Impact of Water and Sanitation Interventions on Childhood Diarrhea: Evidence from Bangladesh

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Abstract

This paper analyses the possible relevance of water and sanitation improvements for diarrhoea reduction in the context of Bangladesh. Much of the public policy thinking in the past was guided by public investment in providing improved access to water. The paper provides evidence that the relevance of water as a tool for fighting diarrhoea may have changed over time although in the past it had done so. However, recent loss of efficacy of improved water in Bangladesh while may have something to do with water quality but more importantly certain environmental developments causing tube well users to rely on unsafe sources for drinking water may also be confounding the water effect. The sanitation intervention has some impact but as the results of the present paper suggest a combined access to improved water and sanitation has greater policy validity now than was the case before. This paper utilized household data collected by the Bangladesh Demographic and Health Survey for 1996/97 and 2007 rounds. Using propensity score matching (PSM) technique, it was found that in 2007 the combined access to improved water and sanitation can lead to reduced incidence of diarrhoea among children significantly both in contrast to their isolated use and non-use of any improved sources. For 2007, the mean probability of childhood diarrhoea incidence for those who have combined access to water and sanitation is 31.5 per cent lower than in case of those *without* the combined access to water and sanitation in the PSM-matched sample. Such observations were however, found absent with 1996/97 data. Thus, the present analyses/ results suggest a case for rethinking public policy at least at present by way of joint investment in water and sanitation (WatSan) measures to reduce diarrhoea in future. This intervention through WatSan may be enhanced by favourable change in health-seeking behaviour also such as sanitary hand-washing practices. The study found significant impact also of such behaviour in reducing the risk for diarrhoea. However, the present study noted a grave challenge for the country in maintaining the present high coverage for improved drinking water in future and such challenges may arise from widespread arsenic contamination of ground water level, environmental changes and faulty management of water and sanitation programme.

I Introduction

Diarrhoea is recognised as a major health problem in children throughout the developing world. Most of the pathogenic organisms that cause diarrhoea and all the pathogens that are known to be major causes of diarrhoea in many countries are transmitted primarily or exclusively by the faecal-oral route (Faechem, 1984).[1] In developing countries transmission of cholera/diarrhoea is believed to be associated with poor quality of water for drinking, bathing, washing utensils etc. with faecal pollution of water sources and the quality of home environment identified as the key source of pathogens causing diarrhoea (Spira et. al, 1980). Hence, for diarrheal disease control, the improvement of water supply and excreta disposal facilities have attracted much interest and the Governments of poor countries have undertaken the water and sanitation improvement programmes with the confidence that such physical investments in water/ sanitation areas will surely result in substantial reductions in the diarrheal incidence. The historical experience of the developed countries also supported this policy stance. The improvements in water / sanitation environments, together with rise in living standards have played a major role in reducing diarrhoea rates and controlling epidemic of typhoid and cholera in Europe and North America between 1860 and 1920 (Esrey et. al., 1985).

Scepticism in the validity of the conventional wisdom, however, surfaced in the recent years. Although the access to improved water supply and sanitation is long advocated to have contributed to better health of the people, particularly that of the children, but a recent review of literature shows that the evidence base, especially with regard to the sanitation is rather weak (World Bank, 2006; Pattanayak et.al. 2007; Waddington et.al. 2009). The evidence base on water is also found to be ambiguous: even though unsafe water is almost universally held to be the major cause of diarrhoea, many apparent contradictions are noticeable in the findings of the published studies exploring this relationship. After a review of 67 studies from 28 countries Esrey et al. (1985) could see a favourable impact of improved water and sanitation on diarrhoea, but they also found improvements in *water quality*[2] to be <u>less</u> important than improvements in *water availability* or excreta disposal. Studies also expressed the opinion that for the purpose of controlling cholera and other water borne diseases, the quality sources of water is not enough (Briscoe 1977): it is likely to be affected more by the water quantity than by water quality. A number of subsequent studies have failed to find any health benefit when the water quality alone was improved (Wall and Keeve, 1974; Levine et al. 1976; Baltazar et, at.

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[1] The literature review, as presented here, draws heavily on Waddington et. al. (2009).
[2] Water quality refers to the water of good bacteriological quality and tube well water falls in this category in Bangladesh .

1988; Young and Briscoe 1988). This is in contrast to studies which have previously detected significant health benefits of the improved quality of water (see, for instance, Wagner & Lanoix 1959). In short, the effectiveness of improved water supply and sanitation on diarrhoea and other water related diseases in the developing countries has been extensively discussed and debated over the last several decades (Saunders and Warford, 1976; McJunkin, 1982; Faechem et.al. 1983; Blum and Faechem, 1983; Merrick, 1983; Esrey & Habicht, 1985) without however reaching a firm conclusion.

1.1 Objective of the Study

In the backdrop of conflicting evidence the present study revisits the issue of the impact of improved water and sanitation interventions on reducing the prevalence of child diarrhoea. The objective of the study is to obtain *unbiased* estimate of the impact of improved water and sanitation in Bangladesh on the prevalence of childhood diarrhoea by using the Propensity Score Matching (PSM) technique. The main question of the investigation of the study is whether and to what extent 'the children from households with access to improved drinking water sources and improved sanitation face less vulnerability to diarrheal attack than those from the potentially similar households who do not have such access'.

1.2 Structure of the Study

The paper is divided into seven sections. In the introductory section we summarise the relevant literature and present the conflicting findings regarding the effects of improved water and sanitation on child diarrhoea, thus foregrounding the analytical relevance of the present exercise. The second section discusses the data used for the study. The third section provides information on the current pattern of access to improved water and sanitation in both rural and urban areas including diarrhoea situation in the country. It also presents the prevalence of childhood diarrhoea in different subgroups of country's population and draws attention to the bivariate association between water/ sanitation interventions with diarrhoea incidence based on BDHS data of 1997/97 and 2007 and also MICS data. Method of estimation based on the Propensity Score Matching (PSM) technique, its advantage over the OLS technique, and related methodological issues in implementing PSM in a household survey data setting are discussed in Section 4. The PSM results using 2007 rounds of BDHS are presented in Section 5 (while those using 1996/97 BDHS data are presented in Annex 2). The magnitude of the 'treatment effects' on diarrhoea incidence of children is captured separately for three household level interventions, namely, (a) isolated use of improved water access, (b) isolated use of improved sanitation access, and (c) the combined access to both improved water and sanitation (or WatSan measure). Section 5 also presents the results of the 'balancing test' undertaken to examine the quality of correspondence between the treatment and control groups generated through propensity score matching for 2007 data and section 6 contains the concluding remarks on the main results.

II. Data

To assess the impact of the improved drinking water and sanitation/toilet facility on the diarrhoea incidence among children, the study has utilised data from two sources, namely, from country's two largest household sample surveys. One of them is the well-known Bangladesh Demographic and Health Survey (BDHS) and present study has used the BDHS data for 2007 (NIPORT et al 2009) and 1996/97 rounds (NIPORT et al. 1997). The other data source is the "Multiple Indicator Cluster Survey" (MICS) that the Bangladesh Bureau of Statistics (BBS) and the UNICEF have been jointly conducting periodically since 1995 to monitor the situation of women and children in Bangladesh. The present study has utilised the information collected during 2006 round of the survey (BBS/UNICEF, 2007). For the impact analysis through the PSM technique the paper uses BDHS data only. The MICS data set is used mainly to generate descriptive statistics on diarrhoea incidence and to generate additional evidence.

Both the surveys contain information on drinking water sources and access to sanitation at the household level as well as data on the incidence of diarrhoea among children aged below five years during the last 15 days prior to the interview.

Besides information on water, sanitation and diarrhoea, the BDHS collects other information on household socio-economic condition, fertility, fertility preference, family planning, infant and child mortality, maternal, new-born and child health, nutrition of children and mother, HIV/AIDS, women empowerment and domestic violence. MICS contains information on socio-economic characteristics of the household, nutrition of the children, child health, hygienic behaviour like hand-wash practice after defecation, disposal of child's faeces, reproductive health, child development, education and child protection.

The BDHS 2007 employs a nationally representative sample that covers the entire population residing in private dwelling units in Bangladesh. The survey used the sampling frame prepared by the Bangladesh Bureau of Statistics (BBS) using population and household information from the 2001 population census which is nationally representative. The BDHS 2007 is based on two-stage stratified sample of households. At the first stage of sampling, 361 primary sampling units (PSUs)[3] were selected and the selection was done independently for each stratum with probability proportional to PSU size in terms of number of households. At the second stage, 10,819 households were selected PSUs using equal probability systematic sample. The survey was designed to obtain 11485 completed interviews with ever-married women aged 10-49; of them 4360 interviews were allocated to urban areas and 7125 to rural areas (NIPORT et.al, 2009). In this study we have considered the cohort of *currently married women* aged 15-49 years. The number of such women interviewed in the BDHS 2007 was 8319 who had 8685 children aged below 5 years.

The data collection methodology of 1996/97 BDHS was the same; in this round of BDHS survey, a total of 316 primary sampling units (PSUs) were selected using above mentioned procedure and from them 9,099 households were selected. The number of currently married women aged 15-49 interviewed from these households was 7889 who have 9557 children aged under 5 years (NIPORT et. al. 1997). The PSM analysis of this study was done utilizing the 'nested samples'.

The MICS 2006 on the other hand has collected information from 1,950 PSUs, and covered as many as 62,463 households throughout the country.

Other than quantitative information and analyses, the study has tried to gather also additional insight on water, sanitation and childhood diarrheal in Bangladesh particularly in its rural areas through qualitative information. Such information was gathered through Focus Group Discussions (FGD) in three rural villages of the country. One of them represent the villages where sanitation coverage is very high, one represents the villages where sanitation coverage is low and third village represents the villages where arsenic contamination of tube well water is high. The first village is *Shonahar* of Chakhar Union which belongs to Barisal District; second one is *Godapar*a in Daogao Union, Mymensingh District and third one *Kala Vomar* village in Babutypara Union of Comilla District.

[3] The Primary Sampling Unit (PSU) is the ultimate sample area from which the Bangladesh Bureau of Statistics (BBS) collect information for its Sample Vital Registration System (SVRS). The PSUs comprised of two contiguous Enumeration Areas (EAs) having about 200 households and they were identified based on 2001 population census (BBS, 2011).

In each of the areas, two FGDs were conducted, one with male villagers and one with female villagers, thus, in all, six FGDs were conducted in three villages. In each of the FGDs there were 12-13 participants and majority of them were aged 45 years or above. Most of the participants in *Shonahar* and *Godapar*a were literate while in *Kala Vomra* illiterate.

III. Water, Sanitation and Childhood Diarrheal: Access, Pattern and Prevalence

Before making an effort to estimate the impact of improved water-sanitation interventions on the incidence of childhood diarrhoea, it may be useful to have an idea about the current sources of drinking water and access to sanitation as well as the status of diarrheal sickness among children in Bangladesh.

