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Technical Annex:
Health Impacts of Air and Water Pollution in Bangladesh

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Health Impacts of Air and Water Pollution in Bangladesh

Executive Summary

1. The health impact of air and water pollution in Bangladesh has been estimated using the most recently available data and widely accepted methodologies reported in the literature. These estimates range between 1.20-3.35% of GNI. Even with the benefit of including more recent data, the results obtained still contain many uncertainties arising from the variety of assumptions made in order to arrive at the values reported.

Ambient Air Pollution

2. The most important pollutant from the health point of view in Dhaka is particulate matter (PM_{10} and $PM_{2.5}$). The levels of these parameters are much higher than the proposed revised standards. The levels of other airborne pollutants are still within the proposed revised standards with the exception of NO_2 which is now close to the standard. The number of cases of mortality and morbidity that can be avoided per year if the PM_{10} pollution level is reduced by a modest 20% of the current level, or to the proposed national standard, are found to be between 1,200-3,500 and 80- 235 million cases respectively. The costs involved are between US$ 169 –492 million per year, which correspond to 0.34 –1.0% of GNI in the WTP based estimates.

Indoor Air Pollution

3. The disease burden due to indoor air pollution has been estimated using WHO recommended fuel based methodology. If the indoor air pollution can be reduced in range from a modest 20% of the current level to 80% of the current level (i.e., approximately equivalent to the reduction to proposed national ambient air quality standard), then 7,600-30,400 deaths and about 0.30- 1.20 million DALYs can be avoided per year. The economic costs of these health impacts are between US$ 114- 458 million per year in the human capital approach. In terms of GNI, these correspond to 0.23 – 0.92 % per year. As some new exposure data have become available recently, these also have been used to calculate the indoor air pollution health burden using the same methodology as for ambient air pollution. It is shown that comparable health burden are obtained in both the methods but cost estimates are much lower in the human capital approach.

Water Supply and Sanitation

4. A total of between 0.82 –1.94 million DALYs can be saved through the provision of clean water and sanitation in Bangladesh. The economic value of water-related mortality and morbidity has been estimated by using the human capital approach and also the GNI-scaled USEPA annualized value of life approach. This latter approach gives higher values compared to the human capital approach. The costs that can be saved per year are estimated to be between US$313–739 million in the human capital approach method. In GNI terms, these correspond to 0.63–1.43 % per year. Compared to the earlier (1997) study, the water-related health costs have increased somewhat. This increase reflects the impact of increase in the population and per capita GNI. Reduced access to clean water as a result of Arsenic contamination has not been considered.

Health Impacts of Air and Water Pollution in Bangladesh

1. Introduction

1. Analysis of the overall burden of diseases in the south and east Asia regions shows that environmental factors account for about a fifth of the total[1]. The main contributors to this burden are ambient air pollution, indoor air pollution and diseases arising from the lack of access to clean water. It is necessary to quantify the nature and the extent of the problems and evaluate their costs in order to prioritize key environmental challenges. The first such work on Bangladesh was done by Brandon [2] in 1997 and it was based on the rather sparse data available at the time. However, this pioneering study provided a first estimate of the economic cost of environmental pollution and helped policy-makers to realize the importance of environmental factors in the national economy. The present work is an attempt to update that work with more recent data.

2. Important developments have taken place in the field of ambient air quality since 1997, both in terms of monitoring and actions to reduce or limit the emissions. Six criteria pollutants (PM_{10}, $PM_{2.5}$, CO, SO_2, NO_2, O_3) are now being regularly measured in Dhaka since April, 2002 under the World Bank financed Air Quality Management Project (AQMP) [3]. These measurements are being made using state of the art equipment and methods conforming to USEPA Federal Reference Methods (FRM). The data are quality assured and the station is located so that it provides the average population exposure to the pollutants. The Bangladesh Atomic Energy Commission (BAEC) has also been monitoring PM_{10} and $PM_{2.5}$ in Dhaka and Rajshahi. They also monitor lead (Pb) levels through the chemical analysis of PM samples and elemental or black carbon through reflectance measurements. These measurements have shown that PM_{10} and $PM_{2.5}$ are the most important pollutants from the health point of view [4]. The level of the other criteria pollutants are still within the proposed revised standards with the exception of NO_2.

3. Regarding actions to reduce air pollution, one of the major achievements was the introduction of unleaded gasoline from July, 1999. The lead level in air has now fallen by about two thirds of the high previous level to well within the recently revised standard [5,6]. In addition, the two-stroke three-wheelers in Dhaka which contributed a large proportion of the PM pollution were withdrawn from 1st of January, 2003. This lead to the immediate decline of PM_{10} and $PM_{2.5}$ levels by about 30% and 40% respectively[7]. The new data available from the measurements at CAMS and by BAEC have been used for health impact and their cost evaluation.

4. Recently, WHO has published a report on the assessment of health burden of Indoor Air Pollution[8] . The methodology in this report has been used in the current work. Until very recently, there was an almost complete data vacuum regarding indoor air pollution in Bangladesh. Fortunately, a recent study by DECRG of World Bank has produced the first measured data [9-10] on this important problem. This work was still in progress while the present work was done and only the provisional data were available at the time. Hence, these were used here to estimate the health impact and the cost of indoor air pollution.

5. In the case of access to clean water, the recently published data on water and sanitation by the Government of Bangladesh (GOB)[(13)] have been used to update Brandon's 1997 estimates. Some estimates of the negative impact of Arsenic contamination are now available in literature [(14)]. However, the impact of Arsenic contamination has not been considered here and the reasons are discussed in the Annex-III.

2. Ambient Air Pollution

2.1 Extent of the problem

6. Economic, industrial and demographic growth are driving urbanization in Bangladesh as in other developing countries. The capital city Dhaka now has a population in excess of 12 million. Emergence of such urban conurbations of extremely high population density is affecting the quality of life in many different ways. Uncontrolled emissions from motor vehicles and other economic activities give rise to severe air and other forms of pollution. High levels of emission of air pollutants in a small area exceed the processes of dilution and dispersal, leading to severe episodes of ambient air pollution, disproportionately affecting the urban poor. There are now three cities in Bangladesh which have populations in excess of one million. In these cities, severe episodes of air pollution can be observed with the unaided eye. In addition, there are eighteen other cities in the country where population now exceeds 100,000, and air pollution is a growing concern. The details on these can be found in Annex-1. Fairly comprehensive air quality data are being collected only for Dhaka, both by the AQMP and BAEC[(3-5)]. The summary of air quality data for Dhaka obtained at the CAMS is shown in Table-1.

Table 1 – Average values for Criteria Pollutants Measured at CAMS, Dhaka with standard deviations during 2003 along with Bangladesh Standards[(3)].

Pollutant	Averaging Time	WHO Guidelines	Proposed Bangladesh Standards	Annual average Concentration during 2003
CO	1 hour	30 mg/m^3	40 mg/m^3(35 ppm)	---
	8 hour	10 mg/m^3	10 mg/m^3 (9 ppm)	1.0 ± 0.8ppm
SO_2	24 hour	125 $\mu g/m^3$	365 $\mu g/m^3$ (140 ppb)	----
	Annual	50 $\mu g/m^3$	80 $\mu g/m^3$ (30 ppb)	7±8 ppb
NO_2	24 hour	---	---	---
	Annual	40 $\mu g/m^3$	100 $\mu g/m^3$ (53 ppb)	59±58 ppb
Ozone	1 hour	---	235 $\mu g/m^3$ (120 ppb)	
	8 hour	120 $\mu g/m^3$	157 $\mu g/m^3$ (80 ppb)	28±20 ppb
PM_{10}	24 hour	---	150 $\mu g/m^3$	
	Annual	---	50 $\mu g/m^3$	133 ± 78$\mu g/m^3$
$PM_{2.5}$	24 hour	---	65 $\mu g/m^3$	---
	Annual	---	15 $\mu g/m^3$	76 ± 57$\mu g/m^3$

7. It can be seen from Table-1 that the main pollutant of concern in Dhaka is particulate matter. Both PM_{10} and $PM_{2.5}$ levels are extremely high, being much above the proposed standard. The NO_2 levels are also now close to the limit and may become a concern in the future. Levels of other pollutants are still low and thus are not important from health point of view. Lead (Pb), one of the criteria pollutants, is not shown in the table. The Pb level is now sufficiently low (i.e., around $100 ng/m^3$) that airborne lead is no longer considered a health issue [(5)]. However, blood lead levels in children are still high[(6)], indicating that other sources may exist. Based on this picture, the following health impact calculations are limited to PM_{10} only.

8. There is no air quality data for the other two cities (Chittagong and Khulna) with more than one million population. For impact calculation the pollution level in these cities is assumed to be same as Dhaka. As in Dhaka, there are high levels of public complaint about the air quality in these two cities. The banning of two-stroke three-wheelers in Dhaka has contributed to the improvement in the air quality in Dhaka, but the influx of these vehicles has made the air quality worse in other cities

9. In Rajshahi, one of the 18 cities with a population over 100,000, data on PM levels are available from BAEC measurements. The yearly average PM_{10} level is reported to be $63 \pm 25\ \mu g/m^3$. This ambient level has been used as an estimate for all the 18 cities. The detail data on the cities can be found in annex-1.

2.2 Methodologies

10. For the calculation of health impacts and their cost, a bottom-up approach has been adopted. From the measurements, pollution levels of PM_{10} have been quantified and exposure levels have been equated to these levels as explained below. The coefficients relating pollution and exposure levels with the epidemiological data available in the literature[(10,11)] have been used to estimate the number of cases of sickness and death. Estimates of the number of cases have been related to the Willingness-To-Pay (WTP) data available in literature using scaling laws. The details of the procedure adopted are to be found in annex-1. Two scenarios have been used to calculate health cost savings. The first scenario is the reduction of pollution levels by 20%, which is considered a possible achievement level with low cost measures, and the second scenario is the reduction of the pollution level to the proposed Bangladesh standards, which is a long term goal.

