FINAL REPORT

COLOMBIA

COST OF ENVIRONMENTAL DAMAGE:

A Socio-Economic
and
Environmental Health Risk Assessment

Prepared for:
Ministry of Environment, Housing and Land Development
Republic of Colombia

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I. INTRODUCTION

This report provides estimates of social and economic costs of environmental damage in Colombia. Costs are presented for six environmental categories: (i) urban air pollution, (ii) water, sanitation and hygiene, (iii) indoor air pollution, (iv) agricultural land degradation; (v) natural disasters; and (vi) road accidents.

Cost estimates were also undertaken in the preparation of this report for inadequate household solid waste collection, and for vector borne illnesses (malaria, dengue, leishmaniasis). While the cost of these two categories is significant in some departments and localities, the cost estimates indicate that they at the aggregate national level are only a fraction of the national cost of the six categories above. They are therefore not presented in this report.

Data limitations have prevented estimation of degradation costs at the national level for coastal zones (fisheries and tourism losses), wetlands, noise pollution, biodiversity, protected areas and any inappropriate solid waste disposal and inadequate industrial and hospital waste management. It is however doubtful that aggregate costs of degradation and health risks arising from these issues are anywhere close to the costs associated with water, sanitation, and hygiene, land degradation, and indoor and urban air pollution. Cost of rangeland degradation is neither estimated. While cost estimates have recently been produced by Colombian researchers for some localities in Colombia, sufficient data are not available to prepare national estimates. However, it is possible that the national cost of rangeland degradation is of magnitudes comparable to agricultural crop land degradation.

It should also be noted that cost of deforestation and water pollution is only partially and indirectly estimated due to data limitations. Some of the cost of deforestation is captured in the cost of natural disasters (flooding, landslides) and agricultural land degradation in so far as deforestation contributes to natural disasters and soil erosion. Other costs of deforestation, such as impacts on water resources and recreational value, are not estimated. The cost of water pollution is only captured in terms of waterborne illnesses (diarrheal illness). Other costs, such as potential impacts on health of heavy metals and chemicals and recreational value, are not estimated.

The monetary valuation of environmental damage, and quantification of environmental damage, involves many scientific disciplines including environmental, physical and biological, health sciences and epidemiology, and environmental economics. Environmental economics relies heavily on other fields within economics, such as econometrics, welfare economics, public economics, and project economics. New techniques and methodologies have been developed in recent decades to better understand and quantify preferences and values of individuals and communities in the context of environmental quality, conservation of natural resources, and environmental health risks. The applied results from these techniques and methodologies can then be, and often are, utilized by policy makers and stakeholders in the process of setting environmental objectives and priorities. And, because preferences and values are expressed in monetary terms, the results can provide an additional guiding principle for allocation of public and private resources across diverse socio-economic development goals.

The cost of environmental damage includes many aspects. Some costs are economic. These include reduced productivity of agricultural land due to erosion, salinity or other forms of land degradation; medical treatment costs and lost work days for illnesses associated with environmental pollution; reduced fishery catch due to pollution and overexploitation; and losses in tourism revenues due to pollution and/or natural resource degradation. Other costs are associated with reduced well-being and quality of life. These include an unclean environment such as inadequate waste management; pain and suffering from ill health and disability; the risk of mortality from pollution; and the loss of recreational quality and natural heritage due to degradation of natural resources.

When estimating the cost of environmental damage a distinction is made between financial and economic costs. To the extent feasible, economic cost should be applied because it captures the cost and reduced welfare to society as a whole. For instance, the financial cost of health services that an individual pays may be substantially less than the cost of providing these services. It is therefore important to estimate the real cost to society of providing those services. Another example is time lost to illness or provision of care for ill family members. If the person being ill or providing care for an ill individual does not earn income, the financial cost of time losses is zero. However, the person is normally engaged in activities that are valuable for the family, and time losses impair on these activities or reduce the amount of time available for leisure activities. Thus there is an economic cost of time losses to the family. In economics and welfare analysis, this is normally valued at the opportunity cost of time, i.e. the salary, or a fraction of the salary that the individual could earn if choosing to work for income.

II. ANNUAL COST OF ENVIRONMENTAL DAMAGE

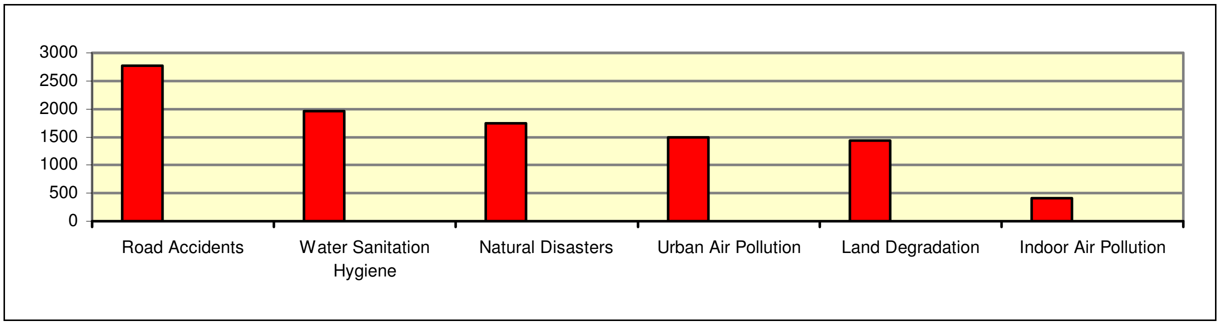
This section provides an aggregate overview of estimated social and economic costs of environmental damage. A discussion of each environmental category is provided in the following sections.

Costs by Environmental Category.

The mean estimated annual cost of environmental damage is presented in Figure 2.1, totaling almost 10 trillion Pesos per year. The highest cost category is road accidents, followed by the cost of inadequate water supply, sanitation and hygiene; natural disasters; urban air pollution; and agricultural land degradation at relatively similar levels. The cost of indoor air pollution is substantially lower than the other categories.

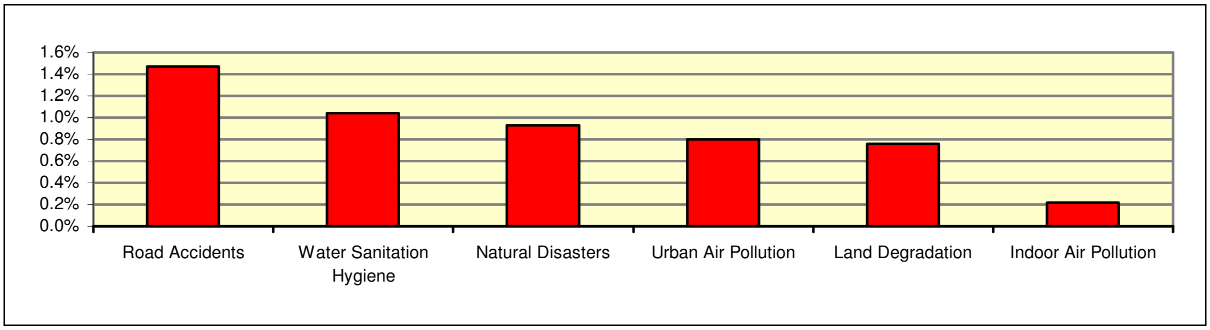
The mean estimated annual costs are presented as a percentage of GDP in Figure 2.2, totaling 5.2 percent of GDP.

Figure 2.1: Annual Cost of Environmental Damage (Billion Pesos per year)



Note: Cost of land degradation is erosion and salinity of cultivated land and does not include pasture/rangeland.

Figure 2.2: Annual Cost of Environmental Degradation (% of GDP)



A “low” and “high” estimate of annual cost is presented in Table 2.1. The largest range is associated with urban air pollution. This is mainly because two valuation techniques for estimating the social cost of mortality have been applied. The large range for indoor air pollution is mainly because of the uncertainty about the exposure level to indoor smoke from the use of fuel wood, and thus a range has been applied for the level of health risk.

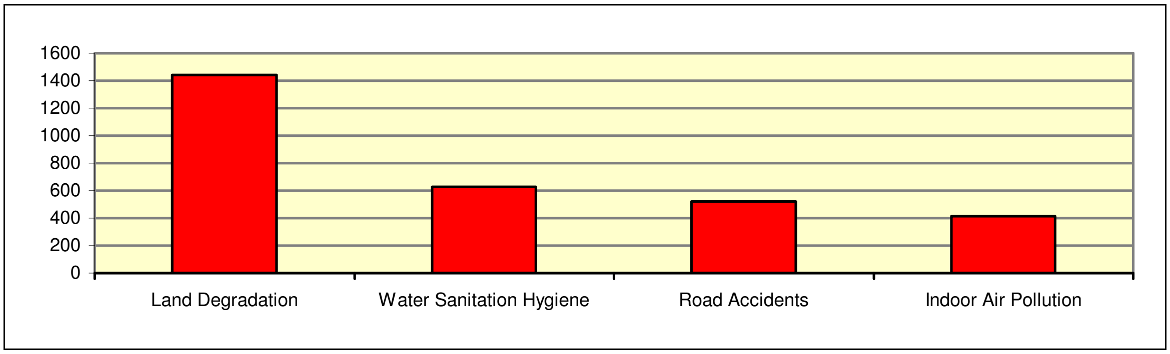
Table 2.1: Annual Cost of Environmental Damage – Low and High Estimates (Billion Pesos per year)

	Billion Pesos per year		
	"low"	**Mean Estimate**	"high"
Environmental Categories			
Road Accidents	2310	**2770**	3230
Water, Sanitation, Hygiene	1700	**1960**	2220
Natural Disasters	1330	**1750**	2175
Urban Air Pollution	720	**1500**	2285
Agricultural Soil Degradation*	1310	**1440**	1570
Indoor Air Pollution	230	**415**	600
TOTAL ANNUAL COST	7600	**9835**	12080

* Erosion and salinity of cultivated land (not including pasture/rangeland).

While the estimates presented in Figure 2.1 and Table 2.1 provide an indication of areas of the environment with highest national cost, a “distributional” assessment would be a further step in the direction of establishing local or regional priorities. An estimate of rural-urban costs are presented in Figure 2.3-2.4 for some of the environmental categories. In rural areas, as can be seen from Figure 2.3, the cost of land degradation (not including pasture) is estimated at more than twice as high as the cost of inadequate water, sanitation and hygiene, and road accidents. Also, in contrast to the national estimate, the cost of indoor air pollution is almost as high as for water, sanitation and hygiene, and road accidents. Rural cost of inadequate water supply, sanitation, and hygiene is based on rural-urban population share and rural-urban diarrheal diarrheal incidence. Rural accident costs are based on accident statistics by rural and urban roads for the year 2002. No adjustments are made to land degradation and indoor air pollution costs, as these are already all rural costs. Sufficiently detailed data for natural disasters are at this time not available to provide rural-urban cost estimates.

Figure 2.3: Estimated Annual Rural Costs (Billion Pesos)



Urban cost estimates are presented in Figure 2.4. Cost of urban pollution is now significantly higher than for water, sanitation, and hygiene in contrast to the national estimate. Moreover, cost or urban air pollution is now much closer to the cost of road accidents.

Figure 2.4: Estimated Annual Urban Costs (Billion Pesos)

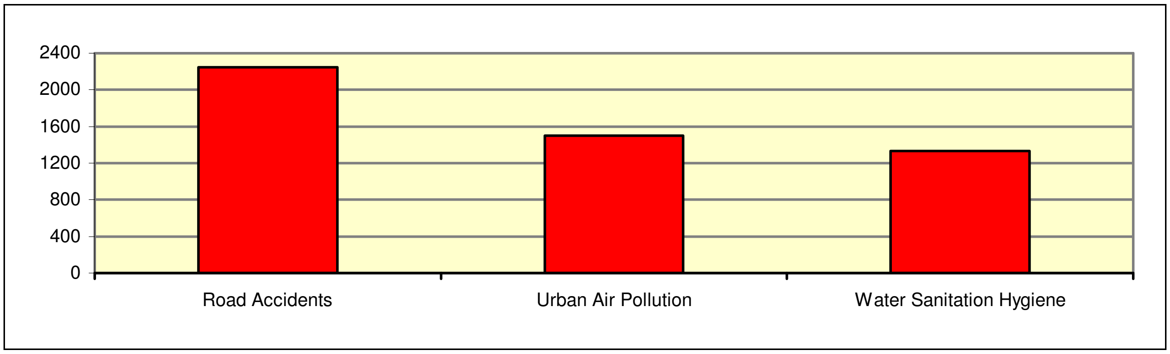


Figure 2.5 presents the annual cost estimates by type of costs. Physical damages, such as land degradation, damages to buildings and infrastructure from natural disasters, vehicle damages in traffic accidents, amount to almost half of total environmental damage cost. This is followed by an almost equal cost share for morbidity and mortality.

Figure 2.6 presents the "physical" costs by environmental category. The categories with the highest cost shares are natural disasters and land degradation. The cost associated with water is avertive expenditures on bottled water, household water purification and boiling of drinking water associated with perceived health risk of water supply sources.

