EFFECT OF IMPROVED DRINKING WATER AND SANITATION SERVICES ON CHILDREN'S HEALTH

Submitted To:

Professor A. K. Enamul Haque, PhD
Dean - Faculty of Business & Economics
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Submitted By:

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ID: 2019 – 1 – 88 – 009
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Date of Submission: 30th September,2023

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BASIC STUDY BASED ON BANGLADESH HIES – 2016 DATA

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To:

Dr. Muntasir Chaudhury,
Chairperson, Assistant Professor,
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Thesis Supervisor:
Dr. A. K. Enamul Haque,
Dean – Faculty of Business & Economics,
Professor - Department of Economics, East West University

Subject: Submission of thesis paper on "Effect of Improved Drinking Water and Sanitation Services on Children's Health"

Dear Sir,

I, Snata Hoq Laura, student ID: 2019 - 1 - 88 - 009, am a candidate for completing MSS in Economics from your department and am currently enrolled in the thesis course ECO699.

As part of the prerequisite for completing the course and the MSS program, I am delighted to submit the thesis paper on Effect of Improved Drinking Water and Sanitation Services on Children's Health for review, reference and record. Requesting you to please acknowledge the submission.

Sincerely,

Snata

Snata Hoq Laura
ID: 2019 - 1 - 88 – 009

Approval:

Name: Snata Hoq Laura

Degree: Master of Social Sciences in Economics

Title: Effect of Improved Drinking Water and Sanitation Services on Children's Health

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Contents

ABSTRACT

Poor drinking water and sanitation services are important policy issues that Bangladesh is facing as achieving global sanitation targets and providing safe drinking to water to everyone requires effectively extending WASH services to Bangladesh's citizens. Unsafe water, unhygienic sanitation and poor sanitation infrastructure are still posing serious health risk in many parts of the country. The main victim of these poor services are children who are vulnerable to water borne diseases as they are mainly caused by poor WASH infrastructure. This thesis paper attempted to investigate the HIES 2016 data to understand the impact of drinking water and sanitation services on water borne diseases for children less than 5 years of age in Bangladesh.

Chapter 1 – Introduction

1.1 Introduction of the study

Reducing child mortality is one of the eight Millennium Development Goals (MDGs) something that was agreed on by world leaders in September 2000 at the UN headquarters. The Millennium Development Goal 4 has only one target that is- "To reduce the under-five mortality rate by two-thirds in the period between 1990 and 2015". One of the achievements of MDG was less deaths of under-five children which dropped from 12.7 million in 1990 to nearly 6 million in 2015, but persistent population growth in developing regions turned this success into a failure.

According to World Bank data, in 2020 under-five child mortality rate for world was 37 deaths per 1000 live births. The most shocking fact is diseases that children commonly suffered from are easily preventable water-borne diseases like diarrhea, dysentery, typhoid and Jaundice. These deaths can be easily prevented with access to safely managed drinking water and sanitation services. Although access to clean water and sanitation was under the third target of MDG 7 which was, "To halve the proportion of the universal population without sustainable access to clean and safe drinking water and basic sanitation by 2015", but MDGs were going to come to an end in 2015. So, the dialogue of a post-2015 agenda arises with Sustainable Development Goals, 17 goals approved by UN General Assembly.

The Sustainable Development Goal 6 seeks to ensure safe drinking water and sanitation for all, focusing on the sustainable management of water resources, wastewater and ecosystems, and acknowledging the importance of an enabling environment within 2030. Over the year, the achievements of SDG 6 are huge. Based on UN-Water SDG 6 data portal, in 2020, 74% of world's population has a safely managed drinking water service, 54% of them uses a safely managed sanitation service and 71% has a handwashing facility with soap and water available at home, but in 2019, diarrheal diseases were the reason behind deaths of 370,000 children while being the second leading cause of under-five child death. In 2020, under five child mortality rate was 37 deaths per 1000 live births. With this high child mortality rate, question remains if water and sanitation services are really helping to prevent water borne diseases. This thesis paper aims to find out how much WASH infrastructures are contributing in prevention of water borne diseases.

1.2 Research problem

It is well understood that, waterborne diseases do have adverse effects on human health specially children's health, such as death, disability, illness or disorders. Most common sufferers are children from south Asian, southeast Asian and sub-Saharan African countries like Bangladesh, India, Indonesia, Nepal, Ethiopia, Kenya, Tanzania. These waterborne diseases are caused by water transmitted pathogenic micro-organisms. This transmission happens specially from fecal matter while bathing, washing, drinking water, or by eating food exposed to contaminated water. Water borne disease causing micro-organisms mainly includes protozoa, bacteria, intestinal parasites. They invade the tissues or circulatory system through walls of the digestive tract. Over the past few decades with the advent of globalization, understanding of different types of water-borne diseases has increased among scientists, health care providers as well as general population. Considerable number of pathogenic microorganisms which were previously unknown, have become the focus of major research in child health development field. Although diarrhea and dysentery are the most commonly reported waterborne diseases among children, other diseases like typhoid, jaundice is also the concern of our paper.

The transmission pattern that diarrhea disease follow is called fecal-oral transmission. Through feces diarrhea causing pathogens get released into the environment. These pathogens stay in the environment as long as they get to re-enter into the body through oral route with contaminated food and water. Thus, overall sanitation and personal hygiene standard of the household or community determines the probability of re-entry of the diarrhea causing pathogen into the body. That is why, communities and households with lower hygiene maintenance as well as improper disposal of feces suffer most from diarrheal diseases. Due to unhygienic disposal of feces, surface water gets contaminated easily by the released pathogens from feces which leads to high level of fecal-oral transmission. Besides bacteria, protozoa infectious units like eggs and cysts of intestinal worms are transmitted through fecal-oral route. Along with protozoa like *Entamoeba histolytica, Giardia lamblia* which transfer through sewage, non-treated drinking water, poor disinfection, pipe breaks, leaks, groundwater contamination, flies in water supply are also responsible for diarrhea. Besides contaminated water through bacteria like *Clostridium botulinum*, *Escherichia coli* is also responsible for diarrhea. Similar, to diarrhea, dysentery or bloody diarrhea occurs from contaminated water though bacteria, protozoa, or parasitic worms. The bacteria from genus Shigella or amoeba Entamoeba histolytica is responsible for this disease. Again, all these bacterial infections occur through contamination of food and water with feces due to poor sanitation. Diseases with similar risk factors are typhoid and Jaundice, both occurs from contaminated water though bacteria and viruses.

A quarter of all illnesses among Bangladeshis are due to water borne diseases. Thus, unhygienic drinking water and sanitation services play a vital role in the overall disease profile of the country. Although Bangladesh has achieved remarkable improvements in WASH sector, according to UNICEF, in Bangladesh, 7% of deaths in children under 5 years of age are caused by diarrhea. So, how much is WASH sector contributing to prevent water borne diseases in our country remains unknown specially when children are the main victims of these diseases. These gastrointestinal illnesses increase malnutrition among children, prevent their healthy growth and even lead to death.

1.3 Research Question

The question waiting for an answer in this study is whether better sanitation and drinking water services prevent or reduce water borne diseases among children in Bangladesh. Quantifying the impact of access to improved sanitation and drinking water services on child health and water borne diseases is important for Bangladesh's policy purpose because it can serve as a guide for the allocation of scarce resources to the numerous other interventions competing for the same funds.

1.4 Research Objective

The objectives of this research paper are following:

- To find out the effect of improved sanitation services on water borne diseases among children while comparing households with and without sanitation services
- To find out the effect of improved drinking water services on water borne diseases among children while comparing households with and without sanitation services

1.5 Conclusion

This thesis attempts to supplement and provide additional information for greater research such as why water borne diseases are so frequent among children in our country and what more can government do to prevent it. With a sound understanding of these, policy makers in Bangladesh can design projects and policies that would enhance the overall wellbeing of children so that we can have a healthy future generation that can contribute to the economy.

Chapter 2 – Research Background

2.1 Introduction

The chapter explains the background of the research. Here we have discussed the present coverage of WASH infrastructure in Bangladesh as well as how that is affecting children's well-being.

