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Activity segment 4

BAPMAN Project Deliverable D4.2, D4.3 and D4.4

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Scientific report

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Activity segment 4

Health impact and scenario research:
Contributing to the development of an air quality management strategy

Deliverable D4.2:

Preliminary survey of possible health impact from air pollution in Bangladesh cities

Deliverable D4.3:

Scenarios for cost- effective air pollution control in Bangladesh cities

Deliverable D4.4:

Investigations of strategies for cost-effective air pollution control in Bangladesh cities

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Preface

The Bangladesh Air Pollution Management (BAPMAN) project is NORAD funded institutional-building program (2010-2013) where NILU lends the necessary Air Quality Management tools and associated training to the Clean Air and Sustainable Environment (CASE) program at the Bangladesh Department of Environment (DoE). BAPMAN project Tasks include:

1. Emission Inventories (Top-down and Bottom-up)
2. Monitoring, Laboratory Procedures, and Data Acquisition
3. Air Quality Management Tools and Data Analysis
4. Health Impact and Scenario Research

Project outcomes are to document the necessary training in the tasks above (as well as tools given), in addition to presenting corresponding results from the exercises, if applicable.

This report (as Deliverable 4.2, 4.2 and 4.4 for Task 4 of the BAPMAN Project) presents a survey of possible health impacts from air pollution (PM_{10}) in Dhaka city, as well as scenarios and strategies for mitigating these impacts.

Contents

Activity segment 4
BAPMAN Project Deliverable D4.2, D4.3 and D4.4

1 Introduction

Dhaka city is facing major pollution problems due to the high population and rapidly increasing urbanization. A large number of motor vehicles and the subsequent traffic congestion have in combination with many kilns located in the area led to the high ambient levels of air pollutants. The pollution problems is leading to a wide range of potential negative environmental and health impacts, and has therefore become a serious concern to both the public and government.

Atmospheric particulate matter (PM) is potentially the most important contaminant when it comes to causing adverse human health effects. Mortality and morbidity effects are generally detected worldwide at various existing urban ambient concentrations. Acute effects of PM exposure can be linked mortality of infants, hospital admissions for cardiovascular and respiratory diseases, as well as mortality both due to respiratory (RD) and cardiovascular diseases (CVD). Long term exposure can lead to mortality of lung cancer (LC) and chronic obstructive pneumonia disease (COPD) as well as morbidity effects, such as bronchitis at both children and adults. According to the World Health Organization (WHO) about 1.4% of total mortality, 0.4% of all disability- adjusted life years (DALYs), and 2% of all cardiopulmonary disease can be attributed to outdoor air pollution measured solely on the effects of PM pollution globally (WHO, 2004).

In Dhaka PM originates from a variety of anthropogenic sources, such as brick kilns and biomass burning, power plants, industrial processes and vehicles. The major sources of PM in Dhaka city are believed to be vehicle emissions and re- suspended dust as well as brick manufacturing (DOE, 2012), but also regional transport affects the concentrations of PM measured in Dhaka. The enormous brick manufacturing industry with its 1000 brick kilns in the Greater Dhaka region is mostly operating in the winter season (October to March) and contributes to about 23.300 t of $PM_{2.5}$ emitted each year according to Guttikunda et al., (2012). It has been observed that during the wet season (May- September) both PM_{10} and $PM_{2.5}$ concentration levels[1] somewhat meet the 24 hours average Bangladeshi National Ambient Air Quality Standard for PM (150ug/m^3 for PM_{10} and 65 ug/m^3 for $PM_{2.5}$), whilst for the rest of the periods, these limits are usually exceeded (DOE, 2012).

Quantifying the relationships between emission sources, ambient air concentrations, human exposure and the resulting effects on health, is important for identifying the resource- efficient pollution abatement strategies (Deliverable D4.4), but also to address the health benefits of measures that typically reduce those emissions. In such way, priorities for controlling air pollution can be compared to other interventions that improve public health and thus optimize the use of scarce resources (Deliverable D4.3 and Deliverable D4.4).

[1] Annual average concentration of PM10 is estimated at 195 ug/m3.

2 T4.2: Health effects end-point selection, extraction of medical data from records, including mortality and morbidity rates, and population data

Health effects end- point selection:

Fine particulate matter is associated with a broad spectrum of acute and chronic illnesses. PM with diameters less than 10 µm (PM_{10}) and 2.5 µm ($PM_{2.5}$) can penetrate deep into the lungs (such as to the bronchioles or alveoli) and cause adverse effects on the respiratory and cardiovascular systems. The elderly, individuals with pre-existing heart and lung disease, children, asthmatics and asthmatic children are at largest risk of developing health problems from exposure to PM.

Potential health endpoints from short- and long- term exposure to PM_{10} were chosen in this study as the basis for health impact calculations. These were based on the following literature:

- Zhang, D., Aunan, K., Seip, H.M., Larssen, S., Liu, J., Zhang, D. (2010) The assessment of health damage caused by air pollution and its implication for policy making in Taiyuan, Shanxi, China. *Energy Policy, 38,* 461-502.
- Aunan, K, Pan, X.C. (2004) Exposure- response functions for health effects of ambient air pollution applicable for china –a meta analysis. *Sci. Total Environ. 329,* 3-16.
- Pope, I.C., Burnett, R.T., Thun, M.J., Thun, M.J., Calle, E.E., Krewski, D., Ito, K., Thurston, G.D. (2002) Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *J. Am. Med. Ass., 287,* 1132-1141.

The selected health effects end- points can be observed in Table 1.

Table 1: Exposure- response coefficients for human health damage by air pollution (PM_{10})

End- point	Age group	Coefficient	Reference
Short- term			
All cause mortality	Infant 0-1	0.39 (0.04)	Aunan and Pan (2004)
Hospital admission for cardiovascular diseases (CVD)	All	0.07 (0.02)	Aunan and Pan (2004)
Hospital admission for respiratory diseases (RD)	All	0.12 (0.02)	Aunan and Pan (2004)
Long- term			
All cause mortality	≥30	0.4 (0.1-0.8%)	Pope et al. (2002)
Mortality due to respiratory diseases (RD)	≥30	0.6 (0.2-1.0%)	Pope et al. (2002)
Mortality due to cardiovascular diseases (CVD)	≥30	0.6 (0.2-1.0%)	Pope et al. (2002)
Mortality due to lung cancer (LC)	≥30	0.80 (0.1-1.5%)	Pope et al. (2002)
Bronchitis in adults	Above 14	0.31 (0.01)	Aunan and Pan (2004)
Bronchitis in children	0-14	0.44 (0.02)	Aunan and Pan (2004)

3 Extraction of medical data from records, including mortality and morbidity rates:

A review of the global World Health Organization`s (WHO`s) health statistics and the extraction of their country- specific statistics for Bangladesh provided the basic data for distribution and rates of potential air pollution related mortality (WHO, 2008). The statistics indicate that people in Bangladesh predominantly die from cardiovascular diseases; however child mortality and respiratory infections were also well represented. Out of 1 151 000 deaths in Bangladesh in 2008, about 14 percent was caused by Ischemic heart disease. Deaths by lower respiratory infections were representing about 9 percent whilst cerebrovascular disease was representing about 7 percent. This was similar to the deaths caused by tuberculosis about (7 percent) while chronic obstructive pulmonary disease led to about 4 percent of the deaths. Child mortality in Bangladesh were representing more than 10 percent of the total deaths if adding up diarrhoeal diseases and prenatal conditions, such as neonatal infections, birth asphyxia and birth trauma, as well as prematurity and low birth weight.