Figure 2.5: Costs By Category (Billion Pesos)

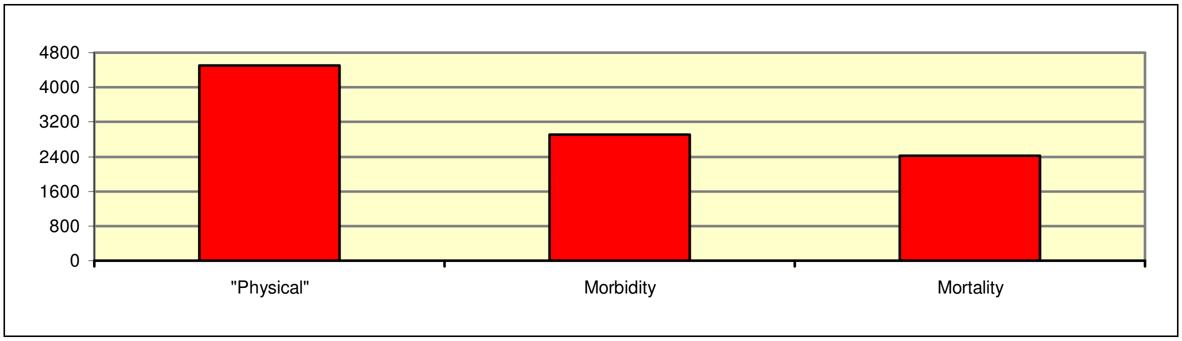


Figure 2.6: "Physical" Costs By Category (Billion Pesos)

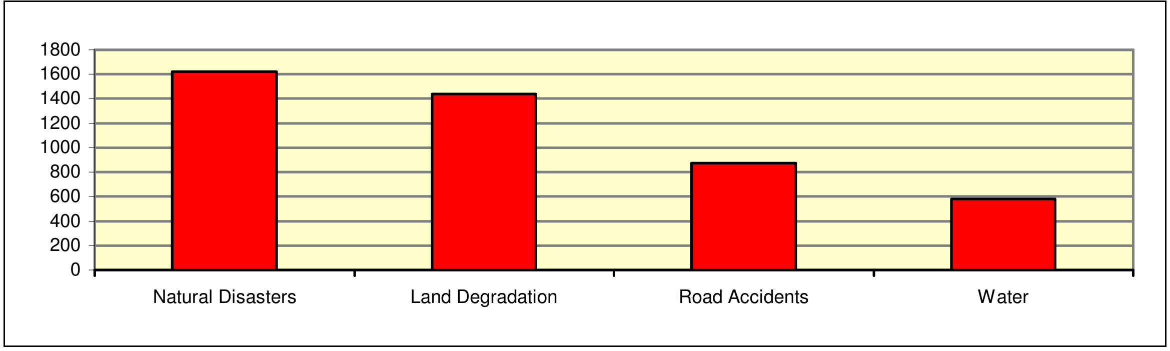


Figure 2.7 presents the estimated number of annual deaths by environmental category. Estimated deaths from urban air pollution and road accidents are several times higher than in the other categories. However, the situation is different for children. This is presented in Figure 2.8. Inadequate water, sanitation and hygiene represent the largest mortality risk for children, followed by road accidents and indoor air pollution.

Figure 2.7: Number of Deaths By Category

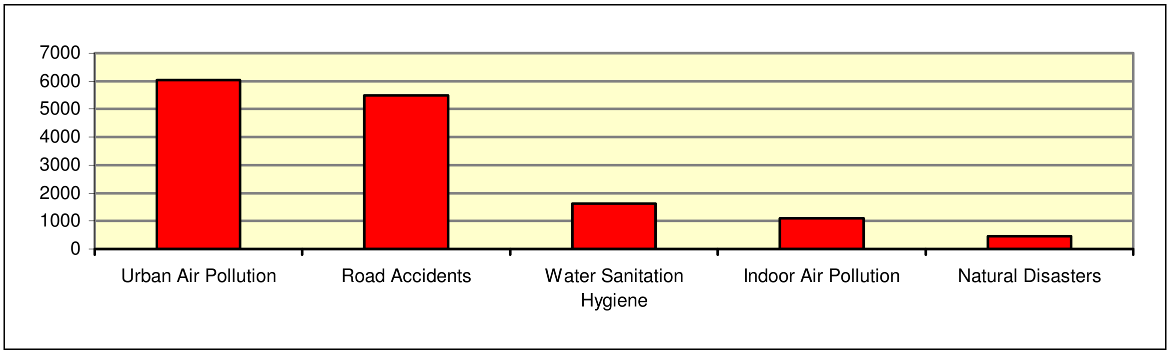
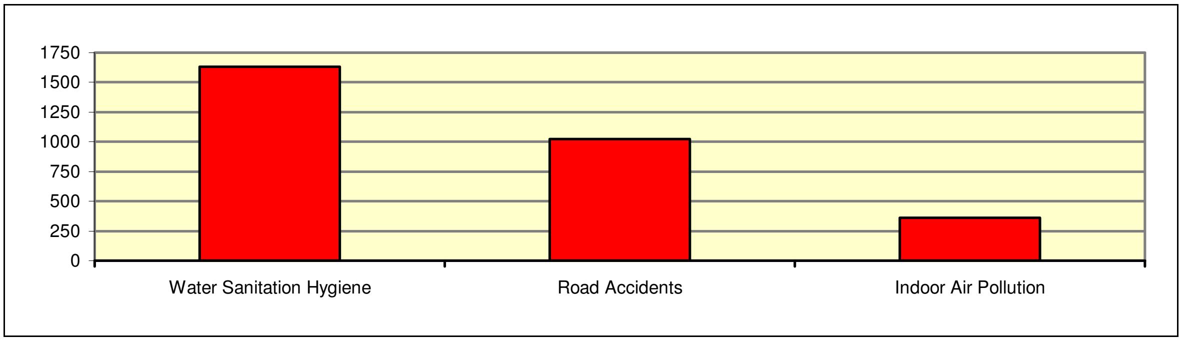


Figure 2.8: Deaths Among Children By Category

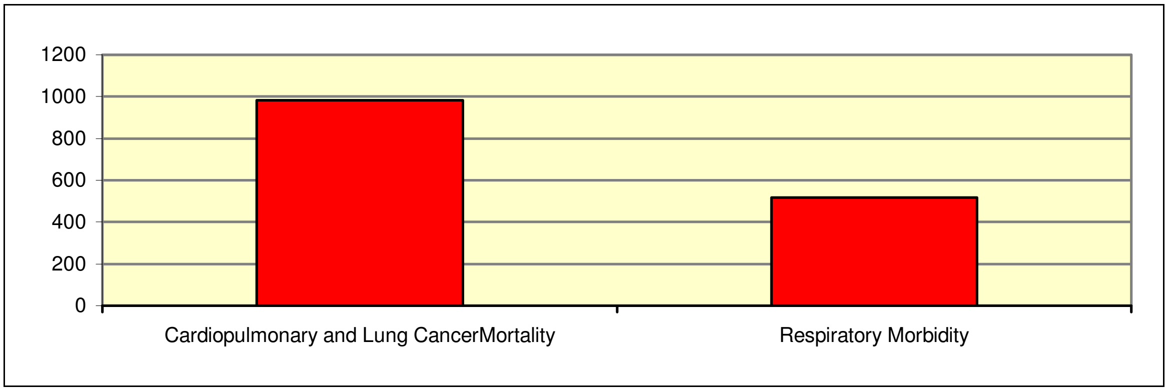


III. URBAN AIR POLLUTION

The mean estimated annual cost of urban air pollution is presented in Figure 3.1, totaling 1500 billion Pesos. About 65 percent of the cost is associated with mortality, and 35 percent with morbidity. Measured in terms of DALYs, mortality represents 50 percent and morbidity 50 percent.

This section discusses the scientific evidence of the impacts of urban air pollution on health, the methodologies used to estimate health impacts in Colombian cities, and the socio-economic valuation of these health impacts.

Figure 3.1: Annual Costs of Urban Air Pollution (Billion Pesos)



There is substantial research evidence from around the world that outdoor urban air pollution has significant negative impacts on public health and results in premature deaths, chronic bronchitis, and respiratory disorders. A comprehensive review of such studies is provided in Ostro (1994). The air pollutant that has shown the strongest association with these health endpoints is particulate matter (PM)[1], and especially particulates of less than 10 microns in diameter (PM 10) or smaller. Research in the United States in the 1990s and most recently by Pope et al (2002) provides strong evidence that it is even smaller particulates (PM 2.5) that have the largest health effects. The gaseous pollutants (SO_2, NOx, CO, and ozone) are generally not thought to be as damaging as fine particulates. However, SO_2 and NOx may have important health consequences because they can react with other substances in the atmosphere to form particulates.

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[1] Also called total suspended particulates (TSP).

The focus of this report is the health effects of fine particulates (PM10 and PM2.5). There are three main steps to quantifying the health impacts from air pollution. First, the pollutant needs to be identified and its ambient concentration measured. Second, the number of people exposed to that pollutant and its concentration needs to be calculated. Third, the health impacts from this exposure should be estimated based on epidemiological assessments. Once the health impacts are quantified, the value of this damage can be estimated.

Baseline Data.

Colombia is highly urbanized with 72 percent of the population in urban areas (DANE 2002). Close to 50 percent of the population lives in cities with more than 100 thousand inhabitants, and close to 30 percent live in cities with more than 1 million inhabitants.

Only some cities in Colombia have PM 10 monitoring data. Population and annual average population weighted PM 10 levels for these cities are presented in Table 3.1a. Their total population is 12.5 million. To calculate population weighted PM 10 levels, each city or metropolitan area (AMVA) was partitioned in four zones (residential, industrial, downtown, and commerial areas). PM 10 concentrations from monitoring stations in each zone were then weighted by the zone's population share to obtain population weighted PM 10 levels.[2]

Table 3.1b presents population figures for cities with more than 100 thousand inhabitants that do not have PM 10 monitoring data. These cities have a total population of almost 9 million. Excluding them from estimating the health impacts of urban air pollution would therefore represent a serious omission. Annual average PM 10 levels were therefore assigned to these cities based on their population size in relation to cities of comparable size with PM 10 monitoring data.

The most credible studies of the mortality effects of long-term exposure to particulates have relied on PM 2.5 monitoring data (e.g. Pope et al 2002). Systematic monitoring of PM 2.5 is unfortunately not available for cities in Colombia. It has therefore been necessary to convert PM 10 to PM 2.5 based on observed ratios from the United States. Table 3.2 presents PM 2.5 / PM 10 ratios for different areas in the United States for the year 2002. The ratio in arid/semi-arid states generally falls in the range of 0.2-0.4, and in the range of 0.4-0.5 in

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[2] Population weighted PM 10 levels are better indicators of population exposure than arithmetic means of PM 10 levels measured at the monitoring stations.

agricultural states, and 0.55-0.75 in more wooded states with less agriculture. Based on these observations, a ratio of PM 2.5 / PM 10 of 0.6 has been applied to the cities in Colombia.

Table 3.1a: Baseline Data for Cities with PM monitoring data

Key parameters	Bogota	Bucaramanga*	AMVA**	Cali
Population (million) 2002	6.68	0.74	2.80	2.26
Adult population >= 15 yrs (000)	4.67	0.49	1.79	1.60
Children population <=14 yrs (000)	2.01	0.25	1.01	0.66
Annual average PM10 (ug/m^3)	62	56	52	46
Annual average PM 2.5 (ug/m^3)	37	34	31	27

Source: Population figures are based on estimates by DANE. PM 10 figures are population weighted by PM 10 levels in four zones in each city. PM 2.5 is calculated based on a PM 2.5/PM 10 ratio of 0.6. * Includes Floridablanca and Giron. ** Area Metropolitana del Valle de Aburra (Medellin, Bello, Envigado, Itagui etc.).

Table 3.1b: Baseline Data for Cities without PM monitoring data

Key parameters	Cities > 1 million Inhabitants*	Cities 0.5-1.0 million Inhabitants**	Cities 0.1-0.5 million Inhabitants***
Total Population (million) 2002	1.30	1.64	5.98
Adult population >= 15 yrs (000)	0.89	1.11	4.03
Children population <=14 yrs (000)	0.41	0.53	1.95
Annual average PM10 (ug/m^3)	50	45	40
Annual average PM 2.5 (ug/m^3)	30	27	24

Source: Population figures are based on city specific estimates by DANE. PM 10 figures are approximations based on population size in relation to cities with PM 10 data . PM 2.5 is calculated based on a PM 2.5/PM 10 ratio of 0.6. *Barranquilla. **Cartagena (0.95 million) and Cucuta (0.69 million). *** 24 cities with an average population of 250 thousand per city.

Table 3.2: Ambient Air Quality: Ratio of PM 2.5 to PM 10 in the United States

	Ratio*
Agricultural states (Iowa, Kansas, Missouri)	0.4 - 0.5
Arid/semi-arid states (Arizona, Nevada, New Mexico, Utah)	0.2 – 0.4
Eastern states (Pennsylvania, Virginia, West Virginia)	0.55 – 0.75

Source: http://www.epa.gov/air/data/reports.html. *Ratio is based on annual average PM 2.5 and PM 10 for the year 2002.

