

Bangladesh

Investigating Nutrition-sensitive WASH

NURTURING THE 'EARLY YEARS' OF LIFE WITH WATER, SANITATION, & HYGIENE: Evidence and Policy Levers for Bangladesh

April 2019

WAT



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Contents

Acknowledgements.....	6
Abreviations	7
I. Executive Summary	9
Key Findings	9
II. Introduction	11
III. Progress in WASH and human development outcomes in Bangladesh	13
Key Points.....	13
2.1 Survival.....	16
2.2 Weakened Health and Nutrition.....	18
3.6 Missed education and economic opportunities	20
IV. Poverty Risk Model Assessment for Bangladesh	22
Key Points.....	22
3.1 Exposure Index.....	22
3.2 Susceptibility Index	24
3.3 Impact of Changes in Water and Sanitation Access	27
3.4 DALY burden of inadequate WASH in Bangladesh	29
IV. WASH in Community Health Centers in Bangladesh	33
Key Points.....	33
Data Sources	34
Method	35
The Status of WASH in Community Health Centers: A Snapshot	36
Discussion.....	41
V. WASH and Well-being of the Urban Poor	43
Key Points.....	43
A Disappearing Health Advantage for Urban Residents.....	43
WASH Services in Slums: High Access, low quality, and informal provision	44
Sanitpath: An Assessment of Fecal Exposure Pathways in Dhaka Slums and High-Income Neighborhoods	44
VI. Stunting and WASH in Bangladesh	48
Key Points.....	48
4.1 Correlates of Stunting- Logit Regression Analysis	48
4.2 Role of WASH in Explaining Stunting- Shapley Decomposition.....	51
4.3 Identifying the Causes of Differences in Stunting Incidence between the T60 and B40: Does the Differences in Access to WASH Play a Role?	52
VIO. The Role of Water Quality in Improving Health, Nutrition, Cognitive Development, and Survival	55
5.1 E. coli contamination of drinking water and childhood stunting in Bangladesh.....	55
5.2 Exposure to Arsenic Contaminated Water and Early Childhood Development (ECD) ...	58
5.3 Salinity and Child Survival	61
VIII. WASH Access and Education	65

6.1 Long Run Educational Impacts of Exposure to Poor Sanitation in the Childhood.....	65
6.2 Salinity, Water Collection Burden and School Enrolment of Girls.....	67
IV. Policy Levers	72
Key Points.....	72
Lever 1: Targeting WASH Investments	72
Lever 2: Improve the quality of service to be more “human development centric”	73
Lever 3: WASH Integration into Traditional Human Development Programs.....	73
Lever 4: Supporting WASH Research and Innovation.....	74

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Abbreviations

B40	Bottom 40 percent
BBS	Bangladesh Bureau of Statistics
BWPD	Bangladesh WASH Poverty Diagnostic
CQ	Core Question of WASH Poverty Diagnostic
DHS	Demographic and Health Survey
DPHE	Department of Public Health and Engineering
FSM	Fecal Sludge Management
GoB	Government of Bangladesh
GP	Global Practices of World Bank
GWPD	Global WASH Poverty Diagnostic
HIES	Household Income and Expenditure Survey
HOI	Human Opportunity Index
ICDDR,B	International Centre of Diarrheal Disease Research, Bangladesh
JMP	Joint Monitoring Programme
LGI	Local Government Institution
LIS	Low-income settlements
MDG	Millennium Development Goal
MICS	Multiple Indicator Survey
NHBS	National Hygiene Baseline Survey
SDG	Sustainable Development Goals
T60	Top 60 percent
UNDP	United Nations Development Programme
UNICEF	United Nations Children’s Fund
WASH	Water, Sanitation, and Hygiene
WASA	Water and Sanitation Sewerage Authority
WB	World Bank
WDB	Bangladesh Water Development Board
WHO	World Health Organization
WSP	World Bank Water and Sanitation Program

I. Executive Summary

Coupled with steady economic growth and pro-poor interventions, Bangladesh was able to lift 20 million people from extreme poverty since the start of the new millennium¹. Job creation stands as the first priority for continuing Bangladesh’s remarkable progress, with a target to bring new jobs for the 2 million youths entering the job market each year. But as Bangladesh strives to create more and better job opportunities, it must also do more to invest in human capital, starting with improving the youth’s ability to reach their full potential in their life course.

Among the best strategies to increase human capital is to target those with the most human capital to gain – that is targeting children living in the bottom 40 percent of the wealth distribution. Risks of poor health and educational attainment are the primary barriers to human capital gains. Socio-economic gradients in health and education outcomes exist in Bangladesh and in most every country. However, as a number of studies have shown, ill health and lack of education are not simply caused by being poor, but are likely caused by the fact that basic services, medical advancements, and education access are last to expand to the poorest. Targeted investments to the disadvantaged, particularly investments in early childhood development that have long-lasting benefits to better health, cognition, and productivity, can better establish Bangladesh as a more competitive economy and a leader in promoting the human right to wellbeing.

Investments in water, sanitation, and hygiene (WASH) should be recognized as fundamental investments in early childhood development and human capital. Children are more likely to thrive in water secure and sanitary environments – in environments where they do not contract enteric infections, drink water contaminated with heavy metals, or are vulnerable to frequent shocks of flooding and natural disasters. Adults, especially women, can generate more income for their families when they are not held back by burdens of water collection, sanitary access in schools and workplaces, and poor health.

“Nurturing the ‘Early Years’ of Life with Water, Sanitation, and Hygiene” presents evidence for how WASH is empirically linked to human capital, particularly to those human capital dimensions related to child health, nutrition, and education outcomes. The presented evidence is a summary of existing literature and original data collection and analyses undertaken by the World Bank Water Global Practice team. The report additionally provides a set of policy recommendations on how the WASH sector can better align to country’s greater development objectives and how other sectors can harness the benefits of WASH in making their programs more effective. We summarize some of the key findings and implications of the report below.

Key Findings

¹ 1.90 per day 2011 Parity Purchasing Power (PPP)

1. Basic WASH access is nearly universal, but the quality of access is not sufficient to guarantee holistically safe WASH environments that generate high-return public health benefits.

Recent rigorous trials, including in Bangladesh, have found that simple household provision of WASH infrastructure has limited impact on health and nutrition outcomes. Piling evidence suggests that WASH must take a transformative approach to ensuring entire communities not only have reliable, high-quality access to water and sanitation infrastructure but also uptake hygienic behaviors to realize health benefits. Though most of Bangladeshis have access to basic improved drinking water sources and sanitation from a technological perspective, over half of all Bangladeshis are exposed to either arsenic or E. coli in drinking water and very few live in environments where waste is safely disposed of and treated. WASH investments need to take a human-centric approach by aiming to relieve common burdens such as reducing exposure to environmental contaminants and increasing reliable access in homes and public places.

2. The poorest have the worst access to WASH and suffer the most consequences from lack of access.

Household wealth determines whether a child will have access to improved water and sanitation about 70-75 percent of the time. Due to higher risk factors of exposure to fecal pathogens and susceptibility to be infected, risk of WASH-related enteric infections is three times greater for the poorest wealth quintile compared to the richest quintile. Stunting rates of children are nearly double in the bottom 40 than top 60 percent of wealth distributions and highest in urban slum populations.

3. Water quality has strong correlates to child survival, stunting, early childhood development skillsets.

Fecal bacteria, arsenic, and salinity are the three major contaminants that threaten Bangladesh's supply of drinking water. Our analyses find that exposure to E. coli bacteria in drinking water raises the risk of stunting by 5 percentage points. Arsenic, a literal neurotoxin, significantly damages development of early childhood skillsets by affecting social, motor and cognitive skills. We additionally find that saline groundwater could be an important source for mineral intake, especially for women during pregnancy, but in excessive amounts affects maternal and infant health and survival.

4. Unreliable water and sanitation access serves as a barrier to enrolling and finishing school.

We find that exposure to poor sanitation during infancy can delay school enrollment by affecting health, and cognitive skills among young children. Water collection duties in salinity prone areas can affect school enrollment especially for girls

II. Introduction

Bangladesh made a number of laudable development achievements in the early millennium but can and should do more to improve human capital and the wellbeing of its population. The share of the population living below the official upper poverty line declined from 49 percent in 2000 to 24.3 percent in 2016 (World Bank 2017). The gross national income (GNI) per capita (Atlas method) increased from USD 100 in 1972 to USD 1,408 in 2016, allowing Bangladesh to be considered as a lower middle-income country. Gross domestic product (GDP) has grown at an average of about 6 percent per year since the start of the new millennium. Coupled with impressive achievements in poverty reduction and economic growth are meeting many of the Millennium Development Goals (MDGs)—such as reaching nearly universal access to primary education, gender parity in primary and secondary education, ensuring food security, lowering infant, child, and maternal mortality rates, improving immunization coverage, and increasing access to improved water sources.

Bangladesh has a lot to celebrate, indeed, but the challenge ahead calls for refining services to improve human capital – that is improvements in skills, education, health, knowledge, and resilience that allows populations to become more flexible, innovative, and productive in an increasingly competitive and globalized economy. The World Bank’s Human Capital Index (HCI) measures² the amount of human capital that a child born today can expect to achieve by the age of 18 in view of the risks of poor health and education currently prevailing in the country they live in. At present, the HCI estimates that a child born in Bangladesh will be 48 percent as productive as they could be. Though this is higher than most countries in the South Asian region, this is lower for Bangladesh’s income group, ranking Bangladesh 106 out of the 157 low- and middle-income countries indexed.

Nurturing a child’s early years can help nations boost human capital to become more diverse, competitive economies. This is because early life experiences impact the first critical stages of growth and development that lay the foundation for a child’s ability to thrive and reach their full potential in childhood, adolescence, and adulthood. The early years are when strong physical health matters the most for preventing disease and early death and when higher cognitive skills begin to emerge to support learning. They have multiplier effects that accumulate through an individual’s life course as well as through population life cycles that ultimately influence the wellbeing and productivity of future generations.

Improving early childhood development requires multi-sectoral action. Physical health, nutrition, cognitive stimulation, and mental stress are known variables to impact early childhood development.

² The index is determined by child survival, test scores, stunting rates, and expected years of school.

Aiming to improve any of these factors are tremendous feats in themselves and require multi-sectoral commitment to implementing an array of interventions that can give children healthy environments to grow and learn.

Childhood stunting, for instance, is a marker of chronic undernutrition and is the lowest scoring component of Bangladesh' HCI. Stunting is regarded as the “non-income” face of poverty because its causes are multifaceted and often overlap with conditions of poverty, such as food insecurity and poor environmental health. Good physical health and cognitive stimulation, similarly, require good caregiving and accessible services. Children living in poorer households often experience higher levels of stress because they are more vulnerable to environmental and economic shocks, social stigmas, and political conflict.

Advancements in early childhood development will not be possible without improvements in water, sanitation, and hygiene (WASH). When taking into account the multifaceted and deleterious effects of inadequate WASH, access to quality WASH services is critical for improving early childhood development and maximizing human capital. Everyday tasks of collecting water, recovering from natural disasters, frequent bouts of diarrhea, chronic exposures to fecal bacteria and chemical contaminants, and poor hygiene behaviors can all serve as barriers to success of children. To have a more human-centric approach to development, the WASH sector needs to close service delivery gaps that can inhibit children from gaining the skills they need to thrive.

This report will discuss several analyses that demonstrate the importance of WASH in nurturing the early years. The report begins with an examination of progress in achieving human development outcomes, many of which are specifically used to measure early childhood development and human capital. The next section will present a poverty risk model used to measure differences in WASH-related disease burden among wealth groups and populations with and without access to basic water and sanitation services. The third section discusses WASH deprivations in community health centers that reduce quality of care, and the fourth section measures the unique environmental exposures from inadequate WASH faced by slum dwellers, an often neglected yet high-risk population for poor health and undernutrition. The proceeding four sections then present original econometric analyses linking various components of WASH to childhood stunting, early childhood skills, infant mortality, and school enrollment. The final section concludes and provides recommendations on how Bangladesh's WASH sector can prioritize the early years in future investments.

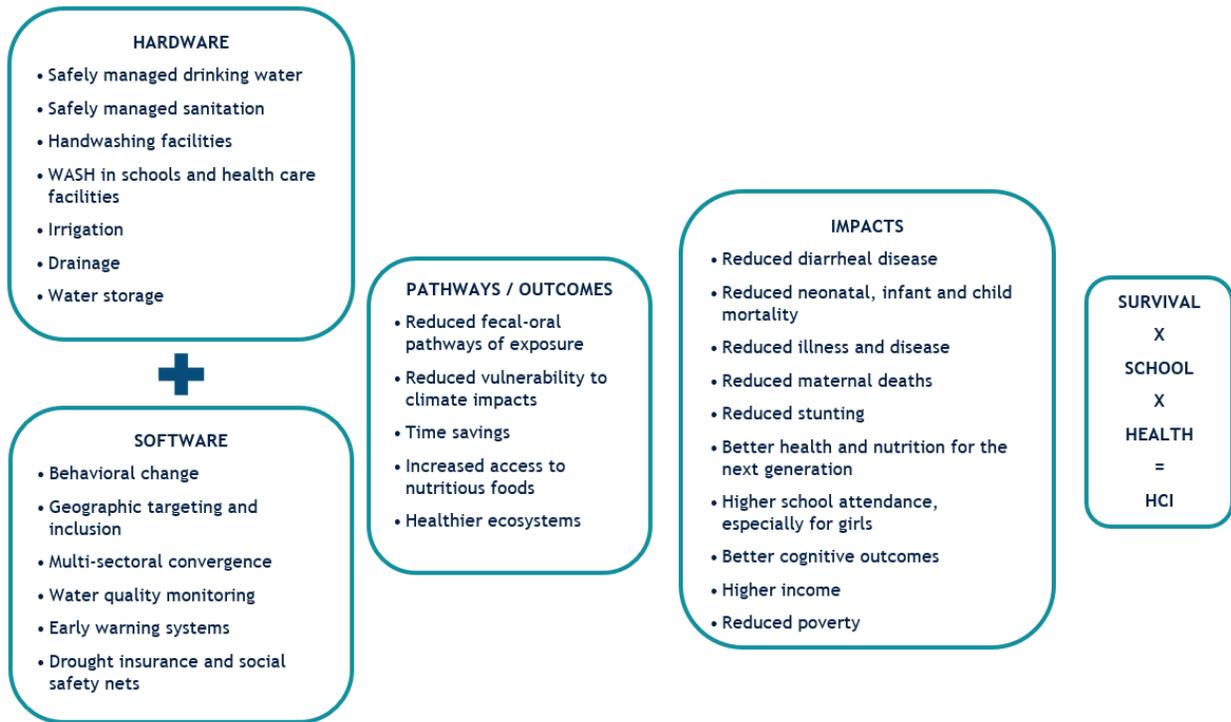
III. Progress in WASH and human development outcomes in Bangladesh

Key Points

From 1990 to 2017, Bangladesh experienced a 20-percentage point increase in access to drinking water sources and 29-percentage point increase in access to sanitation that are considered as “improved” by global standards, with current access at 98 percent and 63 percent respectively (WHO/UNICEF 2017). The eradication of open defecation and advancements in drinking water infrastructure are considered as important strides in Bangladesh’s development for improving human dignity and survival. However, evidence also shows the importance of WASH for prevention of ailments such as undernutrition, cancers, and development disorders. Water’s relevance to public health is not merely lowering rates of mortality but is also improving overall well-being throughout the life course.

But to realize WASH’s full potential, Bangladesh needs to begin investing in transformative WASH services that focus on accessibility, quality, and sustainability. Though nearly all Bangladeshis drink from technologically improved water sources, just 39 percent of Bangladeshis drink from an improved water source that is available within a household’s premise and free of contaminants such as E. coli bacteria and arsenic. Nearly 40 percent of households share a sanitation facility with other households. Some studies estimate that less than 2 percent of fecal sludge is safely managed and treated in Bangladesh’s major cities. Good hygiene practices are lacking throughout the population, with poor access to handwashing stations with soap and water (28%), unsafe child feces disposal practices (40%), limited safe household water treatment (10%), and lack of access to safe menstrual hygiene materials to females (23%). WASH interventions also cannot stop at the household-level but need to be expanded throughout the community and in public places, such as schools, healthcare facilities, and workplaces. Significant disparities exist between geographies and income groups. Hard-to-reach area, climate-change vulnerable regions, urban slums, and the bottom 40 percent consistently fare worse in access to WASH services.

Gaps in WASH provision can disrupt human capital and early childhood development in three main ways: 1) lower chance of child survival; 2) weakened immunity and nutrition; and 3) missed education and economic opportunities. Here, we summarize trends in of human development outcomes related to these three pathways.



Learning from the Bangladesh WASH Benefits Trial and other recent WASH RCTs

The global WASH sector is learning from humbling results from recently completed randomized-controlled trials (RCTs) evaluating the health and nutritional impacts of household WASH interventions. One of the most high-profile evaluations, **WASH Benefits**, was completed in rural Bangladesh and Kenya. WASH Benefits aimed to evaluate the combined effects of traditional nutritional, water, sanitation, and hygiene interventions in improving child health outcomes including diarrhea and child linear growth. The study found minimal but statistically significant reductions in diarrhea prevalence in some arms receiving WASH interventions, but no significant improvements in child linear growth. The results are contrary to a plethora of observational studies that have demonstrated significant linkages between advancements in WASH and health and nutrition outcomes. Yet, the results are in line with other rigorous WASH RCTs completed in Zimbabwe (Humphrey 2019), Kenya (Null 2018), India (Clasen 2014; Patil 2014), Mali (Pickering 2015), and Indonesia (Cameron 2013). These RCTs have nuanced implications and have generated important discourse within the WASH and health and nutrition sectors. We summarize some of the key takeaways and implications of these evaluations.

1. **Community coverage could be a missing factor.** WASH Benefits and similar RCTs implemented interventions at the compound- or household-level. That is, they do not necessarily evaluate improved community coverage of WASH interventions. In WASH Benefits, for example, both study sites in Bangladesh and Kenya only provided interventions to compounds that housed pregnant women. At most, only eight compounds per cluster/village received interventions. However, an increasing body of research shows that community WASH coverage is more important than individual household-level access because community coverage creates positive externalities or herd protection against fecal exposure. Fecal pathogens travel quickly between neighbors, especially in Bangladesh, where even rural areas are densely populated. The compound-level intervention in WASH Benefits was likely unable to protect individuals from fecal exposure throughout the community. WASH programming should focus more on community-wide improvements rather than targeting individual households.
2. **The WASH interventions were not the “right” WASH interventions.** The biological plausibility that good WASH is needed to reduce fecal exposure and prevent disease is strong and has been supported throughout history and the earliest epidemiological studies. However, there are numerous ways to operationalize and implement improvements in WASH. In the case of WASH Benefits Bangladesh, the WASH interventions included compound-level provision of double-pit latrines, sanitary scoops for picking up feces in compounds, child potties, handwashing stations with soap and water, and promotion of safe water handling and chlorinating drinking water. The interventions were not able to reduce E coli prevalence in soil, food, or hands. Only chlorination reduced prevalence of E. coli in drinking water; however, chlorination is not a sufficient water treatment method to kill all enteric pathogens. This implies that these particular WASH interventions could not effectively block all pathways of enteric pathogen transmission. The investigators found evidence of continued E.coli contamination that came from animal feces, child feces, and the natural environment.

(Continued on next page)

Learning from the Bangladesh WASH Benefits Trial and other recent WASH RCTs (cont.)

3. **Need for Measuring Process, Behavioral, and Exposure Outcomes.** WASH Benefits revealed the importance of measuring intermediary outcomes. Improvements in health outcomes are not dependent on simple WASH provision, but rely on following every step in a well thought-out theory of change. Though the investigators provided child potties and improved latrines, children were still observed to openly defecate. Sanitary scoops were not well utilized to pick up feces from compounds. Though stored water had detectable levels of chlorine, household members may still have drunk untreated water from other sources. Improved health is an ultimate impact of improved WASH, but more attention needs to first be given to the effectiveness of WASH interventions in improving behavioral and exposure outcomes, such as fecal contamination in various pathways. Impact evaluations need to be complemented with process evaluations and thorough documentation of contextual factors surrounding how interventions are implemented and how well interventions are taken up and accepted by households. This can help understand why interventions may fail to deliver health impact and whether results can be generalizable to other contexts.

4. **Investing in “Transformative WASH.”** Observational studies find substantial health and nutrition impacts from improvements in WASH. However, these observed linkages can also be explained by a number of confounding factors. Communities that are able to improve WASH conditions are also likely to address other factors that cause poor health and nutrition, such as food insecurity, caregiving practices, education, community infrastructure, housing structures, and general welfare. Although observational studies can account for some of these types of variables, there are some unobservable factors that help facilitate WASH’s influence on health. However, what we do know is that WASH is still a necessary investment. These recent RCTs tell us that the WASH sector needs to reevaluate its current approach and coordinate with other sectors to ensure that its investments are working to create a transformative environment that allows people to reach their full capability.

2.1 Survival

Between 1990 and 2015, infant and child mortality rates (the number of deaths per 1,000 live births) declined from 100 to 31 and 144 to 36, respectively.³ These improvements are at least partially correlated to improvements in WASH access—and more specifically the decline in diarrheal disease, which historically was a leading cause of death for children under five years of age.⁴ Bangladesh was able to reduce the prevalence of diarrheal disease among children under five years of age, from 12.6 to 5.7

³ UNICEF, et al., *Levels and trends in child mortality: report 2015* 2015, UNICEF: New York.

⁴ Global Burden of Disease Pediatrics, C., *Global and national burden of diseases and injuries among children and adolescents between 1990 and 2013: Findings from the global burden of disease 2013 study*. JAMA Pediatrics, 2016. **170**(3): p. 267-287.

percent, allowing diarrheal diseases to fall from the 3rd to the 11th leading cause of death among children under five in Bangladesh.⁵⁶

Maternal mortality rates have also drastically decreased. Between 1990 and 2015, Bangladesh was able to reduce its maternal mortality ratio from 569 deaths per 100,000 live births, to 176 deaths per 100,000 live births—roughly translating into a 70 percent reduction over the span of 15 years. Regionally, the country exhibits performance comparable to neighboring India (174 deaths per 100,00 live births) and Pakistan (178 deaths per 100,000 live births). Early childhood development is significantly determined by maternal health status. Studies suggest that mothers exposed to poor sanitary environments in the home and health centers can lead to higher likelihood of infections during pregnancy, sepsis, and adverse birth outcomes during delivery.