3.1 Access to 'Safe' Water

In Bangladesh, drinking water supply is predominantly based on ground water sources. In the context of very high prevalence of diarrhoeal diseases in Bangladesh, bacteriological quality received priority as a criterion for drinking water supply. Ground water being free from pathogenic micro-organisms and being available in adequate quantity in the shallow aquifers, the water supply through shallow tube wells for scattered rural population soon proved a viable option (DPHE, no date). This enabled even the private drillers to install hand-pump tube wells at an affordable cost. The external donors also generously supported the construction of hand-pump tube wells throughout the country. Through expansion of low-cost shallow tube wells Bangladesh achieved remarkable success in providing access to improved sources of drinking water, especially in rural areas.

In 1996-97, around 95 per cent of the household at national level had access to improved sources for drinking water which include mainly the piped water into the dwelling, public tap/standpipe, and tube well (Table 1). This high coverage for 'improved[4]' drinking water increased only by 2 percentage points during next 10 years i.e. during 1996/97-2007 period and 97 per cent of the country's households showed to have access to improved sources for drinking water in 2007.

In these two periods, the rural access to improved sources for drinking water was also close to the national level; the rural coverage for this in 1996/97 was about 94.8 per cent and 96.5 per cent in 2007. Such access in urban area was almost universal in both periods showing a figure of more than 99 per cent (Table 2). Hence, country's access to improved water sources including both rural and urban areas, for drinking purpose has been persisting at a very high level for quite some time.

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[4]The BDHS 2007 has followed the definition of WHO/UNICEF for improved sources for both water and sanitation. This however has not been the case in 1996/97 BDHS.

Among several improved sources, the tube well serves as the major or most common improved source in both rural and urban areas but this is almost an exclusive improved source in rural areas (94% out of 94.8% in 1996/97 and 95.7% out of 96.5% in 2007). In urban area, although other sources play a significant role in supplying the safe drinking water the tube well persists as the major improved source. In 1996/97 out of 99.2 per cent households having an access to improved water sources, 60 per cent availed the tube well for the purpose while in 2007, 69 per cent out of 99.5 per cent having an access to improved sources was tube well user. Thus, in urban areas, tube well not only persists as the major improved source for drinking water but its role has further increased in recent years. One of the reasons for this apparent enhanced role of tube well in urban area may be the inclusion of newer areas under the 'urban category' over the years where tube well persists as the dominant source (Tables 1 & 2). In short, as the situation persists, the tube well is an overwhelmingly major improved source for drinking water in Bangladesh both rural and urban areas.

Table 1: Source of Drinking Water in 1996/97 and 2007: Bangladesh

Source of drinking water	1996/97	2007
Improved sources	**95.3**	**97.1**
Piped water into dwelling/yard/plot	4.0	6.0
Public tap/standpipe	1.1	0.9
Tube well	90.2	89.9
Protected drug well	-	0.2
Rainwater	-	0.1
Non-improved sources (unprotected drug well/spring, surface water, etc.)	**4.8**	**2.8**

Source: BDHS Reports for 1996/97 and 2007 (NIPORT et. al. (1997, 2009)

Table 2: Source of Household Drinking Water by Residence – 1996/97 & 2007

Source of drinking water	Rural		Urban	
	1996/97	2007	1996/97	2007
Improved sources	**94.7**	**96.5**	**99.2**	**99.5**
Piped water into dwelling/yard/plot	0.4	0.1	32.1	27.3
Public tap/standpipe	0.3	0.2	7.1	3.0
Tube well	94.0	95.7	60.0	69.1
Protected drug well	-	0.3		0.1
Rainwater	-	0.1		0.0
Non-improved sources (unprotected drug well/spring, surface water, etc.)	**5.2**	**3.5**	**0.8**	**0.5**

Source: BDHS Reports for 1996/97 and 2007 (NIPORT et. al. 1997, 2009)

The scenario in the coastal, hilly, urban slums and some of the so-called 'pocket areas' such as char-land, etc.—which together cover actually a large geographical space is somewhat different in this respect. In the coastal belt, high salinity in the surface and ground water remains a major cause of safe water scarcity. The hilly and stony features of some areas are also hampering the supply of safe drinking water. Studies carried out in the mid-2000s show that only about two-third of the households of the Chittagong Hill Tracts (CHT) have access to tube well facilities within a mile distance of their house, and as few as three per cent of the households in these areas own a tube well (Ministry of Health and Family Welfare, 2004).[5]

In the area of safe drinking water provisioning in Bangladesh, another new challenge has surfaced in recent years; the arsenic contamination of shallow aquifers in many parts of the country has made water of shallow tube well unsafe for drinking. Arsenic in the tube well water was first identified in 1993. At present, 280 out of 463 Upazilas (sub-district) report arsenic problem, although the degree of contamination varies across regions (DPHE no date). Excess amount of arsenic intake above the permissible limit in human body makes 'Arsenicosis diseases'. Interestingly, the maximum permissible limit for Bangladesh is 0.05 mg/l which is more liberal than the WHO guideline value is 0.01 mg/l. As reported by the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP), 29 per cent of the Tube wells tested had arsenic contamination (DPHE no date). By physical verification of the household drinking water the Bangladesh Demographic and Health Survey of 2004 noted that one in twelve (8.5 per cent) households had elevated arsenic level in the drinking water[6] (NIPORT et al 2005) .

As gathered from the FGDs, when there is arsenic contamination in tube well water, if the spread is smaller i.e. water of fewer tube wells are contaminated then the households try to avoid such contaminated tube-wells and collect drinking water from uncontaminated ones. But in areas where such contamination persists at a high level the situation turns complicated; in these areas, the richer people generally go for installing a deep tube well to facilitate safe water supply but poor households can hardly exercise this option because installation of such tube well is a costly matter for them. As gathered from the FGDs, in such areas, the water consumption of the poor and poorer households both for drinking and non-drinking purposes suffer greatly; these households while require to fetch water from a distance, collection of safe water from the deep tube wells owned by richer households does not appear also a descent or palatable work sometimes to the women. Consequently, most of the poor and poorer households of these areas go without sufficient water. Also, as gathered from the FGD participants, under such circumstances people sometimes drink arsenic contaminated water or water from unsafe sources and this happens more in case of children who are unable to perceive the bad effect of such water and

[5] The implementation of the Chittagong Hill Tracts Development Facility (CHTDF) project by GoB/ UNDP may have increased this access figure in the recent years, but the relative disadvantage with respect to water and sanitation access in these belts vis-a-vis the rest of the country still remains valid.

[6] No such information is available with the 2007 BDHS.

who at the same time cannot bear the dearth of drinking water in the household. Also, water scarcities in these areas/households greatly affect the cleanliness and hygienic practices of the household members; for example, the water pots etc. often remain insufficiently cleaned, and the personal cleanliness also suffers very much. It is also gathered that in such situation when women need to collect safe water from a distance, they not only they remain unable to collect such water in sufficient quantity but such water being collected in the uncovered, pots, often encounters the risk of getting contaminated through variety of ways on way back to home. In short, in situation where the consumption of safe drinking water both in terms of adequate quantity and quality suffer greatly having ill effects on the health particularly that of the children.

However, an overwhelmingly large proportion of the country's population although has access to improved water sources for drinking purpose, many of them still continue to use water from unsafe sources to meet their 'non-drinking' personal and domestic needs such as cooking, bathing, washing utensils, etc. According to the Bangladesh Bureau of Statistics (BBS), only 55 per cent of the households at national level used water from improved sources to meet such needs in 2009. The proportion of households using improved sources for meeting such water needs was 48 per cent in rural areas and 71 per cent in urban area (BBS 2011). Of unimproved sources, the major supplier of water for other uses has been the surface water from the 'pond/river/canal'. But every day 20,000 metric tons of human excreta are deposited on the public lands and waterways, which remain as the major source of contamination of surface water in the country (Ministry of Health and Family Welfare, 2004). Given these accounts, notwithstanding a notable success is achieved by Bangladesh in making improved provisions for drinking water, many challenges are still ahead to ensure *safe water provision for all people and for all types of use*.

According to Bangladesh Climate Change Strategy and Action Plan 2009, access to drinking water is already a problem in parts of the country e.g. in areas with saline surface and ground water, in drought prone areas, etc. and as it was forecasted, the situation will get worse in future due to increasing prevalence of droughts following the climate change, less or non- availability of surface water and water from the hand tube wells in future (shallow tube wells).

Box 1: Drinking Water situation in Bangladesh: Insights from FGD
As gathered from FGDs, almost all households in villages collect drinking water from shallow/hand tube wells. But in recent years, the deep tube wells have emerged as another source for drinking water. Its emergence was forced by two major factors; one is the arsenic contamination of shallow/hand tube-well water and the other is, lowering of the ground water level in the country which has been causing many shallow tube wells to go without water for few months during the pre-monsoon season. Because of these developments, the initial advantage of the country in providing safe drinking water to the rural people through low cost shallow/hand tube wells has been gradually dwindling giving a way to the deep tube well for drinking water.

But the deep tube well does not have the comparative advantage cost wise, unlike the hand tube-wells; its installation is a costly affaire manageable only by the rich. Such tube-wells installed by a few rural rich households remain highly insufficient to meet the drinking water needs of the full village. Consequently, the water needs of most of the villagers both for drinking and non-drinking purposes suffer greatly these days both in terms of quantity and quality. As gathered from FGDs, due to shortage of adequate quantity of safe drinking water at home, household members particularly the children often drink water from unsafe sources. Thus, in arsenic affected areas, among tube well users, use of unsafe water for drinking purposes has been increasing. More importantly, due to shortage of water and safe water, the practice of hygiene behaviour/cleanliness has been suffering greatly in these areas causing a negative impact on health.

With regard to water use, from FGD, it is further gathered that the use of improved water sources for drinking purpose while is almost universal, the use of unsafe sources for non-drinking purpose i.e. for cooking, bathing, cleaning utensils, washing clothes, etc. is quite common in rural areas which may have some negative impacts. Also as gathered, the water collected by the rural women from improved sources, is often carried and stored by them in not so hygienic manner; the water pots are often not properly cleaned, covered, etc. in the house and when water source is far-off (which is often the case in case of deep tube well) the water gets contaminated sometimes on way back as women often do not collect such water in covered pots. The rural households hardly treat water also before drinking; consider tube-well water as safe, and feel no necessity of doing so. The poverty and physical inconvenience also act as the barriers in this case.