As an additional source of information, the ratios of PM 2.5 / PM 10 for emission sources are presented in Table 3.3. These are mean estimates and vary with type of technologies, industrial sectors, fuels, and by distance from emission source to monitoring location, etc. Cities not located in arid/semi-arid or agricultural zones, but have high traffic emissions and relatively low fugitive road dust, will tend to have very high PM 2.5 / PM 10 ratios. While it is plausible that the PM ratio in Colombian cities falls in the range of 0.55-0.75 (as in some of the eastern parts of the United States), the exact ratio depends on fugitive road dust, the influence of industrial emissions on urban PM ambient concentrations, and on the size distribution of particulates from industrial sources.

Table 3.3: Emission Sources: Ratio of PM 2.5 and PM 10

	PM2.5/PM10 Ratio
Stationary Sources	
Fuel combustion	0.96
Industrial Processes	0.56
Fugitive Dust Sources	
Paved road dust	0.25
Unpaved road dust	0.15
Construction and demolition	0.15
Farming operations (tilling etc.)	0.20
Miscellaneous Processes	
Waste Burning	0.96
Agricultural Residue Burning (Scarborough et al 2002)	0.93-0.96
Forest Fires	0.93
Mobile Sources	
On-road	0.98

Source: Reproduced from table in Countess (2003). The ratio for agricultural residue burning is from Scarborough et al (2002) for rice, wheat and corn.

Dose Response Coefficients.

Ibanez (2003) presents a review of three studies that have assessed the relationship between urban air pollution and health effects in Bogota. These studies estimated dose response coefficients for respiratory hospital admissions, child morbidity, and respiratory mortality. They all find significant effects on health from air pollution. While these studies contribute to the understanding of the health effects of urban air pollution in Colombia, a larger number of studies are needed in order to provide estimates of health effects in all major cities in the country. This report has therefore relied on results from studies around the world.

Based on the current status of worldwide research, the risk ratios, or dose response coefficients from Pope et al (2002) are likely to be the best available evidence for the mortality effects of ambient particulate pollution (PM 2.5). These coefficients were applied by the WHO in the World Health Report 2002, which provided a global estimate of the health effects of environmental risk factors. For the morbidity effects, dose response coefficients from Ostro (1994) and Abbey et al (1995) have been applied. Ostro (1994) reflects a review of worldwide studies, and Abbey et al (1995) provides estimates of chronic bronchitis associated with particulates (PM 10). The mortality and morbidity coefficients are presented in Table 3.4. While the mortality effects are based on PM 2.5, the morbidity effects assessed in most worldwide studies are based on PM 10.

Table 3.4: Urban Air Pollution Dose-response coefficients

Annual Health Effect	Dose-response Coefficient	Per 1 ug/m^3 annual average ambient concentration of:
Mortality (% change in cardiopulmonary and lung cancer mortality)	0.8%	PM 2.5
Chronic bronchitis (% change in annual incidence)	0.9%	PM 10
Respiratory hospital admissions (per 100,000 population)	1.2	PM 10
Emergency room visits (per 100,000 population)	24	PM 10
Restricted activity days (per 100,000 adults)	5,750	PM 10
Lower respiratory illness in children (per 100,000 children)	169	PM 10
Respiratory symptoms (per 100,000 adults)	18,300	PM 10

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

Pope et al (2002) provides the most comprehensive and detailed research study to date on the relationship between air pollution and mortality. The study confirms and strengthens the evidence of the long-term mortality effects of particulate pollution found by Pope et al (1995) and Dockery et al (1993). Pope et al (2002) utilized ambient air quality data from metropolitan areas across the United States for the two periods 1979-83 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 ACS database contained individual specific information for more than 1 million adults that had been obtained through questionnaires. The study could therefore control for a large set of factors that may also affect variations in mortality rates across metropolitan areas, such as age, smoking behavior, education, marital status, body weight, occupational risk factors, and dietary indices.

The study found a statistically significant relationship between levels of PM 2.5 and mortality rates, controlling for all the factors discussed above. All-cause mortality increased by 4-6 percent for every 10 ug/m^3 increase in PM 2.5. The increase in cardiopulmonary mortality was 6-9 percent, and 8-14 percent for lung cancer. No statistically significant relationship was found between levels of PM 2.5 and all other causes of mortality (Table 3.5).

The share of cardiopulmonary and lung cancer deaths in total mortality varies sometimes substantially across countries. It may therefore reasonably be expected that the risk ratios for cardiopulmonary and lung cancer mortality provide more reliable estimates of mortality from PM 2.5 than the risk ratio for all-cause mortality when the risk ratios are applied to countries other than the United States. The former two risk ratios are therefore used in this report. The mortality coefficient in Table 3.4 is a combination of the cardiopulmonary and lung cancer mortality risk ratios in Table 3.5.

Table 3.5: Mortality Risk Associated With a 10 ug/m^3 Change in PM 2.5

	Adjusted Relative Risk Ratios (RR)		
Cause of Mortality	**1979-1983**	**1999-2000**	**Average**
All-cause	1.04	1.06	1.06
Cardiopulmonary	1.06	1.08	1.09
Lung cancer	1.08	1.13	1.14
All other cause	1.01	1.01	1.01

Reproduced from Pope et al (2002).

In order to apply the mortality coefficient in Table 3.4 to estimate mortality from urban air pollution in the Colombian cities in Table 3.1a-b, baseline data on total annual cardiopulmonary and lung cancer deaths are required. These data are published by DANE at the municipal level, including all large cities, based on registered death.[3] However, registered deaths represent an understatement of actual deaths. For instance, DANE reports a registered crude mortality rate of 4.44 while the estimated crude mortality rate by DANE is 5.48.

A two-stage approach was therefore taken in this report to estimate the actual number of cardiopulmonary and lung cancer deaths. First, cardiopulmonary and lung cancer deaths as a percentage of total deaths were calculated from registered cause-specific deaths for each city as published by DANE. This is presented in Table 3.6a-b and ranges from 34-41 percent of all deaths. Second, crude mortality rates were estimated for each city, based on estimated crude mortality rates (CDR) in 2002 for each department published by DANE, using the following regression equation:

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[3] Disease categories 206, 301-309, and 605-608.

$$CDR = a + b_1 U + b_2 P + b_3 D + b_4 C \qquad (1)$$

where U is urban population share, P is population share above the age of 50 years, D is homicide and other intentional death rate, and C is child mortality rate. All the coefficients (b_i) were statistically significant at the 99 percent level, with an $R^2 = 0.69$. The crude mortality rate for each city was then estimated by applying the estimated coefficients to the department level data and setting the urban population share at 100 percent. These mortality rates are presented in Table 3.6a-b.

An estimate of annual incidence of chronic bronchitis (CB) is also presented in Table 3.6a-b, and is required in order to apply the CB coefficient in Table 3.4. In the absence of CB incidence data for Colombia, the rate is from WHO (2001) and Shibuya (2001) for the AMRO B region of WHO in which Colombia is part of. It has therefore not been possible to provide city specific CB incidence rates.

A threshold level of 7.5 ug/m^3 of PM 2.5 has been applied, below which it is assumed there are no mortality effects. This is the same procedure as applied in the World Health Report 2002 (WHO). No threshold level has been applied for morbidity.

Table 3.6a: Baseline Mortality and Morbidity Data for Cities with PM monitoring data

Key parameters	**Bogota**	**Bucaramanga**	**AMVA**	**Cali**
Crude mortality rate (per 1000 population)	4.9	5.3	5.7	5.7
Cardiopulmonary (CP) and lung cancer (LC) deaths (% of all deaths)	36 %	39 %	35 %	34%
Chronic Bronchitis (incidence per 100 000 population)	85	85	85	85
Threshold level for PM 2.5 (ug/m^3)	7.5	7.5	7.5	7.5

Table 3.6b: Baseline Mortality and Morbidity Data for Cities without PM monitoring data

Key parameters	**Cities > 1 million Inhabitants**	**Cities 0.5-1.0 million Inhabitants**	**Cities 0.1-0.5 million Inhabitants**
Crude mortality rate (per 1000 population)	4.9	4.8	5.0
Cardiopulmonary (CP) and lung cancer (LC) deaths (% of all deaths)	41 %	34 %	37 %
Chronic Bronchitis (incidence per 1000 population)	85	85	85
Threshold level for PM 2.5 (ug/m^3)	7.5	7.5	7.5

Other morbidity health endpoints considered are hospital admissions of patients with respiratory problems, emergency room visits (or hospital out-patient visits), restricted activity days, lower respiratory infections in children, and respiratory symptoms. These are the most common health endpoints considered in most of the worldwide studies on air pollution. The coefficients are expressed as cases per 100,000 in the absence of incidence data for Colombia. It should be noted that it would be preferable to have incidence data and use coefficients that reflect percentage change in incidence. Increases in asthma attacks among asthmatics have also been related to air pollution in many studies. This however requires data on the percentage of the population that are asthmatic and frequency of asthma attacks, which is not readily available for Colombia.

The health effects of air pollution can be converted to disability adjusted life years (DALYs) to facilitate a comparison to health effects from other environmental risk factors. DALYs per 10 thousand cases of various health end-points are presented in Table 3.7.

Table 3.7: DALYs for Health Effects

Health Effect	DALYs lost per 10,000 cases
Mortality	75,000
Chronic Bronchitis (adults)	22,000
Respiratory hospital admissions	160
Emergency Room visits	45
Restricted activity days (adults)	3
Lower respiratory illness in children	65
Respiratory symptoms (adults)	0.75

Table 3.8 presents the disability weights and average duration of illness that have been used in this report to calculate the DALYs as presented in Table 3.7. The disability weight for lower respiratory illness (LRI) and chronic bronchitis (CB) are from disability weights presented by the National Institute of Health, United States, for the region of Latin America.[4] Disability weights for the other morbidity end-points are not readily available, and are estimates by the author based on weights for other comparable illnesses.[5] Average duration of CB is estimated based on age distribution in Colombia and age-specific CB incidence in Shibuya (2001). Years lost to premature mortality from air pollution is estimated from age-

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[4] See: http://www.fic.nih.gov/dcpp/weights.xls

specific mortality data for cardiopulmonary and lung cancer deaths, and have been discounted at 3 percent per year. Average duration of illness for the other health end-points are estimates by the author.

Table 3.8: Calculation of DALYs Per Case of Health Effects

	Disability Weight	Average Duration of Illness
Mortality	1.0	(7.5 years lost)
Lower respiratory Illness - Children	0.28	10 days
Respiratory Symptoms – Adults	0.05	0.5 days
Restricted Activity Days - Adults	0.1	1 day
Emergency Room Visits	0.30	5 days
Hospital Admissions	0.40	14 days*
Chronic Bronchitis	0.2	20 years

Note: DALYs are calculated using WHO tables with a discount rate of 3% and full age weighting. * Includes days of hospitalization and recovery period after hospitalization.

Estimated Health Impacts.

Using the information in Table 3.1a-b, 3.4, and 3.6a-b, the annual health effects of ambient particulate air pollution in Colombia are presented in Table 3.9. Urban air particulate pollution is estimated to cause around 6000 premature deaths annually. Estimated new cases of chronic bronchitis are about 7400 per year. Annual hospitalizations due to pollution are estimated at close to 13 thousand, and emergency room visits/outpatient hospitalizations at 255 thousand per year. Cases of less severe health impacts are also presented in Table 3.9.

In terms of annual DALYs lost, mortality accounts for an estimated 51 percent, chronic bronchitis around 18 percent, restricted activity days (RADs) for 14 percent, and respiratory symptoms for 11 percent.

Table 3.10 presents the distribution of estimated health effects across the cities in Table 3.1a-b, as a percentage of total national cases in Table 3.9. More than one-third of all health effects are in Bogota. This is significantly higher than in relation to the population of Bogota, and stems from the higher PM levels in the city than in most other cities. It should also be noted that more than 20 percent of estimated health effects are in the cities with population less than half a million. However, their share of estimated health effects is

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[5] The disability weight for mortality is obviously 1.0.

significantly lower than their population share, because of the lower pollution levels expected in these cities.[6]

Table 3.9: Estimated Health Impact of Urban Air Pollution

Health categories	**Total Cases**	**Total DALYs**
Premature mortality	6040	45300
Chronic bronchitis	7410	16300
Hospital admissions	12970	210
Emergency room visits/Outpatient hospital visits	255 thousand	1150
Restricted activity days	42 million	12640
Lower respiratory illness in children	585 thousand	3800
Respiratory symptoms	135 million	10100
TOTAL		89500

Table 3.10: Estimated Health Impact by City

	Percent of Total Exposed Population*	**Percent of Total Cases****
Cities with Monitoring of PM		
Bogota	31 %	38 %
Ciudad de Bucaramanga	3 %	4 %
AMVA	13 %	13 %
Cali	10 %	10 %
Cities without Monitoring of PM		
> 1 million inhabitants	6 %	7 %
0.5-1.0 million inhabitants	8 %	7 %
0.1-0.5 million inhabitants	28 %	21 %

*Exposed population is reported in Table 3.1a-b. **Total cases are reported in Table 3.9.

