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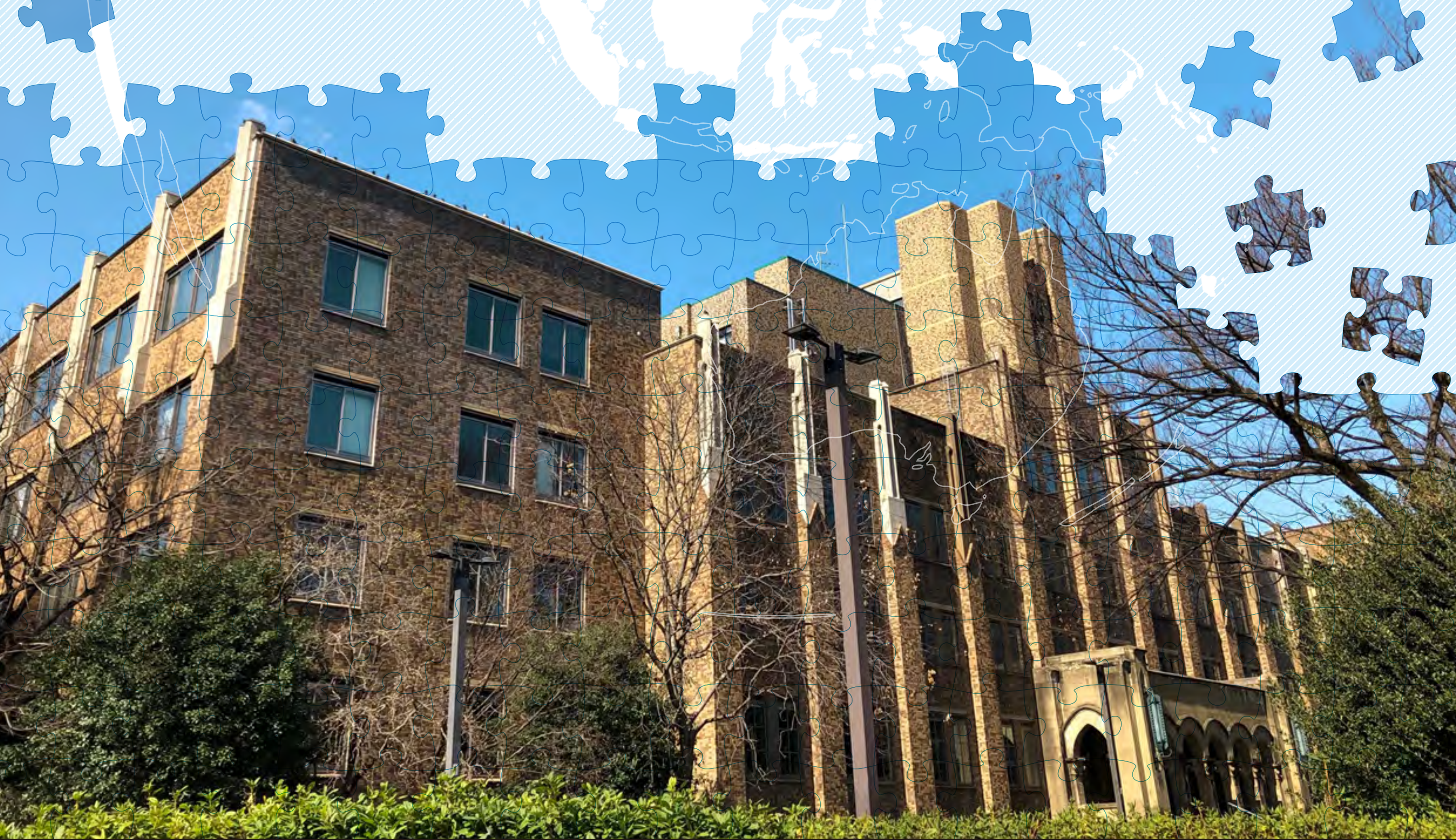
Impact of Contamination Free Water Usage on Child Health Condition: Evidence from Low Income Households



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101	October.2024	3 GOOD HEALTH AND WELL-BEING; 6 CLEAN WATER AND SANITATION