2.2 Background of the study

To attain goal 'SDG 6: clean water and sanitation for everyone', it is essential to accommodate better water and sanitation infrastructure for everyone and absolutely stop open defecation practices. Human or animal excrement, which contains pathogens like germs and viruses, can contaminate drinking water. Therefore, it is essential to obtain drinking water from a better source.

Due to a scarcity of toilets, open defecation behaviors are considered natural and because of this reason people rely on fields, forests, open lakes, and other public locations. Due to the risk of infectious diseases brought on by contact with human waste, open defecation practices and poor sanitation facilities are particularly hazardous. To stop the spread of infections, access to hygienic toilets is essential. According to WHO/UNICEF JMP report, a basic sanitation service consists of a sanitation facility that hygienically separates human excreta from human contact (that is, an improved sanitation facility) that is not shared with other households.

Bangladesh has achieved remarkable improvements in WASH sector. According to 2020 UN-Water SDG 6 data portal, 59% Bangladeshi people have a safely managed drinking water service, 39% Bangladeshi people have a safely managed sanitation service, 58% have a handwashing facility with soap and water available at home but still there is lot more to do to achieve SDG 6 goal within 2030.

World Health Organization (WHO)/UNICEF Joint Monitoring Program (JMP) recently published a report on Water Supply, Sanitation, and Hygiene. The report revealed that, 3 in 10 people worldwide are not able to wash their hands with soap and water within their homes. The situation is far worse in South Asian countries. Here 2 in 5 people cannot afford handwashing facility with soap and water on premises. According to same report, 68.3 million Bangladeshi people lack safely managed drinking water as well as 103 million Bangladeshi people lack safely managed sanitation facilities. Moreover, 61.7 million Bangladeshi people lack access to basic hygiene. Additionally, 107 million Bangladeshi people unable to afford basic handwashing facilities such as soap and water at home. Similar scenarios can be seen in schools here. The study revealed that almost half of schools in Bangladesh lack basic facilities like soap and water.

The International Food Policy Institute (IFPRI) has conducted the Bangladesh Integrated Household Survey (BIHS), a nationally representative three round panel survey of rural Bangladesh which collected information on rural households' main drinking water sources and available sanitation facilities. According to that data, percentage of piped water using rural households has slightly increased from 1.6 per cent in 2011-12 to 2.1 per cent in 2015 and 3.4 per cent in 2018-19. A great majority of Bangladeshi rural households rely on tube wells or other types of wells for drinking water. Percentage of households that collected drinking water from tube wells owned by the respective households has also increased over the time from 51.1 per cent in 2011-12 to 61.9 per cent in 2015 and 64.1 per cent in 2018-19. A great number of rural households still do not own a personal tube well and rely on community tube wells and other types of wells in their locality. Collecting drinking water from such a source also showed a decreasing trend as 34.3 per cent of the households in 2011-12, 33.7 per cent of the households in 2015 and 29.8 per cent of the households in 2018-19 rely on these sources for drinking water collection. According to the report, percentage of households that rely on surface water (from river, canal or pond) also showed a decreasing trend during the three rounds of data collection (2.6 per cent in 2011-12 and 1.6 per cent in both 2015 and 2018-19).

The BIHS survey data have indicated positive changes in sanitation facilities that are used in rural areas of Bangladesh. A greater number of the rural households now mostly rely on pucca latrines and sanitary latrines without flush. The percentage for households with pucca latrines stays almost similar over the three rounds of survey (48.7 per cent in 2011-12, 44.8 per cent in 2015 and 48.8

per cent in 2018-19). The percentage of households rely on sanitary latrines without flush increased from 25.5 per cent in 2011-12 to 42.5 per cent in 2015 and that further increased to 46.5 per cent in 2018-19. Reliance on sanitary latrines with flush is still not common among rural households in Bangladesh as only 0.4 per cent of households rely on it, in 2011-12 which slightly increased to 1.3 per cent in 2015 and further slightly increased to 2.2 per cent in 2018-19. Here good news is, reliance on community latrines is becoming exceptionally unpopular among rural households as 2.3 per cent of households reported to use it in 2011-12 which decreased to 0.2 per cent in both 2015 and 2018-19 which is a great improvement. The data reported that 3.7 per cent households used to rely on open defecation in 2011-12. This percentage decrease to 3.5 per cent in 2015 and 0.6 per cent in 2018-19. So, open defecation is almost nonexistent in rural Bangladesh nowadays.

Furthermore, according to a recently published World Bank report, 97% rural area in Bangladesh has improved water supply and open defecation is almost completely vanished, but even with these impressive achievements that go in tandem with the SDG 6 goals, the same report of World Bank also notifies that the water quality in our country is very bad, and 13% of its water sources carry arsenic levels above the threshold that the government considers as dangerous. There is also evidence of Escherichia coli bacteria in privately owned piped-water taps sampled across the nation. Furthermore, water salinity, iron and various pathogens are still visible in water samples which can cause serious public health issues. Another challenge is maintaining quality of sanitation facilities: only 37% of latrines in Bangladesh are hygienic, and 35% are labeled as extremely unclean. In 2020, according to World Bank, under five child mortality rates for Bangladesh was 29 deaths per 1000 live births and according to UNICEF, 7% of deaths in children under 5 years of age are caused by diarrhea, a water borne disease that is known to be easily prevented by improved sanitation and drinking water facilities.

2.3 Conclusion

Overview of this chapter shows that even with noticeable achievement in WASH sector, loopholes still exit here and there. All these have put question on hygiene level of WASH infrastructures as well as whether they can contribute to prevention of water borne diseases among children.

Chapter 3 – Literature Review

3.1 Introduction

Water, sanitation and hygiene problems have been in the limelight in many developing and underdeveloped countries. One of the most common sufferers of this problem are children as they suffer mostly from water borne diseases originated from WASH insufficiency. Besides wash insufficiency is also responsible for nutritional deficiency, stunting, bacterial and protozoal enteric infections, intestinal parasitic infections, soil transmitted helminth infections, gut inflammation, low height for age z score and child mortality. That is why, WASH problem had been highlighted by many researchers within different geographical regions. The paper seeks to address research evidence of the impact of WASH infrastructures on diseases originated from WASH insufficiency. To estimate this, the paper performs an analysis of relevant literature. The literature review focuses on the prior research context, methodology, and findings.

3.2 Diarrheal diseases and intestinal parasitic infections:

Although diarrhea is mostly described as water-borne disease, but more accurate information is, it is an excreta-related disease because the pathogens are derived from fecal matter (UN factsheet, 2008). The principal route of diarrheal infection is fecal–oral cycle. To break this cycle hand washing and toilet use is considered the most cost-effective public health intervention. In India, Kumar and Vollmer (2012) had worked on District Level Household Survey to determine the relationship between access to improved sanitation and diarrhea occurrences for children less than 5 years of age. By using propensity score matching and multivariate regression model, they found that access to improved sanitation reduces diarrhea occurrence by 2.2 percentage points.

