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Existing sanitation and hygiene conditions in Bangladeshi slums and their association with under-five child morbidity

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ABSTRACT

A cross-sectional survey was conducted using random sampling among five slum residents in Magura municipality. The study analyzed infrastructural factors (latrine conditions, types of houses) and behavioral factors (handwashing and cleaning practices for children and mothers). Water quality was assessed through biological (*E. coli*, fecal coliforms) and physicochemical (pH, total dissolved solids (TDS), and total suspended solids (TSS)) parameters. Associations with common morbidities such as diarrhea, typhoid, and dysentery were also analyzed. Over 40% of the latrines were kacha (unimproved), and 40% were semi-paka (semi-structured). Around 25% of latrines were unhygienic, while 80% of the houses were made of mud, tin, or a fence. Only 22–29% of households used soap and water for cleaning children, and 40–48% of mothers washed their hands with only water before feeding children. Most tube wells were 200–300 ft deep, and about half were located more than 30 ft from latrines. Over the past year, 52–60% of children suffered from diarrhea, and 20% from dysentery. Although diarrhea decreased over 5 years, dysentery cases increased. *E. coli* and fecal coliforms showed a significant negative correlation with diarrhea and dysentery ($p < 0.05$). TDS averaged 353.87 mg/L, and the pH was just above 7 (7.61 ± 0.21).

Key words: child morbidity, diarrhea, dysentery, sanitation and hygiene, slum area, water quality

HIGHLIGHTS

- The study examined the influence of poor sanitation on child health.
- Over 40% of latrines were unimproved, and 80% of homes had substandard structures.
- The study acknowledged low hygiene practices, with only 22–29% using soap to clean children.
- Biological water contamination (*E. coli*, coliforms) was associated with child morbidities.
- The article highlights the crucial need for better sanitation for slum children.

INTRODUCTION

Currently, around 1.1 billion individuals reside in slums or slum-like conditions in urban areas, with an anticipated increase of 2 billion over the next 30 years (UNStats 2022). Whereas improperly handled excreta harms people's health and children's health by contaminating soil, groundwater, surface water, and air quality, with most being untreated or managed dangerously (WHO 2017). Besides, according to the latest report published by the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP), 3.4 billion people still lack safely managed sanitation, while 354 million practice open defecation. And 1.7 billion people still lack basic hygiene services at home, whereas 611 million have no access to any facilities (JMP 2025).

Waterborne infections account for over 80% of all illnesses worldwide, with two-thirds of these cases in Asia's developing nations and nearly half in tainted or hazardous water (Shaibur *et al.* 2019). Diarrhea is a prevalent and harmful health issue in underdeveloped nations, primarily caused by infectious pathogens expelled in infected individuals' feces (Curtis *et al.* 2000).

This contaminated excrement can subsequently enter other uninfected people's digestive systems through their hands, water, food, or insects (Curtis *et al.* 2000). Proper sanitation and hygiene practices are crucial for reducing diarrheal pathogen spread, as they prevent fecal matter contamination and reduce cases of diarrheal illness (Mathers *et al.* 2006). Whereas diarrhea is a major cause of death for children globally, accounting for an estimated 1,438 fatalities every day (Levine *et al.* 2020).

Urban slum environments frequently degrade children's hygiene (Kundu *et al.* 2018). Slum children in South Asia often suffer from diarrheal illness, and 28% of newborns under the age of one in Dhaka (Rahman & Shahidullah 2001) had a diarrheal incident in their first 2 weeks. Whereas, a study conducted in urban slums in Pakistan found that 24.18% of the families had at least one child who had a diarrheal illness in the month before the survey. According to this report, 80% of the families examined get their drinking water from an unimproved source (Mehmood & Arshad 2024). Both dimensions, i.e., water quality and healthcare service satisfaction, denote community confidence in public health systems, signifying the importance of joint service improvements.

A study in Bangladesh found that poor sanitation facilities negatively impact children's health, particularly in flood-prone areas (Kikuchi 2023). Another study found that children from homes with poor sanitation conditions are more likely to suffer from diarrhea and other health issues (Islam *et al.* 2022). In Bangladesh, inadequate WASH access has been unswervingly connected to child undernutrition and morbidity, highlighting the importance of improving sanitation and hygiene to enhance child health outcomes (Tofail *et al.* 2018; Hasan *et al.* 2023). Additionally, research analyzed trends and inequity in improved sanitation facility utilization in Bangladesh. The study found that while access to improved sanitation facilities has increased, significant disparities remain among different socioeconomic groups, indicating the need for targeted interventions to address these inequities (Ahmed *et al.* 2023).