3.2 Access to Sanitation

In contrast to the access of safe water, the degree of success achieved in Bangladesh with regard to the sanitation access has been much more modest. Only about one-fourth of the households at national level reported to have an access to improved sanitation provision. This figure in 1996/97 was 30 per cent. These figures although tend to suggest that the sanitation situation has deteriorated further in Bangladesh over the recent years since 1996/97, the reality indeed may not so; at least, our FGDs for the study suggest so. As gathered from the FGDs, the sanitation situation has improved substantially over the recent years even in rural areas of the country. Indeed, on the basis of BDHS 2007 the low sanitation village that we have selected for our FGD was found quite advanced in this regard during our FGD in 2011 (Box 2). As indicated by the FGD participants, the fixed provision for defecation has been increasingly gaining popularity even in rural areas of the country and rural people in large number have been constructing the 'slab latrine' using 2-3 rings and a slab. However, the apparent anomalous observation made about the improved sanitation during 1996/97 and 2007 viz., compared to 1996/97 the use of improved sanitation is found to be much lower in 2007 may be an outcome of definitional variations used for improved sanitation in these two BDHS surveys. The 2007 BDHS has strictly followed the WHO/UNICEF JMP definition of improved sanitation (http://www.wssinfo.org/en/122_definition.html) but in 1996/97 this was not the case; in 1996/97, the definition for improved sanitation provision was less rigorous than 2007. Following WHO/UNICEF the 2007 BDHS categorized those provisions as improved which had a system of 'flush/pour flush to piped sewer system/septic tank/pit latrine', and 'pit latrine with slab' and remaining ones are categorized as unimproved (see, Table 3).

Unlike drinking water provision, the rural and urban areas of the country differ greatly for sanitation provision; in 2007, 37 per cent of the urban households had access to improved sanitation provisions against 22 per cent households had this provision in rural areas. In 1996/97, these figures were respectively 77.4 and 24.5 percents. Again, these anomalous figures/trends for improved sanitation provisions for recent years both in rural and urban areas are again may be due to definitional variations adopted to classify sanitary provisions in 1996/97 and 2007. Yet, what the statistics for 2007 tend to suggest that the country's majority households including both urban and rural areas still have no improved sanitation provisions and use unimproved facilities only with 2 per cent of of the urban and 10 per cent of the rural households having no facility at all (BDHS 2007).

Despite much progress with regard to improved sanitation, as gathered from the FGDs, women's behaviour regarding hygienic disposal of the stool of the children who cannot use latrine has remained largely unhygienic; such stool is dispose- off in a very casual manner and women/mothers often throw them here and there, to the water bodies, etc.(see Box 2).

Among different improved provisions, as indicated above, the 'pit latrine with slab' represents the most common category in rural areas and in urban areas the latrines with 'flush/pour flush provision to septic tank' is the major category of improved toilet (Tables 3 & 4).

Table 3: Household Sanitation Facilities, 1996/97 & 2007

Sanitation facilities	1996/97	2007[7]
Improved provision*	**30.5**	**25.3**
Flush/pour flush to piped sewer system	-	1.4
Flush/pour flush to septic tank	-	8.9
Flush/pour flush to pit latrine	-	3.2
Pit latrine with slab	-	11.8
Non-improved facility	**43.1**	**66.3**
No facility (bush/ field)	**26.5**	**8.4**

*Includes septic tank, modern, with and slab latrine including water sealed slab latrine
Source: BDHS Report 1996/97 and 2007, NIPORT et. al. (1997, 2009)

[7] For explanation of apparent anomalous figures for improved sanitation provisions in 1996/97 and 2007, see text above tables 3 and 4.

Table 4: Household Sanitation Facilities by Residence, 1996/97 & 2007

Sanitation facilities	Rural		Urban	
	1996/97	2007	1996/97	2007
Improved provision *	**24.5**	**22.0**	**77.4**	**37.4**
Flush/pour flush to piped sewer system	-	0.1		5.9
Flush/pour flush to septic tank	-	5.7		20.3
Flush/pour flush to pit latrine	-	3.0		3.9
Pit latrine with slab	**-**	13.1		7.3
Non-improved facility	**46.3**	**67.8**	**18.4**	**60.7**
No facility (bush/ field)	**29.3**	**10.2**	**4.3**	**1.8**

Source: BDHS Report 1996/97 and 2007; NIPORT et. al. (1997, 2009)

Box 2: Sanitation Situation in Bangladesh: Insights from FGD
Compared to water situation, the sanitation situation is worse in the rural areas. Nevertheless, the situation has been improving and our FGDs even in low sanitation areas too has confirmed this. The most frequently used improved sanitary provision in rural areas is the slab latrine. Most rural people use 2-3 rings with a slab to construct such latrine while a few uses water-sealed slab latrine. The use of hanging latrine, kachcha latrine or open space/bush , etc. for defecation purpose has come down significantly in recent years. According to villagers, this substantial shift to improved latrine provision has been due to pressure from local Union Council, awareness building campaign by the NGOs, media publicity, emerging new values/life style following the increase in education, modernization, etc. This shift is partly an induced behaviour also; because of fast disappearance of open space/bush etc. the rural people have little opportunity these days to use open space for defecation. Also, like hand tube well, construction cost of the slab latrine is very low and construction materials are easily available in local market which have made such latrines popular in rural areas. Also, to popularize such latrine, the Union Paris had (the lowest body of local government) distributes the materials of such latrine to the poor people free of cost and NGOs also distribute them at subsidized price. In rural area, the children who cannot use latrine, mostly defecate in open courtyard and their stool is thrown away around the homestead including nearby bush, pond, canal, agricultural land etc. which has the likeliness to neutralize the benefit of improved latrine used by the adult members; this practice often contaminates the surface water, allow flies to contaminate food, etc. However, in rural area, the distance of the latrine seems to matter much; if it is located at some distance which is often the case, the women, children, and the older people find it's use difficult; this is particularly so in the night, during rainy season, etc. The regular use of latrine also gets affected if it is a shared facility. The rural people are found in general aware of the ill–effects of unhygienic disposal of the child stool, although they practice it. They are now fully aware also of the fact

that the unimproved latrine through contamination of water, facilitate bacterial movement, etc. and cause diseases.

3.3 Prevalence of Childhood Diarrhoea

Due to lack of civil registration system, little is known about the causes of child death in Bangladesh, and data for child morbidity are even scarce. Yet, as the evidence suggests, diarrhoea, measles, fever and acute respiratory diseases account for most of the child deaths in Bangladesh (Chen, Rahman and Sardar 1980; Salway and Nasim 1994; Baqui et al 1998; Baqui et. al. 2001). The available evidence further suggests, with the decline of child mortality in the recent decades, there has been a decline in child mortality in all categories of causes of child death (Baqui et al. 2001) which has kept the importance of leading causes of child death largely unchanged in the country; the diarrhoea, which was once the number one killer, is still one of the top five leading causes of child death in the country (Rahman et al. 2005 and NIPORT et. al. 2005). Over the past three decades, the country has experienced however, a significant decline in child mortality with rate for child mortality coming down from 200 in 1978-84 to 155 in 1991 and dropping further to 65 in 2007[8] (Salway and Nasim, 1994; NIPORT et al 2009) suggesting more than two-third decline in under-5 mortality since the late 1970s.
In the mid-70s, the diarrhoea was responsible for about 44 per cent of the deaths among children aged 1-4 (Chen, Rahman and Sardar, 1980) and this share came down to around one-fifth in the mid-90s (Baqui et. al. 1998; Baqui et al. 2001). In 2004, as per BDHS data, 9.3 per cent of the deaths among children aged 1-4 years were due to diarrhoea ; this accounted for 10 per cent of the post neonatal deaths and 5 per cent of the under 5 deaths (NIPORT et.al, 2005). Over the past few decades, the virulence of diarrhoea in causing child death therefore has come down substantially in Bangladesh.

Indeed, the present diarrhoea situation of Bangladesh looks favourable even in cross-country comparisons: the recent statistics gathered from the DHS studies of different countries confirm this. As these statistics show, the rate for Bangladesh (i.e. 9.8 per cent as per the BDHS 2007) is much lower than that in many contemporary African countries. It is lower than that in Nepal (11.9%), half of that in Pakistan (21.8%) and Cambodia (19.5%), and roughly similar to the level observed in India (9%), Philippines (9%), and Egypt (8.5%) (see, Table 5).

4 rates are per 1000 live births

Table 5: Incidence Rate of Diarrhoea in Different Countries

Country and year	Incidence rate (%)
Bangladesh - 2007	9.8
Cambodia - 2005	19.5
Egypt - 2008	8.5
Ethiopia - 2005	18.0
India – 2005-6	9.0
Indonesia - 2007	13.7
Kenya - 2003	16.0
Nepal - 2006	11.9
Pakistan – 2006-7	21.8
Philippines - 2008	9.0

Source: DHS Reports for different countries.

Incidence of Childhood Diarrhoea across Subgroups

While it is gathered during FGDs (Box 3) that the children under 5 compared to the adults of the country remain more vulnerable to diarrheal attack, according to BDHS of both 1996/97 and 2007 rounds, the ages during which the country's children remain most vulnerable to diarrhoea are between 6 to 35 months, particularly between 6 to 23 months (Table 6). The risk of these diseases for the children starts to decline from age 24 months and it is lower also in the ages below 6 months when the child is mostly breastfed. As regards the vulnerability to these diseases by sex, the two surveys hold different opinion; according to 1996/97 BDHS, sex matters little for the diarrheal risk; both boys and girls aged under 5 are about equally vulnerable to these diseases. But according to 2007 BDHS, boys face a higher risk (11%) for these diseases than the girls (8.5%). As regards diarrheal risk in rural and urban areas, both data sets are of the opinion that children in both places encounter about similar risk for these diseases (Table 6) although country's urban areas enjoy better sanitation situation than the rural areas; also, as noted above, the urban areas, to an extent, enjoy a better water situation too than the rural areas.
According to both BDHS surveys, there are regional variations for diarrheal disease risk; but they do not agree on the regional ranking for the risk; according to 1996/97 BDHS, the highest risk persisted in Chittagong (8.7%) and Khulna divisions (8.7%) and lowest in Barisal division (3.1%) while according to 2007, the highest risk persists in Chittagong and such risk in Dhaka and Sylhet divisions too is high and similar to that of Chittagong (around 11%); the lowest risk on the other hand, persists in Khulna division (8.7 per cent) (NIPORT/Mitra & Associates/Macro International 2005, 2009). These non-uniform observations from two BDHS surveys about the regional risk tend to suggest that the factors that influence diarrheal diseases in the country apparently have no regional boundary and as known, some of the factors may be mobile in nature also, such as, the flood, cyclone, etc.

The influence of mother's education on diarrheal diseases risk is somewhat unclear from BDHS data; according to 2007 BDHS, it is inversely associated with the incidence of childhood diarrhoea, but a threshold effect is there; mother's education up to primary level has no impact on it and starts rendering negative influence only when the education crosses the primary level viz., attain secondary level or more., The 1996/97 BDHS data, in contrast, indicate no systematic influence of mother's education on diarrheal risk of the children (Table 6).

A puzzling observation from Table 6 however is that the overall risk for diarrheal diseases in Bangladesh has increased somewhat in recent years since the mid-1990's; in 1996/97 the national level rate for the diarrhoea incidence among children was 7.6% but this rate was noted to be 9.8% in 2007. To note, this increase took place when the country in reality has moved forward both for accessing improved water sources for drinking purpose and for accessing improved sanitation provision (see Box 2). Such an observation may arise however among other things, for better reporting of diseases/diarrhoea by the mothers who are getting more aware over time about health, diseases, etc. It also however, may be for the reason that the increasing scarcity of safe water in the country following arsenic contamination of tube well water, lack of water in the tube well for few months during dry season and, rise of salinity in the ground and surface water in the coastal belt have been playing a role for this recent increase in diarrhoea incidence.

