skills in childcare practices such as regular hand washing with soap prior to feeding children and preparation of food. They are also likely to be in wealthy households where there are improved sources of drinking water and sanitation facilities (Luby *et al.* 2018; Null *et al.* 2018).

Muslim and Traditional households showed higher odds of childhood diarrhoea compared with the reference group. The causes of these differences are not perceivable and therefore require further studies to delineate these observations. Muslim households tend to be larger because of the polygamous marriage system practiced (Demissie *et al.* 2009) and tend to aggregate geographically in physically poor environments, just like other non-muslim communities. These findings are similar to reports from Kumi-Kyereme & Amo-Adjei (2016), although that study only identified Traditional households.

Furthermore, there is high likelihood of childhood diarrhoea among children with birth order 6 and above. More children in a household mean contact between potential contaminants will be higher than in households with fewer children. Likewise, large families may have less time to accomplish quality child care practices, hence these children may receive poor child care (Gyimah 2003).

Northern, Brong Ahafo and Ashanti regions showed higher odds of childhood diarrhoea prevalence than the reference group. These results therefore signify that these regions have inadequate access to improved sources of drinking water and toilet facilities. The observed relations in this study could be attributed to poor sanitation practices among the residents and their environment. Poor sanitation is common in rural settings, urban fringes, and coastal communities (Yawson Kudu & Adu 2018). These regions over the years have experienced growth rate and urbanization which was not accompanied by investment in water and sanitation infrastructure thereby resulting in

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slum communities that lack basic amenities and social services (Armah *et al.* 2018). Nonetheless, a progressive decline in childhood diarrhoea prevalence within the study period also informs us about the impact of efforts made in getting access to improved water and toilet facilities as well as improved policy intervention in public health in the country.

CONCLUSION

Diarrhoeal disease is the second leading cause of death in children under five years old, and is responsible for killing around 525,000 children every year, although it is both preventable and treatable. Assessing the environmental and social and behavioural risk factors for diarrhoea has been identified as one of most pressing research priorities of our time. In response to this need, this study is one of the first to examine the effect of combined access to water and toilet facilities and residential (rural-urban) wealth status on the likelihood of experiencing household childhood diarrhoea. In Ghana, good progress has been made towards reducing childhood diarrhoea prevalence between 1993 and 2014. The prevalence rate, however, is still alarming and requires interdisciplinary research and policy intervention. While environmental determinants are crucial, contextual and compositional factors mediate the effects of the environmental factors. Current age of child was the variable that most systematically determine childhood diarrhoea prevalence while sex of child was the least. Important contextual factors, particularly geographical region and time (spatio-temporal effects), unveil the dissimilitude in odds of childhood diarrhoea morbidity in Ghana. For this reason, in the short term, spatio-temporal factors should be considered and combined with emphasis on deep-seated socio-environmental determinants in the long term. Either way, it is imperative to promote national policies and investments that support case management of diarrhoea and its complications as well as increasing concomitant access to safe drinking water and sanitation in developing countries such as Ghana. In this regard, national policies should systematically address the impact of acute, prolonged, persistent and recurrent diarrhoea on growth trajectories of children in impoverished endemic areas.

DATA AVAILABILITY STATEMENT

All relevant data are available from an online repository or repositories at www.dhsprogram.com.

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