Colombia: Strengthening Environmental and Natural Resources Institutions

Study 2: Environmental Health in Colombia: An Economic Assessment of Health Effects

July 26, 2012

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Latin America and the Caribbean Region
Colombia and Mexico Country Management Unit
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US $1 = COP 1,817

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Vice President: Hasan Tuluy
Country Director: Gloria Grandolini
Sector Director: Ede Jorge Iijasz-Vasquez
Sector Manager: Karin Kemper
Task Manager: Juan Carlos Belausteguigoita
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<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>ACS</td>
<td>American Cancer Society</td>
</tr>
<tr>
<td>AF</td>
<td>Population-Attributable Fractions</td>
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<td>ALRI</td>
<td>Acute Lower Respiratory Infections</td>
</tr>
<tr>
<td>AMVA</td>
<td>Área Metropolitana del Valle de Aburrá</td>
</tr>
<tr>
<td>ARI</td>
<td>Acute Respiratory Infection</td>
</tr>
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<td>ARI</td>
<td>Acute respiratory illness</td>
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<td>AURI</td>
<td>Acute Upper Respiratory Infections</td>
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<td>BRT</td>
<td>Rapid Transit</td>
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<tr>
<td>CB</td>
<td>Chronic Bronchitis</td>
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<tr>
<td>CEAs</td>
<td>Country Environmental Analyses</td>
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<td>COED</td>
<td>Costs of Environmental Degradation</td>
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<td>COI</td>
<td>Cost of Illness</td>
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<td>COPD</td>
<td>Chronic Obstructive Pulmonary Disease</td>
</tr>
<tr>
<td>DALYs</td>
<td>Disability Adjusted Life Years</td>
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<tr>
<td>DANE</td>
<td>Colombia’s National Statistical Authority</td>
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<td>ENDS</td>
<td>Encuesta Nacional de Demografía y Salud</td>
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<td>GBD</td>
<td>Global Burden of Disease</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>HC</td>
<td>Human Capital</td>
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<tr>
<td>HCA</td>
<td>Human Capital Approach</td>
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<tr>
<td>IAP</td>
<td>Indoor Air Pollution</td>
</tr>
<tr>
<td>LAC</td>
<td>Latin America and the Caribbean</td>
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<tr>
<td>LC</td>
<td>Lung cancer</td>
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<td>MPS</td>
<td>Ministry of Social Protection</td>
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<td>ORT</td>
<td>Oral Rehydration Therapy</td>
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<tr>
<td>PEM</td>
<td>Protein-energy malnutrition</td>
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<tr>
<td>PDDB</td>
<td>Plan Decenal de Descontaminación de Bogotá</td>
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<tr>
<td>PM</td>
<td>Particulate Matter</td>
</tr>
<tr>
<td>RR</td>
<td>Relative Risk Ratios</td>
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<tr>
<td>SD</td>
<td>Standard Deviations</td>
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<tr>
<td>UAP</td>
<td>Urban Air Pollution</td>
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<tr>
<td>VCO</td>
<td>Volatile Organic Compounds</td>
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<tr>
<td>VSL</td>
<td>Value of a Statistical Life</td>
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<tr>
<td>WA</td>
<td>Weight-For-Age</td>
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<tr>
<td>WASH</td>
<td>Water Supply, Sanitation and Hygiene</td>
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<td>WAZ</td>
<td>Weight-For-Age Z-Score</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>WTP</td>
<td>Willingness to Pay</td>
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<tr>
<td>YLL</td>
<td>Years of Life Lost</td>
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Introduction

The 2005 Colombia Country Environmental Analysis, *Environmental Priorities and Poverty reduction*, concluded that: “The analysis of the cost of environmental degradation conducted shows that the most costly problems associated with environmental degradation are urban and indoor air pollution; inadequate water supply, sanitation, and hygiene; natural disasters and land degradation.” Colombia has made substantial progress in the last years in reducing the population exposure to urban air pollution, inadequate water and sanitation, and indoor air pollution from solid fuel use. However, these environmental risks continue to have a significant impact on the Colombian society in terms of premature mortality, disease and high economic costs. These environmental factors, health effects and economic costs which are analyzed in this report are those with the consistently highest impacts among common environmental threats to public health. In the context of Latin America, this include urban air pollution (UAP), indoor air pollution from solid fuel use (IAP), and an inadequate supply of water and sanitation combined with poor hygiene practices (WASH).

In 2005, the costs of environmental degradation (CoED) were estimated in Colombia for the first time by the World Bank. The present report updates and completes previous estimates, accounting for the much increased complexity and availability of relevant data in the country. The analysis relied on large sets of statistics and data from various ministerial departments, institutions, and institutes in Colombia. It also has drawn heavily from Colombian and international research studies, and benefited from various methodological approaches applied by international organizations such as the World Health Organization, in accordance with all previous related work within the World Bank’s Country Environmental Assessments (CEAs). Notwithstanding, the methodology of the analysis was developed further. This new study is aimed at deepening the understanding of the country’s major health challenge associated with environmental pollutions. Publicly available, easily traceable information and indicators were used as much as possible, in order to facilitate contrast and future updates. The estimation of the cost of environmental damage included many aspects, both economic and otherwise, although effects considered were only those related to the three mentioned factors (UAP, WASH, IAP). All costs calculated in this report are expressed in monetary terms, and they include the cost to society due to premature mortality, as well as the cost of healthcare provision to individuals suffering from pollution-related illnesses and the value individuals place in avoiding resulting pain and discomfort. Time losses or savings are valued at the opportunity cost of time.

Both the health impact assessment and the economic valuation can be utilized by policy makers and stakeholders in the process of setting environmental objectives and priorities. The Government of Colombia can use some of the information to assess institutional capacity within the country for sound environmental management and strengthen institutions and governance to enhance environmental outcomes. The World Bank and other donors could use results to provide evidence support to part of their developmental assistance to the Country. Because preferences and values are expressed in monetary terms, the results can provide additional guidance for the allocation of resources across diverse socio-economic development goals.

Lastly, this evidence base helps tracking progress made, as well as furthering environmental protection and environmental health agendas. Ambitious relevant policies, implemented or only planned, can find adequate justification on the large health and economic cost of environmental degradation in Colombian society. Addressing these environmental risks should continue to be a priority in the environmental and public health policy agenda of Colombia.
1. **SUMMARY**

1.1. **The health-related economic cost of selected environmental exposures in Colombia**

1. **The overall objective.** This study is intended to generate technical inputs in the policy dialogue within the Government of Colombia (GoC) and between the GoC and other agencies, such as the World Bank, on the policy priorities on the environmental health agenda. Specifically, this technical assessment has been carried out as part of the broader program of technical assistance and analytical support by the World Bank at the request by the Ministry of Environment and Sustainable Development (MADS) and the National Planning Department (DNP) in order to update and analyze the health impacts and the associated economic costs caused by urban air pollution (UAP), indoor air pollution from solid fuel use (IAP), and an inadequate supply of water and sanitation combined with poor hygiene practices (WASH). These three environmental problems consistently cause the highest health costs across Latin America and the Caribbean. The technical study developed through this program was intended as an input in the broader policy dialogue within the GoC on the progress in the area of air pollution and environmental health management, and as an input for future dialogue on this issue between the GoC and the Bank.

2. **The main findings.** The total health cost attributable to (i) urban air pollution, (ii) inadequate water, sanitation and hygiene, and (iii) indoor air pollution from solid fuel use in Colombia amounts to about 10,200 billion Ps. (about 2 percent of GDP in 2009). The largest cost is attributable to urban air pollution, to which a large share of the population is exposed. Second is the cost due to inadequate water, sanitation and hygiene. Third is the cost attributable to the indoor use of solid fuel. When putting costs in context by using a previous similar evaluation (Larsen 2004), the cost of these three environmental factors combined remained unchanged as a proportion of the gross domestic product (GDP) in the last decade (although Colombia’s GDP has more than doubled since). However, the distribution of these health costs has shifted (see Figure 1.1 below). The health cost associated with urban air pollution has increased as a percentage of GDP, whereas the health cost of indoor air pollution has remained at the same level and the cost of inadequate water, sanitation and hygiene has dropped markedly.

3. These results are disaggregated in a summarized manner below and categorized by environmental factor:

4. **Urban Air Pollution:** In this round of evaluation, the mean estimated annual cost of urban air pollution for Colombia was about 5,700 billion Ps. or 1.1 percent of GDP in 2009 (up from 0.8 percent in 2002, although a slightly different methodology has been used; see Annex 3). Mortality represented about 79 percent of the total estimated cost.

5. **Indoor Air Pollution:** The mean estimated annual cost of health impacts from indoor air pollution associated with the use of traditional fuels (mainly fuel wood) in rural areas of Colombia is 1,129 billion pesos (0.22 percent of GDP in 2009). Mortality in children under age five represents

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1 This technical background study was carried out by Golub, Elena and Gerardo Sanchez (Consultants), under the overall guidance by Juan Carlos Belausteguiotita (Lead Environmental Economist). The team thank the participants of technical workshops held throughout the study’s implementation and the support provided by the Government of Colombia, specifically by the Ministry of Environment and Sustainable Development (MADS) and the National Planning Department (DNP).
6 percent of cost, and mortality in women over 30 years of age represents about 78 percent of cost. Acute respiratory illness (ARI) in children and adult females and Chronic Obstructive Pulmonary Disease (COPD) morbidity of adult females represent 16 percent of the cost.

6. **Water, Sanitation and Hygiene:** The mean estimated annual cost of health impacts from an inadequate supply of drinking water and sanitation and from poor hygiene in Colombia is 3,450 billion pesos (0.68 percent of GDP in 2009). Mortality in children under age five represents 17 percent of cost, with morbidity accounting for the remaining 83 percent. Diarrheal mortality and morbidity represent about 89 percent of total cost and are estimated at about 3,050 billion Ps. annually. Urban cost represents about 77 percent of the total diarrheal cost.

**Figure 1.1:** Health Cost of Selected Environmental Factors in Colombia as a Proportion of GDP in 2002 and 2009

Source: Authors’ estimates for 2009 results; Larsen (2004) for 2002 results.

1.2. **Health impacts of selected environmental factors**

7. The abovementioned health costs are based on the estimated impact of the three factors studied on the health of the Colombian population. These health impacts, in turn, must be interpreted cautiously. In the absence of relevant local epidemiological evidence, internationally accepted rapid assessment methods have been used for the calculations. Details about such calculations are explained in the report and its annexes, but several key indicators are reported in this summary.

8. The environmental factors whose health effects are analyzed in this report are urban air pollution (UAP), indoor air pollution from solid fuel use (IAP), and an inadequate supply of water and sanitation combined with poor hygiene practices (WASH). As of 2010, about 7,700 premature deaths annually were attributable in Colombia to these three factors. UAP caused about 65 percent of this premature mortality, followed by WASH (around 20 percent) and IAP (about 15 percent). See Figure 1.2.
9. In terms of burden of disease (measured in lost Disability Adjusted Life Years [DALYs]; (see Figure 1.3 below), the pattern is similar: nearly 70 percent of DALYs are attributable to UAP, around 20 percent to WASH, and around 10 percent to IAP.

Figure 1.3: Burden of Disease Attributable to Selected Environmental Factors in Colombia, 2010

10. These results are disaggregated below in a summarized manner and categorized by environmental factor:

11. Urban air pollution: About 5,000 premature deaths and almost 65 million DALYs are attributable to urban air pollution each year in Colombia. Bogotá and the Valle de Aburrá
Metropolitan Area (Área Metropolitana del Valle de Aburrá, AMVA) account for over 75 percent of the attributable mortality. Nearly 4,700 new cases of chronic bronchitis each year are also attributable to urban air pollution in Colombia. Mortality represents about half of the burden of disease attributable to air pollution, and morbidity (i.e., diseases) accounts for the other half.

12. **Indoor air pollution:** About 1,000 premature deaths and almost 12 million DALYs are attributable to indoor air pollution caused by solid fuel use each year in Colombia. This burden of disease is almost completely restricted to rural areas, where nearly 50 percent of the population uses solid fuels for household chores.

13. **Water, sanitation and hygiene:** About 1,600 premature deaths and almost 20 million DALYs are attributable to inadequate water and sanitation and poor hygiene each year in Colombia. About 1,000 of these premature deaths occur in children under age five in relation to various types of malnourishment.

### 1.3. Trends and context

14. **Urban air pollution:** Significant progress has been made toward effective air pollution management in Colombia in the last decade. The National Government’s 2010 Air Pollution Control and Prevention Policy (*Ministerio del Ambiente* [MINAM] 2010) lists some of the main areas of progress: air quality assessment, monitoring, standardization of air quality management, fuel quality improvement, and incentives for environmental control and monitoring. It is important to note that a strong effort in this regard allowed the generation of an ample evidence base that revealed systemic weaknesses and areas for improvement. The current action plan for the implementation of the 2010 policy sets ambitious goals to address those areas without compromising achieved gains. To illustrate specific improvements, in the last 10 years PM$_{10}$ concentrations decreased slightly in Bogotá and more significantly in Cali and Bucaramanga. They increased five percent in the Aburra Valley Metropolitan Area (Area Metropolitana del Valle de Aburra, which includes Medellín). At the same time, the amount of registered vehicles per 1,000 inhabitants grew about 105 to 140 percent in these metropolitan areas (Molina et al. 2008). In total, the transportation fleet grew 13 to 53 percent in 2000–2007. Figure 1.4 below presents the relative change in PM$_{10}$ concentrations (2000–2010) and the percent increase in transportation fleet (2000–2007) in these cities.
Figure 1.4: Relative Change in PM10 Concentrations and Transportation Fleet

Source: Authors’ estimates. PM$_{10}$ concentrations are based on data from SISAIRE (http://www.sisaire.gov.co) for 2009–2010 and Larson (2002); transportation fleet estimated from Molina et al. (2008).

15. In the case of Bogota, the concentration of particulate matter has decreased consistently in the last years; from a yearly average of about 70 µg/m$^3$ in 2007 to around 50 µg/m$^3$ in 2011. Furthermore, seasonal variability and dangerous seasonal concentration peaks seem to be decreasing as well (see Figure 1.5).