Estimated Cost of Health Impacts.

The estimated annual cost of urban air pollution health effects is presented in Table 3.11. Cost of mortality is based on the human capital approach (HCA) and the value of statistical life (VSL), thus the large range in cost. This is discussed in the last section of the report.

A measure of the welfare cost of morbidity is often based on the willingness-to-pay (WTP) for avoiding or reducing the risk of illness. This measure is often found to be several times higher than the cost of medical treatment and the value of time losses (Cropper and

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[6] Recall that a PM 10 level of 40 ug/m^3 was assigned to these cities, in absence of monitoring data.

Oates 1992), and reflect the value that individuals place on avoiding pain and discomfort. There are however not a sufficient number of WTP studies from Colombia. For this reason, the cost-of-illness (COI) approach (mainly medical cost and value of time losses) has therefore been supplemented by a proxy for the cost of pain and discomfort in this report. The proxy applied is valuation of DALYs at GDP per capita. This is included in the cost of morbidity in Table 3.11.

Table 3.11: Estimated Annual Cost of Health Impacts (Billion Pesos)

Health categories	**Total Annual Cost***	**Percent of Total Cost***
		(Mean)
Mortality	200 - 1765	65 %
Morbidity:		
Chronic bronchitis	90	6 %
Hospital admissions	25	2 %
Emergency room visits/Outpatient hospital visits	40	3 %
Restricted activity days (adults)	270	18 %
Lower respiratory illness in children	50	3 %
Respiratory symptoms (adults)	45	3%
Total cost of Morbidity	520	35 %
TOTAL COST (Mortality and Morbidity)	720 - 2285	100 %

* Annual cost is rounded to nearest five billion, and percentages are rounded to nearest percent.

Table 3.12 presents the estimated cost per case of mortality and case of illness (or health end-point). The figures in the column with total cost per case was applied to the estimated cases in Table 3.9 to arrive at the total annual costs in Table 3.11. Table 3.12 also presents disaggregated cost per case, in terms of cost of illness (medical cost and time losses) and DALYs valued at GDP per capita. In most case the cost of illness is substantially higher than the proxy for pain and discomfort. The main exception is chronic bronchitis, which often has a severe effect on people's life without necessarily causing substantial medical treatment cost or time losses.

Table 3.13 presents estimated annual cost of morbidity by type of cost. The value of time losses represents almost 50 percent of total cost, and the cost of pain and discomfort (proxied by DALYs valued at GDP per capita) represents somewhat more than one-third.

Table 3.12: Estimated Unit Cost by Health End-Point

Health categories	Total Cost Per Case (000 Pesos)	Cost-of-Illness Per Case (000 Pesos)	DALYs Per Case (000 Pesos)
Mortality	33 000 – 290 000	-	-
Chronic bronchitis	12 325	2 675	9 650
Hospital admissions	1 950	1 880	70
Emergency room visits/Outpatient hospital visits	150	130	20
Restricted activity days (adults)	6.3	5	1.3
Lower respiratory illness in children	90	60	30
Respiratory symptoms (adults)	0.3	0	0.3

Table 3.13: Estimated Annual Cost of Morbidity

	Annual Cost (Billion Pesos)
Cost of medical treatments (doctors, hospitals, clinics)	80 (16%)
Cost of time lost to illness	245 (47%)
DALYs (valued at GDP per capita)	195 (37%)
TOTAL	520 (100%)

Table 3.14 provides the baseline data that were used to estimate the cost per case of illness. Some of these data require explanation. The value of time for adults is based on urban wages. Economists commonly apply a range of 50-100 percent of wage rates to reflect the value of time. The rate of 20000 Pesos per day is about 75 percent of average urban wages in Colombia. This rate for value of time has been applied to both working and non-working individuals. There are two reasons for applying the rates to non-working individuals: First, most of those adult individuals provide a household function that has a value. Second, there is an opportunity cost to the time of non-working individuals, because they could choose to join the paid labor force.[7]

There is very little information about the frequency of doctor visits, emergency visits and hospitalization for CB patients in any country in the world. Schulman et al (2001) and Niederman et al (1999) provide some information on this from the United States and Europe.[8] Figures derived from these studies have been applied to Colombia. Estimated lost work days per year is based on frequency of estimated medical treatment plus an additional 7 days for

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[7] Some may argue that the value of time based on wage rates should be adjusted by the unemployment rate to reflect the probability of obtaining paid work.

[8] CB is a major component of COPD which is the focus of the referenced studies.

each hospitalization and one extra day for each doctor and emergency visit. These days are added to reflect time needed for recovery from illness.

To estimate the cost of a new case of CB, the medical cost and value of time losses have been discounted over a 20-years duration of illness. An annual real increase of 2 percent in medical cost and value of time has been applied to reflect an average expected increase in annual labor productivity and real wages. The costs are discounted at 3 percent per year, a rate commonly applied by WHO for health effects.

Table 3.14: Baseline Data for Cost Estimation

	Baseline	**Source:**
Cost Data for All Health End-Points:		
Cost of hospitalization (Pesos per day)	280 000	Per consultations with medical service providers, and health authorities
Cost of emergency visit (Pesos) - urban	90 000	
Cost of doctor visit (Pesos) (mainly private doctors) - urban	40 000	
Value of time lost to illness (Pesos per day)	20000	Based on urban wages in Colombia
Chronic Bronchitis (CB):		
Average duration of Illness (years)	20	Based on Shibuya et al (2001)
Percent of CB patients being 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 CB patient per year	1	
Percent of CB patients with an emergency doctor/hospital outpatient visit per year	15 %	
Estimated lost work days (including household work days) per year per CB patient	2.6	Estimated based on frequency of doctor visits, emergency visits, and hospitalization
Annual real increases in economic cost of health services and value of time (real wages)	2 %	Estimate
Annual discount rate	3 %	Applied by WHO for health effects
Hospital Admissions:		
Average length of hospitalization (days)	6	Estimates
Average number of days lost to illness (after hospitalization)	4	
Emergency Room Visits:		
Average number of days lost to illness	2	
Restricted Activity Days:		
Average number of days of illness (per 10 cases)	2.5	
Lower Respiratory Illness in Children:		
Number of doctor visits	1	
Total time of care giving by adult (days)	1	Estimated at 1-2 hours per day

IV. WATER, SANITATION, AND HYGIENE

The mean estimated annual cost associated with inadequate water supply, sanitation and hygiene is presented in Figure 4.1, totaling 1700-2220 billion Pesos per year, with a mean of 1960 billion Pesos. The cost of health impacts represents an estimated 70 percent of total mean cost, and avertive expenditures about 30 percent. Health impacts include both mortality and morbidity, and avertive expenditures include bottled water consumption, household water filtering, and household boiling of drinking water. Cost of each of these categories is presented in Figure 4.2.

This section discusses the linkages between health and water, sanitation and hygiene, the environmental health situation in Colombia, the methodologies used to estimate health impacts, and the socio-economic valuation of these health impacts.

Figure 4.1: Annual Costs of Inadequate Water, Sanitation, Hygiene (Billion Pesos)

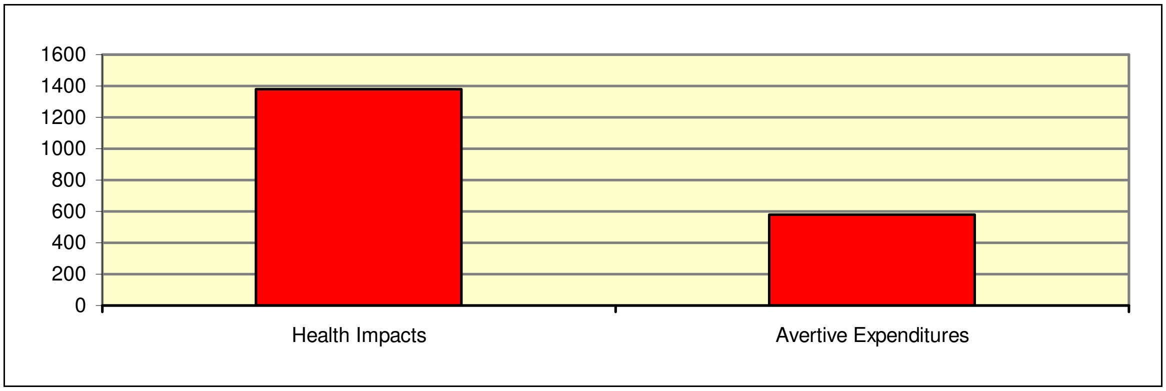
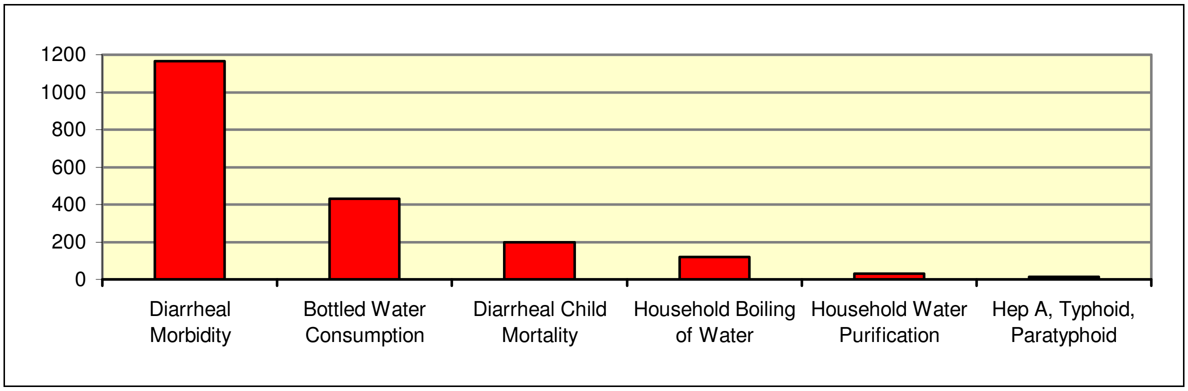


Figure 4.2: Annual Costs by Category (Billion Pesos)



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. Esrey et al (1991) provides a comprehensive review of studies documenting this relationship for diseases such as schistosomiasis (bilharzia), intestinal worms, diarrhea etc. From a review of studies, Curtis (2002) reports a mean reduction of 44 percent in cases of severe diarrhea from good hand washing practices. While diarrheal illness is generally not as serious as some other waterborne illnesses, it is more common and affects a larger number of people.

Water, sanitation and hygiene factors also influence child mortality. Esrey et al (1991) find in their review of studies that the median reduction in child mortality from improved water and sanitation was 55 percent. Shi (1999) provides econometric estimates of the impact of potable water and sewerage connection on child mortality using a data set for about 90 cities around the world. Literacy and education level is also found to be important for parental protection of child health against environmental risk factors. Esrey and Habicht (1988) reports from a study in Malaysia that maternal literacy reduces child mortality by about 50 percent in the absence of adequate sanitation, but only by 5 percent in the presence of good sanitation facilities. Literacy is also found to reduce child mortality by 40 percent if piped water is present, suggesting that literate mothers take better advantage of water availability for hygiene purposes to protect child health. Findings from the Demographic and Health Surveys seem to further confirm the role of literacy in child mortality reduction. Rutstein (2000) provides a multivariate regression analysis of infant and child mortality in developing countries using Demographic and Health Survey data from 56 countries from 1986-98. The study finds a significant relationship between infant and child mortality rates and piped water supply, flush toilet, maternal education, access to electricity, medical services, oral rehydration therapy (ORT), vaccination, dirt floor in household dwelling, fertility rates, and malnutrition. Similarly, Larsen (2003) provides a regression analysis of child mortality using national data for the year 2000 from 84 developing countries representing 95 percent of the total population in the developing world. A statistically significant relationship between child mortality and access to improved water supply, safe sanitation, and female literacy is confirmed.

Baseline Health Data.

Colombia has achieved substantial reductions in child morality and diarrheal child mortality. Child mortality is now about 1/3rd lower than in the region of Latin America and the Caribbean, and almost 50 percent lower than the average for lower middle-income countries. Baseline health data for estimating the health impacts of inadequate water supply, sanitation and hygiene are presented in Table 4.1. Data from DANE indicate that about 7.3 percent of child mortality is from diarrheal illness. The lower bound for diarrheal mortality (i.e., 1450 deaths) is based on 7.3 percent of official death records, while the upper bound (i.e., 1820 deaths) is based on 7.3 percent of total estimated child mortality published by DANE.[9]

For diarrheal morbidity, however, it is very difficult or practically impossible to identify all cases of diarrhea. The main reason is that a substantial share of cases is not treated or does not require treatment at health facilities, and is therefore never recorded. A second reason is that cases treated by private doctors or clinics are most often not reported to public health authorities. Household surveys therefore often provide the most reliable indicator of total cases of diarrheal illness. Most household surveys, however, contain only information on diarrheal illness in children. Moreover, the surveys only reflect diarrheal prevalence at the time of the survey. As there is often high variation in diarrheal prevalence across seasons of the year, extrapolation to an annual average will result in either an over- or underestimate of total annual cases. Correcting this bias is often difficult without knowledge of seasonal variations.

