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Does Access to Safe Water and Improved Sanitation Facility Ensures Better Environmental Health Outcome? A Cross-Sectional Study on Rural Bangladesh

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Abstract: This study investigates the environmental health outcomes of better access to safe and improved water and sanitation facility using the Household Income and Expenditure Survey Dataset of Bangladesh. Applying a cross-sectional analysis, the study examines whether individuals with better access to improved water and sanitation facility are less exposed to water, hygiene and sanitation related diseases in rural Bangladesh. Econometric modelling was applied to identify the determinants of water, hygiene and sanitation related disease prevalence and how those two indicators influence the probability of disease prevalence. Besides, the study also investigates whether this probability varies across different income groups and regions. Results reveal that access to improved sanitation facility significantly reduces the disease prevalence rate, whereas access to safe water fails to show any significant effect. Moreover, the impact of sanitation is relatively more significant in lower-income groups. Among other variables, level of education, gender, and dwelling features significantly determine the probability of disease prevalence. A large regional variation is also prominent regarding both access to those facilities and environmental health outcomes.

Keywords: Environmental health outcome, sanitation, safe water, disease, Bangladesh.

1. Introduction

Access to clean and safe drinking water and improved sanitation facility are considered as the significant indicators for sustainable development which affect the environmental health outcomes directly. According to the World Health Organisation's Global Nutrition Report (2017), the largest part of the disease burden and death in developing countries, comes from water and sanitation contaminated illnesses. Therefore, it is necessary to have a safe, inexpensive, easily accessible and sustainable water supply and latrine facility, to get a healthy and enhanced life. Recognising the importance, these two indicators were set in the Millennium Development Goals and later included in Sustainable Development Goals (UN 2016). However, despite placing such great emphasis, 2.1 billion people are in lack of safe drinking water, and about 4.5 billion are still in lack of access to basic sanitation services and almost 361 000 children under 5 years of age die due to diarrheal diseases according to the latest survey (WHO 2017).

Literature comprehends a strong debate on whether an increase in the coverage of safe water and improved sanitation facility ensures better environmental health outcomes. More precisely, the argument is whether they are capable of reducing the prevalence of water, sanitation and hygiene-related diseases or not. Empirically investigating the causal relationship, studies have produced inconsistent and conflicting evidence. For instance,

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studies have found the evidence that better access to water and sanitation improves the quality of daily life and reduces the risk of water contaminated diseases (Prüss-Ustün et al. 2015; dos Santos & Gupta 2017). There are also a few country-specific studies claiming such an inverse relationship. For example, Duflo et al. (2015) on India, Liu et al. (2013) on Nepal, Abubakar (2017) on Nigeria found that increase in coverage of such facility reduces disease prevalence.

Conversely, another set of studies (e.g., Engell and Lim 2013; Barnard et al. 2013; Dangour et al. 2013; Patil et al. 2014) have found little or no impact of water and sanitation intervention programs on reducing the prevalence rate of those diseases. Among them, Engell and Lim (2013) conducted a meta-analysis which combined the results of 84 relevant studies (conducted in between 2010 and 2012) and found that no additional health benefits can be achieved by increasing the coverage of pipe line water supply or improved latrines rather it largely depends on the proper usage, maintenance and consciousness. Studies have also argued that there are some supplementary issues like, usage of the facility and social practice (Convenient access to water, willingness to pay for improvements in water quality and no hand washing or no safe disposal of child faces) and health beliefs play a vital role in determining the outcome rather than the coverage of those facilities (Barnard et al. 2013; Gertler et al. 2015; Guiteras et al. 2015).

There are also few studies on Bangladesh investigating the relationship (e.g., Rana, 2009; Sultana et al. 2013; Arnold 2013; Akter et al. 2015; Benjamin-Chung et al. 2017). However, the findings of those studies are also mixed and conflicting. For instance, Rana (2009) conducted an experimental study on 50 sub-districts of Bangladesh to investigate the effect of water, sanitation and hygiene (WASH) intervention of BRAC on self-reported waterborne diseases (Diarrhea, dysentery, worm infections and typhoid fever). The study found that the overall prevalence of waterborne diseases reduced from 10% at baseline to 7% and among children aged under-five the reduction rate was from 22% to 13%. Contrarily, Arnold et al. (2013) while investigating the relationship for rural Bangladesh found little evidence in favour of the water and sanitation intervention affects diarrhea and growth of infant and young children. Similar results were also observed by Benjamin –Chung et al. (2017) while investigating the implementation quality of the SHEW-B (water Sanitation and Hygiene) program of UNICEF.

It is evident from the literature that the majority of the studies either investigated the impact of a particular intervention (water and sanitation) program or examined the relationship considering a specific area or region. However, the social practice, health beliefs, and the overall socioeconomic condition vary across different heterogeneous income groups and across different regions. This variation may also influence the causal relationship as the usage and maintenance of the improved facilities (regarding water and sanitation) depends on health and hygiene related consciousness which is determined by household or individual's socioeconomic background. Therefore, program and region-specific studies have limited scope in generalising the results for the whole population. It requires a nation-wide and more comprehensive analysis to incorporate and control the unobserved heterogeneity issue and examine the relationship to make a robust inference regarding the whole population. Hence, this current empirical study intends to mitigate this gap in the literature by investigating whether access to improved water and sanitation infrastructure reduces the probability of related hygiene, sanitation and waterborne disease prevalence in rural Bangladesh, by using a household level national dataset covering the whole country.