Figure 1.5: Monthly Average PM10 Concentration (Ug/M3) in Bogota, 2006-2012

16. Other subnational and local governments have also strengthened efforts through sectoral measures with potential large benefits for air quality, such as urban transportation. Following the example of Bogotá, car-free days, Bus Rapid Transit (BRT) systems and the promotion of non-motorized transport are extending to other large urban centers. The “Pico y Placa” (Peak and License Plate—a car-use restriction by the last digit of the license plate number at peak hours) schemes are also present now in major Colombian cities. A notable improvement is the expansion of the air-quality monitoring network. The population covered by this pool of monitoring stations as of 2010 was estimated at around 18 million people (up from 12.5 million in 2002, as reported in
Larsen 2004) whereas the population living in cities larger than 100,000 inhabitants\(^2\) not covered by air-quality monitoring networks was close to 9 million (about the same as in 2002).

**Box 1: Bogota’s Local Air Quality Management Policies**

The local government in Bogota has made significant efforts in the last years to improve air quality in the metropolitan area. Short of a full policy impact assessment, we cannot attribute a direct causality between already implemented local air quality management policies in Bogota and the featured reductions in particulate matter. However, available indicators suggest that most measures and interventions adopted by the city government have likely had a large positive impact. These actions include, but are not limited to:

- Diesel fuel quality improvement: the maximum permissible sulfur content of diesel fuel sold in Bogota in 2008 (500 parts per million) was reduced to 50 ppm in 2010, although real concentration of locally distributed fuel is around 30 ppm. As of the end of 2012, all diesel fuel in Colombia must be under 50 ppm.

- Restriction on sales of two-stroke engine motorbikes in Bogota and later ban on their circulation in Bogota. According to the emissions inventory in the city’s ten-year decontamination plan (PDDB 2010) motorbikes contribute 25% of total mobile source emissions of PM in the city. Four-stroke engine motorbikes emit 40% less PM than two-stroke ones.

- Increased use of Bus Rapid Transit (BRT) systems: increased occupancy levels in the Transmilenio system have entailed large comparative emissions reductions. Current BRT emissions are about 0.058 grams of PM2.5 per passenger, compared with 0.311 grams in the rest of the current public transportation system in Bogota (a comparative reduction of about 80%). Consistently, CO2 emissions of the BRT system are much lower as well.

Further work in these areas and in others is part of an ambitious 10-year air quality management plan is currently under implementation. One important planned city-wide intervention is the integration of the public transportation system; although still not operational, this integration is projected to have a major impact on the city’s air quality. According to an ongoing study by the Universidad de los Andes, the reorganization has the potential to reduce PM2.5 emissions from public transport between 74% and 80%. That would entail health-related economic savings of 360 Million USD over ten years (PDDB 2010).

**Source:** Clean Air Institute for Latin American Cities (communication).

17. **Indoor air pollution:** Exposure to indoor air pollution continues to be overwhelmingly concentrated in Colombia’s rural households, and there is no obvious decreasing trend (53 percent used solid fuels in 2005 compared to just over 50 percent in 2010) (ENDESA 2005, 2010). By departments, Oriental and Caribe have the highest percentage of solid fuel use: 17.7 percent and 20.1 percent respectively. The only region where solid fuel use for household uses is negligible is Bogotá.

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\(^2\) The cutoff point of 100,000 inhabitants is taken as an indicator that an urban setting is large enough to include substantial amounts of mobile and point sources of pollution to represent a health hazard.
18. **Water, sanitation and hygiene:** Global malnutrition (low weight for age) decreased from 7 percent in 2005 to 4.5 percent in 2010. Severe malnutrition has also decreased slightly, from 0.6 percent to 0.5 percent (ENDESA 2010, p. 298). The use of some sort of oral rehydration therapy (ORT) increased from 61 percent in 2000 to 70 percent in 2005 and 74 percent in 2010 (p. 256). However, systematic differences remain between urban and rural areas as well as among regions in terms of the awareness and care of diarrheal diseases in children.

19. These differences are also present in the supply of safe drinking water and appropriate means of sanitation. For instance, the national demographic and health surveys reflect a worrisome trend regarding the supply of piped water in rural areas, which has been decreasing steadily from 27 percent in 2000 to 22 percent in 2005 and down to 17 percent in 2010 (p. 28). More than 90 percent of urban households are connected to sewers, whereas only 22 percent of rural households are. Inadequate WSH is still a serious environmental health and health equity problem in Colombia.

20. **International comparison:** Similar analyses were conducted in selected LAC countries in 2006–2007 (see Figure 1.6). The methodology in this report was shifted toward the application of value of statistical life (VSL) only for outdoor air pollution mortality valuation (as opposed to the average between the human capital approach (HCA) and VSL in other studies). In practice, this means a higher value compared to the combined HCA-VSL approach. In spite of this, Colombia is on the lower end of the environmental pollution burden compared to other Latin American countries. Outdoor air pollution by far outweighs other environmental health problems. At the same time, the improvement of water supply, sanitation and hygiene remains an important pending task that could effectively reduce mortality and morbidity in children under five years of age.

**Figure 1.6: Annual Estimated Cost of Environmental Health in Selected LAC Countries**

[Graph showing annual estimated cost of environmental health in selected LAC countries]
2. URBAN AIR POLLUTION

2.1. Urban air pollution and health

21. Worldwide evidence on the health effects of urban air pollution has been substantial for decades now, with extensive studies showing the association between certain air pollutants and respiratory and cardiovascular mortality, chronic bronchitis, respiratory infections, and several other related disorders. Most studies show the strongest association between pollutants and health effects for inhalable particulate matter, particularly PM$_{2.5}$ (smaller than 2.5 microns in diameter). To the comprehensive reviews in the late 1990s and early 2000s in European and North American countries, a growing body of evidence can be added from cities in developing countries of Asia (e.g., HEI 2008) and from cities in Latin American countries (Bell et al. 2006, O’Neill et al. 2008, Bell et al. 2011, among others).

22. The amount of information available in Colombia has also increased greatly. Air-pollution monitoring data, which in 2004 were available for four metropolitan areas in Colombia, are currently available for eleven large metropolitan areas comprising several municipalities (SISAIRE 2012). Monitoring of PM$_{2.5}$ has begun experimentally in some stations and there are now local estimates of the PM$_{10}$/PM$_{2.5}$ ratio. There is more accurate information on and better coverage of demographic and statistical information, and health indicators are better disaggregated. Thus, the uncertainty of the analysis has been reduced, but its complexity has increased in proportional to the amount of decisions and generalizations to be made in order to obtain nationwide estimates.

23. With these considerations in mind, the analytical approach to the estimation of the damage value of air pollution follows the same main steps used in Larsen (2004) as well as in most Country Environmental Analyses including air pollution: (i) identification of air pollutants and determination of concentrations; (ii) population exposed and its baseline vulnerability; (iii) calculation of the health impact of exposure to air pollution based on epidemiological techniques; and (iv) estimation of the value of this health impact.

2.2. Baseline population, pollutant concentration and dose-response coefficients

24. The proportion of the urban population was estimated at 74 percent in 2010 (DANE 2011). Nearly 60 percent of the Colombian population now lives in cities with over 100,000 inhabitants and almost 30 percent lives in cities with over 1 million inhabitants; Cartagena is quickly approaching this threshold as well. These figures are in line with a long-term increasing urbanization process in Colombia (see Table 2.1).

<table>
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<tr>
<th>Parameter</th>
<th>DANE 2002</th>
<th>DANE 2010</th>
</tr>
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<tbody>
<tr>
<td>% of urban population</td>
<td>72</td>
<td>74</td>
</tr>
<tr>
<td>% living in cities with over 100,000 inhabitants</td>
<td>49</td>
<td>59</td>
</tr>
<tr>
<td>% living in cities with over 1,000,000 inhabitants</td>
<td>28</td>
<td>29</td>
</tr>
</tbody>
</table>

Source: National Administrative Department of Statistics (Departamento Administrativo Nacional de Estadística, DANE) http://www.dane.gov.co/

25. The population included in this analysis is the one nominally covered by air pollution measurement networks as of 2010. This coverage has increased greatly in the last decade, partly due to the governmental effort to establish environmental monitoring in areas surrounding ports and mining operations. In 2004, only four metropolitan areas (Bogotá, Bucaramanga, Valle de Aburrá, and Cali) measured PM$_{10}$. Today, most of Colombia’s large metropolitan areas are covered by coordinated networks corresponding to environmental jurisdictions. We have organized the
information in areas corresponding to eleven metropolitan areas of various sizes. Unlike previous studies (Larsen 2004), we did not feel that partitioning land use into categories could provide valuable insights on exposure differentials. A quick overview of land use in Bogotá and Medellín with a Geographical Information System showed a completely mixed pattern of land use, blurring any purported systematic differences. However, we weighted PM concentrations by the population of the main urban setting in which each monitoring station or separate network was embedded, assuming a relatively homogeneous dispersion of pollutants. Table 2.2 presents the population and population-weighted PM$_{10}$ and PM$_{2.5}$ annual average concentrations for the metropolitan areas covered by one or more monitoring networks.

Table 2.2: Population and Weighted Average Concentration of PM10 and PM2.5 in Colombian Cities with over 100,000 Inhabitants Covered by Air-Pollution Monitoring Networks

<table>
<thead>
<tr>
<th>Urban area</th>
<th>Population (million) 2009</th>
<th>Annual average population weighted PM$_{10}$ concentration ($\mu$g/m$^3$)*</th>
<th>Annual average population weighted PM$_{2.5}$ concentration ($\mu$g/m$^3$)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogotá</td>
<td>7.26</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>AMVA$^a$</td>
<td>3.25</td>
<td>56</td>
<td>28</td>
</tr>
<tr>
<td>Cali</td>
<td>2.22</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td>Bucaramanga$^b$</td>
<td>0.90</td>
<td>33</td>
<td>17</td>
</tr>
<tr>
<td>Cucuta</td>
<td>0.61</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>Pereira$^c$</td>
<td>0.56</td>
<td>53</td>
<td>27</td>
</tr>
<tr>
<td>Ibague</td>
<td>0.52</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td>Soacha</td>
<td>0.44</td>
<td>48</td>
<td>24</td>
</tr>
<tr>
<td>Manizales</td>
<td>0.39</td>
<td>34</td>
<td>17</td>
</tr>
<tr>
<td>Palmira</td>
<td>0.29</td>
<td>44</td>
<td>22</td>
</tr>
<tr>
<td>Sogamoso$^d$</td>
<td>0.1</td>
<td>58</td>
<td>29</td>
</tr>
<tr>
<td>Yumbo</td>
<td>0.1</td>
<td>50</td>
<td>25</td>
</tr>
</tbody>
</table>

Source: Population figures are based on city specific estimates by DANE. *Based on data from SISAIRE (http://www.sisaire.gov.co) for 2009–2010. **PM$_{2.5}$/PM$_{10}$ ratio of 0.50 is assumed. $^a$Includes 10 conurbated cities in the Valle de Aburrá. $^b$Includes Floridablanca and Girón. $^c$Includes Dos Quebradas. $^d$Includes Nobsa.

26. This evaluation only includes the urban population living in municipalities with real-time, constant monitoring of air pollution. Excluding a potentially exposed population of 9 million (nearly 25 percent of Colombia’s urban population) is a suboptimal analytical choice, but the question remains about how to estimate exposure without information on the pollutants. The obvious option is to estimate their concentrations based on those observed in Colombian cities of comparable size. Such was the approach taken by Larsen (2004) in the absence of emissions inventories from which to derive concentrations (a method with its own drawbacks). However, there may be systematic differences between cities of comparable size according to their pollution monitoring status (see Annex 2) that would render such an extrapolation highly uncertain. The force behind the establishment of air-quality monitoring networks—in Colombia and elsewhere—is precisely the presence of air-quality problems, which are in turn frequently linked to the size and density of urban settings. Therefore, it is expected that municipalities with monitoring networks

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$^3$ Excluding cases where point sources contribute a large proportion of the pool of pollution.
will be larger and more “urban” than those without networks. The likely presence of relevant systematic differences (beyond mere size) between cities with and without monitoring networks provides additional uncertainty to such a method for estimation. Furthermore, the urban population not covered by a monitoring network is shrinking rapidly in Colombia. Based on these considerations, we decided to drop altogether the estimation of mortality and morbidity effects of cities for which there were no data. Although we acknowledge that we are missing out on a potentially substantial proportion of the overall health impact of urban air pollution in Colombia, we believe this approach will provide more robust results for this and future updates. However, for comparison purposes, we also report overall results including mortality in non-monitored cities (see Annex 3).

27. Another divergence from previous studies on this matter is the PM$_{2.5}$/PM$_{10}$ ratio. The relative risks for mortality estimated in the literature most widely used in this type of calculations (Pope 2002, etc.) and in the previous Colombia Country Environmental Assessment relate to the concentration of PM$_{2.5}$. However, widespread monitoring of PM$_{2.5}$ is still uncommon. Colombia is no exception: as of today, only four measuring stations (all of them in Bogotá) measure PM$_{2.5}$ systematically. A recent study (PDDB 2009) for Bogotá places this ratio at 0.50. There is no reason to assume that other Colombian cities will have higher ratios than that; on the contrary, higher concentrations from mobile sources and industry typically account for higher ratios, so the ratios in cities smaller than Bogotá might reasonably be expected to be equal or lower. We used a PM$_{2.5}$/PM$_{10}$ ratio of 0.50.

28. Granted, inhalable particles are not the only health-relevant air pollutant. Many anthropogenic emissions have proved to be associated with adverse health outcomes, including (but not limited to) sulfur oxides, nitrogen oxides, volatile organic compounds (VCOs), carbon monoxide, lead, and especially ozone. Tropospheric (i.e., ground-level) ozone can trigger a large number of respiratory effects and aggravate certain chronic diseases, thus increasing outcomes, such as increased health care usage or absenteeism, with high costs to society (US EPA 2012). An association between ozone concentrations and long-term mortality has been found, but only when PM$_{2.5}$ concentrations were taken into account (Jerrett et al. 2009). In general, evidence shows that the strongest association and magnitude of effects in the interaction between air pollutants and premature mortality/health are related to particulate matter, particularly that with the smallest diameter fraction.