2.3 Summary of the results

11. An important determinant of the health relevance of air quality data is the pattern of exposure. This varies significantly among the population, but is usually consistent in time for a given population group. Exposure can be defined as the event in which an individual remains in contact with a specific concentration of a pollutant for a certain period of time. Exposure assessment consists of describing and quantifying the relevant conditions and characteristics of human exposure. The available exposure data for Dhaka

have been measured as 24-hour average mass-based concentrations of PM_{10} at a suitable location using fixed monitoring equipment. As these measurements were taken for regulatory purpose, such data are usually insufficient for personal exposure assessment since information about diversity in terms of time spent at different places are not captured in such measurements. However, in the present case we shall take the yearly average of PM_{10} level as the measure of exposure. A significant fraction (probably as high as 20%) of the city population live and work near the traffic canyons where the pollution levels may be higher by a factor of 2 or even more. The present calculations may therefore be considered conservative. The results of the calculations are shown in Tables 2 and 3. The number of cases of mortality and morbidity that can be avoided if the PM_{10} pollution level is reduced in a range from a modest 20% of the current level up to the proposed national standard are shown in this table. It can be seen that about 1,200-3,500 deaths and about 80-235 million cases of sickness can be avoided per year in the two scenarios. The costs involved are between US$169 –492 million. In terms of GNI, these correspond to 0.34 –1.0% per year.

Table-2 Annual Reduction in Mortality and Morbidity Cases: Two Scenarios

		Reduction in 3 Major Cities		**Reduction 18 Cities**		**Total**	
Sl	Health Effects	By 20%	To National Standard	By 20%	To National Standard	By 20%	To National Standard
1	Mortality	1,069	3,335	189	195	1,258	3,530
2	Chronic Bronchitis	18,310	57,133	1,775	1,831	20,085	58,964
3	Resp Hospital adm.	5,809	18,127	563	581	6,373	18,708
4	Asthma attack	789,116	2,462,278	76,484	78,907	865,599	2,541,185
5	Emergency room visits	113,962	355,595	11,046	11,396	125,007	366,991
6	Restricted day activities	17,053,611	53,212,396	1,652,888	1,705,263	18,706,500	54,917,659
7	Lower respiratory illness	312,538	975,213	30,292	31,252	342,830	1,006,465
8	Respiratory symptoms	54,751,067	170,839,796	5,306,642	5,474,793	60,057,709	176,314,589
	Total Morbidity	73,044,414	227,920,539	7,079,689	7,304,022	80,124,103	235,224,561

Table-3 Savings per year in health cost in two scenarios (US$ million)

		Reduction in 3 Major Cities		**Reduction 18 Cities**		**Total**	
Sl	Health Effects	By 20%	To National Standard	By 20%	To National Standard	By 20%	To National Standard
1	Mortality	30.2	94.2	5.3	5.5	35.5	99.7
2	Chronic Bronchitis	62.3	194.3	6.0	6.2	68.3	200.5
3	Resp Hospital adm.	0.4	1.3	0.0	0.0	0.5	1.4
4	Asthma attack	0.9	2.7	0.1	0.1	1.0	2.8
5	Emergency room visits	0.3	0.8	0.0	0.0	0.3	0.8
6	Restricted day activities	15.8	49.2	1.5	1.6	17.3	50.8
7	Lower respiratory illness	0.2	0.7	0.0	0.0	0.3	0.8
8	Respiratory symptoms	42.0	131.1	4.1	4.2	46.1	135.3
	Sub-Total(Morbidity)	121.8	380.1	11.8	12.2	133.6	392.3
	Total	152.0	474.4	17.2	17.7	169.2	492.1

3. Indoor Air Pollution

3.1 Extent of the problem

12. The issue of health hazards due to air pollution in Bangladesh has traditionally been linked to urban outdoor air quality problems. Recent studies in developing countries demonstrate, however, that illnesses arising from the use of traditional fuels in the home pose a serious health risk, especially to women and children in rural and urban poor households. These households in Bangladesh continue to be dependent on traditional biomass fuels like dung, firewood and crop residues. Only a small fraction of the households have access to kerosene, far less other clean fuels such as LPG. According to available information, a total of about 70,000 tons of LPG is sold in Bangladesh which is mostly in urban areas. Biomass-fuelled cook-stoves have high emission rates of air pollutants and the houses involved are generally inadequately vented.

13. Continued exposure to smoke from traditional fuels has been shown to cause Acute Lower Respiratory Illnesses (ALRI), Chronic Obstructive Pulmonary Diseases (COPD) and lung cancer among other diseases. ALRI includes viral and bacterial infections of the lungs and respiratory tract, the most severe and fatal being bacterial pneumonia. The burden of disease due to ALRI on a per capita basis is much higher in developing countries than in developed countries. Severe indoor air pollution from biomass burning for cooking is an important contributory environmental factor in Bangladesh.

3.2 Methodologies

14. Different methods to estimate the burden of disease from indoor air pollution in developing countries have been reviewed in a recent WHO publication[8]. The more widely used approaches are the fuel based and the pollutant based method. In the fuel-based approach some fraction of the burden due to selected diseases are attributed to indoor air pollution using a step-wise procedure. The contribution for all the relevant diseases are summed to obtain the total burden of diseases in DALYs (Disability Adjusted Life Years) and number of deaths. By contrast, in the pollutant-based approach, the population exposures to an indicator pollutant, generally PM_{10}, is estimated in terms of some measure of concentration-time. The exposure-response relationship for the indicator pollutant is then used to determine excess morbidity and mortality. Both the methods have advantages and disadvantages and these usually lead to widely different results. The WHO study recommends the fuel based approach. However, both the approaches are used here for comparison and to illustrate the uncertainties involved in the calculations.

3.3 Health Burden using Fuel-Based Methodology

15. In this method a stepwise procedure is used in order to arrive at the estimate for the health burden due to IAP in Bangladesh. The steps involved are:

(i) Collection of data relevant to calculation;
(ii) Calculation of attribute functions;
(iii) Calculation of the attributable burden;
(iv) Summation of all the burdens due to individual diseases; and
(v) Estimation of uncertainty.

The problem with this method is that reasonably reliable Bangladesh specific epidemiological and solid fuel use (SFU) data are not available from the primary national sources. For the DALYs associated with indoor air pollution, it is necessary to depend largely on proxy data from WHO SEAR D region and this source has also been used for SFU data. Such data do not capture the variety of local complexities in the exposure to indoor air pollution. All types of solid fuel are not equivalent in terms of pollution and in a recent study in Bangladesh it has been found that cross-household variation is strongly affected by the structural arrangements such as cooking locations, construction materials and ventilation practices[(9,10)]. The details of the methodology and calculations are given in annex-II.

3.3.1 The Attributable burden of DALYs and Death to SFU in Fuel-Based Method

16. The attributable burden of disease due to SFU in Bangladesh for different diseases is shown in table-4 below (details in Annex-II).

Table-4 Attributable burdens from SFU using fuel based methodology

		DALYs (000)			Deaths (000)		
Sl	Disease, sex, age group	low	central	High	low	central	high
1.	ALRI<5yrs	1107	1326	1481	31	38	42
2.	COPD, Women≥30yrs	139	170	197	8	10	11
3.	COPD, men≥30yrs	0	0	0	0	0	0
4.	Lung cancer, Women≥30y	0	9	14	0	1	1
5.	Lung cancer, men≥30y	0	0	0	0	0	0
	Total	1246	1505	1692	39	49	54

17. The low and the high values in table-4 do not include the uncertainties in the exposure estimates. The results of RMS combination of these uncertainties with the values in table-4 are shown in table-5. Comparison for DALYs lost and the number of attributable deaths for India and Bangladesh per 1000 population is shown in Table-6. The numbers obtained are very similar which is not surprising. The same WHO data for disease burden (for SEAR D region) have been used by population scaling in both the cases. The only country specific input is household SFU data. In Bangladesh, the percentage of households using biomass is higher whereas in India the percentage of households using coal is higher. These differences are offset by one another and results are almost similar except for men≥30 years. The numbers for men≥ 30 years in India are wholly for coal smoke.

Table-5 Attributable burdens from SFU for Bangladesh with exposure uncertainty

Sl		DALY(000)			Deaths(000)		
	Disease, sex, age group	low	central	High	low	central	high
1.	ALRI<5yrs	1097	1326	1495	31	38	42
2.	COPD, Women≥30yrs	138	170	198	8	10	11
3.	COPD, men≥30yrs	0	0	0	0	0	0
4.	Lung cancer, Women≥30y	0	9	14	0	1	1
5.	Lung cancer, men≥30y	0	0	0	0	0	0
	Total	1235	1505	1707	39	49	54

Table-6 DALYs lost and Deaths per 1000 population in Bangladesh and the corresponding values for India from literature (see annex-II)

Sl.	Disease, sex, age group	Bangladesh		India	
		DALY	Death	DALY	Death
1.	ALRI<5yrs	78.93	2.26	78.72	2.22
2.	Women≥30yrs	7.93	0.47	6.14	0.34
3.	Men≥30yrs	0	0	3.7	0

3.3.2 Health Cost of Indoor Air Pollution due to SFU in the Fuel-Based Method

18. Total DALYs lost due to indoor air pollution SFU are between 1.24 –1.71 million for Bangladesh (Table-5). The economic value of the DALYs lost can be estimated by using the human capital approach. This implies that the statistical value of one DALY is equal to the annual average productivity of a worker in Bangladesh. This may be set equal to per capita GNI for Bangladesh. A higher estimate for the cost of a DALY is obtained if GNI-scaled USEPA annualized value of life is used. This value is 2.73 times higher than the GNI as reported by Brandon[(2)].

19. The results of the calculations for cost savings by suitable interventions in two scenarios are shown in Table-7. The first scenario involves 20% reduction in DALYs which can probably be achieved at low cost through actions such as kitchen ventilation improvement. The second scenario involves reduction of the exposure level to proposed national ambient standards. As the measured exposure has been estimated to be about 250 $\mu g/m^3$, it would require about 80% reduction in the exposure level to reach the standard of 50 $\mu g/m^3$ if a linear relationship between DALYs saved and exposure is assumed. It can be seen that about 8-40 thousand deaths and about 0.30- 1.20 DALYs (central estimate) can be avoided per year in the two scenarios (Tables-7). The costs involved range from about US$114 to US$458 million per year. These savings correspond to 0.22–0.92 % of GNI per year.