The top 10 death by cause for three cohorts in Bangladesh in 2008 can be observed in fig 1.

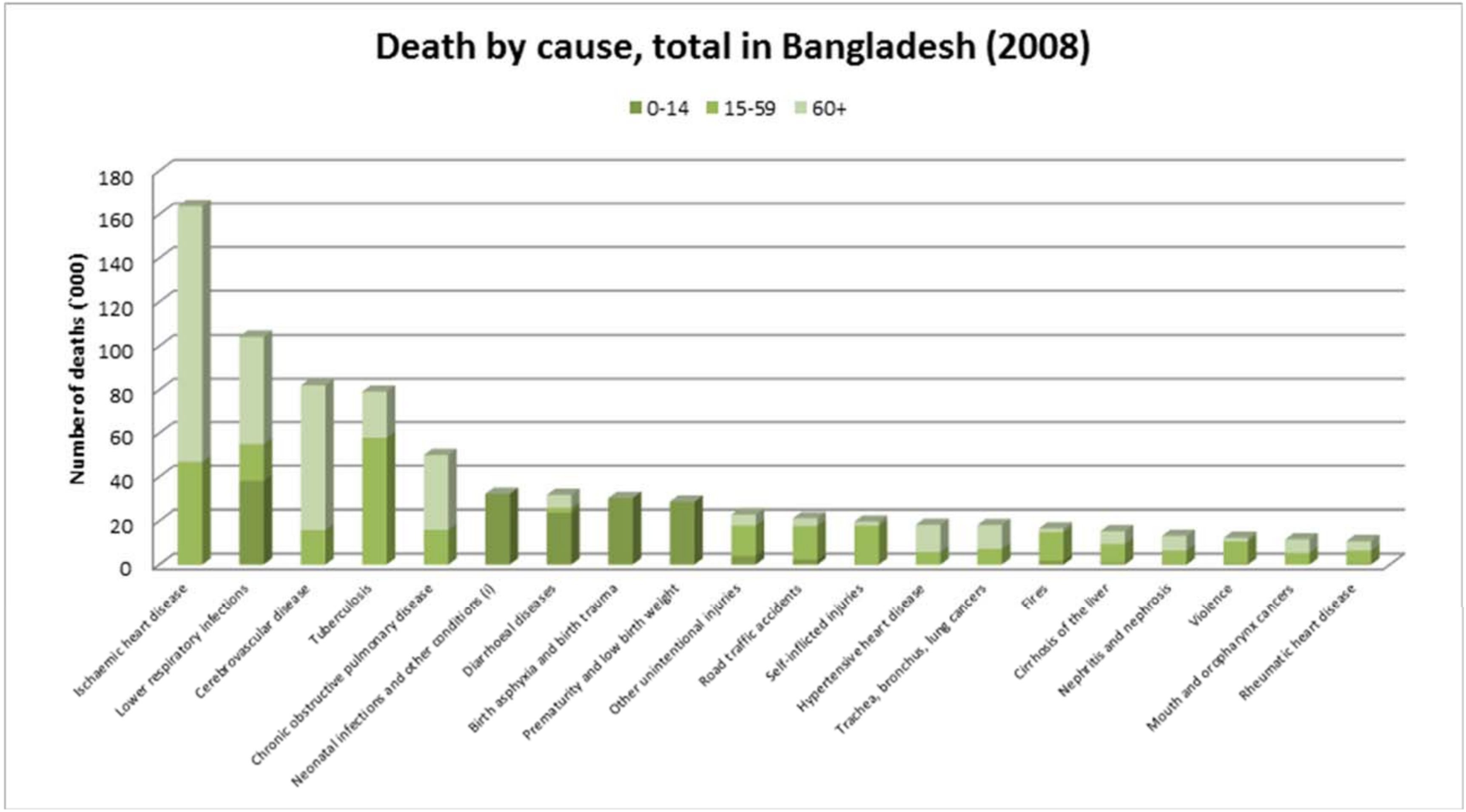

Figure 1: Death by cause in 2008, total in Bangladesh. Based on WHO statistics

Mortality rates are estimated from the WHO statistics by applying the number of deaths in Bangladesh population, scaled to the size of that population, resulting in cases per year per person. For morbidity rates, these are assumed to be similar to the ones presented in Zhang et al., (2010).

An overview of the estimated/selected baseline mortality and morbidity rates can be observed in Table 2 below:

Table 2: Baseline mortality rates and morbidity rates

Health endpoint	Rate (cases per year per person)	Reference
All- cause mortality	0.007	WHO, 2008
Mortality of COPD	0.0003126	WHO, 2008
Mortality of CVD	0.00197	WHO, 2008
Mortality of LC	0.000114	WHO, 2008
Hospital admissions for CVD	0.0067	Zhang et al. (2010) /MoH
Hospital admissions for respiratory diseases	0.0045	Zhang et al. (2010) /MoH
Prevalence rate of chronic bronchitis	0.0139	Zhang et al. (2010) /MoH
Prevalence rate for COPD	0.0220	Zhang et al. (2010) /MoH

Population data for Dhaka was collected from the Bangladesh Bureau of Statistics' community report on population and housing in Dhaka Zila and Dhaka City Corporation (BBS, 2012).

4 Task T4.3: Review of pollutant sources, including the emission inventories collected under Work segment 1

An analysis of the Greenhouse Gas and Air Pollution Interactions and Synergies model (GAINS) derived model data has been performed in Randall, (2011). Due to lack of available compiled data, the GAINS data assessed in the Randall, (2011) analysis was used as the basis for a top-down “screening-type study” tool for PM emissions to be presented under this task. It should be noted that, because of the GAINS data simplified character, closer research and analysis using more specific tools or ground-based monitoring is needed before using it in decision- making. In principle, the GAINS model was chosen because of its integrated assessment approach of capturing interactions between air pollution control and economic development, as well as its focus on presenting cost effective pollution control strategies.

The current level (2010) of PM_{10} emissions for Dhaka city was by GAINS modelled at about 45000 tons/year and further projections was modelled at about 64000 tons/year in 2030. The Dhaka city emission model indicated that industrial processes, especially bricks production (about 17.000 tons/year) and to a lesser degree cement production (about 7.000 tons/year) were causing most of the PM_{10} emissions in 2010. Residential activities, such as cooking stoves (about 11.000 tons/year) as well as other kinds of residential cooking and heating activities show a large contribution, in fact 10 times more than the contribution from the transport sector.

The results of the 2010 modelled emission inventory by sector can be observed in Fig 2 and Table 3.