Similar findings can be seen in Sub-Saharan African countries. In Tanzania, Verdeja et. al (2019) explored relationships between WASH practices and childhood illness in Tanzania. By using multiple logistic regressions analysis, they found that unimproved toilets were positively associated with fever and unsafe disposal of a child’s stool was positively associated with both fever and diarrhea. They also have emphasized on association between water shortages and fever. Cha et. al (2017) conducted cluster-randomized trial in the Democratic Republic of the Congo and concluded that safe water and sanitation reduces diarrheal incidence (cases per 1000 child-week), prevalence and average duration (days per episode) in children under four. Yaya et. al (2018) worked with 2013 Nigeria Demographic and Health survey (NDHS) to quantitatively assess the quality of living arrangement and access to WASH, and their impact on diarrheal outcomes among under-five children in Nigeria. They used household construction material for wall, floor, and ceiling, access to electricity, and improved water and toilet as the main explanatory variables while using multivariate regression method. In the regression analysis, lacking access to improved toilet and water facilities were associated with 14% and 16% higher odds, respectively, of suffering from diarrhea as compared to those who had improved access. The prevalence of diarrhea was 11.3%, with the rate being markedly higher in rural (67.3%) as compared to urban areas (32.7%). In Ethiopia, Gizaw et. al (2019) and Bitew et. al (2017) had also shown similar results when it comes to WASH problem. Another work done by Gizaw et. al (2018) but, on intestinal parasite infection instead of diarrhea using multivariable binary logistic regression. They had shown that child hand washing practice, access to water below 20 l/c/d, unprotected water sources, poor food safety and poor sanitation were associated with intestinal parasites infections. Manalew & Tennekoon (2019) on the other hand investigate the impact of access to drinking water sources and sanitation facilities on the incidence of diarrheal diseases among children below 5 years of age in Ethiopia using propensity score matching technique and only water piped into dwelling, yard or plot leads to a large percentage point reduction in diarrhea incidence. Girma et. al (2021) used data from the four rounds of the Ethiopian Demographic and Health Survey and applied the new World Health Organization (WHO)/UNICEF Joint Monitoring Program (JMP) service standards to assess progress in water, sanitation and hygiene (WASH) coverage between 2000 and 2016. They observed a significant increase in the coverage of safe drinking water and adequate sanitation facilities over the period. At the national level, the use of a basic water source increased from 18% in 2000 to 50% in 2016. Open defecation declined from 82% to 32% over the same period. However, in 2016, only 6% of households had access to a basic sanitation facility, and 40% of households had no handwashing facilities. The reduction in surface water uses between 2000 and 2016 explained 6% of the decline in diarrhea observed among children aged 0–5 months. In children aged 6–59 months, between 7% and 9% of the reduction in stunting were attributable to the reduction in open defecation over this period.

In remote Nepal, it is still difficult to ensure that everyone has access to clean water, sanitation, and hygiene (WASH). A. Shrestha et. al (2020) investigated WASH conditions and their association with children's nutritional status, intestinal parasitic infections and diarrhea by using mixed logistic regression in Nepal. The clinical signs of nutritional deficiencies were significantly associated with water quality and various hygiene factors. They also showed that children from households with simple pit latrines had higher chances of developing an intestinal parasitic infection than did those with water sealed latrines. The caregivers' hands play a critical role in transferring parasites from the household environment to their children. Because there is strong evidence that a high load of pathogens in the household environment and inadequate handwashing increase the density of pathogens on caregivers' hands. In contrast to their findings on the risk factors associated with diarrhea, strong association was also found between diarrhea incidence and reported interruptions of the water supply.

Baker et. al (2016) describe sanitation and hygiene access across the Global Enteric Multicenter Study (GEMS) sites in Africa and South Asia (Gambia, Kenya, Mali, Mozambique, Bangladesh, India, Pakistan) and to assess sanitation and hygiene exposures, including shared sanitation access, as risk factors for moderate-to severe diarrhea (MSD) in children less than 5 y of age by using multivariable & univariable conditional logistic regression. This study suggests that sharing a sanitation facility with just one to two other households can increase the risk of Moderate-to-Severe Diarrhea in young children, compared to using a private facility.

Hasan and Gerber (2016) did an investigation on marginalized rural households of north-western Bangladesh and tried to find out the impacts of piped water on water quality, sanitation, hygiene and health outcomes using a quasi-experimental analysis. A government organization named the Barindra Multipurpose Development Authority (BMDA) – established a piped water network to provide these rural households with improved water as they have poor access to potable water. Using propensity score matching, they compared a treatment and a control group of households to identify gains in water-sanitation, hygiene and health outcomes, but they did not find any evidence of health benefits, such as decreased diarrhea incidence of in under-five children, improved child anthropometrics stunting, underweight and wasting of children due to piped water use.

3.3 Child nutritional deficiency, stunting and child mortality:

Not just water borne diseases instead WASH insufficiency is also one of the reasons behind child nutritional deficiency and stunting. One proof for this is Rah et.al (2015) used multivariate regression model to determine the association between household access to water, sanitation and personal hygiene practices with stunting among children. They done their research on children aged 0–23 months in rural India using the 2005–2006 National Family Health Survey (NFHS-3), the 2011 Hunger and Malnutrition Survey (HUNGaMA) and the 2012 Comprehensive Nutrition Survey in Maharashtra (CNSM). They concluded that compared with open defecation, household access to toilet facility was associated with a 16–39% reduced odds of stunting among children aged 0–23 months. Although in their findings access to improved water supply or piped water was not in itself associated with stunting, however, caregiver's self-reported practices of washing hands with soap before meals or after defecation were inversely associated with child stunting and this inverse association was stronger among households with access to toilet facility or piped water.

In Indonesia, Rah et. al (2020) also used logistic regression model and found children living in a household with improved sanitation facilities had 29% reduced odds of being stunted compared with those in a household with unimproved sanitation facilities although source of drinking water was not associated with stunting or anemia amongst children. They also tried to find the effect of household sanitation and drinking water source on childhood anemia but no effect was observed. There were also no synergistic effects of household sanitation and water supply on stunting and anemia.

Headey and Palloni (2019) worked with panel of 442 subnational regions in 59 countries with multiple Demographic Health Surveys and implemented difference-in-difference regressions. According to their study, improved water access is statistically insignificantly associated with most outcomes, although water piped into the home predicts reductions in child stunting. Improvements in sanitation leads to large reductions in diarrhea prevalence and child mortality but are not associated with changes in stunting or wasting. They estimated that sanitation improvements can account for just under 10 % of the decline in child mortality from 1990 to 2015.

3.4 Bacterial and protozoal enteric infections and soil transmitted helminth infections among children:

Berendes et. al (2017) tried to examine the associations between household sanitation and enteric infection along with diarrheal-specific outcomes. They had worked with caregivers in 100 households for children 0–2 years of age in a dense urban neighborhood in Vellore, India and tested through mixed-effects Poisson regression models. They concluded that the presence of a household toilet was associated with lower risk of bacterial and protozoal enteric infections, but not diarrhea or viral infections after controlling for season and household socio-economic status.

Worrell et. al (2016) tried to examine the associations between household sanitation and soil transmitted helminth infections in Urban School- and Preschool-Aged Children in Kibera, Nairobi, Kenya. In their univariable analysis, STH infection was significantly associated with a household toilet located off-premise.

3.5 Gut inflammation and determinants of child height-for-age, weight-for-height and weight-for-age z score:

There is good amount of evidence on better WASH with child growth. S. K. Shrestha et. al (2020) analyzed data from a nationally representative sample of 2352 children assessed during the 2016 Nepal Demographic and Health Survey by multi-variable linear regression to understand the association between height-for-age (HAZ), weight-for-height (WHZ) and weight-for-age (WAZ) z-scores and WASH variable. The mean z-score [standard deviation] for children's WAZ, HAZ and WHZ scores were − 1.33, − 1.52 and − 0.65, respectively. A unit increase in cluster sanitation coverage was associated with an increase of 0.30 for WAZ and 0.28 for HAZ scores. Household water purification practice was associated with an increase of 0.24 in WHZ score. Handwashing practice with water and soap was associated with an increase of 0.15 in WAZ and 0.13 in WHZ scores. The effect of water purification practice was higher for rural areas compared to urban settings for HAZ scores.

Saxton et. al (2016) worked with rural indigenous communities of Jharkhand and Odisha, Eastern India. They used Generalized Estimating Equations to identify individual determinants associated with children's height-for-age z-score and included these in a multivariable model to identify the strongest HAZ determinants. They concluded that interventions that could improve children's growth include reducing exposure to indoor air pollution, increasing access to family planning, reducing diarrheal infections, improving handwashing practices, increasing access to income and strengthening health and sanitation infrastructure.

In Peru, Exum et. al (2018) used multivariate mixed effects model to determine the causes of gut inflammation instead of only diarrhea and provided preliminary evidence that children less than 24 months of age living in unsanitary conditions will have elevated gut inflammation.

3.6 Summary of literature review:

The consequences of unsafe water, sanitation and hygiene (WASH) on children can be life threatening. Not just diarrheal diseases, researchers have also found other health impact like nutritional deficiency, stunting, bacterial and protozoal enteric infections, intestinal parasitic infections, soil transmitted helminth infections, gut inflammation, low height for age z score on children only due to WASH insufficiency. The most at risk and impacted children are those who reside in rural areas and low-income nations. When a child gets exposed to diseases and infections is his/her early life, it hinders his/her future growth, but every child has the right to a safe and clean environment to grow up in. Children not only thrive when they have access to clean water, basic toilets, and excellent hygiene habits, but they can also have a healthier start in life.