Table-7 Cost for possible savings in DALYS (million) and their Cost

Estimates	DALYs Lost (million)	Savings in DALYs (million)		Cost per DALY	Savings (US$ Million)	
		Scenario-1 (20%)	Scenario-II (80%)	US$	Scenario-1	Scenario-II
Low	1.246	0.2492	0.9968	380	94.7	378.8
Central	1.505	0.301	1.204	380	114.4	457.5
High	1.692	0.3384	1.3536	380	128.6	514.4

3.4 Pollutant-based Method

20. In the pollutant-based method, data on the exposure patterns for different populations are needed. Such patterns are even more important in determining the health relevance of indoor air quality than ambient air. In the case of indoor air pollution, exposure levels are significantly different for men, women and infants. Men in the rural areas mostly spend their time outside the household. Women, however, spend significant amounts of time in the kitchen and infants (0-4 years) spend most of the time inside the household. In dealing with indoor air pollution, one should be aware of the major influence of lifestyle and cultural factors in determining health impacts. In the absence of reliable data on these factors, exposure to indoor environmental factors is inadequately characterized and this leads to large uncertainties in health risk assessments for indoor air pollution.

21. Some provisional data are available on indoor air pollution from rural and peri-urban areas in Bangladesh from the DECRG, WB study[(9,10)]. The measurements were taken in five different kitchen types and for five different fuels which included firewood, cow dung, crop residues (rice husk/straw), bagasse (including jute stick/sawdust) and cleaner fuel like kerosene. The un-weighted 24 hour averaged PM_{10} levels in the kitchen and living room have been found to be 256 ± 108 and 226 ± 114 $\mu g/m^3$ respectively. The ambient levels of PM10 in the rural areas are reported to be below the national standard.

22. In order to maintain consistency with the ambient air methodology, the same approach as in the ambient air case has been adopted. Some of the difficulties in this method[(8)] are reduced by the availability of newer data. For example, coefficients relating exposure to mortality and morbidity which are applicable to developing countries are now available[(11,12)]. The level of exposure in the case of indoor air pollution is also not all that different from highly pollution cities in the developing countries, so it is a reasonable assumption to use these for the indoor air pollution also. Thus, the pollution (i.e., direct exposure) based methodology is progressively becoming less uncertain.

23. As data from survey were unavailable at the time of these calculations, the following contingent estimates have been made in order to derive exposure levels for different population groups:

- Men spend 8 hours indoors (living room).
- Women spend 16 hours indoor out of which 4 hours is in the kitchen.
- Infants spend 20 hours indoors (living room)

New data have become recently available(10), however, and use of these would change some of the details of the pollution based calculations for the health impact of SFU, and their costs are given in annex-II.

3.4.1 Summary of Results from Pollutant-Based Method

24. As in the case of ambient air pollution, two scenarios have been used. The first scenario is the reduction of exposure level by 20% which is a probable achievement level with low cost measures and the second scenario is the reduction of the pollution level to proposed Bangladesh standards which is a long term goal. Under these two scenarios the exposure levels reductions that can be achieved are shown in table 8.

Table 8: Indoor Air exposure level for different population groups in μg/m^3 for PM_{10}.

	Exposure in Scenerio-1			Exposure in Scenerio-2		
	Kitchen	Living room	Total	Kitchen	Living room	Total
1. Men	0.0	15.1	15.1	0.0	58.8	58.8
2. Women	8.5	22.7	31.2	34.3	88.2	122.5
3. Infant	0.0	37.8	37.8	0.0	146.9	146.9

The results of the calculations are shown in Table-9.

Table 9: Cases avoided and annual health cost savings (US$ million), two scenarios

Health Effects	Scenerio-1		Scenario-2	
	Cases	Cost Million $	Cases	Cost Million $
Mortality	5,718	161.5	21,031	594.2
Chronic Bronchitis	77,926	265.0	305,139	1,037.7
Resp Hospital adm.	31,075	2.3	121,493	9.0
Asthma attack	4,220,967	4.6	16,502,854	18.1
Emergency room visits	609,580	1.3	2,383,296	5.2
Restricted day activities	72,577,889	67.1	284,198,084	262.7
Lower respiratory illness	595,725	0.5	2,322,632	1.8
Respiratory symptoms	233,013,223	178.8	912,425,428	700.1
Sub-Total(Morbidity)	311,126,383	519.7	1,218,258,926	2,034.6
Total		681.2		2,628.7

25. The number of cases of mortality and morbidity that can be avoided if the PM10 pollution level is reduced in a range from a modest 20% of the current level up to the proposed national standard are shown in this table. It can be seen that about 5,700-21,000 deaths and about 311- 1,218 million cases of morbidity can be avoided per year in the two scenarios. The costs involved are between US$681 –2,629 million. As pointed out earlier, the present estimates are quite conservative and may be considered underestimates. In terms GNI, these correspond to 1.4–5.2% per year.

3.5 Comparison of the Results for Two Different Methods for Indoor Air Pollution

26. The central estimates for different parameters calculated in the fuel and pollution based methodologies are shown in table-10.

Table 10: Values for different parameters obtained in the fuel and pollutant based approach in indoor air pollution

Item	Scenario-I			Scenario-II		
	Fuel Based	Pollutant Based	Cost(US$) Million	Fuel Based	Pollutant Based	Cost(US$)
1. Mortality (Avoided Deaths)	7,600	5,718	-	30,400	21,031	-
2. Morbidity						
DALYs Saved (million)	0.301	-	114	1.204	-	458
Reduced number of Cases (million)	-	311	520	-	1218	2,629
3. DALY Lost/Case	0.001	-	-	-	-	

It can be seen that the mortality results obtained are remarkably close for both the methods. In the case of morbidity, the results from the two method are obtained in two different units as such they can not be directly compared. The morbidity is found in units of DALY in the fuel based method and in cases for the pollutant based method. However, if we look at the life years lost and compare them with the number of cases, we see that it amounts to about 0.35 days per case, which appears quite reasonable. So, it is probably the methods of valuation rather than health effects which are at the root of the large difference (a factor of about 5) in health costs obtained in the two methods. These are discussed in more detail in Annex-II.

4. Access to Clean Water and Sanitation

4.1 Extent of the problem

27. Availability of water in adequate quality and sufficient quantity is a necessity for human survival, health protection, and social and economic development. Bangladesh is one of the most densely populated countries in the world, with a range of competing demands for water. Microbiological contamination of surface water is so pervasive that there is now no potable surface water available in the country except for a few natural springs in the hilly areas. Infectious diseases from microbiological contaminants such as

viruses, protozoa and bacteria are likely to pose increasing challenges in the future due to increasing water pollution. Urban, agricultural and industrial systems interact with their immediate environment and may involve the release of treated or untreated effluents, fertilizers and other agricultural chemicals into water bodies. All these substances may potentially alter the quality of natural water making it less suitable or, indeed, unsuitable for consumption or even for recreational use. Discharges containing organic matter and especially municipal wastewater near large urban areas may cause deterioration in river water quality sufficient to make existing water treatment plants inoperative. Apart from anthropogenic contamination of water, naturally occurring problems, i.e., ground water contamination with high levels of arsenic affect a large section of the population in Bangladesh.

28. The incidence of water related mortality and morbidity depends in a complex way on a range of parameters and their interactions, including water quality, water quantity, sanitation, and the status of community hygiene practice, among others. The health impact of these parameters and their various interactions are not yet clearly understood and thus many assumptions are needed in order to estimate the effect of any specific parameter and its potential cost implications. This necessarily gives rise to uncertainties in the calculations and in most cases no unique value can be arrived at. Consequently, it is more appropriate to present a range of plausible values under various assumptions.

29. The primary epidemiological data on morbidity and mortality for water and sanitation related diseases are analyzed and reported in terms of DALYs. From the most recent data available, about 3.62 millions of DALYs are lost each year in Bangladesh (annex-3) due to water and sanitation related diseases. The challenge is to quantify the achievable reduction in DALYs due to provision of access to clean drinking water and to compute the savings in health costs that can be achieved.

4.2 Methodology

30. The same methodology reported by Brandon[(2)] has been used here, which was itself based on previous work within the World Bank group. The details of the methodology are given in annex-III. The methodology uses a stepwise procedure to calculate the savings in the DALYs due to improved access to clean water and sanitation. These savings are calculated as a function of parameters which define plausible limits of interventions from the composite value for DALYs obtained from field data through epidemiological surveillance with current level of access to clean water and sanitation. Available data and the analytical framework do not allow unique apportionment of DALYs saved due to access to clean drinking water. Two assumptions are needed to estimate the limits of such savings. One of these relates to the relative importance of water and sanitation for adequate safety from waterborne diseases and the other is a hygiene factor which defines the level of hygiene among two groups of people with and without adequate access to water and sanitation services. Of necessity, these two variables have to be considered as parameters and limits are defined from qualitative consideration of plausibility. As a result, we obtain multiple scenarios for health impacts and related costs. The lowest limit of the range probably gives the indication of the benefits from access to clean drinking water.

4.3 Summary of Results

31. The results of the calculations are summarized in table-11. Total DALYs between 0.82 –1.94 million can be saved through the provision of clean water and sanitation. The economic value of water-related mortality and morbidity can be estimated by using the human capital approach. This implies that the statistical value of one DALY is equal to the annual average productivity of a worker in Bangladesh. This may be set equal to per capita GNI for Bangladesh. Higher estimates for the DALYs are obtained if GNI-scaled USEPA annualized value of life are used. This value is 2.73 times higher than the GNI as reported by Brandon. The cost savings involved in both the approaches are shown in the tables above. The savings are between US$313–739 million in the human capital approach method. In GNI terms, these correspond to 0.63–1.48 % per year. Compared to Bandon's study (1997) the water-related health impacts in terms of DALYs have decreased to some extent but the costs still remain similar. This reflects the impact of increase in the per capita GNI. Reduced access to clean water as a result of Arsenic contamination has not been considered.

32. Some discussion of the numbers obtained for DALYs saved in these calculations is necessary, as it is not clear what quantities impact these savings. The impacts are not due to water pollution per se but a combination of access to water, sanitation and their interactions. However, through parameterization of the relative importance of water and sanitation for adequate safety from waterborne diseases (x) and the hygiene factor which defines the level of hygiene among two groups of people with and without adequate access to water and sanitation services (H), the impacts range from access to clean water to the maximum level of benefits obtainable from access to clean water and sanitation. The lowest value obtained probably corresponds to access to clean water. The range of values obtained is rather large, refinements in methodology since Brandon's work may not reduce the uncertainties to any great extent. The same methodology as Brandon's original paper has been followed as this allows a comparison for the situations then and now.

