**Trends in the prevalence and association between Escherichia coli (E. coli) contamination in household drinking water and the 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 was to ascertain whether E. coli contamination of the household drinking water and childhood under five years of age diarrheal illnesses. 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

1. 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. The spatial risk distribution and underlying causes of E. coli contamination in household drinking water have been identified by a recent study conducted in Bangladesh 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.

1. 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).

* 1. 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.

* 1. 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.

* 1. 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.

* 1. Confounding variables

Based on the available data, the variables child age at months, gender, and mother's educational status 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, types of toilet facility, 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.

* 1. 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, 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, widely used in observational studies with dichotomous variables, 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.

1. 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.

Table 2 shown the logistic regression analysis between E. coli contamination levels in drinking water and childhood diarrhea in Bangladesh 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.

Briefly, according to crude and adjusted models, 12-23 years’ children were 1.41 (95% CI: 0.83-2.39) and 1.29 (95% CI: 0.75-2.23) times more likely to suffer diarrhea in 2019 than they were in 2012 [1.09 (95% CI: 0.60-2.00) and 1.02 (95% CI: 0.56-1.86)]. The crude MICS 2019 model indicates that diarrhea in female children is 1.02 (95% CI: 0.71 - 1.45), which is higher than the crude MICS 2012 model's estimate of 1.27 (95% CI: 0.76 - 2.12). In the 2019 MICS adjusted model, children from livestock-owning families had a 1.09 (95% CI: 0.72-1.65) times greater likelihood of developing diarrhea than children from non-livestock-owning families, a difference that was less in the 2012 MICS adjusted model [0.61 (95 percent CI: 0.35-1.06). In the 2019 MICS adjusted model, children who have access to unimproved toilet facilities had a 1.12 (95 percent CI: 0.39 – 3.23) times higher risk of developing diarrhea than in the 2012 MICS adjusted model. When compared to families who used better toilet facilities, children who had unimproved toilet facility access had a 2.04 (95% CI: 0.61-6.80) times higher risk of developing diarrhea in 2012 MICS adjusted model. According to the 2019 MICS adjusted model, families with children who use water from covered containers have a 1.09 (95% CI: 0.52–2.33) times higher risk of developing diarrhea than families who use water directly from the source, which is down from 1.38 (95% CI: 0.41–4.64) in the 2012 MICS.

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. Table 3 shown the findings of a sensitivity analysis using the PS weighting method in relation to the association between E. coli contamination in household drinking water and diarrhea.

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.

1. 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.

According to the findings, children between the ages of 12 and 23 months and children older than 2 years have the highest chance of contracting diarrheal disease. The first two years of a children life are more common of diarrheal disease. Numerous pieces of evidence point to the first two years of a child's life as the time when diarrheal infections are most common, making infants less than 23 months more susceptible to them 19,20. This could be explained by the fact that young children are typically very reliant on their moms and hence require nutrition that is appropriate for their age 21. Therefore, children's risk of developing diarrheal illness increases when mothers neglect their duties to give them safe and appropriate food at that age. The ingestion of food contaminated with germs that cause diarrhea during this time may expose children to unclean feeding methods, dirty water, filthy utensils, and unhealthy settings. Children over the age of six months are starting to be introduced to meals other than breast milk, which could compromise their immunizations against infectious agents that cause diarrhea 22,23. Additionally, toddlers at this age will begin to crawl, making it possible for them to pick up dirt or other contaminated objects and put them in their mouths 24. In Japan and the United States, outbreaks of diarrhea in adults have been linked to tainted food or water sources 43. Low levels of immunity and an increased risk of infection are contributory variables, yet this phenomenon is difficult to explain.

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. The distribution system may become contaminated due to frequent pipe breaks and unauthorized connections, low or negative water pressure from intermittent service, insufficient household water storage facilities, all of the above, or any combination of the above 26. This study is congruent with research from the Pawi Special District in Benishangul-Gumuz Region and the Derashe district in Southern Ethiopia 27. Unprotected sources, which are those without a barrier or other structure to shield the water from contamination, are more likely to get contaminated and to give rise to diarrhea when consumed. Unprotected water sources are a significant source of intestinal parasites like giardiasis 28, which cause diarrhea. Microbial contamination and a rise in the prevalence of diarrhea are both related to factors including improper storage, interrupted piped water delivery, an untreated source used for the supply, and irregular usage of the improved sources 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. Water storage containers (such as a kolshi, bucket, or jug) may get polluted when water from storage pots is touched with unclean hands. This is true even for very pristine water sources, such as tube wells, where contamination levels are sufficiently low 11. The same conclusion—that better water and sanitation facilities were linked to a lower risk of diarrheal disease—was also made in earlier studies—is repeated here 41.