29. There has been a substantial improvement in available evidence on the links between air pollution and mortality in Latin America in the last decade, although most studies have dealt with short-term effects. A recent study (O’Neill et al. 2008) analyzed the effect of education on the association between PM$_{10}$ concentrations and short-term mortality in Mexico City, São Paulo and Santiago de Chile, and found total nonaccidental adult mortality 1-day lagged increases of 0.39 percent, 1.04 percent and 0.61 percent, respectively, for an increase of 10 µg/m$^3$ in concentration. In Brazil, studies have found associations between exposure to PM$_{10}$ and low birth weight (Gouveia et al. 2004) and also with respiratory mortality in the elderly (Martins et al. 2004).

30. In Colombia, the evidence base for health risks of air pollution is still under development. Ibáñez (2003) reviewed three studies that assessed the relationship between urban air pollution and health effects in Bogotá, and provided dose-response coefficients for hospital respiratory admissions, child morbidity and respiratory mortality. A recent study (Aristizabal et al. 2009) studied the association between air pollution and acute respiratory infection (ARI) in three municipalities within Bogotá and found a higher incidence of objective symptoms in children living in areas with higher exposure to PM$_{10}$. That is, children living in more polluted areas of Bogotá are more likely to develop ARI; these differences are statistically significant when controlled for other
factors, such as cigarette-smoke exposure. This study confirms previous observations (Arciniegas et al. 2005) and is contributing to a growing body of local evidence that will allow for ever more relevant assessments in Colombian urban areas.

31. Although these studies contribute to a greater understanding of the health effects of urban air pollution in Colombia, a larger body of evidence is required to provide reliable estimates of health effects applicable at the national level. For the association between exposure to inhalable particulate matter and mortality, the coefficients of Pope et al. (2002) continue to be the most solid results for long-term effects. Pope et al. (2002) utilized ambient air-quality data from metropolitan areas across the United States for 1979–1983 and 1999–2000, and information on certified causes of mortality of adults in the American Cancer Society (ACS) database over a period of 16 years. The details of the study (which confirms previous observations, such as those of Dockery et al. 1993, Pope et al. 1995) have been discussed extensively elsewhere, and the results still stand as the best available evidence for the association between exposure to inhalable particulate matter and mortality.

32. Likewise, the morbidity coefficients (Ostro 1994, Abbey 1995) presented in Table 2.3 still represent highly relevant indicators of increased risk for the considered categories. These are extracted directly from Larsen 2004, where the details of the studies are discussed extensively. Although the mortality effects are based on associations with concentrations of PM$_{2.5}$, the morbidity effects assessed in most worldwide studies are based on PM$_{10}$.

### Table 2.3: Urban Air Pollution Dose-Response Coefficients

<table>
<thead>
<tr>
<th>Annual health effect</th>
<th>Dose-response coefficient</th>
<th>Per 1 µg/m$^3$ annual average ambient concentration of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality (% change in cardiopulmonary and lung cancer mortality)</td>
<td>0.8%</td>
<td>PM$_{2.5}$</td>
</tr>
<tr>
<td>Chronic bronchitis (% change in annual incidence)</td>
<td>0.9%</td>
<td>PM$_{10}$</td>
</tr>
<tr>
<td>Hospital respiratory admissions (per 100,000 population)</td>
<td>1.2</td>
<td>PM$_{10}$</td>
</tr>
<tr>
<td>Emergency room visits (per 100,000 population)</td>
<td>24</td>
<td>PM$_{10}$</td>
</tr>
<tr>
<td>Restricted activity days (per 100,000 adults)</td>
<td>5,750</td>
<td>PM$_{10}$</td>
</tr>
<tr>
<td>Lower respiratory illness in children (per 100,000 children)</td>
<td>169</td>
<td>PM$_{10}$</td>
</tr>
<tr>
<td>Respiratory symptoms (per 100,000 adults)</td>
<td>18,300</td>
<td>PM$_{10}$</td>
</tr>
</tbody>
</table>

Sources: Pope et al. (2002) for the mortality coefficient; Ostro (1994) and Abbey et al. (1995) for the morbidity coefficients.

2.3. Mortality and morbidity attributable to air pollution

33. In order to ascertain the share of mortality that is attributable to air pollution, baseline data on certain causes of mortality are required. These data are collected by Colombia’s national statistical authority (DANE) and reported by department on an annual basis. The categories included are cardiopulmonary causes and lung cancer (DANE categories 206, 301–309, and 605–608). Crude total and cardiopulmonary mortality rates are listed in Table 2.4.

34. Regarding nonfatal outcomes with known air-pollution associations, perhaps the most burdensome for patients and health systems is chronic bronchitis (CB). Although there is a rather complete recent study on the prevalence of CB in Colombia (PREPOCOL: Caballero et al. 2008), there are still no good data on the annual incidence of the disease. The rates applied are those from
the World Health Organization (WHO, 2001) and Shibuya (2001) for the AMRO-B region\(^4\) of WHO in which Colombia is a part, modified with the known data for clinical prevalence of COPD reported in the PREPOCOL study. The resulting incidence rate for the urban Colombian population over age 30 is 256 cases per 100,000 population in one year, compared to a value of 205 for AMRO-B.

35. For the calculation of an attributable fraction, we established a lower threshold level for PM\(_{2.5}\), below which it is assumed there are no mortality effects. Although there is much debate about the usefulness of these lower limits (WHO recognizes that there is no safe threshold for inhalable particles), it is necessary for practical matters regarding air-quality management. WHO (2002) recommended this threshold to be 7.5 \(\mu\)g/m\(^3\) in the World Health Report for mortality. However, a recent review by Kreviski et al. (2009) lowers the threshold to 5 \(\mu\)g/m\(^3\). We applied the 5 \(\mu\)g/m\(^3\) threshold for mortality effects. No threshold was used for morbidity effects.

### Table 2.4: Baseline Mortality and Morbidity Data for Cities with PM Monitoring Data

<table>
<thead>
<tr>
<th>Cities with PMMN</th>
<th>Crude mortality rate (per 1,000 population)*</th>
<th>Cardiopulmonary and lung cancer deaths (% of all deaths)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogotá</td>
<td>4.2</td>
<td>34</td>
</tr>
<tr>
<td>AMVA(^a)</td>
<td>5.1</td>
<td>36</td>
</tr>
<tr>
<td>Cali</td>
<td>5.6</td>
<td>32</td>
</tr>
<tr>
<td>Bucaramanga(^b)</td>
<td>4.8</td>
<td>34</td>
</tr>
<tr>
<td>Cucuta</td>
<td>5.0</td>
<td>37</td>
</tr>
<tr>
<td>Pereira(^c)</td>
<td>5.8</td>
<td>36</td>
</tr>
<tr>
<td>Ibague</td>
<td>5.0</td>
<td>43</td>
</tr>
<tr>
<td>Manizales</td>
<td>5.4</td>
<td>39</td>
</tr>
<tr>
<td>Palmira</td>
<td>5.6</td>
<td>32</td>
</tr>
<tr>
<td>Sogamoso(^d)</td>
<td>4.5</td>
<td>42</td>
</tr>
<tr>
<td>Yumbo</td>
<td>5.6</td>
<td>32</td>
</tr>
<tr>
<td>Average</td>
<td>5.2</td>
<td>36</td>
</tr>
</tbody>
</table>

Sources: Based on DANE statistics. *Non-accidental based on departmental data. **Based on departmental data.

\(^a\)Includes 10 conurbated cities in the Valle de Aburrá; \(^b\)Includes Floridablanca and Girón; \(^c\)Includes Dos Quebradas; \(^d\)Includes Nobsa.

36. Aside from mortality, health end-points considered in this analysis are listed in Table 2.5. These specific health effects have become the standard health end-points considered in most of the worldwide studies on air pollution. In order to facilitate magnitude comparisons with other risk factors, health effects can be converted to disability adjusted life years (DALYs, a combination of years lost due to premature mortality and years lost due to disability). In order to do so, disability weights and average duration of each outcome are assigned to each health effect.\(^5\) We use the weights determined by Larsen (2004) for the Latin America and the Caribbean (LAC) region. Years lost to premature mortality from air pollution were estimated from age-specific mortality data for cardiopulmonary and lung cancer deaths, discounted at three percent per year.

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\(^4\)Member states of WHO are divided into six geographical regions. this region is further subdivided into sub-regions according to child and adult mortality from A (lowest) to E (highest). The Americas conform one region (AMRO) and Colombia is one of the countries in the sub-region B.

\(^5\)This approach is not free from controversy, since there is considerable uncertainty about duration estimates, and weights include a substantial subjective component. However, it is widely used for convenience in this type of calculations.
Table 2.5: Calculation of DALYs Per Case of Health Effects

<table>
<thead>
<tr>
<th>Health Effect</th>
<th>Disability weight</th>
<th>Average duration of illness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>1.0</td>
<td>(7.5 years lost)</td>
</tr>
<tr>
<td>Lower respiratory Illness: children</td>
<td>0.28</td>
<td>10 days</td>
</tr>
<tr>
<td>Respiratory symptoms: adults</td>
<td>0.05</td>
<td>0.5 days</td>
</tr>
<tr>
<td>Restricted activity days: adults</td>
<td>0.1</td>
<td>1 day</td>
</tr>
<tr>
<td>Emergency room visits</td>
<td>0.30</td>
<td>5 days</td>
</tr>
<tr>
<td>Hospital admissions</td>
<td>0.40</td>
<td>14 days*</td>
</tr>
<tr>
<td>Chronic bronchitis</td>
<td>0.2</td>
<td>20 years</td>
</tr>
</tbody>
</table>

Source: Larsen (2004). * Includes days of hospitalization and recovery period after hospitalization.

37. Once health effects of air pollution are converted to DALYs, quick comparisons can be made between different environmental risk factors. A calculation of DALYs lost per 10,000 cases of the considered health end-points is presented in Table 2.6.

Table 2.6: DALYs Lost per Selected Health Effect Attributable to Air Pollution

<table>
<thead>
<tr>
<th>Health effect</th>
<th>DALYs lost per 10,000 cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>75,000</td>
</tr>
<tr>
<td>Chronic bronchitis (adults)</td>
<td>22,000</td>
</tr>
<tr>
<td>Hospital respiratory admissions</td>
<td>160</td>
</tr>
<tr>
<td>Emergency room visits</td>
<td>45</td>
</tr>
<tr>
<td>Restricted activity days: adults</td>
<td>3</td>
</tr>
<tr>
<td>Lower respiratory illness: children</td>
<td>65</td>
</tr>
<tr>
<td>Respiratory symptoms: adults</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Source: Larsen 2004

38. The estimated health impact of urban air pollution in Colombia is in Table 2.7. The values are calculated by applying relative risks and PM concentrations (minus thresholds, where applicable) to population exposed, adjusting for age groups when necessary and extracting the fraction of these health outcomes that is attributable to this specific exposure. DALYs are calculated simply by multiplying the number of cases by the factors in table 2.6.

Table 2.7: Estimated Health Impact of Urban Air Pollution in Cities with PM Monitoring Data

<table>
<thead>
<tr>
<th>Health categories</th>
<th>Total cases</th>
<th>Total DALYs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premature mortality</td>
<td>5,027</td>
<td>37,703</td>
</tr>
<tr>
<td>Chronic bronchitis</td>
<td>4,675</td>
<td>10,285</td>
</tr>
<tr>
<td>Hospital admissions</td>
<td>9,492</td>
<td>152</td>
</tr>
<tr>
<td>Emergency room/outpatient hospital visits</td>
<td>186,208</td>
<td>838</td>
</tr>
<tr>
<td>Restricted activity days</td>
<td>32,748,479</td>
<td>9,825</td>
</tr>
<tr>
<td>Lower respiratory illness in children</td>
<td>374,314</td>
<td>2,433</td>
</tr>
<tr>
<td>Respiratory symptoms</td>
<td>104,225,594</td>
<td>7,817</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>64,354</td>
</tr>
</tbody>
</table>

Source: Authors’ estimates.

39. The four largest urban centers (Bogotá, AMVA, Cali and Bucaramanga) account for more than 80 percent of the population exposed and attributable cases. There is good concordance between the exposed population and the concentration of cases (Figure 2.1), except in the case of Cali where lower pollutant concentrations result in fewer attributable cases. However, with only three monitoring stations in the Cali Metropolitan Area (SISAIRE 2012), this result should be interpreted cautiously.

* For cities covered by networks measuring concentrations of particulate matter.
40. An important health outcome attributable to air pollution (mortality in children under age 15 from respiratory causes) is not included in this analysis since we lacked age-specific mortality by cause and by city, but it should ideally be part of forthcoming updates. In order to properly link exposure to effects with high confidence, it is necessary to collect health statistics on relevant outcomes within each environmental jurisdiction. This will allow public health and environmental authorities to track real progress in reducing environmental health threats to local communities.

2.4. Health cost of urban air pollution

41. The estimated annual cost of health impacts from urban air pollution is presented in Table 2.8. The cost of mortality is based on the Value of a Statistical Life (VSL). We are not reporting a cost based on the Human Capital Approach (HCA), since we believe that an indicator based on foregone income due to premature mortality severely underestimates the true cost to society that excess mortality represents in a rapidly improving context such as that of urban Colombia. The total estimated annual health cost attributed to outdoor air pollution is about 5,700 Billion Ps., or 1.1 percent of GDP in 2009. Mortality represents about 79 percent of the total estimated cost.

<table>
<thead>
<tr>
<th>Health categories</th>
<th>Total annual cost (billion pesos)</th>
<th>Percent of total cost* (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>4,519</td>
<td>79</td>
</tr>
<tr>
<td>Morbidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic bronchitis</td>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>Hospital admissions</td>
<td>56</td>
<td>1</td>
</tr>
<tr>
<td>ER visits/outpatient hospital visits</td>
<td>58</td>
<td>1</td>
</tr>
<tr>
<td>Restricted activity days (adults)</td>
<td>839</td>
<td>15</td>
</tr>
<tr>
<td>Lower respiratory illness in children</td>
<td>84</td>
<td>1</td>
</tr>
<tr>
<td>Respiratory symptoms (adults)</td>
<td>113</td>
<td>2</td>
</tr>
<tr>
<td>Total cost of morbidity</td>
<td>1,189</td>
<td>21</td>
</tr>
<tr>
<td>TOTAL COST (mortality and morbidity)</td>
<td>5,708</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Authors’ estimates. *Annual cost is rounded to nearest billion, and percentages are rounded to nearest percent.
The estimated cost per case of premature mortality or specific health end-point is presented in Table 2.9. The VSL used in this assessment is that utilized by the government in Bogotá for the Bogotá Ten-Year Decontamination Plan (Plan Decenal de Descontaminación de Bogotá. PDDB 2009). In this report, the value of statistical life was derived from: (i) Ortiz et al. (2009) in São Paulo, (ii) Hammit and Ibarraran (2002) in Mexico City, and (iii) Bowland and Beghin (2001) in Santiago de Chile. The PDDB does not specify which value is chosen or, in the case of a combination of the values from the three studies, which relative weight of pooling method was used. However, since the value is not far off from the most recent and most relevant reference (Ortiz et al. 2009; see Annex 1), we found it most appropriate to use a locally estimated value for VSL. Likewise, the WTP proxy applied is based on the ratio of Cost of Illness to Willingness to Pay (WTP) reported for Bogotá (PDDB 2009). The calculated cost of treatment was based on consultations with health authorities and the upper bound of the publicly listed prices that public insurers pay healthcare providers, which in turn are deemed the most adequate reflection of the true cost of treatment in Colombia (see Annex 3). The cost per case (comprising Cost of Illness plus the proxy for WTP) is the basis for the estimation of the annual costs in Table 2.8 and multiplying each cost for the cases in Table 2.7.

