**Association between Escherichia coli (E. coli) contamination in household drinking water and risk of childhood diarrheal disease in Bangladesh**

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**Abstract**

Escherichia coli (E. coli) is one of the most prevalent agents causing moderate-to-severe diarrhea. We aimed determine the association between E. coli contamination in the family's drinking water and diarrheal diseases of children under five years of age. In this study, data from the 2012 and 2019 waves of the Multiple Indicator Cluster Survey (MICS) were used. Colonies of E. coli were measured per 100 ml of water and divided into three risk categories. Less than one colony of E. coli contamination is considered as low risk, one to ten colonies are considered as moderate risk, and more than ten colonies is considered as high risk. Data were analyzed using logistic regression model with considering complex survey design. We discovered that children who were exposed to moderate levels of E. coli infection were 1.46 times (adjusted odds ratio (AOR) = 1.46, 95% confidence interval (CI: 0.71 - 3.01) and 1.29 times (AOR = 1.29, CI: 0.54 - 3.10) more likely to experience diarrhea than those exposed to low levels of E. coli contamination in MICS data of 2019 and 2012, respectively. Moreover, for MICS 2019 and 2012, high risk of E. coli contamination household children was 1.96 (CI: 1.06-3.63) and 1.29 (0.62-2.69) times more likely to suffer diarrhea than children from low risk of E. coli contamination group. However, all association was not statistically significant except for the high risk of E. coli contamination group of the MICS 2019. The study's conclusion makes obvious policy insinuations and advises minimizing E. coli contamination in drinking water and developing proper hygiene practices to prevent childhood diarrhea.

**Key Words:** Escherichia coli, Drinking water, Childhood disease, Diarrhea, Under-5 children

**Introduction**

Diarrhea is caused by variety of bacterial, viral, and parasite organisms, the majority of which are spread by contaminated water 1. Having at least three loose, liquid, or watery bowel motions each day is the conditions of diarrhea. Due to fluid loss, it frequently lasts for a few days and can lead to dehydration. Diarrhea may be acute, persistent, or chronic. It is one of the leading causes of pediatric sickness and mortality 2. Every year, there are around 1.7 billion cases of childhood diarrhea worldwide 3. In children under the age of five, diarrhea is one of the main causes of malnutrition. Approximately 8% of all fatalities among children under the age of five globally in 2017 were due to diarrhea. Around 525,000 children every year, or over 1,400 young children per day are dying 4. Diarrhea is the second most common cause of death in children under five 3. It is, however, both treatable and preventable by using clean water, maintain proper sanitation, and practice good hygiene 5.

In low- and middle-income nations, Escherichia coli (E. coli) is one of the most frequent etiological agents of moderate-to-severe diarrhea 3. It can be found in the intestines of mammals, including humans 6. E. coli was suspected in 138 samples, and it was discovered that 30 of these samples contained strains that were diarrheagenic 7. Salmanzadeh-Ahrabi et al. investigated at E. coli in youngsters from Tehran who had serious diarrhea 8. It was shown that diarrhea caused by E. coli occurs often in children under the age of five in Eastern Ethiopia 9. In a different study, Yu et al. (2015) evaluated 2524 patients and found that 10.7% cases had diarrhea and 4.6% causes from E. coli (4.6 percent) 10.

Around 7% of Bangladesh's children under five get affected by diarrhea 11. Around half of those surveyed claimed that diarrheal illness had cost them more than 10% of their income, with the cost of treating diarrhea in Bangladesh estimated to be $79 million in 2018 12. Water contamination by E. coli is fairly widespread in Bangladesh. According to MICS 2012 and MICS 2019, respectively, around 62% and 82% of people used contaminated drinking water with bacteria like E. coli 11,13. A recent study in Bangladesh has determined the spatial risk distribution and contributing factors of E. coli contamination in household drinking water 14. After examining data from fifty villages in rural Bangladesh, Luby et al. discovered an association between the severity of childhood diarrhea and E. coli-polluted drinking water 15.

However, there is a lack of empirical study comparing various survey data on the relationship between E. coli risk groups and diarrhea in children under five. The current study aimed to observed E. coli contamination in household drinking water in Bangladesh and its relationship to diarrheal disease in under five children. We sought to determine whether the E. coli, diarrhea and its associated factors changed in two consecutive Multiple Indicator Cluster Surveys (MICS) in Bangladesh. The results of this study will provide information that can help policymakers make decisions about how to manage E. coli in drinking water and how frequently childhood diarrhea is seen in Bangladesh.

**Material and methods**

To improve the reporting of observational cross-sectional studies in epidemiology, we adhered to the STROBE guideline (see Supplementary Materials for more details).

**Data source and sampling design**

Two reports from the Multiple Indicator Cluster Surveys (MICS) of Bangladesh, from 2012 and 2019 (<https://www>.unicef.org/), were used. To gather information at the household level for this nationwide survey, a two-stage stratified cluster sampling method was used. The final report of the Bangladesh MICS surveys from 2012 and 2019 contains information on the comprehensive survey methodology. 64,400 households participated in MICS 2019, compared to 51,895 households in MICS 2012. A randomly determined subset of 2760 and 6440 households, respectively, were chosen in MICS 2012 and MICS 2019 for water quality testing 11,13.