The study conducts the investigation on Bangladesh, a highly populated country where irrespective of achieving considerable progress in ensuring the access of safe water and improved sanitation, water and sanitation contaminated diseases like diarrhea and cholera are still epidemic. Besides examining how access to safe water and improved sanitation facility influences the probability of disease prevalence, the study also investigates the variation of probability across different income groups and different regions by including several determinants (socioeconomic, demographic and geographic) that may differentiate the disease prevalence rate. Results of this study reveal that access to improved sanitation facility is significantly associated with disease prevalence rate. Access to safe water, however, failed to show any significant association. Among the other variables, level of education, gender, and dwelling features significantly determine the probability of disease prevalence. The study also shows that the probability varies significantly across different income groups and across the regions of Bangladesh. The study makes a noble contribution in literature by conducting such an investigation covering the whole country and by showing that the determinants of disease prevalence have diversified effects depending on several socioeconomic, demographic, and regional characteristics.

The rest of this paper is constructed in the following manner: Section 2 establishes the theoretical framework to illustrate the link between water and sanitation facility with water, sanitation and hygiene related diseases. Afterwards, Section 3 provides the methodology of the empirical analysis which contains the variable description and econometric modeling. The article continues with the descriptive and empirical results being thoroughly discussed in Section 4 and Section 5, respectively. Finally, the conclusion is placed in Section 6.

2. Theoretical framework

Environmental health indicators are the "tools for measuring, through direct or indirect procedures, an important feature of an environmental health issue," which "can be used to evaluate and interconnect the status of and trends in overall environmental health" (NACCHO, 2000). According to WHO, the most common environmental health indicators are: "a) Access to basic sanitation (Proportion of the population with access to adequate excreta disposal facilities), b) Access to safe and reliable supplies of drinking water (Percentage of the population with access to an adequate amount of safe drinking water in the dwelling or within a convenient distance from the dwelling) and c) Connections to piped water supply Percentage of households receiving piped water to the home" (WHO, 1999). Diarrhea morbidity and mortality in children under five years of age and Water-borne diseases (outbreaks of water-borne diseases) are the common health indicators to monitor the effect of unsafe water and sanitation (WHO, 1999). Literature suggests that there are multiple pathways through which poor or limited access to those facilities causes multiple health and environmental hazards. Figure-1 (below) displays the plausible channels.

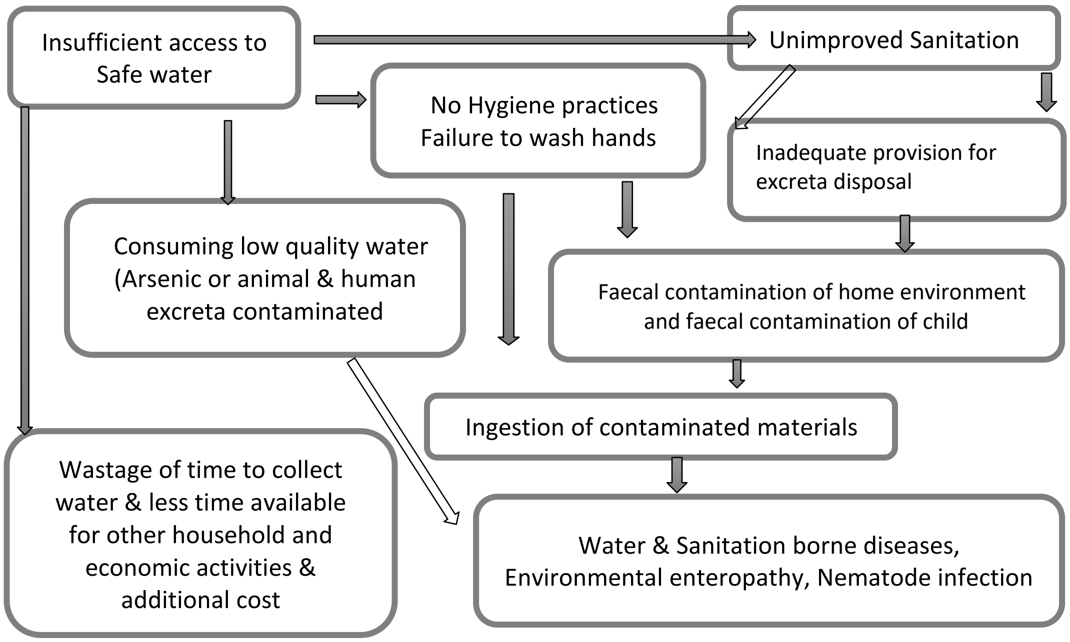

Figure 1: Conceptual framework presenting the channels through which poor water and sanitation facility causes water, sanitation and hygiene related diseases

Source: Adopted from Dangour et al., 2013.

Because of unavailability of safe water people may turn to low quality of water both for drinking and other household activities which will directly cause diarrhea and other waterborne disease (Briend, 1990). Besides, the sanitation system will not work properly because of lack of water. Lack of hygiene practice and inadequate provision for excreta disposal will cause faecal contamination of children and the environment. There will be also direct ingestion of contaminated materials because of such a reason. Moreover, human excreta have been implicated in the transmission of many infectious diseases, including cholera, typhoid, infectious hepatitis, polio, cryptosporidiosis, and arsenicosis. Malnutrition, pneumonia, worm infestations, are also associated with unsafe water, poor sanitation and hygiene resulting in reduced physical growth, weakened physical fitness and impaired cognitive function, particularly for children under the age of five (WWAP, 2015). Ultimately besides causing environmental enteropathy and nematode infection (Humphrey 2009), there will be a considerable amount of wastage of time and loss of financial resource because of limited access to these environmental health indicators.

3. Research method

The objective of this study is to investigate whether better access to water and sanitation facilities reduces the probability of water-sanitation and hygiene-related disease prevalence. As a part of the methodology, descriptive statistics and as well as econometric modelling (Probit model on the probability of disease occurrence for the overall sample and on different income groups) have been used for identifying the influence of water and sanitation facilities on the probability of water and sanitation contaminated diseases prevalence on the rural households of Bangladesh. Bivariate analysis is conducted initially using chi-square and ANOVA test in STATA to find out how different variables are correlated with the dependent variable and how they vary across different income quintiles and regions (administrative divisions).