According to Bangladesh's 2019 Multiple Indicator Cluster Survey (MICS), 39.1% of families are missing basic sanitation, and 43.8% lack handwashing facilities. These issues are associated with a shortage of water, sanitation, and hygiene facilities (Hasan *et al.* 2023). The importance of sanitation for children's health was highlighted by a cross-sectional study that revealed homes with inadequate toilet facilities had a higher chance of child illness (Islam *et al.* 2022). In addition, according to statistics from the Bangladesh Demographic and Health Survey (BDHS), the percentage of households with access to better sanitation rose from 25.4% in 2007 to 45.4% in 2014 before declining a little to 44.0% in 2017–2018 (Ahmed *et al.* 2023).

Despite several national-level studies in Bangladesh that have examined WASH and child health, most of these studies have focused on single aspects, such as sanitation infrastructure or hygiene behavior. In contrast, a few have combined infrastructural, behavioral, and microbiological data in urban slums. The current study addresses this gap by triangulating these magnitudes and connecting them to the consequences of child morbidity, offering novel insights into the effects of child morbidity and providing new perspectives. We aimed to (1) assess sanitation infrastructure and hygiene practices, (2) quantify microbial contamination in drinking water, and (3) describe exploratory associations between WASH factors and child morbidities in five Magura slums.

MATERIALS AND METHODS

Study design, study site, and data collection

This was a quantitative cross-sectional study that analyzed numerous exposure variables using various output indicators. Magura District, located 176 km southwest of Dhaka in Bangladesh, is part of the Khulna Division (Chandni 2018). The 2022 Census of Bangladesh found that of the 1,033,115 people living in the Magura District, 254,154 households had 187,703 (18.17%) children under the age of 10 (Chandni 2018). Data were collected in August–September 2024, and the collected data from residents of five different slums (Shatdoha, Munshipara, Jojcoart Para, Shibrampur, and Sahapara) in Magura municipality under Magura Sadar, focusing on vulnerable areas like sanitation, drainage, and waste disposal.

A preliminary list of households with at least one child under five was generated from local administrative records for each slum. Using this list, a simple random sampling technique with proportional allocation across the five slum areas ensured representativeness of the population.

Data were collected at two complementary levels to capture both household practices and environmental exposures. Individual-level ($n = 150$) data were gathered through structured household surveys documenting demographic characteristics, WASH practices, and self-reported health issues such as diarrhea and other gastrointestinal illnesses. Mothers or primary caregivers provided recall information for illness episodes occurring within the previous 1 and 5 years.

Aggregated-level data ($n = 15$) consisted of water quality assessments using composite samples collected from various neighborhood water sources and points of use. These samples were analyzed for key microbiological and chemical parameters.

This dual-level data collection approach enabled the integration of household behavioral information with broader environmental conditions to better understand potential exposure pathways. The study areas are shown in Figure 1.

Questionnaire development and ethical considerations

The study utilized a draft questionnaire for a pretest in Magura Municipality, collecting primary and secondary data from household respondents, including information on parents' education, income, household details, cleanliness, diseases, and healthcare access. Data were collected from the field by field researchers. Ethical clearance for conducting the field study has been obtained from the Khulna University Ethical Committee (KUEC). Additionally, informed consent has also been taken from each participant before starting interviews.

Sample size calculation

The equation for sample size collection is (Kothari 2004)