Modeled estimate. Source: World Development Indicators

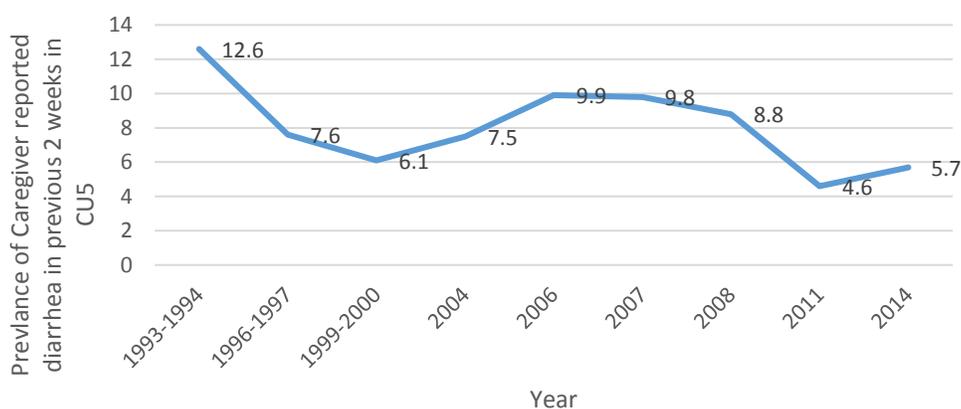
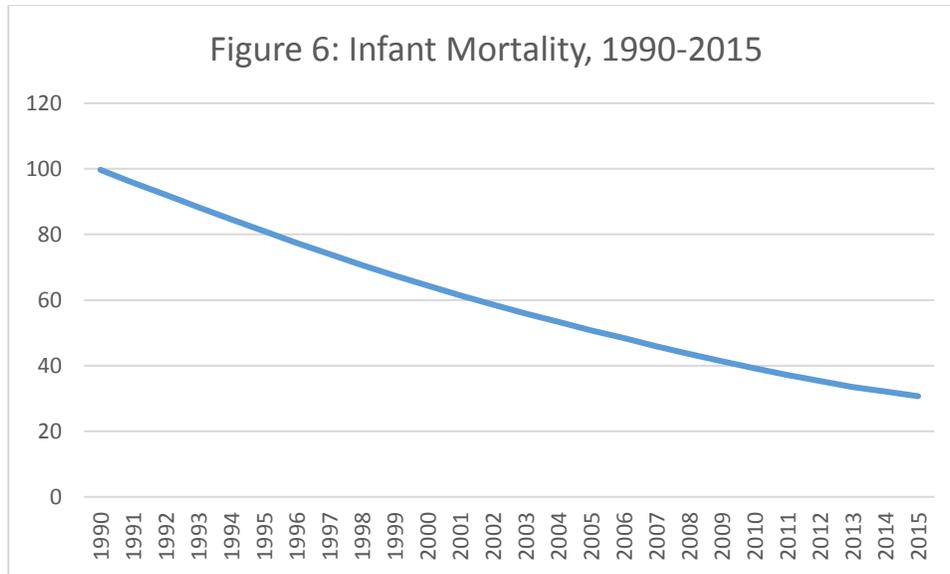


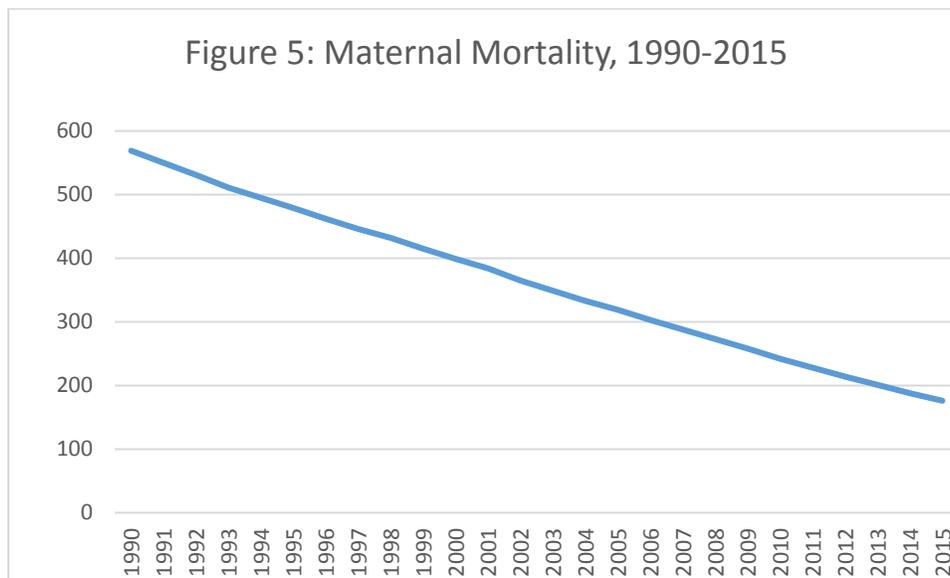
Figure 2: Prevalence of Diarrhea, % Children Under Five Years of Age; Source: DHS, multiple years.

⁵ Unicef child survival

⁶ Global Burden of Disease Pediatrics, C., *Global and national burden of diseases and injuries among children and adolescents between 1990 and 2013: Findings from the global burden of disease 2013 study*. JAMA Pediatrics, 2016. **170**(3): p. 267-287.



Source: World Development Indicators



2.2 Weakened Health and Nutrition

Similar to its South Asian neighbors, Bangladesh experiences unusually high rates of child undernutrition relative to its income levels and health and nutrition investments. Despite a rapid increase in economic growth and substantial reduction in poverty, reduction in undernutrition among children under five over the last one decade could only be described as sluggish at best^{7, 8}. Tripling of rice production over the last

⁷ Deaton and Dreze, 2008

⁸ This is referred to as 'the Asian enigma' (Ramalingaswami, Jonson, and Rohde 1997) which has led to substantial search into possible explanations, including gender and intra-household biases (Jayachandran and Pande 2013; unusually high rates of open defecation (Spears 2013; Spears, Ghosh, and Cumming 2013), genetic predispositions

three decades along with increased per capita food intake is a boasted development achievement for Bangladesh, yet its stunting rates is still among the highest in the world.⁹ Stunting—widely accepted as an indicator of chronic undernutrition—has substantially decreased since 1991, though gains since 2000 have been nominal, with total stunting decreasing by only 14.4 percentage points. Today, about 36 percent of all children under five are considered stunted. Nearly 30 percent are stunted by the age of two. Stunting is highest in the poorest populations. Nearly 50 percent of children living in the bottom wealth quintile are stunted compared to 20 percent in the richest quintile. Stunting among children is associated with long lasting consequences on health, cognitive development, education and earnings.

A wide body of literature has associated inadequate WASH with undernutrition—particularly through chronic diarrhea. Children who suffer from episodes of diarrhea divert energy to fighting off infections, lose essential nutrients, and have little appetite. Diarrhea and undernutrition also have a cyclical relationship. Those who are already undernourished are more susceptible to enteric infections that cause diarrhea, deepening their malnutrition. A growing body of literature is now linking WASH to a sub-clinical condition, environmental enteric dysfunction (EED), which can lead to malabsorption of nutrients. EED is hypothesized to be caused by repeated exposures to fecal pathogens that cause an inflammatory response and reduce the gut’s ability to absorb nutrients. EED is difficult to diagnose because those suffering do not necessarily show overt symptoms of enteric infections, such as onset of diarrhea. Water’s relevance to food security is a last pathway that can impact health and nutrition. Access to irrigation is a vital agricultural input that can lead to higher production of food and wages. Climate-related shocks such as drought, flooding, increased salinity can also impact agricultural productivity.

Anemia is another WASH-related linkage to weakened health and nutrition is anemia, a condition marked by low red blood cell count indicating that the body is not getting enough oxygen to properly function. The condition causes severe fatigue and weakened immunity. Inadequate WASH is purported to high rates of anemia in several ways. Intestinal parasites—often spread through fecal contamination of the environment—increase the risk of developing anemia.¹⁰ Mosquito-borne illnesses such as malaria can cause anemia. Chronic diarrhea and subsequent malnutrition also increase the likelihood that an individual develops anemia.

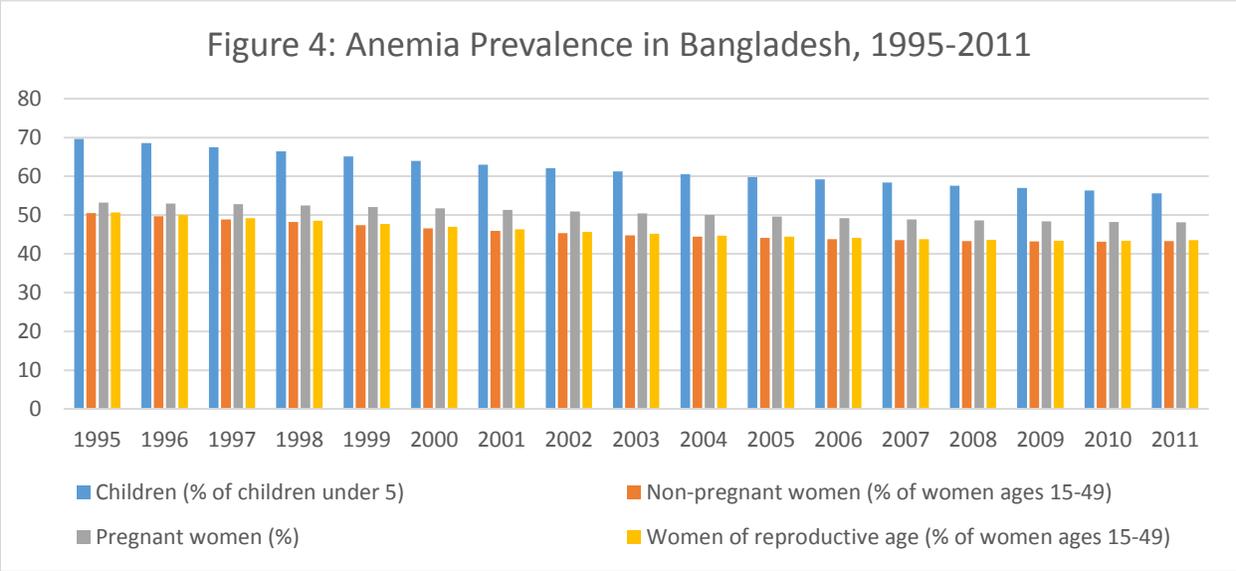
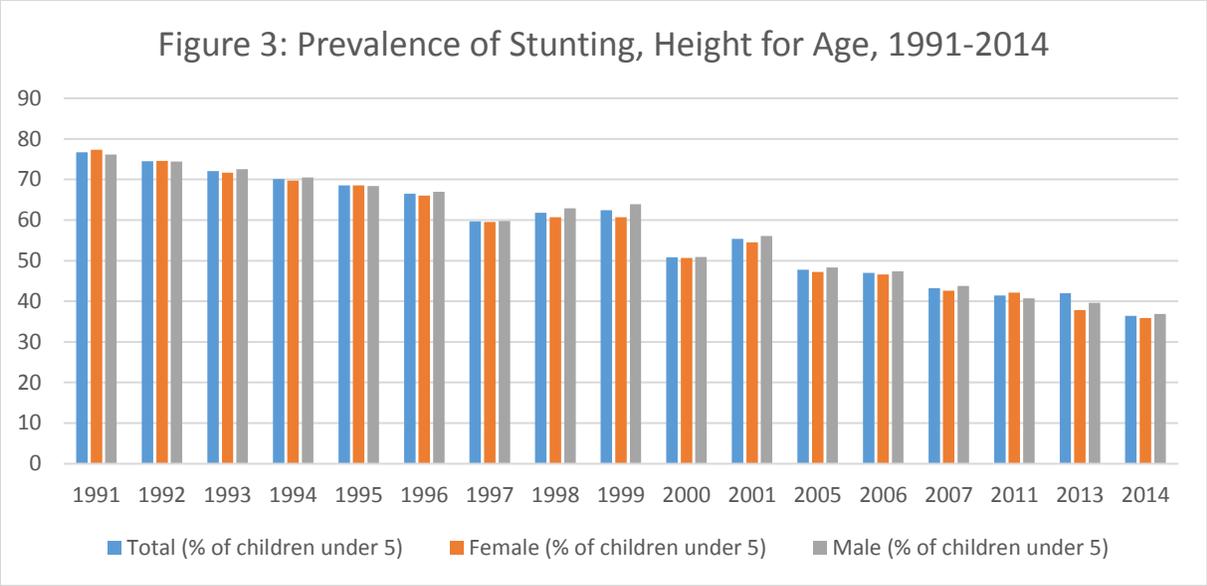
Nationally, it has been estimated that the overall prevalence of anemia in Bangladesh is 51 percent of the population.¹¹ According to WHO estimates in 2011, approximately 55.6 percent of children under the age of 5 were anemic. Furthermore, 48.1 percent of pregnant women, 43.3 percent of non-pregnant women, and 43.5 percent of women of reproductive age were anemic. Since 1995, reductions in anemia across all groups have been relatively modest.

(Nubé 2009), poor-quality diets and food systems (Headey, Chiu, and Kadiyala 2012), and the inefficacy of nutritional programs and strategies (Das Gupta et al. 2005; World Bank 2005a).

⁹ Thanks to the uptake of high-yield varieties, improved availability of fertilizer and other key inputs, and better irrigation, domestic rice production (the main food crop) has risen from around 12.3m metric tons in the 1980s to 37.6m metric tons in 2014

¹⁰ DHS 2014

¹¹ Chaparro C, Oot L, Sethuraman K. Overview of the Nutrition Situation in Four Countries in South and Central Asia. Washington, DC: FHI 360/FANTA; 2014.

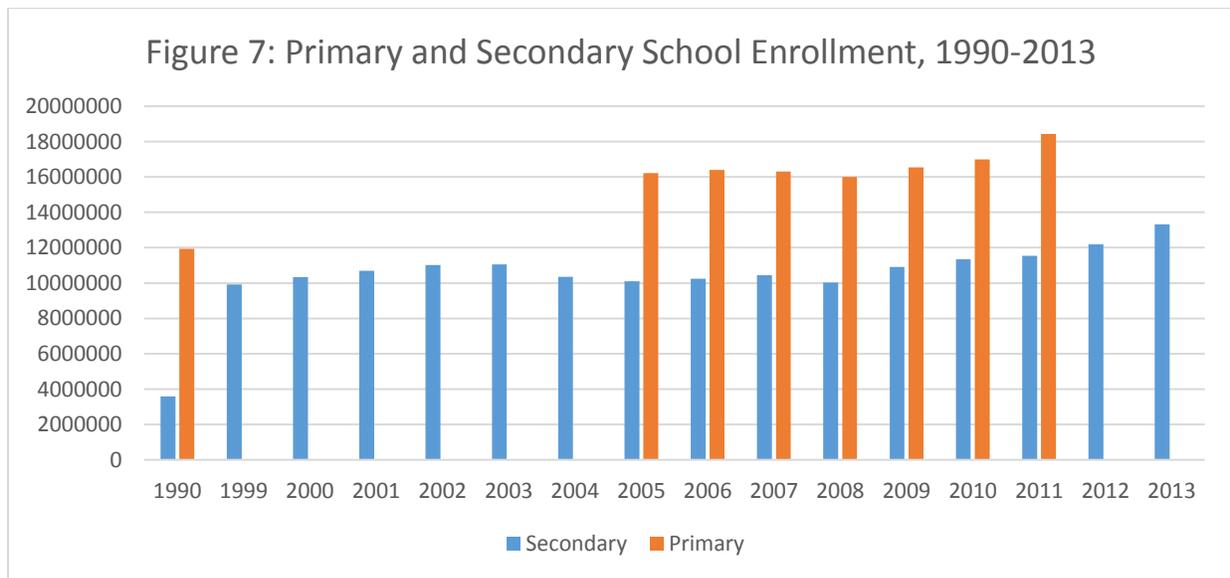


3.6 Missed education and economic opportunities

WASH’s linkages to missed education and economic opportunities are indirect, but are not to be overlooked. WASH’s direct contribution to mortality and morbidity have been shown to have implications on healthcare spending and productivity at school and work. Poor health status can cause children to miss school and be socially isolated or parents to miss a day of wages. The consequences of poor nutrition as exasperated by WASH can also lead to reduced cognitive development that manifests in poor school performance. Drinking water contaminated with heavy metals such as arsenic and lead are literal poisons to the mind that inhibit brain development and function.

Aside from health-related pathways, a lack of basic access to WASH facilities can close education and economic opportunities. Though most Bangladeshis have access to an improved water source for drinking, over a quarter of households have to travel off-premises to collect water. Most of this time burden falls disproportionately on females. Among those households that do not have access to water in their homes, 75% rely on female household members to collect water. Women are also more likely to be in charge of other caregiving tasks, such as treating and storing water or taking care of sick children. Beyond the home, lack of access to WASH materials and facilities in schools and workplaces serve as additional barriers to the human capital of women. About a quarter of adolescent females report missing at least one day of school during her period. A joint study by the Government and Bangladesh and UNICEF revealed that the provision of sanitary latrines led to an 11 percent increase in girls’ enrollment.¹² A study by the International Rescue Committee also notes that there was a 15 percent increase in school attendance, when water was available within a fifteen-minute walk compared to one of an hour or more.”¹³

For years where data is available, school enrollment at the primary level has always outpaced enrollment at the secondary level. Primary school enrollment increased from 3.6 to 13.3 million students in the 23-year period between 1990 and 2013. The most dramatic increase in secondary enrollment occurred between 1990 and 1999—from approximately 3.6 to 9.9 million students—a significant improvement which was not replicated in successive years.



Source: World Development Indicators

¹² DPHE-DPE-UNICEF (1994). Evaluation of the use and maintenance of water supply and sanitation system in primary schools: phase 1: final report. Dhaka, Bangladesh, Consulting Services & Associates.

¹³ International Rescue Committee (IRC). 2007. “Towards Effective Programming for WASH in Schools.”

IV. Poverty Risk Model Assessment for Bangladesh

Key Points

- **The national enteric burden associated with inadequate WASH is 2,413 DALYs / 100,000 children per year.** This is approximately 68% of the Global Burden of Disease (GBD) enteric burden estimated for the country.

The previous section highlighted the major consequences of inadequate WASH on determinants of human capital. Yet, not all people are similarly impacted; significant disparities exist across population groups and geographies in terms of the relative risk of being affected. For instance, within a population that lacks access to safe WASH, some face greater diarrheal risks due to other factors that render them more vulnerable or susceptible, such as access to healthcare and community infrastructure. To demonstrate this, we create a WASH Poverty Risk Index—which combines the relative risk of exposure and susceptibility—to compute an Overall Relative Risk Index to diarrhea for different sub-populations across Bangladesh.

3.1 Exposure Index

Using DHS 2014 data, exposure scenarios based on the coverage of water and sanitation service levels are calculated. Three exposure scenarios from the DHS are estimated for three types of water source coverage, including unimproved water, off-plot or community improved water sources, and on-plot improved (including piped) water sources. Three exposure scenarios for sanitation are also estimated: unimproved sanitation (including open defecation), improved sanitation but no sewerage (onsite), and sewer connection. Scores for the exposure index are calculated individually for each child based on the combined relative risks of each water and sanitation access scenario from literature based on Wolfe et al. (2014). The value for each child is based on the household's access to water and sanitation facilities, estimated using the DHS 2014 data. Exposure values are then estimated for each child, then averaged by cluster using survey weights. After calculating the exposure index, it is rescaled setting the lowest risk to 1.00, yielding a range of 1.00-3.71.

$$ExpIndex_i = SanRR \cdot WatRR$$

Other exposure risk factors to diarrhea such as handwashing, water treatment, child feces disposal and population density are not included in the exposure index because of the lack of information in the literature on their relative risk values in causing diarrhea.

Exposure Index

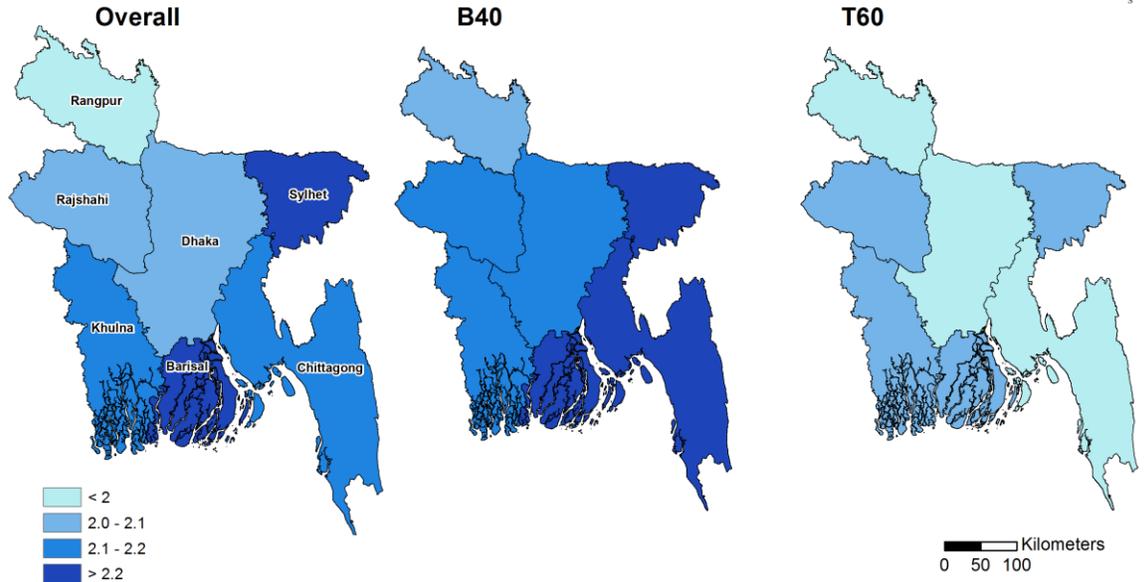


Figure 3.1 Maps exposure indices in Bangladesh by division for the overall population (left), bottom 40% (B40, middle), and top 60% (T60, right)

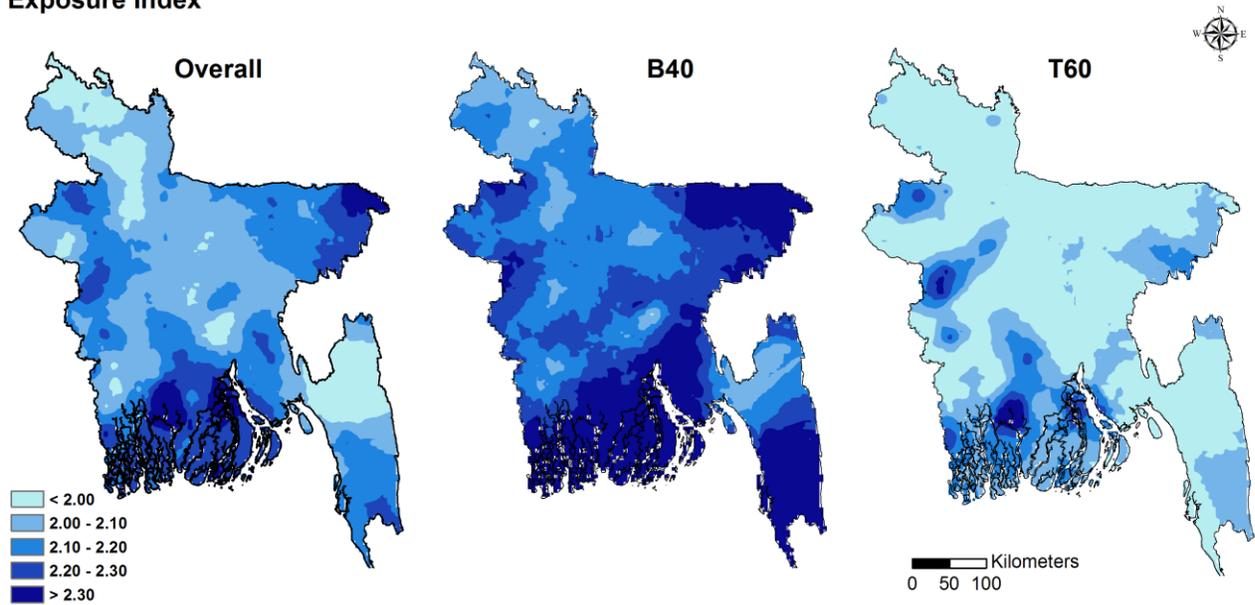
Figure 3.1 shows that the most vulnerable regions in terms of exposure to diarrhoea are Sylhet and Barisal. There are considerable differences in exposure between the overall, B40 and T60 maps. The most vulnerable regions for the B40 in Bangladesh are Sylhet, Chittagong and Barisal. Whereas the most vulnerable regions in the T60 map are Rajshahi, Khulna, and Sylhet. The low exposure seen in the Chittagong for the T60 (< 2) may be masking the high exposure, seen in the B40 map (> 2.2), in the overall map.

Figure 3.2 shows a finer scale spatial resolution map (at 5 km²) of the exposure index value distribution across children under five in Bangladesh, nationally (overall), and by economic group (B40 and T60). In the overall map (left), areas with the highest exposure index values are concentrated in the southwest and northeastern tip of Bangladesh. For the B40 children map, high exposure areas are larger and more widespread across the southwest, northeast, and southeast. There are only a few concentrated areas of high exposure in the T60 map (right map) scattered in central and southwestern Bangladesh.

Figures 3.1 and 3.2 are based on the variables included in the exposure index. It is important to point out that there are substantial disparities in other exposure related variables not included in the index (e.g. hand washing and water treatment). Including these variables would result in greater disparities and heterogeneity.