Table 6: Incidence of Diarrheal among children by different background characteristics in Bangladesh

Background characteristics	BDHS 1996/97	BDHS 2007
Bangladesh	7.6	9.8
Child's age in months		
< 6	4.2	4.6
6-11	14.0	13.9
12-23	11.6	14.2
24-35	7.6	10.2
36-47	6.3	7.6
48-59	3.9	7.0
Sex of the child		
Male	7.5	11.0
Female	7.8	8.5
Residence		
Rural	8.0	9.7
Urban	7.6	10.2
Region/Admn. Division		
Barisal	3.1	9.2
Chittagong	8.7	10.9
Dhaka	7.7	10.6
Khulna	8.7	8.7
Rajshahi	7.0	7.6
Sylhet	7.8	10.7
Mother's Education		
No education	6.9	10.0
Primary incomplete	10.1	10.7
Primary complete	6.9	10.4
Secondary incomplete	8.1*	9.3
Secondary complete & higher		8.5

Rate for secondary and above
source: BDHS Reports for 1996/97 & 2007

Box 3: Childhood Diarrhoea in Bangladesh: Insights from FGD
While diarrhoea still occurs among children in Bangladesh, according to the participants of the FGDs, attack of such diseases has come down substantially in the country over the years[9]. The stated reasons for this have been the increased awareness of people about health and hygiene; higher use and appreciation for quality water and sanitation, higher practice of hygienic behaviour like hand-wash with soap before eating, after defecation etc., cleanliness of all kinds including going to latrine wearing sandal etc. It is also gathered from the FGDs, that compared to the adult people, the children of the country are more vulnerable to diarrheal diseases, and reportedly, the major reason for this has been that the children practice hygienic behaviour less than the adults; they often remain dirty, put dirty hands into mouth, eat dirty things from the floor/courtyard, drink unsafe water, etc. Even mothers are sometimes unaware of good and hygienic practices about them, such as, after cleaning the child, they sometimes feed the children without cleaning hands, etc. Thus, according to the participants of the FGDs, the unhygienic practices of the children and such practices relating to them are primarily responsible for higher vulnerability of the children to diarrheal diseases. It is also gathered from the FGDs that the incidence of diarrhoea although has come down substantially among country's children, this is still a major disease inflicting sufferings on them. In order to bring further improvement in diarrheal risk, the suggestions made by the FGD participants are: (1) safe water is to be made available to people in adequate quantity, and, (2) universal coverage for improved sanitation is to be ensured. They also suggested, there is need to bring improvements in the disposal of child waste, child rearing practices, and in child's behaviour and practices. Also, it would require more care about food preparation and food preservation. For all these, strong media campaign is necessary so that general awareness about child health and diarrhoea can be increased.

3.4 Water, sanitation and diarrhoea: bi-variate association

A simple tabular analysis of the relationship between improved water source for drinking purpose and the incidence of childhood diarrhoea and that between household toilet provision and the diarrhoea incidence as obtained from BDHS 1996/97 and 2007 data is presented in Table 7. As may be seen from Table 7, the access to improved water sources for drinking purpose and improved sanitation have shown an expected association with the childhood diarrhoea i.e. both are negatively associated with the childhood diarrheal risk in Bangladesh. This is observed with both BDHS data of 1996/97 and 2007. As may be noted from Table 7, in case of improved drinking water the strength of the association is about similar both in 1996/97 and 2007 but in case of improved sanitation the association seems to have grown somewhat stronger during this period.

Although access to improved water sources is found associated negatively with diarrhoea incidence in BDHS 2007, surprisingly this data set show no association of diarrhoea incidence with other water related variables signifying the quality of

[9] This confirms the apprehension that recent increase in diarrheal diseases attack shown by the BDHS 1995/96 and 2007 may be due to more awareness and better reporting of these diseases in recent years.

water[10] such as, 'the source of non-drinking water for the household' and 'the treatment of water before drinking'; the latter rather reveals an inverse relationship i.e. children from households where water is treated before drinking are more vulnerable to diarrhoea risk (10.1%) than their counterparts who belong to the households where treatment of water before drinking is absent (9.2%). Also, surprisingly, in 2007, access to improved water sources both for drinking and non-drinking purposes have failed to show any association with the diarrhoea. The 2007 BDHS data also show that the water from pipe/protected dug well/rain water (latter two categories claim highly insignificant proportion) for drinking purpose is not associated with lower incidence of diarrhoea; diarrhoea incidence rate is rather highest among them than those who avail unsafe sources or tube well for drinking water. As evident in the 2007 BDS data, the lowest diarrhoea risk persist among those children who access tube well for drinking water (9.1%) and unsafe sources ranks in the middle (10.4%) (Table 7). All the above mentioned water related variables however, have shown a negative association with diarrhoea incidence in 1996/97; even both the major improved sources for drinking water i.e. piped water and tube well water too separately have shown a negative association with diarrhoea incidence (Table 7).

Hence, as it appears from bi-variate analyses of BDHS surveys, the association of improved water sources or improved water for drinking purpose with the childhood diarrhoea at two points in time were not the same and provide no concrete idea about the association between these two viz., drinking water from improved sources with the risk of diarrhoea among children. Indeed, the past analyses too have failed to demonstrate any relationship between access to improved water sources for drinking purpose with the reduced rate of diarrhoea in Bangladesh (Khan et, al. 1978; Levine et, al. 1976; Curlin et al, 1977; Briscoe J, 1977).

In case of toilet, as noted above, the overall bifurcation of them into the improved and unimproved categories has shown an expected association with the diarrheal diseases both in 1996/97 and in 2007, but compared to 1996/97 the relationship appears to be somewhat stronger in 2007. Interestingly, as the 2007 BDHS data show, while the improved toilet provision matters for diarrheal risk in Bangladesh the unimproved provisions has no influence at all on diarrhoea; it is not associated at all with the reduced risk for diarrhoea among children. In contrast, the 1996/97 BDHS data are of the opinion that even an unimproved toilet provision is able to render negative influence on diarrhoea. According to BDHS 1996/97 any fixed provision has some negative association with diarrhoea risk with improved provision 'having an association of higher degree (Table 7).

Expectedly, both 1996/97 and 2007 BDHS data have shown that the combined access to improved sources for water and sanitation is found to have a negative association with the childhood diarrhoea in Bangladesh i.e. children of the households having access to both improved water and improved sanitation are less vulnerable to these diseases than their counterparts who live in the households

[10] water quality refers to good microbiological quality (Huges James M et. al., 1981)

having access either to improved water sources only or to improved sanitation or have access to unimproved sources for both viz., water and sanitation. This association is found somewhat stronger in 2007 compared to that in 1996/97 (Table 7).

The MICS data of 2006 rounds (BBS/UNICEF, 2007) however, shows some illuminating observations; these data show that the hygienic behaviour/practices of the women/mother and household head have a favourable impact on childhood diarrhoea; hand-wash after defecation using soap or ash and hygienic disposal of child stool are found associated with lower incidence of diarrheal diseases i.e. children in the households where household head washes hand with soap or ash after own and/or child's defecation face lower risk of diarrhoea than their counterparts in the households where hand wash is done either with water and soil or with water only[11]. Similarly, children of the households where the stool of the children is disposed- off hygienically viz., either the children use latrine or the stool is rinsed to the latrine face a lower risk for diarrhoea than their counterparts where child stool is unhygienically disposed of i.e., rinsed to drain/ditch, or thrown into the garbage or left in the open. Interestingly, the time requirement for water collection reflecting perhaps the availability of water in the household which has implications for personal hygiene and cleanliness, too has a negative association with diarrheal risk; the children of the households that access water on the premise or require at most 15 minutes of time to reach the water source are less vulnerable to diarrheal diseases than their counterparts where the households require more than 15 minutes time to reach the water source (Table 8).

[11] MICS 2006 data do not have any category like 'do not wash hand'

Table 7: Incidence of Childhood Diarrhoea by Water and Sanitation Variables: 1996/97 & 2007

Water/sanitation	% of children suffered diarrhoea	
	1996/97	2007
drinking water		
Improved	7.7	9.2
Not-improved	8.4	9.8
non- drinking water		
Improved	7.1	9.3
Not-improved	7.6	9.3
both drinking and non-drinking water		
Improved	7.0	9.3
One of them not-improved	7.7	9.3
improved drinking water by sources		
Tube-well	7.6	9.1
Pipe/protected dug well/rain water	7.8	11.8
Unimproved sources	8.3	10.4
Treatment of water before drink		
Treated	Na	10.1
Not-treated	Na	9.2
Toilet Provision		
Improved	7.5	8.8
Not-improved	7.8	9.6
Type of toilet		
Improved	6.9	8.6
Not-improved	7.6	12.0
Open space/bush/field	9.0	11.6
Water/Sanitation (Watsan)		
both from improved sources	7.6	8.9
either one or both from unimproved sources	7.8	9.5
Watsan (detailed categories)		
improved sources for both	7.6	9.7
improved sources only for drinking water	7.7	9.6
improved sanitation only	7.7	9.5
unimproved for both	8.4	11.7

Source: BDHS 1996/97 & 2007

Table 8: Incidence of Diarrhoea by Hygienic Practice: 2006

	Prevalence rate (%)
Hand wash after defecation*	
Only water or water & soil	8.1
Water & ash or water $ soap	6.7
Disposal of stool of the child *	
Hygienic	7.1
Not- hygienic	9.1
Time taken to fetch water *	
On premise or less than 15 min.	6.9
15 minutes or more	8.4

* Difference is significant at 1 percent level.

Source: MICS 2006

IV. Method of Estimation: Relevance of the PSM Technique for Impact Evaluation

The above observations gathered from the bi-variate analysis while could give us no clear idea about the association between improved water sources for drinking purpose and the diarrhoea and the same between improved sanitation and the latter, to note, these observation made from the bi-variate analyses of the data show only the correlation and do not express the effect that each of these characteristics has on the child health outcomes in terms of diarrhoea. In order to evaluate the ultimate impact of the water and sanitation intervention/treatment[12] on diarrhoea prevalence/incidence among children in Bangladesh, we have used the propensity score matching (PSM) technique, an evaluation technique gaining increasing acceptance in the field of impact evaluation. Rosenbaum and Rubin (1983) introduced the PSM technique in the field of labour economics and it is now considered as appealing tool for impact evaluation, as it ensures the similarity of treatment and control groups based on observable characteristics. Lack of longitudinal or panel data motivated us for applying PSM technique in identifying the impacts of water and sanitation on diarrhoea prevalence among Bangladeshi children. PSM also reduces the selection bias which is commonly an issue that arises while performing the causal analysis using the cross-section data.