$$n = \frac{Z^2 pqN}{e^2(N-1) + Z^2 pq}$$

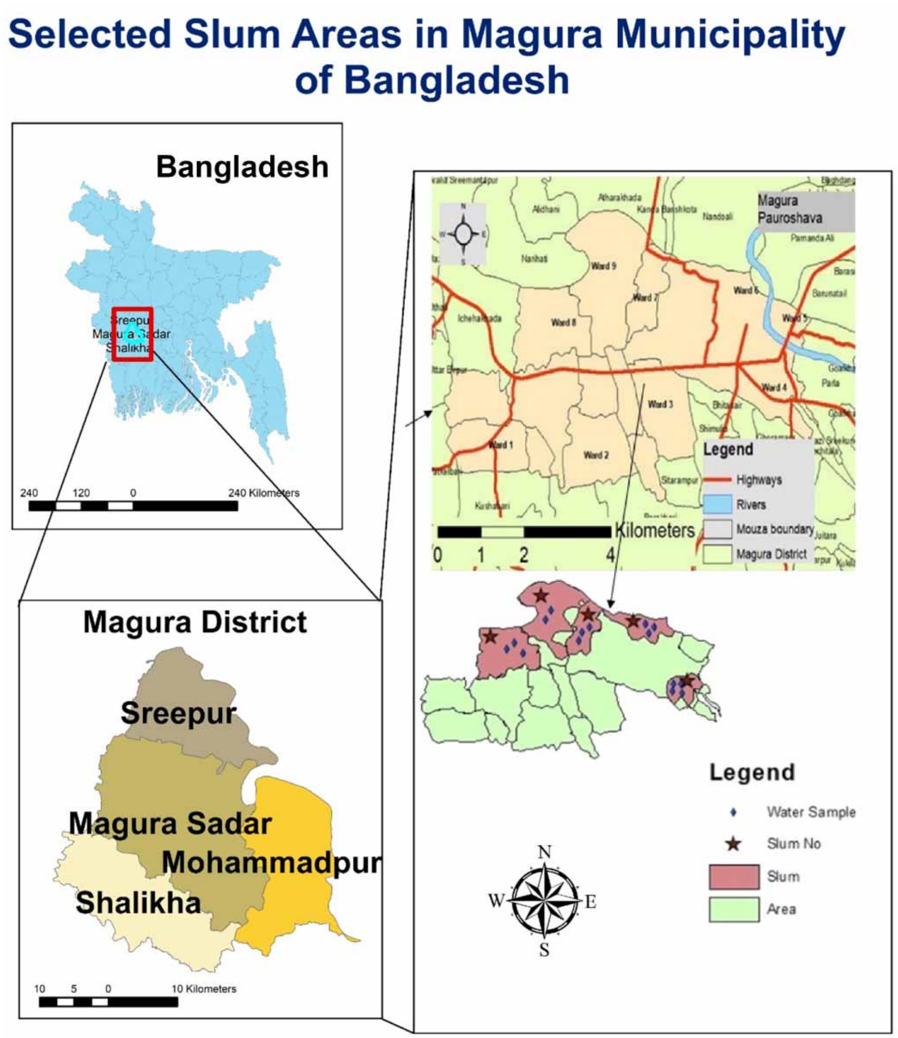

Figure 1 | Location of the study areas in the context of Bangladesh and Magura district.

where n is the sample size, Z^2 is the value of the standard variant at a given confidence level, p is the sample proportion, $q = 1 - p$, e is the acceptance error, 0.05 (since the estimation should be within 5% of the true value), N is the population size of the study area, and $Z = 1.96$ (for a 95% confidence level, the value of Z is 1.96). The total number of participants was 150. To see the household survey and water sample size determination table, see Supplementary Table S1.

Water sample collection and composite sampling

Water quality was assessed at both source points (tube wells, taps, ponds) and points of use (household storage) across the five slums. A composite sampling approach was used: multiple sources were pooled to form one composite source sample per slum, and several household storage containers were pooled to form one composite point-of-use sample per slum, totaling 15 samples.

Sample selection considered source type, household storage, spatial coverage, and accessibility to ensure representativeness. Samples were analyzed for microbiological (*E. coli*, total coliform (TC), fecal coliform (FC)) and physicochemical (pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS)) parameters (Rice *et al.* 2012a, b).

Parameters and water quality analysis

Latrine types were categorized based on the Bangladeshi latrine types (Islam *et al.* 2022). Latrines are commonly divided into three types: paka, semi-paka, and kacha. Paka latrines are durable and permanent, built with concrete or brick to prevent contact with waste. Semi-paka latrines are partly permanent, made from materials such as tin or wood, providing some sanitary benefits but less durability. Kacha latrines are temporary or made of mud or bamboo, often lacking proper containment and sometimes used for open defecation, which were adapted from the WHO/UNICEF sanitation ladder (WHO 2022).

We prepared three composite samples per slum (15 in total): one source composite by pooling equal volumes from 3 to 5 actively used tube wells/taps, and two point-of-use (POU) composites by pooling equal volumes from 3 to 5 households' storage containers. The selection of contributors spanned source type, tube well depth, and latrine–well distance categories to capture spatial variation. Some physicochemical parameters like pH, EC, TSS, and TDS, and some biological parameters like *E. coli*, TC, and FC were tested for understanding the recent water quality in the rainy season. Because water quality becomes worse during heavy rains during Bangladesh's monsoon season, leading to increased contamination from fecal pathogens and other pollutants, it may lead to a rise in waterborne diseases like diarrhea, cholera, and typhoid (Indhumathi & Kumar 2021).

Physicochemical and biological parameters

Advanced instruments were used to analyze water samples in the Environmental Science Discipline laboratory at the Khulna University of Bangladesh, focusing on physical, chemical, and microbiological features listed in Supplementary Table S2 (Rice *et al.* 2012b). pH is crucial for aquatic life's survival, as it maintains the acidic or basic condition of compounds. The pH of the sample water was measured using a dedicated conductivity meter, HANNA Instrument pH 211 (Microprocessor pH meter), a dedicated conductivity meter. EC is a crucial characteristic indicating the capacity to pass electric flux, and measuring EC is essential for displaying chemical and component concentrations. The EC of water was also determined using a HANNA Instrument pH 211. TSS measures the number of solid particles – both organic and inorganic that, after gravity settling, are still suspended in water or wastewater. TDS refers to the dissolved salts, heavy metals, and other organic elements that are present in water. It is expressed in parts per million (ppm) and milligrams per unit volume of water (mg/L).

The levels of TC, FC, and *E. coli* are commonly used to determine drinking water guidelines. After filtering or treatment, no coliforms should remain. Natural water often contains bacteria, so untreated water from lakes or rivers should not be consumed. See Supplementary Table S3 to see the lists of microbial techniques utilized in the study for water analysis, by APHA (1992). Besides, the microbial risk category has been depicted in Supplementary Table S4.