3.1 Theoretical background of probit model

In the case of a binary dependent variable, the Linear Probability Model is not useful as it holds the assumption that the conditional probability function is linear (Gujarati and Sangeetha, 2007). As a solution Probit and Logit models are useful as they use a nonlinear function to model the conditional probability function of the dependent binary variable. In this study, we have used Probit regression model. A cumulative standard normal distribution function $\Phi(\cdot)$ is used in the probit regression. Therefore, the model assumes,

$$(Y|X) = P(Y=1|X) = \Phi(\beta_0 + \beta_1 X) \quad - (1)$$

In the above equation, $\beta_0 + \beta_1 X$ plays the role of a quantile z [where, $\Phi(z) = P(Z \leq z)$, $Z \sim N(0,1)$] such that the coefficient β_1 is the change in z associated with a one-unit change in X. Therefore, although, the effect of change in X on z is linear, the association between the dependent variable Y and z remains nonlinear as Φ is a nonlinear function of X. However, as Y is a nonlinear function of X, the coefficient β_1 does not have the conventional interpretation. To obtain the expected change in the probability that Y=1, first, we need to compute the predicted probability that Y=1 for the original value of the dependent variable. Next, we have calculate the predicted probability that Y=1 for $X+\Delta X$, and finally, we obtain the difference between both predicted probabilities to get the marginal impact of ΔX. However, in STATA software, this can be computed by using *mfx* command after the probit regression or using *dprobit* command which directly reports the marginal effect rather than the coefficients. In this study, we have used *dprobit* command to obtain the marginal impact.

Probit regression (showing the marginal effect) is used in this study to find out the association between the explanatory variables (access to water and sanitation facilities) and the dependent variable (Disease). Furthermore, all the individuals are divided into few income groups (based on per capita household income), and separate Probit regression has been run on each group to investigate the marginal impact of the determinants on the probability of disease in each income groups.

3.2 Data source

This cross-sectional study uses Household Income and Expenditure Survey, HIES-2010 dataset (a survey on 12000 households) which is till now the publicly available updated dataset. This study focuses only on the rural settings. It is 7840 households (which contain 35903 individuals) out of 12400 sample households of HIES-2010 that belongs to the rural areas. The questionnaire of the survey includes a section (section 3) on Health, where self-reported morbidity information is captured (more specifically it asks whether any type of acute or chronic diseases occurred during the 30-day period prior to interview) with other relevant information. The questionnaire contains a long list of diseases. This study considers only the water and sanitation hygiene-related diseases from that list which is used as the dependent variable. It uses WHO classification of water sanitation related diseases. Moreover, section 6 in the questionnaire contains specific questions regarding dwelling information. Access to safe water (source of water for drinking and other household purpose and whether it is arsenic tested and arsenic free) and improved sanitation (which are the main explanatory variables of our study. To avoid the criticism of inaccurate recall or individual's limited knowledge about illness experience on self-reported morbidity (Murray and Chen, 1992), the national questionnaire uses a limited recall period (30 days) incorporating cultural context and necessary training to collect accurate and complete information.

3.3 Model specification and variable description

To investigate the impact of access to water and sanitation facilities on the probability of disease we construct the following model to apply Probit regression:

$$D_i = \alpha + \beta.\, Water_i + \mu\, Sanitation_i + \lambda\, X_i + u_t$$

Where, D_i is a categorical variable which takes value '1' if the individual affected by water, and sanitation related diseases in the last 30 days and equal to '0', if not affected. This variable is used as the indicator for health outcome measured by water and hygiene related diseases among respondents which include Diarrhea, Malaria, Cholera, Dysentery, Typhoid, Scabies, Arsenicosis and Jaundice. The variable $Water_i$ is a categorical variable showing whether the household have access to safe water (pipeline or tube well water with no arsenic contamination) for drinking and other purposes. The variable $Sanitation_i$ is also a categorical variable, which is used to identify whether the household have improved toilets in home compound (Improved toilet is defined as if it is sanitary or water seal or pit). X_i is a set of control variables. Household and individual's demographic and socioeconomic characteristics are taken as control variables based on relevant literature (Pattanayak et al., 2010; Adams et al., 2016; Abubakar, 2017). As per controls demographic features (age, sex, household size, household density), level of education (of the individual, mother and father), dwelling feature (separate kitchen, dining, access to electricity), and socioeconomic condition (earning status, land holding, access to safety net) are included in the model which affects both the access to water and sanitation facility and also the disease prevalence rate as suggested by the literature. A brief description of the variables is presented in Table 1(below).

Table 1: Description of the variables

Variable	Description
Dependent Variable:	
Disease	=1; if individual is affected by water and sanitation borne disease in the last 30 days; = 0, otherwise. This study considers the following diseases related to water, hygiene and sanitation on the basis of relevant literature : Diarrhea, Malaria, Cholera, Dysentery, Typhoid, Scabies, Arsenicosis and Jaundice.
Explanatory Variable:	
Water	=1, if household has access to safe water for drinking and other uses; 0 if otherwise. Piped line supply water and tube-well (not arsenic contaminated) is defined as safe water.

Variable	Description
Sanitation	=1, if household has access to improved toilet; 0, otherwise. Improved toilet in this study is defined as if it is sanitary / water seal / pit;
Control Variables:	
Age of the patient	In years
Sex of the patient	=1, if Female
Education	Years of education of the patient
Religion	=1, if Islam
Mother's age	In years
Mother's education	Years of Education
Age of the head	In years
Head's education	Years of education
Household density	Members living per room.
Separate dining	=1 if separate dining room is available in the dwelling; = 0, otherwise.
Separate Kitchen	=1, if separate kitchen is available in the dwelling; = 0, otherwise
Electricity	=1, if household has electricity connection; =0, otherwise
Patient's earning status	=1, if earner; 0, otherwise
Mother's earning status	=1, if earner; 0, otherwise
Benefit received from safety nets	=1, if Yes; 0, otherwise
Landholdings	(in decimal)
Per capita income*	Per capita income of the household
Regional dummies	7 regional dummies for 7 administrative divisions

Note: per capita income is used to construct the income quintiles.