Table 2.9: Estimated Unit Cost by Health End-Point

<table>
<thead>
<tr>
<th>Health categories</th>
<th>Total cost per case (000 pesos)</th>
<th>Cost of illness per case (000 pesos)</th>
<th>WTP proxy (000 pesos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>1,008,000</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Chronic bronchitis</td>
<td>8,597</td>
<td>2,629</td>
<td>5,968</td>
</tr>
<tr>
<td>Hospital admissions</td>
<td>5,853</td>
<td>1,790</td>
<td>4,063</td>
</tr>
<tr>
<td>Emergency room/outpatient hospital visits</td>
<td>312</td>
<td>95</td>
<td>216</td>
</tr>
<tr>
<td>Restricted activity days (adults)</td>
<td>26</td>
<td>7.8</td>
<td>18</td>
</tr>
<tr>
<td>Lower respiratory illness in children</td>
<td>224</td>
<td>68</td>
<td>155</td>
</tr>
<tr>
<td>Respiratory symptoms (adults)</td>
<td>1.08</td>
<td>0.33</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Source: Authors' estimates.

Table 2.10 details the baseline data that were used for the estimation of the cost of illness and the costs of time lost to illness. For comparability with previous estimates (see Annex 3) we kept most of the assumptions regarding duration of illness, rate and length of hospitalization, average time lost per health end-point, frequency of doctor visits, and discount rate. We also valued time lost to illness at 75 percent of average urban wage, and applied this cost both to working and nonworking individuals, based on the assumption of an equivalent opportunity cost for both categories.
Table 2.10: Baseline Data for Cost Estimation

<table>
<thead>
<tr>
<th>Cost Data for All Health End-Points:</th>
<th>Baseline</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of hospitalization (pesos per day)</td>
<td>246,000</td>
<td>Per consultations with medical service providers and health authorities (see Annex 3). Rounded to the nearest thousand pesos</td>
</tr>
<tr>
<td>Cost of emergency visit (pesos): urban</td>
<td>95,000</td>
<td></td>
</tr>
<tr>
<td>Cost of doctor visit (pesos) (mainly private doctors): urban</td>
<td>29,000</td>
<td></td>
</tr>
<tr>
<td>Value of time lost to illness (pesos per day)</td>
<td>31,000</td>
<td>Based on urban wages in Colombia</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chronic Bronchitis (CB):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average duration of Illness (years)</td>
<td>20</td>
</tr>
<tr>
<td>Percent of CB patients hospitalized per year</td>
<td>1.5%</td>
</tr>
<tr>
<td>Average length of hospitalization (days)</td>
<td>10</td>
</tr>
<tr>
<td>Average number of doctor visits per CB patient per year</td>
<td>1</td>
</tr>
<tr>
<td>Percent of CB patients with an emergency doctor/hospital outpatient visit per year</td>
<td>15%</td>
</tr>
<tr>
<td>Estimated lost workdays (including household workdays) per year per CB patient</td>
<td>2.6</td>
</tr>
<tr>
<td>Annual real increases in economic cost of health services and value of time (real wages)</td>
<td>2%</td>
</tr>
<tr>
<td>Annual discount rate</td>
<td>3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hospital Admissions:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average length of hospitalization (days)</td>
<td>6</td>
</tr>
<tr>
<td>Average number of days lost to illness (after hospitalization)</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emergency Room Visits:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of days lost to illness</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Restricted Activity Days:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of days of illness (per 10 cases)</td>
<td>2.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower Respiratory Illness in Children:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of doctor visits</td>
<td>1</td>
</tr>
<tr>
<td>Total time of caregiving by adult (days)</td>
<td>1</td>
</tr>
</tbody>
</table>
3. IMPACTS FROM INADEQUATE WATER SUPPLY, SANITATION AND HYGIENE

3.1. Inadequate WSH and diarrheal illness

Inadequate quantity and quality of potable water supply, sanitation facilities and practices, and hygiene conditions are associated with various illnesses both in adults and children, as discussed in Larsen (2003). Diarrheal illness in children under age five (mortality and morbidity) and adults (morbidity) is the major burden of disease associated with inadequate WSS. Although diarrheal illness is generally not as serious as some other waterborne illnesses, it is more common and affects a larger number of people. Table 3.1 presents the water supply and sanitation situation in Colombia in 2010. About 98 percent of the urban population and 73 percent of the rural population have access to improved water supply in Colombia.

Table 3.1: Water Supply and Sanitation in Colombia in 2010

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piped water</td>
<td>91.7</td>
<td>59.6</td>
</tr>
<tr>
<td>Well water</td>
<td>0.7</td>
<td>10.8</td>
</tr>
<tr>
<td>Surface water</td>
<td>0.3</td>
<td>19.8</td>
</tr>
<tr>
<td>Rainwater</td>
<td>1.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Tanker truck</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Bottled water/demijohn</td>
<td>5.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Other</td>
<td>0.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Water within 15 minutes</td>
<td>99.7</td>
<td>93.6</td>
</tr>
<tr>
<td>Flush toilet</td>
<td>98.1</td>
<td>80.3</td>
</tr>
<tr>
<td>Pit latrine</td>
<td>0.5</td>
<td>3.8</td>
</tr>
<tr>
<td>No facility</td>
<td>1.3</td>
<td>15.8</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Source: ENDS 2010

In the last 10 years, the amount of the Colombian population with nonimproved sanitation has decreased significantly. Figure 3.1 below presents the percent of the population with improved sanitation in rural areas in 2000–2010.

Figure 3.1: Percent of Population without Access to Improved Sanitation

46. Improvements in sanitation were one of the reasons for substantial reductions in child mortality and diarrheal child mortality in Colombia. Reliable data on the health and nutritional status of the Colombian population are for the most part readily available. Public health information systems contain complete and reliable data on cause-specific adult and child mortality, child nutritional status, and incidence of infectious diseases. These data were applied for estimating the health effects or disease burden from environmental health risk factors. This report uses reported DANE (Ministry of Health) data, household surveys in Colombia (ENDS) and data reported by WHO that, combined, provide indications of several dimensions of health and nutrition in Colombia needed for this study of environmental health. The main household survey with relevant health statistics is Colombia’s National Demographic and Health Survey (Encuesta Nacional de Demografía y Salud 2010 [ENDS 2010]) by the Association for the Well-being of the Colombian Family (Asociación ProBienestar de la Familia Colombiana, Profamilia), the Ministry of Social Protection (Ministerio de Protección Social, MPS) and the US Government through USAID. This survey includes information on child nutritional status, and estimates of the cause-specific structure of child and adult mortality in Colombia by WHO (2009). The reference year for this study is 2009.

3.2. Child mortality and morbidity

47. According to ENDS 2010, the under-five child mortality rate in Colombia was around 22 per 1,000 live births in 2010 (25 in rural areas and 21 in urban areas). It decreased about 9 percent from 2000. Based on statistics of the under-age-five population in Colombia (DANE, 2009), from a population of 3 million children under age five in urban and 1.3 million in rural areas, an estimated 12,600 children under age five died in Colombia in urban areas and 6,400 in rural areas in 2009. WHO and DANE provide estimates of cause-specific child mortality in 2008–2009 for Colombia (WHO 2010; DANE 2010). According to these estimates, about 13 to 16 percent of mortality among children under five in Colombia was from infectious and parasitic diseases, and 84 to 87 percent was from other causes (Figure 3.2). For purposes of this report, it is assumed that the structure of child mortality in urban and rural areas is the same as that estimated for Colombia as a whole.

**Figure 3.2: Estimates of Cause-Specific Non-Accidental Mortality Among Children Under Age Five in Colombia from Infectious and Parasitic Diseases, 2008**

![Figure 3.2: Estimates of Cause-Specific Non-Accidental Mortality Among Children Under Age Five in Colombia from Infectious and Parasitic Diseases, 2008](source: Produced from DANE estimates of mortality among children in Colombia in 2009 (DANE 2010).)
48. The reported data suggest that diarrheal mortality decreased more than 50 percent in relative terms. At the same time, diarrheal prevalence decreased only 10 percent. The estimate of diarrheal cases per person is presented below. ENDS 2010 contains important information on the prevalence of diarrhea and symptoms of respiratory infections in children under age five. ENDS 2010 reports a two-week diarrheal prevalence rate of 11.6 to 15.2 percent in urban-rural areas of Colombia. The annual incidence of diarrhea per child per year is calculated based on the number of prevalence periods in a year and is adjusted for the duration of the diarrheal illness. The average duration of diarrhea is assumed to be 3 to 4 days. The incidence of diarrhea is therefore 2.4 to 3.6 cases per child per year in urban-rural areas, according to ENDS 2010.

Table 3.2: Diarrheal Illness in Colombia Among Children Under Age Five in 2000–2009

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Rural</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children under five mortality, 2000</td>
<td>24</td>
<td>36</td>
<td>28</td>
</tr>
<tr>
<td>(per 1,000 live births)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children under five mortality, 2009</td>
<td>21</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>(per 1,000 live births)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diarrheal mortality, 2000 (%)</td>
<td>7.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diarrheal mortality, 2009 (%)</td>
<td>3.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diarrheal morbidity, 2000 (prevalence last 2 weeks)</td>
<td>13.2%</td>
<td>15.6%</td>
<td>13.9%</td>
</tr>
<tr>
<td>By household wealth index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest</td>
<td></td>
<td>17.5%</td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td></td>
<td>15.9%</td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td></td>
<td>12.9%</td>
<td></td>
</tr>
<tr>
<td>Fourth</td>
<td></td>
<td>10.4%</td>
<td></td>
</tr>
<tr>
<td>Highest</td>
<td></td>
<td>10.2%</td>
<td></td>
</tr>
<tr>
<td>Diarrheal morbidity, 2009 (prevalence last 2 weeks)</td>
<td>11.6%</td>
<td>15.2%</td>
<td>12.6%</td>
</tr>
<tr>
<td>By household wealth index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest</td>
<td></td>
<td>16.1%</td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td></td>
<td>14.4%</td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td></td>
<td>11.3%</td>
<td></td>
</tr>
<tr>
<td>Fourth</td>
<td></td>
<td>10.6%</td>
<td></td>
</tr>
<tr>
<td>Highest</td>
<td></td>
<td>7.4%</td>
<td></td>
</tr>
</tbody>
</table>


49. Although diarrheal prevalence decreased in the last decade, it is still higher than average in children from lower-income households. Thus, the impact of inadequate WSH is higher in these income groups. For diarrhea, 88 percent of cases globally are attributed to water, sanitation and hygiene (Prüss et al. 2002; Prüss-Ustün et al. 2004). None of the surveys reports diarrheal disease among the population aged five years and older. Results from household surveys in other countries indicate that the incidence rate in children under age five is around 7 to 10 times higher than among the population aged five years and older. If this is also the case in Colombia, there are 2.4 to 3.2 cases of diarrhea per person/per year in the population aged five years and older, totaling over 13 million cases. Thus, in total there were over 24 million cases of diarrhea in Colombia in 2009. About 21 million of these cases are attributable to inadequate water supply, sanitation and hygiene, representing a loss of over 29,100 DALYs (see Table 3.3).
Table 3.3: Estimated Annual Cases of Diarrheal Mortality and Morbidity from Water-Sanitation-Hygiene (WSH) in Colombia, 2009

<table>
<thead>
<tr>
<th></th>
<th>Annual Cases of Diarrhea</th>
<th>Attributable Fraction from WSH</th>
<th>Annual cases from WSH</th>
<th>DALYs from WSH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban</td>
<td>Rural</td>
<td></td>
<td>Urban</td>
</tr>
<tr>
<td>Children under age 5:</td>
<td>440</td>
<td>220</td>
<td>88%</td>
<td>400</td>
</tr>
<tr>
<td>mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children under age 5:</td>
<td>7.2</td>
<td>4.0</td>
<td></td>
<td>6.3</td>
</tr>
<tr>
<td>morbidity (million)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population aged 5+:</td>
<td>9.1</td>
<td>3.8</td>
<td></td>
<td>8.0</td>
</tr>
<tr>
<td>morbidity (million)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total morbidity (million)</td>
<td>16.3</td>
<td>7.8</td>
<td></td>
<td>14.3</td>
</tr>
</tbody>
</table>

Source: Authors’ estimates. Note: *DALYS from diarrheal morbidity.

3.3. Child nutritional status and WSH health impact

50. Studies in different low-income countries with similar water supply, sanitation and hygiene problems suggest that measures to reduce environmental damages are justified in a number of areas on cost-benefit grounds as well on grounds of benefiting the poor. For water supply and sanitation, improvements in facilities in rural areas yield benefits in excess of costs under most assumptions. In urban areas, the focus should be on the monitoring of drinking-water monitoring and on the rehabilitation of piped water supply and sewage systems. The programs are justified on the grounds that the benefits are concentrated primarily among the poor. Hygiene programs have estimated benefits far in excess of costs and should receive the highest priority. The same applies to programs aimed at encouraging the disinfection of drinking water. All interventions to improve WSH also have the benefit of reducing the burden of malnutrition.