Health indicators: Morbidity refers to the absence of physiological or psychological well-being, encompassing disease, injury, and disability. Morbidity frequency measures the number of people who become ill or are ill at a given time (Swaminathan *et al.* 2001).

Incidence rate refers to the number of new cases of disease or injury in a population over a specific period, often used to refer to the number of new cases per unit of population, with two commonly used types (Swaminathan *et al.* 2001). The method for calculating the incidence rate is

$$\frac{\text{Number of new cases of disease or injury during specified period}}{\text{Time each person was observed, totaled for all persons}} \times 10n$$

Morbidity data were gathered based on caregivers' recall of health indicators, diagnoses by local healthcare providers, or self-reported illness that caused interruption of daily activities within the last 5 years.

Data processing, analysis, and interpretation

Analyses were conducted using SPSS version 26 and R Studio version 4.3.2. Survey data were entered in individual format for household-level analysis. Water quality data were treated as aggregated by source and point-of-use. The analyzed variables are sanitation infrastructure (latrine type, condition, and housing type), hygiene behavior (handwashing and child cleaning practices), water quality parameters (pH, TDS, TSS, EC, *E. coli*, FC, and TC), and child morbidity indicators (diarrhea, dysentery, typhoid incidence, and prevalence). Statistical analyses comprised descriptive statistics (percentage, mean, standard deviation), Pearson's correlation, and regression analyses were used to examine associations between microbial indicators and childhood diarrhea and dysentery. Results show significant links between poor sanitation, contaminated water, and child morbidity. The small number of slums ($n = 5$) limits generalizability and should be considered when interpreting findings.

RESULTS

Demographic characteristics of the respondents

Supplementary Table S5 depicts that out of the 150 individuals living in the slums who were part of the study, 64.67% of the participants were female, and 31.33% of the participants were over 50. About 50.67% of people lacked formal education, 6% had finished college, and the remaining individuals had only completed elementary (26%) or secondary (17.33%) schooling. Among the respondents, nearly half were housewives (48.67%). Among those engaged in income-generating activities, the largest occupational groups were fishermen (21.33%), day laborers (15.33%), and farmers (14.67%). 4.67% of respondents made over 100,000 BDT annually, whereas 28% of respondents made between 40,000 and 60,000 BDT annually.

Infrastructural characteristics of the studied households

Table 1 summarizes the housing and sanitation conditions of the surveyed households. More than half of the families (55%) lived in mud or tally houses, while nearly one-third (30.8%) resided in tin or fence structures, and only a small fraction (14.2%) had brick-built homes. Sanitation facilities were generally poor. About one-third of households (34.8%) depended on simple pit latrines, while one-fourth (24.8%) used unhygienic or hanging latrines. Improved options were much less common, with fewer than one-fifth of households having either ventilated improved pit latrines (18.0%) or sanitary latrines (14.6%). In terms of latrine condition, nearly half (44.2%) were kacha, about two-fifths (39.8%) were semi-paka, and only one-sixth (16.0%) were paka, highlighting the scarcity of durable and hygienic facilities.

Behavioral characteristics of sanitation of the studied households

As shown in Table 2, hygiene practices were suboptimal across households. For cleaning children, almost two-thirds (64%) relied solely on water, about one-fourth (25.6%) used water with soap, and roughly one-tenth (10.4%) used cloths or tissues. Maternal handwashing showed a comparable distribution: nearly half of the mothers (43.8%) washed with only water, just over two-fifths (40.4%) used water and soap, and around one-sixth (15.8%) used cloths or tissues. These findings indicate

Table 1 | Infrastructural characteristics of the studied households in the study area

Category	Subcategory	*n* (%)
Types of houses in the slums	Mud or tally	83 (55)
	Brick built	21 (14.2)
	Tin or fence	46 (30.8)
Latrine types of the study area	Ventilated improved pit	24 (16)
	Sanitary	22 (14.67)
	Pit	67 (44.66)
	Unhygienic or hanging	37 (24.67)
Latrine condition in the slum area	Kacha (Unimproved)	66 (44.2)
	Paka (Improved)	24 (16)
	Semi-paka (Semi-improved)	60 (39.8)

Table 2 | Behavioral characteristics of sanitation of the studied households in the study area

	Subcategory (%)		
Characteristics	**Only water**	**Water and soap**	**Cloths or tissues**
Cleaning agents used for child cleaning after toilet use	64	25.6	10.4
Mother handwashing agents before feeding the child	43.8	40.4	15.8

that water-only practices dominated both child cleaning and handwashing behaviors, leaving considerable gaps in effective pathogen prevention.