**Outcome variables**

The outcome variable was childhood diarrhea, which was defined if the mother's or caregivers experienced any sort of diarrheal disease with their children within two weeks prior to the survey 11,13.

**Exposure**

The exposure variable was the level of E. coli present in household water. A glass of water that the respondents often drink was requested of them to water test 11,13. In this study, 100 ml sample of drinking water was tested for E. coli and test was done within 30 minutes of sample collection. Colonies of E. coli per 100 ml of water were measured to categorized the risk of water quality 11,13. The information of level of E. coli contamination in household drinking water were categorized into different risk groups. Less than one colony of E. coli contamination is considered as low risk, one to ten colonies are considered as moderate risk, and more than ten colonies are considered as high-risk category. A more detailed description of the water quality test can be found in the Bangladesh MICS reports 11,13.

**Confounding variables**

Based on the available data, the variables child age at months, gender, and mother's educational status (None/primary incomplete, primary complete, secondary incomplete, secondary complete or higher) were included to the study. Household size (<5 or 5/5+), household wealth status (Poor, middle or rich), and other factors were taken into account. Household wealth index was calculated using a principal component analysis and separated into three groups 11,13. Place of residence (rural vs. urban) and administrative division were two variables at the community level (Barisal, Chattogram, Dhaka, Khulna, Mymensingh, Rajshahi, Rangpur and Sylhet).

In addition, toilet facility types (improved or non-improved), shared toilet facilities, and source water quality (low, moderate, and high) should all be considered. Similar to an exposure sample test, source water E. coli test was used to assess the risk of E. coli contamination in the source water.

**Statistical analysis**

In this study, the univariate (unadjusted) and Multivariable (adjusted) logistic regression models were fitted separately. Bivariate analysis was utilized to assess the distribution of the diarrhea variable with other variables. To find out the association between level of E. coli contamination and childhood diarrhea, we also fitted the logistic regression model with complex survey design. All confounding variables are included for the adjusted logistic regression model. The 95% confidence interval (CI), the crude odds ratio (COR), and the adjusted odds ratio (AOR), were presented. All investigations were performed utilizing R software 4.2.1.

The propensity score (PS) approach was used to evaluate the reliability of the conclusions from our primary studies. By balancing observed baseline factors across treatment groups, PS approaches, which are frequently employed to adjust for confounding in observational studies with dichotomous treatment modalities, imitate the intended benefits of randomization 16. All PS techniques seek to generate study populations that are comparable for the treated and untreated categories of target variable, when changes in outcome risk may be attributable to the influence of treatment alone and risk factors for the desired result are balanced at baseline. To emulate a PS weighted population, we employed the PS weighting to reweight both exposed (moderate and high) and unexposed (low) groups. A good covariate balancing (0.1) was determined between exposed and non-exposed by the standardized mean difference 17. Using the same covariates as the primary study, we computed the PS using multivariable logistic regression. To eliminate the residual covariate imbalance between the exposed and non-exposed groups, we changed the model by adding related confounders 18.

**Results**

In the 2019 MICS, among 2332 children, 10.88% of the 12- to 23-month-olds and also had diarrhea. In comparison to all other age groups, the 12- to 23-month-old age group likewise had the greatest prevalence of diarrhea (5.49%) according to the 2012 MICS. Children of mothers with no education or primary incomplete education had diarrhea in 10.17% of MICS 2019 children and 3.30% of MICS 2012 children. In the MICS for 2019 and 2012, 3.81% and 9.12%, respectively, of children from low-wealth status families reported having diarrhea, respectively. In 2019 MICS, 7.47% of children drinking from improved sources suffered diarrhea, compared to 3.61% in 2012 MICS. The 2019 MICS found that 8.48% of children came from households with high levels of E. coli contamination in the drinking water, compared to 3.59% in the 2012 MICS. Also 7.85% and 2.67%, household were used water treatment in 2019 MICS and 2012 MICS, respectively.

The logistic regression analysis between E. coli contamination groups in drinking water and childhood diarrhea in Bangladesh is shown in Table 2 by both crude and adjusted odds ratio. According to the crude odds ratio, diarrhea was linked to high-risk E. coli contamination group 2.09 (COR= 2.09; 95 percent CI: 1.17-3.72) times more often than low risk E. coli contamination group in household drinking water in the 2019 MICS report and 1.13 (COR= 1.13; 95% CI: 0.57–2.24) times more often than low risk group in the 2012 MICS report. After adjusting for confounding variables in model with 2019 MICS data, we found that children from high-risk groups had 1.96 (AOR: 1.96; 95% CI: 1.06-3.63) times higher odds of developing diarrhea from E. coli contamination in their water than children from low-risk groups and that children from high-risk groups had 1.29 (AOR: 1.29; 95% CI: 0.62–2.24) times higher odds of developing diarrhea from E. coli contamination in their water in comparison to children from low-risk groups. In both MICS reports, the odds of diarrhea were higher in the moderate risk group of water contamination than the low-risk group.