Table 11: Annual Health Impacts and Health Costs Avoided through the Provision of Clean Water and Sanitation.

Saving in DALYs (Variable values)	DALYs Reduced (Millions)		Value of Reduced DALYs (Million $)		
			This work		Brandon
	Present work	Brandon	Human Capital	USEPA AVOL	
Lowest Savings Range (X=0.9, H=0.7)	0.82	1.31	313	856	289-788
Highest Savings X=0.5, H=0.5	1.94	2.3	739	2017	506-1,380
Average Savings of 15 Scenarios	1.39	1.82	528	1441	401-1,093

5. Discussion and Conclusions

33. The three environmental factors considered here account for about 1.2-3.35 % of GNI in terms of health impact. The values of disease burden obtained in the present calculations are rather conservative estimates compared with the regional figures available in literature(1) for the Asia region in Table 12. It may be noted that the calculations reported here are based on the economic indicators for the base year 2002. These indicators change with time (e.g., GNI), so absolute cost figures are likely to vary substantially with time. However, the costs in terms percentage of GNI are likely to be fairly stable in the short and even in the medium term.

Table 12: Environmental Factors in the Burden of Disease in Bangladesh and Asia

Environmental Health group	Percentage of total DALYs			Bangladesh		
	India	China	Asia & Pacific	DALYS (Millions)	Cost * ($ Million)	DALY (%)**
Water Supply & Sanitation	9.0	3.5	8	3.62	838	9.0
Indoor Air Pollution	6.0	3.5	5	-	458	4.9
Urban Air Pollution	2.0	4.5	2	-	169	1.8
Malaria	0.5	0	1.5	-	-	-
Agro-Industrial Waste	1.0	1.5	1.5	-	-	-
Total Environmental	18.5	18.5	17	-	-	15.7

*For air pollution the reduction scenario correspond to reduction to proposed national standard (for ambient) and by 80% in case of indoor air pollution. In the case water and sanitation the cost correspond to average of 15 scenarios for WSS
**Normalized to water and sanitation DALY percentage in India using cost estimates

34. It should again be emphasized that there are a lot of uncertainties in the economic valuation of environmental impacts as discussed earlier and the figures here should be considered as indicative only. The costs calculated here are not the maximum health costs imposed by air and water pollution. In the case of ambient air pollution, the lower limit correspond to health cost savings for 20% reduction in pollution level and the higher limit corresponds to reduction of the pollution level to proposed national standards. In fact, health cost savings due to air pollution do not stop at the standards and benefits can be derived by reducing the pollution levels below the standards. In the case of health cost savings from improved water supply and sanitation, the average of 15 scenarios has been taken in view of the complexities introduced by coupling of water and sanitation impacts and the hygiene factor.

35. For comparison, the monetary value for water and sanitation in Bangladesh has been normalized to Indian DALY percentage. With such normalization all the different units are converted to same units (i.e., percentage DALYs). In view of the uncertainties in the estimates, the level of the burden of disease due to environmental causes can be considered as comparable in the Asia region. As such, similar policy measures for the remediation of pollution may be applicable regionally with customization to suit the local needs.

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ANNEX- I

METHODOLOGY AND CALCULATION OF HEALTH COSTS OF AMBIENT AIR POLLUTION IN BANGLADESH

1. Introduction

The methods for calculating the health effects of air pollution are quite well developed and are routinely used. With appropriate scaling these methods can be used for Bangladesh with a reasonable degree of confidence. The present calculations are based on the methodology in the World Bank study by Lvovsky et al (2000)[(1)]. The models used in this work can be scaled for population and income levels for application in Bangladesh, as was done in the work for six major cities in six different developing countries. Only the health effects of PM_{10} have been considered here as data are available only for this component of air pollution in Bangladesh. The health impacts shown here are, therefore, underestimates and actual health burden of the total effects of air pollution are likely to be higher. This aspect and other issues are taken up in more details in the latter sections.

2. Estimate for Health Impacts

Health impact are calculated from the relation

$$\Delta H_i = b_{ij} * \Delta A_j * P \quad \text{……………………………………} (1)$$

Where: Δ stands for change; H_i is the health impact of type i per year; b_{ij} stands for the slope of the dose response function of health effect of type i for exposure to pollutant j per year; A_j is the ambient concentration of pollutant j and P is the population exposed to the pollutants.

The quantity ΔA_j is defined as

$$\Delta A_j = \max [\, 0, A_j^1 - \max(A_j^0 , S_j)] \quad \text{…………………………………} (2)$$

Where: A_j^1 is the observed concentration; A_j^0 is the background concentration and S_j is the relevant threshold or air quality standard.

The coefficients b_{ij} are available in literature [(1,2)] from health research work and are given in table1. The changes in the ambient concentrations are obtained from measurements.

Table 1: Air pollution dose response function slope (b_{ij}) per μg/m^3 change in the mean annual level

Sl	Health Effects	Units	b_{ij}	
			PM_{10}	SO_2
1.	Mortality	Percentage change	0.046*, 0.084	-
2.	Chronic Bronchitis	Per 100,000 adults	6.12	-
3.	Respiratory Hospital admission	Per 100,000 population	1.2	-
4.	Asthma attack	Per 100,000 asthmatics	3,260	-
5.	Emergency room visits	Per 100,000 population	23.54	-
6.	Restricted day activities	Per 100,000 adults	5,700	-
7.	Lower respiratory illness	Per 100,000 Children	169	-
8.	Respiratory symptoms	Per 100,000 adults	18,300	-
9.	Cough days	Per 100,000 children	-	1.81
10.	Chest discomfort	Per 100,000 adults	-	1,000

* Lower value is appropriate for high exposure levels in major cities [(2)].

3. Methodology for the Estimation of cost of health effects

The values for the cost of health effects including VOSL (Value of Statistical Life) have been obtained in US through extensive research. These values are related to economic indicators and these have to be scaled by per capita GNI (Gross national Income) for variation in time and space. It has been shown that Country specific variation can be scaled by using the relation[(1)]:

$$\text{Log}(V_k) = r * \log(Y_k / Y_{us}) + \log(V_{us}) \quad \ldots\ldots(3)$$

Where: V is the valuation parameter for given country k and Y is the per capita GNI. Various value of r in the range of 0.4 to 1.2 have been reported but it has been observed that r=1 provides conservative estimates[(1)]. With this approximation, the relation for Bangladesh (indicated by subscript B) becomes linearized to:

$$V_B = V_{us} * (Y_B / Y_{us}) \quad \ldots\ldots(4)$$

This simplified relation is used in the calculations here and are given in table 2. The VOSL value obtained is considered high and so is the value obtained in the case for chronic bronchitis.

Table 2: WTP based health effect costs per case in Bangladesh
Obtained by per capita GNI scaling from values in US(GNI(1990)=$21,790). (Reference-1: Table 4.4.). (Bangladesh per capita GNI (2002) [3]: $380. (1$=Tk58))

Sl	Health Effects	WTP US(1990)	BD(2002) US$	BD(2002) in Taka
1.	Mortality (VOSL)	1,620,000	28,251	1,638,587
2.	Chronic Bronchitis	195,000	3,401	197,237
3.	Respiratory Hospital admission	4,225	73.68	4,273
4.	Asthma attack	63.00	1.10	64
5.	Emergency room visits	126.00	2.20	127
6.	Restricted day activities	53.00	0.92	54
7.	Lower respiratory illness	44.00	0.77	45
8.	Respiratory symptoms	44.00	0.77	45
9.	Cough days	44.00	0.77	45
10.	Chest discomfort	50.00	0.87	51

4. Some data and assumptions in the health impact and cost estimates

The following data have been used in obtaining the numbers in table-2. The percentage of asthmatics in the Bangladesh population has been taken from unpublished informal literature and thus can only be considered as a contingent estimate.

i. Crude Mortality Rate per 1000 is 4.8 [4]
ii. Population under 15 years 38.2% [5]
iii. Adult population (61.8%)[5]
iv. Percentage of Asthmatic population is assumed to be 5%.

5. Urbanization and city population

There are 3 cities in Bangladesh where population exceeds one million and there are 18 more cities where population exceed 100,000. The population statistics for these cities are shown in table 3 & 4.

Table 3: Cities in Bangladesh with more than one million population[5].
Per capita income has been assumed to same as GNI which is taken as US$ 380.

Sl.	City	Population (2003) in Million	Per capita Income($)
1	Dhaka	13.07	380.
2	Chittagong	3.70	380.
3	Khulna	1.43	380.
	Total	18.20	

Table 4: Cities in Bangladesh with more than 100,000 population[5].
Per capita income has been assumed to same as GNI which is taken as US$ 380.

Sl.	City	Population In million	Per capita Income($)
1	Rajshahi	0.740	380.
2	Sylhet	0.440	380.
3	Rangpur	0.268	380.
4	Barisal	0.240	380.
5	Mymensingh	0.215	380.
6	Jessore	0.207	380.
7	Nawabganj	0.171	380.
8	Bogra	0.174	380.
9	Comilla	0.167	380.
10	Dinajpur	0.163	380.
11	Srimangal	0.134	380.
12	Jamalpur	0.134	380.
13	Madhabdi	0.123	380.
14	Tangail	0.122	380.
15	Pabna	0.114	380.
16	Naogaon	0.108	380.
17	Brahmanbaria	0.104	380.
18	Saidpur	0.100	380.
	Total	3.724	

6. Air Quality Data

For the first group of three cities, fairly comprehensive air quality data are being collected only for Dhaka by the Air Quality Management Project of the Department of Environment (AQMP)[6]. The PM data (both PM_{10} and $PM_{2.5}$) are also collected by the Bangladesh Atomic Energy Commission (BAEC)[7]. The summary of air quality data for Dhaka obtained at the Continuous Air Monitoring Station (CAMS) of AQMP are shown in table-5.

Table 5: Average values for Criteria Pollutants Measured at CAMS, Dhaka with standard deviations during 2003 along with proposed revised Bangladesh Standards[6].