51. Commonly used indicators of poor nutritional status in children are underweight, stunting and wasting. Underweight is measured as weight-for-age relative to an international reference population. Stunting is measured as height-for-age, and wasting is measured as weight-for-height. Underweight is an indicator of chronic or acute malnutrition or a combination of both. Stunting is an indicator of chronic malnutrition, and wasting an indicator of acute malnutrition. Underweight status among children under age five is most commonly used in assessing the risk of mortality and morbidity from poor nutritional status (Fishman et al. 2004).

52. A child is defined as moderately underweight or stunted if his or her weight or height is in the range of -2 to -3 standard deviations (SD) below the weight or height of the median child in the international reference population, and severely underweight or stunted if the child’s weight or height is -3 SD below the weight or height of the median child in the reference population. The standard deviations are also called z-scores and noted as WAZ (weight-for-age z-score). ENDS 2010 is used here to provide some perspectives on the nutritional status among children under age five in Colombia.

7 The recently published WHO international reference population (representing a diverse group of countries) is increasingly replacing the international reference population defined by the US National Center for Health Statistics (NCHS).
Table 3.4: Prevalence of Underweight in Children Under Age Five in Colombia

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Rural</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate and severe underweight 2009</td>
<td>2.9%</td>
<td>4.7%</td>
<td>3.4%</td>
</tr>
<tr>
<td>Severe underweight 2009</td>
<td>0.5%</td>
<td>0.9%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Moderate and severe underweight by household wealth index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest</td>
<td></td>
<td></td>
<td>7.7%</td>
</tr>
<tr>
<td>Second</td>
<td></td>
<td></td>
<td>5.0%</td>
</tr>
<tr>
<td>Middle</td>
<td></td>
<td></td>
<td>3.4%</td>
</tr>
<tr>
<td>Fourth</td>
<td></td>
<td></td>
<td>3.3%</td>
</tr>
<tr>
<td>Highest</td>
<td></td>
<td></td>
<td>1.6%</td>
</tr>
<tr>
<td>Moderate and severe underweight, 2000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe underweight 2000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate and severe underweight by household wealth index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest</td>
<td></td>
<td></td>
<td>9.3%</td>
</tr>
<tr>
<td>Second</td>
<td></td>
<td></td>
<td>9.0%</td>
</tr>
<tr>
<td>Middle</td>
<td></td>
<td></td>
<td>5.6%</td>
</tr>
<tr>
<td>Fourth</td>
<td></td>
<td></td>
<td>4.4%</td>
</tr>
<tr>
<td>Highest</td>
<td></td>
<td></td>
<td>3.0%</td>
</tr>
</tbody>
</table>

Source: ENDS 2010

Figure 3.3: Malnutrition Status (percent) by Income Groups in Colombia

Sources: ENDS 2000, ENDS 2010.

53. Malnutrition status improved in all income groups, with the greatest improvement achieved in the second-lowest income group (about four percent fewer children under age five were malnourished in Colombia by 2009).

54. Measuring the burden of disease and subsequent economic costs from environmental health risks is important in helping policy makers to better integrate environmental health into economic
development, and specifically in their decisions related to resource allocation among various programs and activities to improve child health. Building on previous estimates, and due to the linkages among environmental health, malnutrition and disease, WHO recently revised the burden-of-disease estimates, taking into account malnutrition-mediated health impacts associated with inadequate water and sanitation provisions and improper hygiene practices (Fewtrell, Prüss-Üstün et al. 2007).

55. The new WHO estimates reveal that the environmental health burden in children under age five is substantially higher when all linkages through malnutrition, especially in those subregions where malnutrition and poor environmental conditions coexist, are incorporated. In a study of the linkage between the global disease burden and the environment (Prüss-Üstün and Corvalán 2006), it was estimated that 50 percent of malnutrition is attributable to the environment, essentially to water, sanitation and hygiene (pooled expert opinion based on literature review).

56. Blössner and de Onis (2005) presented a methodology to quantify the burden of disease associated with malnutrition. To quantify the impact of malnutrition, it is necessary to factor in population data of weight-for-age (WA) in children and the disease burden (deaths, incidence and DALYs) of infectious diseases and protein-energy malnutrition (PEM). For Bolivia, such information may be obtained from DHS 2008 and WHO deaths, incidence and DALY tables from Global Burden of Disease (GBD) 2008.

57. The basic method applied to estimate the consequences of malnutrition in terms of health impact from infectious diseases in children under age five consists of the following steps (Blössner and de Onis 2005; Fishman et al. 2004):

- estimation of the number of children with a WA below -1 standard deviations (SD) of the mean;
- estimation of fractions of mortality due to diarrheal disease, malaria, measles, lower respiratory infections, other infectious diseases (besides HIV) and PEM that are attributable to malnutrition, based on relative risks from the literature;
- calculation of the disease burden attributable to malnutrition by multiplying mortality, incidence and DALY statistics with attributable fractions.

58. Fishman et al. (2004) present estimates of increased risk of cause-specific mortality and all-cause mortality in children under age five with mild, moderate and severe underweight from a review of available studies. Severely underweight children (WA < -3 SD) are 5 times more likely to die from measles, 8 times more likely to die from acute lower respiratory infections (ALRI), nearly 10 times more likely to die from malaria, and 12 times more likely to die from diarrhea than non-underweight children (WA > - 1 SD). Even mild underweight doubles the risk of death from major diseases in early childhood (see Table 3.5).

59. Child underweight also increases the risk of illness. Fishman et al. (2004) present estimates of increased risk in children under age five with moderate and severe underweight (WA < -2 SD). The largest increased risk of illness is for pneumonia/ALRI. No increased risk of measles is confirmed (see Tables 3.5 and 3.6).
Table 3.5: Relative Risk of Mortality from Mild, Moderate and Severely Underweight in Children Under Age Five

<table>
<thead>
<tr>
<th>Weight-for-age (WA)</th>
<th>&lt;-3 SD</th>
<th>-2 to -3 SD</th>
<th>-1 to -2 SD</th>
<th>&gt;-1 SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia/ALRI</td>
<td>8.1</td>
<td>4.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>12.5</td>
<td>5.4</td>
<td>2.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Measles</td>
<td>5.2</td>
<td>3.0</td>
<td>1.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Malaria</td>
<td>9.5</td>
<td>4.5</td>
<td>2.1</td>
<td>1.0</td>
</tr>
<tr>
<td>All-cause</td>
<td>8.7</td>
<td>4.2</td>
<td>2.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Source: Fishman et al. (2004).

Table 3.6: Relative Risk of Illness from Moderate and Severe Underweight in Children Under Age Five

<table>
<thead>
<tr>
<th>Weight-for-age (WA)</th>
<th>&lt;-2 SD</th>
<th>&gt;-2 SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia/ALRI</td>
<td>1.86</td>
<td>1.0</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>1.23</td>
<td>1.0</td>
</tr>
<tr>
<td>Measles</td>
<td>1.00</td>
<td>1.0</td>
</tr>
<tr>
<td>Malaria</td>
<td>1.31</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Source: Fishman et al. (2004).

60. The WA prevalence rates and the relative risks of cause-specific mortality can be used to estimate the population-attributable fractions (AF) of mortality from underweight in children under age five:

\[
AF = \left( \sum_{i=1}^{n} P_i RR_i - 1 \right) / \sum_{i=1}^{n} P_i RR_i
\]

where RR\(_i\) is the relative risk of mortality for each of the four WA categories (i) in Table 5; and P is the percent of children in each of the four categories (i).

61. In addition to these malnutrition-related mortalities, Fishman et al. (2004) include 100 percent of PEM mortality and a share of mortality from perinatal conditions (low birth weight associated with low maternal pre-pregnancy body mass index \([\text{BMI} < 20 \text{ kg/m}^2]\)). About nine percent of infants had low birth weight (<2,500 g) in Colombia in 2008.\(^8\)

62. ENDS 2010 data, needed to estimate the prevalence of child underweight in Colombia using the NCHS reference population, were not available at the time this report was being prepared. Applying the assumption (Blossner, Ortiz 2005) about normal distribution of malnourished children under age five, mild underweight children under age five were estimated for Colombia.

63. The application of the relative risks of illness and WA malnutrition rates to (1) indicates that about six percent of pneumonia/ALRI mortality and seven percent of diarrhea mortality in children under age five in Colombia are from malnutrition (Table 3.7).

Table 3.7: Attributable Fractions of Under-Five Child Mortality and Morbidity from Underweight

<table>
<thead>
<tr>
<th></th>
<th>Mortality</th>
<th>Morbidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia/ALRI</td>
<td>5.7%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>7.4%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Malaria</td>
<td>6.3%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Measles</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Protein-energy malnutrition (PEM)</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Other causes</td>
<td>6.0%</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Source: Estimated in this report.

\(^8\) Source: ENDS 2010.
Table 3.8 presents the deaths among children under age five that could be associated with malnutrition. Since mortality and incidence from diarrheal and lower respiratory diseases in children were already counted as an impact of inadequate WSH and of indoor air pollution, only other diseases were included in the costs of malnutrition. Morbidity was not included because no data were available on the prevalence of other diseases.

Table 3.8: Estimated Deaths Among Children Under Age Five that Could be Associated with Malnutrition in Colombia, 2009

<table>
<thead>
<tr>
<th>Number of malnutrition-related deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-neonatal deaths</td>
</tr>
<tr>
<td>Measles</td>
</tr>
<tr>
<td>Protein-energy malnutrition (PEM)</td>
</tr>
<tr>
<td>Other causes</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Source: Estimated in this report.
Box 2: The Association Between Inadequate Water Supply, Sanitation and Hygiene and Prevalence of Malnutrition

Malnutrition in children under five years of age makes infections worse and often more frequent. Substantial research confirms that early childhood repeated infections, including diarrhea, may account for at least one third of weight gain retardation in children under five years of age, thus contributing as much as half of disease burden from malnutrition. WHO study (Fewtrell et al. 2007) reports that malnourished children have a risk of dying from various diseases that is several times higher than non-malnourished children. Then the disease burden from inadequate water supply, sanitation and hygiene (WSH) as much as doubles compared to only considering the direct effect of inadequate WSH on diarrhea. The methodology proposed by WHO incorporates not only direct health risks from environmental factors (such as diarrheal disease burden from poor water and sanitation), but also seeks to include the indirect risks (concentrating on WSH and its indirect impact on mortality through malnutrition). Thus, while a traditional burden of disease calculation would associate WSH with only diarrheal diseases (see figure below), the inclusion of the indirect path implies the need to include all diseases attributable to malnutrition (as 50% of the consequences of malnutrition are, in turn, attributed to poor WSH).

The Health Effects of Environmental Risks Factors

3.4. Cost of inadequate WSH in Colombia

65. The estimated annual cost of health impacts from urban air pollution is presented in Table 3.9 and Figure 3.4. The cost of mortality among children under age five is based on using the human capital (HC) approach (discounted lifetime income of the average person in Colombia). Annual mortality cases associated with inadequate WSH (Tables 3.3 and 3.8) are multiplied by an average value of mortality case using the HC approach. Morbidity is valued using the cost of illness (COI) approach (Annex 1). The WTP proxy applied is based on the ratio of cost of illness to willingness to pay reported for Bogotá (PDB 2010). The cost per case (comprising cost of illness plus the proxy for WTP) is the basis for the estimation of the COI for diarrhea (Annex 1) by multiplying each cost for the cases in Table 3.3.

Table 3.9: Estimated Annual Cost of Health Impacts (Billion Pesos)

<table>
<thead>
<tr>
<th>Health categories</th>
<th>Urban annual cost (billion pesos)</th>
<th>Rural annual cost (billion pesos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children under age 5: diarrheal mortality</td>
<td>140</td>
<td>70</td>
</tr>
<tr>
<td>Children under five: malnutrition-related mortality</td>
<td>232</td>
<td>148</td>
</tr>
<tr>
<td>Morbidity:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diarrheal illness</td>
<td>2,214</td>
<td>629</td>
</tr>
<tr>
<td>ARI illness</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL COST (mortality and morbidity)</td>
<td>2,596</td>
<td>849</td>
</tr>
</tbody>
</table>

* Annual cost is rounded to nearest billion.
Source: Estimates by the authors.

Figure 3.4: Estimated Annual Cost of Health Impacts Associated with Inadequate WSH

Source: Authors’ estimates.

9 351 million Ps.
10 Malnourishment-related illness.
66. Table 3.10 details the baseline data that were used for the estimation of the cost of illness and the costs of time lost to illness. For purposes of comparability with previous estimates (see Annex 3), we kept most of the assumptions regarding duration of illness, rate and length of hospitalization, average time lost per health end-point, frequency of doctor visits, and discount rate. We also valued time lost to illness at 75 percent of the average urban wage, and applied this cost both to working and nonworking individuals, based on the assumption of an equivalent opportunity cost for both categories.

**Table 3.10: Baseline Data for Cost Estimation**

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Source:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of diarrheal cases treated at medical facilities (children &lt; age 5) and with medicines</td>
<td>37–46%</td>
<td>ENDS 2010</td>
</tr>
<tr>
<td>Percent of diarrheal cases treated with ORS (children &lt; age 5)</td>
<td>68–77%</td>
<td>ENDS 2010</td>
</tr>
<tr>
<td>Percent of diarrheal cases treated at medical facilities (population &gt; age 5) and with medicines</td>
<td>30–35%</td>
<td>Estimated from a combination of INS data and ENDS 2010</td>
</tr>
<tr>
<td>Average cost of doctor visits (urban and rural): pesos</td>
<td>29,000</td>
<td>Per consultations with pharmacies, medical service providers, and health authorities</td>
</tr>
<tr>
<td>Average cost of medicines for treatment of diarrhea: pesos</td>
<td>3,600–12,600</td>
<td></td>
</tr>
<tr>
<td>Average cost of ORS per diarrheal case in children: pesos</td>
<td>1200</td>
<td></td>
</tr>
<tr>
<td>Average duration of diarrheal illness in days (children and adults)</td>
<td>3–4</td>
<td>Assumption</td>
</tr>
<tr>
<td>Hours per day of caregiving per case of diarrhea in children</td>
<td>2</td>
<td>Assumption</td>
</tr>
<tr>
<td>Hours per day lost to illness per case of diarrhea in adults</td>
<td>2</td>
<td>Assumption</td>
</tr>
<tr>
<td>Value of time for adults (caregiving and ill adults): pesos/hour</td>
<td>1,500–3,600</td>
<td>Based on urban and rural wages in Colombia</td>
</tr>
<tr>
<td>Hospitalization rate (% of all diarrheal cases): children under age 5</td>
<td>0.75%</td>
<td>Adjusted based on evidence from Egypt (Larsen 2004).</td>
</tr>
<tr>
<td>Hospitalization rate (% of all diarrheal cases): children under age 5</td>
<td>0.50%</td>
<td>No data available for Colombia</td>
</tr>
<tr>
<td>Average length of hospitalization (days)</td>
<td>2</td>
<td>Adjusted from Egypt (Larsen 2004)</td>
</tr>
<tr>
<td>Time spent on visitation (hours per day)</td>
<td>4</td>
<td>Assumption</td>
</tr>
<tr>
<td>Average cost of hospitalization (pesos per day)</td>
<td>180,000</td>
<td>Per consultations with hospitals</td>
</tr>
<tr>
<td>Percent of diarrheal cases and hospitalizations attributable to water, sanitation and hygiene</td>
<td>88%</td>
<td>Prüss-Ustün et al. 2004</td>
</tr>
</tbody>
</table>

67. The mean estimated annual cost of health impacts from indoor air pollution associated with the use of traditional fuels (mainly fuelwood) in rural areas of Columbia is 3,450 billion pesos (0.68 percent of GDP in 2009). Child mortality represents 17 percent of cost; morbidity represents about 83 percent of cost. Diarrheal mortality and morbidity represent about 89 percent of total cost and
are estimated at about 3,050 billion Ps. per year. Urban cost represents about 77 percent of total diarrheal cost (Figure 3.5).