The propensity score (PS) measures the conditional probability of household's participation in an intervention given its observable characteristics, X. In other words

$$PS= P(X) =P(T=1 \mid X)=f(X) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The predicted value of standard binomial logit model based on the equation (1) is drawn as propensity score. However, the choice of covariates in the estimation of propensity score should maintain the assumption of '*Conditional Independence Assumption'* (CIA). CIA requires the outcome variables must be independent of treatment assignment. Hence implementing matching requires choosing a set of

[12] From now on we will use the term "treatment" for the availability of improved water or/and sanitation to the households and the term "control" for the unavailability of water or/and sanitation to the households.

observable covariates X which are unaffected by participation in the program. To maintain CIA, we used a set of observable characteristics of households all of which are unaffected by participation in water and sanitation treatment. Moreover, the assumption of consistently estimated propensity scores is also required for PSM analysis.

Besides CIA, a further requirement of common support has to be maintaining in propensity score matching. This condition requires that there is not perfect predictability of covariates in participation of water and sanitation program, and it requires that persons with the identical characteristics have a positive probability of being both participants and non-participants to the program (Heckman, LaLonde and smith, 1999).

Given CIA and common support conditions hold, estimated propensity scores allow us to construct comparison groups by matching propensity scores of the households with water and sanitation and households without water and sanitation. Once program samples are matched with control samples, the difference between the mean outcome of the program samples and the mean outcome of the matched control samples can be measured. This difference is defined as 'the average effect of treatment on the treated' (ATT).

The PSM estimate of ATT can be obtained as follows:

$$ATT= E_{P(X)|T=1}\{E[Y(1)|T=1, P(X)]-E[Y(0)|T=1, P(X)]\}\ldots\ldots\ldots\ldots..(2)$$

ATT can be interpreted as the mean difference in the outcome of program and control samples over the common support (appropriately weighted (in case of Kernel Matching) by the propensity distribution of participants).

However, only the estimation of propensity score is not enough to estimate the ATT of interest using equation (2). This is because the possibility of observing two samples, one from treatment and other from control, with same propensity score is in principle zero, since propensity score, P(X), is a continuous variable. Several matching methods have been proposed in PSM literature to overcome this problem. We do not discuss the technical details of all methods[13] here; rather we will discuss two most widely used matching methods, nearest neighbour matching (NNM) and kernel matching (KM), and select one of them for our evaluation purpose. To note, when there is substantial overlap in the distribution of propensity score between the control and treatment groups, both of the matching algorithms will yield similar results (Dehejia and Wahba, 2002).

With kernel matching all untreated observations are used to estimate the missing counterfactual outcome and greatest weight being given to observations with closer scores, whereas with NN matching only the closest neighbours within caliper are used. NN matching faces the risk of bad matches, if the closest neighbour is far away

[13] See Smith and Todd (2005) or Imbens (2004) for more technical details.

and this can be avoided by imposing a tolerance level on the maximum propensity score distance which is known as caliper. However, it is difficult to know a priori what choice for the tolerance level is reasonable (Smith and Todd, 2005). Moreover, estimation of ATT is sensitive to the sort order of the data if matching is performed without replacement. Since the weighted average of all samples from control group is used to construct the counterfactual outcome, kernel matching has an advantage of lower variance because more information is used (Heckman et al., 1998). Hence we decided to estimate ATT using kernel matching technique with a view to analysing the effect of water and sanitation interventions on the diarrhoea prevalence among children in Bangladesh.

In order to get the unbiased estimate of ATT and to assess the matching quality, we have done 'balancing test' which is primarily concerned with the extent to which the difference in the covariates between the treated and control groups have been eliminated so that any difference in outcome variables between the two groups can be inferred as coming solely from the treatment or intervention (Heckman and Smith, 1995). There are two ways through which balancing of the covariates can be examined. t stats of difference in means of covariates in the treated and non-treated groups, before and after matching are used to examine the quality of the matching. Before matching, differences between the groups are expected; but after matching, the covariates should be balanced in both groups and hence no significant differences should be found (Caliendo and Kepeinig, 2005). And standardized bias[14] before and after matching, together with the achieved percentage reduction in bias are also used to assess the matching quality. These exercises have been carried out to examine the balance in covariates for this study.

Under this PSM approach, we have matched households that are participated in the intervention of water and sanitation and households that share similar characteristics but remained away from water and sanitation intervention anyway. Once the matching is made we computed the average effect of treatment on the treated (ATT). In the application of PSM technique, we used STATA 10.0 version using psmatch2 package, a PSM function, developed by Leuven and Sianesi (2009) (for detail of psmatch2 package, see Leuven and Sianesi, 2009).

The impact assessment of water and sanitation on diarrheal attack among children under 5 started with descriptive statistics viz., with naïve comparison of the difference between incidence of diarrheal attack between the groups i.e. between children of the households who have access to improved water sources and sanitation provisions to those who do not have such accesses. Subsequently, the assessment was done considering access to improved drinking water sources and sanitation as the exogenous variables which influence health and the causal effect of the former on the latter was estimated through propensity-score matching (PSM) methods. PSM balances the distributions of observed covariates between a

[14] Standardised bias is defined as the difference of sample means in the treated and matched control sub samples as a percentage of the square root of the average of sample variances in both groups.

treatment group (which in the present case represents those with access to improved water sources and sanitation) and a control (without any access) based on similarity of their predicted probabilities of having a given facility (their 'propensity-scores').

V. Estimates of Water and Sanitation Interventions on Diarrheal Incidence: Evidence from DHS Data

We estimate the impacts of water and sanitation interventions by using BDHS data in three stages: (a) at first stage, we estimate a participation equation to derive the "propensity score" across all the DHS households irrespective of their "treatment status"; (b) at second stage, we estimate the magnitude of ATT using matching method of the kernel; and (c) at third stage, the 'balancing test' has been performed to assess the matching quality between the treatment and the control group in the matched sample.

5.1 Correlates of Participation and Estimation of Propensity Score

As a first step, the impact evaluation through the propensity score matching requires the estimation of propensity score using standard probability model with a binary dependent variable to indicate the presence (or absence) of the intervention with a number of independent covariates. In our case, we estimate the <u>binomial logit</u> model to estimate the propensity scores for matching purpose. We generate three sets of propensity scores using three different binary outcome variables. Three dependent binary variables are access to safe water, access to improved sanitation, and access to both safe water and improved sanitation (denoted by "watsan", henceforth). The binary outcome for water intervention takes a value of one if the household has access to improve water sources for drinking purpose and zero otherwise. Similarly, binary outcome for the sanitation treatment takes a value of one if the household has access to improved sanitary latrines and zero otherwise; while the third binary outcome has been generated combining both water and sanitation treatment whereby the outcome variable takes a value of one if the household has access <u>both</u> to improved water sources and improved sanitation and zero if the household has access to improved sources for none of them.

The covariates comprises of a wide range of controls such as demographics, education, religion, and regional dummy variables. From BDHS, we have considered age and gender of the household heads, household size, religion, education status of the respondents (mothers) and their partners (they are used as "categorical dummies" to capture the "threshold effects" of human capital rather than as a continuous variable), employment status of the respondents (mother), and regional dummies. We also separately consider the ownership of homestead land and access to media (television) as additional variables[15].

The estimation of the propensity score was calculated by applying the procedure

[15] We have avoided the use of wealth index representing wealth status of the household as it includes water and sanitation in it.

discussed earlier in the section on methodology. The estimates of the logit regressions for generating propensity scores are reported in Table 9. For sanitation and 'watsan' except for religion all the covariates have come out to be statistically highly significant (most of them are significant at 1% level) in influencing the likelihood of the participation in the "treatment" and all significant variables appeared with expected signs. In case of water, except for 'partners' education' and 'gender of the household head' all other covariates have come out significant and they also appeared with expected signs. The observations from the participation equations as obtained from the 1996/97 BDHS data are again similar (Annex 2, Table 1) but in case of education including that of both of women and their partners are found somewhat erratic again. This may be due to the fact that the installation of tube well, the major improved source for drinking water in Bangladesh as noted in section 3.1 is generously supported by the government and donors to ensure universal coverage for safe drinking water. Also, as noted above, installation of tube well not being a costly affaire in Bangladesh most people can afford it. All these may have made access to the tube well a relatively easy matter in the country and access to it therefore does not depend much on factors like education.

Table 9: Coefficients of Binomial Logit Model Estimated for Generating Propensity Score (new)

Dependent Variable: Treatment=1, Control=0	Water		Sanitation		WatSan	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant	1.67	0.786**	-3.007	0.34***	-3.28	0.34***
Age of Household Head (HH)	0.071	0.026***	0.047	0.0001***	0.062	0.012***
Squared Age of HH	-0.0005	0.0002**	-0.0004	0.0001***	-0.0005	0.0001***
Gender of HH (Male=1)	-0.500	0.317	-0.547	0.112***	-0.511	0.11***
Household Size	-0.074	0.02***	0.0668	0.0123***	0.0369	0.012***
Respondent's Education (Reference Category: Below Primary)						
Respondent Completed Primary Education	0.404	0.175**	0.1407	0.083*	0.137	0.085*
Respondent Completed Secondary Education	0.769	0.228***	0.607	0.092***	0.602	0.092***
Respondent Completed Higher Education	1.26	0.675*	1.377	0.1835***	1.37	0.182***
Partner's Education (Reference Category: Below Primary)						
Partner Completed Primary Education	-0.259	0.167	0.249	0.08***	0.275	0.081***
Partner Completed Secondary Education	0.414	0.252*	0.456	0.088***	0.499	0.089***
Partner Completed Higher Education	-0.197	0.406	1.117	0.138***	1.09	0.137***
Respondent Employed, (Yes=1)	-0.138	0.37	-0.249	0.073***	-0.272	0.074***
Division Dummy (Reference Category: Dhaka)						
Barisal	-0.783	0.375**	0.3737	0.111***	0.353	0.112***
Chittagong	-1.21	0.334***	0.307	0.097**	0.320	0.097***
Khulna	-1.793	0.3436***	0.349	0.112***	0.239	0.112**
Rajshahi	-0.1203	0.407	0.402	0.104***	0.3865	0.105***
Sylhet	-1.823	0.3196***	0.399	0.102***	0.327	0.103***
Urban or Rural (Urban=1)	1.367	0.245***	0.740	0.067***	0.338	0.07***
Religion (Muslim=1)	0.449	0.216**	-0.39	0.107	0.0167	0.108
Any Homestead Land (Yes=1)	0.951	0.158***	0.1415	0.074**	-0.5438	0.291*
Whether have TV (Yes=1)	0.797	0.179***	0.569	0.067***	0.611	0.067***
Living in Slum(Yes=1)			-0.560	0.2907***	-0.544	0.291*
Pseudo-R^2	0.1637		0.1480		0.15	
Log-likelihood	-782.13241		-3197.8514		-3157.738	
Prob>Chi^2	0.000		0.000		0.000	
N	5473		5541		5541	

Note:*, **, and*** denote statistical significance at the 10, 5, and 1percent levels, respectively
Note: WatSan=1 if both water and sanitation are improved, and WatSan=0 if otherwise.