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Impact of Contamination Free Water Usage on Child Health Condition: Evidence from Low Income Households

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Abstract: Low income households frequently struggle with the challenge of ensuring access to clean water. The usage of contaminated water exposes individuals to a myriad of diseases. This study aims to examine the impact of contamination free water usage on the health status of children of low income households, leveraging data from Luby et al. (2015) who conducted Randomized Control Trial to examine the impact of the installation chlorine dispenser on improvement of water quality. We used their treatment variable the installation chlorine dispenser as an instrumental variable and their outcome variable, contamination free water usage, as our treatment variable. The study considered 602 children aged more than one year to four years from two low-income communities living in Dhaka as units of analysis. The results show a significant improvement in health conditions of children as a result of using contamination free water. Specifically, the probabilities of respiratory disease and diarrhea occurrence decrease at the 1% significance level as a result of using contamination free water.

Key Words: Water Quality, Child Health, Disinfection, Contamination free water

1. Introduction

World Water Day is organized by the United Nations every year to raise awareness of the value of freshwater and the need for sustainable management of freshwater resources (Stoler et al., 2012). Access to safe water is considered as a basic human right but very few households can afford contamination free water (Langford, 2005). Up to 2017, 2.2 billion people lack access to safe water and 579 million people depend on untreated water sources (Chowdhury et al., 2021). The surface and underground aquifers near the rivers or canals are main sources of drinking water (Daud et al., 2017). Unfortunately, the quality of sources of drinking water decreasing rapidly because of excessive raw municipal and industrial effluents as well as agricultural runoff into the water sources (Daud et al., 2017). Globally, contaminated water causes 4% of all deaths and 5.7% of the total preventable diseases (Sari et al., 2019). Every year a total of 1.5 million people die in diarrheal diseases and around 0.55 million people die of diseases related to drinking contaminated water (Szálkai, 2023). Ensuring safe water is a global challenge as sources of safe water are decreasing day by day. The Sustainable Development Goal (SDG) 6.1 aims at achieving universal and equitable access to safe and affordable drinking water for all by 2030. However, getting contamination free water has become challenge to most countries globally.

Compared to the well-off urban society, scarcity of access to safe water is more prevalent in urban low income society (Bekele & Teka, 2023). Low income households including slum dwellers who struggle to meet their basic needs can hardly ensure contamination free water. Only 38.64% of people living in a typical slum in a developing country have access to a safely managed drinking water service (Rahaman et al., 2021). Several studies have pointed out that the cities might suffer numerous water management issues, such as inadequate water availability and quality, water losses through the piped system, a lack of tap water infrastructure in low-income neighborhoods, and an unreliable electricity supply (Price et al., 2021; Adams and Zulu, 2015). Prior research has been conducted on safe water crisis based on urban slums (Price et al., 2021; Price et al., 2019), but the academic research specifically focusing on the usage of safe water on child health outcomes have not found yet (De Guzman et al., 2023; Khaliq et al., 2022). Inquest of fulfilling the research gap, the study attempts to examine the impact of usage of safe water on child health outcomes from the urban low income households' perspective.

To reduce under-five mortality to at least 25 per 1,000 livebirths by 2030 is the 3rd goal of Sustainable Development Goal 2030 (Sharrow et al., 2022). Bangladesh encounters major challenges in attaining SDG 3 of improving child health as under-five mortality was 32.4 per 1,000 livebirths in 2017. One of the major reasons for the high mortality rate is drinking unsafe water (Wolf et al., 2023). For low income households, under-five mortality is around 50 per cent higher than the national average (Razzaque et al., 2022). Globally, the predominant causes of child mortality are attributed to acute diarrheal diseases and acute respiratory infections (Khanam & Hasan, 2020). Around 22% child death is attributed to diarrheal diseases and 32% is attributed to respiratory infections (Cissé, 2019). Around 5.5 million under-five children die of diarrhea every year. One of the main reasons of acute diarrheal diseases and acute respiratory infections is consumption of contaminated water (Haseena et al., 2017). Drinking water is a major source of pathogens, microbial disease-causing organisms, and Escherichia coli (E.coli) strains acquired through contaminated water are a leading cause of infantile diarrhea in developing countries (Ashbolt, 2004; Cabrera-Sosa & Ochoa, 2020; Robins-Browne, 1987). Contaminated water is attributed as one of the major causes of 89% of diarrhea related deaths. In Bangladesh, 8.5% of death is related to l contaminated water (Hasan et al., 2019).