3.7 Conclusion

After in-depth research, no empirical investigation focusing on water borne diseases are found. Most the authors talked only about diarrheal diseases and infections. Some authors did focus on nutritional deficiency and other health issues, but that's not the end of the story. Wash insufficiency is also responsible for many other water-borne diseases like dysentery, jaundice, typhoid, scabies etc. Besides work on Bangladesh is very little when it comes to water borne diseases. Some papers did focus on diarrheal diseases but that's not the only thing children suffer from

Chapter 4 – Data and Methodology

4.1 Introduction

In the previous chapters, various theoretical concepts and scholarly research papers were reviewed which provided the effects of poor WASH infrastructures on child health and given the knowledge of various water borne diseases that present among children, not only in Bangladesh but also countries around the world. To study the effect of sanitation and drinking water services on water borne diseases among children, this study has used the Household Income and Expenditure Survey (HIES) data of 2016 where information on household characteristics, including the members, income sources, education level, assets, and many other variables are readily available. This dataset contains data from 46,080 households. The reason for using HIES data is that it contains all the demographic information. Using HIES data, this chapter aims to identify the list of variables that will be used in this research to fulfil the research objectives that has been explained in previous chapters. This chapter explains the theoretical framework, data design and survey technique and methodology which are used in carrying out the research work.

4.2 Theoretical framework

In this paper, the attempt is to estimate the causal impact of improved water and sanitation services on children in terms of water borne diseases using 2016 Household Income and Expenditure Surveys using propensity score matching.

4.3 Propensity score matching

Estimating the impact of improved water and sanitation infrastructures is a major methodological challenge because the outcomes cannot be observed for the same children in both states: treatment and counterfactual state (Heckman and Robb, 1985). For example, here, we can work with households with either access to improved water and sanitation services or without, but we cannot find outcomes for the same households in both states. The easiest to work with this missing data problem is to conduct a randomized experiment, where we can build the counterfactual from a random subset of the eligible population, but it is not feasible randomizing infrastructures like roads, ports, electricity, water and sanitation.

That is why when it is impossible to work with experimental data, we rely on observational data and implement a non-experimental method called PSM, try to estimate the impact of improved water and sanitation services on child health. In observational studies, estimation of the treatment effect can be biased owing to confounding factors because subjects are allocated non-randomly to treatment and control groups. PSM is an alternative to correct the bias by creating treated and control groups that are not confounded by differences in observed covariate distributions (Rosenbaum and Rubin, 1983). In recent years, matching methods have become increasingly popular and widely used in the evaluation of economic policy interventions (Becker and Ichino, 2002).

The fundamental idea in PSM is to create treatment and control groups that have similar characteristics such that comparisons can be made within these matched groups. When there is large number of observed characteristics, direct matching becomes infeasible, so PSM (a single-index variable) is used. The propensity score p(X) is the estimated probability of receiving treatment given a set of background covariates. The difference in the average outcome of treated and control groups can be attributed to the program under the assumption that selection into program participation is based on observable factors alone.

4.4 Average treatment effect on the treated

Let Y_{1i} and Y_{0i} be the outcome variables for treated and control households, respectively, and $D \in \{0, 1\}$ the indicator of treatment status. The propensity score p(X) is defined by Rosenbaum and Rubin (1983) as the conditional probability of receiving treatment given observed characteristics:

$$p(X) \equiv \Pr(D = 1|X) = E(D|X) \qquad (1)$$

where X is the multidimensional vector of observed characteristics. Given the propensity score p(X), the average effect of treatment on the treated (ATT) can be estimated as follows:

$$\widehat{ATT} \equiv E\{Y_{1i} - Y_{0i}|D_i = 1\} \quad (2)$$
$$= E[E\{Y_{1i} - Y_{0i}|D_i = 1, p(X_i)\}]$$
$$= E[E\{Y_{1i}|D_i = 1, p(X_i)\} - E\{Y_{0i}|D_i = 0, p(X_i)\}|D_i = 1]$$

Equation (2) gives the average program impact under the conditional independence (CIA) and overlap assumption.

4.5 Nearest-neighbor matching method

In this paper, we employ nearest-neighbor (NN-1) matching with replacement, which is the most widely used matching algorithm. With nearest-neighbor matching, the individual from comparison group is chosen as a matching partner for a treated individual that is closest in terms of propensity score. We consider single-nearest-neighbor matching. We matched the treatment household with the nearest neighbor. Formally, the NN matching estimator with replacement within caliper is,

$$\widehat{ATT} = \frac{1}{N1}\sum_{i=I}\{Y_i - Y_j\} \quad (3)$$

For a pre-specified caliper $\delta > 0$, j is chosen such that,

$$\delta > |p(X_i) - p(X_j)| = \min_{k\epsilon I} \{|p(X_i) - p(X_j)|\}$$

If none of the non-treated units is within d from the treated unit i, then i is left unmatched.

4.6 Data definition

The data used here is data from 2016 Household Income and Expenditure Surveys (HIES). Household Income and Expenditure Surveys (HIES) is one the most popular activities of the Bangladesh Bureau of Statistics (BBS), containing a large collection of socio-economic information at the household level. This survey has strong contribution in the decision-making process for the government of Bangladesh. This standalone survey gives reliable and credible estimate of Bangladesh's poverty and its correlates. That is why, it is extensively used all over the world, especially in the low-income developing countries, to evaluate poverty level and the living standard of the people at large. This survey bears beneficial data on household income, expenditure, consumption, savings, housing condition, household's access to water supply and electricity, education, employment, health and sanitation, social safety nets, remittance, micro credit, crisis coping, disability etc.

The HIES 2016 covers the highest ever numbers 46,080 households drawn from 2,304 Primary Sampling Units (PSUs), from 20 strata: 8 rural, 8 urban and 4 statistical metropolitan areas namely Dhaka, Chattogram, Rajshahi and Khulna.

While designing sample of HIES 2016, two different levels of Stratification were followed. First, as of 2016 Bangladesh had eight administrative divisions. They were Barisal, Dhaka, Chattogram, Rajshahi, Khulna, Mymensingh, Rangpur and Sylhet. These 8 divisions of the country were stratified by 3 basic localities namely- Rural, Urban and City Corporation. Thus, there should have been 8x3=24 strata. BBS included only the four main city corporations (Dhaka, Chattogram, Khulna and Rajshahi) in the city corporation locality. This brought the number of main strata to 20 (8 rural divisions + 8 urban divisions + 4 main city corporations). Secondly, as the PSUs of HIES 2016 will be allocated at district (zila) level, the sample was implicitly sub-stratified at the district level. Since there are a total of 64 districts in Bangladesh, the sample design includes a total of 132 sub-strata: (64 rural, 64 urban and 4 city corporations)

The HIES 2016 followed a stratified two stage cluster sampling design. At the first stage, a total of 36 PSUs (EAs) was drawn from each Zila (Domain) applying PPS systematic sampling technique, number of households in each PSU being the measure of size. These 36 PSUs were selected independently from rural, urban and city corporation sub-stratum. Therefore, in total, there will be 64x36=2,304 sample PSUs for the survey. Enumeration Area (EA), a cluster of around 110 households of population census 2011, was treated as PSU for this sample design. The sampling frame for this purpose was developed from the population census 2011 data. A file containing all the EAs of the population census 2011 was created. This file contains all the unique geographic codes from division down to EA and locality code (rural, urban and city corporation). To select the sample PSUs independently by stratum and Zila, the sampling frame was properly sorted by stratum and geo-codes. Then, at the first stage, the required number of PSUs was selected using probability proportional to size (PPS) systematic sampling, size measure being the number of households in each PSU. After selection of the PSUs, a complete household listing in these selected PSUs was done in the field. Subsequently, this was computerized and used to draw the 20 households along with 5 reserved households from each of the selected PSUs at the second stage. Thus, total sample size for the survey stands at 2304x20=46,080 households.

4.7 Choice of Variables

The impact of improved water and sanitation services on child health will be identified by examining the relationship between access to different types of water and sanitation services and if any children have suffered from water borne diseases, after controlling for the characteristics of household.