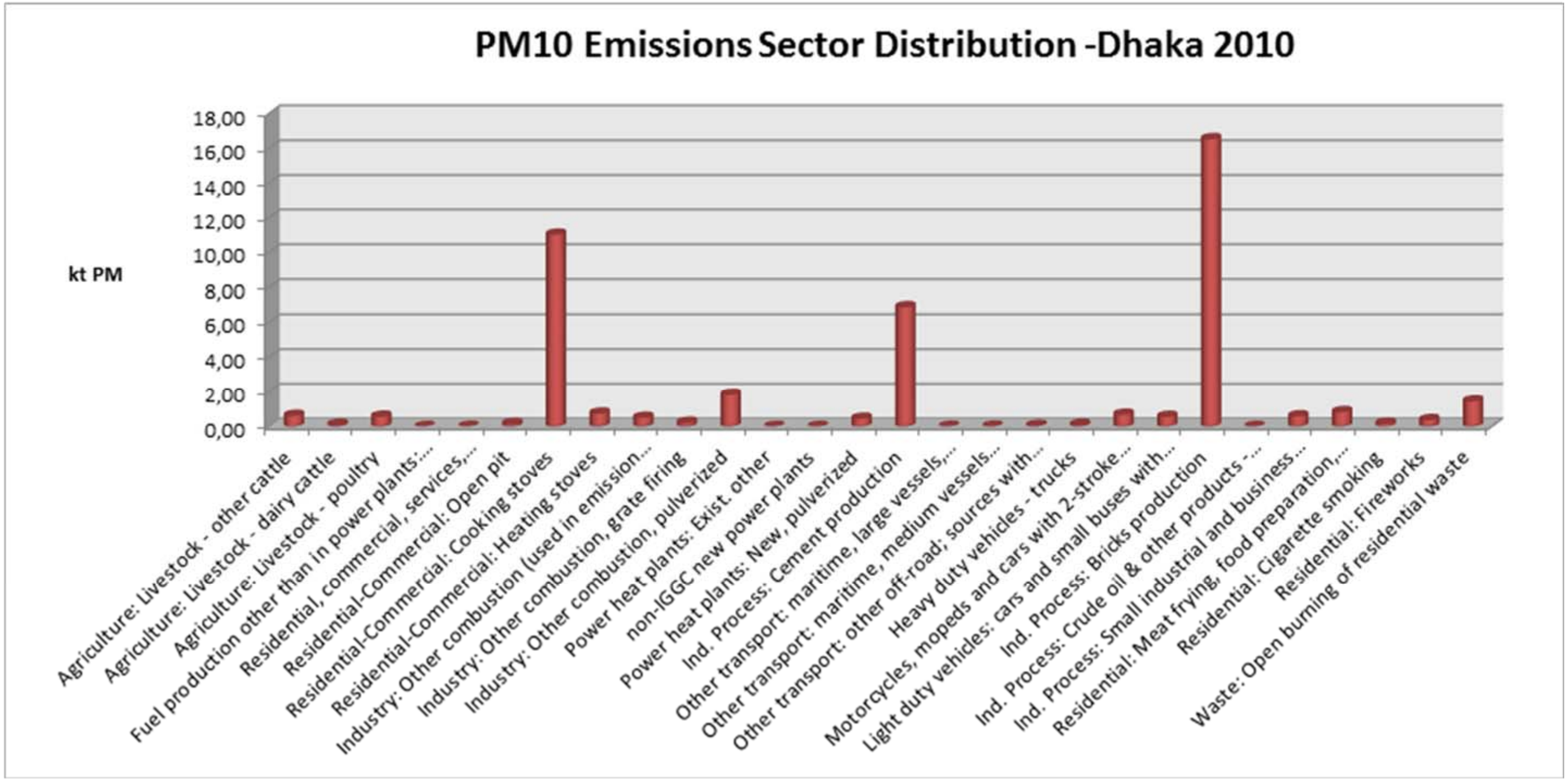

Figure 2: PM_{10} emission sector distribution in Dhaka in the year 2010. Source: Randall, 2011; Gains South Asia Model.

Table 3: The 2010 PM_{10} emissions by sector

Sector	**2010 Emissions (kt)**
Ind. Process: Bricks production	16.56
Residential-Commercial: Cooking stoves	11.04
Ind. Process: Cement production	6.91
Industry: Other combustion, pulverized	1.85
Waste: Open burning of residential waste	1.48
Residential: Meat frying, food preparation, BBQ	0.86
Residential-Commercial: Heating stoves	0.77
Motorcycles, mopeds and cars with 2-stroke engines	0.71
Agriculture: Livestock - other cattle	0.64
Ind. Process: Small industrial and business facilities - fugitive	0.62
Agriculture: Livestock - poultry	0.59
Light duty vehicles: cars and small buses with 4-stroke engines	0.58
Industry: Other combustion (used in emission tables)	0.53
Power heat plants: New, pulverized	0.48
Residential: Fireworks	0.40
Industry: Other combustion, grate firing	0.24
Residential: Cigarette smoking	0.19
Residential-Commercial: Open pit	0.17
Agriculture: Livestock - dairy cattle	0.12
Heavy duty vehicles - trucks	0.12
Other transport: other off-road; sources with 4-stroke engines	0.06
Other transport: maritime, medium vessels <1000GRT	0.02
Other transport: maritime, large vessels, >1000 GRT	0.01
Residential, commercial, services, agriculture, etc.	0.01
non-IGGC new power plants	0.01
Power heat plants: Exist. other	0.00
Ind. Process: Crude oil & other products - input to Petroleum refineries	0.00
Total	**44.95**

Source: Randall, 2011; Gains South Asia Model.

5 Task T4.4: Construction of pollution fields, including results from observations and modelling

5.1 Ambient air PM concentrations in Dhaka City:

The DOE has recently presented a report on spatial distribution of Particulate Matter (PM) concentrations in Dhaka City (DOE, 2012). By using a satellite monitoring network and portable air monitoring instruments at three different locations in Dhaka city, they collected PM_{10} and $PM_{2.5}$ concentrations for the time period of February 2011 to June 2012.

In Dhaka, the seasonal variations in precipitation are marked distinctly for the four seasons: pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November), and winter (December-February) (DOE, 2012). DOE observed that during wet season (May- September) both PM_{10} and $PM_{2.5}$ concentration levels meet the 24 hours average Bangladeshi National Ambient Air Quality Standard for PM (150ug/m^3 for PM_{10} and 65 ug/m^3 for $PM_{2.5}$), while for the rest of the periods, these limits usually are exceeded.

As a result of the nearly flat topography of Dhaka City it is assumed that PM concentration levels over the city would not vary significantly (DOE, 2012). Local sources may however, influence the PM concentration levels in some periods in which spikes of the PM levels can be observed.

The observed PM_{10} and $PM_{2.5}$ concentrations are illustrated in fig. 3 and 4 below:

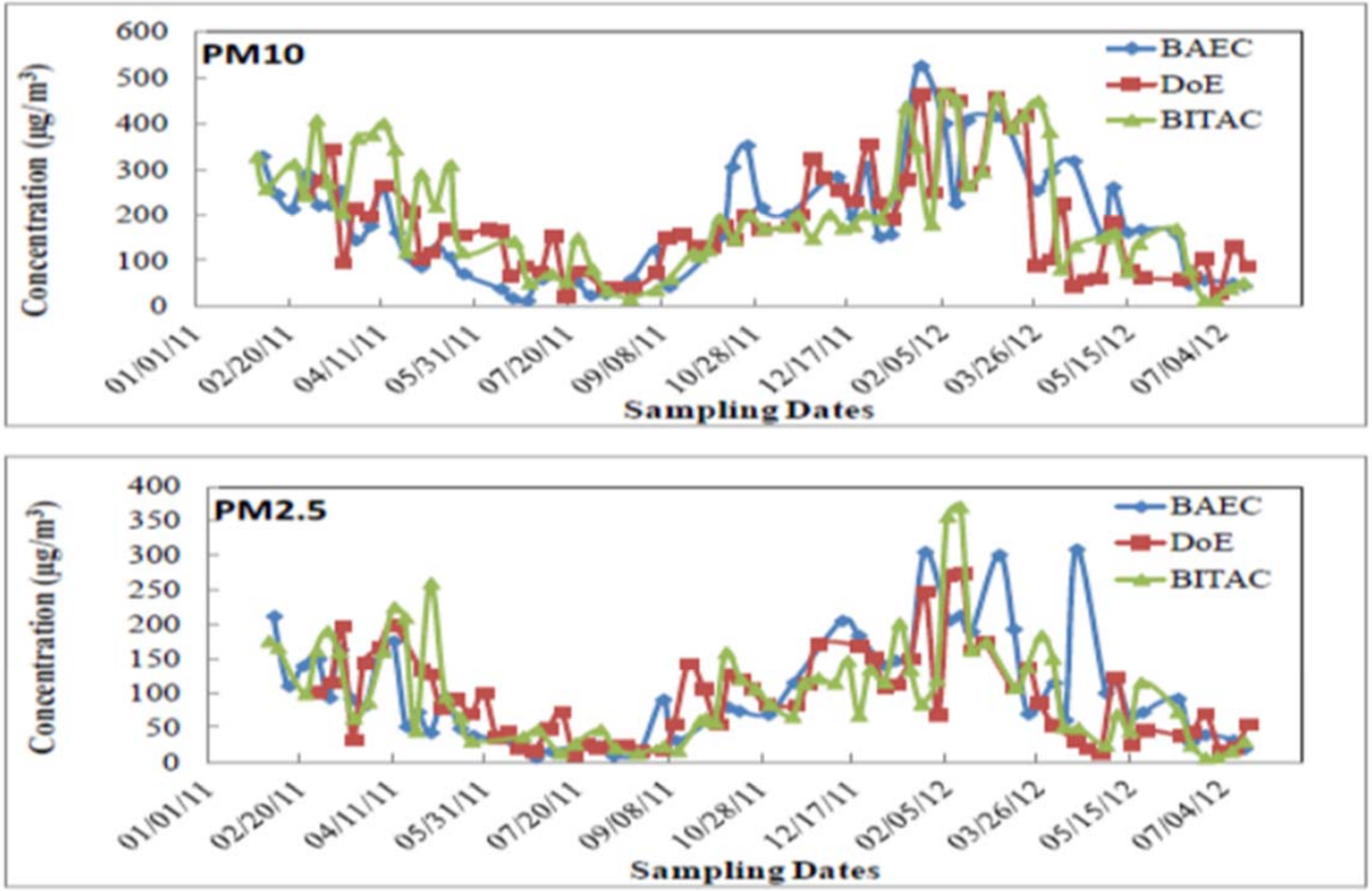

Figure 3 and Figure 4: *Observed PM_{10} and $PM_{2.5}$ concentrations in Dhaka. (Source: DOE, 2012).*

6 Task T4.5: Synthesis of exposure and health impact assessment, including a first estimate on the impact of air pollution upon health in Dhaka

The impacts of air pollution upon health in Dhaka are based upon the method recommended by the WHO for calculating the disease burden. It starts with estimating the relative risk (RR), i.e. the risk of an event relative to the exposure. WHO recommends that for short term exposure, a linear risk function should be applied, while for long term exposure, a log- linear risk function should be applied. The formulas for a short- term and a long- term risk function are given below:

Relative risk (linear):

$$RR = \exp[\beta(X - X_0)]$$

Relative risk (log-linear):

$$RR = [\frac{(X + 1)}{(X_0 + 1)}]^{\beta}$$

$$\beta - exposure - response\ function, X - annual\ average\ PM\ conc.,$$
$$X_0 - \ target\ PM\ conc.$$

The exposure- response functions used for this analysis is the ones presented in Table 1 while the annual average PM_{10} concentration is estimated from the DOE (2012). The target PM concentration is assumed to equal the Bangladesh standards, indicating that no health endpoints will be observed below the standard level (threshold level of no effects).

Next, the RR is used for calculating the attributable fraction (AF) of health effects. The AF is describing the difference in rate of condition between an exposed and an unexposed population. Since it is expected that the entire Dhaka city population are assumed to be exposed to a uniform concentration, the AF simplifies to the following:

Attributable function (AF):

$$AF = \frac{RR - 1}{RR}$$

The number of expected cases is given by the AF times the mortality or morbidity rate times the Dhaka city population. This can be shown as the following formula:

Expected number of cases:

$$E = (\text{AF} * \text{Mortality rate} * \text{Pop})$$

6.1 Impact of air pollution upon health in Dhaka: Results

The impact results from the estimating method presented above can be observed in Table 4.

Table 4: The short- and long term impact of PM_{10} air pollution upon health in Dhaka in the year 2010

End- point	Age group	Coefficient	Mortality/ morbidity rate	Incidence from exposure (Estimate range)
Short- term				
All cause mortality	Infant 0-1	0.39 (0.04)	0.0072	**185** (167-202)
Hospital admission for cardiovascular diseases (CVD)	All	0.07 (0.02)	0.0067	**1 450** (1 040-1 856)
Hospital admission for respiratory diseases (RD)	All	0.12 (0.02)	0.0045	**1 382** (1651-1917)
Long- term				
Mortality due to respiratory diseases (RD)	≥30	0.6 (0.2-1.0%)	0.0019	**5 205** (2 216-6 948)
Mortality due to cardiovascular diseases (CVD)	≥30	0.6 (0.2-1.0%)	0.0004	**1 134** (483-1 514)
Mortality due to lung cancer (LC)	≥30	0.80 (0.1-1.5%)	0.0001	**345** (66-454)
Bronchitis in adults	Above 14	0.31 (0.01)	0.0139	**22 568** (21 977-23 151)
Bronchitis in children	0-14	0.44 (0.02)	0.0139	**29 566** (28 567-30 538)

The short term annual impacts of the average annual PM_{10} concentrations in Dhaka are on the basis of the chosen exposure- responses linked to almost 200 premature deaths among infants as well as 1400- 1500 incidences of hospital admissions for people with respiratory and cardiovascular diseases respectively. Long term impacts of adults are estimated to more than 5000 premature deaths from respiratory diseases and more than 1100 deaths among adults from cardiovascular diseases. More than 300 cases are estimated for deaths connected to lung cancer. Incidents of bronchitis among adults and children were estimated to about 22000 and 30000 respectively.

6.2 Limitations of the data sources:

Clearly, there are many limitations connected to the data sources used for estimating the health impacts from PM_{10} pollution in Dhaka which affects the reliability of the results. First, the WHO data on burden of disease used are not national data reported for Bangladesh, but national estimates based on experiences from other countries in the same region. These national results were in this study, assumed to be representative for the Dhaka population.

The exposure- response functions selected was collected from epidemiological literature available. Since the health impacts are the product of ambient concentration of a pollutant, the population affected and an exposure- response function, the local pollution status, and the availability of exposure- response relationships for a given combination of pollutants, will thus determine the health effect analysis. Most of the air pollution health effects existing in the epidemiological literature have been assessed from studies carried out in Western countries. Since, the composition of air pollution differs significantly between Asian and most Western countries, uncertainties remain regarding the extrapolation of exposure- response coefficients based on Western studies to developing countries. Aunan and Pan, (2004) have proposed exposure- response functions for health effects of PM_{10} and SO_2 in China. At the same time, the coordinated Public Health and Air Pollution in Asia (HEI) studies has focused on providing time- series of health effects of short- term exposure to air pollution in Bangkok, Hong Kong, Shanghai, and Wuhan. Based on the measurements of four different pollutants (PM_{10}, O_3, NO_2, and SO_2), effects were found on cardiovascular and respiratory mortality (HEI Report, 2010).