**Figure 3.5: Estimated Annual Diarrheal Cost Associated with Inadequate WSH in Colombia, 2009**

![Graph showing estimated annual diarrheal cost with urban and rural costs.](image)

Source: Authors’ estimates.
4. HOUSEHOLD AIR POLLUTION FROM USE OF SOLID FUELS

4.1. Indoor smoke and health

68. Household air pollution from use of solid fuels for cooking and other purposes is associated with substantial health effects, particularly among young children and adult women, because these groups tend to spend the most time in the household environment. Combustion of solid fuels generates fine particulates (smoke) and other pollutants harmful to human health. Combustion of biomass (straw/shrubs/grass, agricultural crop residues, and animal dung) tends to generate the most smoke, followed by wood and coal/charcoal. Modern fuels (e.g., liquid petroleum gas [LPG], biogas, kerosene) are the cleanest and generate the least smoke.

69. About 50 percent of rural households in Colombia use wood/charcoal and other solid fuels (e.g., agricultural residues, straw), according to ENDS 2010. The rate was about 60 percent in 2000 (ENDS 2000). Only about 2 percent of urban households use these fuels (Table 4.1).

Table 4.1: Household Fuels Used for Cooking in Colombia, 2010

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>4.5</td>
<td>2.7</td>
</tr>
<tr>
<td>LPG, natural gas</td>
<td>90.9</td>
<td>45</td>
</tr>
<tr>
<td>Kerosene</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Coal, lignite</td>
<td>0.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Firewood, straw</td>
<td>1.9</td>
<td>49.3</td>
</tr>
<tr>
<td>No cooking in household</td>
<td>2.5</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Source: ENDS, 2010

70. Combustion of solid fuels for cooking is a major source of household air pollution in developing countries. Combustion of these fuels is associated with an increased risk of several health outcomes. The risks are generally reported relative to the risks of health effects from the use of liquid fuels (e.g., LPG). The evidence from studies around the world is summarized in meta-analyses by Desai et al. (2004), Smith et al. (2004), Dherani et al. (2008), Kurmi et al. (2010), and Po et al. (2011) and include elevated risks of acute lower respiratory infections (ALRI) in children under age five, and chronic obstructive pulmonary disease (COPD), chronic bronchitis (CB), lung cancer, and tuberculosis in adult women. Ezzati and Kammen (2001, 2002) also document elevated risks of ALRI in adult women and acute upper respiratory infections (AURI) in children and adult women. Studies of the health effects of outdoor ambient particulate matter (PM) have found that exposure to PM increases the risk of cardiovascular mortality (Pope et al. 2002). A recent study in Guatemala found that cooking with wood on open fires, compared to cooking with wood and using an improved chimney stove, is associated with higher systolic blood pressure among adult women (McCracken et al. 2007). Elevated systolic blood pressure is associated with an increased risk of cardiovascular disease and mortality (Lawes et al. 2004).

71. In light of the evidence from these studies, the relative risks of health effects from the use of wood and other biomass fuels for cooking applied in this study to Colombia are presented in Table 4.2. These relative risks are applied to children under age five and to adult women in households using these fuels, because these are the household members who are most exposed to air pollution from cooking. Only acute respiratory infections and COPD were considered as health impacts of indoor air pollution in Larsen (2002).

---

11 CB is a subset of COPD.
Table 4.2: Relative Risks of Health Effects from Cooking with Wood and other Biomass Fuels Applied to Colombia

<table>
<thead>
<tr>
<th>Population group</th>
<th>Health outcome</th>
<th>Relative risk ratios (RR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children &lt; age 5</td>
<td>Acute respiratory infection (ALRI)</td>
<td>2.0</td>
</tr>
<tr>
<td>Women ≥ age 30</td>
<td>Chronic obstructive pulmonary disease (COPD)</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Chronic bronchitis (CB)</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Ischemic heart disease</td>
<td>1.19</td>
</tr>
<tr>
<td></td>
<td>Cerebrovascular disease</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>Hypertensive heart disease</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>Other cardiovascular disease</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>Lung cancer (LC)</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Source: Based on Desai et al. (2004), Smith et al. (2004), Dherani et al. (2008), Kurmi et al. (2010), Po et al. (2011), and estimates of cardiovascular disease risks based on McCracken et al. (2007) and Lawes et al. (2004) as presented in Larson (2012).

72. To calculate the fraction of health outcomes associated with the use of wood and other biomass for cooking, the following attributable fraction formula is applied:

\[
AF = \left( \frac{\sum_{i=1}^{n} P_i RR_i}{\sum_{i=1}^{n} P_i} - 1 \right) / \sum_{i=1}^{n} P_i RR_i
\]

(7.1)

\( P_i=1 \) and \( P_i=2 \) is the share of the population cooking with wood or other biomass and with other types of fuels, respectively; and \( RR \) is the relative risk of morbidity and mortality from indoor cooking with wood and biomass. The attributable fractions are then multiplied by the estimated annual baseline mortality in Colombia for each health outcome in order to arrive at annual premature mortality associated with the use of wood and biomass.

4.2. Baseline mortality and morbidity

73. Baseline mortality is estimated from DANE 2010, which presents estimates of cause-specific mortality in Colombia by age group. ARI mortality and morbidity in children under age five is presented in Table 4.3 below.

Table 4.3: ARI Illness in Colombia Among Children Under Age Five in 2000–2009

<table>
<thead>
<tr>
<th>ARI mortality, 2000 (%)</th>
<th>Urban</th>
<th>Rural</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARI mortality, 2009 (%)</td>
<td>7.5%</td>
<td>7–12%</td>
<td></td>
</tr>
<tr>
<td>ARI morbidity, 2000 (prevalence last 2 weeks)</td>
<td></td>
<td></td>
<td>12.3%</td>
</tr>
<tr>
<td>ARI morbidity, 2009 (prevalence last 2 weeks)</td>
<td>6.1%</td>
<td>5.7%</td>
<td>6.0%</td>
</tr>
<tr>
<td>By household wealth index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest</td>
<td>6.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td>6.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>6.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fourth</td>
<td>4.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest</td>
<td>3.8%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sources: ENDS 2000, ENDS 2010.

74. ARI prevalence among children under age five decreased by more than 50 percent in the last 10 years. ARI mortality is at about the same level; the difference may be explained by reporting errors and the uncertainty of WHO estimates of deaths by cause among children under age five.
4.3. Mortality and morbidity attributable to indoor household solid fuel use

75. An estimated 950 to 1,050 children and women died prematurely from the use of wood and other biomass fuels for cooking in Colombia in 2009 (see Table 4.4). About 200 of these deaths were among children under age five and 800 were among adult women. The deaths represent 11,600 years of life lost (YLL) per year, of which about 60 percent are among children under age five.12 Morbidity from the use of wood and other biomass fuels can be estimated in the same manner as for mortality by multiplying the attributable fractions from equation (1) with baseline cases of morbidity. Baseline cases of ARI in Colombia are estimated from ENDS in the same manner as for diarrheal prevalence. The baseline prevalence of COPD is estimated from Caballero et al. (2008) and Shibuya et al. (2001).

76. Estimated annual cases of ARI and CB from the use of wood and other biomass fuels are about 3 million in 2009, representing a loss of about 6,400 DALYs (see Table 4.4).13

Table 4.4: Estimated Annual Mortality from Household Use of Wood and Biomass for Cooking in Colombia, 2009

<table>
<thead>
<tr>
<th>Health outcome</th>
<th>Population group</th>
<th>Annual baseline mortality</th>
<th>Attributable fraction from use of solid fuels</th>
<th>Annual mortality from use of solid fuels</th>
<th>DALYs (YLL) from use of solid fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALRI</td>
<td>children u-5</td>
<td>603</td>
<td>33%</td>
<td>201</td>
<td>6,837</td>
</tr>
<tr>
<td>COPD</td>
<td>females 30+</td>
<td>442</td>
<td>47%</td>
<td>209</td>
<td>1,255</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>females 30+</td>
<td>2,320</td>
<td>9%</td>
<td>201</td>
<td>1,208</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>females 30+</td>
<td>1,427</td>
<td>12%</td>
<td>164</td>
<td>985</td>
</tr>
<tr>
<td>Hypertensive heart disease</td>
<td>females 30+</td>
<td>556</td>
<td>20%</td>
<td>113</td>
<td>678</td>
</tr>
<tr>
<td>Other cardiovascular disease</td>
<td>females 30+</td>
<td>950</td>
<td>6%</td>
<td>54</td>
<td>323</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>females 30+</td>
<td>310</td>
<td>20%</td>
<td>62</td>
<td>350</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>6,608</td>
<td>n/a</td>
<td>1,004</td>
<td>11,635</td>
</tr>
</tbody>
</table>

Source: Authors’ estimates.

77. Annual cases of mortality attributed to indoor air pollution are presented in Figure 4.1 below.

---

12 Years of life lost (YLL) are estimated according to WHO’s calculation of DALYs using age weighting and a three-percent discount rate.
13 Cases of cardiovascular disease and lung cancer are not estimated due to data constraints. DALYs are estimated according to WHO’s calculation of DALYs.
Figure 4.1: Annual Cases of Mortality Attributed to Indoor Air Pollution in Colombia

![Annual cases graph](image)

Source: Authors' estimates.

<table>
<thead>
<tr>
<th>Health outcomes</th>
<th>Population group</th>
<th>Annual baseline cases</th>
<th>Attributable fraction from use of solid fuels</th>
<th>Annual cases from use of solid fuels</th>
<th>DALYs from use of solid fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARI</td>
<td>children u-5</td>
<td>1,825,000</td>
<td>33%</td>
<td>608,300</td>
<td>1,004</td>
</tr>
<tr>
<td>ARI</td>
<td>females 30+</td>
<td>1,148,000</td>
<td>33%</td>
<td>382,698</td>
<td>2,679</td>
</tr>
<tr>
<td>COPD</td>
<td>females 30+</td>
<td>2,500</td>
<td>47%</td>
<td>1,184</td>
<td>2,664</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2,975,500</td>
<td>n/a</td>
<td>992,182</td>
<td>6,347</td>
</tr>
</tbody>
</table>

Source: Authors' estimates.

4.4. Health cost of indoor household solid-fuel use

78. The estimated annual cost of health impacts attributed to indoor air pollution in rural areas is presented in Table 4.6. The cost of mortality is based on the Value of a Statistical Life (VSL) for adult women and the HC approach for children under age five.

Table 4.6: Estimated Annual Cost of Health Impacts (Billion Pesos)

<table>
<thead>
<tr>
<th>Health categories</th>
<th>Total Annual Cost (billion pesos)</th>
<th>Percent of total cost*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children under age 5</td>
<td>73</td>
<td>6%</td>
</tr>
<tr>
<td>Adult females over age 30</td>
<td>882</td>
<td>78%</td>
</tr>
<tr>
<td>Morbidity:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COI</td>
<td>46</td>
<td>4%</td>
</tr>
<tr>
<td>WTP to avoid illness</td>
<td>128</td>
<td>11%</td>
</tr>
<tr>
<td>TOTAL COST (mortality and morbidity)</td>
<td>1129</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Annual cost is rounded to nearest billion, and percentages are rounded to nearest percent.
79. The estimated cost per case of premature mortality or specific health end-point is presented in Table 4.7. Adult mortality is valued with the VSL approach. The VSL used in this assessment is that utilized by the government in Bogotá for the Bogotá Ten-Year Decontamination Plan (Plan Decenal de Descontaminación de Bogotá, 2010). In that report, the value of statistical life was derived from: (i) Arigoni et al. (2009) in São Paulo, (ii) Hammit and Ibarra (2002) in Mexico City, and (iii) Bowland and Beghin (2001) in Santiago de Chile. The PDDB does not specify which value is chosen or, in the case of a combination of the values from the three studies, which relative weight of pooling method was used. However, since the value is not far off from the most recent (and perhaps most relevant) reference (Arigoni et al. 2009; see Annex 1), we found it most appropriate to use a locally generated value for VSL. The mortality of children under age five is valued using the human capital approach (discounted lifetime income of the average person in Colombia). Morbidity is estimated using the COI approach (Annex 1). Likewise, the WTP proxy applied is based on the ratio of cost of illness to willingness to pay reported for Bogotá (PDDB 2010). The cost per case (comprising cost of illness plus the proxy for WTP) is the basis for the estimation of the annual costs in Table 4.6 by multiplying each cost for the cases in Table 4.5.