The Colombia Demographic and Health Survey 2000 (DHS 2000) provides data on diarrheal prevalence in children under the age of five years. It reports that diarrheal prevalence (preceding two weeks) was 13.9 percent. This rate was used to estimate annual cases per child under-5, and then total annual cases in all children under-5. The procedure applied is to multiply the two-week prevalence rate by 52/2.5 to arrive at an approximation of

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[9] Official death records represent a significant understatement of actual deaths in most developing countries due to under-reporting by households. DANE therefore publishes estimated mortality in addition to official records.

the annual cases of per child. The prevalence rate was not multiplied by 26 two-week periods (i.e. 52/2), but multiplied by 52/2.5 for the following reason: The average duration of diarrheal illness is assumed to be 3-4 days. This implies that the two-week prevalence captures a quarter of the diarrheal prevalence in the week prior to and a quarter in the week after the two-week prevalence period.

The DHS household survey does not (nor does any other household survey in Colombia) provide information on diarrheal illness in the population above 5 years of age. However, the National Institute of Health (INS) has a large database on cases of diarrheal illness for several years reported by each department in Colombia based on reported information from health care facilities. While this database is not complete, it provides an indication of the annual incidence of diarrhea per child relative to annual incidence for the rest of the population.[10] An analysis of the database suggests that diarrheal incidence in children under 5 years is up to seven times higher than the incidence in the population above 5 years of age. It should be noted however that the database contains information on cases of diarrhea treated at health facilities. In general, the percentage of cases of diarrhea that are treated at health facilities is higher among young children that older children and adults. For instance, according to the DHS 2000, the percentage of cases of diarrhea among 4-year old children is 28 percent lower than among 0-4 year olds. Thus the incidence ratio of seven, as suggested from the INS database is likely an overestimate. The annual cases of diarrhea per person among the population above 5 years of age, presented in Table 4.1, are therefore estimated at 1/7th to (1/0.72)*1/7th of the annual cases per child under-5.

Sometimes diarrheal illness require hospitalization. There are however no centralized records in Colombia that provide data on the annual number of diarrheal hospitalization. An estimate of hospitalization rate is therefore taken from evidence in Egypt (Larsen 2004), as presented in Table 4.1.

Table 4.1 also presents DALY per cases of diarrheal illness, which are used to estimate the number of DALYs lost because of inadequate water supply, sanitation and hygiene. While the disability weight for diarrheal morbidity is similar for children and adults (i.e., 0.119 for children under-5 and 0.086 for the rest of the population), and the duration of

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[10] The database is not complete because not all health facilities have reported diarrheal to the public health authorities.

illness is assumed to be the same (i.e., 3-4 days), the DALYs per 100 thousand cases of diarrheal illness is much higher for adults. This is because DALY calculations involve age weighting that attaches a low weight to young children, and a higher weight to adults, that corresponds to physical and mental development stages.[11] For diarrheal child mortality the number of DALYs lost is 34. This reflects an annual discount rate of 3 percent of life years lost.

Table 4.1: Baseline Data for Estimating Health Impacts

	Baseline	**Source:**
Diarrheal mortality in children under 5 years (% of child mortality)	7.3 %	Based on data from DANE
Total annual diarrheal mortality in children under 5	1450-1820	
Diarrheal 2-week Prevalence in Children under 5 years	13.9 %	DHS 2000
Estimated annual diarrheal cases per child under 5 years	2.9	Estimated from DHS 2000
Estimated annual diarrheal cases per person (> 5 years)	0.4-0.57	Estimated from a combination of INS data and DHS 2000
Hospitalization rate (% of all diarrheal cases) –children under 5 years	0.75 %	Adjusted to Colombia based on evidence from Egypt (Larsen 2004). No data available for Colombia
Hospitalization rate (% of all diarrheal cases) –children under 5 years	0.5 %	
Percent of diarrheal cases and hospitalizations attributable to water, sanitation and hygiene	90 %	WHO (2002b)
DALYs per 100 thousand cases of diarrhea in children under 5	30-40	Estimated from WHO tables
DALYs per 100 thousand cases of diarrhea in persons >5 years	100-130	
DALYs per case of diarrheal mortality in children under 5	34	

Estimated Health Impacts from Inadequate Water, Sanitation and Hygiene.

Table 4.2 presents the estimated health impacts from inadequate water, sanitation and hygiene. The estimates are based on the data in Table 4.1, taking into account the WHO estimate that 90 percent of diarrheal illness is attributable to water, sanitation and hygiene.

DALYs lost to diarrheal illness (mortality and morbidity) is presented in Table 4.3, based on the estimated cases in Table 4.2. More than 60 percent of the DALYs are from diarrheal child mortality.

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[11] It should be noted that some researchers elect not to use age weighting, or reports DALYs with and without

Table 4.2: Estimated Annual Health Impacts from Water, Sanitation, Hygiene

	Estimated Annual Cases	
	"Low"	"High"
Cases of Diarrheal illness		
Children (under the age of 5 years) – increased mortality	1305	1635
Children (under the age of 5 years) – increased morbidity	12.4 million	12.4 million
Population over 5 years of age – increased morbidity	14.5 million	20.0 million
Cases of Diarrheal Hospitalization		
Children (under the age of 5 years)	90 thousand	95 thousand
Population over 5 years of age	75 thousand	100 thousand
Total Disability Adjusted Life Years (DALYs)-mortality and morbidity	64 000	91 000

Table 4.3: Estimated DALYs Lost to Diarrheal Mortality and Morbidity

	Estimated Annual DALYs		
	"Low"	"High"	% of Total DALYs
Children (under the age of 5 years) – increased mortality	44 000	55 500	62-69 %
Children (under the age of 5 years) – increased morbidity	4 000	5 500	6 %
Population over 5 years of age – increased morbidity	16 000	29 000	25-32 %
TOTAL	64 000	91 000	

Estimated Cost of Health Impacts.

Total annual cost of health impacts associated with inadequate water, sanitation and hygiene is estimated at 1210-1525 billion Pesos (Table 4.4). The cost of diarrheal child mortality is based on the on the human capital approach (HCA). The cost of morbidity includes the cost of illness (medical treatment, medicines, and value of lost time) and DALYs from morbidity valued at GDP per capita to reflect the cost of reduced well-being associated with illness.

Cost-of-illness is presented in Table 4.5 for diarrheal morbidity.[12] About 40-50 percent of these costs are associated with the value of time lost to illness (including care giving), and 50-60 percent are from cost of treatment and medicines.

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age weighting.

Table 4.4: Estimated Annual Cost of Diarrheal Illness (LE million)

	Estimated Annual Cost (Billion Pesos)	
	"Low"	**"High"**
Mortality		
Children under age 5	178	224
Morbidity		
Children under age 5	432	480
Population over age 5	493	704
Hospitalization – children under age 5	54	54
Hospitalization – population over age 5	53	53
TOTAL ANNUAL COST	1210	1525

Table 4.5: Estimated Annual Cost-of-Illness (Morbidity) by Category

	Estimated Annual Cost (Billion Pesos)	
	"Low"	"High"
Cost of medical treatments (doctors, hospitals, clinics)	351	351
Cost of medicines	232	232
Cost of time lost to illness	361	567
TOTAL ANNUAL COST	944	1150

Baseline data for the cost estimates of morbidity in Table 4.4 -4.5 are presented in Table 4.6. Cost of mortality is discussed in the last section of the report. Percent of diarrheal cases in the age group older than 5 years treated at medical facilities is estimated from percent of treated cases among children (DHS 2000) and the ratio of treated cases among children under-5 to treated cases among the population above 5 years of age. The latter ratio is from the INS database discussed in the Baseline Health Data section.

The value of time for adults is based on national average wages. Economists commonly apply a range of 50-100 percent of wage rates to reflect the value of time. The hourly rate of 2100 Pesos, or 17 000 Pesos per day, reflects around 75 percent of average wages in Colombia.[13] These rates for value of time have been applied to both working and non-working individuals. There are two reasons for applying the rates to non-working individuals: First, most of those adult individuals provide a household function that has a

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[12] These costs do not include the valuation of DALYs.

[13] This corresponds to a daily national average wage rate of about 22000-23000 Pesos.

value. Second, there is an opportunity cost to the time of non-working individuals, because they could choose to join the paid labor force.[14]

Table 4.6: Baseline Data for Cost Estimation

	Baseline	**Source:**
Percent of diarrheal cases treated at medical facilities (children < 5 years) and with medicines	29 %	DHS 2000
Percent of diarrheal cases treated with ORS (children < 5 years)	36 %	DHS 2000
Percent of diarrheal cases treated at medical facilities (population > 5 years) and with medicines	18-25 %	Estimated from a combination of INS data and DHS 2000
Average Cost of doctor visits (urban and rural) - Pesos	35 000	Per consultations with pharmacies, medical service providers, and health authorities
Average Cost of medicines for treatment of diarrhea - Pesos	30 000	
Average cost of ORS per diarrheal case in children (Pesos)	3850	
Average duration of diarrheal illness in days (children and adults)	3-4	Assumption
Hours per day of care giving per case of diarrhea in children	2	Assumption
Hours per day lost to illness per case of diarrhea in adults	2	Assumption
Value of time for adults (care giving and ill adults) – Pesos/hour	2100	Based on urban and rural wages in Colombia
Hospitalization rate (% of all diarrheal cases) –children under 5 years	0.75 %	Adjusted based on evidence from Egypt (Larsen 2004). No data available for Colombia
Hospitalization rate (% of all diarrheal cases) –children under 5 years	0.5 %	
Average length of hospitalization (days)	2	Adjusted from Egypt (Larsen 2004)
Time spent on visitation (hours per day)	4	Assumption
Average cost of hospitalization (Pesos per day)	280 000	Per consultations with hospitals
Percent of diarrheal cases and hospitalizations attributable to water, sanitation and hygiene	90 %	(WHO 2002b)

Hepatitis A, Typhoid and Paratyphoid.

Recorded annual cases of hepatitis A and typhoid/paratyphoid in Colombia are presented in Table 4.7 for the years 2000 to 2003. The data for 2003 reports cases by age. Close to 20 percent and 10 percent of cases of hepatitis A and typhoid/paratyphoid, respectively, were among children under 5 years.

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[14] Some may argue that the value of time based on wage rates should be adjusted by the unemployment rate to reflect the probability of obtaining paid work.

Table 4.7: Annual Cases of Hepatitis A and Typhoid/Paratyphoid (2000-2003)

	Hepatitis A	Typhoid and Paratyphoid
Year 2000	4438	99
Year 2001	6405	373
Year 2002	11236	256
Year 2003	6513	1503
Annual Average	7148	558

Source: National Institute of Health, Colombia.

Estimated annual cost of these illnesses is presented in Table 4.8 based on annual average cases from 2000 to 2003. About 55 percent of estimated cost is from hospitalization and 40 percent from time losses for the ill individuals and their care givers during illness. More than 70 percent of the cost of time losses is associated with ill individuals and almost 30 percent with care giving.

Table 4.8: Estimated Annual Cost of Hepatitis A and Typhoid/Paratyphoid

	Estimated Total Annual Cost (billion Pesos)
Cost of Hospitalization	6.50
Cost of Medication	0.40
Cost of time losses	4.90
Total Annual Cost	11.80

Table 4.9 presents the baseline data for estimating the costs presented in Table 4.8. It is assumed that all cases of hepatitis A and typhoid/paratyphoid are hospitalized. The estimated cost of hospitalization in Table 4.8 is therefore an upper bound. The value of time lost to illness and care giving is around 75 percent of average wage rates. This issue is discussed in more details in other sections. Average duration of illness is estimated to be 30 days, and the cost estimate in Table 4.8 assumes that 30 days are lost to illness, valued at 17 000 Pesos per day.[15] This is likely to be an upper bound because some individuals recover faster and part of the day during recovery may be of productive use.

Even with baseline data that are likely to upper bounds, the total annual estimated cost of hepatitis A and typhoid/paratyphoid is only a small fraction of the cost of diarrheal illness.

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[15] The cost of time losses for children under 5 years is assumed to be zero.

Table 4.9: Baseline Data for Cost Estimation

	Baseline:	**Source:**
Percent of cases being Hospitalized	100%	Assumption
Average length of Hospitalization (days)	3	Estimate
Average Cost of hospitalization (Pesos per day)	280 000	Based on consultation with health care providers and health care authorities
Average Cost of medication (Pesos per case)	50 000	
Average duration of illness (days)	30	Estimate
Value of time lost to illness and care giving (Pesos per day)	17 000	Based on average wages
Care giving at home per day of illness (hours per day)	3	Estimate

Avertive Expenditures.

In the presence of perceived health risks, individuals often take avertive measures to avoid these risks. Economists usually consider these measures a cost of health risks. If consumers perceive there is a risk of illness from the municipal water supply, or from other sources of water supply they rely on, some consumers are likely to purchase bottled water for drinking purposes, or boil their water, or install water purification filters. Estimated cost of these measures is presented in this section.