5.2 Estimation of ATT for Water, Sanitation and Watsan

After generating the propensity scores, we move forward to estimate the average treatment effects on the treated by taking the mean difference in mean outcomes between treatment and control household observations. In the estimation of ATT, we impose common support as well as the caliper. Imposition of common support excluded the treatment observations with propensity scores outside the boundary of the highest propensity scores of the control group and also excluded the control observations outside the boundary of the lowest propensity scores in the treatment group. Imposition of caliper ensures the matching of treatment observations with the control observations only within a limited range of probability and the smaller the caliper level, the better the matching quality. In our case, we chose a caliper level of 0.0001 which implies samples will be in the comparison group if the difference in their propensity score (probability of being treated) falls below 0.0001.

The use of common support and the caliper while enhances the match quality and facilitates more precise estimation of ATT, their use reduces the number of observations significantly. The number of observations, from the treated and control groups that have been off-supported during analyses with BDHS 2007 due to the application of common support and the caliper are presented in Table 10 (for off-supported cases for BDHS 1995/96, please see Annex 2 Table 2). In estimation of ATT considering water treatment with BDHS 2007, in total 4339 observations (86 from control and 4253 from treated) have been off-supported out of 5473 observations. In case of sanitation treatment, total 3351 observations (2054 from control and 1297 from treated) have been off-supported out of 5541 observations while for water and sanitation combined, 3446 observations have been off-supported (2115 from control and 1331 from treated) out of 5541 (Table 10).

Table 10: Use of Common Support, BDHS 2007 (new)

Intervention		Common Support		Total
		Off support	On support	
Water	Control	86	138	224
	Treated	4253	996	5249
	Total	4339	1134	5473
Sanitation	Control	2054	1207	3261
	Treated	1297	983	2280
	Total	3351	2190	5541
WatSan	Control	2115	1216	3331
	Treated	1331	879	2210
	Total	3446	2095	5541

Water:

The estimates for ATT using 2007 data for three categories of water and sanitation types using the kernel matching are shown in Table 11 (that for 1996/97 data are shown in Annex 2 Table 3). The choice of kernel matching as *the preferred method* for estimation of ATT has been explained earlier in the methodology section[16]. We find that for access to improved water, the difference in the diarrhoea incidence between treatment and control groups is not statistically significant both in the unmatched and matched samples in 2007. This is so in 1996/97 too (Annex 2 Table 3). Rather in 2007, the direction was even reverse viz., the treated group in the matched sample has shown a higher diarrhoea incidence rate than the untreated group viz., who lacks access to improved water provisions for drinking purpose (9.7% against 6.3%). However, in 1996/97, this was not the case, the treated group both in unmatched and matched samples has shown a lower diarrhoea incidence than the control group (Annex 2 Table 3). As these findings therefore indicate, in Bangladesh access to improved water makes no significant difference for diarrheal risk among children **OR that 'improved' water is not safe enough to have a significant impact on the diarrhoea incidence**. To note, in Bangladesh 97 per cent of the households has access to improved water sources for drinking purpose and as most people of the country have access to improved sources for drinking water, quality of water alone no longer seems enough to explain the variation in the current level of diarrhoea incidence.

One plausible explanation is widely mentioned however, in the literature is that the quality of non-drinking water might be important in explaining the diarrhoea incidence in situation like Bangladesh where use of unsafe water is widespread for non-drinking purpose. We examine the impact of using improved water for non-drinking purpose utilizing 2007 data and the result shows no significant differences between ATTs of treatment and control households. Interestingly, in the matched sample, the households which use water from improved sources for non-drinking purpose and which use improved sources both for drinking and non-drinking purposes have shown a higher probability of getting diarrhoea for their children than the households which use unimproved sources for the purposes. but as noted above, the differences are found statistically insignificant (Annex 1, Table 1).

Although pipe represent an improved source for water, it is often said that piped water in countries like Bangladesh gets easily contaminated because of leakages in the supply pipe network which facilitates interconnection between the water and the sewerage pipes. We therefore, tried to see impact of drinking water from different sources such as pipe and tube well in the case Bangladesh. The piped or tap water is supplied centrally and tube well is set up locally. The estimated ATT for them using PSM technique shows that neither the piped nor the tube well water has any significant impact on the mean probability of diarrheal incidence rates among children and this is noted both in the unmatched and matched sample of BDHS 2007 data. In case of both water sources, the matched samples rather have shown a

[16] For the purpose of robustness check of our results, we carried out PSM using nearest neighbourhood method also and found almost similar results.

higher probability of diarrhoea incidence than those who use unsafe sources for the purpose (Table 12). However, in case of piped water, the comparison may not be a reliable one as the number of on-support cases in case of piped water based on which the comparison has been made is highly insufficient; such cases in 1996/97 were 10 in the control group and 8 in treated group and in 2007 the e numbers were respectively 8 and 6 only (Annex 1 Table 2).

Interestingly, the ATT estimates for tube well as obtained using 1996/97 BDHS indicates a different picture; according to ATT estimates the mean probabilities of diarrhoea incidence rate for piped water although has been insignificant both in the unmatched and matched samples but for tube well water, the difference between the treated and control groups has been found significant (at 10% level) in the matched sample. According to the estimated mean probabilities for matched sample; in 1996/97 the diarrhoea incidence rate among children who use tube well water for drinking purpose was more than 37.0% lower than the rate for their counterparts who drank water from unsafe sources (the difference in the unmatched sample was statistically insignificant) (Table 12).

The water related evidence from BDHS 2007 and BDHS 1996/97 thus tend to suggest that the tube well water in the mid-90's (1996/97) (may be in the past too) was effective in reducing the diarrhoea risk in Bangladesh but has lost its efficacy for the purpose in recent years. This recent loss of efficacy of the tube well water in reducing diarrheal risk however, may be due to some emerging reality in the area of tube well water. As noted during the FGDs (see Box 1), a large number of tube well users particularly the children, these days are vulnerable to use other unsafe sources for drinking purpose due to wide spread arsenic contamination of tube well water, water scarcity in the tube well in some parts of the country and some seasons of the year due to lowering of the ground water level, and for rising sea water level causing salinity in the ground water in the coastal belt, etc. Also, as the experts suggest, contamination of tube well water in recent years has been arising from large scale construction of latrines in the country; the animal and human faecal matters are leeches down to the ground water layer through latrine pits when the rules for safe distance between the latrine and the water point is not maintained (http://watsaninbd.blogpost.com/2009/06/secondary-contamination-worsening-water.html). Thus, other than the environmental causes forcing people to use unsafe sources, the tube well water also has a chance at least in some cases to lose its quality for above mentioned distance factor between water point and sanitation provisions. Hence, in case of water, the problem may not lie with the improved water sources but with some other realities surrounding improved water sources and other challenges both in case of tube well and pipe water in the country.

Sanitation:
Regarding the sanitation treatment, the ATT shows no significant difference for the diarrheal incidence rate between treatment and the control groups in the *matched sample* (also for the unmatched sample). This is noted both with the BDHS 2007 and BDHS 1996/97 (see Table 11 and Annex 2 Table 3). However although the difference

is not significant, results using both data sets found to be in the desired direction viz., children of the households using improved sanitation provisions encounter lower incidence of diarrhoea than those who belong to the households having unimproved provision and this is noted both in the matched and unmatched sample of both data sets. In the matched sample of 2007 BDHS the sanitation intervention is found associated with 6% reduced rate of diarrhoea incidence while in 1996/97 the reduction was of 15% but as noted before in none of the cases the difference is found significant.

Water and Sanitation (Watsan):

While the isolated access to improved water or improved sanitation has failed to show any impact on diarrhoea risk in Bangladesh, we tried to see the effect of combined access to improved water and sanitation viz., if this has any effect diarrhoea incidence among children. As the ATT results using 2007 BDHS data show, in the matched sample the children of the households which have access to both improved water and sanitation provisions face lower diarrhoea risk than those who have access either to improved water or to improved sanitation or have access to improved sources for none of them. Both the data sets hold this view (see Table 11, and Annex 2, Table 3) but the difference is found highly significant in the matched sample of BDHS 2007 (Table 11). According to the ATT estimates for BDHS 2007 show, the mean probability of diarrhoea incidence for the treated group with combined access to both improved water and sanitation has a diarrhoea incidence rate which is more than 31% lower than the same for control group and this difference is found highly significant at 1% level (Table 11)

In the above analyses for combined intervention, the control group however, represents a mixed category comprised of households having either isolated access to improved water or isolated access to sanitation or have no access to improved provisions for any. Thus, to have a clearer idea about different interventions, we conducted another PSM analysis where each of the treated group is considered separately and compared with those who have no access to any improved sources neither for water nor for sanitation. So in these latter analyses we considered each of the treated groups i.e. households having access to improved sources of water only, households having access to improved sanitation only and households having access to both separately and conducted separate PSM analysis for them taking households having no access to improved sources for any, as the control group. The ATT results using BDHS 2007 are presented in Table 13 and those using BDHS 1996/97 are presented in Annex 1 Table 3. Interestingly, this time too, the 1996/97 BDHS shows no significant impact of combined access of water and sanitation (watsan) on diarrhoea but such access is found to have significant negative effect on diarrhoea in 2007 (Table 13). Further interesting observation from the ATT results for 2007 is that in the matched sample, the diarrhea incidence among children using improved sanitation is found significantly lower than that of the children who have access to no improved sources for any viz., water and sanitation. In the unmatched sample too the treated group has shown lower incidence but the difference is not significant (Table 13). Water has failed to show any impact in this detailed or segregated comparison too; in fact, in the matched sample the direction for water intervention impact is found of reverse direction viz., children from households using drinking water from improved sources are more vulnerable to diarrhoea than those who belong to the households having access to improved sources neither for water nor for sanitation. So, this analyses too suggest that water at present plays no role in Bangladesh in causing differentiation in vulnerability to diarrhoea. However, a caution to be exercised about the observations obtained through detailed analyses; the comparison in these cases are done based on small number of control group; 122 in case of water, 78 in case of sanitation and 91 in case of watsan or combined access (Table 14).

Table 11: PSM Estimates of ATT for Probability of Diarrhea Incidence for Different Types of Interventions based on Kernel Matching, BDHS 2007 (new)

		Treatment	Control	Δ	S.E.	T-Stat
Water	Unmatched	0.093	0.098	-0.0056	0.0198	-0.28
	Matched	0.097	0.063	0.034	0.045	0.76
Sanitation	Unmatched	0.088	0.096	-0.008	0.008	-1.03
	Matched	0.096	0.102	-0.007	0.0175	-0.41
WatSan	Unmatched	0.089	0.095	-0.006	0.007	-0.79
	Matched	0.085	0.124	-0.038	0.017	-2.20***

Note:*, **, and*** denote statistical significance at the 10, 5, and 1percent levels, respectively.