Another challenge in using established dose- response functions to estimate health end points is to approach the actual observations on gas mixtures to a function that originally is developed for specific pollutants or other pollutant mixtures than those observed. Air pollutants may have a synergic effect on human health; -for instance, the combined effect of SO_2 and PM_{10} may be higher (or lower) than the sum of the two components when they occur in isolation. The contribution of each of these pollutants to health damage may be difficult to distinguish, and adding both effects may lead to double accounting.

7 T4.6: Construction of scenarios, including assumptions on hypothetical emission reductions and their effects on human health in Dhaka

The main objective of this task was to develop fundamental expertise at the DoE by which objectives and strategies for air quality management can be developed into the future. The health impact assessment presented under tasks T4.1-T4.5 was used to produce estimates of population impacts from PM_{10} under hypothetical technology scenarios for the brick kiln production in the year 2030. The task contributed to the analysis of effects of technology options in terms of damage avoidance and cost as well as to the discussion on relevant control strategies and enforced regulations.

A key issue when it comes to quantification of future emissions and their impacts is to identify the future development of the main drivers of the system. Main drivers are typically ***introduction of policies and legislations***, ***technology change***, ***population developments***, and ***development of the economy (including consumption increases or decreases)***. In addition, it is important to be aware of various behavioural responses from the stakeholders who are affected by the interventions and how they can influence the drivers of the system. The expected impacts from the scenario are made by applying the predicted changes in the key drivers to the present situation. Statistical data obtained are used to predict the trends that can be expected in the chosen time frame.

7.1 Existing policies and legislations:

As some emission sources may already or in the near future be eliminated by existing regulations or policies, the baseline scenario considers any relevant legislations/directives or modifications to these during the timescale undertaken in the analysis.

The primary legislation instituted to mitigate air pollution is the 1995 Bangladesh Environmental Conservation Act (ECA) and the 1997 Environmental Conservation Rules. Regulations for the brick kiln industry were introduced already under the Brick Burning Act in 1989; however, recommendations of various policy options and incentives to introduce cleaner brick manufacture technologies and enhance energy efficiency in the sector were not undertaken before 2005/2006. Standards for gaseous discharge from industries were provided from 1997. DOE’s air pollution responsibilities include the control and analysis of ambient air quality, the identification of polluting industries, and providing support for the implementation of pollution prevention and control (CAI, 2006).

The Policies, laws, and regulations in Bangladesh concerning the brick sector are presented in table 5.

Table 5: Policies, laws, and regulations in Bangladesh concerning the brick sector (taken from The World Bank, 2011)

Year	Policies, laws, and regulations	Government responsibility	Details	Remarks
1989	The Brick Burning (Regulation) Act of 1989	DOE, MOEF	Bangladesh's first brick-making law banned the use of firewood for brick manufacturing and introduced licensing for brick kilns.	Use of firewood has large been discontinued, but in remote areas this practice still continues on a limited scale.
2001	Revision of the Brick Burning (Regulation) Act of 1989	DOE, MOEF	The 1989 Act was amended to regulate the location of brick kilns. The new provision required that brick kilns not be set up within 3 km of the upazilla or district center, municipal areas, residential areas, gardens, and the government's reserve forests.	Using the given criteria, it is nearly impossible in reality to find land for brick kilns in Bangladesh. The BBMOA often cites this as a major deficiency in the law. Despite this amendment, the location requirements have not been enforced.
2002 Oct.	Brick Burning rules	DOE, MOEF	The GOB introduced a rule that made the use of 120-ft chimneys for brick kilns compulsory.	This requirement was successfully enforced, especially in the vicinity of urban areas, and most Bull's Trench Kilns (BTKs) were upgraded to FCK technology. However, some BTKs continue to operate, albeit illegally.
2007 March	GOB Notification	DOE, MOEF	GOB issued notification that environmental clearance certificates would not be renewed if owner did not shift to alternative fuel and improved technologies by 2010.	This regulation has not been implemented since little on-the-ground activity occurred to facilitate the switch.
2010 July	GOB Notification	DOE, MOEF	A new notification was issued banning FCK operation three years from this date.	Activities are being undertaken under GOB's CASE project with World Bank support
2011	Revision of Brick Burning Act	DOE, MOEF	The revision of Act has the objective to facilitate transition of the brick industry for improved energy efficiency and lesser pollution level.	Still in process. Promulgation may take more than one year.
Regulations on air pollution				
1977	Environment Pollution control Ordinance,1977.	DOE, MOEF	This Act provided limited provisions for the conservation of the environment	This ordinance had limited provisions and was replaced by ECA95.
1992	Environmental Policy and Action Plan	MOEF	Prioritizes areas of attention for Environment Conservation.	This is a document of intent, without legal mandate. The ECA of 1995 provides the necessary legal framework.

Year	Policies, laws, and regulations	Government responsibility	Details	Remarks
1995	Environmental Conservation Act (ECA), 1995	DOE, MOEF	This Act provides for conservation of the environment, improvement of environmental standards and control and mitigation of environmental pollution.	The 1977 ordinance is replaced by this Act. The Government can issue notification in the official Gazette and make rules for carrying out the purposes of this Act, including emission standards.
1997	Environmental Conservation Rules (ECR), 1997	DOE, MOEF	Sets air emission standards for industries including brick kilns.	The SPM standard for brick kiln emission is set at 1000 mg/m^3, which is rather lenient. Even this standard could not be enforced due to limited capacity in the DOE.
2005	Revision of ECR97	DOE, MOEF	Sets Ambient Air Quality for criteria pollutants and Vehicular Emission standards	$PM_{2.5}$ standard is defined and violation of ambient air quality standards can be enforced under this rule.

7.2 Alternative brick kiln technologies:

Brick making is an important industry in Bangladesh that produces 15 billion bricks per year which is growing every year by about 3% and contributing 1% to the national GDP providing employment to more than 1 million people directly and caused employment of about 10 million people in the construction industry. At present, there are five types of brick kiln technologies exist in Bangladesh including Bull Trench Kilns (BTK), Fixed Chimney Kilns (FCK), Hybrid Hoffman Kilns (HHK), Zigzag Brick Kilns (ZBK) and Vertical Shaft Brick Kilns (VSBK). Due to the shortage of gas resources the Hybrid Hoffman Kilns that are using gas as a fuel will be limited in the (near) future. The BTKs are not permitted by the government as environment polluter and was replaced by FCK in the past. There are only very few BTKs exist in the rural areas.

7.2.1 Fixed Chimney Kilns (FCK):

FCK has become the most popular brick kiln technology in Bangladesh with 92% of share of total brick kilns existing but it has got serious emission problem. The high fixed chimney could not help reduce carbon emission due to use of very low level firing technology. As a result FCKs emit a huge amount of Suspended Particulate Matter (SPM) as well as other flue gases causing environment pollution. The government has decided to impose ban on FCK to save the environment from black carbon emission. Even though it is very polluting and energy intensive, it requires relatively low-cost investment. FCKs are located on lowlands and operate for 5-6 months a year. The FCK is based on the traditional BTK technology, which dates back to the last century. While the BTK uses two 30 feet (ft) high moveable chimneys, the FCK has a fixed chimney of about 120-130 ft height. The tall chimney provides a faster and better dispersion of the flue gas and its pollutants, compared to the BTK. The FCK has an elliptical shape and measures about 250 ft long and 60 ft wide. It is constructed mostly in open fields either over ground or partially underground. The bottom and the sidewalls are lined with bricks. The FCK uses green bricks that are manually produced from mud processed in pug mills. The wet green bricks are sun dried and loaded in the kiln in a standard way developed over time with provisions for airflow and coal stoking. Once the green bricks have been loaded in the kiln, the top is covered with two layers of bricks and dirt for insulation.