In brief, children aged 12-23 years were 1.41 (95% CI: 0.83 – 2.39) and 1.29 (95% CI: 0.75 – 2.23) times more likely to develop diarrhea in 2019 which was comparatively higher than 2012 MICS’s data [1.09 (95% CI: 0.60-2.00) and 1.02 (0.56 - 1.86)], according to crude and adjusted model. According to MICS 2019 crude model, diarrhea in female child were develop 1.02 (95% CI: 0.71 – 1.45) times more likely, which was higher in 2012 MICS 1.27 (95% CI: 0.76 – 2.12). Children from livestock ownership family were 1.09 (95% CI: 0.72-1.65) times more chance to develop diarrhea compare to children without livestock ownership family in 2019 MICS adjusted model, which is smaller in 2012 MICS crude model [0.61 (95% CI: 0.35-1.06). Children who have unimproved toilet facility access were 1.12 (95% CI: 0.39-3.23) times more chance to develop diarrhea in 2019 MICS adjusted model which is higher than 2012 MICS adjusted model. In 2012 MICS adjusted model, children who have unimproved toilet facility access were 2.04 (95% CI: 0.61-6.80) times more chance to develop diarrhea compared to improved toilet facility using family. Families of children who using water from covered container had 1.09 (95% CI: 0.52 – 2.33) times more chance to develop diarrhea, according to 2019 MICS adjusted model, which is 1.38 times in 2012 MICS (95% CI: 0.41 – 4.64) compared to families who are using water direct from the source.

In PS-weighted samples, Figure 1 shows the standardized mean difference between E. coli concentrations in household drinking water with all other covariates. The covariates were unbalanced prior to weighing, but after weighting, we saw a reasonable balance as standardized mean difference less than 0.1. The results of sensitivity analysis utilizing the PS weighting approach with the association between E. coli contamination in household drinking water and diarrhea are shown in Table 3. High risk E. coli contamination in drinking water was associated to 1.96 (95% CI: 1.06-3.63) and 1.07 (95% CI: 0.53-2.16) times higher odds of diarrhea than low risk group E. coli contamination water in 2019 MICS and 2012 MICS data, respectively, according to sensitivity analysis using the PS weighting instead of sample weight in the multivariable logistic regression model. In 2019 MICS and 2012 MICS data, E. coli contamination in the high-risk group was associated with 1.46 (95% CI: 0.71-3.01) and 1.01 (95% CI: 0.45-2.28) times higher odds of diarrhea than in the low-risk group.

**Discussion**

The study investigated the level of E. coli contamination and childhood diarrhea in under-five children in Bangladesh using data collected across the country. This study discloses the E-coli contamination in drinking water in Bangladesh which could result from educational and wealth status of household, source water type, storage status (unsafe and safe), inadequate treatment.

The findings from this study indicates that the prevalence of diarrheal disease is higher within the first 2 years of a child’s life, the risk of developing diarrheal disease is highest in children between 12 and 23 months and lowest in greater than 2 years of child. There is a myriad of evidence suggesting that diarrheal diseases are most prevalent in the first 2 years of a child’s life, thus making children aged less than 23 months being at higher risk of diarrheal diseases 19,20. This could be explained from the point that children in such early years tend to be heavily dependent on their mothers and therefore require appropriate feeding that is proportional to their age 21. Hence, when mothers slack in their responsibilities to provide safe and appropriate feeding to the children at that age, then their risk of diarrheal increases. In this period children might be exposed to unhygienic feeding practices, impure water, unhygienic utensils and unhealthy environments consumption of food containing pathogens that cause diarrhea 22,23. Children above the age of 6 months are at the age where they are introduced to foods other than breast milk, this may expose their undeveloped immunity to infectious agents causing diarrhea. Besides children at these ages will start to crawl, thus they may pick dirt or other contaminated objects and take to their mouth 24.

In this study, households that drank water from covered containers had a higher incidence of childhood diarrhea. According to a nationally representative water quality assessment, E. coli was present in 41% of all improved water sources studied across Bangladesh 25. Contamination may happen in the distribution system as a result of frequent pipe breaks and unauthorized connections, low or negative water pressure from sporadic service, inadequate domestic water storage facilities, or all of the above 26. This study is consistent with the study Derashe district, Southern Ethiopia and Pawi Special District in Benishangul-Gumuz Region 27. Since unprotected sources are those with no barrier or other structure to protect the water from contamination; they can get contaminated easily and cause diarrhea while ingested. Unprotected water sources are also important source of diarrhea causing intestinal parasites like giardiasis 28. Factors such as unsafe storage, interrupted supply of piped water, an untreated source used for piped water supply and irregular use of the improved sources are all associated with microbial contamination and a subsequent increase in diarrhoea incidence 29,30.