Table 12: PSM Estimates of ATT for Probability of Diarrhea Incidence for Intervention by Different Water Sources - 1996/97 and 2007 (new)

		Treatment	Control	Δ	S.E.	T-Stat
			2007 BDHS			
Piped water	Unmatched	0.12	0.096	0.024	0.026	0.92
	Matched	0.33	0.5	-0.167	0.417	0.40
Tube-well	Unmatched	0.091	0.096	-0.0055	0.0194	-0.28
	Matched	0.091	0.074	0.016	0.044	0.37
			1996/97 BDHS			
Piped water	Unmatched	0.09	0.84	0.007	0.0264	0.26
	Matched	0@	0.14	-0.14	0.1428	-1.00
Tube-well	Unmatched	0.076	0.084	-0.008	0.0153	-0.51
	Matched	0.075	0.120	-0.046	0.0256	-1.79*

* Significant at 10% level
@ no one had diarrhea in this category

Table 13: PSM Estimates of ATT for Probability of Diarrhea Incidence for Different Intervention by Water and Sanitation based on Kernel Matching – BDHS 2007 (control group: have access to improved sources for none) (new)

		Treatment	Control	Δ	S.E.	T-Stat
Water	Unmatched	0.096	0.117	-0.02	0.024	-0.84
	Matched	0.103	0.091	0.011	0.06	0.19
Sanitation	Unmatched	0.095	0.116	-0.021	0.025	-0.87
	Matched	0.079	0.27	-0.19	0.09	-1.99*
WatSan	Unmatched	0.097	0.117	-0.02	0.025	-0.81
	Matched	0.086	0.27	-0.18	0.10	-1.85**

Note:*, **, and*** denote statistical significance at the 10, 5, and 1percent levels, respectively.

Table 14: Use of Common Support separately for different interventions, BDHS 2007

Intervention		Common Support		Total
		Off support	On support	
Water	Control	32	122	154
	Treated	2093	2776	4869
	Total	2125	2898	5023
Sanitation	Control	76	78	154
	Treated	1446	494	1940
	Total	1522	572	2094
WatSan	Control	63	91	154
	Treated	1407	466	1873
	Total	1470	557	2027

Hygienic Practices:

We have noticed during the bi-variate analyses of the data (Table 8) that the hygienic practices of the household members/women in the form of hand wash after defecation, disposal of the child stool and distance of water having implications for hygienic practices/behaviour of the household members have negative association with the diarrheal incidence among children. We have conducted 3 separate PSM analyses for each of above mentioned three hygienic practices. While doing so we considered three binary dependent variables for three of them viz., distance of water, hand wash practices and disposal of child stool. The binary variable for 'distance of water' takes a value of 1 if the water source is located on premise or within a distance of 15 minutes time and 0 otherwise; for hand wash, it takes a value of 1 if one washes the hand after defecation using soap or ash and 0 otherwise and in case of 'child stool disposal' the variables takes a value of 1 if the child use either latrine for defecation or stool is rinsed into the toilet and zero otherwise.

The ATT results for them are presented in Table 15. As these results suggests both distance of water from the household measured in terms of time requirement to fetch water and the disposal of child stool have come highly significant in influencing the diarrheal risk in the country; according to these results the children from households which can avail drinking water either on premise or can reach the water sources within 15 minutes of time are significantly less vulnerable to diarrheal risk than their respective control groups viz., who need to fetch drinking water from a greater distance requiring more than 15 minutes time and the households where child stool is disposed-off hygienically. This is noted both in the unmatched and matched sample for them. In the matched sample the children from households located nearby the water sources encounter a diarrheal risk which is nearly 65% lower than that faced by the children from households located at a distance; similarly, where child stool is disposed off hygienically face about 30% lower risk for diarrhoea than their counterparts who belong to the households where child stool is unhygienically disposed-off (Table 15). Surprisingly, the difference in the mean probability for diarrhoea in case of hand-wash practice after defecation although is found highly significant in the unmatched sample, has turned out to be insignificant in the matched sample but in both unmatched and matched samples the scientific hand-wash practice has shown to be associated with lower diarrhoea risk than the unhygienic hand wash[17]. To note, the information relating to hand wash practice after defection as collected by MICS 2006 do not relate to all members of the household but to the household head only viz., whether s/he washes hand after own or child's defecation, and does not reflect child's behaviour as such, so, there is some imperfection in the definition and many children below 5 years in Bangladesh use own hand for cleaning after defecation.

Table 15: PSM Estimates of ATT for Probability of Diarrhea Incidence for Hygienic Practices based on Kernel Matching: MICS 2006 (new)

		Treatment	Control	Δ	S.E.	T-Stat
distance of water	Unmatched	0.069	0.089	-0.0198	0.0049	-4.03***
	Matched	0.071	0.206	-0.1349	0.0298	-4.53***
disposal of child stool	Unmatched	0.070	0.089	-0.0191	0.0050	-3.80***
	Matched	0.071	0.101	-0.0301	0.0154	-1.96**
hand wash after defecation	Unmatched	0.067	0.081	-0.0136	0.0032	-4.29***
	Matched	0.069	0.075	-0.0061	0.0213	-0.28

Note:*, **, and*** denote statistical significance at the 10, 5, and 1percent levels, respectively.

5.3 Balancing Test

In order to assess the matching quality, the 'balancing test' has been performed for 2007 data (Table 16). Before matching, the differences in observable characteristics between the treated and control households are expected. However, when the 'kernel type' matching has been performed, the differences in observable

[17] BDHS has no category as 'do not wash hand after defecation'

characteristics between treated and control households have reduced significantly. Table 16 presents observable characteristics (e.g. age of household head, mother's education, parent's education, , etc.) of both treated and control households and after kernel type matching. After such matching is performed, the differences in most of the observable characteristics have come out insignificant particularly in case of 'watsan'. This is expected, as ATT has been estimated based on the propensity scores of those households who share similar observable characteristics. The result of 'balancing test' confirms about the quality of kernel type matching and estimates of ATT using 2007 data are reliable (for 1996/97 see Annex 2, Table 4).

Table 16: Major Observable Characteristics of Households after Matching (new)

	Water			**Sanitation**			**WatSan**		
Variable	**Treated**	**Control**	**|t/z| stat**	**Treated**	**Control**	**|t/z| stat**	**Treated**	**Control**	**|t/z| stat**
Age of Household Head (HH)	40.93	43.91	-2.23	40.59	40.44	-0.64	40.56	41.43	-2.56
Age of Household Head (HH)	0.91	0.87	0.84	0.91	0.90	2.93	0.92	0.91	1.42
Household Size	5.99	5.45	4.62	5.98	5.87	-1.07	6.07	6.03	-0.57
Mother Education (% of Mothers in Each Category)									
Illiterate	0.24	0.17	6.00	0.28	0.28	1.95	0.30	0.32	0.85
Primary	0.34	0.39	-2.01	0.34	0.32	2.35	0.35	0.33	1.16
Secondary	0.35	0.38	-1.78	0.35	0.38	-4.14	0.33	0.33	-1.91
Higher	0.06	0.06	-2.25	0.02	0.02	-0.66	0.03	0.03	-0.68
Father Education (% of Fathers in Each Category)									
Illiterate	0.36	0.25	5.44	0.36	0.33	3.42	0.34	0.36	2.23
Primary	0.30	0.30	-0.32	0.34	0.33	1.44	0.35	0.32	1.19
Secondary	0.24	0.35	-5.03	0.25	0.29	-4.84	0.25	0.26	-3.25
Higher	0.10	0.10	0.23	0.05	0.05	-1.27	0.06	0.06	-1.32
Religion (Islam=1)	0.93	0.98	-3.37	0.91	0.93	-1.60	0.23	0.26	1.16
Having Homestead Land	0.72	0.77	-1.34	0.73	0.73	0.49	0.73	0.71	1.55
Having TV	0.53	0.48	-5.77	0.51	0.52	-2.94	0.52	0.48	-0.90
Living in Urban	0.36	0.20	0.40	0.35	0.30	0.34	0.31	0.35	-4.07

VI. Concluding Remarks

Using BDHS data of recent years gathered at 10 years apart i.e. in 1996/97 and 2007 and MICS 2006 the present study using the latest statistical technique called PSM tried to understand the impact of interventions of water and sanitation on childhood diarrheal diseases. The evidence gathered in some cases however, may not be very conclusive, yet, they are illuminating.

The PSM analysis with both BDHS 1996/97 and 2007 data suggested that access to improved sources for drinking water has no significant impact on diarrhoea risk. But a detailed analysis bifurcating the improved water sources into pipe and tube well revealed that piped water has no impact at all on incidence of childhood diarrhoea and this is noted both with 1996/97 and 2007. The tube well water on the other hand showed a negative impact on diarrhoea risk in 1996/97 but such impact could not be found in 2007. This tend to suggest that the tube well water in Bangladesh in recent years has lost its quality or efficacy in reducing diarrhoea risk. However, as gathered from the FGDs conducted for the study, the absence of any impact of the tube well water may be circumstantial one related to climate and other water related changes taking place in the country that are forcing tube well users to resort to some other unsafe sources for drinking water in some parts of the country and in other, during some seasons of the year and in some other areas on a continuous basis due to arsenic contamination of tube well water. However, as experts guess, some recent practices of not maintaining a safe distance between water source and sanitation also may be interfering with the quality of tube well water as animal and human faecal matters leeches down to the ground water layer through the latrine pits when the rules for safe distance between the latrine and water point is not maintained. In case of non-impact of piped water also although our observation is less reliable due to very small size of treatment and control groups, yet, the probable faulty water-sewerage management in the country may also influence the quality of piped water neutralizing the effect of such water. So the ultimate outcome for the analyses is that the present analyses could say very little about the impact of water intervention on diarrheal diseases risk in the country at present. The data at hand also, is of little help in this regard.

The present analyses however tend to suggest that the access to improved sanitation at present (2007) has some negative impact on the diarrhoea risk in Bangladesh; the detailed comparison of the diarrheal incidence among children who have access to improved sanitation in comparison to those who have access neither to improved water nor to sanitation has shown significantly (at 10% level) lower incidence of diarrhoea. However, such an impact is found absent with the 1996/97 BDHS data. One reason for this could be that according to WHO /UNICEF definition only 25% households in 2007 are found to have an access to improved sanitation and this proportion definitely was much smaller 10 years ago in 1996/97 which could have little overall impact on environment sanitation necessary to protect children from such diseases.

The present study using latest round of BDHS data of 2007 however has found a significant impact of combined access to improved water and sanitation on reducing the diarrhoea. This is noticed both in overall and detailed comparisons of treated and control groups using 2007 data. The ATT estimates using 2007 data showed that the watsan (water and sanitation combined) currently reduces the mean probability of childhood diarrhoea incidence for the treatment group by 31.5% per cent as compared to similar individuals who have either isolated access to water or sanitation or have access to improved sources for none. In the case of detailed comparison taking only the last group i.e. 'who have access to improved sources for none' as the control group, the reduction is noted to be significant and of much higher degree (68%). Such influence of 'watsan' however is found absent in 1996/97 and one of the reason for this may be that the definition for improved sanitation in 1996/97 was not that strict. However, as the analyses with latest round of BDHS 2007 tend to suggest that for Bangladesh at present there is a strong case for rethinking of public policy in terms joint investment in water and sanitation measures to reduce the diarrhoea in future; but the evidence further suggest that such investment has to be done in a very cautious or judicious manner so water and sanitation does interfere with each other. For a combined intervention there are support from the MICS 2006 data as well, this data too indicated the importance of combining water and sanitation in reducing the incidence of childhood diarrhoea[18] in Bangladesh.