Figure 3.2 Maps of exposure index in Bangladesh at 5 km² resolution for overall (left), bottom 40% (B40, middle), and top 60% (T60, right) populations of children under 5 (BD DHS, 2014).

Exposure Index



3.2 Susceptibility Index

Susceptibility index is calculated using three risk factors related to susceptibility of diarrheal disease and mortality. These range from acquisition of susceptibility-related micronutrients (Vitamin A) to effective treatment (e.g. oral rehydration therapy) and undernutrition assessed by child weight-for-age. For undernutrition, relative risks from Caulfield et al.,(1982) are used, which estimated the relative risk of cause-specific mortality (including diarrhea) for different levels of stunting (low height-for-age), wasting (low weight-for-height) and underweight (WFA).

Scores for the susceptibility index are calculated individually for each child based on the combined relative risks of each of the three susceptibility factors. The Susceptibility Index ($SusIndex_i$) is designed to be proportional to the excess risk associated with all of the factors.

$$SusIndex_i = \prod_k \sum_{i,j} (RR_{j,k} \cdot RiskFactor_{i,j,k})$$

Where $RR_{j,k}$ is the relative risk associated with the j^{th} level of risk factor k . $RiskFactor_{i,j,k}$ is the level of that risk factor for individual i . For vitamin A supplementation, there is only two levels (yes or no) and $RiskFactor_{i,j,k}$ serves as a dummy variable. For the other risk factors, the levels are continuous. Susceptibility values are estimated for each child subpopulation using appropriate survey weights.

Susceptibility Index

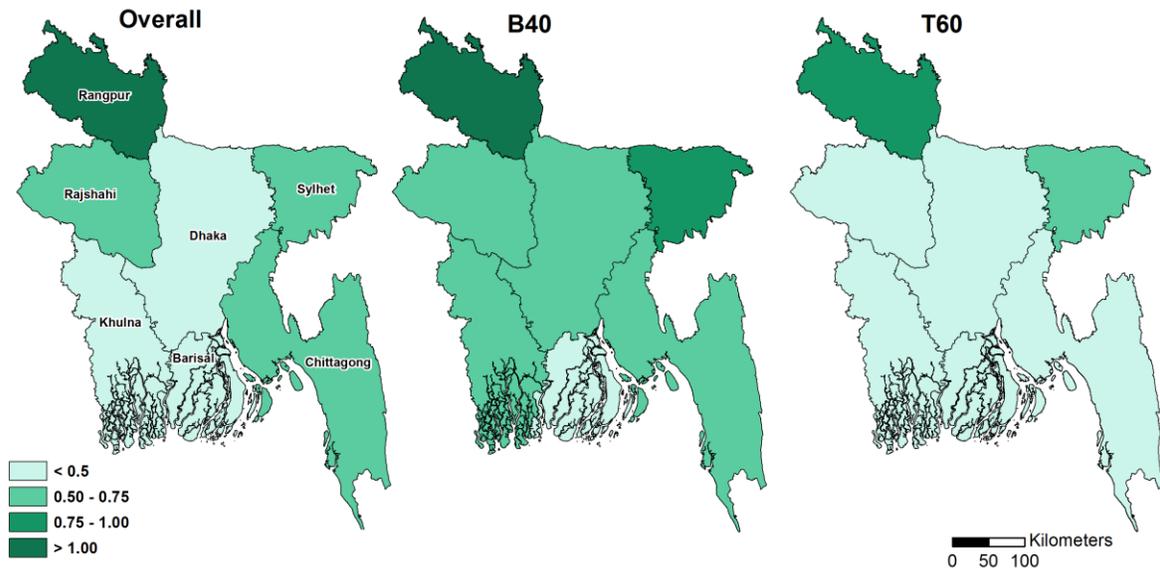
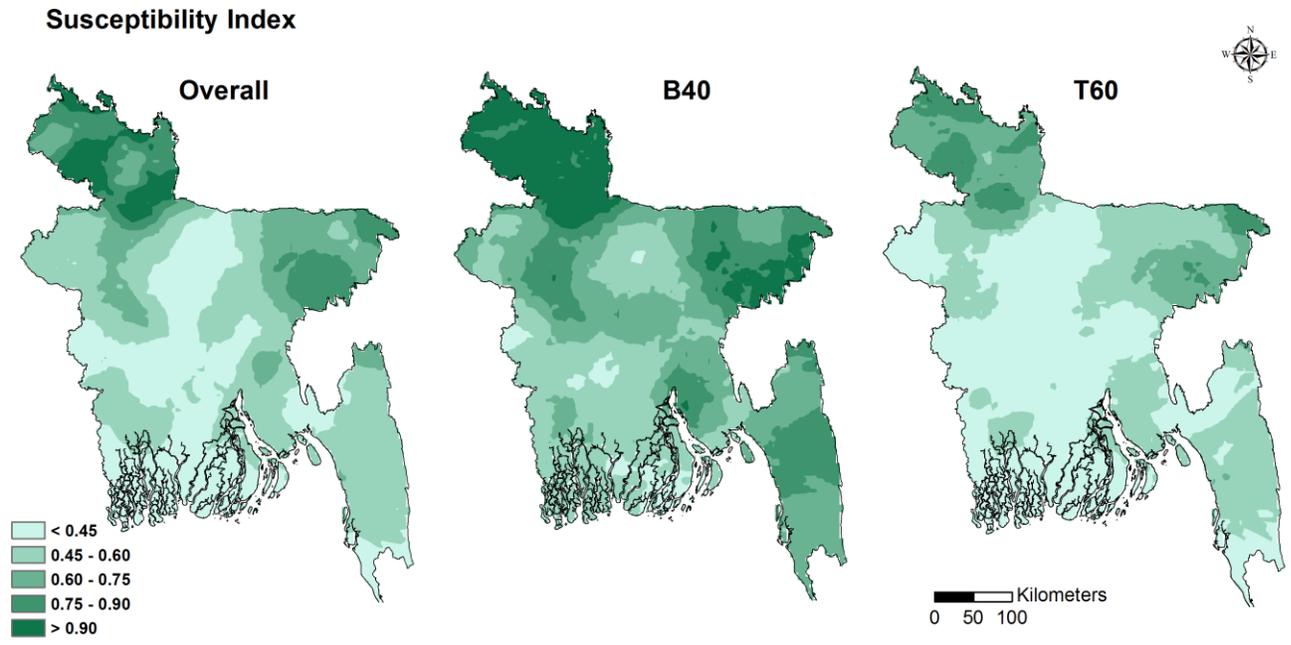


Figure 3.3 Maps of susceptibility indices in Bangladesh by division for overall population, B40, and T60

Figure 3.3 shows the susceptibility indices by division for overall, B40 and T60 of the population. These maps show some differences between the overall, the T60 and the B40 map. In the overall map, Sylhet, Dhaka and Khulna appears to be of low susceptibility though for the B40 high susceptibility indices are observed. For example, Sylhet, Dhaka and Khulna all have susceptibility indices greater than 1.0 (in Sylhet) and between 0.75 and 1.0 in Dhaka and Khulna.

Figure 3.4 shows a finer scale spatial resolution map (at 5 km²) of the child susceptibility index value distribution across children under five in Bangladesh, nationally (overall), and by economic group (B40 and T60). Most of the patterns in Figure 3.3 are seen in Figure 3.4. The overall map (left), highlights that although Rangpur has a concentration of higher susceptibility index values, there is heterogeneity within the region. Areas with the lowest child susceptibility index values are concentrated in central Bangladesh in the overall map (left) and the T60 population map (right). For the B40 children population, there are larger areas of the highest susceptibility index values (>0.90), concentrated especially in northwestern, northeastern, and southeastern areas of Bangladesh. In the T60 children population, there are small areas with higher (0.60-0.75) susceptibility index values in northwestern and northeastern Bangladesh.

Figure 3.4 Maps of susceptibility index for Bangladesh at 5 km² resolution for overall (left), bottom 40% (B40, middle), and top 60% (T60, right) populations of children under 5 (BD DHS, 2014).



Combined Risk Index

Susceptibility ($SusIndex_i$) and exposure risk ($ExpIndex_i$) are combined into the overall Risk Index ($RiskIndex_i$), which is simply the product of the two indices. Risk index scores are calculated individually for each child less than five years of age and then aggregated into subpopulation estimates.

$$RiskIndex_i = ExpIndex_i \cdot SusIndex_i$$

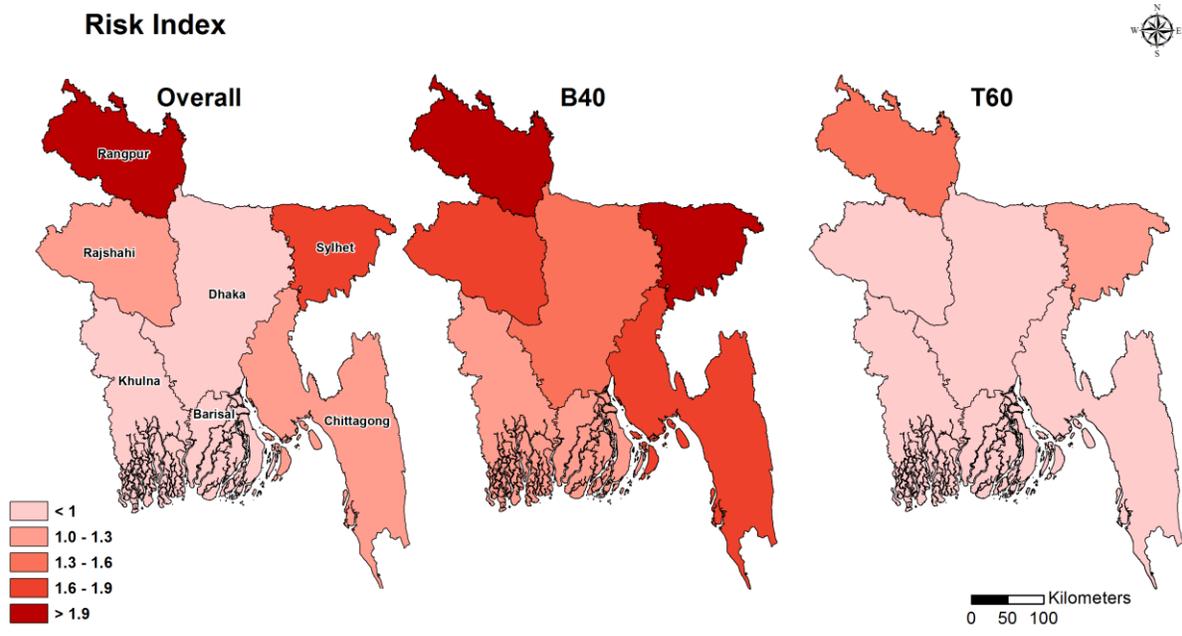
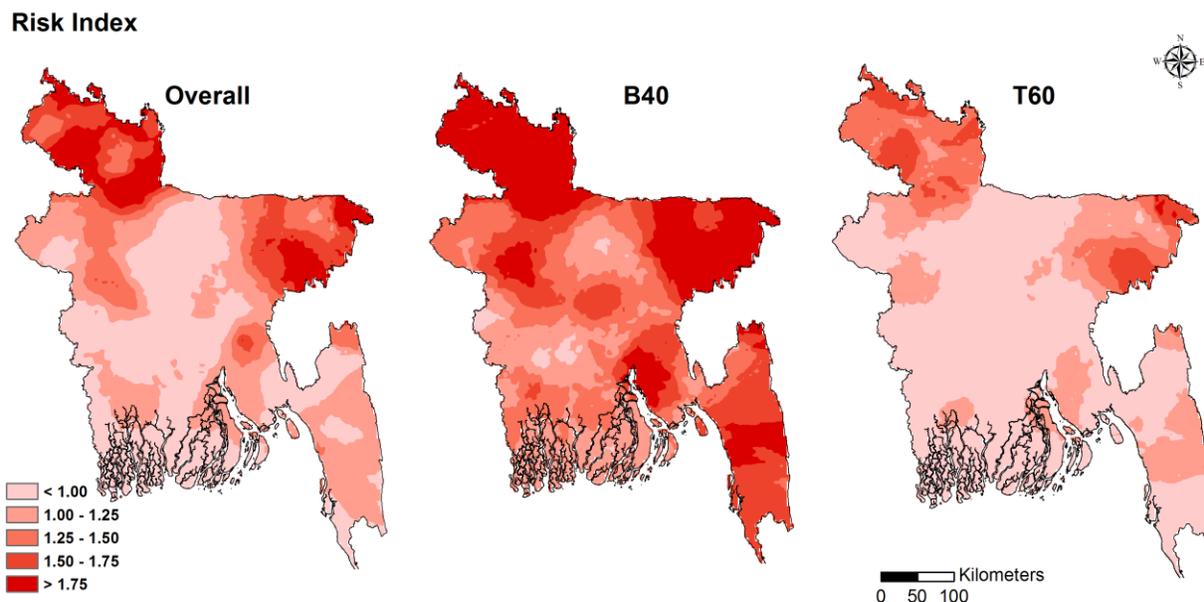


Figure 3.5 Maps of risk indices in Bangladesh by division for overall population, B40, and T60

Figure 3.5 shows that the risk among the B40 is widespread. B40 vulnerability is concentrated in the north, central and south-eastern provinces. Khulna and Barisal have lower risk while Rangpur is an important high-risk area, overlapping across the T60, B40, and overall maps. Figure 3.6 shows a finer scale spatial resolution map (at 5 km²) of the disease risk index value distribution across children under five in Bangladesh, nationally (overall), and by economic group (B40 and T60).

Most of the patterns apparent in Figure 3.5 are seen in Figure 3.6, with some additional areas of concentrations of high risk. According to the overall map (left), the highest risk areas are in the northwest and northeast regions of the country, and lowest risk areas are largely concentrated within the center. For the B40 children population, there are larger areas of the highest susceptibility index values (>1.75), concentrated especially in northwestern, northeastern, and southeastern area of Bangladesh. The highest risk across the country is found mainly in the B40 populations, following similar trends to overall population, with some addition high risk foci in the center of the country, and in the southeast. The T60 map (right) shows some concentrated high risk areas in the northwest and northeast, but they are substantially smaller than for the B40 population.

Figure 1.6 Maps of risk index for Bangladesh at 5km² resolution for overall (left), bottom 40% (B40, middle), and top 60% (T60, right) populations of children under 5 (BD DHS, 2014).



3.3 Impact of Changes in Water and Sanitation Access

Figures 3.7 and 3.8 provide visual representations showing the impact of water access (Figure 3.7) or sanitation (Figure 3.8) improvements by division in Bangladesh. In each figure, Representation A shows risk reduction if the group with the lowest level of water or sanitation receives interventions that will improve them one level higher on the improved sanitation or water scale (from unimproved or none to

improved). Representation B shows the impact of moving every group to the highest level possible of access to improved water or sanitation.

Figure 3.7A, shows that Rangpur and Sylhet will have the greatest impact while Rajshahi and Chittagong will also benefit from improved water access. If the highest level of improvements in improved water access were made, the situation will not be much different- (Figure 3.7B), WASH risk would decrease and have the greatest impact in Rangpur and Sylhet.

Figure 3.8A shows that improved sanitation would have the greatest impact on Rangpur and Sylhet. If the highest level of improvements in sanitation were made (Figure 3.8B), WASH risk would decrease in Rangpur, Sylhet, Rajshahi and Chittagong, with the greatest improvements in northwest and northeastern regions of Bangladesh. Overlapping inequalities in WASH and child health suggest that careful targeting to those in greatest need can increase the impact of improving water and sanitation on reducing diarrheal incidence by up to 4 fold.

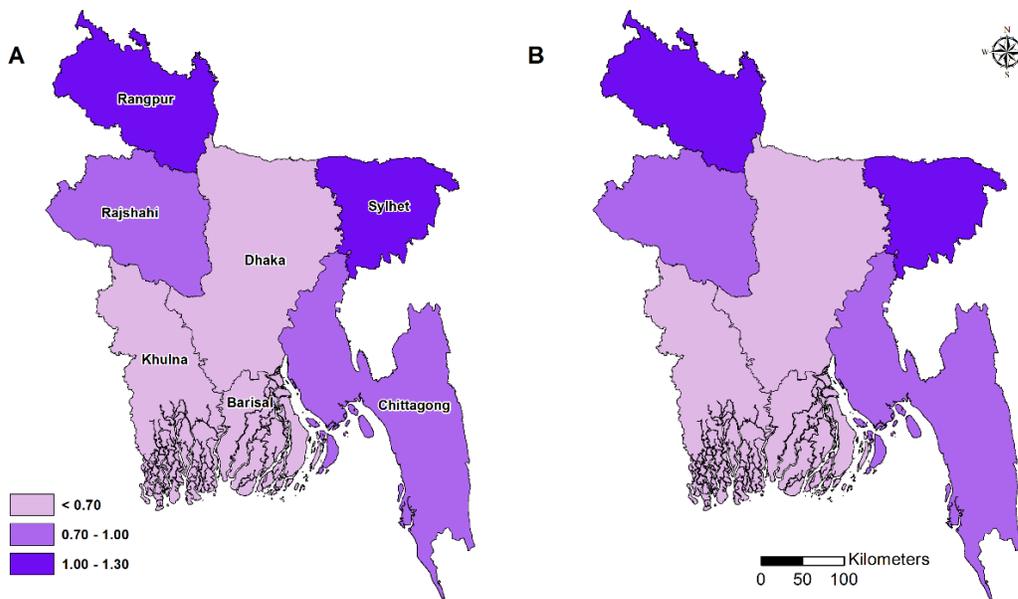


Figure 3.7 A and B Effect of water access improvement on WASH risk reduction by division. Map A partial improvement in water access (unimproved to improved), Map B increasing household access to the most improved water source

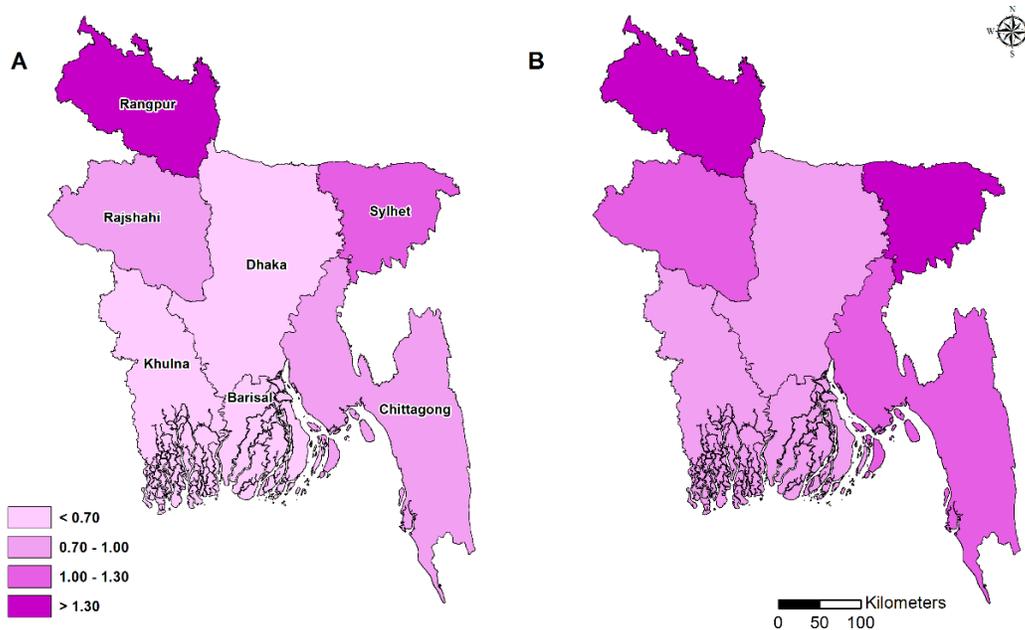


Figure 3.8 A and B Effect of sanitation improvement on WASH risk reduction by division. Map A partial improvement in sanitation (unimproved to improved), Map B improving all households to the highest level of sanitation

3.4 DALY burden of inadequate WASH in Bangladesh

While the previous sections assess variation in susceptibility to diarrheal disease, and consider the potential benefits of improved WASH, it is also worthwhile to consider the total enteric burden for children, occurring due to inadequate WASH. Enteric burden is measured in terms of disability-adjusted life years (DALYs)—or the number of years lost due to illness.

Figure 3.9 shows our calculated total enteric burden rate divided into the fraction associated with having inadequate WASH and burden rates unrelated to WASH by wealth quintile for national, rural, and urban populations of under 5 children. It is important to clarify aspects of what is meant by associated and unrelated to inadequate WASH. First, some enteric infections are not preventable with improved WASH. For example, almost all children under 5 years of age experience rotavirus infection, but improvements in WASH do not prevent the infection. These are unrelated to inadequate WASH in that they would not be prevented with improvements. Second, the DALY burden associated with inadequate WASH here accounts for both the level exposure due to inadequate WASH and children susceptibility do to other factors. That is, the DALY burden associated with inadequate in a particular sub-population reflects both exposure and susceptibility in that sub-population. Child susceptibility (e.g. undernutrition and likelihood of ORT) affects both the WASH associated and the unrelated burden.

Figure 3.9 Total and inadequate WASH- related DALY enteric burden for children under 5 in Bangladesh (BD DHS, 2014)

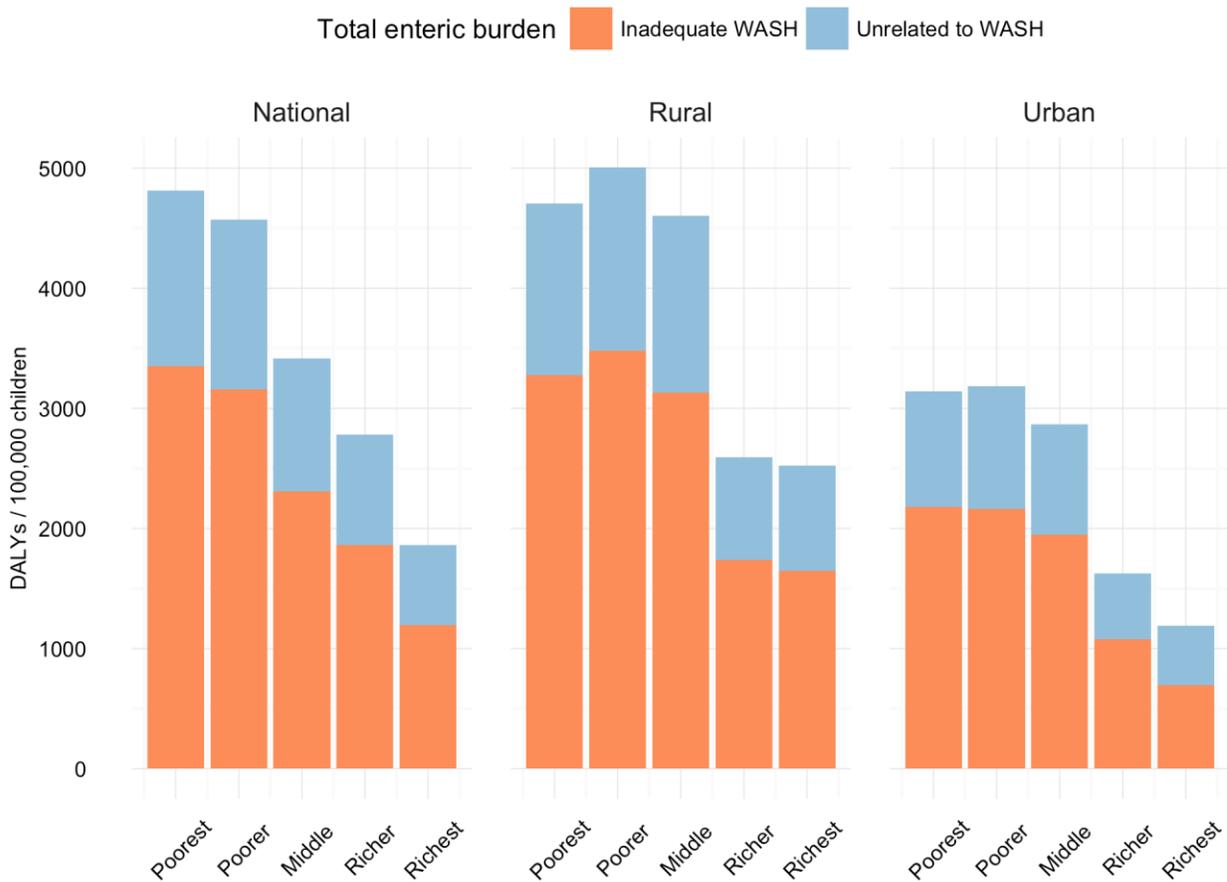


Figure 3.10 shows the total enteric burden rate geographically for the overall, B40, and T60 populations of children under five. Here, children from Rangpur and Sylhet regions have higher total enteric burden DALY rates in all three maps. The B40 children (center map) from Rangpur have the overall highest average regional enteric burden (7,036 DALYs/100,000 children).