Prior studies tried to explore correlation between contamination free water usage and health conditions. Wang and Yang (2016) argue that water pollution was negatively correlated with mental and physical health in China, using random effect model. Random effect model can only capture correlation not causation. Lu et al., (2015) used simple before after scenario to argue that contamination free water usage is correlated to health conditions. Ly et al., (2022) used logistic regression models to suggest a strong association between access to improved water and sanitation with child mortality. Several previous studies tried to explore the impact of contamination free water usage improvement programs on health conditions (Fida et al., 2023; Gondal et al., 2023). Null et al. (2015) used randomized cluster design and estimated impact of chlorination dispenser installation on diarrhea occurrence of children of rural Kenya. Zhang (2012) estimated contamination free water usage improvement programs on health conditions.

Null et al. (2015) and Zhang et al. (2012) estimated intention to treat (ITT) impact of contamination free water usage. However, ITT captures only treatment assignment effect instead of treatment receipt. Thus, ITT analysis is incapable of capturing the actual causal effect of treatment receipt (Imai et al., 2021). The studies could have applied instrumental variable estimation to examine the local average treatment effect of contamination free water usage. This study aims to examine the impact of contamination free water usage on the health status of children residing in low income households, leveraging data from Luby et al. (2015) who conducted Randomized Control Trial to examine the impact of the installation chlorine dispenser on improvement of water quality and health outcomes. We used their treatment variable the installation chlorine dispenser as instrumental variable and one of their outcomes, contamination free water usage as our treatment variable. The study aims at addressing the research gap to identify causal impact of contamination free water usage instead of contamination free water usage improvement programs on health outcomes. This paper uses instrumental variable estimation to examine local average treatment effect of contamination free water usage for the first time.

Providing water free of contaminants is a crucial component of improving healthcare policies. Developing and putting into action the right initiative is required in this regard. Therefore, it is important to consider what consequences we would face if we were able to supply water free of contaminants. Thus, the research would like to investigate the research questions based on the above-mentioned research gaps: -

> *RQ: What is the impact of contamination free water usage on the health condition of children of low income households?*

By answering the question, the study aims to examine the impact of contamination free water usage on health condition of children of low income households. This present study uses children aged more than 1 year to 4 years as units of analysis. The children are treated if chlorine dispenser was installed in the shared water points of their household. On the other hand, the children are control assigned if chlorine dispenser was not installed in the shared water points of their household. A total of 602 children constitute the units of the study among which 274 are treatment assigned whereas 328 are control assigned. Urban children of low income households are selected because of combatively higher scarcity of safe water in children of low income households than in rural children of low income households as around 1 billion people living in urban slums struggle to ensure contamination free water (Price et al., 2019). Seven rounds of surveys are pooled together in the present study. As usage of contaminated water is not random, examining the impact of contamination free water usage on household level health outcomes has to address selection bias. To the best of our knowledge, this is the first attempt to quantify the causal impact of contamination free water usage on the health condition of children. The randomized installation of water disinfecting technology has been considered as an encouragement or instrumental variable to estimate the impact of contamination free water usage on health outcomes. This study focuses on contamination-free water usage, measured by the presence of total coliforms and Escherichia coli (E.coli). Total coliforms, indicative of environmental vulnerability, highlight potential contamination (Divya et al., 2016), while E.coli signals fecal contamination (Akyala et al., 2014) and the presence of disease-causing pathogens (An et al., 2002). Safe drinking water is defined as having <1 colony forming unit per 100 milliliters for both total coliforms and E.coli (Sauvé et al., 2012). The study employs this standard to assess contamination-free water quality.

Contingent upon the objective of the study, the study offers several research contributions in the existing literature. First, it explores the causal impact of contamination free water usage on health outcomes and is the main contribution of the present study. Second, this study considers health status of children as unit of analysis in the context of contamination free water usage impact evaluation for the first time.