Two treatment variables are used – types of water services and types of sanitation services while using tendency to water borne diseases as outcome variable. Household characteristics variables include household monthly income, child gender, number of children in the household, number of females in the household, total usable area of covered room, tv ownership, family size, internet access, highest education level of woman in household, construction material of the wall of the main room, if the household share the sanitation facility with other households, whether is it a slum household, stove type and access to electricity, number of sick member in the household and living area.

The expectation is that households with higher monthly income and more educated women will have less tendency towards water borne diseases as more income means more available resources and educated women tend to have more child caring knowledge. Wall type, stove type, access to electricity and total usable room area have been used here as a proxy for better living conditions. Not sharing toilet with other households also represents the same thing. Not living in a slum also represents that the household has good living conditions along with a better and hygienic surrounding environment. TV and internet access mostly shows the possibility of household members having more WASH knowledge.

4.7.1 Types of sanitation services

HIES 2016 data shows that households normally use six types of toilet facilities- sanitary, water sealed pacca latrine, pacca latrine with pit, permanent kacha latrine, temporary kacha latrine, open space/no latrine.

Table 1: Types of available sanitation services

Types of toilet facilities	Household percentage
Sanitary	22.22%
Water sealed pacca latrine	16.48%
Pacca latrine with pit	17.76%
Permanent kacha latrine	24.41%
Temporary kacha latrine	16.20%
Open space/no latrine	2.93%

Source: Authors calculation from HIES 2016 dataset, BBS

Table-1 shows that 22.22% households use sanitary latrine which is the second highest in usage among all. Households that are using pacca latrine varies from 16% to 18%, but households with permanent kacha latrine are 24.41%, the highest percentage among all. However, households with temporary kacha latrine are 16.20%, the second lowest percentage among all. On the other hand, usage of open space as toilets has reduced remarkably which is 2.93%.

So, there is less variation in terms of usage of toilet facilities and percentage of households that are using open space is also very low. That is why, to make the calculation easier, we have created two categories of toilet facilities from six categories. One is household with improved toilet facilities derived from combining the percentage of households with sanitary, water sealed pacca latrine, pacca latrine with pit and second is household with unimproved toilet facilities derived from combining the percentage of households with permanent kacha latrine, temporary kacha latrine, open space/no latrine. Table-2 shows the result of this modification.

Table 2: Types of toilet facilities

Types of toilet facilities	Household percentage
Improved toilet facilities	56.46
Unimproved toilet facilities	43.54

Source: Authors calculation from HIES 2016 dataset, BBS

Now after modification, we can see that, 56.46% households have improved toilet facilities and 43.54% households have unimproved toilet facilities. So, we have turned this treatment variable into binary variable where improved toilet facilities =1 and unimproved toilet facilities =0.

4.7.2 Types of drinking water services

According to HIES 2016 data, households normally use five types of water sources for drinking purpose. The sources are - supply water, tubewell, pond/river, well and waterfall/string.

Table 3: Types of available drinking water services

Types of drinking water sources	Percentage
Supply water	6.61%
Tubewell	89.78%
Pond/river	1.44%
Well	1.46%
Waterfall/string	0.72%

Source: Authors calculation from HIES 2016 dataset, BBS

Table-3 shows that 89.78% households use tubewell to get drinking water, while supply water users are 6.61%, a huge difference. Other sources contribute much less than them. Only 1.44% household use pond/river water, 1.46% use well water and 0.72% use waterfall/string water as drinking water source.

Like toilet facilities there is less variation in terms of usage of water sources and most of the households are dependent on tubewell for collecting drinking water. So, we have created two categories of drinking water sources from these five categories. One is household with improved drinking water services derived from combining the percentage household with supply water and tubewell and another is household with unimproved drinking water services derived from combining the percentage of household with pond/river, well, waterfall/string. Table-4 shows the result of this modification.

Table 4: Types of drinking water services

Categories of drinking water services	Percentage
Improved drinking water services	96.39%
Unimproved drinking water services	3.61%

Source: Authors calculation from HIES 2016 dataset, BBS

Now after modification, we can see that, 96.39% households have improved drinking water services and 3.61% households have unimproved drinking water services. So, we have turned this treatment variable into binary variable where improved drinking water services =1 and unimproved drinking water services =0.

4.8 Empirical model: A propensity-based weighted regression

A method widely used in program evaluation literature is estimation of a probit regression model, using the propensity score as sampling weight. It has been found in several studies that weighting the data with the propensity score balances the distribution of covariates and results in fully efficient estimates (Rosenbaum, 1987; Hirano and Imbens, 2001; Hirano et al., 2003). This approach uses the propensity score ($\hat{\lambda}$) to weight treatment and control groups in order to make the covariate distribution similar across both groups. The weight is defined as the inverse of the propensity score $1\backslash\hat{\lambda}$ for treated households and the inverse of one minus the propensity score $1\backslash 1-\hat{\lambda}$ for untreated households.

Equation (1) and (2) are the mathematical way of writing the model,

$$\begin{aligned}\text{Water borne diseases} = {} & \beta_0 + \beta_1 \text{ Household monthly income} + \beta_2 \text{ Child gender} \\ & + \beta_3 \text{ Number of children} + \beta_4 \text{ Number of females} \\ & + \beta_5 \text{ Room area} + \beta_6 \text{ TV ownership} + \beta_7 \text{ Family size} + \beta_8 \text{ Internet access} \\ & + \beta_9 \text{ Living area} + \beta_{10} \text{ Highest education level of woman} \\ & + \beta_{11} \text{ Wall material} + \beta_{12} \text{ Shared toilet} + \beta_{13} \text{ Slum Household} \\ & + \beta_{14} \text{ Stove type} + \beta_{15} \text{ Electricity access} \\ & + \mu_1 \text{ Toilet facilities} + \epsilon_1 \qquad (1)\end{aligned}$$

Here, outcome variable is if any children have suffered from water borne diseases and treatment variable is types of toilet facilities. β_1 is the coefficient of household monthly income. The co-efficient of child's gender is β_2. Child's gender is a dummy variable where child's gender=1 if male and child's gender=0 if female. Here, β_3 and β_4 represents the co-efficient of number of children and number of females in the household. β_5 is the co-efficient of total usable area of covered room in square feet. β_6 is the co-efficient of dummy variable TV ownership. That means if a household owns TV, then TV ownership will be=1 or 0 otherwise. β_7 is the co-efficient of the variable family size. β_8 is the co-efficient of dummy variable internet access, if a household has internet access, then internet access=1 and if not internet access=0. β_9 is the coefficient of categorical variable living area of household with categories named rural (=1), PSA (=2) and city corporation (=3). β_{10} is the co-efficient of women's highest education level, a dummy variable with five categories named no class (=0), primary education (=1), secondary education (=2), higher secondary education (=3) and graduated (=4). β_{11} is the coefficient of categorical variable construction material of the wall of the main room with categories named cheap sources (=1), tin (CI sheet) (=2) and brick/cement (=3). β_{12} is the coefficient of the dummy variable if a household share the toilet with other households. β_{13} is the coefficient of dummy variable representing if a household is a slum household or not. β_{14} is the coefficient representing the types of stove a household uses. It is a categorical variable with four categories named none (=1), non-electric & non-gas (=2), gas (=3) and electric (=4). β_{15} is the coefficient of dummy variable electricity access. That means if a household has electricity access, then electricity access=1 or 0 otherwise. μ_1 is types of toilet facilities. Finally, ϵ_1 is a white noise error term.

$$\begin{aligned}\text{Water borne diseases} = {} & \Theta_0 + \Theta_1 \text{ Household monthly income} + \Theta_2 \text{ Child gender} \\ & + \Theta_3 \text{ Number of children} + \Theta_4 \text{ Number of females} \\ & + \Theta_5 \text{ Room area} + \Theta_6 \text{ TV ownership} + \Theta_7 \text{ Family size} + \Theta_8 \text{ Internet access} \\ & + \Theta_9 \text{ Living area} + \Theta_{10} \text{ Highest education level of woman} \\ & + \Theta_{11} \text{ Wall material} + \Theta_{12} \text{ Shared toilet} + \Theta_{13} \text{ Slum Household} \\ & + \Theta_{14} \text{ Stove type} + \Theta_{15} \text{ Electricity access} \\ & + \mu_2 \text{ Drinking water services} + \epsilon_2 \qquad (2)\end{aligned}$$