7.2.2 Zigzag Brick Kilns (ZBK):

The Zigzag kilns used in Bangladesh are replications of similar Indian kilns developed by the Central Building Research Institute (CBRI) in Roorkee, India during the 1970s. They are fairly similar to Habla kilns once widely used in Getmany and Australia. In Bangladesh, approximately 150 such kilns are in operation according to DOE (Department of Environment) statistics. The Zigzag kilns if properly constructed and operated, should result in better energy efficiency and lower emissions. The energy efficiency gains are due to better insulation and improved heat transfer to the green bricks. The emission reductions are due to lesser fuel use, better brick stacking, Zigzag air flow over longer path and flue gas scrubbing in a water filled duct connecting to the outlet chimney.

The flue gas 'repeated changes in direction and impinging on the walls and stacked bricks lead to the deposition of significant amounts of particulate matter mostly on the green brick surface. The deposition of particulates implies that the flue gas has much less particulate load. This could be the reason for reduced Zigzag emission compared to FCKs emissions. The Zigzag kiln also incorporates a simplified flue gas scrubber. The connecting duct between the center of the kiln and the inlet of the induced draft fan is half to two-third filled with water. The flue gas laden with dust particles impinges on the water thus losing some of its particulate load. The water is periodically cleaned to ensure continued scrubbing.

The Zigzag kilns in Bangladesh have been implemented with the help of artisans without expert supervision. Thus, it has not been possible to ensure proper construction according to certified design, which is important in reducing the level of particulate emissions. To achieve this goal, it is essential to: (1) try out the technology with expert professional input; (2) develop certified design specifications for construction and standard operating procedures; (3) establish good operational practices and management. In the absence of such a systematic approach, not only there may not be significant reductions in emission levels, but the local pollution may actually increase due to reduced chimney height.

7.2.3 Vertical Shaft Brick Kilns (VSBK):

The vertical shaft brick kilns (VSBK) is an emerging technology better suited for the small-sized brick kilns with a production capacity of 8,000 to 10,000 per day. This technology further reduces the fuel consumption and toxic emissions compared to FCKs via higher heat efficiency in multiple shaft architecture and better ratio of land used to production output. The sun-dried bricks and combustion fuel are stacked in batches on to the top of the shaft, which progressively move from the pre-heating, firing, and cooling zones before reaching the bottom of the shaft for periodic removal. These kilns can also be designed for all weather conditions with roof-protected arrangement. VSBK design and construction details based on a pilot implementation in Bangladesh are presented as a manual in World-Bank (2011).

7.2.4 Hybrid Hoffman Kilns (HHK):

Developed in China, the HHK represents a hybrid version of the Hoffmann Kiln technology developed in Germany in the mid-l9th century. Unlike the gas-based Hoffmann Kiln, the HHK uses coal as fuel. The HHK combines fuel injection and external firing in highly insulated kilns, leading to lower energy use, high-quality bricks, and reduced pollution. The technology was introduced in Bangladesh through a Clean Development Mechanism Project .Improving Kiln Efficiency in the Brick Making Industry in Bangladesh (Bundle-1 & Bundle-2),' jointly initiated by the World Bank and IIDFC. Some 10 HHKs are operating in Bangladesh, with 20 in the pipeline.

The HHK design combines a highly efficient kiln technology, known as Forced Draft Tunnel Kiln (FDTK), with a unique technique of forming green bricks: Granulated coal is injected for internal combustion. Nearly 80 percent of the total energy required is injected into the bricks, while the remainder is fed externally into the firing chamber. Most of the fuel injected into the green bricks is completely burned during firing. This technology improves energy efficiency in two ways (i) internal combustion of injected fuel in green bricks and (ii) application of heat optimization techniques in a minimum heat-loss chamber in the kiln's combustion zone. The HHK, like traditional technologies, does not require a tall chimney.

The HHK bricks are stronger and their price more competitive than those of the FCK. The HHK initiative promises to be successful in the marketplace; however, there are barriers to adopting the technology. First, HHK implementation requires a substantially higher capital (about TK140 million per kiln) compared to the FCK (TK5 million). Second, the HHK needs higher land (above the monsoon Flood level), which is scarce and extremely expensive in the area surrounding the city of Dhaka and other major urban senters.

A comparison of the technical and operational benefits and constraints of alternative brick kiln technologies are presented in table 6.

Table 6: Comparison of technical and operational benefits and constraints of current and alternative brick manufacturing technologies available in Bangladesh (Table based on Guttikunda and Khaliquzzaman, 2013 and WB, 2011)

Tech-nology	Fuel consumed per 100,000 bricks	Investment and operational costs (million USD)[f]	Brick production capacity (million/kiln)	Number of kilns required to produce 3.5 billion bricks	Contri-bution to average PM_{10} concen-tration (ug per m^3)	Average reduction in PM emissions compared to FCK
FCK[a]	20–22 t coal	1.7	4.0	1,000	25	
ZBK[b]	16–20 t coal	1.6	4.0	1,000	12.5	50 %
HHK[d]	12–14 t coal	5.7	15.0	270	12.7	51 %
VSBK[e]	10–12 t coal	1.6	5.0	800	8.2	33 %

a FCK fixed chimney bull trench kiln, NG natural gas, VSBK vertical shaft brick kiln
b Some zigzag pilot kilns are in operation, listed as poor to medium performance. Any improvement in the efficiency of operations can lead to further reductions in coal consumption
c Manufacturing period for Hoffmann kilns is round the year, compared to the current non-monsoonal month operations for the other kilns, thus increasing the land and raw material requirements; link to natural gas grid and continuous fuel supply is a major constraint
d Initial investments are higher for Hoffmann kilns
e Operational models are available in India and Kathmandu (CAI-Asia, 2008)
f Costs include initial investment, land, building, operational, and taxes estimates (World-Bank, 2011)

7.3 Population developments:

The future population developments are important for estimating the number of people who are likely to be exposed to the future concentrations of a certain pollutant. For expectations on the future population developments in Dhaka until 2030, probabilistic population projections for Bangladesh were collected from the 2010 revision of the World Population Prospects made by the UN (UN database, 2010). The UN projections can be observed in Fig. 5.

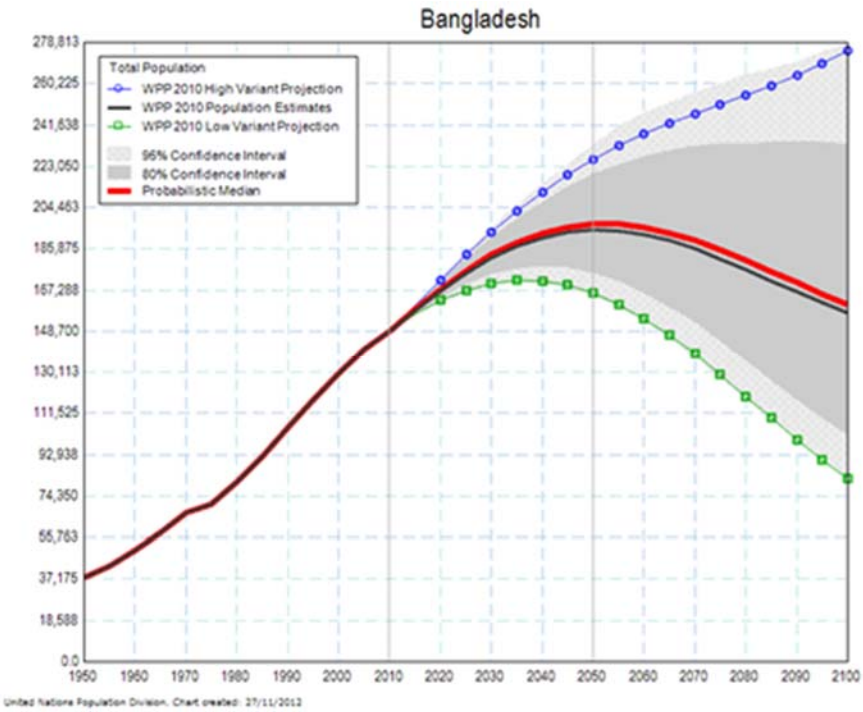

Figure 5: Probabilistic population projections for Bangladesh. Fig. presented by the UN Population Division