2. Empirical Strategy:

The usage of contamination free water in daily purpose is not determined randomly but it depends upon the socio-economic status of a household. Therefore, comparing the average outcome of the treatment group and the control group will result in self-selection bias (Cao et al., 2010). Randomized encouragement design has been applied as an identification strategy to address selection bias (Paloyo et al., 2016). Randomized encouragement design utilizes instrumental variable concept to examine local average treatment effect (Sajons, 2020). Randomized control trials often suffer from non-compliance issues and most researchers deal the non-compliance issue with either ITT analysis or instrumental variable analysis. However, ITT analysis is often unreliable and even misleading to capture treatment effect (Hirano et al., 2000). On the other hand, Instrumental variables analysis provides an unbiased estimate of local average treatment effect which reflects causality (West et al., 2008).

The randomized installation of water disinfecting technology has been considered as an encouragement or instrumental variable to estimate the impact of contamination free water usage on health outcomes to address selection bias. The installation of water disinfecting technology is considered as instrumental variable in the present study (Small and Rosenbaum, 2008). Instrumental variable takes the value 1 for the children if chlorine dispenser was installed in the shared water points of their households; it takes the value 0 if otherwise. This present study estimates local average treatment effect of compliers only instead of average treatment effect. Following instrumental variable set up, there are three types of children in the present study: compliers, never takers and always takers. Children are termed as compliers if contamination free water usage in daily purpose of their household depends on installation of water disinfecting technology. Firstly, if water disinfecting technology is installed, contamination free water usage increases. Secondly, if water disinfecting technology is not installed, contamination free water usage in daily purpose does not increase. The children are always takers if the contamination free water usage increases whether disinfecting technology was installed or not. In contrast, the children are never takers if their contamination free water usage does not increase whether disinfecting technology was installed or not.

In randomized encouragement design setting, there are three conditions of an instrumental variable needs to be checked to validate the application of instrumental variable setup (Baiocchi, et al., 2014). The relevance condition constitutes the first condition of instrumental variable. The relevance condition requires that instrumental variables should have direct impact on the treatment variable (Heckman et al., 2006). The first stage estimation confirms whether instrumental variable has correlation with the treatment variable. Next the exogeneity condition, the second condition of instrumental variable, requires that instrumental variable should be assigned randomly. In this study, water disinfecting technology was installed randomly so it fulfills the exogeneity condition. Then exclusion restriction condition, third condition of instrumental variable, requires that instrument should have no direct impact on the outcome variable. In this study, water disinfecting technology has impact on child health outcomes only through enhancing contamination free water usage. Thus water disinfecting technology as an instrument fulfills the exclusion restriction condition too.

Randomized encouragement design uses two stage estimation like an instrumental variable set up. In this study, we estimated the following first-stage estimation equation:

First stage Equation: $\boldsymbol{W_i = a_0 + \pi C_i + \mu_i}$

In this case, $\boldsymbol{W}_i$ is a dummy variable for the defined treatment which takes the value 1 if the household of a child use water containing total coliforms and E.coli less than 1 colony forming unit per 100 milliliters (<1CFU/100mL); it takes the value 0 if otherwise. $\boldsymbol{C}_i$ is the dummy acting as instrumental variable which equals to 1 if water disinfecting technology is installed and it equals 0 if otherwise.

From the first stage predicted $\boldsymbol{W}_i$ is estimated and then the following second stage equation was used to examine the local average treatment effect.

Second stage equation: $\boldsymbol{H_i = \beta_0 + \beta_c \widehat{W}_i + \varepsilon_i}$

$\boldsymbol{H}_i$ are the outcome variables. Here, the local average treatment effects are estimated by β_c. $\boldsymbol{\widehat{W}_i}$ is the predicted contamination free water usage. N_c is the main treatment effect of contamination free water usage on diverse slum child health outcomes.