Pollutant	Averaging Time	Who Guidelines	Proposed Bangladesh Standards	Annual average Concentration during 2003
CO	1 hour	30 mg/m^3	40 mg/m^3(35 ppm)	---
	8 hour	10 mg/m^3	10 mg/m^3 (9 ppm)	1.0 ± 0.8ppm
SO_2	24 hour	125 μg/m^3	365 μg/m^3 (140 ppb)	----
	Annual	50 μg/m^3	80 μg/m^3 (30 ppb)	7±8 ppb
NO_2	24 hour	---	---	---
	Annual	40 μg/m^3	100 μg/m^3 (53 ppb)	59±58 ppb
Ozone	1 hour	---	235 μg/m^3 (120 ppb)	
	8 hour	120 μg/m^3	157 μg/m^3 (80 ppb)	28±20 ppb
PM_{10}	24 hour	---	150 μg/m^3	
	Annual	---	50 μg/m^3	133 ± 78μg/m^3
$PM_{2.5}$	24 hour	---	65 μg/m^3	---
	Annual	---	15 μg/m^3	76 ± 57μg/m^3

It can be seen from table-5 that the main pollutant of concern in Dhaka is particulate matter. Both PM_{10} and $PM_{2.5}$ levels are extremely high being much above the proposed standard. The NO_2 levels are also now close to the standard and may become a concern in the future. The level of other pollutants is still low and thus not important from a health point of view. One of the criteria pollutant i.e., Pb (Lead) is not shown in the table. The lead level is now sufficiently low (i.e., around 100ng/m^3), so that air borne lead is no longer considered as a health issue [8]. However, blood lead levels in children are still high which come from other sources[9]. So, the health impact calculations will be limited to PM_{10} only. There is no air quality data for other two cities (Chittagong and Khulna) with more than one million population. For impact calculation, the pollution level in these cities is assumed to be same as Dhaka. In these cities also, there are high levels of public complaints about the air quality. The banning of two stroke three wheelers in Dhaka has contributed to the improvement in the air quality in Dhaka but the influx of these vehicle has made the air quality worse in Chittagong and Khulna. So, it is a plausible assumption that the decrease in the pollution levels in Dhaka and increase in the levels in Chittagong and Khulna have made the levels comparable in all the three cities. For one of the 18 cities i.e., Rajshahi data on PM levels are available from BAEC measurements[7] which are given in table 6. The yearly average PM_{10} level is reported to be 63±25 μg/m^3. This is the ambient level which has been used in the case of all the 18 cities with population more than 100,000.

Table 6: PM_{10} data for Dhaka and Rajshahi [7] in $\mu g/m^3$

Month	PM10 level in Dhaka (2003)	PM10 level in Rajshahi	Comments
January	271	89	Monthly data for Rajshahi generated from measurements during 2001-03 by month wise averaging as data are not available for all the months in any given year
February	244	112	
March	202	88	
April	104	58	
May	97	58	
June	68	36	
July	46	37	
August	50	34	
September	65	39	
October	92	51	
November	183	75	
December	173	76	
Average	133	63	
Stdev	78	25	

7. Health Impact and cost calculation for Ambient Air Pollution

An important aspect determining the health relevance of air quality is the exposure patterns. These vary significantly among the population but are usually consistent in time for a given population group. Exposure can be defined as the event in which an individual remains in contact with a specific concentration of a pollutant for a given period of time. Exposure assessment consists of describing and quantifying the relevant conditions and characteristics of human exposure. Air quality data have been measured as 24 hour average mass-based concentrations of PM_{10} at a suitable location in Dhaka using fixed monitoring equipment. These measurements were done for regulatory purposes and such data are usually insufficient for personal exposure assessment, as information about diversity in terms of time spent at different places are not captured in such measurements. However, in the present case we shall take yearly average of PM_{10} level as the measure of exposure. A significant fraction (probably as high as 20%) of the city population live and work near the traffic canyons where the pollution level may be higher by a factor of 2 or even more. So, the present calculations may be considered conservative.

The results of the calculations are shown in tables 7 and 8. The number of cases of mortality and morbidity that can be avoided if PM_{10} pollution level is reduced in a range from a modest 20% of the current level up to the proposed national standard are shown in this table 7. It can be seen that about 1,200-3,500 deaths and about 80- 235 million cases of morbidity can be avoided per year in the two scenarios (table-7). The costs involved range from about US$169 to US$492 million as shown in table-8.

Table-7 Number of case reduction for mortality and morbidity per year for two different scenarios

		Reduction in 3 Major Cities		Reduction 18 Cities		Total	
Sl	Health Effects	By 20%	To National Standard	By 20%	To National Standard	By 20%	To National Standard
1	Mortality	1,069	3,335	189	195	1,258	3,530
2	Chronic Bronchitis	18,310	57,133	1,775	1,831	20,085	58,964
3	Resp Hospital admission.	5,809	18,127	563	581	6,373	18,708
4	Asthma attack	789,116	2,462,278	76,484	78,907	865,599	2,541,185
5	Emergency room visits	113,962	355,595	11,046	11,396	125,007	366,991
6	Restricted day activities	17,053,611	53,212,396	1,652,888	1,705,263	18,706,500	54,917,659
7	Lower respiratory illness	312,538	975,213	30,292	31,252	342,830	1,006,465
8	Respiratory symptoms	54,751,067	170,839,796	5,306,642	5,474,793	60,057,709	176,314,589
	Total Morbidity	73,044,414	227,920,539	7,079,689	7,304,022	80,124,103	235,224,561

Table-8 Savings per year in health cost in two scenarios in million US$

Sl	Health Effects	Reduction in 3 Major Cities		Reduction 18 Cities		Total	
		By 20%	To National Standard	By 20%	To National Standard	By 20%	To National Standard
1	Mortality	30.2	94.2	5.3	5.5	35.5	99.7
2	Chronic Bronchitis	62.3	194.3	6.0	6.2	68.3	200.5
3	Resp Hospital admission.	0.4	1.3	0.0	0.0	0.5	1.4
4	Asthma attack	0.9	2.7	0.1	0.1	1.0	2.8
5	Emergency room visits	0.3	0.8	0.0	0.0	0.3	0.8
6	Restricted day activities	15.8	49.2	1.5	1.6	17.3	50.8
7	Lower respiratory illness	0.2	0.7	0.0	0.0	0.3	0.8
8	Respiratory symptoms	42.0	131.1	4.1	4.2	46.1	135.3
	Sub-Total(Morbidity)	121.8	380.1	11.8	12.2	133.6	392.3
	Total	152.0	474.4	17.2	17.7	169.2	492.1

8. Discussion

As pointed out above the estimates in terms of health impacts (mortality and morbidity) are underestimates in the current calculation because only one pollutant impact has been considered and elevated exposures at hot spots have not been taken into account. However, in the case of cost estimates this may not necessarily so. As discussed in more detail in the case of indoor air pollution (annex-2), the costs obtained per case for chronic bronchitis in the GNI scaling method used here is much higher compared to contingent market based estimate(treatment cost+ income loss). The cost of mortality using GNI scaled VOSL are higher compared to human capital approach which is also discussed in annex-2. Hence, the cost estimates reported here are still probably underestimates but may not be grossly so.

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Annex-II
Health Burden due to IAP in Bangladesh

1. Introduction

Different methods to estimate the burden of disease from indoor air pollution in developing countries have been reviewed in a recent WHO (2004) publication[1]. The more widely used approaches are the fuel-based and the pollutant-based methods. In the fuel-based approach some fraction of the burden due to selected diseases are attributed to indoor air pollution using a step-wise procedure. The contribution of all relevant diseases is summed to obtain the total burden of diseases in DALYs and number of deaths. By contrast, in the pollutant-based approach, the population exposures to an indicator pollutant, generally PM_{10}, is estimated in terms of some measure of concentration-time. The exposure-response relationship for the indicator pollutant is then used to determine excess morbidity and mortality. Both the methods have advantages and disadvantages and these usually lead to significantly different results. The WHO study recommends the fuel-based approach, however, both the approaches are used here for comparison and to illustrate the uncertainties involved in the calculations.

2. Health Burden using Fuel-Based Methodology

2.1 The Methodology

The stepwise procedure prescribed in WHO document[1] are used here in order to arrive at the estimate for health burden due to IAP in Bangladesh. The steps involved are the following:

(vi) Collection of data relevant to calculation;
(vii) Calculation of attribute functions;
(viii) Calculation of the attributable burden;
(ix) Summation of all the burdens due to individual diseases; and
(x) Estimation of uncertainty.

2. 2 Data relevant to Bangladesh

2. 2.1 Diseases relevant to IAP

It has been shown from epidemiological studies that the diseases shown in table-1 are relevant to IAP disease burden estimation. A relative risk of 1 indicates no health effect.

Table-1 Diseases relevant to IAP

Sl	Evidence	Health outcome	Group	Relative Risk	Confidence Interval
1.	Strong	ALRI	Child <5y	2.3	1.9-2.7
2.		COPD	Women ≥30y	3.2	2.3-4.8
3.		Lung cancer(Coal Smoke)	Women ≥30y	1.9	1.1-3.5
4.	Moderate-I	COPD	Men ≥30y	1.8	1.0-3.2
5.		Lung cancer(Coal Smoke)	Men ≥30y	1.5	1.0-3.2

Abbreviations: ALRI= Acute lower respiratory infection, COPD= Chronic Obstructive pulmonary disease.

2. 2.2 Household Solid Fuel Use in Bangladesh

Household solid fuel use (SFU) is given in table-2. As there is no indigenous retail market for coal in Bangladesh, it is not used for cooking and almost all the solid fuel used is biomass.

Table-2 Household SFU in Bangladesh[1]

Fuel Type	Household%	Comments
SFU	96	Probably high estimate
Biomass	96	
Coal	0	

Fraction of the population exposed (F) to air pollution due to SFU can be found using the following equation:

$$F = P_e / P = (H*V_1 + (1-H)*V_2) \qquad (1)$$

Where:

F = Fraction of the population exposed
P = Population of the country
P_e= Population exposed
H = Percentage of household using SF
V_1 = Ventilation coefficient for household using SFU (V_1=1)
V_2 = Ventilation coefficient for household using improved stove or outside cooking (V_2 =0.25)

As improved cook stoves are rarely used in Bangladesh and no reliable statistics are available, all the households will be assumed to be exposed where SF is used (i.e., F=0.96). The uncertainty is taken to be 5% as suggested in ref-1(table-5.1 in Annex-5).