Figure 3.10 Total enteric burden DALY rate by region for overall (left), bottom 40% (B40, middle), and top 60% (T60, right) populations of children under 5 in Bangladesh (BD DHS, 2014).

Total Enteric Burden

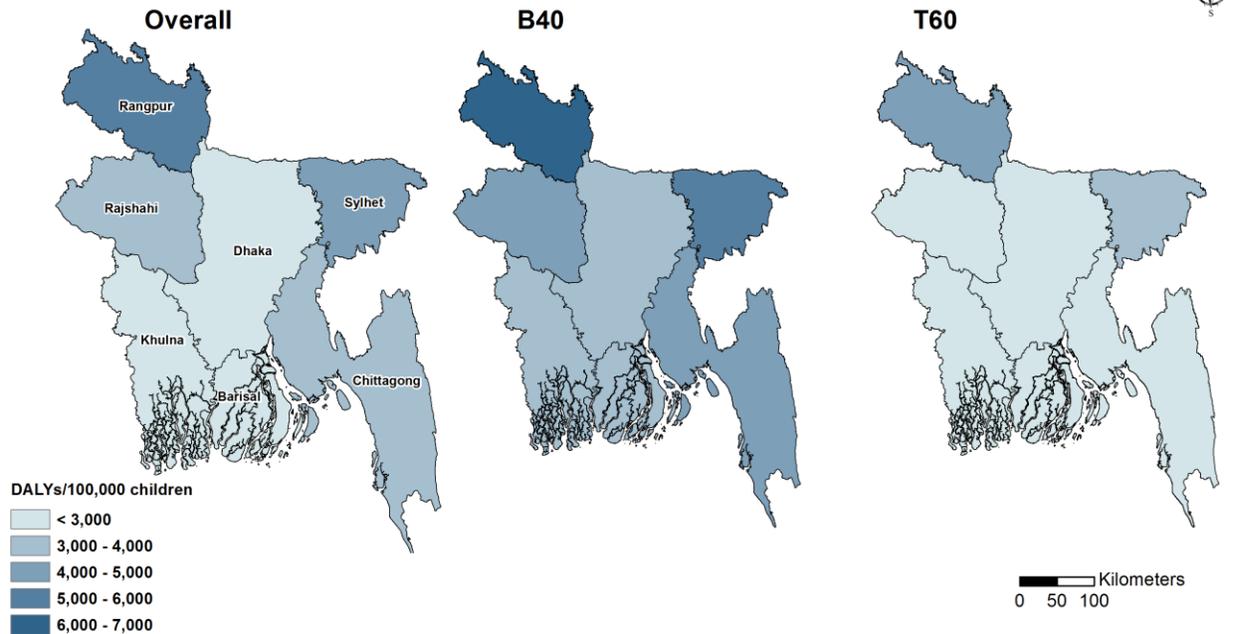
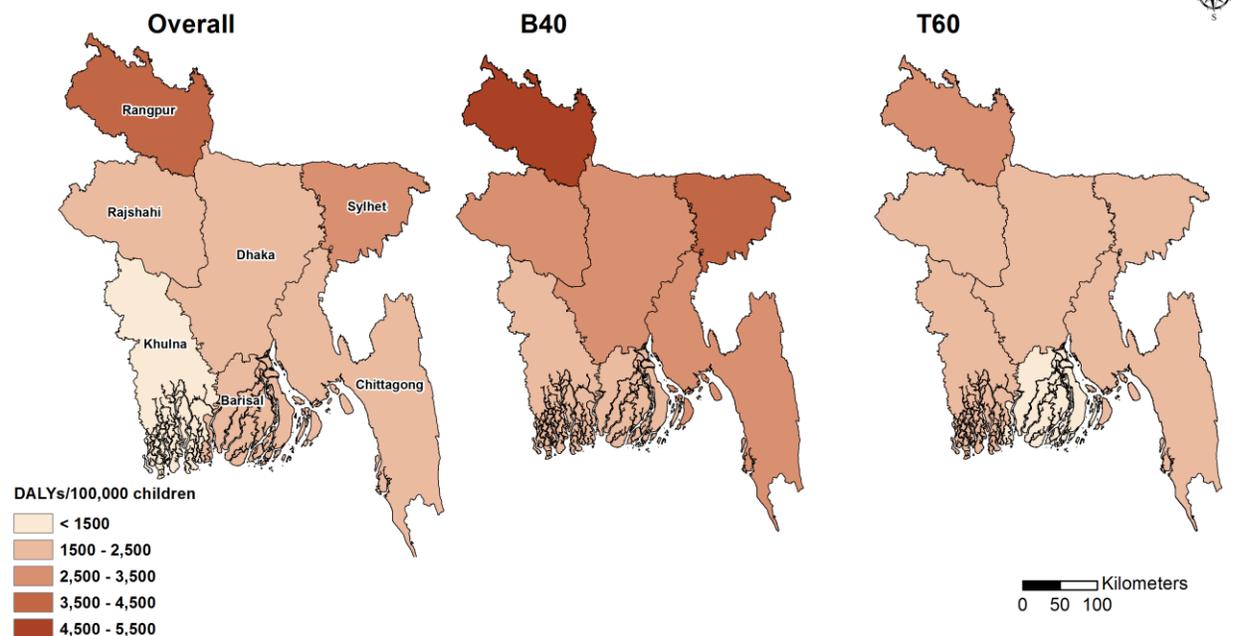


Figure 3.11 shows the geographic distribution of the enteric burden associated with inadequate WASH for the overall, B40, and T60 populations of children under five. Here, children from the Rangpur and Sylhet regions have higher inadequate WASH-related burden DALY rates in all three maps. The B40 children (center map) from the Rangpur region have the overall highest average regional inadequate WASH burden (4,737 DALYs/100,000 children).

Comparing Figures 3.10 and 3.11 indicates that higher total enteric burden rates for the B40 and in specific regions are the result of higher WASH related exposures and higher vulnerability.

Figure 3.11 Inadequate WASH-attributable enteric burden DALY rate by region for overall (left), bottom 40% (B40, middle), and top 60% (T60, right) populations of children under 5 in Bangladesh (BD DHS, 2014).

WASH-related Enteric Burden



Based on these estimates, the national enteric burden associated with inadequate WASH is 2,413 DALYs / 100,000 children per year. This is approximately 68% of the GBD (Global Burden of Disease) enteric burden estimated for the country.

It is worth noting that the GBD project provides its own estimate of the burden attributable to inadequate WASH. However, that differs from our burden calculation in several important ways. First, our burden calculation uses the WASH PRM risk index, which accounts for the co-distribution of inadequate WASH and child susceptibility. That is, we use data on the co-distribution of risk factors to account for the fact that children with inadequate WASH often also are more vulnerable due to under-nutrition and lack of access to care. Second, by using the underlying data on the distribution of risk factors, we can examine the distribution across economic and geographic sub-populations. Last, in some cases we use slightly different assumptions regarding the relative risk associated with different WASH service levels.

Our distributional analysis of WASH-associated burden suggests that the health burden of inadequate WASH is disproportionately borne by poorer children and those in vulnerable geographic areas. Nationally, the WASH-related enteric burden for the poorest quintile is about 3 times greater than the enteric burden for the richest quintile. WASH-related enteric burden is lower within urban than in rural populations, but the disparities in both are equivalent. Burden for the urban poorest is 2.6 times higher than the richest, and 2.4 times higher for the rural poorest than the richest.

It should be noted that this analysis, like the underlying GBD estimates, accounts for the impact of inadequate WASH on acute morbidity and mortality from enteric infections. It does not account for the effect these infections may have on undernutrition and its chronic sequelae, which will be addressed in future analyses.

IV. WASH in Community Health Centers in Bangladesh

Key Points

- **Healthcare access is among the main underlying determinants of maternal and infant mortality and undernutrition.** Improving basic infrastructure and services, including WASH, should be budget priorities for strengthening quality of and trust in Bangladesh's health systems
- **Bangladesh Health care facilities (HCFs) often lack basic WASH facilities that are critical to providing safe, hygienic environments.** Our rapid assessment shows that less than 31 percent of the health centers had at least a functional improved water source (tubewell or piped), at least one functional latrine (type unknown), and a handwashing station with water and soap.
- **Spatial analysis reveals that highest coverage of WASH in HCFs are in areas with lowest rates of stunting.** WASH coverage in HCFs is likely a slight indicator of quality of care, capturing availability of basic services and resources of HCFs.

The lack of adequate WASH in health care facilities (HCFs) has the potential do harm in spreading infectious disease to healthcare providers, staff, and patients. Highly infectious diseases such tuberculosis, pneumonia, norovirus, etc need to be controlled with stringent hygiene and waste management practices that can only be achieved with reliable WASH infrastructure. Newborns and patients are immunocompromised and can have severe health complications from having additional co-morbidities (Caincross et al.,1996). HCF-acquired neonatal infection rates are 3 to 20 times higher in resource-limited countries than in high-income countries (Zaidi et al., 2005). WHO (2014) reports that in low-income settings, an estimated 10-15% of maternal deaths are due to infections that are linked to unhygienic conditions. Poor WASH in HCFs may discourage women from giving birth in health facilities or cause delay in care-seeking (Velleman et al.,2014). This is relevant to Bangladesh where the percentage of births accompanied by a skilled birth attendant is already low (32%) (Tatem et al., 2014). Improving WASH conditions could reduce endemic HCF infections and help establish trust in HCFs and encourage mothers to seek prenatal care and delivery services at facilities (Russo et al. 2012).

Traditionally, WASH interventions have been narrowed to households. However, the new SDGs have now specified targets for WASH in health centers and schools using guidelines set forth by the JMP (WHO, UNICEF, 2018). The guidelines include indicators for health care waste management and environmental cleaning at HCFs (not shown in figure).

Bangladesh's decentralized institutional framework for primary health care provision ultimately influences WASH provision. Theoretically, a decentralized system can be more efficient and have greater accountability. However, in countries with high regional disparities in income, decentralization often reduces the redistributive powers of the central government and limits the level of transfers from richer to poorer jurisdictions, worsening equity (Akin et al.,2005). In Bangladesh, this means that the Union Parishads (UPs) are responsible for allocating resources towards community health centers. The poorer the UPs, the less likely they are to have sufficient resources to allocate towards WASH in health centers in the face of competing budget demands. Therefore, without an intervention that enables such resource

allocation towards WASH in HCFs, community health centers in poorer UPs may not have the means to improve their conditions.

While this analysis presents a snapshot of the status of WASH in community health centers at the upazila (sub-district) level in Bangladesh, it also seeks to understand the extent of the problem in relation to the incidence of poverty and stunting. Specifically, it identifies regions with elevated levels of poverty, high stunting and low WASH in community health centers, which are those where the UPs may not be able to improve outcomes on their own and prioritized interventions are called for.

The remaining sections of this section describe the data used for this analysis and method used to create a WASH index, the status of WASH in upazilas and concludes with a discussion on ways forward.

Data Sources

This analysis uses three main sources of data to combine upazila level HCF WASH data, poverty data, and stunting data for children under five.

For WASH indicators, data from a 2017 rapid assessment survey of WASH by the Community Based Health Care (CBHC), Directorate General of Health Services (DGHS) and the Ministry of Health and Family Welfare (MoH&FW) were used. The survey covers 63 zilas (districts) and 469 upazilas out of 492 upazilas. The survey does not include city corporations where hospitals and clinics are more prevalent than health centers. The rapid assessment is a telephone survey designed for scale rather than depth. It contains six questions on the type of water, sanitation and hand-washing facility at the HCF premises and the state of their functionality.¹⁴ The questions on functionality highlights the value-added of this survey as this information is not usually captured in surveys.

The poverty figures at the upazila level are derived from the predicted poverty estimates from Steele et al. (2017).¹⁵ It uses overlapping data from i) traditional household surveys (DHS, HIES, 2010 and Census 2011); ii) remote sensing data such as night-time lights, distance to roads, distance to closest urban settlements, climate variables; and iii) call detail records at varying spatial resolutions to estimate poverty rates using Bayesian geostatistical models (BGMs) (See **Error! Reference source not found.** for a upazila level map with poverty estimates).

The upazila-level stunting estimates for children under five were taken from the *Small-Area Estimation of Child Undernutrition in Bangladesh* report by Haslett et al. (2014), Bangladesh Bureau of Statistics (BBS) and the World Food Programme (WFP). The estimates combine survey data from the Child and Mother Nutrition Survey of Bangladesh 2012 (CMNS) and the Health and Morbidity Status Survey 2011 (HMSS) which some additional data from the BBS Census 2011.

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¹⁴ For details, see **Error! Reference source not found.**

¹⁵ Mean probability of households being below \$2.50/day using the Progress Out of Poverty Index (POPI) computed using survey data.

Table 1: WASH Tiers

<i>Tier</i>	<i>Water</i>	<i>Sanitation</i>	<i>Handwashing</i>
0	No supply/ Not functional	No latrine/ Not functional	No facility
1	Functional hand-pump	One functional latrine	Facility with water
2	Functional piped water	Two functional latrines	Facility with water and soap
3	-	Three functional latrines	-
4	-	Four functional latrines	-

Table 2: HCFs at each WASH Tier, by category

<i>Water</i>	<i>Freq.</i>	<i>%</i>
0	7,690	64.67
1	3,692	31.05
2	509	4.28
<i>Total</i>	<i>11,891</i>	<i>100</i>
<i>Sanitation</i>	<i>Freq.</i>	<i>Percent</i>
0	3,539	30.03
1	6,402	54.33
2	1,586	13.46
3	183	1.55
4	74	0.63
<i>Total</i>	<i>11,891</i>	<i>100</i>
<i>Handwashing</i>	<i>Freq.</i>	<i>Percent</i>
0	1,697	14.27
1	4	0.03
2	10,190	85.7
<i>Total</i>	<i>11,891</i>	<i>100</i>

Method

We first create tiers for each category of WASH using the available survey data. The questions in the survey are not comprehensive enough to follow all JMP definitions. However, we follow the JMP guidelines to the extent possible. Each of the three category tiers are coded as shown in Table 1.¹⁶ Table 2 shows the number and proportion of community health centers that fall under each tier.

¹⁶ The survey includes whether there was arsenic testing done at the HCF, however, no further information on water treatment or quality was solicited. The survey also includes a question on when the pit latrine was last emptied. However, this information is not complete enough to make a proper assessment of the state of sanitary

Each of the three tiers are then scaled into an index between 0 and 1. The WASH score for each HCF is the aggregate of the three indices combined. The WASH index is the mean of the HCF WASH scores at the upazila level, scaled between 0 and 1. The upazilas with WASH index below 0.5 are categorized as ranking “low” in WASH, whereas those with a score above 0.5 are categorized as ranking “high” in WASH. **It is important to note that a perfect score of 1 indicates relatively better WASH but not necessarily adequate WASH based by JMP standards. Therefore, it is most useful to read these results to compare across upazilas keeping in mind that bad scores indicate very poor WASH in community health centers but good scores do not necessarily reflect adequate WASH.** Similarly, the upazila level poverty probabilities and stunting estimates are also rescaled to range

The Status of WASH in Community Health Centers: A Snapshot

Table 3: HCFs with limited/ basic WASH, by category

<i>WASH Category</i>	Freq.	%
<i>Basic Water</i>	4,201	35.33
<i>Limited Sanitation ≥ 1 latrines</i>	8,352	70.24
<i>Limited Sanitation ≥ latrines</i>	1,950	16.4
<i>Limited Sanitation ≥ 4 latrines</i>	181	1.52
<i>Limited Handwashing</i>	10,190	85.7

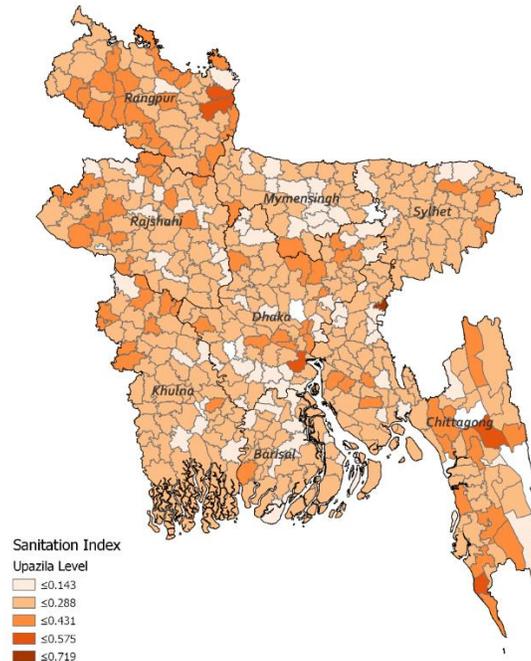
A large majority of the community health centers lacked limited WASH facilities. Table 3 shows the number of community health centers that met individual WASH category criteria. Less than 36 percent of the health centers had basic water supply, i.e. a functional improved water source. Around 30 percent did not have any functional sanitation facility. Only 16 percent had two functional latrines on premises. According to the 2008 WHO guidelines, health centers should have at least 4 functional, improved sanitation facilities on premises. Less than 2 percent of the health centers met this WHO criterion. Eighty-five percent of the health centers have adequate handwashing facility with soap and water. However, it is unclear to what extent the handwashing facilities were affected by the lack of functional water supply.

Many community health centers lack any type of WASH facility within premises. A staggering 2,280 health centers (19 percent) did not have any functional water, sanitation or hand-washing facility.¹⁷ **Of the 11,891 community health centers surveyed, only 3,660 health centers reached the ‘limited’ JMP standard detailed in Figure 1.** In other words, less than 31 percent of the health centers had at least a functional improved water source (tubewell or piped), at least one functional latrine (type unknown), and a handwashing station with water and soap. If we set a stricter standard of at least two functioning latrines (one for each gender) as suggested as one of the criterion in the JMP ‘basic’ sanitation tier, the number of health centers with adequate overall WASH falls to 1,003. These preliminary numbers show that most rural and peri-urban residents in Bangladesh have less than reliable primary health services in community health centers.

facilities beyond functionality. Therefore, we leave those out in constructing our index. See Annex-Table 1 for questionnaire.

¹⁷ For further details, please refer to **Error! Reference source not found.** and **Error! Reference source not found.**

Figure 2: Community Health Centers with Limited Sanitation Access, by Upazila



Most health centers (87 percent) relied on tubewells as their water source. However, only 14.5 percent were tested for arsenic¹⁸. Due to limited data, the result of the test or treatment measures taken to improve water quality before use is unknown.

While all the health centers had technologically improved sources of water supply such as tubewell, rain water jar or piped water, 64.7 percent of them were not functional. Other surveys report 97% of HCFs have water coverage without considering the functionality of the water source WHO (2015)¹⁹. It is unclear to what extent handwashing facilities are affected by a lack of functional water supply primary source is non-functional and whether the secondary sources were improved sources. Due to the high frequency of non-functional water sources, the water index in Figure 3 shows a dismal picture of water coverage in community health centers in Bangladesh. Mymensingh and Barisal divisions have the highest concentration of upazilas with the lowest water index scores, although the problem is widespread in other divisions as well.

Non-functionality was a significant problem for sanitation facilities as well. While 99 percent of the community health centers had at least one latrine, 29 percent of them did not have any functional latrines. Around 13 percent had two functional latrines and about 2 percent had three or more functional latrines. Figure 2 shows the map of the sanitation index by upazila. Again, Mymensingh and the south of Dhaka appear to have the highest number of upazilas with poor sanitation at health centers.

¹⁸ In Bangladesh, naturally occurring Arsenic in ground water is a major problem in many regions of the country.

¹⁹In addition, the report puts sanitation coverage at 0.53 and hygiene coverage 0.79. Again, these figures do not take functionality into account.

The extent of unimproved facilities in health centers is unknown, as there is no information about the type of latrine provided in the survey. Moreover, it also does not contain any information on whether the facilities are separated for staff and patients, segregated by gender, or if they are accessible to people with limited mobility. This additional data will be crucial for Bangladesh to establish a baseline status of WASH in health centers if they are to adequately measure their progress towards the SDGs.

Fourteen percent of the community health centers did not have any facility for handwashing, which is critical to prevent the spread of diseases. About 74 percent of the health centers had bucket and soap available for handwashing. Six percent of health centers used basin with soap, and another six percent used tippy taps with soap. It is likely that handwashing facilities lack water in the health centers where the water sources were not functional. However, assuming that the facilities did have both water (from secondary sources) and soap, handwashing was adequate in most of the upazila health centers by JMP's 'limited' standard. Figure 4 shows that Mymensingh and south of Dhaka, again, have the most upazilas that rank the lowest.

Figure 3: Community Health Centers with Basic Water Access, by Upazila

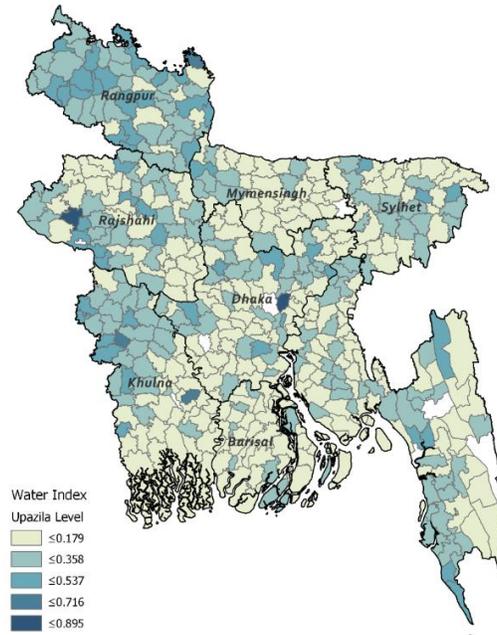


Figure 4: Community Health Centers with Handwashing Coverage, by Upazila

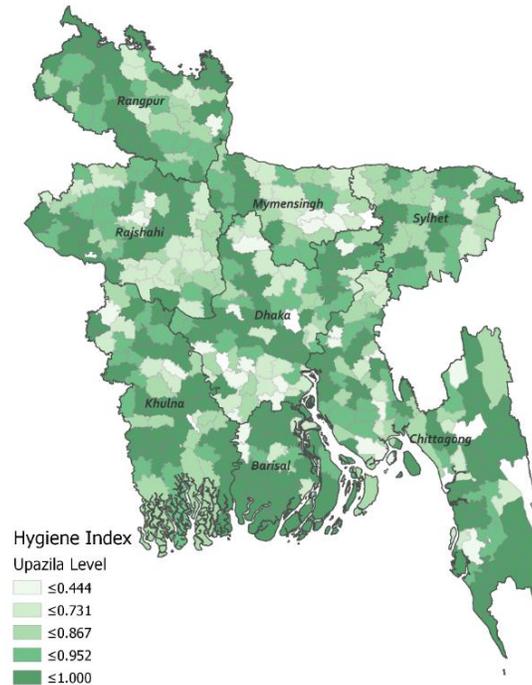


Figure 5 shows an aggregated picture of the status of WASH in health centers at the upazila level. The upazilas that had the worst WASH conditions --with an index score below 0.4-- appear in orange or red and are labeled in the map (a list of these upazilas can also be found in Annex-Table 5). Mymensingh, Dhaka and Rajshahi divisions have the most number of upazilas with health centers with low WASH. Rangpur, on the other hand, ranks higher in terms of WASH score despite ranking high in poverty rate. Nonetheless, keeping in mind that higher scores do not necessarily mean adequacy in absolute terms, more information is needed to ensure that community health centers in high poverty areas have adequate WASH for proper service delivery.