Bottled Water. Approximately 775 million liters of bottled water were sold in Colombia in 2001 according to the Annual Manufacturer Survey (DANE). The average factory price was about 275 Pesos per liter. Per observations in stores in Bogota, average retail price ranged from 200 Pesos per liter for 5-gallon containers to 1000 Pesos per liter for 1 liter bottles.

To estimate the total annual retail cost of bottled water consumption in Colombia, a retail price range of 480-625 Pesos per liter was applied. The lower bound represents a 75 percent mark-up of average factory price. The upper bound represents an arithmetic average of retail prices for the most commonly sold quantities of bottles (and containers).

On this basis, total annual cost of bottled water consumption is estimated at 375-485 billion Pesos.

Boiling of Water. According to the Quality of Life Survey 2003 (DANE), 48 percent of households in Colombia boil their drinking water, either all the time or sometimes. Table 4.10 presents the estimated annual cost of boiling water for those households, totaling 75-160 billion Pesos per year.

Table 4.10: Estimated Annual Cost of Boiling Drinking Water

	Estimated Annual Cost (Billion Pesos)	
Cost of bringing water to boiling point	**"Low"**	**"High"**
Households using electricity	35	70
Households using natural gas	10	20
Households using propane	18	35
Households using other types of energy (mainly fuel wood)	6	24
Cost of boiling water for 10 minutes		
All households boiling water	6	11
Total Annual Cost	75	160

Table 4.11 presents the data used to estimate the annual cost of boiling drinking water. It is assumed that the average daily consumption of drinking water per person is 0.5-1.0 liters among households boiling water. Residential cost of energy is estimated based on data from UPME. The average stove efficiency is for electric, natural gas and propane stoves.

Table 4.11: Baseline Data for Cost Estimation

	Data:	
Percentage of households that boil their drinking water	48 %	DANE survey
Average daily consumption of drinking water	0.5-1.0	Liters per person per day
Percent of households using electricity	14 %	DHS 2000 and data from UPME
Percent of households using natural gas	34 %	
Percent of households using propane	31 %	
Percent of households using other types of energy	21 %	
Energy requirement of heating of water (100% efficiency)	4200	Joules/ltr/1 degree C
Average Stove efficiency for heating of water	50 %	Varies by type of stove
Cost of residential electricity (economic cost)	350	Pesos/kWh
Cost of residential natural gas	406	Pesos per cubic meter
Average cost of bottled propane	39 000	Pesos (17.7 gallons)

Water Purification. The Quality of Life Survey 2003 (DANE) reports that 4.2 percent of households have drinking water purification filters installed in their homes. The annual cost of household water purification is estimated at 30-35 billion Pesos. This is estimated by annualizing the cost of purification equipment and filters over their expected useful life, using a discount rate of 10 percent, an average useful life of equipment of 15 years, and an average lifetime of filters of 0.6 to 6 years. These useful lives represent averages for the most common equipment and filters used in Colombia. Unit costs for equipment and filters are presented in Table 4.12. These figures, and useful life of equipment and filters, were obtained from stores in Bogota.

Table 4.12: Unit Costs of Water Purification

	"Low"	**"High"**
Percent of households using water purification equipment/filters	4.2 %	4.2 %
Cost of water purification equipment (most commonly used) - Pesos	295 000	270 000
Cost of replacement filter - Pesos	95 000	22 500
Average useful life of filters (years)	6	0.6
Average useful life of equipment (years)	15	15

Table 4.13 presents a summary of the cost of avertive expenditures, amounting to a total of 480-680 billion Pesos per year. This represents 30 percent of the total estimated annual cost of inadequate water supply, sanitation and hygiene.

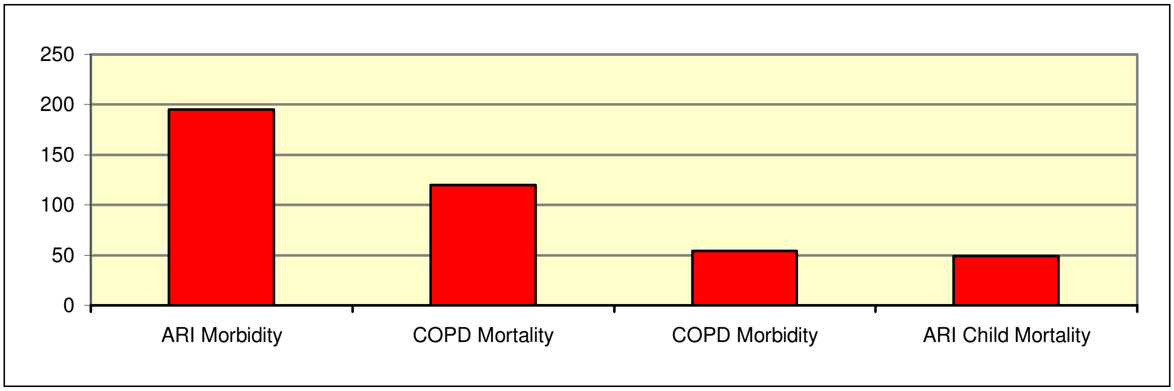
Table 4.13: Estimated Total Annual Household Cost of Avertive Expenditures

	Total Annual Cost (Billion Pesos)	
	"Low"	**"High"**
Cost of bottled water consumption	375	485
Cost of household boiling drinking water	75	160
Cost of household water purification	30	35
Total cost	480	680

V. 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) is 415 billion Pesos. As presented in Figure 5.1, adult female COPD mortality represents 28 percent of this cost. Acute respiratory illness (ARI) in children and adult females represents 47 percent of the cost, and respiratory child mortality about 12 percent. Chronic obstructive pulmonary disease (COPD) morbidity in adult females represents 13 percent of the total cost.

Figure 5.1: Annual Costs of Indoor Air Pollution (Billion Pesos)



WHO (2002b) estimates that 1.6 million people die each year globally due to indoor smoke from the use of traditional fuels in the homes. The most common of such fuels are wood, agricultural residues, animal dung, charcoal, and, in some countries coal. The strongest links between indoor smoke and health are for lower respiratory infections, chronic obstructive pulmonary disease (COPD), and for cancer of the respiratory system. Indoor smoke is estimated to cause about 37.5 percent, 22 percent, and 1.5 percent of these illnesses globally (WHO 2002b).

There are two main steps in quantifying the health effects. First, the number of people or households exposed to pollution from solid fuels needs to be calculated, and the extent of pollution, or concentration, should ideally be measured. Second, the health impacts from this exposure should be estimated based on epidemiological assessments. Once the health impacts are quantified, the value of this damage can be estimated.

Traditional Fuel Use.

The Demographic and Health Survey (DHS) in 1995 and 2000, conducted among urban and rural households throughout Colombia, contains information on household use of traditional fuels for cooking. The data from the DHSs are presented in Table 5.1a, indicating that around 60 percent of rural households and less than 3 percent of urban households used fuel wood or charcoal/coal products in the year 2000. Nationally, this represents around 18 percent of all households.

Table 5.1a also indicates that LPG or gas made rapid inroads both among rural and urban households from 1995 to 2000, replacing both traditional fuels and electricity for cooking. The number of rural households using traditional fuel declined by more than a percentage point per year from 1995 to 2000. Nevertheless, the share of rural households using traditional fuels remains substantial, and can be suspected of being associated with significant respiratory health impacts.

Table 5.1a: Fuels Used for Cooking in Colombia

	Percent of Households					
	Rural		Urban		National Total	
Year	2000	1995	2000	1995	2000	1995
Fuel wood	57.4	63.7	2.1	2.9	17.0	21.0
Charcoal, coal, lignite	3.2	2.5	0.3	0.7	1.1	1.2
Sub-total	*60.6*	*66.2*	*2.4*	*3.6*	*18.1*	*22.2*
LPG and Gas	32.0	18.0	76.6	56.2	64.6	44.8
Electricity	5.0	9.9	17.0	32.3	13.8	25.6
Kerosene	0.6	2.0	0.8	1.8	0.8	1.8
Other	1.8	3.9	3.2	6.1	2.7	5.6
Sub-total	*39.4*	*33.8*	*97.6*	*96.4*	*81.9*	*77.8*

Source: Colombia Demographic and Health Survey 1995 and 2000.

An estimate of the percentage of households using traditional fuels can also be provided from UPME energy balances. This is presented in Table 5.1b based of total fuel wood consumption and a broad estimate of fuel wood use per household (among households using fuel wood). The trend from 1988 to 2003 shows a substantial decline in the percentage of total households using fuel wood, and the estimates for 1995 and 2000 are quite consistent with the data from the DHS surveys.

Table 5.1b: Household Fuel Wood Use

	1988	1995	2000	2003
Fuel wood consumption (million tons/year)	8.97	5.62	4.92	4.64
Average household consumption (tons/year)*	3.15	3.15	3.15	3.15
Percentage of households using fuel wood (national level)	42 %	23 %	18 %	17 %

Source: Fuel wood consumption is from UPME energy balances. * Average household consumption is a broad estimate, and is for households using fuel wood.

Health Risk Assessment.

Smith (2000) provides are review of research studies around the world that have assessed the magnitude of health effects from indoor air pollution from solid fuels. The odds ratios for acute respiratory illness (ARI) and chronic obstructive pulmonary disease (COPD) are presented in Table 5.2. The odds ratios represent the risk of illness for those who are exposed to indoor air pollution compared to the risk for those who are not exposed. The exact odds ratio depends on several factors such as concentration level of pollution in the indoor environment and the amount of time individuals are exposed to the pollution. A range of "low" to "high" ratios are therefore presented in Table 5.2 that reflects the review by Smith (2000).

Dennis et al (1996) present estimates of impacts of indoor air pollution on obstructive airways disease (OAD) among a sample of women in Bogota. A sample of case subjects with OAD and control subjects without OAD was drawn from hospitals in the city. Information was collected from the subjects on their life-history of fuel wood use, and other variables known to be associated with OAD. The average age of the subjects was 63 years. The study found an odds ratio (OR) of 3.9 (controlling for tobacco smoking, passive smoking, age, and socio-economic variables), i.e., the risk of developing OAD was found to be 3.9 times higher among the women that had a life-history of fuel wood use compared to women from households not using fuel wood. The average number of years of fuel wood use was 33 years among the subjects with OAD, and 18 years among the subjects without OAD.

Studies around the world have also found linkages between indoor air pollution from traditional fuels and increased prevalence of tuberculosis and asthma. It is also likely that indoor air pollution from such fuels can cause an increase in ischaemic heart disease and other cardiopulmonary disorders. As discussed in the section on urban air pollution, Pope et al

(2002) and others have found that the largest effect of urban fine particulate pollution on mortality is for the cardiopulmonary disease group. As indoor smoke from traditional fuels is high in fine particulates, the effect on these diseases might be substantial. More research is however required in order to draw a definite conclusion about the linkage and magnitude of effect.

The odds ratios in Table 5.2 have in this report been applied to young children under the age of five years (for ARI) and adult females (for ARI and COPD) to estimate the increase in mortality and morbidity associated with indoor air pollution.[16] It is these population groups who suffer the most from indoor air pollution. This is because they spend much more of their time at home, and/or more time cooking than older children and adult males.

Table 5.2: Health Risks of Indoor Air Pollution

	Odds Ratios (OR)	
	"Low"	"High"
Acute Respiratory Illness (ARI)	2	3
Chronic obstructive pulmonary disease (COPD)	2	4

Source: Smith (2000).

Baseline Health Data.

To estimate the health effects of indoor air pollution from the odds ratios in Table 5.2, baseline data for ARI and COPD have to be established. These data are presented in Table 5.3, along with unit figures for disability adjusted life years (DALYs) lost to illness and mortality. Data on COPD mortality and especially morbidity incidence, according to international disease classification, are not readily available for Colombia. Regional estimates from WHO (2001) and Shibuya et al (2001) have therefore been applied.[17]

The national average two-week prevalence rate of ARI in children under 5 years from the Colombia Demographic and Health Survey (DHS) 2000 is used to estimate total annual cases of ARI in children under-5 and annual cases per child under-5. The procedure applied is to multiply the two-week prevalence rate by 52/3 to arrive at an approximation of the

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[16] Although Smith (2000) presents odd ratios for lung cancer, this effect of pollution is not estimated in this report. This is because the incidence of lung cancer among rural women is generally very low. The number of cases in rural Colombia associated with indoor air pollution is therefore likely to be minimal.

[17] Colombia belongs to the AMRO B region of WHO, which is one of three WHO regions in the Americas.

annual cases of ARI per child. The prevalence rate was not multiplied by 26 two-week periods (i.e. 52/2), but multiplied by 52/3 for the following reason: The average duration of ARI is assumed to be about 7 days. This implies that the two-week prevalence captures half of the ARI prevalence in the week prior to and the week after the two-week prevalence period.