Water source pollution may be caused by a variety of environmental factors, such as tube wells near ponds and latrines. And results from different study evince that, the establishment of tube wells near the latrines can be the major cause of contamination of drinking water at the source. In this case, water treatment can meager the risk of water contamination from difference sources. When water from storage pots is touched with dirty hands, water storage containers (like a kolshi, bucket, or jug) might get contaminated. This is true even for relatively clean sources of water where contamination levels are low enough, like tube wells 11.

This study looked into the possibility that children from low-income households were more likely to having diarrhea. Similar research showed that middle-class or low-income household with high E. coli contamination at the source had a 90% chance of having high levels of contamination in their household drinking water 31. This corroborates previous related studies from Bangladesh 32, that also reported higher risk of diarrhea among children belonging to poor households. Therefore, the pivotal reason for the decline in water quality is point of use pollution of water storage. Additionally, unsanitary practices such not washing hands with soap before preparing, eating, and defecating can contribute to water pollution at the point of use. This could be justified from the perspective that poorer households have difficulty to get pure water which may exacerbate their risk of diarrheal disease. Finally, children may be impacted by the high degree of contamination in drinking water due to E. coli and other harmful organisms that cause diarrhea 33.

This study discovered a stronger link between diarrhea and place of residence, despite the fact that flooding during the summer is supposed to increase diarrhea transmission because contaminated matter can be moved from source sites to nearby locations more easily in rural area rather than urban area 34. We also found statistically significant association between geographical region and the risks of diarrheal disease. It was found that children who lived in Barisal region were at higher risk of developing diarrheal disease. This is consistent with previous studies from Bangladesh 21, that also found similar findings in relation to the regional differences in the prevalence of diarrheal disease. According to Sarker et al21 regions like Barisal are densely populated and is also characterized by the existence of more rivers and water reservoirs that create an enabling environment for diarrhoeal disease to spread among the population. Perhaps, this could be the reason for the high prevalence of ARI and CDD within the Barisal region. This could be because these regions, especially in Barisal, Dhaka, and Chittagong, divisions have more rivers, water reservoirs, natural hazards, and densely populated areas than the other areas; however, most of the slums are located in Dhaka and Chittagong regions, which are already proven to be at high risk for diarrheal-related illnesses because of the poor sanitation system and lack of potable water 21 .

In this study, the incidence of E coli diarrhea is clearly related to wealth status, education of mother, hygiene, general sanitation, and the opportunity for contact. Begum and her colleagues also reported a higher diarrhoeal prevalence among children aged below 5 years in the similar setting and found that water, sanitation and hygiene education to the mothers was effective to reduce the burden of diarrhea 35. Higher parental educational levels have great importance in the prevention and control of morbidity because knowledge about prevention and promotional activities reduces the risk of infectious diseases in children of educated parents 36,37. However, in Bangladesh, it was found that higher educational levels are also associated with improved toilet facilities in both rural and urban settings, which means better access to sanitation and hygiene in the household 38. Consistent with other studies in Bangladesh, we found that the provision of an improved sanitation facilities reduced the prevalence of childhood diarrhea among under five children 39,40. The simple explanation might be that the availability of latrine reduces fecal contamination of the environment and also it reduces the chance of mechanical vectors’ access to diarrhea-causing organisms thereby reducing diarrheal disease.

The same finding is also reported in previous research that that the improvement of both water and sanitation facilities were associated with a reduced risk of diarrheal disease 41. This because most of the common cause of diarrheal illnesses in under-five children are hygiene related in the prepation and serving of foods to children. Thus, sanitation facilities such as improved latrines and hand hygiene can decrease the transmission of bacterial pathogens between childrens and the environment 42.

Outbreaks of diarrhea involving contaminated water supplies or food have been found in adults in the United States and Japan 43. This phenomenon is not readily explained, but contributing factors are low levels of immunity and an increased opportunity for infection.

**Strengths and limitations**

This study basically based on recent MICS data in the context on developmental status of Bangladeshi children. We used a sufficiently large nationally representative dataset, which represents the respective children and women of Bangladesh. We considered a great variety of influential factors that affect the dependent variable. This study however is not devoid of some drawbacks. The selection variables, data quality, and indicator measurement were out of control because the data was secondary data. Furthermore, it is challenging to determine the relationship between the exposure and the outcome variable due to the cross-sectional data. To distinguish between pathogenic and non-pathogenic E. coli, our E. coli definition falls short. We don’t get any potential contaminants other than E-coli bacteria that result in childhood diarrhea. No microbiological testing of such water sources was done to determine levels of contamination and evaluate water quality, even though it was known which water sources were used for which household and private uses.

**Recommendations**

The findings of our study have some potential implications for our policy makers. Different government and non-government organizations, international agencies and public health professional who work for the betterment of children health can initiate awareness rising activities to make aware about E-coli contamination in drinking water. For this, the awareness-raising campaign should also emphasize educating people how to use water that has been tested or inspected by the appropriate authorities. The relevant authorities must carry out the awareness-raising initiatives. In Bangladesh it is found that high education level of parents has sense about the sanitation and hygiene of their children. The household access to electronic media can seek concern of public for childhood diarrhea. Specially, the young women are likely to be more exposed than older women can contribute for better health seeking behavior of younger mother. Future research should concentrate on both the amount and quality of water in Bangladesh’s rural villages. Water storage capabilities play a role in how much water is available for washing and cleaning in the home.