Overlaying areas of high/low WASH in the community health centers over areas of high/low poverty (Figure 6.a) and areas of high/low stunting (Figure 6.b), we find that there isn't much of a correlation between poverty and status of WASH in health centers. Whereas, we find some correlation between the areas with relatively higher WASH and areas with low stunting. Notably, the western half appears to have higher levels of WASH in health centers, lower levels of stunting despite higher levels of poverty. WASH coverage could be a proxy for overall quality of services offered in these HCFs (e.g. if WASH is inadequate in these HCFs, other basic services are also likely lacking). Health care access is one of the three main underlying determinants of stunting.

Figure 6.a and 6.b show that Mymensingh appear in both maps as a region with high poverty and high stunting with low levels of WASH in health centers. However, the problem is more widespread; there are upazilas scattered throughout Bangladesh with high poverty, high stunting and low WASH in health

centers. **Error! Reference source not found.** shows the upazilas with high stunting and high poverty whereas, **Error! Reference source not found.** shows its subset where health center WASH also ranks low. The list of upazilas in the latter figure is also available in **Error! Reference source not found.**. These are the upazilas with the highest need but are most likely faced with the highest budget constraints to improving WASH facilities in health care and public domains in general.

Figure 5: WASH Index by Upazila

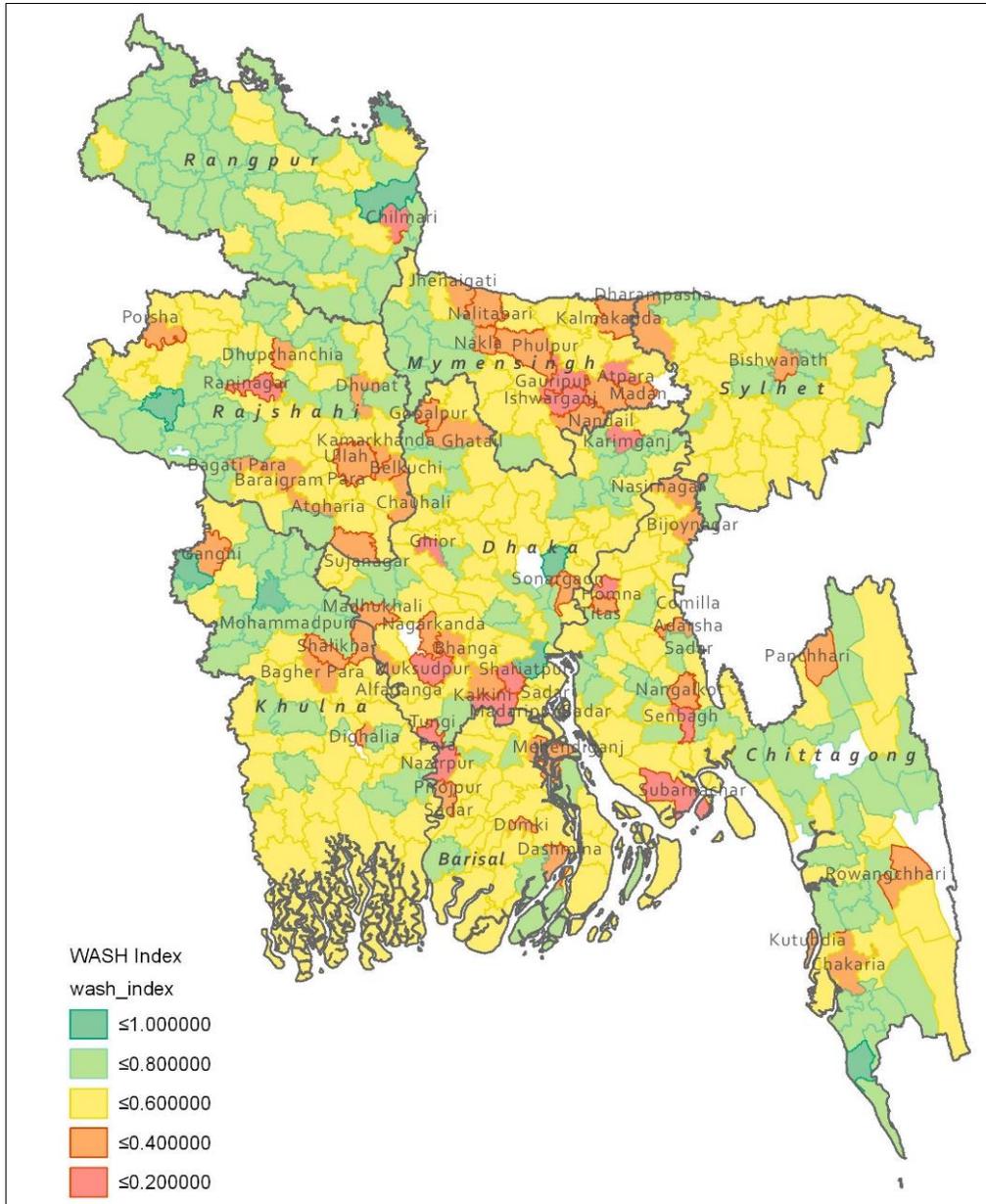
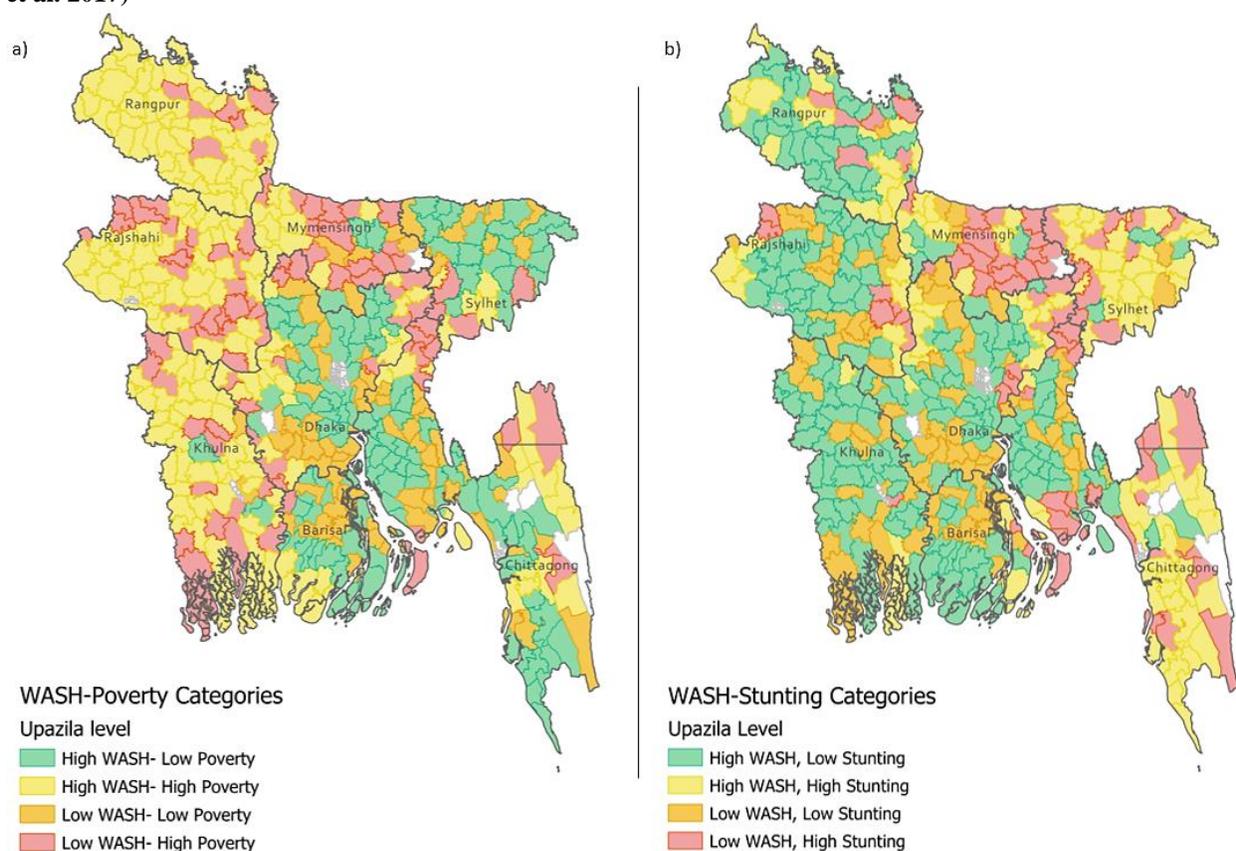


Figure 6.a & 6.b: State of WASH in Health Centers and Poverty, by Upazila (Source: DGHS, WB, 2017; Steel et al. 2017)



Discussion

Preliminary results from the rapid assessment data indicate that the state of WASH in health centers in Bangladesh should be a matter of high concern.

One of the main findings is that the prevalence of non-functional water and sanitation facilities is a significant issue. More information is necessary to establish what the secondary sources are, and if they are adequate for effective health service delivery.

In relation to health indicator, the degree of overlap between upazilas with high levels of stunting and low levels of WASH is remarkably high and calls for a closer look at overall quality of health service delivery in these areas.

Despite low-income levels, the west of Bangladesh had relatively higher levels of WASH in its community health centers. As noted in the above sections, there are two main caveats to keep in mind. One, that the index is a relative measure and a perfect score of 1 is by no means indicative of adequate WASH. Two, it is worth entertaining the possibility that there could have been measurement errors in the collection of data for the rapid assessment. If that is the case, we can expect to see over- or under-estimated rates of WASH at community health centers.

While the lowest income areas are not necessarily the ones where WASH is the poorest, it is worth noting that the Union Parishad's limited revenues, particularly own resource mobilization, will most probably be a constraint to achieving adequate level of WASH by the SDG standards. Therefore, local governments who are accountable for the improvement of community health centers need support at the national level through dedicated budget accounts. This pattern where WASH levels are higher in poorer regions could also reflect that more Bangladeshis in poorer regions use community health centers whereas those who live in richer regions bypass community health centers and may prefer to use private health services or hospitals even for the first line of care, causing greater neglect of community health centers in richer regions. If this happens to be the case, then the poorest of the poor in relatively higher income regions are likely to be left out to a greater degree than the poorest of the poor in relatively low-income regions.

However, this assessment only gives us a partial picture. To understand the depth of the problem, a more extensive analysis would be necessary. The simplicity of the rapid assessment survey affords localized representativeness at the cost of depth of information. Therefore, while this analysis provides a preliminary account of the state of WASH in community HCFs, it does not sufficiently establish a baseline against which progress towards SDGs can be measured. The DGHS and MoHFW will benefit from adopting the core survey components designed to assess SDG indicators detailed in the WHO/UNICEF (2018) guidelines, which can then be adjusted to fit the Bangladeshi context.

V. WASH and Well-being of the Urban Poor

Key Points

- **Bangladesh is rapidly urbanizing.** Currently, 36% of Bangladesh’s total population is considered urban. However, the urban population is expected to surpass the rural population by 2030
- **With this rapid urbanization, urban poverty and inter-city disparities are increasing and the “urban advantage” of better health is decreasing.** Child health and nutrition outcomes in slum populations and the urban poor are among the worst in the country.
- **Slum populations and the urban poor need to have safe and formalized access to basic water and sanitation services.** The absolute number of people without improved WASH access is largest in urban centers. Slum populations may also be more vulnerable to unregulated, informal markets of WASH service provision.
- **WASH environments in slums are dangerous for child health and nutrition.** Children living in slums are exposed to high levels of fecal contamination from interacting with open drains, municipal water, surface water, produce, street food, and flood water. Insufficient drainage, shabby water and sanitation infrastructure, poor hygiene behaviors, and crowding contribute to this fecal contamination.

A Disappearing Health Advantage for Urban Residents

The highest recorded rates of stunting in Bangladesh are not in the countryside but are in major cities, specifically in slum populations. The 2013 Urban Health Survey, one of the few datasets to monitor health indicators in slum populations, found that nearly half of all children under 5 living in City Corporation slums are stunted. As a comparison, 31 percent of urban children (including slum and non-slum households) and 38 percent of rural children are stunted, with national prevalence at 36 percent. Other surveys have found similar disparities between slum and non-slum households in Bangladesh. Under-5 child mortality is 79 percent higher in slums areas compared to other urban areas and 44 percent higher compared to rural areas (UNICEF 2010). Adult and youth literacy and primary and secondary school attendance rates are also significantly lower among slum populations.

These drastic disparities are counter intuitive to the “urban advantage” hypothesis. That is, urban households are more likely to have better social and health outcomes due to their relatively better access to services, infrastructure, and jobs. The related “wealth to health” hypothesis, where higher economic standing should lead to better health status, especially breaks down in slum settings. In Dhaka, for instance though slums have relatively higher rates of poverty than other Dhaka neighborhoods, Dhaka slums have a heterogeneous mix of expenditure and consumption patterns and have relatively lower poverty rates compared to rural and national estimates (). This means that though slum dwellers are benefiting from better economic opportunities in cities, they are likely making tradeoffs between financial gains and living conditions that are detrimental to their human capital. Slum households are often excluded from city planning, formalized service provision, and even routine data collection, yet the slum population has been growing throughout Bangladesh perhaps because of unplanned urbanization. Inter-city disparities will likely grow as urbanization places stress on existing infrastructure and capacity to deliver services. By proportion of the population, urban areas have higher coverage of improved WASH

services compared to rural areas. However, when considering population size, the absolute number of people without improved access is actually larger in urban than rural areas.

Further, though poverty rates are historically higher in rural areas, they have been on the decline in rural areas and on the rise in cities. Slum communities and the entire urban poor will need to be a focal population in sustainable development strategies limited not only to poverty reduction, but also to improving health, equitable access to basic services, and economic, social, and environmental resilience. Doing this will require better monitoring and research efforts that can better describe the unique problems slums residents face as well as the institutions and stakeholders that impact their communities.

WASH Services in Slums: High Access, low quality, and informal provision

To better understand WASH service provision in slums, a survey was carried out in Dhaka slums to better characterize WASH access and mechanisms of service delivery. Until recently, Dhaka utilities have not been mandated to deliver WASH services to households residing in slums due to their informal tenure. The survey found evidence that water and sanitation services in Dhaka slums were largely being operated by middlemen at various stages of service provision such as installation, management, and payment collection. Informal services may contribute to the deterioration of living standards in slums because they undermine formal accountability systems that allow monitoring and enforcement of a minimum quality of service (UNICEF 2010; Hanchett et al 2003; Muhammad et al 2016; Adams et al. 2015; Panday 2017).

Despite this informal market, the survey found that slum households had surprisingly high access to basic water and sanitation services, but such services were of low quality. Though nearly all households had access to a sanitation facility, hanging or unimproved latrines were prevalent and over 90 percent of households shared their sanitation facility with at least one other household. The average number of slum households to a sanitation facility was 16 to 1. Sanitation that is shared is excluded from the definition of “improved sanitation” due to concerns surrounding safety and upkeep of communal facilities. Water services were also found to be unreliable with frequent service interruptions. Over 12 percent of households reported that their main water source was not functional for a full day in the past week. Resilience of water and sanitation infrastructure is also a major issue. About a third of slum households report that they were unable to access their water source during flooding, and among those households that were affected, the average number of days that they were unable to access their water source and sanitation facility during a flood was between 9 and 10 days. Low standards and irregular services ultimately opens pathways for environmental exposures that are hazardous to health and wellbeing.

Sanitpath: An Assessment of Fecal Exposure Pathways in Dhaka Slums and High-Income Neighborhoods

A number of studies have noted the increasing environmental exposures prevalent throughout Bangladesh’s urban centers. Cross-sectional studies on water quality estimate that urban areas have the highest rates of fecal contamination in drinking water, despite having access to piped water distribution systems. One study finds that between 55-82 percent of drinking water samples obtained from piped water sources were found to be contaminated with some level of E. coli bacteria. As a comparison, drinking water samples from tube wells and surface water sources such as ponds, rivers, lakes had contamination rates of 38 percent and 83 percent respectively. This contamination could be due to factors related to water pressure, amount of treatment, intermittency, tank storage, and leakages and breaks (Aisopou 2012; Elala 2011; Kumpel 2013).

As a follow up to the survey on WASH service characterization in Dhaka slums, a second survey was carried out to measure environmental fecal contamination. The *SaniPath Exposure Assessment Tool* assesses multi-pathway quantitative exposure using a combination of data on environmental microbial samples and information on the frequency of behavior leading to exposure. The survey was done in 6 large-sized Dhaka slum neighborhoods (300+ households) and additionally was expanded to a sample of 4 relatively “high-income” neighborhoods to examine disparities between rich and poor neighborhoods. Across these 10 neighborhoods, 1,000 samples were taken from 1) latrine surface swabs from shared/communal and/or public latrine accessed by any neighborhood residents; 2) soil/sand/mud from areas where people gather and children commonly play; 3) open drain water from an open channel, carrying liquid and solid waste including rainwater, flood and sewage; 4) bathing water from both municipal and non-municipal supplied water, 5) municipal drinking water supplied by Dhaka Water Supply and Sewerage Authority (WASA²⁰); 6) non-municipal drinking water²¹; 7) surface water from community pond and/or lake; 8) flood water that remained stagnated for at least one hour after raining; 9) raw produce; and 10) street food. *E. coli* levels were quantified²² across environmental samples. These particular environmental samples were chosen because they were reported to be important pathways by WASH practitioners or have been significantly linked to adverse health outcomes, including diarrhea, enteric dysfunction, and stunting in previous research. Using household, community, and school surveys, behavioral data was also collected to examine frequency of behavior of adults and children that leads to interactions with these exposure pathways.

Among all samples, surface water, flood water, soil, municipal drinking water, bathing water, street food, and produce had the highest *E. coli* contamination levels. Similar *E. coli* contamination levels were found between poor and non-poor neighborhoods in latrine surface swab, drain water, municipal water, produce and street food. However, *E. coli* levels were significantly higher in slum compared to non-slum neighborhoods for soil, bathing water, non-municipal water, surface water, and flood water samples.

Combining this quantitative assessment of *E. coli* levels with behavioral data allowed us to create unique risk profiles for children, adults, and slum/non-slum neighborhoods. The emerging trends and differences give us a snapshot on which fecal exposure pathways are dominant and need to be prioritized for public health interventions for various Dhaka populations.

The dominant pathways for adults, in order of decreasing dominance, are produce, street food, municipal water, open drains, and surface water (Figure 1). However, for children, the dominant pathways, in order of decreasing dominance, are open drains, municipal water, surface water, produce, street food, and flood water (Figure 2). When comparing overall population (e.g. adults and children) exposure in slum and non-slum neighborhoods, the priority pathways in slums include municipal water, produce, and surface water. In high-income neighborhoods, street food and produce contribute the most to total exposure (Figure 3). Municipal water is also a dominant pathway but of lesser importance than compared to slum neighborhoods. There are additionally some important trends relating to geography of neighborhoods. Unlike in Dhaka North City Corporation, in Dhaka South City Corporation, municipal water is a consistent dominant pathway contributing to total fecal exposure. This could be due to the fact that Dhaka South

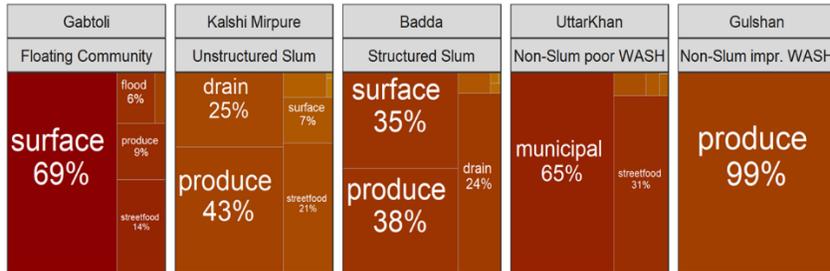
²⁰ Both legal and illegal connections, water accessed through piped water into compound (including flexible pipes), public tap/standpoint, provided by the government, or managed by someone in the community,

²¹ 20L commercially available jar and submersible pump

²² *E. coli* levels were assessed using IDEXX QuantiTrays in 100 mL samples.

has comparatively poorer drainage, older infrastructure, more industrial plants than Dhaka North. These results can inform some of the priority areas that city planners and WASH interventions should address in future programming and investments.

North



South

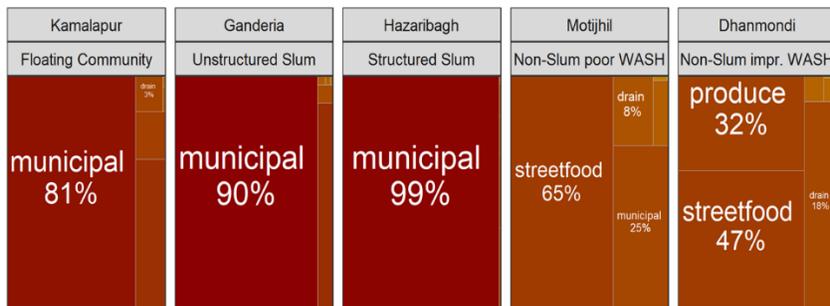


Figure 7 Dominant Environmental Pathways in Total E. coli Exposure for Adults

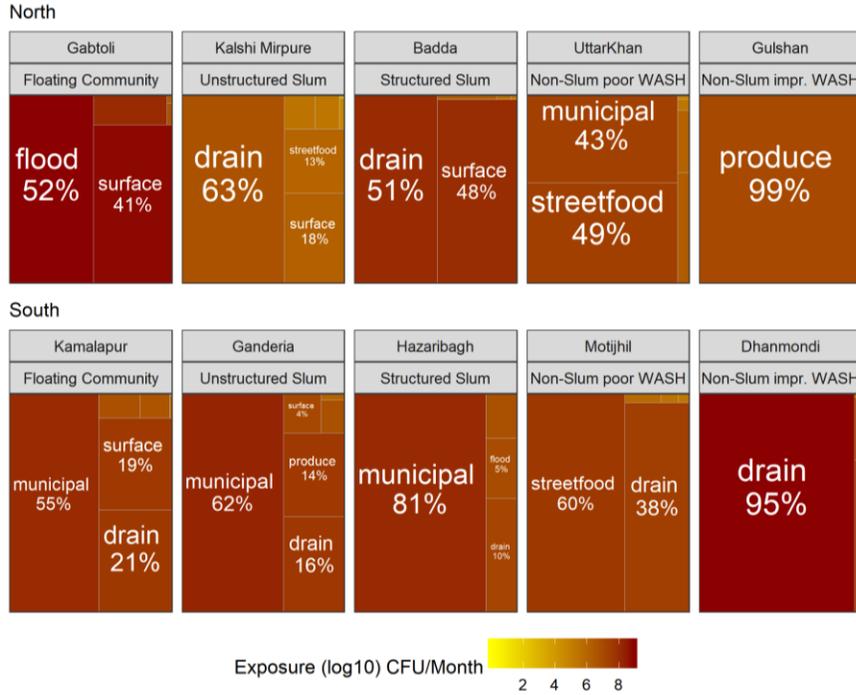


Figure 8. Dominant Environmental Pathways in Total E. coli Exposure for Children

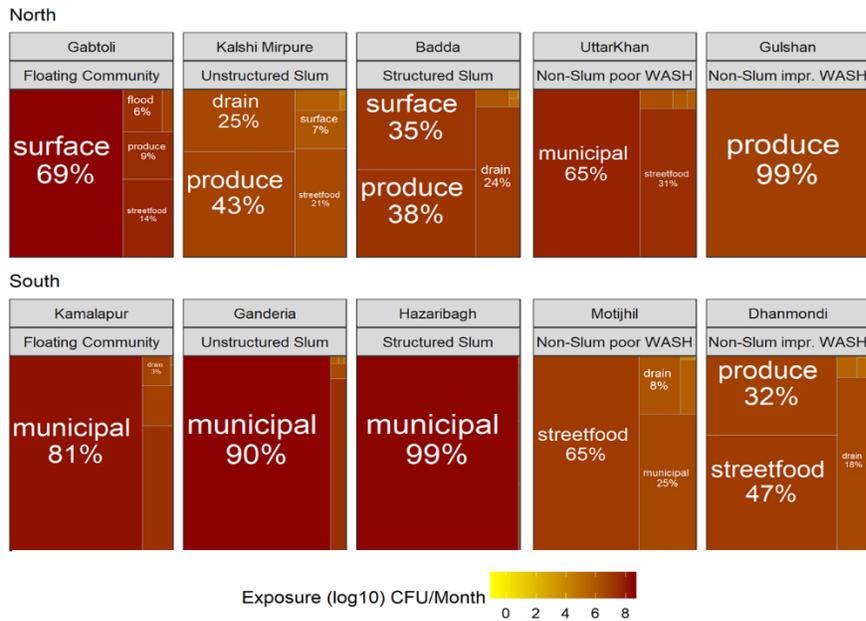


Figure 9. Dominant Environmental Pathways in Total E. coli Exposure for Children and Adults in Slum and Non-Slum Neighborhoods

VI. Stunting and WASH in Bangladesh

Key Points

- **WASH interventions alone cannot improve nutrition outcomes, but do have synergistic effects with other nutrition-specific and nutrition-sensitive interventions.**

In the following analysis, we specifically seek to understand the relationship between WASH and stunting in Bangladesh. Poor WASH conditions at the household and community tend to stunted growth of children through frequent occurrence of diarrhea and environmental enteropathy. Using International Food Policy Research Institute's (IFPRI) Bangladesh Integrated Household Survey, 2011, three questions are of particular interest: **i) what are the correlates of moderate stunting and extreme stunting among rural children under five in Bangladesh; ii) among the various correlates of stunting, what is relative weight of WASH in explaining the observed level of stunting; and iii) how much of the observed difference in stunting between the T60 and B40 households can be explained by the difference in the level of improved water supply, improved sanitation and hygiene among the two groups.**²³

As per the BIHS survey in Bangladesh which collected information on rural households across Bangladesh, the stunting prevalence is about 43 percent and that among the T60 and B40 are 43 percent and 57 percent, respectively. Similarly, stunting rates among those whose caloric consumption above the minimum required of 2140 calories a day (calorie sufficient) is 44 percent while that among those who are calorie deficient is 52 percent.