The DHS household survey does not (nor does any other household survey in Colombia) provide information on ARI in adults. However, the National Institute of Health (INS) has a large database on cases of ARI for several years reported by each department in Colombia based on reported information from health care facilities. While this database is not complete, it provides an indication of the annual incidence of ARI per child relative to annual incidence per adult.[18] An analysis of the database suggests that ARI incidence in children under 5 years is up to six times higher than the incidence in the population above 5 years of age. It should be noted however that the database contains information on cases of ARI treated at health facilities. In general, the percentage of cases of ARI that are treated at health facilities is higher among young children that older children and adults. For instance, according to the DHS 2000, the percentage of cases of ARI among 4year old children is 10 percent lower than among 0-4 year olds. Thus the incidence ratio of six, as suggested from the INS database is likely an overestimate. The annual cases of ARI per adult female (>15 years) presented in Table 5.3 is therefore estimated at 1/6th to (1/0.9)*1/6th of the annual cases per child under-5.

ARI mortality in children under 5 years, as presented in Table 5.3, is based on data from DANE on child mortality rates and estimated percentage of child mortality due to ARI. The lower bound for ARI mortality (i.e., 1510 deaths) is based on official death records, while the upper bound (i.e., 1890 deaths) is based on 7.5 percent of total estimated child mortality published by DANE.[19]

Table 5.3 also presents DALY per cases of ARI and COPD, which are used to estimate the number of DALYs lost because of indoor air pollution. While the disability weight for ARI morbidity is the same for children and adults (i.e., 0.28), and the duration of

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[18] The database is not complete because not all health facilities have reported ARI to the public health authorities.

[19] Official death records represent a significant understatement of actual deaths in most developing countries due to under-reporting by households. DANE therefore publishes estimated mortality in addition to official records.

illness is assumed to be the same (i.e., 7 days), the DALYs per 100 thousand cases of ARI is much higher for adults. This is because DALY calculations involve age weighting that attaches a low weight to young children, and a higher weight to adults, that corresponds to physical and mental development stages.[20] For ARI child mortality the number of DALYs lost is 34. This reflects an annual discount rate of 3 percent of life years lost.

DALYs lost per case of COPD morbidity and mortality is based on life-tables and age-specific incidence of onset of COPD reported by Shibuya et al (2001). A disability weight of 0.2 has been applied to COPD morbidity, which is for the region of Latin America as published by the National Institute of Health, United States.[21] A discount rate of 3 percent is applied to both COPD morbidity and mortality.

Table 5.3: Baseline Data for Estimating Health Impacts

	Baseline	**Source:**
Female COPD mortality rate (% of total female deaths)	3.1 %	WHO (2001) and Shibuya et al (2001)
Female COPD incidence rate (per 100 thousand)	80	
ARI 2-week Prevalence in Children under 5 years	12.6 %	DHS 2000
Estimated annual cases of ARI per child under 5 years	2.2	Estimated from DHS 2000
Estimated annual cases of ARI per adult female (> 15 years)	0.36-0.41	Estimated from a combination of INS data and DHS 2000
ARI mortality in children under 5 years (% of child mortality)	7.5 %	Based on data from DANE
ARI mortality in children under 5 years (cases per year)	1510-1890	
DALYs per 100 thousand cases of ARI in children under 5	165	Estimated from WHO tables
DALYs per 100 thousand cases of ARI in female adults (>15)	700	
DALYs per case of ARI mortality in children under 5	34	
DALYs per case of COPD morbidity in adult females	2.25	
DALYs per case of COPD mortality in adult females	6	

Estimated Health Impacts.

Annual new cases of ARI and COPD morbidity and mortality (D_i) from fuel wood smoke was estimated from the following equation:

$$D_i = PAR * D_i^B \qquad (1)$$

where D_i^B is baseline cases of illness or mortality, i (estimated from the baseline data in Table 5.3), and PAR is given by:

$$PAR = PP*(OR-1)/(PP*(OR-1)+1) \qquad (2)$$

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[20] It should be noted that some researchers elect not to use age weighting, or reports DALYs with and without age weighting.

[21] See: http://www.fic.nih.gov/dcpp/weights.xls

where PP is the percentage of population exposed to fuel wood smoke (18 percent of the population according to Table 5.1a-b), and OR is the odds ratios (or relative risk ratios) presented in Table 5.2.

The results are presented in Table 5.4. Estimated cases of ARI child mortality and ARI morbidity (children and female adults) from indoor air pollution represent about 16-25 percent of total ARI in Colombia. Similarly, the estimated cases of COPD mortality and morbidity represent about 15-35 percent of total estimated female COPD in from all causes. In contrast, Dennis et al (1996) found that indoor air pollution was the cause of 50 percent of COPD in the sample of women in Bogota. This high number is largely due to the fact that most of those women had been using fuel wood during part of their lives, and that the odds ratio estimated by Dennis et al is close to the upper bound used in this report.

Table 5.4: Estimated Annual Health Impacts of Indoor Air Pollution

	Estimated Annual Cases	
	"Low"	"High"
Acute Respiratory Illness (ARI):		
Children (under the age of 5 years) – increased mortality	265	455
Children (under the age of 5 years) – increased morbidity	1.6 million	2.8 million
Females (15 years and older) – increased morbidity	0.9 million	1.5 million
Chronic obstructive pulmonary disease (COPD):		
Adult females – increased mortality	455	1040
Adult females – increased morbidity	2800	6400
Total Disability Adjusted Life Years (DALYs)-mortality and morbidity	27000	51700

Table 5.5: Estimated DALYs Lost to Indoor Air Pollution

	Estimated Annual DALYs		
	"Low"	"High"	% of Total DALYs
Acute Respiratory Illness (ARI):			
Children (under the age of 5 years) – increased mortality	9 000	15 600	30-33%
Children (under the age of 5 years) – increased morbidity	2 700	4 600	9-10%
Females (15 years and older) – increased morbidity	6 300	10 900	21-23%
Chronic obstructive pulmonary disease (COPD):			
Adult females – increased mortality	2 700	6 200	10-12%
Adult females – increased morbidity	6 300	14 400	23-28%

Table 5.5 presents the estimated health impacts in terms of disability adjusted life years (DALYs). An estimated 27-52 thousand DALYs are lost each year due to indoor air pollution. About 40-45 percent is from mortality, and about 55-60 percent from morbidity.

Estimated Cost of Health Impacts.

Total annual cost of indoor air pollution is estimated at 240-630 billion Pesos, with a mean estimate of 415 billion (Table 5.6). The cost of mortality is based on the value of statistical life (VSL) for adults, and on the human capital approach (HCA) for children. The cost of morbidity includes the cost of illness (medical treatment, value of lost time, etc) and DALYs from morbidity valued at GDP per capita to reflect the cost of reduced well-being associated with illness.

About 42 percent of this cost is associated with COPD, and 58 percent with ARI.[22] COPD and ARI mortality represents about 40 percent of the total cost, and morbidity about 60 percent.

Table 5.6: Estimated Annual Cost of Indoor Air Pollution

	Estimated Annual Cost (Billion Pesos)	
	"Low"	"High"
Acute Respiratory Illness (ARI):		
Children (under the age of 5 years) – increased mortality	35	62
Children (under the age of 5 years) – increased morbidity	70	122
Adult females – increased morbidity	72	124
Chronic obstructive pulmonary disease (COPD):		
Adult females – increased mortality	20	218
Adult females – increased morbidity	33	74
TOTAL COST	**230**	**600**

Cost-of-illness is presented in Table 5.7 for ARI and COPD morbidity.[23] About 60 percent of these costs are associated with the value of time lost to illness (including care giving), and 40 percent are from cost of treatment and medicines.

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[22] Based on the mean estimated annual cost.

[23] These costs do not include the valuation of DALYs.

Table 5.7: Estimated Cost-of-Illness by Category

	Estimated Annual Cost (Billion Pesos)	
	"Low"	"High"
Cost of medical treatments (doctors, hospitals, clinics)	21	38
Cost of medicines	22	39
Cost of time lost to illness	65	113
TOTAL	108	190

Baseline data for the cost estimates of morbidity in Table 5.6-7 are presented in Table 5.8. Cost of mortality is discussed in the last section of the report. Percent of adult ARI cases treated at medical facilities is estimated from percent of treated cases among children (DHS 2000) and the ratio of treated cases among children under-5 to treated cases among the population above 5 years of age. The latter ratio is from the INS database discussed in the Baseline Health Data section.

The value of time for adults is based on rural wages. Economists commonly apply a range of 50-100 percent of wage rates to reflect the value of time. The hourly rate of 1500 Pesos, or 12 000 Pesos per day, reflects around 75 percent of rural wages in Colombia.[24] These rates for value of time have been applied to both working and non-working individuals. There are two reasons for applying the rates to non-working individuals: First, most of those adult individuals provide a household function that has a value. Second, there is an opportunity cost to the time of non-working individuals, because they could choose to join the paid labor force.[25]

There is very little information about the frequency of doctor visits, emergency visits and hospitalization for COPD patients in any country in the world. Schulman et al (2001) and Niederman et al (1999) provide some information on this from the United States and Europe. Figures derived from these studies have been applied to Colombia. Estimated lost work days per year is based on frequency of estimated medical treatment plus an additional 7 days for each hospitalization and one extra day for each doctor and emergency visit. These days are added to reflect time needed for recovery from illness.

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[24] This corresponds to a daily rural wage rate of 16 000 Pesos. In contrast, average wages in major cities in Colombia are around 25 000 Pesos.

[25] Some may argue that the value of time based on wage rates should be adjusted by the unemployment rate to reflect the probability of obtaining paid work.

To estimate the cost of a new case of COPD, the medical cost and value of time losses have been discounted over a 20-years duration of illness. An annual real increase of 2 percent in medical cost and value of time has been applied to reflect an average expected increase in annual labor productivity and real wages. The costs are discounted at 3 percent per year, a rate commonly applied by WHO for health effects.

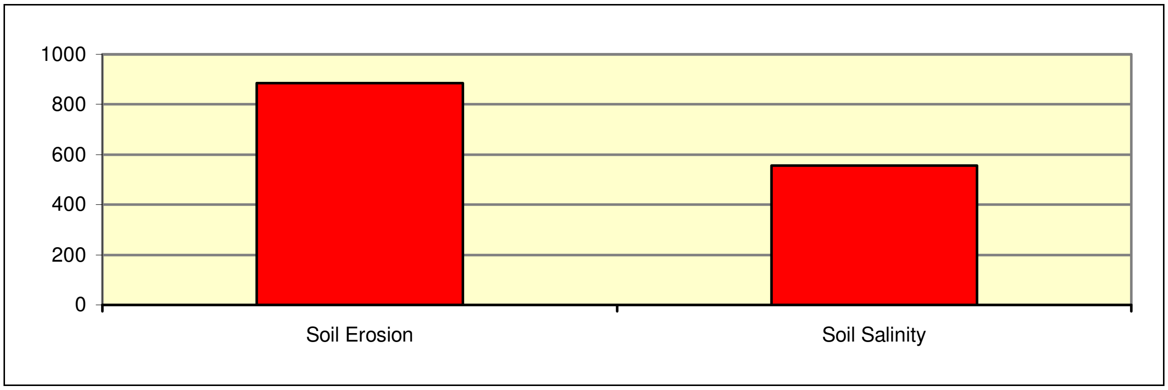
Table 5.8: Baseline Data for Cost Estimation

	Baseline	**Source:**
Acute Respiratory Illness (ARI):		
Percent of ARI cases treated at medical facilities (children < 5 years)	35 %	DHS 2000 (rural children)
Percent of ARI cases treated at medical facilities (adults > 15 years)	32 %	Estimated from a combination of INS data and DHS 2000
Average Cost of doctor visits in rural areas (mainly primary health care centers) - Pesos	20 000	Per consultations with pharmacies, medical service providers, and health authorities
Cost of medicines for treatment of ARI - Pesos	16 000-21 000	
Percent of ARI cases treated with medicines	50 %	DHS 2000
Average duration of ARI in days (children and adults)	7	Assumption
Hours per day of care giving per case of ARI in children	2	Assumption
Hours per day lost to illness per case of ARI in adults	3	Assumption
Value of time for adults (care giving and ill adults) – Pesos/hour	1500	Based on rural wages in Colombia
Chronic Obstructive Pulmonary Disease (COPD):		
Average duration of Illness (years)	20	Based on Shibuya et al (2001)
Percent of COPD patients being 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 work days (including household work days) per year per COPD patient	2.6	Estimated based on frequency of doctor visits, emergency visits, and hospitalization
Cost of hospitalization (Pesos per day)	280 000	Per consultations with medical service providers, and health authorities
Cost of emergency visit (Pesos) - rural	25 000	
Cost of doctor visit (Pesos) (mainly primary health clinic) - rural	20 000	
Value of time lost to illness (Pesos per day)	12000	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

VI. AGRICULTURAL LAND DEGRADATION

The mean estimated annual cost of land degradation is 1440 billion Pesos, of which soil erosion represents about 60 percent and soil salinity about 40 percent (Figure 6.1). These costs are the value of crop yield reductions associated with salinity and erosion. It should be noted that data limitations have prevented an estimate of the cost of pasture (rangeland) degradation.

Figure 6.1: Annual Costs of Agricultural Land Degradation (Billion Pesos)



An estimated 4.25 million hectares are under cultivation in Colombia, of which 0.9 million hectares are irrigated. Permanent pasture constitutes close to 42 million hectares, according to FAO statistics for the year 2001.