2. 2.3 Bangladesh Population

The population distribution data available from 2001 census[2] have been normalized to projected total for 2004. The data are given in table-3.

Table-3 Population distribution by age and sex for Bangladesh (2004)

Age	Population in Million			Population Fraction		
(Years)	Male	Female	All	Male	Female	All
0-4	8.65	8.15	16.80	0.06	0.06	0.12
5-14	17.43	16.72	34.15	0.13	0.12	0.25
>15	21.67	20.82	42.49	0.16	0.15	0.31
>30	23.06	21.45	44.51	0.17	0.16	0.32
Total	70.81	67.14	137.95	0.51	0.49	1.00

2. 2.4 Burden of Disease in Bangladesh

Data specific to Bangladesh for the burden of diseases (B_i) relevant to indoor air pollution (shown in table-1) are not available from national health surveillance sources. So, following the example in WHO report [1], the data have been obtained from WHO SEAR D region data. This region of WHO encompasses eight countries including Bangladesh. Bangladesh population is 11.03% of the region, so the same percentage of burden of disease has been assumed for the country as for the region, and are shown in table-4. The numbers in row 3 and 5 for men≥ 30 years' age are due to coal smoke. Hence, these are set to zero in the subsequent steps as coal smoke is not important in Bangladesh.

Table-4 Bangladesh Burden of disease from selected diseases in 2000
(11.03% of WHO region SEAR D)

Sl	Disease, sex, age group	DALYs Lost (000)	Deaths (000)	Comments
1.	ALRI<5yrs	2,389	67	
2.	COPD, Women≥30yrs	251	14	
3.	COPD, men≥30yrs	255	14	As the numbers are due to coal smoke, this will be set to zero during calculations.
4.	Lung cancer, Women≥30y	28	2	
5.	Lung cancer, men≥30y	103	10	,,
	All causes	3,027	108	

2.3 The Attributable fraction of DALYs and Death to SFU

The attributable fraction (A_i) of a given disease (i) to SFU can be calculated using the equation (ref-1):

$$A_i = ((F^* R_i + (1-F))-1)/ (F^* R_i + (1-F)) \quad \ldots\ldots (2)$$

Where:

F= Fraction of the population exposed as explained in the context of equation-1.
R_i = Relative risk or odds ratio for a disease i as given in table-1 for specific diseases.

The calculated attributable fractions for different diseases in Bangladesh are shown in table-5.

Table-5 Attributable fraction from SFU in Bangladesh

Sl.		Attributable fraction			Comments
	Disease, sex, age group	Low	Central	High	
1.	ALRI<5yrs	0.46	0.56	0.62	
2.	COPD, Women≥30yrs	0.56	0.68	0.78	
3.	COPD, men≥30yrs	0	0	0	Cole smoke effect-set to zero
4.	Lung cancer, Women≥30y	0	0.32	0.51	
5.	Lung cancer, men>=30y	0	0	0	Cole smoke effect-set to zero

2.4 The Attributable burden of DALYs and Death to SFU

The attributable burden of diseases due to SFU can be found by multiplying burden of diseases in table-4 by the attributable fractions in table-5. The attributable disease burden (D_i) for a given disease can be written as (ref-1):

$$D_i = A_i * B_i \quad \text{...}(3)$$

The values obtained for different diseases are shown in table-6 below.

Table-6 Attributable burdens from SFU for Bangladesh

		DALYs (000)			Deaths (000)		
Sl	Disease, sex, age group	low	central	High	low	central	high
1.	ALRI<5yrs	1,107	1,326	1,481	31	38	42
2.	COPD, Women≥30yrs	139	170	197	8	10	11
3.	COPD, men≥30yrs	0	0	0	0	0	0
4.	Lung cancer, Women≥30y	0	9	14	0	1	1
5.	Lung cancer, men≥30y	0	0	0	0	0	0
	Total	1,246	1,505	1,692	39	49	54

The low and the high values in table-6 do not include the uncertainties in the exposure estimates discussed in section-2.2. The results of RMS combination of these uncertainties with the values in table-6 are shown in table-7.

Table-7 Attributable burdens from SFU for Bangladesh with exposure uncertainty

Sl		DALY(000)			Deaths(000)		
	Disease, sex, age group	low	central	High	low	central	high
1.	ALRI<5yrs	1097	1326	1495	31	38	42
2.	COPD, Women≥30yrs	138	170	198	8	10	11
3.	COPD, men≥30yrs	0	0	0	0	0	0
4.	Lung cancer, Women≥30y	0	9	14	0	1	1
5.	Lung cancer, men≥30y	0	0	0	0	0	0
	Total	1235	1505	1707	39	49	54

Comparison for DALYs lost and the number of attributable deaths for India and Bangladesh per 1000 population are shown in table-8. The numbers obtained are very similar which is not surprising. The same WHO data for disease burden (for SEAR D region) have been used by population scaling in both the cases. The only country specific input is household SFU data. In Bangladesh, the percentage households using biomass is higher whereas in India households using coal is higher. These differences are offset by one another and results are almost similar except for men≥30 years. The numbers for men≥ 30 years in India are wholly for coal smoke.

Table-8 DALYs lost and Deaths per 1000 population in Bangladesh and India[1]

Sl.	Disease, sex, age group	Bangladesh		India	
		DALY	Death	DALY	Death
1.	ALRI<5yrs	78.93	2.26	78.72	2.22
2.	Women ≥30yrs	7.93	0.47	6.14	0.34
3.	Men ≥30yrs	0	0	3.7	0

2.5 Health Cost of Indoor Air Pollution due to SFU

Total DALYs lost due to indoor air pollution SFU are between 1.24 –1.71 million for Bangladesh. The economic value of the DALYs lost can be estimated by using the human capital approach. This implies that the statistical value of one DALY is equal to the annual average productivity of a worker in Bangladesh. This may be set equal to per capita GNI for Bangladesh[3]. Higher estimate for the cost DALY is obtained if GNI-scaled USEPA annualized value of life is used. This value is 2.73 times higher than the GNI as reported by Brandon[4].

The results of the calculations for cost savings by suitable interventions in two scenarios are shown in table-9. The first scenario involves 20% reduction in DALYs which can probably be achieved at low cost such as kitchen ventilation improvement. The second scenario involves reduction of the exposure level to proposed national ambient standards. As the measured exposure has been estimated[5] to be about 250 $\mu g/m^3$, it would require about 80% reduction in the exposure level to reach the standard of 50 $\mu g/m^3$. A linear relationship between DALYs saved and exposure is assumed in this estimate. It can be seen that about 8-40 thousand deaths and about 0.25- 1.35 DALYs can be avoided per year in the two scenarios (tables-7&9). The cost involved range from about US$95 to US$514 million as shown in table-9. These savings correspond to 0.02–0.11 % of GNI per year.

Table-9 Cost for possible savings in DALYS (million) and their cost

Estimates	DALYs Lost (million)	Savings in DALYs (million)		Cost per DALY	Savings (US$ Million)	
		Scenario-1 (20%)	Scenario-II (80%)	US$	Scenario-1	Scenario-II
Low	1.246	0.2492	0.9968	380	94.7	378.8
Central	1.505	0.301	1.204	380	114.4	457.5
High	1.692	0.3384	1.3536	380	128.6	514.4

3. Health Burden Using Pollutant (Exposure) Based Methodology

3.1 Exposure for Indoor Air Pollution

The exposure patterns for different population discussed in the case of ambient air pollution are even more important in determining the health relevance of indoor air quality. In the case of indoor air pollution, the exposure levels are significantly different for men, women and infants. Men in the rural areas mostly spend their time outside the household. Women spend significant amount of time in the kitchen and the infants (0-4 years) spend most of the time inside the household. In dealing with indoor air pollution one should be aware of the major influence of lifestyle and cultural factors in the occurrence of indoor related health impacts. In the absence reliable data on these factors, exposure to indoor environmental factors is inadequately characterized and this leads to large uncertainties in health risk assessment for indoor air pollution.

Some provisional data are available on indoor air pollution from rural and peri-urban areas in Bangladesh now for DECRG, WB study(5). The measurements were done in five different kitchen types and for five different fuels which included firewood, cow dung, crop residues (rice husk/straw), bagasse (including jute stick/sawdust) and cleaner fuel like kerosene. The un-weighted 24 hour averaged PM_{10} levels in the kitchen and living room have been found to be 256 ± 108 and 226± 114 $\mu g/m^3$ respectively. The ambient levels of PM10 in the rural areas are reported to be below the national standard. In the absence of any survey data the following contingent estimate have been made for the estimation of exposure levels:

- Men spend 8 hours indoors (living room).
- Women spend 16 hours indoor out of which 4 hours is in the kitchen.
- Infants spend 20 hours indoors (living room)

However, recently new data have become available (10) and use of these with minor changes in the figures obtained here. The demographic data for the three groups of population have been taken from the latest available BBS data(5) and are shown in table-10.

Table-10 Demographic data for population groups for indoor air exposure

Population Group	Population (%)	Total Rural Population in Million	Population in Million
1. Men	43.2	103.1	44.5
2. Women	43.2	103.1	44.5
3. Infant	13.6	103.1	14.0

As in the case of ambient air pollution, two scenarios have been used. The first scenario is the reduction of exposure level by 20% which is a probable achievement level with low cost measures and the second scenario is the reduction of the pollution level to proposed Bangladesh standards which is a long term goal. Under these two scenarios the exposure levels reductions that can be achieved are shown in table 11.