4.1 Correlates of Stunting- Logit Regression Analysis

The correlates of stunting among 0-23 months, 24-60 months and the combined sample on 5100 children are analyzed using logit regression models. The following specification is estimated for each group.

$$Stunting_{ijk} = \alpha + \beta Child_{ijk} + Household_{jk} + WASH_{jk} + Community_k + \varepsilon_{ijk} \quad (1)$$

The moderate or severe stunting is the dependent variable of interest and i, j and k represents the i^{th} child in j^{th} household and k^{th} community respectively. *Child* includes characteristics of the child such as the age and gender.

Household represents the characteristics of the household the child belong to such as number of years of education of the mother, age of the mother, wealth status of the household, food security status of the household and so on. *WASH* represents the water, sanitation and hygiene conditions in the household such as whether the household has improved water, whether the household has improved sanitation, and whether the household members are aware of the critical times to wash hands. Mother's education is included as a predictor variable of stunting because of the mounting evidence that shows how education

²³ Moqet et al., 2016

plays an important role in child health and growth of children²⁴²⁵. An educated mother is more likely to have greater health knowledge and awareness and higher social status in the community²⁶²⁷ which can help the nourishment of the child. In a country like Bangladesh where child marriage is highly prevalent especially in the rural areas, age of the mother tends to have an impact on child health as several studies point out the younger mothers tend to have less healthy children. Household wealth is linked with positive growth through its influence on food security and access to healthcare.²⁸ The wealth index is constructed using a principal component analysis²⁹ which includes household ownership of durable goods, land, and livestock and exclude improved water and sanitation access. T60 and B40 are constructed such that the poorest two quintiles of the asset distribution fall into the B40 and the top two quintiles fall into the T60.

WASH represents household's access to improved water supply and sanitation and hygiene. Access to improved and safe water can also play a positive association with child's growth.³⁰³¹ This analysis includes information on whether a household relies on an improved drinking water supply facility and has access to an improved sanitation facility. Handwashing before feeding a child is an indicator of good hygiene and can reduce the incidence of diarrhea, intestinal parasitic infection, and environmental enteropathy, all of which are related to stunting³². Due to limitations of observational data, the presence of a handwashing station and the availability of soap and water in a given household act as a proxy for the practice of handwashing.

Community refers to the level of improved sanitation the community has been able to achieve as measured by the share of household in the community with unimproved sanitation facility. Community-level sanitation can influence child health through externalities, particularly if a household is located in an area with high open defecation density. In such areas, children who use improved sanitation facilities in their own household can still be exposed to fecal matter if their neighbors use poor sanitation³³. The community sanitation ratio measures the proportion of households that rely on improved sanitation at the cluster level. Further district level fixed effects are included to control for regional specificities.

The main results of the combined sample are discussed here. In the results for the combined sample, belonging to a calorie sufficient or T60 household, number of years of education of the mother, and improved sanitation reduces the probability of stunting. In the case of extreme stunting for the combined

²⁴ Caldwell, 1982

²⁵ Abuya, 2012

²⁶ Reed 1996

²⁷ Glewwe 1999

²⁸ Hong, 2006

²⁹ Prichett et al 2013

³⁰ Schmidt, 2014

³¹ Merchant et al., 2003

³² Nizame et al., 2013

³³ Andres et al., 2014

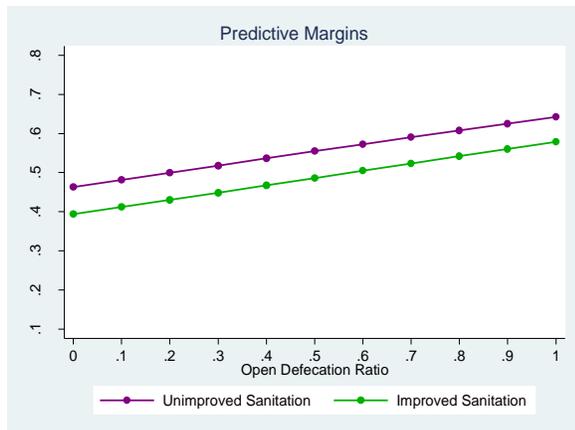


Figure 5.5 Stunting and Mothers Education

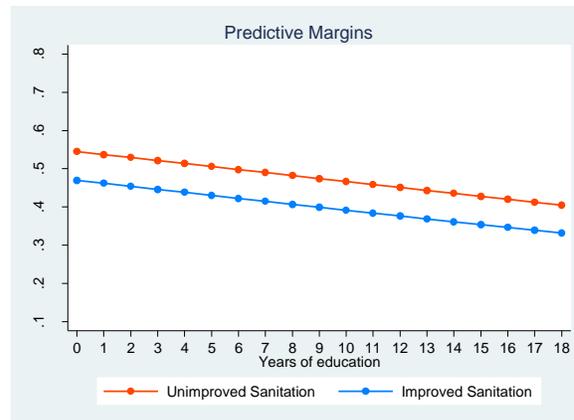


Figure 5.6 Stunting and unimproved sanitation in the community

sample, belonging to a calorie sufficient or T60 household, number of years of education of the mother, improved sanitation and incidence of open defecation in the community reduce the probability of extreme stunting. **In particular, controlling for household and individual characteristics, improved sanitation in the household reduces the likelihood of being stunted by about 6 percentage points and the likelihood of extreme stunting by nearly 5 percentage points. The results show the association between unimproved sanitation ratio in the community and the likelihood of moderate and extreme stunting. A 10 percent increase in the open defecation ratio increases the likelihood of stunting by 19 percentage points while that of extreme stunting by 14 percentage points.** In the case of both moderate stunting and extreme stunting, access to improved water does not seem to have a statistically significant effect on the likelihood of being stunted. It should also be noted that increase in the education of the mother reduces the likelihood of stunting and extreme stunting and the effects are substantial.

Insufficiency in food and being poor in terms of wealth can be identified as markers of having stunted children in the household. Belonging to a food sufficient household in terms of per capita minimum calorie requirement, seems to have a statistically significant effect on reducing the likelihood of stunting by about 6 percentage points while food sufficiency does not seem to have an effect on extreme stunting, probably due to the fact that most if not all households with extremely stunted children belong to food insufficient household thus reducing the explanatory power of the variable. Further belonging to a non-poor household (T60) as measured by asset ownership reduces the chances of stunting by about 9 percentage points while it reduces extreme stunting by about 6 percentage points.

Considering the significant association between stunting and unimproved sanitation in the community and education of the mother, we undertake two comparative statics exercise to understand how the incidence of stunting changes in households with and without improved sanitation when community level unimproved sanitation and mother's education changes. Panel a Figure 5.6 shows the marginal changes in stunting levels in households with and without improved sanitation as community level unimproved sanitation incidence increases and panel b in Figure 5.5 shows the years of education of the child's mother increases. It should be noted that in both cases, stunting levels are unambiguously higher in households with unimproved sanitation at all levels of community unimproved sanitation ratio, thus highlighting the advantages of private ownership of sanitary toilets. However, in communities with higher incidence of unimproved sanitation, stunting levels increases in households even if they have improved and

unimproved sanitation. This suggests that household level sanitation does not necessary ensure lower stunting levels, but the negative externalities arising out of community level unimproved sanitation does significantly reduce the private benefits from owning sanitary toilets. It is also interesting to note that among children with more educated mothers, the incidence of stunting falls arguably due to the improved hygiene and cleanliness practices of the mother that typically tend to go hand in hand with better education. These results suggest the need for a multi sectoral approach towards combating stunting.

4.2 Role of WASH in Explaining Stunting- Shapley Decomposition

Though, the logit regression analysis in the previous section explains the correlates of the likelihood of stunting, it does not provide any indication of the explanatory power of the different variables in explaining the likelihood of being stunted or extremely stunted. Such a measure will be helpful to identify the relative importance of different factors in explaining stunting thus pointing towards areas of priority action. Shapely decomposition^{34,35} provides a method towards the determination of the exact contributions and statistical significance of each explanatory variable to the variance of the dependent variable in the regression.

The R^2 value of a regression is usually taken as the portion of the variance of the dependent variable accounted for by the explanatory variables, that is:

$$R^2 = \frac{RSS}{TSS} = \frac{Var(\widehat{y})}{Var(y)} = 1 - \frac{Var(e)}{Var(y)} = 1 - \frac{Cov(e, y)}{Var(y)}$$

Hence the decomposition $R^2(y)$ yields the contribution of each independent variable of the regression towards explaining the explained portion of the variance in y . The following figures (5.7 and 5.8) show the results of the Shapley decomposition technique which decompose explained portion of the regression (1) into the average marginal contributions from each of the explanatory variables.

³⁴ Sharocks, 1999

³⁵ Israel, 2007

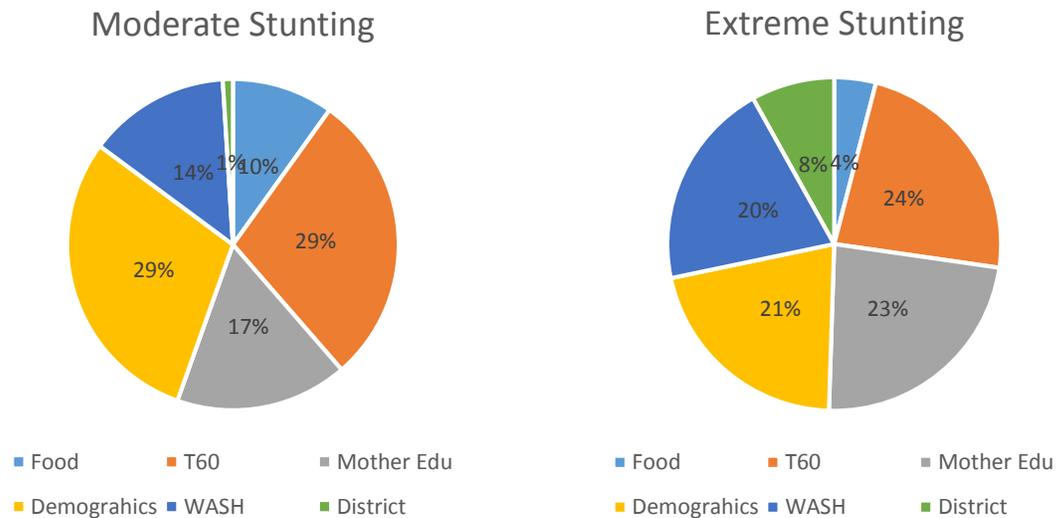


Figure 5.7 Shapley Decomposition- Contribution of the Covariates to Stunting

For the ease of interpretation, we have grouped the variables together into six groups. For moderate stunting, belonging to the calorie sufficient household (food) explains 10 percent of the explained part of stunting while it explains only 4 percent in the case of extreme stunting. Belonging to a household in the top60 explains 29 percent of moderate stunting and 23 percent of extreme stunting. Mother’s education explains 17 percent and 23 percent respectively of the variations in moderate and extreme stunting respectively. WASH (improved sanitation in the household, improved water supply in the household, handwashing facility with soap in the household and unimproved sanitation ratio) variables together explain 14% of moderate stunting and 20 percent of extreme stunting among children under the age of 5 years. Among the WASH variables, improved sanitation plays a more vital role in reducing moderate stunting while open defecation in the community explains the major part of the extreme stunting. Interestingly, education of the mother of the child also have a significant effect in reduction moderate stunting and extreme stunting, suggesting the very important role education of the mother and the associated impact on improved awareness and child care practices have in reducing the incidence of moderate and severe stunting among children.

4.3 Identifying the Causes of Differences in Stunting Incidence between the T60 and B40: Does the Differences in Access to WASH Play a Role?

In the overall sample, the average stunting incidence is 49 percent, but as expected the stunting rates among the B40 is 59 percent while that among the T60 is 43 percent. Similarly, though the average extreme stunting rate in the sample population is 19 percent, that among the T60 is 14 percent and B40 is 25 percent. These differences are quite substantial and one may be prompted to ask whether the observed differences in stunting between the poor and the non-poor could be explained by the innate differences in characteristics (endowments) between the two groups or by the return to these endowments. A related question is whether the differences in the level of access to improved water supply and sanitation between the T60 and B40 explain part of the difference in stunting and extreme stunting in a statistically significant manner.

Despite a significant amount of government and international interventions and targeted programming in the sector, inequities exist between the T60 and B40 in Bangladesh. **Annex Table 8** provides information on the average differences in the characteristics between B40 and T60 populations in rural Bangladesh. The differences in access to improved water supply and sanitation is quite substantial between the T60 and B40 households: T60 households have 21 percentage point more access to improved sanitation and 11 percentage points more access to improved water supply when compared to B40 households. On the average, B40 households live in more unhygienic environments: they typically live in communities with 10 percentage points more unimproved sanitation in the community than the T60 households. Furthermore, on the average, mothers in T60 are about 3 years more educated than those in the B40 and households in T60 tend to be larger.

We use Fairlie decomposition technique³⁶- which is a nonlinear variant of the Oaxaca decomposition- to decompose the explains the gap in the mean stunting rates ($\bar{Y}^{T60} - \bar{Y}^{B40}$) between two groups namely, T60 and B40.

$$\bar{Y}^{T60} - \bar{Y}^{B40} = \left[\sum_{i=1}^{N^{T60}} \left[\frac{F(X_i^{T60} \widehat{\beta}^{T60})}{N^{T60}} \right] - \sum_{i=1}^{N^{B40}} \left[\frac{F(X_i^{B40} \widehat{\beta}^{T60})}{N^{B40}} \right] \right] + \left[\sum_{i=1}^{N^{B40}} \left[\frac{F(X_i^{B40} \widehat{\beta}^{T60})}{N^{B40}} \right] - \sum_{i=1}^{N^{B40}} \left[\frac{F(X_i^{B40} \widehat{\beta}^{B40})}{N^{B40}} \right] \right]$$

The gap is decomposed into that part that is due to group differences in the magnitudes of the determinants of stunting, on the one hand, and group differences in the effects of these determinants, on the other. For example, children in B40 households may be less healthy not only because they have less access to piped water but also because their parents are less knowledgeable about how to obtain the maximum health benefits from piped water^{37, 38}

Table 5.1. Fairlie: Difference in Incidence of Stunting between Top 60 and Bottom 40

Variable	6-60 months	
Years of education	104%**	67%**
Mother's age (log)	0%	0%
Mother's age squared (log)	-1%	0%
Child's age (log)	0%	0%
Child's age squared (log)	1%*	-2%
Child's sex	0%	0%
Household size (log)	-42%*	-30%*

³⁶ Fairlie, 2007, 2013

³⁷ Jalan and Ravallion 2003

³⁸ Wagstaff and Nguyen 2003

Improved sanitation	38%	18%
Open defecation ratio	0%	29%*
Improved water	3%	4%
Handwashing	4%	2%
District	-8%	12%*
Number of obs	2,101	2,101
N of obs G=0	973	973
N of obs G=1	1128	1128
Pr(Y!=0G=0)	0.57	0.25
Pr(Y!=0G=1)	0.43	0.14
Difference	0.14	0.11
Total explained	0.03	0.04

We examine the results of the decomposition for the full sample (6- 60 months) and focus our attention on the explained part of the gap which is the differences in endowments between the B40 and T60. Differences in the education attainment of the mother between the T60 and B40 explains a large portion of the explained portion of the gap in moderate and severe stunting. Difference in the level of access to improved water and sanitation between the B40 and T60 do not seem to explain the differences in stunting between the two groups in a statistically significant manner. Unhygienic locations where the B40 live which have higher share of households with unimproved sanitation explain a large part of the difference in extreme stunting between the two groups.

This analysis brings forth two important points. **First, moderate stunting is more a multi-dimensional problem in Bangladesh which goes well beyond rich- poor divide- even richer households have relatively high stunting rates. Second, differences in access to improved water and sanitation fail to explain the differences in stunting between the T60 and B40- a large proportion of the richer households do not have access to improved sanitation (35 percent and 14 percent of improved sanitation and 88 percent and 76 percent of improved water respectively in T60 and B40 households) and water access. Finally, location of households matters- the differences in the community sanitation where the B40 and T60 live, is an important contributor to the explaining the differences in extreme stunting between the two groups.**

VIO. The Role of Water Quality in Improving Health, Nutrition, Cognitive Development, and Survival

- **Exposure to fecal contaminants may lead to diarrhea, environmental enteropathy, and undernutrition. Drinking water is one possible exposure pathway to poorer health and nutrition outcomes.** We find that the presence of E. coli in water increases the probability of stunting by 5 percentage points while higher concentrations increases the probability by 9 percentage points
- **Inorganic arsenic is a neurotoxin that can interrupt cognitive development and damage cognitive function.** We find that arsenic exposure through drinking water significantly affects an array of early childhood development outcomes, including motor, social, learning, and literacy-numeracy skills. We find a clear dose-response relationship, where children exposed to higher levels of arsenic are more likely to have poorer ECD outcomes.
- **Minerals in groundwater can protect and threaten infant survival. Salinity intrusion in groundwater sources is increasing in coastal areas.** We find infants born in areas with severe levels of salinity in groundwater are at higher risk of early death. However, infants born in areas with mild to moderate levels of salinity may have protected early survival because groundwater could be an important source of maternal mineral consumption.

Though Bangladesh has made significant strides in providing access to improved water to a large proportion of the population, access to safely managed water still remains a distant dream. Nearly 60 million people are exposed to arsenic contamination in drinking water while E. coli contamination has been affecting drinking water quality particularly in the urban areas. In this section, using secondary data on water quality from MICS, we examine the linkages of E. coli contamination of drinking water with stunting and linkages of arsenic contamination with cognitive outcomes among children.

5.1 E. coli contamination of drinking water and childhood stunting in Bangladesh

Globally, studies examining the link between water supply and nutritional outcomes are rare primarily due to the relative absence of reliable measures of water quality as well as anthropometric measures of children. As with poor sanitation, it is plausible that water contaminated with E. coli could affect nutritional status of children through various possible biological pathways such as repeated episodes of diarrhea, environmental enteropathy, parasites, or other mechanisms that inhibit nutrient uptake and absorption^{39, 40, 41, 42}

³⁹ Luby 2015

⁴⁰ George, 2015

⁴¹ Lin 2013

⁴² Nizame et al., 2013

Using MICS 2012-2013 data, the effect of E. coli contamination on stunting in Bangladesh is examined⁴³. E. coli contamination in drinking water is measured at both household and source points. The magnitude of contamination is quantitatively defined by the number of E. Coli cfu per 100 ml. As per the data, 51 percent of water collected for testing from the water source is contaminated while about 62 percent of water collected for testing at the consumption point is contaminated. This apparent discrepancy can be attributed to the unhygienic ways of water collection, handling and storing which increase the chances of contamination. Stunting is measured using height-for-age z-scores for children under five, where a child is considered stunted when he or she is two or more standard deviations below the median of the WHO reference population.

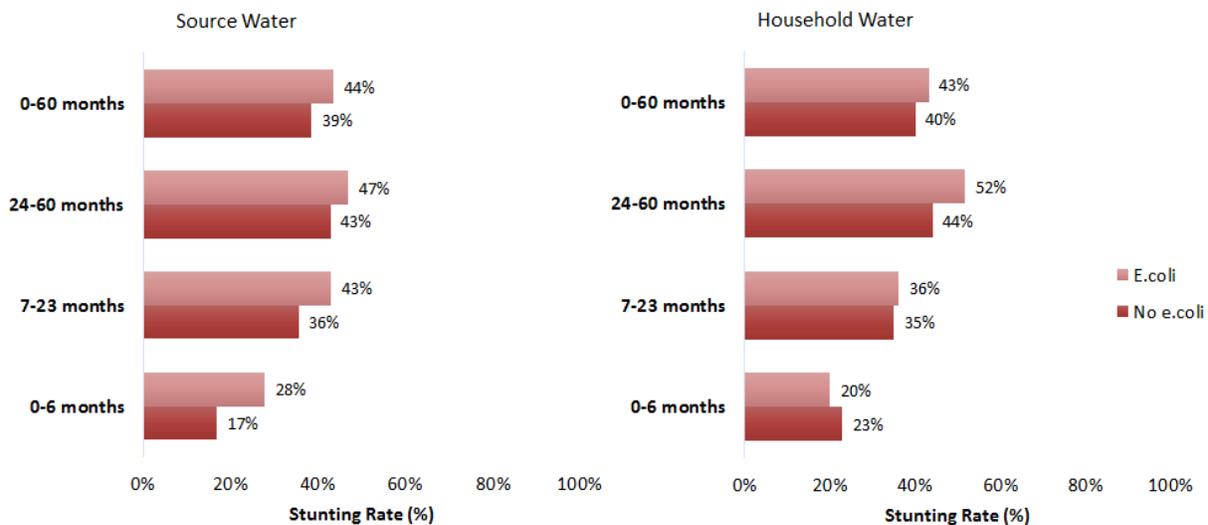


Figure 5.8. E.coli contamination and the incidence of stunting

Figure 5.8 shows, E. coli contamination at both the source and the point of consumption are associated with the incidence of stunting across almost all of the relevant age groups. We estimate the following logit regression model;

$$Stunting_{ijk} = \alpha + \beta Child_{ijk} + Household_{jk} + WASH_{jk} + EColi_{jk} + Community_k + \varepsilon_{ijk} \quad (2)$$

Where $EColi_{jk}$ represents E. coli contamination in the water source or point of consumption and $Child$. , $Household$ and $Community$ denote child, household and community characteristics. Two separate specifications are estimated; one showing the mere presence of E. coli in drinking water and the second indicating its intensity. In the first specification, the primary explanatory variable is E. coli contamination, which compares no E.coli (<1 cfu in 100 ml) with some E. coli (>1cfu in 100 ml) in the household sample. Though exposure to a minimal level of E.coli is considered to be detrimental to child health, there is

⁴³ Joseph et al (2016)

evidence showing that children who drink highly contaminated water (>100 cfu in 100 ml) have a significantly higher risk of diarrheal disease than those who drink moderately contaminated water (2-100 cfu in 100 ml) (Moe 1991). Therefore, in the second specification, the main explanatory variable of interest indicate the intensity of E. coli in drinking water E. coli variable that compares a low and medium level of contamination (0-10 cfu in 100 ml) to a high level (11-200 cfu in 100 ml) to examine whether higher levels of contamination has a more stronger and significant effect on increasing stunting. These two specifications are estimated for water collected at the household consumption point and at the water source and for the different age groups of children.