Following the probabilistic mean (medium- fertility scenario), a continued growth in population is expected (at least) until 2050, before the population number starts to decrease. The total Bangladeshi population until 2030 is expected to increase with about 22% compared to the 2010 situation (from about 150 million in 2010 to about 185 million in 2030). As a simplification, it is assumed the same relative population increase in Dhaka.

7.4 Developments of the economy:

It is assumed that the future production of bricks follow the developments of the economy in Bangladesh. The GDP per capita have increased rapidly in Bangladesh the last 3-4 decades, leading to a growth in economic activities, including industries. The World Bank database presents statistics of GDP per capita for Bangladesh since 1986. With the exception of 1988 and 1989, there has been a continuous growth in GDP per capita over the reported period. The GDP per capita ppp developments can be observed in Fig. 6.

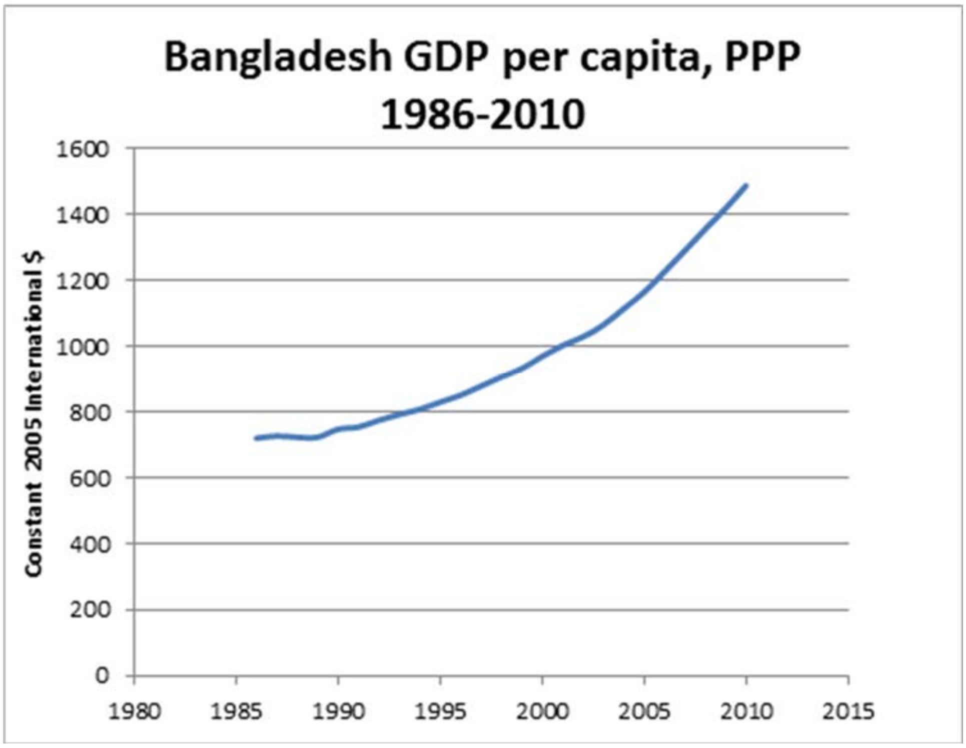

Figure 6: Bangladesh GDP per capita purchase power parity (PPP) 1986-2010. Figure based on World Bank (WB) statistics

Based on WB statistics, a simple linear forecast model were applied for the year 2030, forecasting an annual growth rate in GDP per capita purchase power parity of about 6.5% in the period 2010-2030. This corresponds to a factor of 1.3.

8 Results of hypothetical emission reductions (from the introduction of alternative kiln technologies) and their effects on human health in Dhaka

As a baseline scenario, it is assumed that the Brick Burning Act will not mean any significant implications to the brick burning sector other that other/new technologies will be considered to replace FCK brick production in the future. The scenario have therefore been focusing on estimating the future (year 2030) situation under the assumption on the use of available brick production technologies and their implications for health impacts. The production of number of bricks is assumed to increase in line with the expected increase in GDP per capita. Dhaka population developments are assumed to follow the probabilistic population projections for Bangladesh as presented by the UN.

The scenarios, presenting the baseline situation with the FCK technology and the situation with the use of the FCK technology and the alternative technologies in the year 2030, lead to different results on mortality and morbidity estimates. The various alternative results can be observed in Table 7.

Table 7: Number of incidences from exposure of PM_{10} in Dhaka in the year 2010 (FCK) and 2030 under the assumption of various kiln technologies used (keeping other emission sources constant)

Incidence from exposure	Age group	FCK (2010)	FCK (2030)	ZBK (2030)	VSBK (2030)	HHK (2030)
Short- term						
All cause mortality	Infant 0-1	**185**	261	243	238	244
Hospital admission for cardiovascular diseases (CVD)	All	**1 450**	2 079	1 926	1 873	1 929
Hospital admission for respiratory diseases (RD)	All	**1 382**	2 363	2 191	2 132	2 194
Long- term						
Mortality due to respiratory diseases (RD)	≥30	**5 205**	6 485	6 426	6 405	6 427
Mortality due to cardiovascular diseases (CVD)	≥30	**1 134**	1 413	1 400	1 395	1 400
Mortality due to lung cancer (LC)	≥30	**345**	428	425	424	426
Bronchitis in adults	Above 14	**22 568**	28 250	27 930	27 818	27 935
Bronchitis in children	0-14	**13 913**	14 210	14 064	14 013	14 066

9 Strategies for cost- effective air pollution control in Bangladesh cities

9.1 Discussion and conclusions:

Bricks production were causing most of the PM_{10} emissions in 2010 (about 17 000 tons/year). Compared to the FCK technology use, alternative technologies for kiln production, such as IFCK, VSBK, and HHK can lead to emission decreases and thus health impact benefits. Based on the comparison of technical and operational benefits, fuel efficiency and impact of health assessment including incidence of different health end points VSBK and HHK technology should be chosen for brick production as this stage in Bangladesh as these technologies are fuel efficient and contributing less pollution in the environment in comparison to the other technologies available in Bangladesh. HHK is benefiting from the production of high- quality bricks. Less HHK kilns are needed for producing a given amount of bricks, which will affect the investment and operating costs (per kiln).

If continuing with the FCK technology until 2030 (and all other emission sources are constant), about 1 300 additional cases of mortalities from respiratory diseases are expected compared to the present situation (2010). More than 150 lives can be saved annually (in 2030) in Dhaka from less mortality from respiratory-cardiovascular- diseases and lung cancer by replacing the FCK brick technology with cleaner brick technologies, such as the HHK technology.