4. Descriptive results and discussion

The analysis starts with an overall overview reported in Figure 2 (below), which shows the scenario of water and sanitation contaminated disease prevalence in rural Bangladesh. Figure 2 shows that among the total rural observations (35,903), 91.44% people have safe water, 44.09% have sanitary latrine facility and 42.57% people have both the facilities. Amid the rural observations, about 2.22% of people are affected by water-borne and hygiene contaminated diseases. Among them, 60.65% (484) have no access to safe water and improved latrine facility, which shows the rationale behind taking safe water and latrine as the main dependent variables. Surprisingly, 39.35% (314) people have access to safe water and sanitary latrine although they are affected by diseases, which project the necessity of including other predisposing and enabling factor into the analysis of the study.

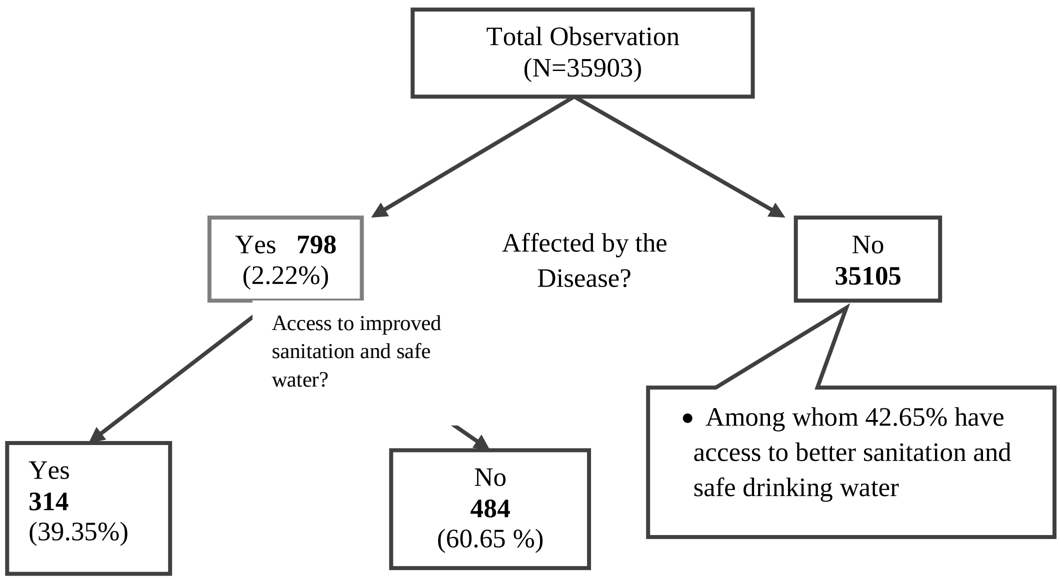

Figure 2: Water and sanitation related disease prevalence in rural Bangladesh.

Source: Own construction based on HIES data

4.1 Variation in disease prevalence

The study also investigates the variation in water and sanitation related disease prevalence across different income groups and different administrative divisions. Table 2 (below) confirms that disease prevalence rate does not vary significantly across the income quintiles as more or less the percentile distribution is the same for all income quintiles. Moreover, the chi-square value (2.046) is low and not statistically significant.

Table 2: Quintile wise variation in disease prevalence

Variable Name		Income Quintiles						Chi square
		Poorest	2nd	3rd	4th	Richest	Obs.	
Disease	Affected	19.05	21.05	21.05	18.67	20.18	798	2.0455*
	Not Affected	20.06	19.94	20	20.02	19.98	35,105	

***p<0.01, **p<0.05, *p<0.1

Table 3 (see Appendix) displays the regional variations (considering administrative Divisions) in disease occurrence by income quintiles. Data shows that 77(9.65%), 163(20.43%), 145(18.17%), 142(17.79%), 122(15.29%), 80(10.03%) and 69(8.65%)

patients are from Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur and Sylhet Divisions, respectively. Therefore, the highest disease occurrence is found in Chittagong (20.43%), and the lowest is in Sylhet (8.65%). In Barisal and Rangpur, the poorest quintiles contain the highest share of disease prevalence, and it declines as we move from poorest to the richest quintile. Usually, the richest quintiles have the lowest share of all except in Chittagong and Sylhet Division (where the share of the richest quintile is 31% and 21%, respectively). However, the variation in disease occurrence across the income group is statistically significant only in Chittagong and Khulna (at 1% and 5% level of significance).

4.2 Variation in access to safe water and improved toilets facility

Table 4 and Table 5 (see Appendix) shows quintile and regional variation of access to safe water and sanitation facilities. We start our discussion with access to safe water. Table 4 shows that in all the regions (Divisions) there is significant quintile wise variation (at 5% and 1% level) in access to safe water apart from Rajshahi Division. The table also shows that about 3.7%, 18%, 6.9%, 14%, 1.8%, 0.8% and 6.1% people do not have access to safe water in Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur and Sylhet Division respectively (in our sample). Therefore, Rangpur division has the lowest rate and Khulna division has the highest percentage of individuals with the unavailability of safe water. In the overall sample, we find that 8.6% people do not have access to safe drinking water, and there is also significant quintile wise variation in access to this facility.