**Conclusion**

Diarrhea is still an important public health issue in children younger than 5 years in Bangladesh. The current investigation revealed a substantial correlation between E. coli contamination in drinking water and instances of childhood diarrhea as well as a high degree of E. coli contamination in drinking water. As the prevalence of diarrhea and behavior of mothers in Bangladesh is patterned by their age, wealth, educational status, ethnicity interventions should focus the mothers of low-income country like Bangladesh. Additionally, appropriate authorities should improve drinking water management (such as handling practices, treatment, and storage) and make sure that water supplies are safe, help modify personal hygiene behavior, improve health literacy and engaging community health workers in the prevention of diarrhea prevention, control and treatment.

**Tables and Figures**

**Table 1 Frequency distribution of diarrhea among children younger than 5 years of MICS 2019 and MICS 2012 data in Bangladesh.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Characteristics | MICS 2019 | | | MICS 2012 | | |
| Diarrhea | | | Diarrhea | | |
|  | Yes | No | Total | Yes | No | Total |
| Total | 173 (7.42) | 2159 (92.58) | 2332 (100.00) | 74 (3.7) | 2000 (96.3) | 2074 (100.00) |
| Child Characteristics | | | | | | |
| Age |  |  |  |  |  |  |
| 0-11 | 38 (7.96) | 438 (92.04) | 476 (20.40) | 21 (5.04) | 387 (94.96) | 408 (19.64) |
| 12-23 | 49 (10.88) | 398 (89.12) | 446 (19.14) | 25 (5.49) | 439 (94.51) | 464 (22.40) |
| 24-35 | 37 (7.79) | 440 (92.21) | 478 (20.48) | 13 (3.15) | 394 (96.85) | 407 (19.62) |
| 36-47 | 29 (6.17) | 443 (93.83) | 472 (20.23) | 9 (2.23) | 382 (97.77) | 391 (18.84) |
| 48-59 | 20 (4.35) | 440 (95.65) | 460 (19.74) | 6 (1.57) | 398 (98.43) | 404 (19.50) |
| Sex |  |  |  |  |  |  |
| Male | 91 (7.35) | 1152 (92.65) | 1244 (53.33) | 34 (3.17) | 1028 (96.83) | 1062 (51.21) |
| Female | 81 (7.48) | 1007 (92.52) | 1088 (46.67) | 40 (3.98) | 971 (96.02) | 1011 (48.79) |
| Maternal Characteristics | | | | | |  |
| Education Status |  |  |  |  |  |  |
| None/Primary incomplete | 28 (10.17) | 248 (89.83) | 276 (11.86) | 24 (3.30) | 690 (96.70) | 714 (34.42) |
| Primary Complete | 30 (5.59) | 513 (94.41) | 543 (23.31) | 12 (3.53) | 317 (96.47) | 329 (15.85) |
| Secondary | 91 (7.88) | 1059 (92.12) | 1150 (49.31) | 32 (4.40) | 704 (95.60) | 736 (35.50) |
| Secondary Complete/ Higher | 24 (6.52) | 338 (93.48) | 362 (15.53) | 6 (2.16) | 288 (97.84) | 295 (14.22) |
| Household Characteristics | | | | | | |
| Household size |  |  |  |  |  |  |
| <5 | 76 (7.89) | 884 (92.11) | 960 (41.18) | 47 (3.91) | 1165 (96.09) | 1213 (58.51) |
| 5/5+ | 97 (7.07) | 1275 (92.93) | 1372 (58.82) | 26 (3.07) | 834 (96.92) | 860 (41.49) |
| Livestock ownership |  |  |  |  |  |  |
| Yes | 102 (7.39) | 1276 (92.61) | 1378 (59.14) | 47 (3.98) | 1139 (96.02) | 1186 (57.31) |
| No | 71 (7.45) | 881 (92.55) | 952 (40.86) | 27 (3.02) | 857 (96.98) | 883 (42.69) |
| Wealth status |  |  |  |  |  |  |
| Poor | 90 (9.12) | 894 (90.88) | 984 (42.19) | 36 (3.81) | 903 (96.19) | 939 (45.28) |