Availability of water sources

In a slum neighborhood, Figure 2 shows the distance between sanitary latrines and tube well depths. 25.33% of tube wells are between 100 and 200 ft deep, whereas the bulk (62.67%) is between 200 and 300 ft deep. Less than 4% are less than 100 ft deep, while only 8% are deeper than 300 ft. 29.33% of tube wells are fewer than 10 ft from sanitary latrines, while 50.67% are positioned more than 30 ft away. The cause of contaminated water differs with the closeness and depth of tube wells; 8.67% are situated between 11 and 20 ft, and 11.33% are between 21 and 30 ft from latrines. These numbers show how installing wells with latrines can organize different pollution levels.

Disease prevalence and impact on children under age five in the study area

Figure 3 compares the impact of disease prevalence over the past 1 and 5 years among children under five in five different slum regions. Both dysentery and diarrhea are common in all of the slums, with Slums 1, 3, and 5 having higher rates of diarrhea. Dysentery is highest in Slums 2 and 4, but it consistently ranks second in Slums 1, 3, and 5. Although typhoid and overall prevalence rates have reduced over the last 5 years, diarrhea and dysentery may be the common causes of illness in children. So public awareness is very important for ensuring good health.

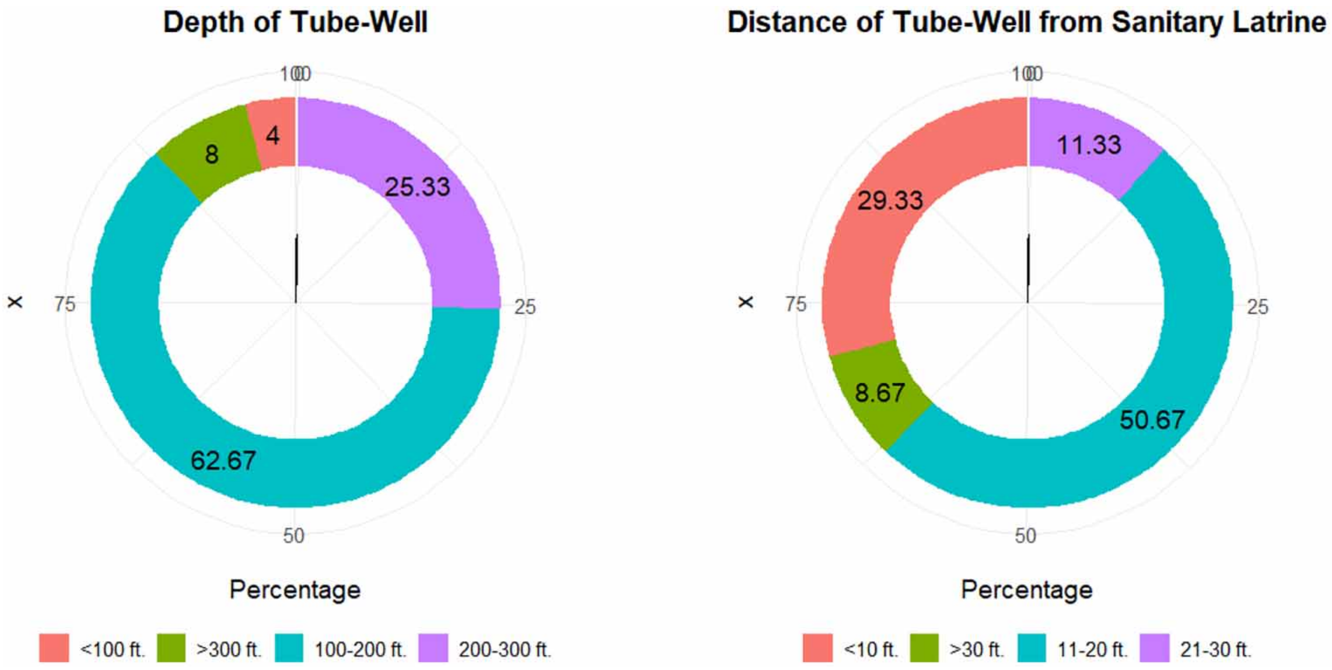

Figure 2 | Estimation of the depth of the tube well and the distance of the tube well from the sanitary latrine in the slum area.