Table 4.7: Estimated Unit Cost by Health End-Point

<table>
<thead>
<tr>
<th>Health categories</th>
<th>Total cost per case (000 pesos)</th>
<th>Cost-of-Illness per case (000 pesos)(^{14})</th>
<th>WTP proxy(^{15}) (000 pesos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality: women over age 30</td>
<td>1,100,000</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Mortality: children under age 5</td>
<td>351,000</td>
<td>351,000</td>
<td>N/A</td>
</tr>
<tr>
<td>COPD</td>
<td>8,060</td>
<td>2,500</td>
<td>5,560</td>
</tr>
<tr>
<td>ARI: children under age 5</td>
<td>300</td>
<td>90</td>
<td>210</td>
</tr>
<tr>
<td>ARI: women over age 30</td>
<td>420</td>
<td>130</td>
<td>290</td>
</tr>
</tbody>
</table>

80. Table 4.8 details the baseline data that were used for the estimation of the cost of illness and the costs of time lost to illness. For purposes of comparability with previous estimates (see Annex 3), we kept most of the assumptions regarding duration of illness, rate and length of hospitalization, average time lost per health end-point, frequency of doctor visits, and discount rate. We also valued time lost to illness at 75 percent of the average urban wage, and applied this cost both to working and nonworking individuals, based on the assumption of an equivalent opportunity cost for both categories.

\(^{14}\) Per treated case.
\(^{15}\) Per all cases attributed to indoor air pollution.
Table 4.8: Baseline Data for Cost Estimation in Rural Colombia

<table>
<thead>
<tr>
<th><strong>Acute Respiratory Illness (ARI):</strong></th>
<th>Baseline</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of ARI cases treated at medical facilities (children &lt; age 5)</td>
<td>44.5%</td>
<td>ENDS 2010 (rural children)</td>
</tr>
<tr>
<td>Percent of ARI cases treated at medical facilities (adults &gt; age 15)</td>
<td>35–40%</td>
<td>Estimated from a combination of INS data and DHS 2000</td>
</tr>
<tr>
<td>Average cost of doctor visits in rural areas (mainly primary healthcare centers): pesos</td>
<td>29,000</td>
<td>Per consultations with pharmacies, medical service providers, and health authorities</td>
</tr>
<tr>
<td>Cost of medicines for treatment of ARI: pesos</td>
<td>4,000–24,000</td>
<td></td>
</tr>
<tr>
<td>Percent of ARI cases treated with medicines</td>
<td>44.5%</td>
<td>ENDS 2010</td>
</tr>
<tr>
<td>Value of time for adults (caregiving and ill adults): pesos/hour</td>
<td>1,500</td>
<td>Based on rural wages in Colombia</td>
</tr>
</tbody>
</table>

| **Chronic Obstructive Pulmonary Disease (COPD):** | | |
|-----------------------------------------------|----------|
| Average duration of Illness (years) | 20 | Based on Shibuya et al. (2001) |
| Percent of COPD patients hospitalized per year | 1.5% | From Schulman et al. (2001) and Niederman et al. (1999) |
| Average length of hospitalization (days) | 10 | |
| Average number of doctor visits per COPD patient per year | 1 | |
| Percent of COPD patients with an emergency doctor/hospital outpatient visit per year | 15% | |
| Estimated lost workdays (including household workdays) per year per COPD patient | 2.6 | Estimated based on frequency of doctor visits, emergency visits, and hospitalizations |
| Cost of hospitalization (pesos per day) | 213,000 | Per consultations with medical service providers and health authorities |
| Cost of emergency visit (pesos): rural | 72,000 | |
| Cost of doctor visit (pesos) (mainly primary health clinic): rural | 29,000 | |
| Value of time lost to illness (pesos per day) | 12,000 | Based on rural wages in Colombia |
| Annual real increases in economic cost of health services and value of time | 2% | Estimate |
| Annual discount rate | 3% | Applied by WHO for health effects |

81. The mean estimated annual cost of health impacts from indoor air pollution associated with the use of traditional fuels (mainly fuelwood) in rural areas of Colombia is 1,129 billion pesos (0.22 percent of GDP in 2009). Child mortality represents 6 percent of cost; female mortality represents about 78 percent of cost. Acute respiratory illness (ARI) in children and adult females and COPD morbidity of adult females represent 16 percent of the cost.
5. CONCLUSIONS AND NEXT STEPS

82. The 2005 Colombia Country Environmental Analysis, Environmental Priorities and Poverty Reduction, concluded that: “The analysis of the cost of environmental degradation conducted shows that the most costly problems associated with environmental degradation are urban and indoor air pollution; inadequate water supply, sanitation, and hygiene; natural disasters and land degradation.” Colombia has made substantial progress in the last years in reducing the population exposure to urban air pollution, inadequate water and sanitation, and indoor air pollution from solid fuel use. However, these forms of environmental degradation continue to have a significant impact on the Colombian society in terms of premature mortality and disease.

83. The analysis in this report relied on large sets of statistics and data from various ministerial departments, institutions, and institutes in Colombia. It also has drawn heavily from Colombian and international research studies, and benefited from various methodological approaches applied by international organizations such as the World Health Organization. Publicly available, easily traceable information and indicators were used as much as possible, in order to facilitate contrast and upcoming updates. The estimation of the cost of environmental damage included many aspects, both economic and otherwise, although effects considered were only those related to the three mentioned factors (UAP, WASH, IAP). All costs calculated in this report are expressed in monetary terms, and they include the cost to society due to premature mortality, as well as the cost of healthcare provision to individuals suffering from pollution-related illnesses and the value individuals place in avoiding resulting pain and discomfort. Time losses or savings are valued at the opportunity cost of time.

84. In addition, the results of the health costs analysis are useful to track progress made by policy interventions as well as to further environmental protection and environmental health agendas. Ambitious policy interventions can find adequate justification in the large health and economic cost of environmental degradation in Colombia. The results show that addressing these environmental risks should continue to be a priority in the environmental and public health policy agenda of Colombia. The mean estimated annual cost of health impacts from indoor air pollution associated with the use of traditional fuels (mainly fuelwood) in rural areas of Colombia is 1,129 billion pesos (0.22 percent of GDP in 2009). Child mortality represents 6 percent of cost; female mortality represents about 78 percent of cost. Acute respiratory illness (ARI) in children and adult females and COPD morbidity of adult females represent 16 percent of the cost.

85. Both the health impact assessment and the economic valuation can be utilized by policy makers and stakeholders in the process of setting environmental objectives and priorities. The World Bank and other donors could also use the results to establish support priorities. The report may be useful for the Colombian Ministry of Finance and the National Planning Department because preferences and values are expressed in monetary terms, thus the results can provide additional guidance for the allocation of resources across diverse socio-economic development goals.

86. At the request of the GoC, the methodology used in this study as well as other approaches to environmental valuation and case studies from the region will be presented to a group of technical experts and decision-makers in an “Andean Workshop on the Costs of Environmental Degradation” planned for November 2012, and intended to transfer the methodology to the local experts and government agencies, to enable them to carry out similar periodic assessments.
6. REFERENCES


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Annex 1.

Economic Basis for Choice of VSL and WTP

The evidence base for willingness to pay (WTP) to avert mortality and morbidity risks from air pollution in Colombia is still scarce. However, there are some important studies that derive estimates from other examples in the Latin American context. One such study was conducted as a technical background for the Bogotá Ten-year Decontamination Plan (Plan Decenal de Descontaminación de Bogotá, 2010). In this report, the value of statistical life from was derived from: (i) Arigoni et al. (2009) in São Paulo, (ii) Hammit and Ibarran (2002) in Mexico Cit, and (iii) Bowland and Beghin (2001) in Santiago de Chile. The PDDB does not specify which value is chosen or, in the case of a combination of the values from the three studies, which relative weight of pooling method was used. For the cost of illness, the following assumptions were made by analysts in the PDDB evaluation:

- 90 percent of all urgent cases that are treated at a healthcare facility are in Acute Respiratory Illness (ARI) rooms.
- Average duration of the hospitalization for respiratory causes is 5 days. Average disability duration for respiratory causes is 10 days. For cardiovascular disease (CVD) causes, the values are 5.5 days and 11 days, respectively (AHA 2008).
- One emergency room (ER) visit entails 1 lost workday and 3 additional days of average disability duration.
- One visit to an ARI room entails 0.5 lost workday and 1.5 total average disability duration.
- Average duration of Intensive Care Unit (ICU) hospitalization is 8 days, with an average total duration of disability of 24 days.
- Symptoms from a respiratory disease entail an average total duration of disability of 3 days.

The resulting unit costs by health end-point from the PDDB are listed below:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost of medical care</th>
<th>Lost productivity</th>
<th>Cost of illness (COI)</th>
<th>Willingness to pay (WTP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VSL</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>1,008,000</td>
</tr>
<tr>
<td>Hosp. adm.: respiratory causes</td>
<td>1,290</td>
<td>470</td>
<td>1,760</td>
<td>4,000</td>
</tr>
<tr>
<td>Hosp. adm.: CVD causes</td>
<td>1,370</td>
<td>520</td>
<td>1,980</td>
<td>4,600</td>
</tr>
<tr>
<td>ER care: respiratory causes</td>
<td>310</td>
<td>130</td>
<td>440</td>
<td>670</td>
</tr>
<tr>
<td>Care in ARI rooms</td>
<td>50</td>
<td>60</td>
<td>110</td>
<td>N/A</td>
</tr>
<tr>
<td>Care in ICUs</td>
<td>6,600</td>
<td>1,000</td>
<td>7,600</td>
<td>N/A</td>
</tr>
<tr>
<td>Respiratory symptoms (&lt; age 5)</td>
<td>95</td>
<td>95</td>
<td>400</td>
<td></td>
</tr>
</tbody>
</table>

The most recent reference used by the PDDB report is a study by Ortiz et al. (2009), which was considered for this analysis and later discarded in the presence of a locally generated VSL. This study aims to estimate the population’s willingness to pay (WTP) to reduce risks of death associated with “typical” air pollution policies and consequently the value of a statistical life (VSL) in São Paulo, Brazil. Uniquely for that country, the study uses a methodology that has previously been tested in several industrialized countries (US, Japan, Canada, South Korea, England, France and Italy) and involves a computer-based contingent valuation survey. This survey instrument was
adapted to the Brazilian context and was used to elicit willingness-to-pay measures of reductions in risk of death in Brazil.

Key features of the survey instrument involve eliciting the health status of the respondents and their families; explaining basic concepts of probability and proposing simple practice questions to familiarize the respondents with the probability concepts introduced; presenting the leading causes of death for a Brazilian individual of the respondent’s age and gender, and setting these in the context of common risk-mitigating behaviors; and asking about the individual’s willingness to pay for risk reductions of a given magnitude that occur at a specified time.

The mean and median willingness-to-pay values were estimated using the interval data model that can be generated from the dichotomous choice with a follow-up question format. The responses to willingness-to-pay and follow-up questions were combined to generate intervals in which the unobservable respondents’ willingness to pay is to be found. The Weibull probability distribution was selected for the random variable of willingness to pay. The statistical willingness-to-pay model using the Weibull distribution is estimated using the maximum likelihood method. The corresponding values of a statistical life were estimated using both median willingness-to-pay estimates (conservative estimates) and mean willingness-to-pay values. They were obtained by dividing the willingness-to-pay figures by the corresponding annual risk reduction being valued. It was assumed that respondents implicitly considered the risk reduction even over the ten-year period, which makes it possible to avoid discounting the respondents’ annual payments.

The values of a statistical life estimated from 1-in-1,000 risk reductions are much higher than those estimated using the 5-in-1,000 risk reduction. This is purely due to the lack of proportionality between the willingness-to-pay estimates regarding the differences in the size of risk reductions. It is suggested that the VSL estimates derived from mean and median willingness-to-pay estimates for a 5-in-1,000-risk reduction are of greater policy relevance since they represent more conservative estimates than those estimated using willingness-to-pay estimates for 1-in-1,000-risk reduction. Thus, for policy assessments in São Paulo conservative values of a statistical life ranging between US$0.77–1.31 million (VSL estimate based on median and mean 5-in-1,000 risk reduction correspondingly) are suggested. An upper value of US$1.3 million was adopted as a higher bound to apply benefit transfer to Colombia.

When compared with European and North American estimates, these values seem to be higher than expected. Given the close link between willingness-to-pay estimates and the population’s income, lower willingness-to-pay values for developing countries might be expected. A possible reason for the high WTP and VSL estimates found in the current study might have been the “cooperative” behavior observed in many of the respondents. It is possible that those respondents tried to be “cooperative” or helpful by saying “yes” to every question. It was believed that the relatively high figures in this valuation exercise may be partly due to this bias. The value of a statistical life excluding possible “yeah-say” responses using parametric estimation of mean and median annual willingness to pay in 2003 (Weibull distribution, 95 percent CI ) is US$0.4 to 0.5 million (VSL estimate based on median and mean 5-in-1,000 risk reduction correspondingly) and in 2009 US$0.45 to 0.56 million. A lower value of US$0.4 million (VSL based on median 5-in-1,000 risk reduction, excluding “yes-”saying respondents) was adopted as a lower bound to apply benefit transfer to Colombia.

Applying a similar analysis, in the “Plan Decenal de Descontaminación de Bogotá” (PDDB 2009) a VSL at the level of US$0.47 million was applied. Thus, the midpoint of all estimates described above is 1.09 billion Ps. or US$0.5 million. The latter estimate was applied in the report (Table A1).

---

Table A.1.2: Application of Benefit Transfer Approach to Estimate VSL for the Population Dying from Pollution in Colombia

<table>
<thead>
<tr>
<th>Series Name</th>
<th>Source</th>
<th>Brazil</th>
<th>Colombia</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita (current US$)</td>
<td>WDI 2012</td>
<td>8,251</td>
<td>5,166</td>
</tr>
<tr>
<td>Value of Statistical Life (VSL):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VSL estimates from Brazil</td>
<td>Ortiz et al. 2009</td>
<td>0.45</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.77</td>
<td>1.46</td>
</tr>
<tr>
<td>Colombia GDP (US$ billion), 2009</td>
<td>WDI 2012</td>
<td>235</td>
<td>235</td>
</tr>
<tr>
<td></td>
<td></td>
<td>235</td>
<td>235</td>
</tr>
<tr>
<td>Colombia GDP (Ps. billion), 2009</td>
<td>WDI 2012</td>
<td>5.09E+05</td>
<td>5.09E+05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.09E+05</td>
<td>5.09E+05</td>
</tr>
<tr>
<td>Population (million) in 2009</td>
<td>WDI 2012</td>
<td>45.65</td>
<td>45.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45.65</td>
<td>45.65</td>
</tr>
<tr>
<td>GDP per capita (US$) in 2009</td>
<td></td>
<td>5,166</td>
<td>5,166</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5,166</td>
<td>5,166</td>
</tr>
<tr>
<td>Exchange rate (year average 2003)</td>
<td></td>
<td>2,156</td>
<td>2,156</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,156</td>
<td>2,156.3</td>
</tr>
<tr>
<td>VSL in Colombia mln USD.</td>
<td></td>
<td>0.28</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.54</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>VSL in Colombia bln Ps.</td>
<td></td>
<td>0.61</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.16</td>
<td>1.97</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.008*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Plan Decenal de Descontaminación de Bogotá (PDDB 2009).
Annex 2.