| Middle | 23 (5.10) | 425 (94.90) | 448 (19.21) | 15 (3.56) | 398 (96.44) | 412 (19.90) |
| Rich | 60 (6.70) | 840 (93.30) | 900 (38.59) | 23 (3.25) | 698 (96.75) | 722 (34.82) |
| Source water type |  |  |  |  |  |  |
| Improved | 171 (7.47) | 2120 (92.53) | 2291 (98.27) | 73 (3.61) | 1944 (96.39) | 2017 (97.28) |
| Unimproved | 2 (3.77) | 39 (96.23) | 40 (1.73) | 1 (1.79) | 55 (98.21) | 56 (2.72) |
| Toilet facility type |  |  |  |  |  |  |
| Improved | 168 (7.44) | 2083 (92.56) | 2251 (96.54) | 69 (3.45) | 1915 (96.54) | 1984 (95.69) |
| Non-improved | 5 (6.43) | 76 (93.57) | 81 (3.46) | 5 (5.98) | 84 (94.02) | 89 (4.31) |
| Toilet facility shared |  |  |  |  |  |  |
| Yes | 58 (7.85) | 675 (92.15) | 733 (31.81) | 14 (2.67) | 514 (97.33) | 528 (25.77) |
| No | 115 (7.32) | 1456 (92.68) | 1571 (68.19) | 59 (3.86) | 1462 (96.14) | 1520 (74.23) |
| Household water E. coli concentration |  |  |  |  |  |  |
| Low | 16 (4.25) | 369 (95.75) | 386 (16.54) | 13 (3.19) | 383 (96.81) | 396 (19.08) |
| Moderate | 31 (6.63) | 438 (93.37) | 469 (20.10) | 14 (3.88) | 359 (96.12) | 373 (18.00) |
| High | 125 (8.48) | 1352 (91.52) | 1477 (63.36) | 47 (3.59) | 1258 (96.41) | 1305 (62.92) |
| Source of water |  |  |  |  |  |  |
| Direct from source | 11 (7.37) | 134 (92.63) | 145 (6.21) | 3 (2.51) | 106 (97.49) | 108 (5.26) |
| Covered container | 117 (7.99) | 1346 (92.01) | 1463 (62.86) | 48 (3.70) | 1259 (96.30) | 1307 (63.35) |
| Uncovered container | 45 (6.28) | 675 (93.73) | 720 (30.93) | 23 (3.52) | 625 (96.48) | 648 (31.39) |
| Source water E. coli concentration |  |  |  |  |  |  |
| Low | 96 (7.25) | 1227 (92.75) | 1323 (57.37) | 49 (4.00) | 1186 (96.00) | 1235 (60.50) |
| Moderate | 39 (7.44) | 488 (92.56) | 527 (22.86) | 13 (2.67) | 476 (97.33) | 489 (23.98) |
| High | 38 (8.23) | 418 (91.76) | 456 (19.77) | 10 (3.24) | 307 (96.76) | 317 (15.52) |
| Water treatment |  |  |  |  |  |  |
| Yes | 58 (7.85) | 675 (92.15) | 733 (31.81) | 14 (2.67) | 514 (97.33) | 528 (25.77) |
| No | 115 (7.32) | 1456 (92.68) | 1571 (68.19) | 59 (3.86) | 1462 (97.14) | 1520 (74.23) |
| Community characteristics | | | | | | |
| Place of residence |  |  |  |  |  |  |
| Rural | 36 (7.49) | 438 (92.51) | 474 (20.33) | 18 (4.17) | 423 (95.82) | 441 (21.29) |
| Urban | 137 (7.39) | 1720 (92.61) | 1858 (79.67) | 55 (3.40) | 1576 (96.60) | 1632 (78.71) |
| Division |  |  |  |  |  |  |
| Barisal | 23 (17.34) | 108 (82.66) | 131 (5.62) | 2 (2.09) | 117 (97.91) | 119 (5.74) |
| Chattogram | 38 (7.18) | 496 (92.82) | 534 (22.92) | 20 (3.95) | 488 (96.05) | 508 (24.53) |
| Dhaka | 38 (7.00) | 500 (93.00) | 537 (23.04) | 19 (3.16) | 580 (96.84) | 598 (28.87) |
| Khulna | 15 (6.67) | 212 (93.33) | 228 (9.76) | 10 (4.43) | 211 (95.57) | 221 (10.64) |
| Mymensingh | 23 (12.56) | 158 (87.44) | 181 (7.77) | - | - | - |
| Rajshahi | 15 (5.26) | 278 (94.74) | 293 (12.58) | 6 (2.62) | 226 (97.38) | 232 (11.21) |
| Rangpur | 14 (5.68) | 235 (94.32 | 249 (10.67) | 11 (4.30) | 242 (95.70) | 253 (12.18) |
| Sylhet | 7 (3.69) | 172 (96.31) | 178 (7.64) | 6 (4.01) | 136 (95.99) | 142 (6.83) |