Here, outcome variable is if any children have suffered from water borne diseases and treatment variable is types of drinking water services. Θ_1 is the coefficient of household monthly income. The co-efficient of child's gender is Θ_2. Child's gender is a dummy variable where child's gender=1 if male and child's gender=0 if female. Here, Θ_3 and Θ_4 represents the co-efficient of number of children and number of females in the household. Θ_5 is the co-efficient of total usable area of covered room in square feet. Θ_6 is the co-efficient of dummy variable TV ownership. That means if a household owns TV, then TV ownership will be=1 or 0 otherwise. Θ_7 is the co-efficient of the variable family size. Θ_8 is the co-efficient of dummy variable internet access, if a household has internet access, then internet access=1 and if not internet access=0. Θ_9 is the coefficient of categorical variable living area of household with categories named rural (=1), PSA (=2) and city corporation (=3). Θ_{10} is the co-efficient of women's highest education level, a dummy variable with five categories named no class (=0), primary education (=1), secondary education (=2), higher secondary education (=3) and graduated (=4). Θ_{11} is the coefficient of categorical variable construction material of the wall of the main room with categories named cheap sources (=1), tin (CI sheet) (=2) and brick/cement (=3). Θ_{12} is the coefficient of the dummy variable if a household share the toilet with other households. Θ_{13} is the coefficient of dummy variable representing if a household is a slum household or not. Θ_{14} is the coefficient representing the types of stove a household uses. It is a categorical variable with four categories named none (=1), non-electric &

non-gas (=2), gas (=3) and electric (=4). Θ_{15} is the coefficient of dummy variable electricity access. That means if a household has electricity access, then electricity access=1 or 0 otherwise. μ_2 types of drinking water services. Finally, ϵ_2 is a white noise error term.

4.9 Conclusion:

In this chapter, the selection of variables for matching such as household monthly income, number of children and females in the household, room area, tv ownership, family size etc. have been selected based on the understanding achieved through literature review. Then the characteristics of the data has been investigated to ensure good data is being used for the research and also done some modification in the data by using STATA 15 to make the calculation easier. All these will better act as supporting information for findings.

Chapter 5 – Empirical Analysis

5.1 Introduction

In these chapter, we will represent our analysis on data and different socioeconomic characteristics of households. Finally, we will show our findings from regression while applying propensity score matching method.

5.2 Descriptive Statistics

The descriptive statistics of the variables, presented in table 5. Total number of households in HIES 2016 dataset is 46,080. We have done all our work only on children up to 5 years old age which has narrowed the dataset down to 21,253 observations from 1,86,078 observations. Table 5 shows that household's average monthly income is 12786.99. Average household size is 4-5 persons with average female member being 2 persons and average children number being 2 children in a household. The mean value of some dummy variables like if a household is a slum household, if the household share the sanitation facility with other households, household's TV ownership, internet access and electricity access are also shown here.

Table 5: Descriptive statistics of the variables

Variable	Unit/ description	Observation	Mean	Standard deviation
Household monthly income	Taka	17,572	12786.99	74414.51
Family size	Persons	17,572	4.71	1.54
Number of children in Household	Persons	17,572	1.21	.45
Number of females in Household	Persons	17,572	2.44	1.11
Total usable area of covered room	Square feet	17,568	394.58	505.61
Household that owns TV	Yes=1, No=0	17,511	.39	.49
Household that has Internet access	Yes=1, No=0	17,572	.06	.24

Household that shares the sanitation facility with other households	Yes=1, No=0	17,572	.26	.44
Slum household	Yes=1, No=0	17,572	.04	.20
Household that has Electricity access	Yes=1, No=0	17,572	.72	.45

Source: Authors calculation from HIES 2016 dataset, BBS

We have said before, wall type, stove type, access to electricity and total usable room area have been used here as a proxy for better living conditions. By studying the HIES data, we found that, average total usable area of covered room is 394.58 square feet. 26% households share their toilet facility with other households which is a very large percentage and a representation of unhygienic sanitation facilities and poor living condition, but only 4% households are slum households which definitely proves that more households have relatively healthy and hygienic surrounding environment. Besides 72% households have electricity connection which is another proxy for better living condition. Although only 6% households have internet access, but good number of households have ownership of TV which is 39%. We hope that members of these households have more WASH knowledges than others.

According to HIES data, construction materials of the wall of the main room are straw/bamboo/ polythene/plastic/ canvas, mud/unburnt brick, tin (CI sheet), wood and brick/cement. We have modified this list and created three categories- cheap sources, tin (CI sheet) and brick/Cement. Table-6 represents the result of the modification. 50.22% households use tin (CI sheet) which is case for majority households and 26.54% households use brick/cement as their wall material. Others mostly depend on cheap sources. The percentages clearly prove that more households have better residential place to live. HIES data also have the information on type of stoves that are popular among households. To make our calculation easier, we have created three categories of stoves. Table-7 represents the result after our calculation. It shows that 84.88% households use gas stove and 12.51% use electric stove. In table 8, we have showed the percentage of living area of households. 71.36% household living in rural area, 24.48% living in PSA and 4.17% living in city corporation. So, population is mostly concentrated in rural areas.

Table 6: Construction material of the wall of the main room

Construction material of the wall of the main room	Percentage
1=Cheap Sources	23.24
2=Tin (CI sheet)	50.22
3=Brick/Cement	26.54

Source: Authors calculation from HIES 2016 dataset, BBS

Table 7: Stove type in households

Stove type	Percentage
1=None	0.89
2=Non-Electric & Non-Gas	1.72
3=Gas	84.88
4=Electric	12.51

Source: Authors calculation from HIES 2016 dataset, BBS

Table 8: Percentage of living area of households

Living area	Percentage
Rural=1	71.36
PSA=2	24.48
City corporation=3	4.17

Source: Authors calculation from HIES 2016 dataset, BBS

In table 9, we have showed the percentage of male and female among children. It says that 50.94% children are male and 49.06% are female. We have also tried to find out the education status of women in households. By using HIES data we calculated the highest education level of women in a household. We have presented the result separately in table 10. It represents that in most of the household women are mostly educated up to primary and secondary level with 30.18% and 47.28% being highest education level of women in households. It's rare for women to pursue more education than that. There are also households with uneducated women but that's only 13%.

Table 9: Gender of children

Child gender	Percentage
Male=1	50.94%
Female=0	49.06%

Source: Authors calculation from HIES 2016 dataset, BBS

Table 10: Education level of women in households

Highest education level of woman in household	Percentage
0=No Class	13.87
1=Primary Education	30.18
2=Secondary Education	47.28
3=Higher Secondary Education	5.82
4=Graduated	2.86

Source: Authors calculation from HIES 2016 dataset, BBS

5.3 Results and discussion

The outcome variable is if any children have suffered from water borne diseases and treatment variables are types of toilet facilities and types of drinking water services. Table 12 shows the effect of treatments before and after matching where matching is done based on propensity score derived from household characteristics explained in section 5.2.

The table indicate that, the result for types of toilet services is significant after matching although it was insignificant before matching. After matching, the results clearly shows that children in control group are 2.3% more likely to suffer from water borne diseases. That means, children from households with improved toilet facilities are 2.3% less likely to get sick from water borne diseases. Similar scenery can be seen for types of drinking water services as results are significant after matching and children in control group are 4.5% more likely to suffer from water borne diseases due to poor drinking water services which means children from households with improved drinking water facilities are 4.5% less likely to get sick from water borne diseases. The result also indicates that poor drinking water services are 2.2% more responsible for children's sickness than poor sanitation infrastructure.

Table 11: Effects of types of toilet facilities and types of drinking water services on outcome variable

Effects of toilet facilities	Treated	Controls	Difference	S.E.	T-stat
Unmatched	.072	.076	-.004	.004	-1.12
ATT	.072	.095	-.023	.010	-2.28
Effects of drinking water services	Treated	Controls	Difference	S.E.	T-stat
Unmatched	.074	.067	.007	.010	0.70
ATT	.074	.119	-.045	.023	-2.01

Source: Authors calculation from HIES 2016 dataset, BBS using STATA 15

5.4 Conclusion:

Our result suggests that both poor drinking water and sanitation infrastructures are responsible for children's sickness from water borne diseases. The result also shows that poor drinking water services are more responsible for children's sickness.