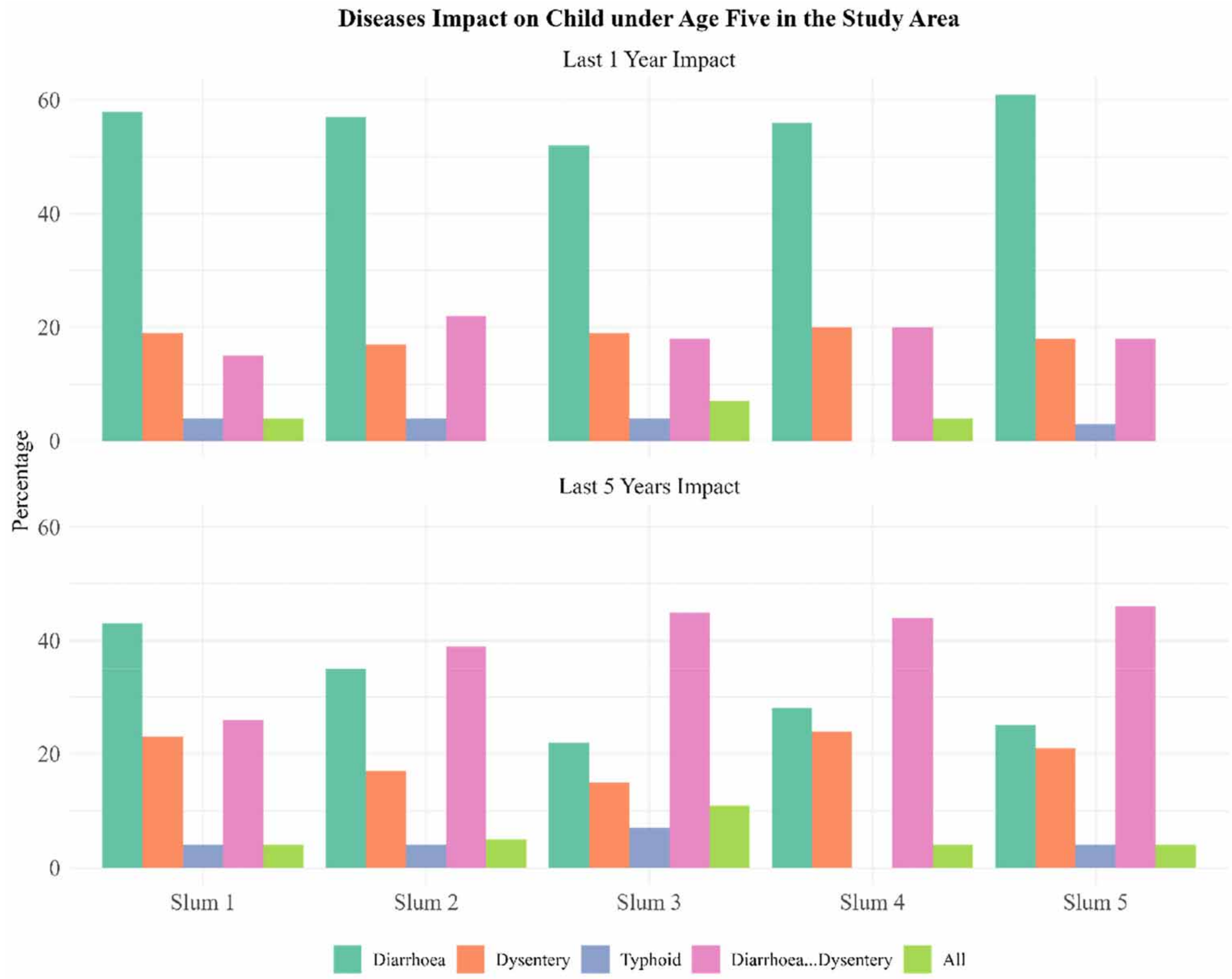

Figure 3 | Disease prevalence and impact for the last 1 and 5 years among under age 5 children of slum area. (*Data source*: Household survey, 2024).

Associations between sanitation factors, microbial contamination, and child morbidities

Pearson's correlation analysis showed significant associations between *E. coli*, FC, and diarrhea incidence ($p < 0.05$), signifying that sanitation conditions contribute to disease occurrence.

The largest incidence of diarrhea is associated with tube well depths between 100 and 200 ft, accounting for 77.08% of cases, and 200 and 300 ft, accounting for 16.67%. Thirty-three percent of cases are linked to shallow tube wells (less than 100 ft), and no instances have been documented from wells deeper than 300 ft. These findings demonstrate a robust relationship between childhood diarrheal disease prevalence and sanitation conditions (see Supplementary Table S6).

Table 3 presents the statistical analysis, utilizing correlation coefficients (r) and p-values, of the association between microbiological characteristics and disorders associated with water. FC and diarrhea ($r = -0.49$, $p = 0.041$) show a strong inverse link with *E. coli* and diarrhea ($r = -0.54$, $p = 0.035$), both of which have a significant negative correlation. Likewise, a significant correlation has been shown between TC and dysentery ($r = -0.43$, $p = 0.047$). Though no relationship was found between typhoid and *E. coli*, FC, or TC, the results showed a correlation between microbiological contamination and waterborne diseases such as dysentery and diarrhea.

All microbial and morbidity data were combined at the slum level ($n = 5$) for correlation analysis, while negative correlation denotes an opposite statistical relationship rather than a causal or protective effect. Hence, these results should be interpreted with caution.