3. Data Description and Study Area

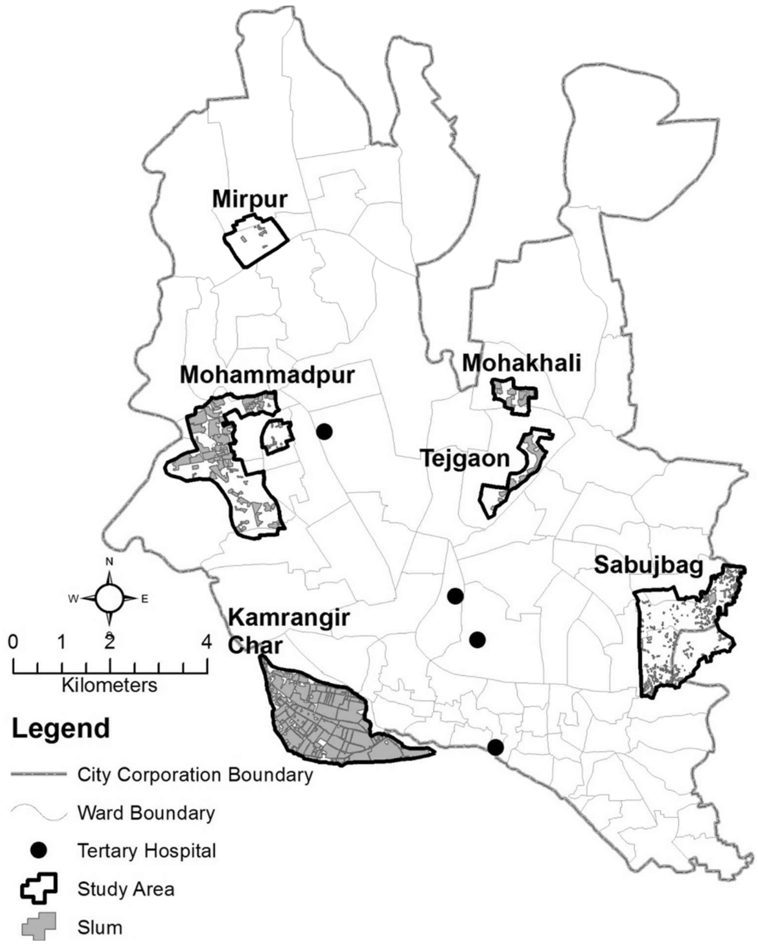

Figure 1: Map of Our Study Area (Adams et al., 2015)

This study uses the dataset prepared by Luby et al., (2015) available at https://microdata.worldbank.org/index.php/catalog/5731/get-microdata. The authors of the dataset considered the low-income communities living in Dhaka, demonstrated in Figure 1 adapted from Adams et al., (2015). Luby et al., (2015) implemented cluster randomized installation of water disinfecting technology. Around 10-15 households in the selected communities use a shared water point. 160 shared water points were randomly sampled. Then water disinfecting technology, a chlorine dispenser, was randomly installed to 80 shared water points whereas the other 80 shared water points stayed unchanged. The study planners arranged a one-hour knowledge sharing meeting with each household before installing the technology. The study planners also resupplied chlorine to the installed dispenser every week. The study enumerators surveyed households and water from the taps or pumps every two months for 14 months, conducting seven survey rounds. The present study includes 602 children aged more than one year to four years. The age limit is set at 4 years because children aged more than 4 years start going to schools thus they are exposed to use water from different sources. Four outcomes which are considered as indicators of child health condition are respiratory disease occurrence during last week, diarrhea occurrence during last week, number of days sick during last two months and health expenditure for the child during last two months.

3. Results

3.1 Main Results

Table 1 reports the first stage estimation of the impact on instrumental variable on treatment receipt probability. In other words, this table reports the impact of water disinfecting technology installation on improved contamination free water usage. The table shows that water disinfecting technology installation increases the usage of contamination free water at 1% significance level. Here water disinfecting technology installation acts as an encouragement increases the usage of contamination free water in daily life of low income households. The first stage estimation proves the relevance condition of water disinfecting technology installation as a strong instrument which increases the usage of contamination free water in daily life of low income households.

Table 1: Impact of Water Disinfecting Technology Installation on Improved Contamination free water usage

VARIABLES	(1) **Contamination Free Water Usage (0/1)**
Water Disinfecting Technology Installation	0.12*** (0.01)

Notes: Significance levels use a robust method where * for *p < 0.10, ** for p < 0.05, and **** for p < 0.01.