A recent analysis of brick kiln technologies and their cost and benefits (Croituru and Serraf, 2012) support the conclusion that replacing existing brick kiln technologies with cleaner ones, would lead to large social benefits. The results of the cost and benefit analysis in Croitoru, L., Serraf, M. (2012) is presented in Table 8 below.

Table 8: Results of the private cost- benefit analysis (copied from Croituru and Serraf, (2012))

Table 2. Results of the private cost-benefit analysis (present value, 20 years, 10%, 2009).

	FCK	IFCK	VSBK	HHK
Basic information about kilns				
Area occupied by kiln (bigha)	15	15	4	12
Investment cost (TK million)	4	8	7	47[a]
Coal consumption (t/100,000 bricks)	20 - 24	13 - 16	13	13
Annual production (million bricks)	4	4	5	15
High-quality bricks (% of total production)	50 - 75	60 - 80	95	85
Costs (million TK/kiln) (1)	**119**	**109**	**106**	**386**
Investment	4	7	6	56
Land	1	1	1	3
Buildings	0	0	1	9
Operations	109	95	92	300
Taxes	5	5	6	19
Benefits (million TK/kiln) (2)	**198**	**200**	**214**	**746**
Net benefit (2-1)	**79**	**91**	**109**	**360**
Net benefit (TK/thousand bricks)	**103**	**107**	**108**	**116**

Sources: field survey in 2009 and [5] for FCK and IFCK; [10-12,16] for VSBK and HHK. [a]In addition, investments in HHK improvement include TK16 million in the 11th cycle of production. Notes: 1 bigha = 407 m^2; US $1 = TK70.

Croitoru, L., Serraf, M. (2012) estimate that introducing the HHK technology would give the largest net benefit to the society. Even though the investment and operation cost is high, the HHK kiln technology capacity of producing high quality bricks result in large revenues which indicates the largest net benefit estimate in comparison to the other technology options.

The following conclusions can be drawn from the BAPMAN training on human health impact assessment:

- Health benefits can be expected in the future from replacing existing brick kiln technologies with cleaner ones in Dhaka.

- A dialogue with stakeholders should be established for the selection process of the best use of technology. To rank the technology options, cost and benefits associated with introducing the technologies should be compared.

- More research is needed on quantifying costs and benefits of replacing brick kiln technologies in Dhaka/Bangladesh.

- Uncertainties in the health impact assessment should be reduced by obtaining more accurate data on health statistics, measured pollution concentrations and modeling results.

10 References

Aunan, K, Pan, X.C. (2004) Exposure- response functions for health effects of ambient air pollution applicable for china –a meta analysis. *Sci. Total Environ. 329,* 3-16.

Barrett, K. and Sivertsen, B. (2008) Dose- response in air pollution management. A review for application in AQMS. Kjeller, NILU (NILU OR, 15/2008).

BBS (2011) Bangladesh Bureau of Statistics. Area, Population, Household and Household Characteristics. Chapter 2 **URL:** http://www.bbs.gov.bd/PageWebMenuContent.aspx?MenuKey=230 (Accessed 2014-04-02).

CAI-Asia (2006) Country synthesis report on urban air quality management, Bangladesh. Discussion draft. Asian Development Bank and the Clean Air Initiative for Asian Cities (CAI-Asia) Center. **URL:** http://cleanairinitiative.org/portal/sites/default/files/documents/bangladesh_0.pdf (Accessed 2014-04-01).

Croitoru, L., Serraf, M. (2012) Benefits and costs of the informal sector: The case of brick kilns in bangladesh. *J. Environ. Protect., 3,* 476-484.

DoE (2012) Spatial Distribution of PM concentrations in Dhaka City (January 2011-June 2012). Clean Air and Sustainable Environment Project. Department of Environment, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh. **URL:** http://www.case-moef.gov.bd/file_zone/reports_publications/Spatial-Distribution-of-PM-concentrations-in-Dhaka-City.pdf (Accessed 2014-04-01).

Guttikunda, S.K., Khaliquzzaman, M. (2013) Health benefits of adapting cleaner brick manufacturing technologies in Dhaka, Bangladesh. *Air Qual. Atmos. Health., 7,* 103-112.

HEI Public Health and Air Pollution in Asia (2010) Public Health and Air Pollution in Asia (HEI): Coordinated studies of short-term exposure to air pollution and daily mortality in four cities. Executive Summary. HEI Public Health and Air Pollution in Asia Program. Boston, Health Effects Institute (HEI Research Report, 154).

HEI International Scientific Oversight Committee (2010) Outdoor air pollution and health in the developing countries of Asia: A Comprehensive Review. Boston, Health Effects Institute (HEI Special Report, 18).

Hurley, F., Hunt, A., Cowie, H., Holland, M., Miller, B., Pye, S., Watkiss, P. (2005) Service contract for Carrying out Cost- Benefit Analysis of air Quality Related Issues, in particular in the Clean Air for Europe (CAFÉ) Programme. Methodology for the Cost- Benefit analysis for CAFÉ: Volume 2 – Health Impact Assessment. Didcot, Oxon, AEA Technology Environment (AEAT/ED51014/Methodology Volume 2: Issue 2).

Pope, I.C., Burnett, R.T., Thun, M.J., Thun, M.J., Calle, E.E., Krewski, D., Ito, K., Thurston, G.D. (2002) Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *J. Am. Med. Ass., 287,* 1132-1141.

Randall, S. (2011) Top-down assessment of air pollution and GHGs for Dhaka, Bangladesh. Analysis of GAINS derived model data. Kjeller, NILU (NILU TR, 03/2011).

WHO (2008) The global burden of disease. 2004 Update. Geneva, World Health Organization. **URL:** http://www.who.int/healthinfo/global_burden_disease/GBD_report_2004update_full.pdf (Accessed 2014-04-01).

World Bank (2011) Introducing Energy-efficient Clean Technologies in the Brick Sector of Bangladesh. Washington, The World Bank.

Zhang, D., Aunan, K., Seip, H.M., Larssen, S., Liu, J., Zhang, D. (2010) The assessment of health damage caused by air pollution and its implication for policy making in Taiyuan, Shanxi, China. *Energy Policy, 38,* 461-502.

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Scott Randall

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ABSTRACT
The Bangladesh Air Pollution Management (BAPMAN) project is NORAD funded institutional-building program (2010-2013) where NILU lends the necessary Air Quality Management tools and associated training to the Clean Air and Sustainable Environment (CASE) program at the Bangladesh Department of Environment (DoE). This report (as Deliverable 4.2, 4.2 and 4.4 for Task 4 of the BAPMAN Project) presents a survey of possible health impacts from air pollution (PM_{10}) in Dhaka city, as well as scenarios and strategies for mitigating these impacts.

NORWEGIAN TITLE

Helseeffekter knyttet til luftforurensning i Bangladesh (Dhaka): Bidrag til nasjonal strategi

KEYWORDS

Miljø. Samfunn og helse	Helseeffekter	Utslippskontroll

ABSTRACT (in Norwegian)
Bangladesh Air Pollution Management (BAPMAN) er et kapasitetsbyggingsprosjekt finansiert av NORAD hvor NILU bidrar med nødvendige verktøy og kompetansebygging til Clean Air and Sustainable Environment (CASE) programmet ved Miljøverndepartementet (DoE) i Bangladesh. Denne rapporten presenterer en oversikt over mulige helseeffekter fra luftforurensning (PM_{10}) i Dhaka så vel som fremtidige strategier og mulige strategier for å redusere disse helseeffektene.

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