Air Quality Monitoring Data and Pollution Concentration Extrapolation in Medium-Large Municipalities in Colombia

A large number of Colombians potentially exposed to air pollution live in cities that lack systematic measurements of air pollutant concentrations. The question for the analyst estimating the health impacts of air pollution is whether to drop those cities from the analysis or to extrapolate measurements from cities that do have monitoring networks. For a fair extrapolation, cities with and without measurements should otherwise be largely comparable. A complete analysis of this comparability is beyond the scope of this report, but some basic variables can shed light on the uncertainties involved. In this and other CEA-related work, the size and proportion of the urban population of municipalities are used as proxies for exposure to significant concentrations of inhalable particles. The minimum cutoff point of 100,000 inhabitants is explicitly set as a proxy for exposure to significant concentrations of particulate matter (PM) in outdoor air. Therefore, it is expected that the municipalities with monitoring networks are by definition larger than those without such networks. Moreover, the force behind the establishment of air-quality monitoring networks (in Colombia and elsewhere) is precisely the presence of air-quality problems, in turn commonly linked to the size of urban settings. Tables A.2.1 and A.2.2 below summarize basic size and urban population parameters for cities with and without monitoring networks in Colombia.

Table A.2.1: Size of Cities With and Without Air Pollution Monitoring Network Coverage in Colombia

<table>
<thead>
<tr>
<th>Type of municipality</th>
<th>Sum population</th>
<th>Avg. mun. pop.</th>
<th>Max. mun. pop.</th>
<th>Avg. urban pop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>With M.N.</td>
<td>17,943,138</td>
<td>780,136</td>
<td>7,259,597</td>
<td>754,120</td>
</tr>
<tr>
<td>Without M.N.</td>
<td>8,617,545</td>
<td>239,376</td>
<td>1,179,098</td>
<td>210,914</td>
</tr>
</tbody>
</table>

Table A.2.2: Proportion of Urban Population (Out of Total Population) in Colombian Cities With Over 100,000 Inhabitants

<table>
<thead>
<tr>
<th>Parameter</th>
<th>% Urban population cities &gt;100,000 with M.N.</th>
<th>% Urban population cities &gt;100,000 without M.N.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>91.12</td>
<td>82.76</td>
</tr>
<tr>
<td>Minimum</td>
<td>68.76</td>
<td>39.31</td>
</tr>
<tr>
<td>Maximum</td>
<td>99.78</td>
<td>99.86</td>
</tr>
<tr>
<td>SD</td>
<td>7.80</td>
<td>15.48</td>
</tr>
<tr>
<td>N (S. size)</td>
<td>23</td>
<td>36</td>
</tr>
</tbody>
</table>

*The city of Uribia was considered an outlier and excluded from the analysis

With regard to the “urban” character of both groups of cities, the question remains whether the proportion of the urban population within those unmonitored municipalities is comparable to the proportion in cities where air pollution is monitored. According to Table A.2.2, the average proportion of the urban population seems to be lower in cities without a monitoring network. With regard to the significance of that difference, the dissimilarly sized, small and non-normally distributed samples preclude the use of a t-statistic contrast, an acceptable alternative being a non-parametric test (e.g., a Mann-Whitney U test\(^\text{17}\) featured below):

\[
U_1 = 561,0 \quad U_1 = n_1n_2 + 0.5(n_1)(n_1 + 1) - R_1
\]

\[
U_2 = 267,0 \quad U_2 = n_1n_2 + 0.5(n_2)(n_2 + 1) - R_2
\]

\(^{17}\) Where \(n_1, n_2\) are the sizes of samples 1 and 2, and \(R_1, R_2\) are the sums of the ranks for samples 1 and 2.
Level of significance 5 percent; $U_{crit}=287$. Null hypothesis (no differences between the mean of the two samples) is rejected at the set level of significance.

Graph A.2.1 below represents the samples’ respective point estimates of proportion of urban population.

Graph A.2.1: % Urban Population in Cities > 100K Inhabitants in Colombia

Therefore, we cannot rule out the possibility that the two groups of cities have a different proportion of urban population. Similarly, other health-relevant baseline variables (e.g., population structure, access to health services) might show systematic differences between the two groups. The uncertainty in such an extrapolation, along with the rapidly shrinking size of the population not covered by monitoring networks, are the reasons why we decided to exclude from the analysis the cities for which there were no measurement data as of 2012.
Annex 3.

Methodological Differences and Similarities, and Comparative Results with Previous Estimates

One objective of this report is to update results from a previous study (Larsen 2004) on the economic cost of environmental degradation in Colombia. As such, and for purposes of comparability, it draws heavily from that study in terms of structure, references and assumptions. In terms of structure, it is identical: the steps toward this update are sequential, starting with the existing evidence on environmental exposures, re-estimating the mortality and morbidity effects attributable to such exposure, and valuing their socioeconomic impacts. Below are the main points of disagreement and, where relevant, continuity.

Mortality: In previous estimates for the effect of urban air pollution (Larsen 2004), and because of the admitted underestimation that registered deaths supposed with regard to the total amount of deaths in DANE statistics, crude mortality rates were estimated for each city, using a regression equation that included urban population share, population share above age 50, external death rate and child mortality rate. However, reporting and statistical methodologies have improved substantially in the last decade; DANE no longer reports an issue with differences between registered and estimated death rates, so data are drawn directly from its departmental databases without further transformation.

Exposed population: For purposes of comparison with previous results (Larsen 2004), it is important to mention once more that we are not taking into account those mortality and morbidity end-points occurring in cities for which there are no data on urban air-pollutant concentration. In Larsen 2004, the population in that category of cities represented 42 percent of the exposed population and 35 percent of the total cases considered. Therefore, caution should be exercised when comparing these percentages with previous reported figures. For instance, we cannot conclude that total premature mortality attributable to urban air pollution in 2009 (a total of 5,027 premature deaths/37,703 lost DALYs) represents an improvement over the previous estimate of 2004 (6,040 deaths/45,300 lost DALYs). In fact, when cities without monitoring networks are included in the analysis, assuming an exposure of the average PM$_{2.5}$ and PM$_{10}$ concentrations of cities with measurement data, there is a net increase in the total reported cases and DALYs (see Table A.3.1 below). Most of this increase can be explained through the increase in the urban population and consequently of the population exposed.

Table A.3.1: Comparison Between 2004 Results for Health Effects of Urban Air Pollution and Current Analysis Including All Cities with Over 100,000 Inhabitants in Colombia

<table>
<thead>
<tr>
<th>Health categories</th>
<th>2012 Update Cities Without M.N.</th>
<th>2004 results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total cases</td>
<td>Total DALYs (000)</td>
</tr>
<tr>
<td>Premature mortality</td>
<td>7,147</td>
<td>53,601</td>
</tr>
<tr>
<td>Chronic bronchitis</td>
<td>6,604</td>
<td>14,528</td>
</tr>
<tr>
<td>Hospital admissions</td>
<td>14,806</td>
<td>237</td>
</tr>
<tr>
<td>ER/outpatient hospital visits</td>
<td>290,451</td>
<td>1,307</td>
</tr>
<tr>
<td>Restricted activity days</td>
<td>51,081,865</td>
<td>15,325</td>
</tr>
<tr>
<td>LRI in children</td>
<td>583,864</td>
<td>3,795</td>
</tr>
<tr>
<td>Respiratory symptoms</td>
<td>162,573,589</td>
<td>12,193</td>
</tr>
<tr>
<td>Total</td>
<td>N/A</td>
<td>100,986</td>
</tr>
</tbody>
</table>

ER: Emergency room; LRI: Lower Respiratory Infections.
**Human Capital Approach:** We are not reporting a cost based on the Human Capital Approach, since we believe that an indicator based on foregone income due to premature mortality severely underestimates the true cost to society that excess mortality represents in a rapidly improving context such as that of urban Colombia.

**Willingness-to-pay proxy:** Although we also translate different health effects from environmental risks into DALY metrics for purposes of comparability, we are discontinuing in this report the approach based on supplementing cost-of-illness (medical costs and costs of time lost to illness) values with a proxy of willingness to pay (WTP) multiplied by GDP per capita to avoid or reduce the risk of illness. There is sound evidence that individuals place a much higher value on avoiding pain and discomfort associated with illness than that reflected solely in medical costs; this has also been observed specifically in connection with air-pollution risks (Cropper and Oates 1992, Alberini and Krupnick 2000, Arigoni et al. 2009). However, using DALYs and per capita GDP as components for a proxy to lost value is too far-fetched a step. Instead, we apply the WTP proxy used in the Bogotá ten-year air-quality management plan (PDDB 2009), which in turn is based on Inter-American Development Bank (IADB) estimates (Cifuentes et al. 2005) and a local study (Lozano 2004) which used benefit transfer to calculate the WTP value. For morbidity outcomes, the WTP/COI ratio is 2.27, which is a figure remarkably similar to the upper estimate reported by Alberini and Krupnick (2000) between 1.61 and 2.26 times, depending on pollution levels. The latter also note that such ratios are similar to those for the United States, despite the differences between countries, which further reinforces the solidity of such a proxy for WTP value. By using this WTP/COI ratio instead of the DALY-GDP proxy, the cost per case is bound to differ substantially in this study compared to the previous 2004 report. One especially drastic contrast is the cost per case of chronic bronchitis. Although we agree on placing a larger cost in a burdensome illness such as CB, we would rather apply consistent WTP values for all air pollution-related outcomes in the absence of specific information for CB.

**Baseline data for cost estimation:** We kept most of the assumptions regarding duration of illness, rate and length of hospitalization, average time lost per health end-point, frequency of doctor visits and discount rate. We also valued time lost to illness at 75 percent of the average urban wage, and applied this cost both to working and nonworking individuals, based on the assumption of an equivalent opportunity cost for both categories.

In the context of updating the results from the Larsen (2004) study, the differences between the estimated costs in 2002 and those in 2010 might seem surprising. It is certainly counterintuitive to obtain unit costs of healthcare services that are lower a decade later, currency value shocks excluded. After the passage of the healthcare reform law (Law 100 of 1993), healthcare financing in Colombia relies in essence on a public insurance scheme funded mainly through social security contributions, taxes and subnational transfers. Virtually everyone in Colombia receives health services in one of three possible ways: (i) *Régimen contributivo*, a mandatory healthcare insurance linked to and paid through deductions from salaries of those who are formally employed. Coverage provided is comprehensive; (ii) *Régimen subsidiado*, a less-comprehensive insurance scheme for those whose payment capacity is lower; and (iii) Those without any payment capacity whose healthcare is provided almost exclusively by the network of public hospitals and healthcare facilities, and paid for by departmental governments. As of 2010, the percentage of the population covered by publicly paid health insurance was around 93 percent (Ministerio de la protección social - MIPS 2011).

Public and private healthcare providers compete in the provision of services, most of which are funded by public entities that act effectively as insurance providers themselves. Private voluntary insurance represents only about 16 percent of healthcare payment in Colombia, largely concentrated in higher-income groups (Baron 2007). Unsurprisingly, reliable estimates of private healthcare costs
are hard to obtain and difficult to contrast. Private healthcare providers, both independent professionals and entities, represent about 60 percent of healthcare expenditure, with services largely paid for by these public insurance entities at fixed rates (Gideon et al. 2010). Therefore, the publicly listed prices that public insurers pay providers are considered an adequate reflection of the true cost of illness.

Another approach considered was to use Bogotá costs (PDDB) for whole of urban Colombia. However, true costs (i.e., unsubsidized or without controlled pricing) of healthcare delivery in Bogotá are likely larger than in the rest of the country’s urban settings. Real urban wages in Bogotá are on average 29 percent higher than the mean wage of all urban areas of Colombia combined (DANE-GEIH 2011), which suggests a lower value of time lost to illness at a national level. However, whereas the private medical salaries in Bogotá might reflect a similar difference with the rest of urban areas, other inputs to the cost of medical care would not necessarily follow the same patterns. The average cost of hospitalization resulting from the PDDB estimates would be around 258,000 Colombian pesos per day. We found that the values used in the PDDB were quite close to the upper bound of the public prices (SOAT 2009) of the most common treatment and healthcare usage scenarios for health outcomes attributable to air pollution. The result of applying Larsen’s (2004) assumptions to these values is summarized in Table A.3.2 below:

| Cost of Selected Health Services and Time Lost to Air Pollution-Related Health Outcomes |
|---------------------------------|-----------------|-----------------|
| 2002 values (Larsen 2004) | Update 2012 |
| Cost of hospitalization (pesos per day) | 280,000 | 259,601 |
| Cost of emergency visit (pesos): urban | 90,000 | 71,635 |
| Cost of doctor visit (pesos): urban | 40,000 | 28,654 |
| Value of time lost to illness (pesos per day) | 20,000 | 31,320 |

Cost of chronic bronchitis (CB): There is still little evidence of healthcare usage and costs of patients regarding the cost of a new case of chronic bronchitis. Moreover, estimates of incidence are rare in general. In Colombia, a recent study (PREPOCOL 2009) estimates the prevalence of clinical COPD at 3.2 percent in adults over age 40, but we could not find data either on incidence or regarding usage and cost of healthcare by patients. Therefore, we relied on the same information used before—by Schulman et al. (2001) and Niederman et al. (1999)—from the United States and Europe and applied it to Colombia. The estimate of lost workdays per year is based on the frequency of estimated medical treatment plus seven additional days for each hospitalization and one extra day for each doctor and emergency visit. These days are added to reflect the time needed for recovery from illness. The estimated cost of a new case of CB assumes a 20-year duration of illness over which medical costs and value of time experience an annual real increase of two percent, and costs are discounted at a three-percent rate per year, a value commonly applied by WHO for health effects.