Table 3 | Statistical analysis of microbial parameters and water-related disease

	Output of analysis		
Analyzed data	Correlation coefficient (*r*)	*p*-value	Remark
E. *coli* and diarrhea	−0.54	0.035	Significant
FC and diarrhea	−0.49	0.041	Significant
TC and diarrhea	+0.2	0.750	Non-significant
E. coli and dysentery	−0.39	0.520	Non-significant
FC and dysentery	−0.34	0.570	Non-significant
TC and dysentery	−0.43	0.047	Significant
E. coli and typhoid	+0.13	0.840	Non-significant
FC and typhoid	+0.08	0.890	Non-significant
TC and typhoid	+0.08	0.900	Non-significant

Water quality assessment in the slum area

Table 4 presents the physicochemical properties of drinking water samples. The average pH was 7.61 (range: 7.34–8.00), which falls within the acceptable drinking water standard. TDS averaged 353.87 mg/L, remaining well below the recommended limit of 1,000 mg/L. TSS were negligible, with a mean value of 0.042 mg/L, reflecting generally clear water. However, EC levels were elevated, averaging 769.47 µS/cm and ranging from 684 to 917 µS/cm, suggesting a relatively high mineral concentration in the water supply.

Bacteriological data analysis

The statistical summary of the indicator bacteria found in 15 water samples from the impoverished area, including *E. coli*, FC, and TC, is shown in Table 5. Across 15 samples, *E. coli* was non-detect at the 25th–75th percentiles (median 0; max 8 CFU/100 mL). FC showed greater variability (median 8; 75th percentile 32; max 44 CFU/100 mL). TC reached 546 CFU/100 mL in one sample, indicating intermittent contamination.

Relation between water quality and morbidity

Table 6 shows the recoil analysis and coalition among microbiological water quality and morbidity, with a special focus on dysentery and diarrhea. A negative connection and a positive correlation are exhibited by both FC and *E. coli*, respectively,

Table 4 | Water samples' physicochemical parameter statistics

Parameter	Average	Minimum	Maximum	Standard deviation
pH	7.61	7.34	8	0.21
TDS (mg/L)	353.87	260	481	45.49
TSS	0.042	0.03	0.05	0.01
EC (µS/cm)	769.47	684	917	52.43

Table 5 | Statistics of indicator bacteria of water samples

		Quartile				
Indicator bacteria	No. of sample (*N*)	Minimum	25 Percentiles	Median	75 Percentiles	Maximum
E. coli (CFU/100 mL)	15	0	0	0	0	8
Fecal coliform (CFU/100 mL)	15	0	0	8	32	44
Total coliform (CFU/100 mL)	15	0	0	0	0	546

Table 6 | The relation between water quality and morbidity

	Correlation-regression analysis of microbial parameters and morbidity					
	For the incidence rate of disease			For the prevalence rate of the disease		
Variables	Coefficient (r)	p-value	t-test value ($\alpha = 0.05$)	Coefficient (r)	p-value	t-test value ($\alpha = 0.05$)
E. *coli* and diarrhea	+0.39	0.052	−34.47	−0.61	0.027	−7.37
FC and diarrhea	+0.44	0.046	−9.01	−0.57	0.032	−0.33
E. *coli* and dysentery	−0.75	0.014	−22.09	−0.41	0.049	−7.84
FC and dysentery	−0.75	0.140	−0.64	−0.37	0.530	0.97
TC and dysentery	−0.67	0.220	1.18	−0.56	0.330	1.40

with the outbreak and occurrence of diarrhea ($r = 0.44$, 0.39; $p = 0.046$, 0.052). The occurrence of dysentery is highly interrelated with both factors ($r = -0.75$; $p = 0.014$), whereas the prevalence of dysentery is softly correlated ($r = -0.41$, -0.37; $p =$ 0.049, 0.530). Dysentery and TC normally correlate ($r = -0.67$, $p = 0.220$). These results show a clear correlation between morbidity rates, dysentery, and poor water quality (see Supplementary Tables S7 and S8).

DISCUSSION

The survey revealed poor sanitation and hygiene practices, with many households utilizing unimproved latrines and ineffective handwashing techniques. Shallow tube wells near latrines increased the risk of contamination, which is a key driver of diarrheal and dysenteric illnesses among children under five (Hanchett 2003; Sujauddin). Although increased contamination risk is biologically plausible for shallow wells near latrines, most wells in our study were 200–300 ft, and roughly half were >30 ft from latrines; therefore, our ecological analyses remain exploratory. The findings reveal a clear pattern: poor sanitation infrastructure, inadequate hygiene practices, and bacteriologically contaminated water together contribute to a high burden of childhood illnesses in slum environments. While physicochemical parameters of drinking water generally met national standards, microbial contamination and unsafe sanitation practices remain significant health risks.

Diarrheal illness in children under five is influenced by various behavioral, environmental, and sociodemographic factors (Farzana *et al.* 2024). Factors including age, residence, education, household income, environmental factors like drinking water, sanitation, waste disposal, and housing, and socioeconomic factors like malnutrition and unhygienic habits are listed as influential in an Indian study (Paul 2020). In this study, children in households with poor sanitation and hygiene exhibited higher morbidity, consistent with prior research in low-income urban settings (Luby *et al.* 2018; Rahman *et al.* 2025).