Table 2 and 3 demonstrates respectively short term (after six months) and long term (after fourteen months) impact of using contamination free water on child health outcomes, namely, respiratory disease occurrence during last week, diarrhea occurrence during last week, number of days sick during last two months and health expenditure for the child during last two months.

Table 2 displays that the usage of contamination free water decreases respiratory disease occurrence, diarrhea occurrence and number of days sick significantly after six months of treatment. However, health expenditure does not decrease significantly in the short term after six months. Probabilities of respiratory disease and diarrhea occurrence decrease respectively by 0.06 and 0.42. The number of days sick in last sixty days decreases by 2.05 days. Thus usage of contamination free water improves the health condition of the child significantly.

Table 2: Impact of Contamination Free Water on Child Health Conditions after Six Months

VARIABLES	**(1) Respiratory Disease**	**(2) Diarrhea Occurrence**	**(3) No Days Sick**	**(4) Health Expenditure**
Usage of Contamination Free Water	-0.06**	-0.42***	-2.05**	-685.40
	(0.02)	(0.12)	(0.87)	(492.40)

Table 3 displays that the usage of contamination free water decreases respiratory disease occurrence, diarrhea occurrence, number of days sick and health expenditure significantly after fourteen months of treatment. Probabilities of respiratory disease and diarrhea occurrence decrease respectively by 0.06 and 0.26 at 1% significance level. The number of days sick in the last sixty days decreases by 1.11 days. The health expenditure of children decreases by Bangladesh Taka (BDT) 606.20 (USD1=BDT80) in last sixty days. Thus, usage of contamination free water improves the health condition of the child significantly in the long term too.

Table 3: Impact of Contamination Free Water on Child Health Conditions after Fourteen Months

VARIABLES	(1) **Respiratory Disease**	(2) **Diarrhea Occurrence**	(3) **No Days Sick**	(4) **Health Expenditure**
Usage of Contamination Free Water	-0.06***	-0.26***	-1.11**	-606.20**
	(0.02)	(0.08)	(0.47)	(281.40)

Notes: Significance levels use a robust method where * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

3.2 Balance Check

Table 3 demonstrates the pretreatment covariates of treatment assigned and control assigned households. In other words, this table shows balance check between the households in which water disinfecting technology was installed with the households in which water disinfecting technology was not installed. Number of children aged below 2 years, number of children under 5 years, respiratory disease occurrence during last week, diarrhea occurrence during last week and number of days sick during last two months are the pretreatment covariates of which balance was checked. The balance check confirms that there was no significant difference between the treatment assignment and control assignment groups. This balance check further confirms that water disinfecting technology installation as instrumental variable fulfills exogeneity condition or randomness condition.

Table 4: Balance Check of Pre-Treatment Covariates

Covariates	**Treatment**		**Control**		**Difference**	
No of Children below 2 Years	0.35	[0.49]	0.33	[0.48]	-0.02	(0.04)
No of Children above 2 to 5 Years	0.80	[0.60]	0.76	[0.50]	-0.05	(0.05)
No of Children above 5 to 18 Years	0.61	[0.92]	0.82	[1.21]	0.21	(0.27)
No of Adults above 18 Years	2.18	[0.61]	2.31	[0.80]	0.13	(0.18)
Household Size	3.89	[1.20]	4.26	[1.57]	0.36	(0.35)
Monthly Rent (BDT)	3591.20	[980.63]	3302.41	[1083.80]	-288.79	(283.14)
Land Ownership (Decimal)	749.75	[498.50]	377.88	[514.34]	-371.88	(312.09)
Gender of the Child	1.49	[0.50]	1.47	[0.50]	-0.02	(0.04)
Age of the Child (Months)	29.46	[10.26]	30.09	[10.26]	0.64	(0.84)
Observations	274		328		602	

Note: Standard Deviation in square brackets. Standard Error in parenthesis. * p<0.10 ** p<0.05 *** p<0.01