**Table 2 Association with level of E. coli contamination in household drinking water and childhood diarrhea in Bangladesh.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | MICS 2019 | | | | MICS 2012 | | | |
|  | Crude odds ratio | p-value | Adjusted odds ratio | p-value | Crude odds ratio | p-value | Adjusted odds ratio | p-value |
| Age |  |  |  |  |  |  |  |  |
| 0-11 | Reference |  | Reference |  | Reference |  | Reference |  |
| 12-23 | 1.41 (0.83 – 2.39) | 0.200 | 1.29 (0.75 - 2.23) | 0.351 | 1.09 (0.60 - 2.00) | 0.770 | 1.02 (0.56 - 1.86) | 0.957 |
| 24-35 | 0.98 (0.57 – 1.66) | 0.931 | 0.89 (0.51 - 1.55) | 0.688 | 0.61 (0.29 - 1.28) | 0.193 | 0.52 (0.24 - 1.11) | 0.092 |
| 36-47 | 0.76 (0.41 – 1.39) | 0.373 | 0.73 (0.39 - 1.37) | 0.331 | 0.43 (0.16 - 1.17) | 0.098 | 0.39 (0.14 - 1.06) | 0.065 |
| 48-59 | 0.53 (0.27 – 1.01) | 0.054 | 0.48 (0.25 - 0.94) | 0.031\* | 0.30 (0.13 - 0.70) | 0.006\*\* | 0.23 (0.09 - 0.57) | 0.001\*\* |
| Sex |  |  |  |  |  |  |  |  |
| Male | Reference |  | Reference |  | Reference |  | Reference |  |
| Female | 1.02 (0.71 – 1.45) | 0.916 | 1.00 (0.69 - 1.45) | 0.991 | 1.27 (0.76 - 2.12) | 0.367 | 1.33 (0.78 - 2.27) | 0.301 |
| Education Status |  |  |  |  |  |  |  |  |
| None/Primary incomplete | Reference |  | Reference |  | Reference |  | Reference |  |
| Primary Complete | 0.52 (0.28 – 0.97) | 0.041 | 0.48 (0.25 - 0.94) | 0.032\* | 1.07 (0.55 - 2.09) | 0.837 | 1.28 (0.62 - 2.65) | 0.508 |
| Secondary | 0.76 (0.44 – 1.31) | 0.317 | 0.77 (0.42 - 1.41) | 0.394 | 1.35 (0.76 - 2.39) | 0.309 | 1.60 (0.88 - 2.93) | 0.123 |
| Secondary Complete/ Higher | 0.62 (0.31 – 1.23) | 0.170 | 0.65 (0.30 - 1.40) | 0.274 | 0.65 (0.26 - 1.59) | 0.341 | 0.67 (0.21 - 2.16) | 0.504 |
| Household size |  |  |  |  |  |  |  |  |
| Small (<5) | Reference |  | Reference |  | Reference |  | Reference |  |
| Large (5/5+) | 0.89 (0.61 – 1.28) | 0.528 | 0.86 (0.56 - 1.32) | 0.477 | 0.78 (0.46 - 1.31) | 0.349 | 0.71 (0.40 - 1.26) | 0.245 |
| Livestock ownership |  |  |  |  |  |  |  |  |
| Yes | Reference |  | Reference |  | Reference |  | Reference |  |
| No | 1.01 (0.70 – 1.46) | 0.967 | 1.09 (0.72 - 1.65) | 0.675 | 0.75 (0.46 - 1.23) | 0.254 | 0.61 (0.35 - 1.06) | 0.078 |
| Wealth status |  |  |  |  |  |  |  |  |
| Poor | Reference |  | Reference |  | Reference |  | Reference |  |
| Middle | 0.54 (0.30 – 0.95) | 0.031 | 0.55 (0.31 - 0.97) | 0.039\* | 0.93 (0.51 - 1.70) | 0.816 | 0.81 (0.43 - 1.54) | 0.522 |
| Rich | 0.72 (0.48 – 1.07) | 0.099 | 0.72 (0.43 - 1.20) | 0.204 | 0.85 (0.48 - 1.51) | 0.576 | 0.65 (0.30 -1.41) | 0.275 |
| Source water type |  |  |  |  |  |  |  |  |
| Improved | Reference |  | Reference |  | Reference |  | Reference |  |
| Unimproved | 0.48 (0.17 – 1.40) | 0.180 | 0.32 (0.09 - 1.16) | 0.084 | 0.49 (0.07 - 3.62) | 0.482 | 0.66 (0.09 -5.06) | 0.687 |
| Toilet facility type |  |  |  |  |  |  |  |  |
| Improved | Reference |  | Reference |  | Reference |  | Reference |  |
| Non-improved | 0.85 (0.35 – 2.08) | 0.728 | 1.12 (0.39 - 3.23) | 0.841 | 1.78 (0.65 - 4.84) | 0.261 | 2.04 (0.61 - 6.80) | 0.245 |
| Toilet facility shared |  |  |  |  |  |  |  |  |
| Yes | Reference |  | Reference |  | Reference |  | Reference |  |
| No | 0.93 (0.63 – 1.37) | 0.700 | 0.91 (0.59 - 1.41) | 0.674 | 1.47 (0.83 - 2.58) | 0.184 | 1.46 (0.76 - 2.81) | 0.254 |
| Household water E. coli concentration |  |  |  |  |  |  |  |  |
| Low | Reference |  | Reference |  | Reference |  | Reference |  |