Chapter 6 – Conclusion

6.1 Conclusion of the study

This study applies PSM to quantify the health loss of children from lack of improved sanitation and drinking water infrastructure in Bangladesh. We find lesser water borne diseases among children when households have improved sanitation and drinking water facilities. Although both of these services provide health benefit, poor drinking water services are 2.2% more responsible for children's sickness than poor sanitation infrastructure. This is can be considered an essential finding from a public health perspective. From our previous analysis from data and literature, we can say, although Bangladesh has made progress in water supply and sanitation coverage, the country still has the burden of child mortality and morbidity related to water borne diseases among South Asian countries. We suggest that benefits from improved WASH infrastructures have not been fully perceived yet in our country. How can this problem be treated, and how can policy help to fully comprehend the benefits from improvements in water and sanitation infrastructures that have been achieved in recent years? Both health and hygiene behavior can be a very beneficial target for intervention. First, it is mandatory to have more data especially for more years that allow to explicitly test the hypothesis. And second, policies should be made and implemented to make sure that improved sanitation facilities are complemented with a reliable drinking water supply. To conclude, improved sanitation and drinking water facilities both are essential public health intervention to reduce burden of morbidity and consequently mortality among children from water borne diseases in Bangladesh. Continuing improvements in drinking water and sanitation infrastructures along with harmonizing policies for behavior change through community participation, education, awareness, and health promotion activities may successfully reduce water borne diseases among children in Bangladesh and elsewhere.

Appendix 1: STATA Output of PSM for Toilet Services

```
Probit regression                               Number of obs     =     21,160
                                                LR chi2(22)       =    4831.19
                                                Prob > chi2       =     0.0000
Log likelihood = -12074.801                     Pseudo R2         =     0.1667
```

Ttypenew	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
hhincome_monthly	8.33e-08	1.47e-07	0.57	0.571	-2.05e-07	3.71e-07
ChildMale	-.0032205	.0235935	-0.14	0.891	-.0494629	.0430219
ChildNumber	.0335547	.0179811	1.87	0.062	-.0016876	.0687971
FemaleNumber	.0205709	.0144054	1.43	0.153	-.0076631	.0488049
RoomArea	.0003977	.0000357	11.14	0.000	.0003278	.0004677
tv	.1722818	.0232075	7.42	0.000	.1267958	.2177677
FamilySize	.0035939	.0095596	0.38	0.707	-.0151427	.0223304
InternetAccess	.2980121	.052768	5.65	0.000	.1945887	.4014356
ruc						
2	.2305444	.0247567	9.31	0.000	.1820221	.2790667
3	1.289882	.0909452	14.18	0.000	1.111632	1.468131
HighestEducatedWoman						
Primary Education	.1874622	.030208	6.21	0.000	.1282555	.2466688
Secondary Education	.3658303	.0297387	12.30	0.000	.3075435	.4241171
Higher Secondary Education	.6916778	.0550538	12.56	0.000	.5837744	.7995812
Graduated	.9323252	.087583	10.65	0.000	.7606657	1.103985
WallType						
Tin(CI sheet)	.3670486	.0231041	15.89	0.000	.3217655	.4123317
Brick/Cement	.7717076	.0307887	25.06	0.000	.7113629	.8320523
SharedToilet	-.037925	.0225028	-1.69	0.092	-.0820296	.0061796
SlumHouse	-.0873432	.0498119	-1.75	0.080	-.1849728	.0102864
StoveType						
Non-Electric & Non-Gas	-.1130968	.1491145	-0.76	0.448	-.4053558	.1791622
Gas	-.5303342	.1266401	-4.19	0.000	-.7785442	-.2821242
Electric	-.0065518	.1309679	-0.05	0.960	-.2632441	.2501405
ElectricityConnection	.2047369	.0230441	8.88	0.000	.1595713	.2499026
_cons	-.5747575	.133576	-4.30	0.000	-.8365617	-.3129533

Note: 0 failures and 3 successes completely determined.

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
WDiseases	Unmatched	.071578066	.075637547	-.004059481	.003614694	-1.12
	ATT	.072398983	.09527566	-.022876676	.010017491	-2.28
	ATU	.07566218	.070343031	-.005319149	.	.
	ATE			-.015033219	.	.

Note: S.E. does not take into account that the propensity score is estimated.

psmatch2: Treatment assignment	psmatch2: Common support		
	Off suppo	On suppor	Total
Untreated	3	9,212	9,215
Treated	536	11,409	11,945
Total	539	20,621	21,160

Appendix 2: STATA Output of PSM for Drinking Water Services

```
Probit regression                               Number of obs     =     21,160
                                                LR chi2(22)       =    1431.67
                                                Prob > chi2       =     0.0000
Log likelihood = -2568.3906                     Pseudo R2         =     0.2180
```

Watertype	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
hhincome_monthly	-2.26e-07	1.81e-07	-1.25	0.212	-5.80e-07	1.28e-07
ChildMale	-.0199297	.0460384	-0.43	0.665	-.1101633	.070304
ChildNumber	-.0476128	.0328349	-1.45	0.147	-.111968	.0167424
FemaleNumber	-.084012	.0270135	-3.11	0.002	-.1369575	-.0310665
RoomArea	.0000674	.0000693	0.97	0.331	-.0000685	.0002033
tv	.0329819	.0591128	0.56	0.577	-.082877	.1488408
FamilySize	.0025254	.0179732	0.14	0.888	-.0327014	.0377522
InternetAccess	-.2069143	.0996615	-2.08	0.038	-.4022474	-.0115813
ruc						
2	.2485982	.0631476	3.94	0.000	.1248312	.3723651
3	.918347	.3238118	2.84	0.005	.2836875	1.553006
HighestEducatedWoman						
Primary Education	.3305597	.0506092	6.53	0.000	.2313674	.4297519
Secondary Education	.4559132	.0529693	8.61	0.000	.3520952	.5597311
Higher Secondary Education	.4611067	.1160094	3.97	0.000	.2337324	.6884809
Graduated	.3849116	.1589946	2.42	0.015	.0732878	.6965354
WallType						
Tin(CI sheet)	.8547518	.0422833	20.21	0.000	.7718781	.9376255
Brick/Cement	.6398818	.0663444	9.64	0.000	.5098492	.7699144
SharedToilet	.421897	.0550547	7.66	0.000	.3139918	.5298022
SlumHouse	-.0471607	.0990317	-0.48	0.634	-.2412592	.1469378
StoveType						
Non-Electric & Non-Gas	-.0953797	.3223112	-0.30	0.767	-.7270981	.5363387
Gas	-.0577971	.2824984	-0.20	0.838	-.6114839	.4958896
Electric	-.0681491	.2953089	-0.23	0.817	-.6469438	.5106456
ElectricityConnection	.5765298	.0456133	12.64	0.000	.4871293	.6659303
_cons	.9211453	.2889695	3.19	0.001	.3547756	1.487515

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
WDiseases	Unmatched	.073589253	.066841415	.006747838	.009613349	0.70
	ATT	.073980512	.119399907	-.045419395	.022645093	-2.01
	ATU	.066841415	.073394495	.00655308	.	.
	ATE			-.043452381	.	.

Note: S.E. does not take into account that the propensity score is estimated.

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	0	763	763
Treated	1,000	19,397	20,397
Total	1,000	20,160	21,160

Reference

1. Baker, K. K., O'Reilly, C. E., Levine, M. M., Kotloff, K. L., Nataro, J. P., Ayers, T. L., Farag, T. H., Nasrin, D., Blackwelder, W. C., Wu, Y., Alonso, P. L., Breiman, R. F., Omore, R., Faruque, A. S. G., Das, S. K., Ahmed, S., Saha, D., Sow, S. O., Sur, D., … Mintz, E. D. (2016). Sanitation and Hygiene-Specific Risk Factors for Moderate-to-Severe Diarrhea in Young Children in the Global Enteric Multicenter Study, 2007–2011: Case-Control Study. *PLOS Medicine*, *13*(5), e1002010. https://doi.org/10.1371/journal.pmed.1002010

2. Becker SO, Ichino A. (2002). Estimation of average treatment effects based on propensity scores. *Biometrika, 70*(1), 41–55.