On the other hand, regarding improved toilet facility, Table 5 (see Appendix) shows that about 21%, 55%, 57%, 38%, 63%, 14% and 35% people do not have access to an improved sanitary toilet in Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur and Sylhet Division respectively. Therefore, except Barisal and Khulna division, in all divisions have a relatively higher percentage of individuals who do not have access to an improved toilet facility. Therefore, the condition is most severe in Dhaka and least severe in Rangpur Division. The quintile wise variation is also statistically significant ($p<0.01$) in all cases. Data confirms that in all divisions, poor incomes groups' access to the facility is the poorest. Regarding the overall scenario, we find 44.09% people do not have access to improved toilet and the quintile wise variation is also statistically significant.

5. Regression result

Table 6 (see Appendix) presents the regression results of Probit regression (showing the marginal impact) considering *Disease* (=1, if the person affected by disease and 0, otherwise) as the Dummy Dependent Variable and including all the relevant explanatory and control variable. We have a two folded objective–besides investigating the marginal impact of the determinants on the probability of the incidence of disease for the overall sample; we try to find out whether the probability varies within and across different income quintiles. Dividing each observation in terms of income quintile we have conducted Probit regression to each quintiles with the same model specification. This allows us to show in each quintile how the access to safe and improved water and sanitation system influences the probability of the disease prevalence.

A set of post-diagnostic tests were performed in this study. LR Chi-square scores of the overall regression and the quintile wise regressions are large and statistically significant (at 1% and 5% level of significance), which confirms that all the slope coefficients are simultaneously significant (see Table 6 in the Appendix). Besides, the Pseudo R^2 values show that all the models are well fitted, although, R^2 is not a good measure of goodness of fit in binary models (Gujarati and Sangeetha, 2007). Ramsey RESET test (1969) was conducted on the model to test whether the model is correctly specified. Test score confirms that we cannot reject the null hypothesis that the model is correctly specified (p-value is 0.1470). Breusch-Pagan test (1979) confirms that we cannot reject the null hypothesis of constant variance, i.e., indicating no heteroskedasticity in the model (p-value is 0.3930). To check multicollinearity in the model, we have obtained the VIF (Variance Inflating Factor) values of each variable. However, none of the VIF scores was greater than 3 (i.e., below the threshold value of 5) indicating that there is no multicollinearity in the model. For further confirmation, we have obtained the covariance matrix of the parameter estimates of the model (using *estat vce* command in STATA) which also shows that none of the correlation values are higher than one, which indicates that there is no multicollinearity in the model (all the test scores can be provided on request).

Turning to the regression results, column 1 of Table 6 shows the marginal impact for the overall sample and column 2 -5 shows the quintile-wise marginal impacts (starting from the poorest to the richest quintile). We start the result analysis with the overall sample. The coefficient of *Water* is -0.00624, which implies that the probability of getting affected by water-borne diseases is 0.00624 percentage point lower for the individuals who have access to safe water compared to those who does not, ceteris paribus. The coefficient is very weakly significant (at 10% level of significance). The probable reason behind this may be only a very small number of individuals have replied that they do not have the access to safe water. In rural areas of Bangladesh, Tube wells are the main source which are widely available and treated as a public good. This is probably why the variable failed to show a significant impact of the probability of disease.

Regarding our second explanatory variable – *Sanitation*, results in column 1 shows that the marginal impact of access to sanitary latrine on the probability of disease prevalence is - 0.0056 and which is highly significant (as $p<0.001$). This implies better access to sanitary toilet decreases the probability of getting affected by sanitation and hygiene contaminated diseases by 0.56% compared to those who do not have this facility. The result goes in line with the literature (e.g., Sultana et al. 2013; Huda et al. 2012).

Analysing the predisposing features of disease prevalence i.e., socio-demographic features that influences the probability of disease as defined by (Anderson 1995) our study finds the following outcomes. Result in column 1 shows that Patient's age is positively but insignificantly associated with disease prevalence meaning that elder people are more prone to water and sanitation contaminated disease. Regarding sex of the individual, the study finds that there is a gender biasness in disease prevalence as the coefficient of the variable *sex of the patient* (=1 if male) is negative and significant at 1% level of significance (coefficient is – 0. 0076). This implies male have a lower probability of getting affected than their counterpart. Literature claims that women are more likely to report ill health than men as women are more involved in household cooking and cleaning activity they are more likely to be vulnerable to such water and sanitation contaminated diseases (Wang et al. 2013). The coefficient of the variable *education* is -0.00114 which is also highly significant level ($p<0.01$). This implies with one more year of education of the patient, the probability of disease prevalence decreases by 0.11%, ceteris paribus. This is expected as with education, the health consciousness increases and high education usually generate a higher level of income. As a result, it enables individual's economic capability and increases the access to improved sanitation and safe water facilities. Moreover, no religious biasness in the probability of disease prevalence is found in this study as the sign of the coefficient of the dummy variable *religion* (=1 if Islam) is positive but not statistically significant.

Mother's age positively related to the probability of disease occurrence, on the other hand, family head's age is negatively associated with the probability; neither of them is statistically significant. Regarding parent's education we find that both mother's level of education (years of education) is positively associated with the probability of disease occurrence in the lower income groups. Head's level of education is positively but not significantly associated with disease prevalence. Hence, with parent's level of education the probability of disease prevalence increases, which is contradictory to the conventional relationship. However, the average level of education is very low (2.41 years for mother and 3.08 years for father) therefore, an increase in education fails to the conventional relationship with disease prevalence.

Neither of the household characteristic variables are statistically significant for the overall sample. Among the enabling factors, we find that earning status of the head and the mother is negatively associated with the probability of disease prevalence implying that earning parent's children have a lower probability of getting affected by water and sanitation contaminated disease. The coefficient of the variable is not significant though. Among the other enabling factors, households receiving benefits from social safety nets are more exposed to the disease prevalence as we find that the coefficient is statistically significant ($p<0.05$). This is due to the fact that these families are the most vulnerable one in terms of income. On the other hand, the coefficient of total landholding by the household is negative, meaning households with more lands have less probability to be affected by those diseases. Although, the magnitude of the marginal effects of landholding is not significant.