4. Discussion

The results of the study demonstrate a significant improvement in the health conditions of the children from low income households with enhanced usage of contamination free water. The use of improved water significantly reduces the occurrence of respiratory diseases, diarrhea, and the number of sick days, both six and fourteen months after the implementation of the treatment. Notably while the impact on health expenditure was not statistically significant after six months, after fourteen months the use of improved water also leads to a significant decrease in health expenditure at a 5% significance level, the findings underscore the substantial positive effects of contamination free water usage on child health outcomes. The findings of the study suggest that contamination free water usage has better health outcomes after more than a year. The decrease in the number of sick days and health expenditure suggest that contamination free water usage improves health condition of the children from low income households. Moreover, contamination free water usage also reduces respiratory disease and diarrhea incidence of the children from low income households. Our result is supported by previous studies conducted by Fink et al. (2011) who argue that contamination free water is negatively associated with diarrhea incidence.

Water contamination has been considered as a major reason of high child mortality (Sari et al., 2019). However, the evidence of the impact of using safe water on child health is not conclusive in previous literature. Previous studies focused only either on correlation or on the impact of water quality improvement mechanism on health outcomes. This study examines the causal impact of using improved water on child health outcomes. The findings suggest that the health condition of the children from low income households improves significantly as a result of usage of improved quality water by households. Furthermore, the study offers crucial policy guidance for policymakers striving to meet SDG 3, which targets the reduction of child mortality to 25 per 1,000 live births by 2030. Policy makers who want to improve child health need to ensure access to contamination free safe water. Ensuring access to safe water can reduce child mortality significantly by reducing occurrence of diarrhea and respiratory diseases which are considered as two major reasons of high child mortality (Khanam & Hasan, 2020). Reduction of days being sick indicates that the children from low income households enjoy a healthy life through getting access to safe water. Reduction in health expenditure indicates improving health conditions of children who get access to safe water. Further, reduction in health expenditure allows the children from low income households to expend more on child nutrition, clothing and education.

5. Conclusion

Access to safe water is considered as a human right. However, ensuring access to safe water is a challenging issue for developing countries. The findings of the study give empirical evidence on how usage of contamination free safe water can improve health status of children aged between one year and four years. In other words, usage of contaminated water deteriorates health condition of children aged between one year and four years. The findings of the study are crucial for both environmental and health policymakers as it connects an environmental issue with child health outcomes.

This study provides strategic guidance for the attainment of Sustainable Development Goal (SDG) 3. The findings imply that public health policy makers need to formulate long term policy initiatives or strategic plans to ensure contamination free water supply, targeting better health conditions for the children from low income households. Further, these findings contribute valuable evidence to the significance of achieving Sustainable Development Goal (SDG) 6.1, which aims to ensure universal and equitable access to safe and affordable drinking water by 2030. This study urges that child mortality rate decrease goal should be integrated with the goal of ensuring access to safe water. Our study is supported by the study by Howden-Chapman et al. (2017) arguing the need to integrate SDG 6.1 with SDG 3. The findings suggest that safe water can improve child health significantly and thus ensuring access to safe and affordable drinking water is a crucial research question. Government initiatives, integrated design financial capacity building of the vulnerable households and awareness creation can help to attain long term solutions to ensure contamination free water supply to slums (Bartram et al., 2018).

However, it is essential to acknowledge certain limitations in the study. Firstly, the measurement of water quality solely relies on the presence of total coliforms and E. coli, neglecting the consideration of other potential pathogens. While this decision was made to accommodate budget constraints, it does leave room for questioning the overall water quality. Secondly, the study evaluates the quality of tap water or stored water within households, without estimating the quality of the actual water consumed. Children may access water from alternative sources, potentially impacting their health outcomes. Nevertheless, the present study lacks the capacity to assess the impact of the quality of the actual water consumed. Thirdly, the study does not address potential spillover effects, which may have occurred and could influence the observed outcomes. Fourthly, we limited our analysis to health outcomes of children aged between one year and four years. Children aged above five years are excluded because they start going to school, thus becoming exposed to use water sources other than the household one. These limitations should be considered when interpreting and generalizing the study's findings. Further, research needs to be conducted to examine how contamination free water usage helps to improve health outcomes in general to formulate comprehensive policy to ensure access to safe water for all.

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Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

The dataset used is available at https://microdata.worldbank.org/index.php/catalog/5731/get-microdata.