Further analyses using MICS 2006 data interestingly suggest that other than water and sanitation intervention, for reducing childhood diarrhoea in the country the hygienic practices/behaviour now have a great role for this; simple health-seeking behaviour like hand-wash practices after defecation, hygienic disposal of child stool and availability of adequate water facilitating personal hygiene and cleanliness can play a great role in this regard; all of them are found significant player in reducing diarrhoea risk in the country. Thus, planners and policy-makers should take note of these factors as well while rethinking about appropriate policies for reduction of diarrheal diseases which are still a major cause of child death in the country.

However, in this connection it may be mentioned that maintaining current high level coverage for safe drinking water through the tube well may pose a great challenge in future to the country. This is for two reasons primarily; one is the arsenic contamination of the tube well water representing the dominant source of safe drinking water in Bangladesh. The current contamination of ground water by arsenic in Bangladesh is the largest poisoning of a population in history, with millions of people exposed to it (Smith et al 2000). As gathered from the FGDs this is causing people either to go for unimproved sources for drinking water or remain at the risk of arsenic poisoning through consumption of arsenic contaminated water. The other challenge for safe drinking water comes from the climate change; following climate change the sea level has been rising which through enhancing salinity has been affecting both the ground and surface water in coastal belts. Also, as learnt from the

[18] The MICS results do not form the core of the present paper. However, the relevant results are available from the authors on request.

FGDs, the climate change has been causing increasing prevalence of droughts in parts of the country and causing lowering of the ground water level which in turn render tube wells of those areas water less for few months in pre-monsoon period. So for all these reasons the availability of both surface water and drinking water from tube wells in future may get adversely affected. Hence, the sustainability of current availability of safe drinking water in future would depend much on how successfully the above problems could be addressed in the country.

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Annex 1

Table 1: PSM Estimates of ATT for Probability of Diarrhea Incidence for Different Interventions- BD HS 2007 (new)

		Treatment	Control	Δ	S.E.	T-Stat
Non-drinking Water (Improved=1, 0 Otherwise)	Unmatched	0.093	0.092	0.0005	0.009	0.06
	Matched	0.098	0.086	.012	0.041	0.30
Drinking and Non-drinking Water (Improved=1, 0 Otherwise)	Unmatched	0.093	0.092	0.0005	0.009	0.06
	Matched	0.098	0.086	.012	0.041	0.30

Note:*, **, and*** denote statistical significance at the 10, 5, and 1percent levels, respectively.

Table 2: Use of Common Support for piped and tube well water: (new) (caliper .0001)

		common support		Total
		off support	on support	
			BDHS 2007	
piped water	Control	221	8	229
	Treated	359	6	365
	Total	580	14	594
tube well water	Control	51	178	229
	Treated	1645	3234	4879
	Total	1696	3412	5108
			BDHS 1995/96	
piped water	Control	275	10	285
	Treated	168	8	176
	Total	443	18	461
tube well water	Control	26	259	285
	Treated	1991	2936	4927
	Total	2017	3195	5212

Table 3: PSM Estimates of ATT for Probability of Diarrhea Incidence for improved water, sanitation and watsan (control group: no access to improved water and sanitation) based on Kernel Matching: BDHS 1995/96 (new)

		Treatment	Control	Δ	S.E.	T-Stat
Water	Unmatched	0.0768	0.842	-0.0074	0.016	-0.45
	Matched	0.0751	0.0898	-0.0147	0.029	-0.51
Sanitation	Unmatched	0.0768	0.842	-0.0076	0.017	-0.44
	Matched	0.067	0.046	0.021	0.06	0.35
WatSan	Unmatched	0.0764	0.842	-0.0078	0.017	-0.45
	Matched	0.088	0.0735	0.0147	0.047	0.31

Table 4: Use of Common Support for Water, Sanitation and WatSan (control group: no access to improved water and sanitation): BDHS 1996/97 (new) (caliper .0001)

Intervention		Common Support		Total
		Off support	On support	
Water	Control	19	266	285
	Treated	2120	2983	5103
	Total	2139	3249	5388
Sanitation	Control	185	100	285
	Treated	1263	239	1502
	Total	1448	339	1787
WatSan	Control	161	124	285
	Treated	1194	272	1466
	Total	1355	396	1751

Table 5: Use of Common Support for Hygienic Practices: MICS 2006 (new) (caliper .0001)

Interventions		common support		Total Cases
		off support	on support	
distance of water	Control	56	2980	3036
	Treated	4583	22,527	27,110
	Total	4639	25,507	30,146
disposal of child stool	Control	1273	12,677	13,950
	Treated	558	3,385	3,943
	Total	1831	16,062	17,893
hand wash after defecation	Control	101	9,259	9,360
	Treated	3436	18,754	22,190
	Total	3537	28,013	31,550

Annex 2

Table 1: Coefficients of Binomial Logit Model Estimated for Generating Propensity Score: 1996/97 (new)

Dependent Variable: Treatment=1, Control=0	Water		Sanitation		WatSan	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant	1.89	0.64***	-3.19	0.41***	-3.33	0.42***
Age of Household Head (HH)	-0.02	0.03	0.05	0.02***	0.06	0.02***
Squared Age of HH	0.00	0.00	0.00	0.00***	0.00	0.00***
Gender of HH (Male=1)	0.42	0.24*	-0.06	0.15	-0.05	0.15
Household Size	0.03	0.03	0.04	0.01***	0.04	0.01***
Respondent's Education (Reference Category: Below Primary)						
Primary	0.15	0.15	0.68	0.09***	0.68	0.09***
Secondary	0.46	0.27*	0.97	0.12***	1.00	0.12***
Higher	.	.	2.57	0.50***	2.68	0.50***
Partner's Education (Reference Category: Below Primary)						
Primary	0.19	0.14	0.50	0.09***	0.48	0.09***
Secondary	0.21	0.20	0.99	0.10***	0.98	0.10***
Higher	0.41	0.46	1.66	0.18***	1.59	0.18***
Respondent Employed, (Yes=1)	0.03	0.13	-0.04	0.08	0.00	0.08
Urban or Rural (Urban=1)	1.80	0.48***	1.54	0.12***	1.57	0.12***
Religion (Muslim=1)	0.07	0.20	-0.16	0.12	-0.16	0.12
Living in Slum(Yes=1)	0.56	1.06	-0.88	0.25***	-0.85	0.25***
Any Agricultural Land (Yes=1)	0.10	0.13	-0.10	0.08	-0.12	0.08
Whether have TV (Yes=1)	1.45	0.52	1.34	0.13***	1.35	0.13
Division Dummy (Reference Category: Barisal)						
Chittagong	1.92	0.29***	0.09	0.13	0.15	0.13
Dhaka	1.07	0.20***	-0.34	0.13***	-0.23	0.13*
Khulna	1.19	0.28***	0.52	0.14***	0.62	0.14***
Rajshahi	0.74	0.20***	-0.30	0.13**	-0.20	0.13
Sylhet	-0.38	0.19**	-0.29	0.15**	-0.18	0.15
Pseudo- R^2	0.1023		0.2483		0.2492	
Log-likelihood	-1094.1402		-2525.3487		-2498.6856	
Prob>Chi^2	0.0000		0.0000		0.0000	
N	5424		5553		5555	

Note:*, **, and*** denote statistical significance at the 10, 5, and 1percent levels, respectively

Note: WatSan=1 if both water and sanitation are improved, and WatSan=0 if otherwise.

Table 2: Use of Common Support: 1996/97 (new) (caliper .0001)

Intervention		Common Support		Total
		Off support	On support	
Water	Control	62	259	321
	Treated	3909	1194	5103
	Total	3971	1453	5424
Sanitation	Control	2701	1224	3925
	Treated	1010	618	1628
	Total	3711	1842	5553
WatSan	Control	2745	1218	3963
	Treated	1001	591	1592
	Total	3746	1809	5555

Table 3: PSM Estimates of ATT for Probability of Diarrhoea Incidence for Different Interventions based on Kernel Matching: 1996/97 (new)

		Treatment	**Control**	**Δ**	**S.E.**	**T-Stat**
Water	Unmatched	0.0768	0.0841	-0.007	0.0154	-0.47
	Matched	0.0779	0.108	-0.0301	0.0279	-1.08
Sanitation	Unmatched	0.0749	0.0774	-0.0025	0.0078	-0.32
	Matched	0.0760	0.089	-0.0129	0.0194	-0.67
WatSan	Unmatched	0.0747	0.0777	-0.0030	0.0079	-0.38
	Matched	0.0677	0.0745	-0.0068	0.019	-0.36

Note:*, **, and*** denote statistical significance at the 10, 5, and 1percent levels, respectively

Table 4: Major Observable Characteristics of Households after Matching DHS 1996/97

	Water			Sanitation			WatSan		
Variable	**Treated**	**Control**	**|t/z| stat**	**Treated**	**Control**	**|t/z| stat**	**Treated**	**Control**	**|t/z| stat**
Age of Household Head (HH)	40.45	40.47	-1.78	40.10	39.17	2.96	39.92	39.92	-0.98
Sex of Household Head (HH)	0.95	0.94	0.57	0.95	0.97	-1.16	0.94	0.96	-1.45
Household Size	6.50	6.44	-2.73	6.30	5.99	1.38	6.57	6.45	-3.36
Mother Education (% of Mothers in Each Category)									
Illiterate	0.53	0.52	6.27	0.63	0.55	1.32	0.57	0.53	7.76
Primary	0.33	0.35	-4.23	0.25	0.34	-0.33	0.33	0.38	-6.56
Secondary	0.14	0.13	-3.93	0.11	0.11	-1.62	0.10	0.09	-2.99
Higher	0.00	0.00	1.01	0.00	0.00	.	0.00	0.00	0.70
Father Education (% of Fathers in Each Category)									
Illiterate	0.41	0.44	5.31	0.54	0.53	0.01	0.45	0.44	6.29
Primary	0.33	0.30	-1.00	0.26	0.22	1.38	0.34	0.33	-1.74
Secondary	0.22	0.22	-4.95	0.15	0.19	-0.59	0.19	0.21	-5.91
Higher	0.04	0.02	-1.76	0.04	0.04	-0.87	0.02	0.02	-2.32
Religion (Islam=1)	0.92	0.91	2.12	0.92	0.90	0.05	0.90	0.93	-1.29
Having Homestead Land	0.55	0.53	-1.51	0.56	0.54	1.09	0.55	0.55	-2.91
Having TV	0.07	0.05	-2.70	0.04	0.02	1.07	0.05	0.05	-1.86
Living in Urban	0.10	0.11	-5.29	0.05	0.05	-2.93	0.07	0.06	-0.89
Living in Slum	0.02	0.02	-1.21	0.01	0.02	-2.05	0.02	0.02	1.19