In the overall sample at the consumption point, presence of E. coli drinking water does not seem to have a significant effect on stunting while a high level of E. coli increases the probability of stunting by 6 percentage points. In the household point regressions, mother’s completion of secondary education and breastfeeding significantly decrease the incidence of stunting by 15 and 26 percentage points, respectively. In addition, improved sanitation and water treatment are strongly associated with lower stunting. Appropriate water treatment decreases the likelihood of stunting by around 24 percentage points while improved sanitation lowers stunting by 7 percentage points.

Similarly, for the overall sample at the water source, the presence of E. coli in water increases the probability of stunting by 5 percentage points while higher concentration of E-coli in water increases the probability of stunting by about 9 percentage points. Again, mother’s completion of secondary education has the highest association with the likelihood of stunting, indicating about 26 percentage point decrease in the likelihood of stunting. Further, improved sanitation reduces stunting by about 9 percentage points. In both specifications and for most of the age groups, breastfeeding, being in the topmost quintile, access to improved sanitation, and higher levels of mother’s education have the most significant statistical association with stunting, especially among children aged 24–60 months. It is also interesting to note that ‘community improved sanitation ratio’ which indicates the share of

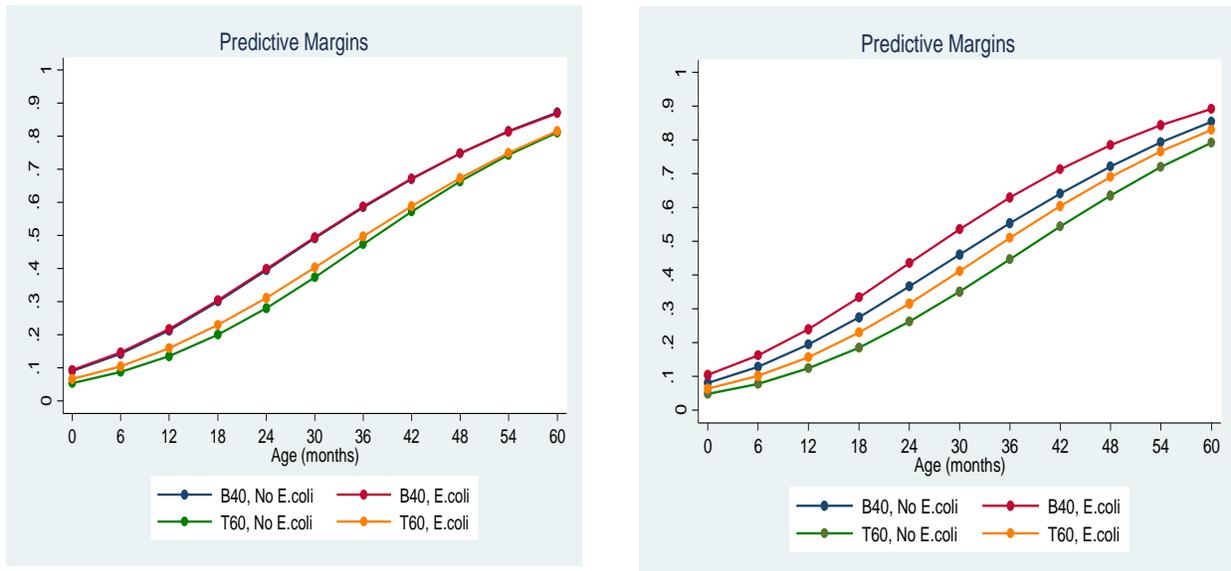


Figure 5.9 Predicted Margins: E.coli and Stunting- Stunting and E.coli in Household Water and Stunting and E. Coli in Source Water

Figure 5.9 shows that predicted marginal changes of stunting for the B40 and T60 across the age distribution for children who are exposed to and not exposed to *E. coli*. When children are exposed to *E. coli* in water, the chances of them being stunted increases for all age groups in both B40 and T60 segments of the population. Besides, prevalence of stunting is higher among the children born in B40 households when compared to T60 across the entire age distribution and exposure to *E. coli* increases stunting in both groups. Higher incidence of stunting among the B40 households may be due to the availability of better coping mechanisms that economically better of households have which can potentially offset at least partially the chances of stunting among children.

5.2 Exposure to Arsenic Contaminated Water and Early Childhood Development (ECD)

Arsenic contamination in shallow groundwater aquifers remains a major barrier to providing universal access to safe drinking water in Bangladesh. The effect of arsenic on health has long been established. Chronic exposure to arsenic has been shown to cause costly and deadly health impacts including various cancers, skin lesions, neurological damage, cardiovascular and pulmonary disease⁴⁴ and hypertension. The neurotoxic effects of arsenic can be particularly apparent in children during their critical growth periods and are shown to have significant impairments to their cognitive development, with a negative impact on memory and the ability to focus and solve problems⁴⁵. This effect on cognitive development can, in turn, lead to long-term reductions in educational attainment and performance.

Epidemiological studies demonstrate adverse effects of arsenic on cognition in both children and adults. Wasserman et al. found that children exposed to low to moderate levels of arsenic had overall lower intellectual functioning among 10-year old and 6-year old Bangladeshi children (Wasserman, et al., 2004) (Wasserman, et al., 2007). Bangladeshi school-aged children exposed to arsenic had poorer memory, ability to focus and solve problems, sensory and motor function, and verbal and linguistic capability (Rosado, et al., 2007; Asadullah & Chaudhury, 2008; Parvez, et al., 2011; Tsai, et al., 2003). There are also indirect effect of arsenic poisoning on economic opportunities through health status and cognition of victims. Those suffering from symptoms of arsenicosis may subsequently have relatively poorer school or work attendance and performance. Victims have been noted to be socially excluded from public settings due to misconceptions on the infectiousness of skin lesions (Asadullah & Chaudhury, 2008). Bangladeshi children (aged 6-10 years) who drank arsenic contaminated water have also been observed to attend fewer days of school per year compared to those who drank arsenic-free water. Further young adults (aged 19-21 years) who relied on arsenic contaminated water had six months less schooling, on average, compared to their counterparts who drank arsenic-free water (Murray & Sharmin, 2015). Furthermore, lowering the concentrations of retained arsenic among Bangladeshi prime-aged males to those levels found in unaffected countries would increase earnings by 9 percent (Pitt, et al., 2012).

There have been few studies to examine the effects of arsenic contaminated drinking water on young children. We use cross-sectional data from the nationally representative 2012-13 Bangladesh Multiple Indicator Cluster Survey (MICS) to investigate the effect of arsenic contamination in drinking water on early childhood development outcomes in a sample of around 7,500 children aged 3-5 years.⁴⁶ Early

⁴⁴ Smith et al., 1998, Sohel et al., 2009, Flanagan et al., 2012

⁴⁵ Rosado et al., 2007

⁴⁶ Haque et al (2016).

childhood development is measured in four domains: literacy-numeracy, physical, social-emotional, and learning using the Early Childhood Development Indicators (ECDI), a novel 10-item module developed by UNICEF to systematically monitor milestones a child is expected to reach by the age of 3 and 4. Table X shows the four domains and the respective milestones to be attained. A composite Early Childhood Development Index (ECDI) is constructed for every child such that ECD Index will take a value of 1 if a child meets at least three out of the four domains above. Arsenic contamination is measured in source drinking water at the cluster-level.

Table 5.2 10-item module used to construct the ECDI (Source: MICS 2012-13 Report, Bangladesh)

Domain	Component	Criteria for being on track
Literacy-numeracy	Identify at least ten letters of the alphabet	2/3 components must be true
	Read at least four simple and popular words	
	Name and recognize symbols of numbers 1 to 10	
Learning	Follow simple instructions	1/2 components must be true
	Carry out tasks independently	
Physical	Pick up a small object with two fingers	1/2 components must be true
	Healthy enough to play	
Social	Gets along well with other children	2/3 components must be true
	Does not kick, bite, or hit other children	
	Does not get distracted easily	

As per MICS 2012 data, 65 percent of children aged 3-5 years are developmentally on track based on Early Childhood Development Index (ECDI) suggesting that almost two third of the child population meets at least three of the four domains. Of the four domains in the ECDI, literacy and numeracy standards are the least met, with only 21 percent of children being able to recognize words, letters of the alphabet, or numbers. Learning standards are met by 89 percent of children while physical and social standards are met by 93 percent and 90 percent of children respectively. 27 percent of all households are exposed to arsenic based on the WHO standard of >10 ppb compared to 13 percent when using the Bangladesh standard of >50 ppb. Most of the arsenic exposure comes from using water from tube wells.

Logit regression analysis is used to estimate the association between arsenic contamination in drinking water and the combined ECD index and the four component domains.

$$ECD_{ijk} = \alpha + \beta Child_{ijk} + Household_{jk} + WASH_{jk} + Arsenic_{jk} + Community_k + \varepsilon_{ijk} \quad (2)$$

Where ECD_{ijk} is the outcome variables of interest which are : ECD Index, literacy, physical, social and learning domains; and $Child$, $Household$ and $Community$ explanatory variables denote child, household and community characteristics.

Three specifications are used to examine the effect of varying degrees of arsenic contamination based on: a) whether the drinking water is contaminated above the international (WHO) standards (>10 ppb) ; b) whether the drinking water is contaminated above the Bangladesh standards (>50 ppb and c) intensity of the level of arsenic in drinking water which is measured as falling into three intervals- $x < 10$ ppb, $10 < x < 50$ ppb, and $x > 50$ ppb; which effectively combines the WHO and Bangladesh standards in a measurable manner.

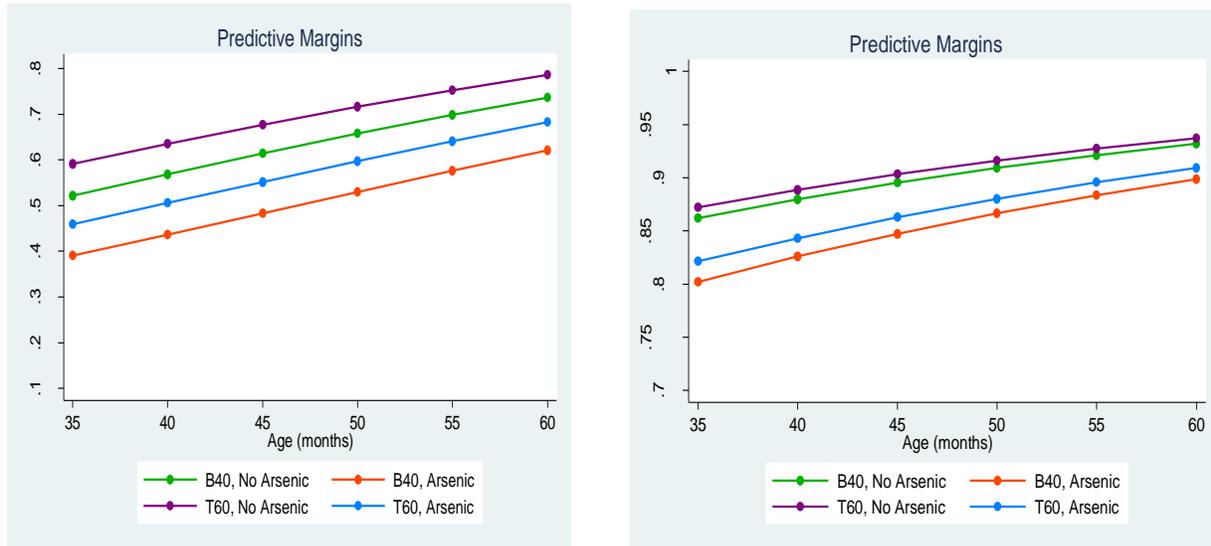


Figure 5.10 Predicted Margins: arsenic and ECDI

After controlling for individual, household and community characteristics, the models show that arsenic contamination is significantly and negatively associated with the overall ECD index and specifically on outcomes representing the physical, social-emotional, and learning domains. **The presence of arsenic in drinking water above the WHO standard of greater than 10ppb reduces the likelihood of meeting the combined ECD level by about 7 percentage points while the presence of arsenic above the Bangladesh standards reduces the likelihood by about 11 percentage points. Similar effects can be found for three out of four domains such as learning, physical and social, ranging from 3 to 8 percentage points. However, the effect of arsenic contamination on the child’s achievement in the literacy domain is not significant.**

Based on the specification (c) where the explanatory variables of interest is the intensity levels of arsenic in drinking water, the analysis further reveals that there is a clear dose-response relationship, where those children with exposure to higher concentrations of arsenic tend to have worse developmental outcomes. Medium level of arsenic concentration (between 10-50ppb) reduces the chances of attaining overall child development by about 4 percentage points while high concentration of arsenic (above 50ppb) tends to reduce this by about 12 percentage points. Similar results suggesting the increasing detrimental effects of the increase in arsenic concentration on physical, social and learning outcomes are observed.

Most of the arsenic incidence falls on households that rely on tubewells for drinking water and tube wells tend to be the main source of drinking water for about 90 percent of the population in Bangladesh. **While the incidence of arsenic is nearly uniform between the B40 and T60, its impact on early childhood**

development outcomes are considerably different with the children in B40 bearing higher burden than the children in T60 households. As an illustration, Figure 5.10 shows the marginal impact of arsenic on overall ECDI and learning for the B40 and T60. Children living in households that consume arsenic contaminated water tend to perform relatively less in meeting the Early Childhood Development index regardless of whether they belong to the B40 or T60. **In fact, children belonging to B40 households without arsenic tend to perform better than children in T60 households with arsenic indicating that the arsenic contamination more than offsets the advantages of belonging to a non-poor household. Similar patterns are reflected in the learning outcomes as well.**

The above analysis reaffirms the negative consequences of arsenic on human health, but explicitly highlights the developmental domains that are most affected by arsenic during childhood. The findings assert that arsenic mitigation, especially in high-risk areas, should be a multi-sectoral priority for stakeholders working on water, education, and early childhood development in Bangladesh and globally.

5.3 Salinity and Child Survival

Over 97 percent of rural Bangladeshis depend on groundwater for drinking purposes [11]. Groundwater in Bangladesh is subject to an array of contaminants including fecal bacteria, arsenic, and fluoride. As a consequence of climate change, groundwater is also increasingly vulnerable to salinity intrusion. Salinity intrusion has severe agricultural consequences on food production and livelihood, but may also have direct consequences on health, such as causing hypertension. However, saline groundwater may also have some protective health benefits since it can serve as important source of mineral intake. Major minerals in saline water include sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺), magnesium (Mg²⁺), chloride (Cl⁻) and sulfate (SO₄²⁻). These are all essential macro-minerals that are needed in bulk amount daily [23]. Mineral intake can especially effect maternal health and nutrition and influence pregnancy and birth outcomes [12, 13]. Neonatal and infant deaths are high but have declined in recent years in Bangladesh [15]. High amounts of salinity in drinking water could even lead to adverse birth outcomes. For example, increased concentrations of sodium in drinking water has been associated with higher prevalence of gestational hypertension among pregnant women in coastal Bangladesh [14]. However, there is limited investigation on the role of drinking water salinity in explaining neonatal and infant deaths in Bangladesh. Using five rounds of Bangladesh Demographic Health Surveys (BDHS) and Bangladesh Water Development Board spatial groundwater salinity data, we conducted analyses to evaluate the effect of groundwater salinity on neonatal and infant deaths in Bangladesh.

We compiled BDHS data from years 2000, 2004, 2007, 2011, and 2014. Our primary health outcomes under investigations are neonatal and infant mortality. Women between 15-49 years old were interviewed for live birth and neonatal and infant mortality within a 3-year period window prior to the interview year. Neonatal death was defined if a child died within the first month of life, and infant death was defined if the child died before the first birthday. The primary exposure variable was average groundwater electrical conductivity (EC), a common indicator of salinity, at the pixel-level. EC data was first collected by Bangladesh Water Development Board (BWDB) using monitoring wells throughout Bangladesh. Using the geo-code of monitoring well, we interpolated the electrical conductivity for entire Bangladesh. One random geo-code location per geographically selected cluster was taken during each of the five BDHS years. We then spatially linked the geo-code of the BDHS clusters with the interpolated Bangladesh groundwater salinity map to get the salinity data for each of the BDHS clusters. EC in

groundwater was tested as a continuous variable and a categorical variable. Drinking water salinity categories were defined by the Food and Agricultural Organization (FAO) of the United Nations: freshwater ($EC < 0.7$ mS/cm), mild-salinity ($EC \geq 0.7$ and < 2 mS/cm), moderate-salinity ($EC \geq 2$ and < 10 mS/cm), and severe-salinity ($EC \geq 10$ mS/cm) [20]. We restricted the sample size to only households reporting tubewells as their primary source of drinking water.

Other covariates used to build the logistic models include sex of the deceased child, birth order, age and marital status of the mother during time of delivery, educational status of both parents, rural/urban residence, asset-based wealth quintiles, access to improved water and sanitation, and depth of groundwater sources.

After pooling the five BDHS datasets, we calculated revised sampling weights following de-normalization of the standard weights [17]. We calculated the survey-weighted proportions of neonatal and infant mortality for each 100 live birth, and compared these proportions among different categories of exposure and covariates with respect to reference categories using chi-square test.

Sensitivity analyses:

In sensitivity analyses for the salinity categories based on FAO classification, we recoded mild-salinity as the reference category and evaluated the effect of freshwater, moderate- and severe-salinity water on neonatal and infant mortality using survey design specific logistic regression models.

Mortality prediction

We predicted the infants and neonatal deaths in coastal region of Bangladesh due to severe salinity for BDHS 2011 and 2014. We used linear probability models with full multivariable adjustments in the final model, and restricted cubic splines for three knots set at 0.7, 2, 10 mS/cm electrical conductivity distribution. The first derivatives of neonatal and infant deaths with respect to groundwater electrical conductivity were deduced to predict the probability of neonatal or infant death due to salinity for BDHS 2011 and 2014. We then de-normalized the BDHS standard weights to estimate the live births of the population for BDHS 2011 and 2014. We then estimated the number of neonatal and infant deaths for each coastal region.

Results

A total of 56,367 live births were reported among the women recruited in five BDHS survey between year 2000 and 2014. Of them, 12,053 neonatal and 16,015 infant deaths were reported. We calculated 995 neonatal and 1183 infant deaths within the three-years of five BDHS survey (Table 1). Of them, households of 862 neonatal and 1022 infant deaths reported to use tubewell as the primary source of drinking water.

For every unit increase of salinity per square centimeter, we found no significant protective or adverse effects of salinity in drinking water after adjusting for covariates (Table 1). However, when testing salinity as a categorical variable, as in comparing freshwater to mild, moderate, and severe levels, we found significant effects on neonatal and infant mortality rates. For those live birth households exposed to mild and moderate levels of salinity, the odds of having a deceased child were respectively 0.74 and 0.78 times the odds of having a deceased child when households were exposed to freshwater (e.g. saline free water). However, if households were exposed to severe levels of salinity, the odds of having a deceased child were 1.30 times the odds if exposed to freshwater (Table X). **This implies that mild to moderate levels of**

salinity have a protective benefit in preventing neonatal and infant death, while severe levels of salinity increase the odds that a child does not survive.

Table 4: Odds ratios of neonatal and infant mortality due to 1 mS/cm increase in drinking water salinity.

Outcomes	Model 1* β (95% CI)	Model 2 † β (95% CI)	Model 3‡ β (95% CI)
Neonatal mortality	0.96 (0.92, 0.99)	0.96 (0.92, 0.99)	1.00 (0.95, 1.05)
Infant mortality	0.97 (0.95, 1.00)	0.97 (0.95, 1.00)	1.01 (0.97, 1.05)

*Model 1 : unadjusted; † Model 2: adjusted for maternal age, birth order and sex of the child; ‡ Model 3: additionally adjusted for both parents years of education, rural or urban residence, household wealth score , improved sanitation, child’s birth year, maternal marital status, depth of tubewell, geographical division, and riven basin for the BDHS cluster. All co-variates used as fixed effects.

β: Odds ratio; CI: Confidence Interval

Table 5: Odds ratios of neonatal and infant mortality among different drinking water salinity drinkers, relative to the freshwater drinkers

Water salinity categories	Model 1* β (95% CI)	Model 2 † β (95% CI)	Model 3‡ β (95% CI)
Neonatal mortality			
Freshwater	referent	referent	referent
Mild-salinity water	0.65 (0.50, 0.83)	0.65 (0.50, 0.83)	0.74 (0.56, 0.98)
Moderate-salinity water	0.61 (0.48, 0.77)	0.61 (0.49, 0.77)	0.78 (0.55, 1.09)
Severe-salinity water	1.02 (0.73, 1.44)	1.04 (0.74, 1.45)	1.30 (0.84, 2.00)
Infant mortality			
Freshwater	referent	referent	referent
Mild-salinity water	0.62 (0.50, 0.78)	0.62 (0.50, 0.78)	0.70 (0.54, 0.91)
Moderate-salinity water	0.68 (0.55, 0.83)	0.68 (0.56, 0.83)	0.82 (0.60, 1.11)
Severe-salinity water	1.13 (0.85, 1.50)	1.14 (0.87, 1.51)	1.35 (0.93, 1.97)

*Model 1 : unadjusted; † Model 2: adjusted for maternal age, birth order and sex of the child; ‡ Model 3: additionally adjusted for both parents years of education, rural or urban residence, household wealth score , improved sanitation, child’s birth year, maternal marital status, depth of tubewell, geographical division, and riven basin for the BDHS cluster. All co-variates used as fixed effects.

FAO salinity categories: Freshwater (EC: <0.7 mS/cm); Mild salinity water (EC: ≥0.7 — < 2 mS/cm); Moderate salinity water (EC: ≥2.0 — <10 mS/cm); and Severe salinity water (EC: ≥10 mS/cm)

β: Odds ratio; CI: Confidence Interval

These findings have several implications for informing public policy on water quality. The first is that saline groundwater is likely an important source of maternal mineral intake that are essential for a healthy pregnancy. An earlier study in coastal Bangladesh supports this analysis because it found that drinking mild- salinity water was associated with higher urinary concentrations of calcium, magnesium and sodium compared to freshwater drinkers [26] Studies suggest that bioavailability of essential minerals from drinking water is very high [27], and some population in coastal Bangladesh can get up to 50% of their daily calcium and magnesium requirement by drinking 2 L of groundwater [28]. General diet in Bangladesh is low in calcium contents [29], and globally magnesium concentration in general diet is declining [30]. Therefore, drinking water may contribute an appreciable proportion of daily calcium and magnesium intake among Bangladeshi population [28], and drinking fresh or low mineral water can led to deficiency of these essential minerals.

The second implication is that households living in regions with severe salinity are at greater risk of having higher neonatal and infant deaths. Mitigation strategies such as improved piped water systems or rainwater harvesting interventions need to be targeted in these regions. However, it is important to acknowledge groundwater as a source of nutrition and that appropriate amounts of minerals may need to be re-introduced into drinking water to avoid any unintended health consequence.

VIII. WASH Access and Education

- Exposure to poor sanitation during infancy can delay school enrollment
- Water collection duties in salinity prone areas can affect school enrollment especially for girls

A large amount of evidence exists on the availability of WASH facilities in schools on increasing enrolment, reducing dropouts and improving attendance especially among female children⁴⁷. Since children spend a significant amount of time in schools, availability of good quality WASH facilities in schools reduces the chances of exposure to pathogens and fecal contamination, thus reducing the likelihood of diarrhea and environmental enteropathy which tend to have adverse long run consequences on children⁴⁸. On the other hand, lack of improved water access at home and the burden of water collection limit education enrolment and attendance of girls who are typically in charge of water collection.