The study also included regional dummies (six Divisions are including keeping Dhaka as the base category). Result shows that Barisal, Chittagong, Khulna and Rangpur have significantly higher disease prevalence rate than Dhaka Division ($p<0.05$). The other two Divisions, Sylhet and Rajshahi have lower prevalence rate than Dhaka.

5.1 Does the impact vary across different income groups?

To investigate the relationship more elaborately, the study conducts Probit analysis on different income quintiles to show whether the impact of the determinants vary across different income groups. Regression results (the marginal impact) are shown from column 2-6 of Table 6 (see appendix), using the same specification of the model. Results show that access to safe water is negatively associated with the probability of disease prevalence for all income quintiles however, the coefficient is weakly statistically significant in the 2^{nd}, 3^{rd}, 4^{th}, and the 5^{th} quintile (at 10% level of significance). This result indicates that for lower income group access to safe water does not influence the probability of disease prevalence but for a higher income group it decreases the probability of being affected by water-borne disease.

Considering the second indicator, we find that access to improved latrine is negatively and significantly associated with the probability of disease in the lower three quintiles (at 1% and 5% level of significance respectively) and weakly significant in the upper two quintiles (i.e., at 10% level of significance). This suggests that by improving the sanitary latrine facility it is possible to reduce the disease prevalence significantly especially in the lower income groups.

None of the quintiles show significant results for patient's age. All the quintiles show positive estimates except the poorest quintile, where the coefficient is negative indicating that in the poorest quintile young people are more vulnerable to diseases. However, in the other quintiles elder people are more vulnerable to disease prevalence. The study finds that gender biasness remains significant ($p<0.01$) in each income quintiles implying women are more vulnerable to such diseases compared to their counterpart. Patient's education attainment is negatively and significantly (at 1% level of significance) associated with the probability of disease occurrence in all quintiles, which is expected. This implies that for all income groups increase in patient's years of education reduces the likelihood of disease prevalence. However, there is no significant religious biasness in the quintile wise variation. Regarding parent's age, the study finds that mother's age is positively associated with disease prevalence in all income groups (weakly significant association in 2^{nd} and 3^{rd} quintile). However, household head's age is negatively associated with disease prevalence and results shows that the association is significant in 2^{nd}, 3^{rd} and in the richest quintile (at 5%, 10% and 10% level of significance, respectively). Regarding education we find that mother's education is positively related with disease prevalence and highly significant in the poorest quintiles (at 1% level of significance). However, because of a very low level of educational attainment we ignore this result. Head's level of education, however shows positive insignificant association, except in the richest quintile, where the association is rather significant ($p<0.05$).

Household density is positively associated with the probability of disease prevalence in poorest and 4^{th} quintile, but the coefficients are not significant. In the rest of the quintiles, the relation is negative though insignificant. Among the other household dwelling features, *separate dining* and *separate kitchen* is negatively associated with the probability of disease occurrence in each income quintile. The coefficient of *separate kitchens* variable is statistically significant at 5% level of significance in all income quintiles implying that it has a significant influence on the probability of water and sanitation borne disease prevalence. However, the result is not significant for *separate dining* though. Access to electricity is negatively associated with the probability of disease occurrence for the middle-income groups. Access to electricity increases the likelihood of owning electronic media which makes the households better informed about health and hygiene-related issues which increases the probability of disease prevention. Although, the association is statistically significant (at 5% level of significance) for the 2^{nd} poorest income group and very weakly significant in the 3^{rd} and richest quintile (at 10% level of significance).

Among the enabling factors, earning status of the individual and the mother does nor not doesn't influence the probability significantly throughout the quintiles. Though in all quintiles (except the poorest), they exhibit negative relation indicating earning individuals and individuals with earning mother have less probability of getting affected by water and sanitation related diseases. On the other hand, households who are included in any social safety net program (i.e., receives government transfers) have a higher probability of disease prevalence in all income groups (except the households in the richest quintile) compared to those who are not included in the program. However, the association is only significant in the poorest quintile ($p<0.05$). This is logical as only the poor and marginalised people are included in such programs and because of their lack of financial strength they are relatively more vulnerable to such diseases. Again, in all the quintiles except the richest quintile, with a higher amount of land holding, the probability of disease occurrence decreases. Though, none of the coefficients is statistically significant. Therefore, landholding fails to show any significant association with the likelihood of disease prevalence. Considering the regional variation, the study finds that in Rangpur and Khulna all the income groups have significantly higher disease prevalence rate whereas in other divisions income group wise variation is not significant.

6. Conclusion

This study uses the national survey dataset (HIES-2010) to investigate the effects of access to safe water and improved sanitation facilities along with some predisposing and enabling factors on the probability of water, sanitation and hygiene related disease occurrence. The cross-sectional study focuses on rural Bangladesh, where the water and sanitation contaminated diseases are the highest prevalent. Investigating marginal effects of the determinants of disease prevalence, the study finds that access to improved latrine facility significantly influences the probability of disease prevalence. The impact is more significant for the lowest income groups compared to higher-income quintiles. Therefore, increasing the sanitation facility especially to the lower-income group, will significantly decrease the disease prevalence. However, the other indicator, access to safe water fails to show any significant impact on the overall sample though the influence becomes weakly significant in the highest quintile.

Among the other variables, individual's level of education plays a significant role to overcome the disease burden. The study also finds that female patients are more likely to be affected by disease compared to their counterparts; however, the study finds no evidence of children getting affected more. Also, there are significant variations in the marginal effects across different income quintiles in terms of both directions and magnitude. The study finds some contrasting results, for instance, mother's level of education and the family head's level of education does not play any role in determining the outcome. Enabling factors like earning status, landholding and access to social benefit do not have any significant effect in reducing disease occurrence. However, findings show that predisposing factors play a more significant role than the enabling factors in influencing the disease prevalence. Access to a separate kitchen and electricity plays a more important role than other variables.