3. Berendes, D., Leon, J., Kirby, A., Clennon, J., Raj, S., Yakubu, H., Robb, K., Kartikeyan, A., Hemavathy, P., Gunasekaran, A., Roy, S., Ghale, B. C., Kumar, J. S., Mohan, V. R., Kang, G., & Moe, C. (2017). Household sanitation is associated with lower risk of bacterial and protozoal enteric infections, but not viral infections and diarrhoea, in a cohort study in a low-income urban neighbourhood in Vellore, India. *Tropical Medicine & International Health*, *22*(9), 1119–1129. https://doi.org/10.1111/tmi.12915

4. Bitew, B. D., Woldu, W., & Gizaw, Z. (2017). Childhood diarrheal morbidity and sanitation predictors in a nomadic community. *Italian Journal of Pediatrics*, *43*(1), 91. https://doi.org/10.1186/s13052-017-0412-6

5. Cha, S., Lee, J., Seo, D., Park, B. M., Mansiangi, P., Bernard, K., Mulakub-Yazho, G. J. N., & Famasulu, H. M. (2017). Effects of improved sanitation on diarrheal reduction for children under five in Idiofa, DR Congo: A cluster randomized trial. *Infectious Diseases of Poverty*, *6*(1), 137. https://doi.org/10.1186/s40249-017-0351-x

6. Exum, N. G., Lee, G. O., Olórtegui, M. P., Yori, P. P., Salas, M. S., Trigoso, D. R., Colston, J. M., Schwab, K. J., McCormick, B. J. J., & Kosek, M. N. (2018). A Longitudinal Study of Household Water, Sanitation, and Hygiene Characteristics and Environmental Enteropathy Markers in Children Less than 24 Months in Iquitos, Peru. *The American Journal of Tropical Medicine and Hygiene*, *98*(4), 995–1004. https://doi.org/10.4269/ajtmh.17-0464

7. Girma, M., Hussein, A., Norris, T., Genye, T., Tessema, M., Bossuyt, A., Hadis, M., Zyl, C., Goyol, K., & Samuel, A. (2021). Progress in Water, Sanitation and Hygiene (WASH) coverage and potential contribution to the decline in diarrhea and stunting in Ethiopia. *Maternal & Child Nutrition*. https://doi.org/10.1111/mcn.13280

8. Gizaw, Z., Adane, T., Azanaw, J., Addisu, A., & Haile, D. (2018). Childhood intestinal parasitic infection and sanitation predictors in rural Dembiya, northwest Ethiopia.

Environmental Health and Preventive Medicine, *23*(1), 26. https://doi.org/10.1186/s12199-018-0714-3

9. Gizaw, Z., Biks, G. A., Yitayal, M., Alemayehu, G. A., Alemu, K., Awoke, T., Tsegaye, A. T., Tariku, A., Derso, T., Abebe, S. M., & Chala, M. B. (2019). Sanitation predictors of childhood morbidities in Ethiopia: Evidence from Dabat Health and Demographic Surveillance System. *Environmental Health and Preventive Medicine*, *24*(1), 43. https://doi.org/10.1186/s12199-019-0801-0
10. Headey, D., & Palloni, G. (2019). Water, Sanitation, and Child Health: Evidence from Subnational Panel Data in 59 Countries. *Demography*, *56*(2), 729–752. https://doi.org/10.1007/s13524-019-00760-y
11. Heckman J, Robb R. (1985). Alternative methods for evaluating the impact of interventions: an overview. *Journal of Econometrics, 30*(1–2), 239–267.
12. Hirano K, Imbens G. (2001). Estimation of causal effects using propensity score weighting: an application to data on right heart catheterization. *Health Services and Outcomes Research Methodology, 2*(3–4), 259–278.
13. Hirano K, Imbens G, Ridder G. (2003). Efficient estimation of average treatment effects using the estimated propensity score. *Econometrica, 71*, 1161–1189.
14. Kumar, S., & Vollmer, S. (2013). DOES ACCESS TO IMPROVED SANITATION REDUCE CHILDHOOD DIARRHEA IN RURAL INDIA?: DOES ACCESS TO IMPROVED SANITATION REDUCE CHILDHOOD DIARRHEA IN INDIA? *Health Economics*, *22*(4), 410–427. https://doi.org/10.1002/hec.2809
15. Manalew, W. S., & Tennekoon, V. S. (2019). Dirty hands-on troubled waters: Sanitation, access to water and child health in Ethiopia. *Review of Development Economics*, *23*(4), 1800–1817. https://doi.org/10.1111/rode.12604
16. Rah, J. H., Cronin, A. A., Badgaiyan, B., Aguayo, V. M., Coates, S., & Ahmed, S. (2015). Household sanitation and personal hygiene practices are associated with child stunting in rural India: A cross-sectional analysis of surveys. *BMJ Open*, *5*(2), e005180–e005180. https://doi.org/10.1136/bmjopen-2014-005180
17. Rah, J. H., Sukotjo, S., Badgaiyan, N., Cronin, A. A., & Torlesse, H. (2020). Improved sanitation is associated with reduced child stunting amongst Indonesian children under 3 years of age. *Maternal & Child Nutrition*, *16*(S2). https://doi.org/10.1111/mcn.12741
18. Rosenbaum PR. (1987). Sensitivity analysis for certain permutation inferences in matched observational studies. *Biometrika, 74*(1), 13–26.
19. Rosenbaum PR, Rubin DB. 1983. The central role of the propensity score in observational studies for causal effects. *The Stata Journal 4*, 358–377.

20. Saxton, J., Rath, S., Nair, N., Gope, R., Mahapatra, R., Tripathy, P., & Prost, A. (2016). Handwashing, sanitation and family planning practices are the strongest underlying determinants of child stunting in rural indigenous communities of Jharkhand and Odisha, Eastern India: A cross-sectional study: Child stunting in Jharkhand and Odisha. *Maternal & Child Nutrition*, *12*(4), 869–884. https://doi.org/10.1111/mcn.12323

21. Shrestha, A., Six, J., Dahal, D., Marks, S., & Meierhofer, R. (2020). Association of nutrition, water, sanitation and hygiene practices with children's nutritional status, intestinal parasitic infections and diarrhoea in rural Nepal: A cross-sectional study. *BMC Public Health*, *20*(1), 1241. https://doi.org/10.1186/s12889-020-09302-3

22. Shrestha, S. K., Vicendese, D., & Erbas, B. (2020). Water, sanitation and hygiene practices associated with improved height-for-age, weight-for-height and weight-for-age z-scores among under-five children in Nepal. *BMC Pediatrics*, *20*(1), 134. https://doi.org/10.1186/s12887-020-2010-9

23. UN Factsheet (2008). Sanitation is vital for health, Number 1.

24. Verdeja, M., Thomas, K., Dorsan, G., Hawks, M., Dearden, K., Stroupe, N., Hoj, T., West, J., Crookston, B., Ezekial, M., & Hall, C. (2019). Water, Sanitation, and Hygiene Factors Associated with Child Illness in Tanzania. *Health*, *11*(06), 827–840. https://doi.org/10.4236/health.2019.116066

25. Worrell, C. M., Wiegand, R. E., Davis, S. M., Odero, K. O., Blackstock, A., Cuéllar, V. M., Njenga, S. M., Montgomery, J. M., Roy, S. L., & Fox, L. M. (2016). A Cross-Sectional Study of Water, Sanitation, and Hygiene-Related Risk Factors for Soil-Transmitted Helminth Infection in Urban School- and Preschool-Aged Children in Kibera, Nairobi. *PLOS ONE*, *11*(3), e0150744. https://doi.org/10.1371/journal.pone.0150744

26. Yaya, S., Hudani, A., Udenigwe, O., Shah, V., Ekholuenetale, M., & Bishwajit, G. (2018). Improving Water, Sanitation and Hygiene Practices, and Housing Quality to Prevent Diarrhea among Under-Five Children in Nigeria. *Tropical Medicine and Infectious Disease*, *3*(2), 41. https://doi.org/10.3390/tropicalmed3020041