Table 11: Exposure Level in two scenarios

	ΔA		Exposure		
20% Reduction (Scenerio-1)	Kitchen	Living Rm	Kitchen	Living Rm	Total
1. Men	51.2	45.3	0.0	15.1	15.1
2. Women	51.2	45.3	8.5	22.7	31.2
3. Infant	51.2	45.3	0.0	37.8	37.8
Reduction to standard (Scenerio-2)					
1. Men	205.9	176.3	0.0	58.8	58.8
2. Women	205.9	176.3	34.3	88.2	122.5
3. Infant	205.9	176.3	0.0	146.9	146.9

3.2 Health Impact and cost calculation using exposure based approach

In order to keep consistency with ambient air methodology, the same approach as in the ambient air case has been adopted here. Some of the difficulties in this approach[7] mentioned by Smith (2000) in this method are less so now due to the availability of newer data. For example, the coefficients relating exposure to mortality and morbidity which are applicable to developing countries are now available[8,9]. The level of exposure in the case of indoor air pollution is also not all that different from high pollution cities in the developing countries. The exposure levels being different for the three different population groups as discussed above, the impacts have to be calculated separately for each group and then added together. The lower coefficient for morbidity has been used as the exposure levels are also high in the case of indoor air pollution. The results from the calculations are given in tables 12 A, B and C.

Table 12A: Health effect cases for scenario-1 (20% Reduction)

Sl	Health Effects	Men	Women	Infants	Total
1	Mortality	1,484	3,066	1,168	5,718
2	Chronic Bronchitis	25,414	52,512	0	77,926
3	Resp Hospital adm.	8,063	16,661	6,350	31,075
4	Asthma attack	1,095,279	2,263,092	862,596	4,220,967
5	Emergency room visits	158,177	326,829	124,574	609,580
6	Restricted day activities	23,670,111	48,907,778	0	72,577,889
7	Lower resp. illness	82,865	171,218	341,641	595,725
8	Respiratory symptoms	75,993,513	157,019,710	0	233,013,223
	Total Morbidity	101,033,422	208,757,800	1,335,161	311,126,383

Table 12B: Health effect cases for scenario-2 (Reduction to national standard)

Sl	Health Effects	Men	Women	Infants	Total
1	Mortality	4,453	12,036	4,541	21,031
2	Chronic Bronchitis	98,964	206,175	0	305,139
3	Resp Hospital adm.	31,399	65,415	24,679	121,493
4	Asthma attack	4,265,058	8,885,538	3,352,258	16,502,854
5	Emergency room visits	615,948	1,283,224	484,124	2,383,296
6	Restricted day activities	92,172,352	192,025,733	0	284,198,084
7	Lower respiratory illness	322,681	672,252	1,327,700	2,322,632
8	Respiratory symptoms	295,921,760	616,503,668	0	912,425,428
	Total Morbidity	393,428,162	819,642,003	5,188,761	1,218,258,926

Table 12C: Cases avoided and savings (in million US$) per year in health cost in two scenarios

Health Effects	Scenerio-1		Scenario-2	
	Cases	Cost Million $	Cases	Cost Million $
Mortality	5,718	161.5	21,031	594.2
Chronic Bronchitis	77,926	265.0	305,139	1,037.7
Resp Hospital adm.	31,075	2.3	121,493	9.0
Asthma attack	4,220,967	4.6	16,502,854	18.1
Emergency room visits	609,580	1.3	2,383,296	5.2
Restricted day activities	72,577,889	67.1	284,198,084	262.7
Lower respiratory illness	595,725	0.5	2,322,632	1.8
Respiratory symptoms	233,013,223	178.8	912,425,428	700.1
Sub-Total(Morbidity)	311,126,383	519.7	1,218,258,926	2,034.6
Total		681.2		2,628.7

The results of the calculations in tables 12 show the number of cases of mortality and morbidity that can be avoided if PM_{10} pollution level of indoor air can be reduced by 20% of the current level and to the proposed national standard. It can be seen that about 5.7-21 thousand deaths and about 311- 1218 million cases of morbidity can be avoided per year in the two scenarios (table-12C). The cost involved range from about US$681 to US$2,629 million as shown in table-12C in the GNI scaled US WTP method.

4. Comparison and discussion health cost savings in the methods for Indoor Air Pollution

4.1 Comparison

The central estimates for different parameters calculated in the fuel and pollution based methodologies are shown in table-7.

Table 7: Values for different parameters obtained in the fuel and pollutant based approach in indoor air pollution (central estimates)

Item	Scenario-I			Scenario-II		
	Fuel Based	Exposure Based	Cost(US$) Million	Fuel Based	Exposure Based	Cost(US$)
1. Mortality (Avoided Deaths)	7,600	5,718	-	30,400	21,031	-
2. Morbidity						
DALYs Saved (million)	0.301	-	114	1.204	-	458
Reduced number of Cases (million)	-	311	681	-	1218	2,629
3. DALY Lost/Case	0.001	-	-	-	-	-

It can be seen that the mortality results obtained are remarkably close for both the methods. In the case of morbidity, the results from the two method are obtained in two different units and as such they can not be directly compared. The morbidity is found in units of DALY in the fuel based method and as number of cases for the exposure based method. However, if we look at the life years lost, we see that it is about 0.35 days per case which appears quite reasonable. So, it is probably the methods of valuation rather than health effects which are at the root of large difference (a factor of about 5) in health costs obtained in the two methods. These are discussed in more detail in the next sections.

4.2 Contingent cost estimates for Chronic Bronchitis and death

All the estimates for costs obtained in the WTP based method (table 2 in annex-I) appear reasonable except for the chronic bronchitis (about 9 times per capita GNI). An attempt has, therefore, been made to arrive at some contingent estimate using local information available and some parameters available in informal literature. It is assumed that 50 working days are lost per year in each of these cases and it needs 9.5 days of hospitalization per year on the average. Hence,

Cost = 50*W(=Tk.60.) + 9.5* (Hospitalization cost/day (=Tk.1000.)
+ Medication/day (=Tk.50)* Sick days(=60)= Tk.15,500.

The cost is estimated as Tk.15,600 per case in this approach, compared to Tk 196,296 per case obtain by GNI scaled the USWTP value. The difference in the values possibly arises due to large difference in the hospitalization cost which does not scale by GNI. The contingent estimate is more in tune with local market value.

Similarly, in the case of cost for mortality, the value obtained in WTP method is considerably higher than in the human capital approach. Assuming that 10 life years are lost on the average in each case of mortality due to air pollution, the cost comes to US$ 3800 per case compared to $28,251 in the GNI scaled VSL (Value of Statistical Life) method.

4.3 Changes in cost due to pricing options

The health cost of indoor air pollution in various pricing options can vary considerably as shown in table-8. The various options considered in the table are given below.

(i) WTP-1: In this estimate all the per unit costs are derived from US WTP estimates using GNI scaling.
(ii) WTP-2: In this option, the cost for chronic bronchitis is replaced with contingent estimate.
(iii) WTP-3: In this option, in addition to chronic bronchitis, the mortality cost is also replaced by contingent estimate based on human capital approach.
(iv) Human Capital: Human capital approach for costing DALY.
(v) USEPA Annualized Value: GNI scaled USEPA annualized value of life is used for the cost of DALY which is 2.73 times higher than the GNI as reported by Brandon (annex-III).

Table-8 : Health Cost variation due to pricing options IAP (in million US$)

	Pollution Based approach			Fuel based Approach	
	WTP-1	WTP-2	WTP-3	Human Capital	USEPA Annualized Value
Scenario-I	681	437	297	114	311
Scenario-II	2629	1657	1158	458	1250

It is seen that that the human capital approach for the fuel based method gives the least cost. This is only to be expected as this approach does not capture the suffering and toil due the disease conditions. The USEPA annualized value of life which is 2.73 times higher than the human capital approach value capture some the suffering due to disease condition and hence may be more realistic.

On the other hand WTP based approach in the exposure based method provides the highest estimates. This is probably due to the fact that some of the WTP based costs do not scale by GNI due to difference in the pricing structure in the different countries.

When the per unit values for chronic bronchitis and VSL based values for mortality are replaced by contingent estimates (WTP-3), the values obtained in the exposure based approach is quite close to fuel based WHO recommended method when USEPA annualized value of life is used for the cost of DALY.

However, as per latest methodology recommended in the WHO report[(1)], the possible cost saving range due to avoided mortality and morbidity are taken as the central cost for the two scenarios in the fuel based method in table 9. These values are 114 and 458 million US dollars per year which corresponds to about 0.23 – 0.92% of GNI.

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Annex- III
Health cost for Water and Sanitation

1. Methodology

The incidence of water related mortality and morbidity depends in a complex way on parameters such as water quality, water quantity, sanitation, status of community hygiene practice among others and their interactions. The health impact of these parameters and their various interactions are not yet clearly understood and thus a lot of assumptions are needed in order to quantify the effect of any specific parameter and their potential cost implications. This necessarily gives rise to uncertainties in the calculations and in most cases no unique value can be arrived at. Usually, one arrives at a range of plausible values under various assumptions.

The primary epidemiological data on morbidity and mortality for water and sanitation related diseases are analyzed and reported in terms of DALYs. The problem here is to quantify the achievable reduction in DALYs due to provision of access to clean drinking water and to compute the savings in health cost that can be achieved.

The same methodology reported by Brandon(1) will be used here which was itself based on previous work within the World Bank group. The incidence of water related DALYs (R_t) can be written as:

$$R_t = P*R_w + (1-P)* R_{wo} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where
R_t = Incidence of DALYs in the population is derived from primary epidemiological data;
R_{wo} = Water related DALYs for people without clean water and sanitation;
R_w = Water related DALYs for people with clean water and sanitation available; and
P= Fraction of people with adequate service in the form of safe water and sanitation.

All the three variables on the right hand side of the equation are unknown and have to be related to other quantities i.e., more equations are needed to quantify any of the variables.

As the variable P has to specify what is adequate in terms of water and sanitation, this must relate to accessibility to clean water and sanitation. In general, the accessibility levels for water and sanitation are quite different in different areas of the country(2) as shown in table-1. The variable P can be written as:

$$P= x*F_w + (1-x)*F_s \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where;
F_w = Fraction of people with access to clean water;
F_s= Fraction of people with access to sanitation, and
x = Relative importance of water and sanitation for adequate safety,

The value of x can vary from 0 to 1 depending on the weight of water and sanitation required for adequate safety. A value of x=0.5 implies both clean water and sanitation are equally important for adequate safety.

The quantities F_w and F_s are primary data and are available as shown in the table-1. However, the data do not include the impact of Arsenic contamination which affects about 35 million people in the country. It has been estimated that access to safe drinking water has been reduced to about 74% due to Arsenic contamination[3]. The consequences of Arsenic contamination can be quite different from other diseases and this introduces further uncertainty in the values for x in the literature($0.5<x<0.9$) [1].