| Moderate | 1.60 (0.79 – 3.25) | 0.193 | 1.37 (0.66 - 2.84) | 0.398 | 1.23 (0.54 - 2.78) | 0.628 | 1.25 (0.53 -2.97) | 0.613 |
| High | 2.09 (1.17 – 3.72) | 0.012 | 1.93 (1.02 - 3.63) | 0.042\* | 1.13 (0.57 - 2.25) | 0.727 | 1.25 (0.60 - 2.60) | 0.556 |
| Source of water |  |  |  |  |  |  |  |  |
| Direct from source | Reference |  | Reference |  | Reference |  | Reference |  |
| Covered container | 1.09 (0.52 – 2.28) | 0.816 | 1.09 (0.52 - 2.33) | 0.814 | 1.49 (0.42 - 5.36) | 0.537 | 1.38 (0.41 - 4.64) | 0.599 |
| Uncovered container | 0.84 (0.38 – 1.88) | 0.673 | 0.92 (0.40 - 2.10) | 0.837 | 1.42 (0.39 - 5.22) | 0.597 | 1.38 (0.36 - 5.30) | 0.643 |
| Source water E. coli concentration |  |  |  |  |  |  |  |  |
| Low | Reference |  | Reference |  | Reference |  | Reference |  |
| Moderate | 1.03 (0.64 – 1.65) | 0.911 | 0.93 (0.56 - 1.54) | 0.774 | 0.66 (0.34 - 1.28) | 0.216 | 0.61 (0.29 - 1.28) | 0.190 |
| High | 1.15 (0.73 – 1.82) | 0.556 | 1.00 (0.60 - 1.69) | 0.990 | 0.80 (0.39 - 1.65) | 0.552 | 0.78 (0.34 - 1.76) | 0.551 |
| Water treatment |  |  |  |  |  |  |  |  |
| Yes | Reference |  | Reference |  | Reference |  | Reference |  |
| No | 0.95 (0.51 – 1.77) | 0.875 | 0.79 (0.40 - 1.56) | 0.498 | 1.05 (0.46 - 2.40) | 0.913 | 0.84 (0.33 -2.13) | 0.720 |
| Place of residence |  |  |  |  |  |  |  |  |
| Rural | Reference |  | Reference |  | Reference |  | Reference |  |
| Urban | 0.99 (0.62 -1.56) | 0.948 | 0.92 (0.56 - 1.53) | 0.757 | 0.81 (0.40 - 1.62) | 0.548 | 0.68 (0.32 -1.44) | 0.310 |
| Division |  |  |  |  |  |  |  |  |
| Sylhet | Reference |  | Reference |  | Reference |  | Reference |  |
| Barisal | 5.48 (2.08 – 14.42) | <0.001 | 5.12 (1.83 - 14.26) | 0.002\*\* | 0.51 (0.14 - 1.80) | 0.297 | 0.41 (0.11 - 1.58) | 0.194 |
| Chattogram | 2.02 (0.78 – 5.20) | 0.145 | 2.22 (0.86 - 5.77) | 0.101 | 0.98 (0.39 - 2.48) | 0.971 | 1.01 (0.38 - 2.72) | 0.985 |
| Dhaka | 1.97 (0.75 – 5.15) | 0.169 | 1.97 (0.73 - 5.32) | 0.182 | 0.78 (0.31 - 1.99) | 0.602 | 0.67 (0.24 - 1.83) | 0.435 |
| Khulna | 1.87 (0.69 – 5.04) | 0.218 | 2.19 (0.76 - 6.31) | 0.147 | 1.11 (0.43 - 2.88) | 0.832 | 0.94 (0.36 - 2.50) | 0.908 |
| Mymensingh | 3.75 (1.36 – 10.31) | 0.010 | 3.82 (1.35 - 10.85) | 0.012 | - | - | - | - |
| Rajshahi | 1.45 (0.51 – 4.14) | 0.486 | 1.53 (0.49 - 4.79) | 0.464 | 0.64 (0.21 - 2.01) | 0.448 | 0.59 (0.19 - 1.87) | 0.370 |
| Rangpur | 1.57 (0.56 – 4.40) | 0.388 | 1.82 (0.60 - 5.54) | 0.291 | 1.08 (0.41 - 2.80) | 0.882 | 0.84 (0.32 - 2.23) | 0.729 |

**Table 3 Exploring the relationship between the categories of E. coli contamination and childhood diarrhea in household drinking water in Bangladesh using sensitivity analysis and the propensity score weighting method.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | MICS 2019 | | MICS 2012 | |
|  | Adjusted odds ratio | p-value | Adjusted odds ratio | p-value |
| Exposure group |  |  |  |  |
| Low | Ref |  | Ref |  |
| Moderate | 1.46 (0.71 – 3.01) | 0.301 | 1.01 (0.45 – 2.28) | 0.981 |
| High | 1.96 (1.06 – 3.63) | 0.032 | 1.07 (0.53 – 2.16) | 0.847 |



Supplementary files

|  |
| --- |
| E:\Update - Ecoli\Rplot02.tiff |
| MICS 2019 |
| E:\Update - Ecoli\Rplot06.tiff |
| MICS 2012 |

**Fig. 1 Categories of E. coli contaminations in unweighted and propensity score-weighted samples with Standardized mean differences (SMD) in household drinking water in Bangladesh**

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