This study looked into the possibility that children from low-income households were more likely to having diarrhea. Similar studies revealed that middle-class or low-income households had a 90% risk of having high levels of contamination in their household drinking water if there was high E. coli contamination at the source 31. This supports other research from Bangladesh that were related to this and found that children from low-income households had a higher risk of developing diarrhea 32. As a result, point-of-use pollution of water storage and middle-class or lower-class families' inability to maintain safe water storage are the main causes of the reduction in water quality. This could be supported by the fact that it can be difficult for poorer households to obtain clean water, which may increase their risk of developing diarrheal disease. The high level of pollution in drinking water caused by dangerous bacteria like E. coli and other organisms that cause diarrhea may also have an effect on children 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. Additionally, we discovered a statistically significant association between geographic location and the likelihood of developing diarrhea. The Barisal region was shown to have the highest risk of diarrheal illness in children, followed by Mymensingh, Chattogram, Dhaka, and so on. This is in line with earlier research from Bangladesh that discovered comparable results in respect to regional variations in the prevalence of diarrheal illness 21. Regions like Barisal, according to Sarker et al. 21, are defined by being more densely populated and having more rivers and water reservoirs, both of which promote an environment that is conducive to the spread of diarrheal disease among the inhabitants. The regions have more rivers, water reservoirs, and high populated areas than other places, especially those in the Barisal, Dhaka, and Chittagong divisions. The majority of the slums, however, are located in the Dhaka and Chittagong areas, which have already been shown to have a significant risk of diarrhea-related diseases due to the inadequate sanitation system and lack of drinkable water 21. High prevalence of diarrheal infections in these areas may have this as the more plausible cause.

As was already mentioned, there is a direct correlation between the likelihood of contracting E. coli diarrhea and factors such as maternal education, wealth status, personal hygiene, and general sanitation. Begum and her colleagues discovered that providing mothers with information on water, sanitation, and hygiene was an effective way to lessen the burden of diarrhea in children under the age of five, who had a greater prevalence of diarrhea 35. Higher parental education levels are crucial for the prevention and control of morbidity because informed parents can lower their children's risk of contracting infectious diseases through education and other preventative measures 36,37. However, it was found that in Bangladesh, higher levels of education are also linked to better toilet facilities in both rural and urban settings, which means better access to sanitation and hygiene in the families 38. In line with other research conducted in Bangladesh, we discovered that the availability of better sanitary facilities decreased the prevalence of childhood diarrhea among children under the age of five 39,40. The most straightforward explanation would be that having access to latrines minimizes fecal contamination of the environment and the likelihood that mechanical vectors will come into contact with organisms that cause diarrhea, hence reducing diarrheal disease. This is due to the fact that the majority of prevalent causes of diarrheal diseases in children under five are hygiene-related in terms of food serving and predation. In order to reduce the spread of bacterial infections between children and the environment, sanitation infrastructure such as upgraded latrines and hand hygiene are also important 42.

1. Conclusion

In Bangladesh, children under the age of five still frequently experience diarrhea as a serious public health issue. 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. The mothers of low-income countries like Bangladesh should be the main target because the prevalence of diarrhea and the behavior of mothers in that nation are influenced by factors like age, wealth, and educational attainment. Public health professionals, community-based organizations, and policymakers should concentrate on educating the public about the use of safe drinking water. 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.

1. 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. However, 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.

1. 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. Particularly, the young mother is more likely to be exposed than the older mother due to the older mother's superior health-seeking behaviors. 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.

CRediT Authorship Contribution Statement

Md Jamal Uddin: Conceptualization, Supervision, Writing-Reviewing and Editing. Mohammad Nayeem Hasan: Methodology, Formal Analysis, Writing-original draft. Muhammad Abdul Baker Chowdhury: Supervision, Methodology, Writing-Reviewing and Editing. Maya Biswas: Methodology, Data curation, Moumita Paul: Methodology, Data curation, Tanvir Ahammed: Methodology, Data curation.

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**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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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) | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 | Ref. |  | Ref. |  | Ref. |  | Ref. |  |
| 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 |

*Ref. = Reference*

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 |

*Ref. = Reference*

Supplementary files

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

Figure S1. Categories of E. coli contaminations in unweighted and propensity score-weighted samples with Standardized mean differences (SMD) in household drinking water in Bangladesh