Table 1: Access to Drinking Water and Sanitation[2]

		Water Supply (%)				Sanitation (%)	
Year	Region	Tap	Tubewell	Others	Total Clean	Sanitary	Others
2001	National	5.96	84.67	9.37	90.63	36.87	63.13
	Urban	25.54	69.92	4.54	95.46	67.3	34.7
	Rural	0.34	87.99	11.67	88.33	28.15	71.85
1991	National	4.3	85.19	10.51	89.49	12.46	87.54
	Urban	22.49	72.34	5.07	94.83	40.24	59.76
	Rural	0.14	88.12	11.74	88.26	6.09	93.91

It has been reported that 52.4% of water related DALYs can be reduced through water and sanitation improvement[1]. Thus 47.6% of the DALYs represent the floor for hygiene related improvements.

Worldwide evidences show that positive correlation exists between clean water and sanitation and hygiene. This implies that hygiene levels are higher among the population with access to safe water and sanitation provision. This positive correlation can provide a relation between the variable R_w and R_{wo} through the introduction of a hygiene parameter ($H <= 1$). This relation can be written as [1]

$$R_w = R_{wo} * 0.476 * H \quad \ldots\ldots (3)$$

Where H is a parameter which defines the difference in the levels of hygiene (i.e., between the two groups with and without adequate access to clean water). The value H=1 implies poor are equally hygienic with less access to clean water and sanitation facilities. Brandon estimates that H between 0.5 and 0.7 may be realistic.

By combining equations 1-3, we can get the equation for R_w which is DALYs with adequate access to clean water and sanitation as:

$$R_w = 0.476 * H * R_t / ((1 - P) + 0.476 * H * P) \quad \ldots\ldots (4)$$

With this formulation we are now in a position to compute a range of values for R_w under different assumptions for the values of x and H.

Possible savings in DALYs (R_s) is therefore given by:

$$R_s = R_t - R_w \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(5)$$

The economic value of water related mortality and morbidity can be estimated by using the human capital approach. This implies that the statistical value of value of one DALY is equal to the annual average productivity of a worker in Bangladesh. This may be set equal to per capita GNI for Bangladesh. A higher estimate for the DALY is obtained if GNI scaled USEPA annualized value of life is used. This value is 2.73 times higher than the GNI as reported by Brandon.

2. Water and Sanitation Related DALYs lost in Bangladesh

The water and sanitation related DALYs lost in Bangladesh per year was reported to be 3.6 million in 1997 by Brandon(1). Recently, this value has been estimated to be 5.75 million(4) per year. However, it is not clear how this number was derived or if this value includes the impact of Arsenic contamination of drinking water on health. Data specific to Bangladesh for the burden of diseases relevant to water and sanitation are not available from national health surveillance sources. So, the required data have been derived from WHO SEAR D region data(5) by population scaling. This region of WHO encompasses eight countries including Bangladesh. Bangladesh's population is 11.03% of the region, so the same percentage of burden of disease has been assumed for the country.

It has been reported(6) that 9% of the total DALYs belong to water and sanitation related diseases in this region. This approach provides an estimate of water and sanitation related DALYs. Alternatively, certain fraction of a given disease can be assigned to water and sanitation accessibility(6). The estimate obtained results are given in table 2.

Table 2: Estimate for Water and Sanitation Related DALYs in Bangladesh from WHO SEAR D region assignments.

Sl	Item	Values	Comments
1.	Total DALYs for the SEAR D region in million	364.58	
2.	Bangladesh Population as percentage of the region	11.03%	
3.	DALYs for Bangladesh (million)	40.21	11.03% of item-1
4.	Percentage of Water and Sanitation DALY	9%	
5.	Bangladesh Water and Sanitation DALYs (Million)	3.62	9% of item-3

The result obtained from disease-wise assignment of DALYs to water and sanitation related diseases is given in table-3.

Table 3: Estimate for Water and Sanitation Related DALYs in Bangladesh from WHO SEAR D region by disease-wise assignment[6].

			DALYs (Million)	
Sl.	Disease	Percent assigned	Total	Water and Sanitation
1.	Diarrhoeal Diseases	80	22.39	17.91
2.	Hepatitis	30	0.76	0.23
3.	H. Pylori	20	1.31	0.26
4.	Trachoma	25	0.05	0.01
5.	Intestinal Helminthes	70	1.04	0.75
	Total		25.55	19.16
	Bangladesh Share(11.03%)		2.82	2.11

It appears that some water borne diseases like typhoid may not have been included in the assignments shown in table 3 and thus a lower estimate of disease burden is obtained in this method. Hence, the total water and sanitation related DALYs in Bangladesh is taken to the value of 3.62 million as shown in table 2.

3. Results

The savings in DALYs were calculated for 15 combinations of values for H ($0.5 \leq H \leq 0.9$) and ($0.5 \leq x \leq 0.7$). The correct coding of the formulas was verified by reproducing benchmark values by Brandon. Data on access to water and sanitation from table-1 is used in the present calculations. Decreases in accessibility to clean water due to Arsenic contamination have not been reported here. Such calculations have shown that introduction of decrease in water accessibility introduces feedback effects in the health impacts which are not easy to understand. The results of the calculations are shown in table-4, 5 & 6.

Table 4: Calculation for P values (equation-2)

Sl.	Fw	Fs	X	P	Comments
1	0.73	0.14	0.9	0.671	Brandon’s Benchmark (P =0.67)
2	0.73	0.14	0.5	0.435	Brandon’s Benchmark (P=0.44)
3	0.9063	0.369	0.9	0.85257	High importance to clean water
4	0.9063	0.369	0.8	0.79884	
5	0.9063	0.369	0.7	0.74511	
6	0.9063	0.369	0.6	0.69138	
7	0.9063	0.369	0.5	0.63765	Equal importance to clean water and sanitation
8	0.9063	0.369	0.4	0.58392	Low importance clean water

Table 5: Calculations for R_s and costs for 15 combinations of x and H Values and Brandon's benchmark values.

Sl.	R_t (Million)	P	H	R_w (Million)	$Rs=R_t - R_w$ (Million)	Cost/ DALY ($)	Cost in Million $		Range of x and H values
							Human Capital	Scaled USEPA	
1	3.62	0.85257	0.70	2.80	0.825	380.0	313.4	855.6	Lowest x=0.9, H=0.7
2	3.62	0.79884	0.70	2.58	1.039	380.0	394.8	1077.9	Medium x=0.8, H=0.7
3	3.62	0.74511	0.70	2.40	1.223	380.0	464.7	1268.5	Medium x=0.7, H=0.7
4	3.62	0.69138	0.70	2.24	1.382	380.0	525.2	1433.8	Medium x=0.6, H=0.7
5	3.62	0.63765	0.70	2.10	1.522	380.0	578.2	1578.5	Medium x=0.5, H=0.7
6	3.62	0.85257	0.60	2.64	0.975	380.0	370.6	1011.8	Medium x=0.9, H=0.6
7	3.62	0.79884	0.60	2.41	1.212	380.0	460.5	1257.1	Medium x=0.8, H=0.6
8	3.62	0.74511	0.60	2.21	1.409	380.0	535.6	1462.1	Medium x=0.7, H=0.6
9	3.62	0.69138	0.60	2.04	1.577	380.0	599.3	1636.1	Medium x=0.6, H=0.6
10	3.62	0.63765	0.60	1.90	1.721	380.0	654.0	1785.6	Medium x=0.5, H=0.6
11	3.62	0.85257	0.50	2.46	1.161	380.0	441.1	1204.2	Medium x=0.9, H=0.5
12	3.62	0.79884	0.50	2.20	1.418	380.0	538.9	1471.2	Medium x=0.8, H=0.5
13	3.62	0.74511	0.50	1.99	1.627	380.0	618.1	1687.5	Medium x=0.7, H=0.5
14	3.62	0.69138	0.50	1.82	1.799	380.0	683.7	1866.5	Medium x=0.6, H=0.5
15	3.62	0.63765	0.50	1.68	1.944	380.0	738.8	2016.9	Highest x=0.5, H = 0.5
				Average of 15 scenarios			527.8	1440.9	

Table 6: Annual health Impacts and Health costs avoided through the provision of clean water

Saving in DALYs (Variable values)	DALYs Reduced (Millions)		Value of Reduced DALYs (Million $)		
			This work		Brandon
	Present work	Brandon	Human Capital	USEPA AVOL	
Lowest Savings Range (X=0.9, H=0.7)	0.82	1.31	313	856	289-788
Highest Savings X=0.5, H=0.5	1.94	2.3	739	2017	506-1,380
Average Savings of 15 Scenarios	1.39	1.82	528	1441	401-1,093

Total DALYs between 0.82 –1.94 million can be saved through the provision of clean water and sanitation. The economic value of water-related mortality and morbidity can be estimated by using the human capital approach. This implies that the statistical value of one DALY is equal to the annual average productivity of a worker in Bangladesh. This may be set equal to per capita GNI for Bangladesh. Higher estimates for the DALYs are obtained if GNI-scaled USEPA annualized value of life are used. This value is 2.73 times higher than the GNI as reported by Brandon. The cost savings involved in both the approaches are shown in the tables above. The savings are between US$313–739 million in the human capital approach method. In GNI terms, these correspond to 0.63–1.48 % per year. Compared to Bandon's study (1997) the water-related health costs have increased to some extent. This increase reflects the impact of increase in the population and per capita GNI as reduced access to clean water. The impact of Arsenic contamination has not been considered.

Some discussions on the numbers obtained for DALYs saved in these calculations are necessary, as it is not clear what quantities impact these savings. The impacts are not due to water pollution per se but a combination of access to water, sanitation and their interactions. However, through parameterization of the relative importance of water and sanitation for adequate safety from waterborne diseases (x) and the hygiene factor which defines the level of hygiene among two groups of people with and without adequate access to water and sanitation services (H), the impacts probably range from access to clean water to the maximum level of benefits obtainable from access to clean water and sanitation are included. The lowest value obtained probably corresponds to access to clean water. Although the range of values obtained is rather large, refinements in methodology since Brandon's work may not reduce the uncertainties to any great extent. The same methodology as Brandon's original paper has been followed as this allows a comparison over results over time.

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