Inadequate hygiene, such as washing hands or cleaning children with water only, is common in slum households and increases the risk of fecal–oral transmission, driving high childhood diarrhea rates. Similar trends are reported in South Asian slums, where low soap use is strongly linked to diarrheal disease (Ercumen *et al.* 2017; Pickering *et al.* 2018).

In our study, poor sanitation, inadequate hygiene, and microbial contamination drive high childhood diarrhea in slum households. Nearly half of families used unimproved latrines, and most caregivers cleaned children or washed their hands with water only. Shallow tube wells near latrines were linked to higher diarrhea incidence. Positive correlations between *E. coli* and FC with diarrhea, and some negative associations with dysentery, likely reflect data aggregation, seasonal variation, or alternative transmission pathways. These findings align with South Asian and less developed country studies, showing environmental contamination and hand-to-mouth exposure as key contributors to childhood diarrheal disease (Ercumen *et al.* 2017; Mostafa *et al.* 2018; Asgedom *et al.* 2023).

The World Health Organization (WHO) identifies FC, especially *E. coli*, as significant health risks in areas with poor sanitation, causing illnesses like diarrhea, dysentery, cholera, and enteric fever, which can cause serious or fatal illnesses, and are a significant public health issue (WHO 2021; Salam *et al.* 2024).

Although our study observed a negative association between some coliform indicators and dysentery/diarrhea, this pattern is not uncommon in the South Asian context. For instance, Yang *et al.* (2013) reported weak or no association between FC and diarrhea in their meta-analysis. Studies in Bangladesh also highlight the importance of alternative transmission routes. Pickering *et al.* (2018) found that *E. coli* on children's hands rather than in water was more strongly linked with subsequent diarrhea, suggesting that non-water pathways such as hand-to-mouth contact may play a larger role in disease transmission (Pickering *et al.* 2018). Similarly, Ercumen *et al.* (2017) showed that animal feces contribute substantially to household *E. coli* contamination, raising questions about using *E. coli* solely as an indicator of human pathogen risk (Ercumen *et al.* 2017). Furthermore, a report in 2021 from Bangladesh found that most *E. coli* in slum drinking water were non-pathogenic, reinforcing that its presence does not necessarily indicate disease-causing bacteria (Ferdous *et al.* 2021).

Our findings align with evidence from Bangladesh and other regions, showing that fecal contamination and poor environmental hygiene drive childhood diarrheal disease in slums. In Dhaka, Parvin *et al.* (2021) reported that feces on household compounds and source water with >100 CFU/100 mL *E. coli* increased diarrhea risk in children. Similarly, Uddin *et al.* (2023) found that visible feces near kitchens and food storage, combined with poor food hygiene, elevated diarrheal illness, highlighting the role of non-water exposure pathways. Pickering *et al.* (2018) demonstrated that *E. coli* on children's hands, rather than in water or soil, was most strongly linked to diarrhea. A global meta-analysis in 2014 found only modest associations: *E. coli* correlated with diarrhea, whereas FC showed inconsistent effects, indicating that FC alone may be an unreliable indicator of pathogen risk in complex slum environments (Gruber *et al.* 2014).

Study limitations

The findings of this study must be taken in light of limitations: the cross-sectional design impedes causal inference, self-reported morbidity may be subject to recall bias, and sampling was limited due to the rainy season. That's why we could not compare any seasonal variations of disease morbidity and other risk factors in the selected slums. Additionally, due to the limited number of slum-based samples ($n = 5$) and the use of composite sampling, the results may not consistently reflect pathogen presence or dose, and point-of-use contamination may differ from source water. In spite of these limitations, the study may make a significant contribution and leave a valuable mark on the interrelated effects of sanitation, hygiene behavior, and microbial contamination in urban slums.

Future prospects and policy directions

While studies in other countries, such as India and Ghana, highlight similar associations between sanitation and health, the native country (Bangladesh) differs in socioeconomic and climatic context and may require suitable policy interventions. Future initiatives should prioritize upgrades from kacha/semi-paka to improved latrines; promote soap use for child cleaning and caregiver handwashing; increase latrine–well separation where feasible; and institute routine POU *E. coli* monitoring with rapid feedback to households. To guarantee long-lasting, sustainable benefits, policies should also encourage home behavior changes and community involvement.

CONCLUSION

In Magura's slums, unimproved sanitation and water-only hygiene practices co-occur with a high reported burden of childhood diarrhea. Intermittent fecal contamination was observed in drinking water. Ecological correlations were exploratory and should not be interpreted causally. Over half of children under five experienced diarrheal illness in the past year, emphasizing the urgent need for targeted interventions. Expanding access to safe latrines, providing clean water through deep tube wells, improving waste management and drainage, and raising community awareness are critical steps supported by the study findings. To build on this work, future research could include longitudinal monitoring of latrine upgrades to evaluate changes in child health over time, randomized trials of hygiene education programs to assess behavior change and disease reduction, and comparative studies of water quality at source versus point-of-use to better understand contamination pathways, which would strengthen evidence-based interventions and guide policy decisions to improve child health in slum communities.

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DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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