Descriptive results of this study reveal that availability of the facilities and the distribution of the probability of getting affected significantly vary across divisions. This variation should be taken into observation while creating a national health policy for the country. However, self-reported illness is often overrated in rural areas, and it may have affected the outcome of the study to some extent which can be considered as a limitation of this investigation. Moreover, this study only concentrated on the rural setting; therefore, future studies can focus on urban areas and make a comparative analysis. Irrespective of such a limitation, this empirical study makes a novel contribution to the literature by investigating the determinants of environmental health outcomes and how they vary across different income groups and regions of a country.

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APPENDIX

Table 3: Regional variation in diseases by income quintiles

Regions	Disease	Income quintiles					Total Obs.	Chi-square
		Poorest	2nd	3rd	4th	Richest		
Barisal	Yes	32.47	28.57	20.78	10.39	7.79	77	7.0451
	otherwise	26.82	23.13	17.72	16.63	15.70	3,031	
Chittagong	Yes	19.02	10.43	19.02	20.25	31.29	163	5.2430***
	otherwise	18.51	15.77	18.85	21.51	25.36	7,039	
Dhaka	Yes	17.93	26.21	21.38	18.62	15.86	145	3.9953
	otherwise	19.3	19.91	20.98	18.68	21.13	10,038	
Khulna	Yes	21.13	21.83	28.87	14.79	13.38	142	10.8083**
	otherwise	18.6	20.88	19.36	19.51	21.65	4,527	
Rajshahi	Yes	22.13	22.95	22.95	20.49	11.48	122	6.8704
	otherwise	18.49	20.71	20.71	18.34	21.75	3,917	
Rangpur	Yes	23.75	26.25	18.75	12.5	18.75	80	4.3003
	otherwise	18.52	20.47	21.31	19.36	20.33	3,749	
Sylhet	Yes	21.71	17.39	20.29	18.67	21.18	69	9.2383*
	otherwise	20.03	21.4	21.12	17.83	19.62	3,602	

***p<0.01, **p<0.05, *p<0.1

Table 4: Variation in access to safe water across regions and income quintiles

Regions	Access to safe water	Income Quintiles					Total obs.	Chi square
		Poorest	2nd	3rd	4^{th}	Richest		
Barisal	Yes	98.19	97.22	97.71	98.53	90.34	2,991	88.85***
	No	1.81	2.78	2.29	1.47	9.66	117	
Chittagong	Yes	79.84	83.52	83.94	82.24	79.77	5,888	14.77**
	No	20.16	16.48	16.06	17.76	20.23	1,314	
Dhaka	Yes	95.07	92.16	92.66	92.63	92.82	8,735	16.23**
	No	4.93	7.84	7.34	7.37	7.18	650	
Khulna	Yes	83.7	86.39	86.32	89.6	84.01	4,010	15.38**
	No	16.3	13.61	13.68	10.4	15.99	659	
Rajshahi	Yes	97.41	98.66	98.86	97.99	97.75	3,964	6.74
	No	2.59	1.34	1.14	2.01	2.25	75	
Rangpur	Yes	100	98.05	99.62	98.2	100	3,798	35.80***
	No	0	1.95	0.38	1.8	0	31	

Regions	Access to safe water	Income Quintiles					Total obs.	Chi square
		Poorest	2nd	3rd	4th	Richest		
Sylhet	Yes	86.74	90.51	93.79	97.51	98.08	3,444	109.89***
	No	13.26	9.49	6.21	2.49	1.92	227	
Overall	Yes	83.96	87.24	87.52	83.63	86.94	32,830	11.2831**
	No	16.04	12.76	12.48	16.37	13.06 |	3,073	

***p<0.01, **p<0.05, *p<0.1

Table 5: Variation in access to improved toilets across regions and income quintiles

Regions	Access to latrine	Income Quintiles					Total obs.	Chi square
		Poorest	2nd	3rd	4th	Richest		
Barisal	Yes	78.73	73.22	74.85	83.33	88.06	2,453	54.62***
	No	21.27	26.78	25.15	16.67	11.94	655	
Chittagong	Yes	28.33	33.08	38.27	45.73	64.35	3,171	183.58***
	No	71.67	66.92	61.73	54.27	35.65	4,031	
Dhaka	Yes	31.97	38.86	45.01	51.68	57.74	4,014	199.73***
	No	68.03	61.14	54.99	48.32	43.26	5,371	
Khulna	Yes	54.5	57.53	52.67	63.27	77.41	2,855	160.26***
	No	45.5	42.47	47.33	36.73	22.59	1,814	
Rajshahi	Yes	24.74	25.57	27.78	37.67	64.48	1,480	392.52***
	No	75.26	74.43	72.22	62.33	35.52	2,559	
Rangpur	Yes	8.96	7.46	7.55	16.48	39.1	544	390.27***
	No	91.04	92.54	92.45	83.52	60.9	3,285	
Sylhet	Yes	30.00	23.06	33.01	43.01	61.86	1,313	224.661***
	No	70.00	76.94	66.99	56.99	38.14	2,358	
Overall	Yes	33.11	36.85	38.11	48.73	63.73	20,073	0.0017***
	No	66.89	63.15	61.89	51.27	36.27	15,830	