6.1 Long Run Educational Impacts of Exposure to Poor Sanitation in the Childhood

The literature on the impact of water and sanitation on later life educational attainment is rare. We⁴⁹ examine whether in Bangladesh, exposure to poor sanitary environments during early childhood has an impact on late enrolment of children in primary schools. As discussed earlier, children living in communities with a large proportion of households who have unimproved sanitation or practice open defecation tend to be more exposed to bacteriological or fecal pathogens which in turn lead to poor nutritional outcomes and poor cognitive and early childhood development. Several longitudinal studies have been undertaken on the long term impact of nutrition outcomes on schooling attainment. It was found that low stature in childhood delayed enrollments in and years of school accomplished in Tanzania⁵⁰. Similar results were found for Uganda and other African countries⁵¹ and Guatemala⁵²

For the purposes of the analysis, DHS data from 2011 and 2004 are used for which location of the primary sampling unit is available with some random error⁵³. Of all the primary sampling units in 2011, 196 PSUs are identified which has a matching PSU within 5 kilometer radius in the 2004 DHS survey. Of these 118 are urban PSUs and 74 are rural. 577 children are identified who have completed age 6 but have not turned 7 years who should ideally be enrolled in the primary school. A probit regression of the following type is estimated;

$$Enrollment_{ijkt} = \beta Child_{ijkt} + Household_{jkt} + WASH_{jk} + Community_{kt} + Sanitation_{kt-1} + \varepsilon_{ijk} \quad (2)$$

Where $Enrollment_{ijkt}$ is the outcome variable of interest which indicates whether the child who has completed six years but has not turned seven years is currently enrolled in primary school in 2011; and $Child$, $Household$ and $Community$ explanatory variables denote child, household and community characteristics in 2011;

⁴⁷ Hunter et al., 2015; Barde and Walkiewicz 2014

⁴⁸ Freeman et al., 2012; Duflo 2001

⁴⁹ Joseph, George, Olivier, Françoise and Chellaraj, Gnanaraj, 2016

⁵⁰ Alderman et al., 2012

⁵¹ Alderman et al., 2007; 2006; 2001; Glewwe et al. 2001; Almond and Currie, 2011

⁵² Maluccio et al., 2009

⁵³ In publically available DHS data where GIS information is made available, the rural clusters are randomly shifted by 5km while the urban clusters are randomly shifted by 2km to ensure anonymity.

$Sanitation_{kt-1}$ indicates the share of households with unimproved sanitation in the community with no toilets (unimproved toilets)

In particular, to account for the density of population in the PSU, population density of the PSU with a two kilometer radius is computed from LandScan and is included. The main independent variables of interest are the share of households with no toilets or unimproved toilets in the PSU in 2004 which indicates the extent of open defecation or unimproved sanitation in the community around the time the child was born. A child who is observed to be six to seven years would have been less than or equal to one year of age in 2004. Controlling for other covariates, the level of exposure to unimproved community sanitation in their environment during their infancy may have implications on their health, nutritional status and can have impacts on their enrolment in primary schools. Children who are unhealthy tend to enroll later than normal children. One importance limitation of this analysis is the assumption that children who are observed in 2011 were living in the same or nearby PSU when they were infants. However, considering the low migration rates of the entire households including children, this assumption is relatively robust.

The results indicate that an increase in the proportion of households with no toilets in the community during infancy reduces the likelihood of primary school enrolment among six year olds by about 11 percentage points. On the other hand an increase in the proportion of households with no toilets and unimproved toilets reduces the likelihood of late enrolment by about 33 percentage points. Current sanitation condition of the household and the community has only a limited effect on late enrollment of children in primary schools. As expected, higher education status of the mother and household wealth has a positive and significant effect on increasing the likelihood of enrollment. One possible hypothesis explaining this result is that communities with poor sanitation might be poor in several other dimensions and it is this community underdevelopment that would be captured by the community sanitation variable. In order to test for this, we replaced the community sanitation variable with access to electricity in the community and did not find any statistically significant relationship, thus falsifying the hypothesis.

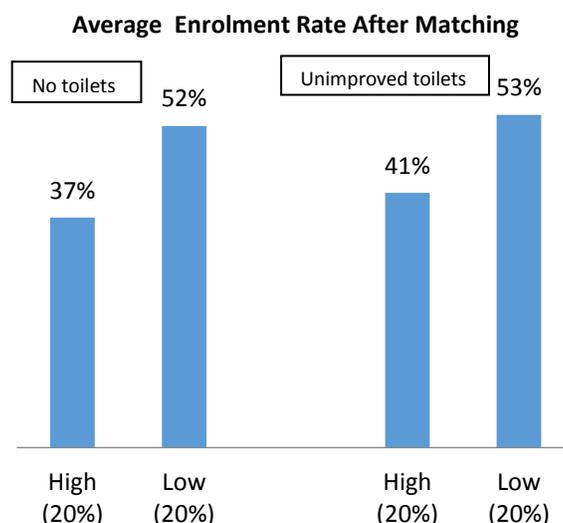


Figure 5.11 Average enrollment rate after matching

For further verification, PSUs in 2011 were ranked based on the share of households with no toilets and share of households with unimproved toilets in 2004. Twenty percent of PSUs were chosen from the top and bottom of the distribution and a subset was chosen using matching techniques such that the matched households are similar in the other observable characteristics except only the level of sanitation at the community level in 2004. As Figure 5.11 shows, PSUs that had high share of no toilets or unimproved toilets tend to have low enrolment rates among the six year olds. Specifically, PSUs with high share of no toilets in 2004, enrolment rates in 2001 were 15 percentage points less among the six year old children when compared to PSUs with low share of no toilets. Similarly, PSUs with high share of unimproved toilets in 2004, enrolment rates in 2011 were 12 percentage points less among the six year old children when compared to PSUs with low share of no toilets. This analysis further highlights the importance of improved sanitation at the community level in the early years of childhood on educational outcomes in later years.

6.2 Salinity, Water Collection Burden and School Enrolment of Girls

While the impact of access to safe water and adequate sanitation on schooling has been studied in recent years⁵⁴, the impact on the burden of collecting water among children has been relatively unexplored. This is primarily to be due to the relative absence of gender-disaggregated data on the household member is responsible for these chores. Using detailed household survey data collected as part of the Social Dimensions of Climate Change program (2011) in the World Bank from the Sundarbans in Bangladesh and West Bengal, we examine whether greater salinity in water and the lack of access to quality water tend to have a gendered impact on children's schooling in the Sundarbans in Bangladesh and West Bengal, India.⁵⁵

⁵⁴ Koolwal and van de Walle 2013, UNESCO 2010

⁵⁵ Komatsu, Hitomi and Joseph, George, 2016

Bangladesh has made significant achievements in increasing primary and secondary enrollment over the last 25 years, and attaining gender parity at these levels. Further, girls have accomplished better results than boys in primary school completion rate and secondary school enrollment.⁵⁶ However, at the post-secondary education levels, girls' school enrollment is lower than boys'. Several reasons including early marriage, household responsibilities and prevailing social norms are cited as the major reasons for girls dropping out of school in later years. A number of studies find a negative effect of domestic work on girl's schooling such as in Egypt⁵⁷ and Peru⁵⁸. The literature on the linkage between environmental degradation and schooling find that that deforestation increases children's time in collecting firewood water and reduce schooling such as) in Malawi⁵⁹, Ethiopia,⁶⁰ and Kenya⁶¹, while Jenson (2000) finds that weather shocks have a negative impact on schooling in Cote d'Ivoire.

In most LMICs, including Bangladesh, the burden of collecting water falls on women⁶² thus restricting their ability to stay in schools. A small number of studies find that increased access to water improves children's schooling⁶³. However, there is relatively less attention given to the impact of saline water and lack of access to improved water on schooling and on the incidence of children being responsible for fetching water.

In Bangladesh, the Sundarbans household survey has collected information from 2,144 households (9,799 household members). Sundarban is the largest delta in the world which belongs to the Coastal districts in the South of the country. As discussed earlier, like the rest of the coastal areas in Bangladesh, Sundarban is also affected by salinity intrusion, frequent natural disasters such as cyclones and ocean surges which make the drinking water sources such as surface water and shallow tube wells saline. Figure 5.12 show the households marked along the map of coastal Bangladesh which were selected for the survey. Figure 5.12 below shows the share of children aged 11-16 who attend school in the academic year 2010-2011 and are responsible for fetching water for the household disaggregated by gender. Water collection is largely a responsibility of girls. While the girls' attendance rate appears relatively high at the secondary level, it masks the gender assigned roles of performing tasks of collecting water, which falls more heavily on girls. According to the survey, in the Sundarban, about 7 percent of girls are responsible for fetching water and do not attend school, while this is the case for only about 4 percent of boys. Only half the girls attend school without being responsible for water collection compared to 64 percent of boys in Bangladesh.

⁵⁶ World Bank 2008

⁵⁷ Levison and Zibani, 2010

⁵⁸ Levison and Moe, 1998

⁵⁹ Nankhuni and Findeis, 2004

⁶⁰ Gebru and Bezu (2013)

⁶¹ Ndiritu and Nyangena (2010)

⁶² Brewster, Hermann, Bleisch and Pearl 2006

⁶³ Dreibelbis et al 2013, Koolwal and van de Walle 2013, and Nauges and Strand 2013

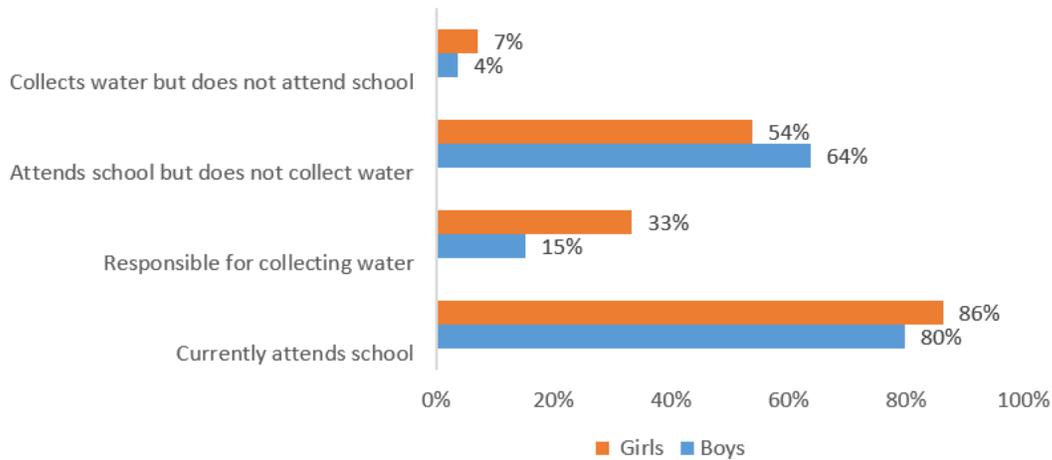


Figure 5.12 School attendance and Water Collection (ages 11-16)

The impact of increased burden of water collection on schooling is examined using a bivariate probit model.

$$S_i^* = X_i\alpha + u_i, \text{ where } S_i = 1 \text{ if } S_i^* > 0, \text{ and } 0 \text{ otherwise}$$

$$W_i^* = X_i\beta + e_i \text{ where } W_i = 1 \text{ if } W_i^* > 0, \text{ and } 0 \text{ otherwise}$$

Where S_i^* and W_i^* denote latent variables. The dependent variable in the first equation is whether the child attends schools ($S_i = 1$ if attend school, 0 otherwise), and the dependent variable in the second equation is whether he or she is responsible to collect of water ($W_i = 1$ if collect water, 0 otherwise). The vector X_i includes individual and household characteristics and variables related to reported information on salinity and other weather related variables.

Parameters α and β are coefficients to be estimated. Since the water collection responsibilities and school attendance may be jointly determined by the other factors at the household and community level, these two decisions may be endogenous. For instance, there could be unobserved characteristics such as the child being strongly motivated to study which increase the likelihood that he or she attends school, while the same characteristics could reduce the probability that the child is responsible for water collection. If this were true, the correlation coefficient of the error terms u_i and e_i would be negative. Therefore a bivariate probit model is used which allows for the error terms u_i and e_i to be correlated.⁶⁴ Since we expect household unobserved characteristics to have similar effects on children in the same household, we cluster the standard errors by household.

⁶⁴ (Greene 2003).

The covariates in X_i include individual characteristics (such as age, whether disabled or chronically ill) and household characteristics (such as age of the household head, the household heads' education, highest education level of any woman in household, an asset index⁶⁵, whether the household has access to electricity, the log of time it takes to reach the secondary school and the log of time it takes to reach markets). The variable that measures the quality of water is a dummy variable on whether the household draws water from poor drinking water sources, namely from ponds, rivers or canals. The water quality is also measured by several dummy variables such as; whether the household experienced in the last five years more saline water in rivers and ponds etc. The distance to the embankment and rivers indicates the vulnerability to damages from cyclones or monsoons. In order to assess whether the household gender composition affects schooling and water collection, the number of women aged 11-18, 19-59 and 60 and over, and the number of men in the same age categories are also included as regressors. Presence of young children could impact schooling and household chores, especially for girls, hence the number of children aged 0-4 and 5-10 are also included as regressors.

The bivariate probit estimates reveal that girls in households affected by greater salinity in water in rivers and ponds are 11.8 percent less likely to attend school without being in charge of collecting water (in column 3). They are also 5.3 percentage points more likely to be responsible for water collection while skipping school (in column 4) if salinity in rivers and ponds increases. Furthermore, girls with unimproved drinking water sources in the household are 10.2 percentage points less likely to focus on school attendance, although it is only significant at 10 percent. Salinity in water and poor drinking water do not affect boys' probabilities, however. Figure 5.13 presents the predicted marginal effects of the interaction between greater salinity in rivers and ponds and unimproved drinking water sources at home on the probability that girls and boys are made responsible for water collection while skipping school.

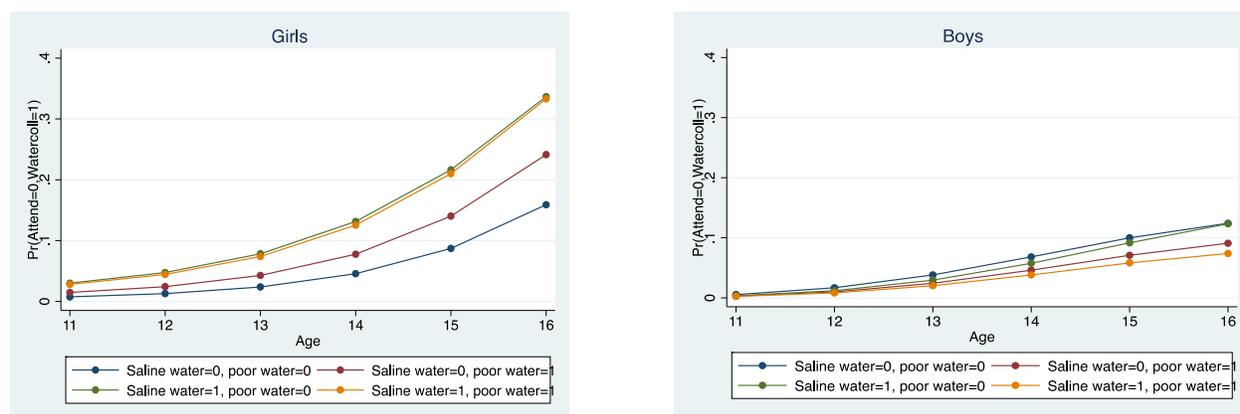


Figure 5.13 Bangladesh: Predicted marginal effects of collecting water but not attending school for girls and boys

⁶⁵ A composite asset index was created by using dummy variables for whether the household owns a bicycle, motorbike, car, TV, radio, telephone, refrigerator, sewing machine; the number of rooms in the house; dwelling has pucca wall and pucca roof; dwelling has concrete flooring; the walls are made of high quality materials (cement or burnt brick); and owns more than 1 acre of land. For justification on the use of asset index on schooling, see Filmer and Pritchett (2001) who study the effect of asset index on schooling in India.

For girls, salinity in water and having unimproved drinking water sources greatly increase the chance of being made responsible for water collection while not attending school. The gap with girls in households who have improved drinking water sources and do not experience salinity widens with age. By age 16, saline water and lack of access to improved water sources increase the chances of girls dropping out of school and becoming responsible for water by 33.7 percent, versus 15.9 percent if the water is not saline and it uses improved water sources. In contrast, for boys, there is little difference among the households with different water quality and water source. This analysis indicates the importance of provision of improved water to improve secondary education of girls especially in areas where poor water quality of drinking water leads to girls being diverted to water collection from distance sources.

IV. Policy Levers

Key Points

- **Target WASH investments.**
- **Multi-sectoral coordination.**
- **Improve quality of service delivery.**
- **Assess the health benefits and potential unintended consequences before investing.**

Lever 1: Targeting WASH Investments

Consider targeting WASH interventions using a “high risk approach” (e.g. targeting individuals who are at the most risk for poor human capital). Those among the bottom 40 percent are at most risk for early death, undernutrition, and interrupted education. Spatial analysis from the Bangladesh WASH Poverty Diagnostic finds that only 3 out of 64 districts are classified as “high-level performers” for serving B40 households. This means that B40 households have comparatively lower access to either clean water or improved sanitation than the national average in 61 out of 64 districts. Meanwhile, all but one district are classified as high- or mid-level performers when it comes to serving T60 households. Further, the below maps illustrate the geographical disparities in basic water and sanitation access. Basic access tends to be worst in remote areas (e.g. Chittagong Hill Tracts), coastal regions, and in some densely populated urban centers.

Because Bangladesh has reached nearly universal access to improved drinking water and ended open defecation, it may be appropriate to dedicate funds into “last mile” service basic service delivery in jurisdictions with low access. Funds (e.g. block or performance grants) can be allocated to the neediest Local Government Institutions (LGIs eg union parishads) with technical support from central institutions. Targeting jurisdictions based on poverty rates, WASH coverage, or climate vulnerability could be appropriate starting points. It may also be worthwhile to target based on indicators related to human capital, such as maternal and infant mortality rates, undernutrition prevalence, or even educational attainment. Our analysis on community health centers, for example, found that health facilities in areas of high rates of stunting were the most likely to have poor access to WASH. This could imply that WASH access in health centers is an indicator of an overall weak health system that may not be able to provide other essential preventative services needed for good health and nutrition.

Apart from geographic targeting, B40 household-level targeting should also be used. This report recommend utilizing LGI knowledge or existing social protection platforms on identifying the neediest beneficiaries to receive WASH improvements through subsidies, microfinance, or conditional cash transfer programs. Local communities should also be engaged to the extent possible in program planning and implementation as they know best the priorities and unique constraints to delivering and sustaining services.

In carrying out these actions, it is also necessary to formalize institutional responsibilities for serving B40 populations. For example, utilities historically have not had a clear mandate for serving slum populations, and which leaves slum populations vulnerable to informal service provision that may not uphold standards of service. Utilities are beginning to better incorporate informal settlements into formal service provision.

Formal institutional mandates may also bridge stronger partnerships and coordination between communities, development partners, private sector, and government to exchange knowledge and identify appropriate technology and implementation plans to overcome barriers unique to serving low-income or hard-to-reach communities. Departing from exclusive WASH provision will have multiple spillover effects on health and productivity for the entire population.

Lever 2: Improve the quality of service to be more “human development centric”

More and more studies show that installing wells and household latrines is not enough to tackle “heavy-weight” public health and development challenges such as undernutrition and strengthening skillsets. To begin to have more impact on human capital, the WASH sector must step away from a strictly engineering approach to more human centric delivery that ensures that WASH services are relieving daily burdens that prevent individuals from reaching their full capability. This means that the WASH sector needs to give more attention to alleviating human health risks such as reducing environmental exposures like fecal bacteria, heavy metals, or salinity and improving reliable access and uptake of services throughout communities, including in workplaces, schools, and health centers. This will require focusing on better water quality, fecal sludge management, and improving uptake of hygienic behaviors.

Much of the analyses outline in the report focused on linkages between water quality and human development outcomes. Relying less on decentralized service provision such as tube wells and moving to continuous, safe on-premise piped water supply could be one step in this direction. Tube wells are difficult to monitor and regulate given that the infrastructure is geographically scattered and that there are unclear responsibilities of well installers and owners. Centralized piped water schemes are theoretically easier to monitor and treat and can potentially relieve health and time burdens. However, piped water in Bangladesh, as it stands, is highly contaminated with fecal bacteria and suffers from a number of service delivery gaps including adhering to rigorous water quality standards, intermittency, and leakages. The sector should focus on strengthening institutional and take enforcement-based approaches to regulating water quality, such as utilizing payment-for-results financing mechanisms or empowering LGIs to deliver on their mandates.

Safe fecal sludge management and higher uptake of hygienic behaviors are difficult challenges to address, but are the essential interventions in order for WASH to take on its preventative function in limiting fecal exposure. A number of studies suggest that less than 2 percent of fecal sludge is treated and properly disposed of in major cities, which is an especially high public health risk in densely populated areas. In our analysis, we found that fecal exposure was pervasive throughout Dhaka environments, including both slum and high-income neighborhoods. Sanitation does not only mean intervening on where individuals go to relieve themselves, but also must focus on other common exposure pathways, such as food hygiene, soil/flooring, and flood water. Alternative on-site sanitation options, sewerage/drainage, centralized or decentralized wastewater treatment options need to be prioritized in urban planning and development.

Lever 3: WASH Integration into Traditional Human Development Programs

WASH access alone does not determine human capital. However, its synergies with other risk factors to poor health and education are what drives its WASH’s influence. WASH should be integrated into

traditional human development programs such as health systems strengthening, maternal and child health and nutrition, social protection, gender empowerment, and education.

Awareness and education on water quality issues and good hygiene practices such as proper child feces management and handwashing should be taught by all health care providers including community health workers. WASH hardware and behavior change promotion should be added into the package of interventions for improving early childhood development. It is essential that schools and healthcare centers have access to reliable, safe water and sanitation and model key hygiene behaviors. Convergence of multiple human development programs and WASH should have multiplier effects in relieving burdens and improving overall human development.

However, the WASH sector also needs to be more mindful of health, social, and environmental consequences of its investments. The “do no harm” principle upheld in the medical and public health fields should also hold true for the WASH sector. Arsenic contamination of drinking water supply in Bangladesh is known globally as the largest mass poisoning of population in history, and is unfortunately an unintended consequence of newly installed shallow tube wells that were aimed to prevent households from retrieving drinking water from ponds and lakes. Emerging research on mineral intake from groundwater could have implications on technology choices for filtration and water treatment. For example, any intervention that proposes to move away from groundwater sources should ensure that populations obtain needed minerals elsewhere in their diet or drinking water supply (e.g. mineralization of rain water or desalinated water). Thorough assessment of hydrogeological, geographical, and population characteristics that could raise risk of environmental exposures, health, and social vulnerabilities can better align the WASH sector with human development objectives.

Lever 4: Supporting WASH Research and Innovation

Finally, Bangladesh’s government, civil society, research institutions, and development partners need to continue being a global leader in WASH research and innovation. Bangladesh has exported a number of WASH and health innovations to the rest of the world. Community-Total Led Sanitation (CLTS), originally developed in Rangpur, is the leading behavior-change model for low-and middle income communities to end open defecation. Developed in Dhaka’s “cholera hospital,” oral rehydration solution (ORS) therapy has saved countless children from dying from diarrheal diseases. BRAC is the world’s largest NGOs and supporter of WASH programs, and ICDDR,B stands as one of the leading WASH and health research institutions, developing a number of low-cost water and sanitation technologies. The country has a number of unique and rich datasets on neglected WASH issues such as water quality and menstrual hygiene management. Bangladesh’s WASH sector should continue to support research and innovation and further support collaboration with other sectors and countries to exchange learning and experiences.