***p<0.01, **p<0.05, *p<0.1

Table 6: Regression results of the Probit model

	Dependent Variable: ***Disease*** (*Disease*=1 if individual is affected by water or sanitation borne diseases)					
Variables	Overall	poorest	2nd poorest	3rd	4th	richest
Explanatory variables						
Water	-0.00624*	-0.00764	-0.0162*	-0.00647*	-0.00643*	0.000167*
(=1, having access)	(0.00350)	(0.00756)	(0.00929)	(0.00845)	(0.00768)	(0.00595)
Sanitation	-0.00565***	-0.0120***	-0.00952**	-0.00274**	-0.00189*	-0.00146*
(=1, having access)	(0.00188)	(0.00377)	(0.00343)	(0.00423)	(0.00383)	(0.00415)
Control variables:						
Individual's age	5.76e-06	-0.000102	2.66e-05	2.50e-05	3.45e-05	7.44e-05
	(5.35e-05)	(0.000116)	(0.000107)	(0.000120)	(0.000110)	(0.000111)
Sex	-0.00765***	-0.00730***	-0.00377**	-0.0109**	-0.00461**	-0.0102**
(=1, if Male)	(0.00202)	(0.00402)	(0.00386)	(0.00456)	(0.00428)	(0.00453)
Level of education	-0.00114***	-0.00127***	-0.00072***	-0.00201***	-0.00063***	-0.00125***
(in years)	(0.000269)	(0.000646)	(0.000550)	(0.000672)	(0.000511)	(0.000493)
Religion	0.00269	0.00944*	0.000781	0.00153	0.000739	0.00487
(=1, is Islam)	(0.00241)	(0.00440)	(0.00509)	(0.00549)	(0.00529)	(0.00474)
Mother's age	0.000231	0.00152	0.000130*	0.00071*	0.000733	0.000544
	(0.000212)	(0.000494)	(0.000381)	(0.000468)	(0.000432)	(0.000501)
Mother's education	0.000927***	0.00108***	0.00115***	0.00166**	0.000290*	0.000211*
(in years)	(0.000322)	(0.000681)	(0.000623)	(0.000767)	(0.000690)	(0.000653)
Head's age	-0.000257	-0.00136	-0.000182**	-0.000491*	-0.000342	-0.000733*
	(0.000184)	(0.000439)	(0.000315)	(0.000393)	(0.000375)	(0.000454)
Head's education	0.000543**	0.000035	0.000983	0.000554	0.000341	0.000291**
(in years)	(0.000274)	(0.000599)	(0.000531)	(0.000664)	(0.000548)	(0.000576)
Household density	0.00137	0.0109	-0.0129	-0.00471	0.00217	-0.00300
(members per room)	(0.00362)	(0.0100)	(0.00959)	(0.00916)	(0.00715)	(0.00609)
Separate dining room	-0.00322	-0.00632	-0.00696	-0.00164	-0.000469	-0.00478
(=1, if yes)	(0.00269)	(0.00579)	(0.00515)	(0.00753)	(0.00550)	(0.00427)
Separate kitchen	-0.00313	-0.0135***	-0.000791**	-0.00210**	-0.00597**	-0.00247***
)=1, if yes)	(0.00213)	(0.00506)	(0.00382)	(0.00438)	(0.00476)	(0.00479)
Access to electricity	-0.00317*	-0.00712	-0.00260**	-0.00729*	-0.00240	-0.00974*
(=1,if yes)	(0.00180)	(0.00451)	(0.00341)	(0.00395)	(0.00375)	(0.00440)
Earning status	-0.00261	-0.00164	-0.00177	-0.00306	-0.00698	-0.00244
(=1, if earner)	(0.00245)	(0.00534)	(0.00512)	(0.00540)	(0.00475)	(0.00533)
Mother's earning status	-0.000758	0.00887	-0.00222	-0.00022	-0.00247	-0.00316
(=1, if earner)	(0.00292)	(0.00465)	(0.00534)	(0.00635)	(0.00730)	(0.00580)
Included in safety net	0.00457**	0.0126**	0.000215	0.00288	0.0195	-0.00513

	Dependent Variable: ***Disease*** (*Disease*=1 if individual is affected by water or sanitation borne diseases)					
Variables	Overall	poorest	2nd poorest	3rd	4th	richest
(=1, if yes)	(0.00233)	(0.00526)	(0.00413)	(0.00488)	(0.00532)	(0.00520)
Total land holding	-2.29e-06	1.87e-05	8.55e-06	3.49e-06	1.68e-05	-1.42e-05
(in decimal)	(5.15e-06)	(2.05e-05)	(1.61e-05)	(1.41e-05)	(1.05e-05)	(7.86e-06)
region1dummy	0.0103**	0.0283**	0.0284*	0.0126*	0.00701	0.00796
(Barisal Division)	(0.00468)	(0.0122)	(0.0130)	(0.0117)	(0.00672)	(0.00672)
region2 dummy	0.00816**	0.00310	0.00159*	0.0107*	0.00709	0.0153*
(Chittagong Division)	(0.00326)	(0.00607)	(0.00571)	(0.00798)	(0.00677)	(0.00716)
region4 dummy	0.0155***	0.0201**	0.0122*	0.0162**	0.0140**	0.0175**
(Khulna Division)	(0.00400)	(0.0100)	(0.00822)	(0.00892)	(0.00815)	(0.00897)
region5 dummy	0.0148***	0.0106**	0.0131**	0.0302***	0.0173**	0.00509*
(Rangpur Division)	(0.00416)	(0.00836)	(0.00803)	(0.0117)	(0.00953)	(0.00779)
region6 dummy	0.00276	0.00326	-0.00123	0.00656	0.0134	0.00131
(Rajshahi Division)	(0.00338)	(0.00575)	(0.00579)	(0.00851)	(0.00907)	(0.00750)
region7 dummy	0.00291	-0.00482	0.00558	-0.00566	-0.00638	-0.03007
(Sylhet Division)	(0.00375)	(0.00612)	(0.00737)	(0.00929)	(0.00602)	(0.0151)
Observations	29,410	6,020	6,047	5,969	5,820	5,554
LR Chi square	114.38***	73.14***	38.37**	39.14**	49.34***	54.09***
Pseudo R-square	0.5180	0.5527	0.4887	0.4145	0.4845	0.5118

Standard errors in parentheses, ***p<0.01, **p<0.05, *p<0.1