There is a general perception that pasture (rangeland) is overextended in Colombia, that crop cultivation in many instances is marginalized to erosion prone hillsides (World Bank 1996; Heath and Binswanger 1998), and that the Atlantic Region in the northern part of Colombia suffers from soil salinity.

There are very few studies of the extent of land degradation in Colombia, and how degradation affects agricultural productivity. No systematic and comprehensive studies have been undertaken of soil salinity levels in the Atlantic Region. A recent study of salinity in Cauca valley, however, found that about 7 percent of a study area of 192 thousand hectares have soil salinity exceeding 3 dS/m. About 55 percent have salinity in the range of 07-3.0 dS/m, and 38 percent of the area have salinity of less than 0.7 dS/m.[26] While soil salinity

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[26] Regional Autonomous Corporation of Cauca Valley.

levels below 3 dS/m is generally considered moderate, yields of many vegetables are affected by salinity exceeding 1.0-2.0 dS/m.

CORPOICA (I. Baquera Haeberlin, et al 2003) has recently undertaken a study of the cost of soil erosion in select sites in four departments. The departments are Caqueta, Meta, Santander, and Tolima. Several methodologies were employed, including hedonic price and productivity models. The results indicate that the cost of erosion, in terms of impacts on agricultural yields, is substantial in erosion prone areas.

Land Area Affected by Erosion and Salinity.

While the study by Corpoica is a very important contribution to the understanding of the cost of erosion in Colombia, it is difficult to extrapolate the findings of the study to the national level. In the absence of nationwide studies of erosion and salinity, it is necessary to rely on data published by IDEAM that provide some broad perspectives on land degradation in each department in Colombia. These data are presented in Table 6.1. They indicate that around 10 percent of the land area in the country is subject to “moderate” to “high” levels of soil salinity, and 23 percent is subject to “high” or “very high” levels of erosion. The data are consistent with the general view that the northern region of Colombia is particularly affected by soil salinity, with saline conditions in 45-85 percent of land area in the northern departments. In terms of erosion, according to Table 6.1, “high” or “very high” erosion is present in more than 50 percent of land area in seven departments.

Estimation of the Cost of Land Degradation.

The aim of this report is to provide an estimate of the cost of land degradation at the national level. The indicators of land degradation that are utilized are land erosion and salinity. The data in Table 6.1 have been combined with crop yield data from the National Farming Survey (2002), provided by DANE and the Ministry of Agriculture and Rural Development (MARD). Two relative crop yield indices were constructed for each department based on yields of individual crops for each department and national average crop yields. One index is based on arithmetic averages of relative yields. The second index is a weighted average by hectares under cultivation for each crop. The erosion variable is the percentage of land area subject to “very high” and “high” erosion in each department. The salinity variable is the percentage of land area subject to “high” and “moderate” soil salinity.

Table 6.1: Indicators of Land Degradation

DEPARTMENTS	**Total Area Km^2**	**Area with Erosion (High or Very High) % of Total Area**	**Saline Land (Moderate or High) % of Total Area**
AMAZONAS	110213	0%	0%
ANTIOQUIA	63307	12%	10%
ARAUCA	23784	48%	0%
ATLANTICO	3324	73%	74%
BOGOTA, D.C	1642	8%	0%
BOLIVAR	26644	17%	45%
BOYACA	23076	29%	5%
CALDAS	7444	6%	13%
CAQUETA	89645	13%	0%
CASANARE	44435	66%	0%
CAUCA	29883	16%	2%
CESAR	22614	50%	63%
CORDOBA	25061	55%	44%
CUNDINAMARCA	22490	32%	16%
CHOCO	47321	1%	2%
GUAINIA	70679	1%	0%
GUAVIARE	55080	5%	0%
HUILA	19240	32%	20%
LA GUAJIRA	20506	81%	79%
MAGDALENA	23076	33%	84%
META	86047	50%	0%
NARINO	30832	9%	3%
NORTE DE SANTANDER	21995	15%	6%
PUTUMAYO	26011	4%	0%
QUINDIO	1948	3%	0%
RISARALDA	3599	7%	5%
SANTANDER	30475	20%	8%
SUCRE	10719	54%	80%
TOLIMA	24061	24%	32%
VALLE DEL CAUCA	21277	23%	18%
VAUPES	53546	1%	0%
VICHADA	99874	41%	0%
All Colombia		23%	10%

Source: Based on data from IDEAM (2004).

Based on the above data, a regression analysis was undertaken with the following equation:

$$q_i = \alpha + \beta_E E_i + \beta_S S_i + \beta_t t_i + \varepsilon_i \qquad (1)$$

where q is the index of relative crop yields, E is percentage of land area that is eroded, S is the percentage of land area that is saline, t is farm technology, and i= 1,…,n represents departments.

The data provided by DANE and MARD were not sufficient to construct a relative yield index for all departments, and the econometric estimation of (1) was therefore limited to 19 departments and an aggregate of "other departments, i.e., 20 observations. Department specific data on farm technology was limited to share of cultivated land under irrigation from World Bank (1996). However, no statistical significance was found, and the technology variable was therefore left out of the final estimation of (1).[27]

The estimated coefficients for erosion and salinity are presented in Table 6.2, based on the relative yield index that was constructed from the arithmetic average crop yields.[28] The coefficients suggests that department crop yields decline by about 0.3 to 0.35 percentage points (relative to the national average yield) for every one percentage point increase in saline or eroded land area.[29]

Table 6.2: Estimated Regression Coefficients

	β	t-statistic
Erosion (E)	-0.36	-2.61
Salinity (S)	-0.31	-3.64
$R^2 = 0.79$; n = 20		

The coefficients in Table 6.2 were then applied to equation (1) to provide predicted yields for each department based on the departmental soil erosion and salinity data. A simulation was then undertaken whereby the salinity and erosion variables were set at zero, in order to estimate expected yields in the absence of salinity and erosion. The difference in yields is the estimated reduction in yields associated with erosion and salinity. The national average statistics of this simulation are presented in Table 6.3.

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[27] It might be that the irrigation variable is too outdated to reflect currently irrigated areas.

[28] Equation (1) was also estimated using the weighted yield index. The erosion and salinity coefficients were quite similar to the estimates in Table 6.2, but R^2 was lower.

[29] Equation (1) was estimated in levels. Log and semi-log forms provided very poor results.

Table 6.3: Simulated Relative Yields

	National Average Relative Yield*
Yield at current levels of soil erosion and salinity	0.82
Predicted yield if NO "very high" and "high" erosion	0.92
Predicted yield if NO "high" and "moderate" salinity	0.90
Predicted yield if NO erosion and salinity ("high-very high" and "moderate-high"	1.00

* Arithmetic average of the departments in the regression analysis.

The results of the simulation discussed above were then applied to the gross output value in each department to estimate the cost of erosion and salinity. The gross output value was calculated based on producer prices in Colombia reported by FAO.

Aggregate national estimates of land degradation costs are presented in Table 6.4. It should be noted that cost of erosion relative to salinity is much higher than the statistics in Table 6.3 would indicate. This is because Table 6.3 is based on arithmetic averages of percentage effects on yields of land degradation, while the estimated costs in Table 6.4 is based on crop composition and total hectares under cultivation in each department.

Table 6.4: Estimated Annual Cost of Land Degradation

	Estimated Annual Cost (Billion Pesos)	
	"Low"	**"High"**
Soil erosion	805	965
Soil salinity	505	605
Total cost	1310	1570

An alternative approach to estimating the cost of soil salinity was also undertaken in this study for the 7 departments in the Atlantic Region that are most effected by salinity. Crop-specific soil salinity thresholds and salinity yield coefficients from the empirical international literature were applied to estimate the cost of soil salinity (FAO 1998; Kotuby-Amacher, J. et al 1997; Resources Science Centre 1997). Costs were estimated for a plausible range of soil salinity levels ranging from 3-5 dS/m. A plausible range was used because there are no systematic salinity measurements from the Atlantic Region.[30] Estimated cost of soil salinity was found to be in the same range as the estimate from the regression analysis

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[30] Salinity measurements are available for Valle del Cauca, but the total losses are not very large because of relatively low average levels.

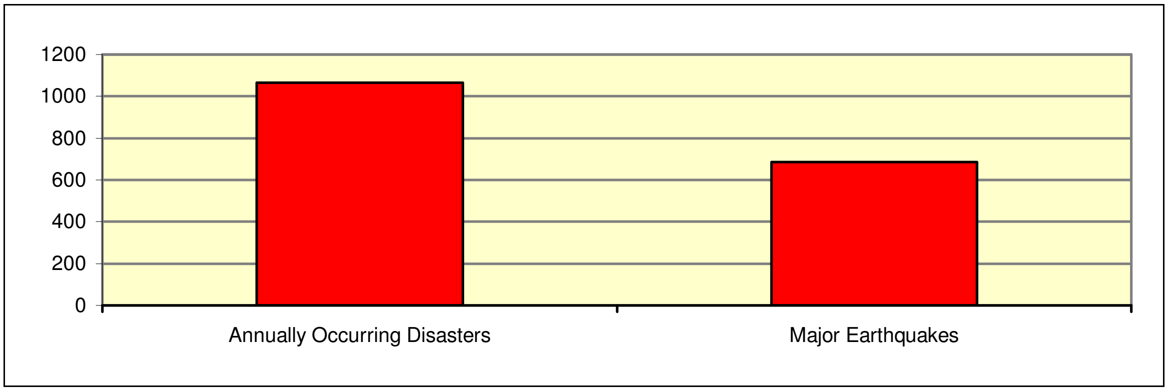
presented in Table 6.4. A salinity level of 4 dS/m is associated with a loss close to the mean econometric estimate in Table 6.4

An important issue is that cost of pasture degradation has not been estimated in this report because of lack of data. However, the CORPOICA study by Baquero Haeberlin et al (2003) includes an estimate of pasture degradation in Caqueta, estimated at 58,000 Pesos per hectare per year. If 25-50 percent of pasture in Colombia is experiencing a similar level of degradation, total annual cost at the national level would be on the order of 600-1200 billion Pesos. An amount of this magnitude might warrant further assessment of pasture degradation in other departments in order to provide a better sense of scope and magnitude of cost of degradation at the national level.

VII. NATURAL DISASTERS

Colombia is annually afflicted by natural disasters such as floods, landslides, avalanches, and storms, and severe earthquakes occur periodically. The total mean annual cost of natural disasters is estimated at 1750 billion Pesos, as presented in Figure 7.1.

Figure 7.1: Estimated Annual Costs of Natural Disasters (Billion Pesos)



The Department for Disaster Prevention and Attention at the Ministry of Interior and Justice maintains a large database on disasters. Up to 1998, the database contains information on fatalities, number of individuals affected, and houses affected by disasters. From 1999 to 2003, the database also contains information on the number of injured persons, several forms of infrastructure and public buildings affected, and distinguishes between destroyed and damaged houses. The number of people and units affected by natural disasters is presented in Table 7.1. The table does only include disaster that occur more or less annually, and does not include the large Armenia earthquake in 1999, in order to facilitate a comparison across years. As can be seen, the impacts of disasters were particularly high in 1999 mainly due to severe floods.

Table 7.2 provides average annual impacts for three periods over the past decade. There does not seem to be any detectable trend in impacts over these periods. To test for any time trends a regression analysis was undertaken for total number of people affected by disasters, but the time trend is statistically insignificant.

Table 7.1: Number of People and Units Affected by Natural Disasters

	2003	2002	2001	2000	1999*
Deaths	122	142	74	96	276
Injured Persons	420	39	379	111	351
Missing Persons	18	52	28	15	60
Number Of People Affected (000)	436	343	205	468	1,214
Families Affected (000)	88	67	40	94	240
Houses Destroyed (000)	2.1	1.3	1.6	2.5	5.5
Houses Damaged (000)	16.8	10.2	14.5	10.9	26.2
Roads Damaged	31	83	66	135	375
Bridges Damaged	8	13	14	61	123
Pedestrian Overpasses/Bridges Damaged	10	22	20	57	126
Water Sypply Systems Affected	6	119	21	91	136
Sewage Systems Affected	1	1	1	5	30
Health Centers Affected	6	8	8	11	7
Schools, Education Centers Affected	45	65	64	76	89
Community Centers Affected	31	62	40	31	62

Source: From the disaster database at Department for Disaster Prevention and Attention, Ministry of Interior and Justice. * Not including the Armenia earthquake.

Table 7.2: Annual Average Impacts for Three Periods

	2000-2003	1999-2003	1993-1997
Deaths	109	142	196
Number Of People Affected (000)	363	533	372
Houses Affected (000)	15	18	22

- Not including the Armenia earthquake.

Table 7.3: Percentage of Disaster Impacts by Type of Disaster 1999-2003

EVENT	Deaths	Injured Persons	Number of People Affected	Houses Destroyed	Houses Damaged
LANDSLIDES	18%	6%	3%	6%	5%
FLOODS	8%	3%	71%	20%	35%
STORMS	0%	5%	7%	5%	25%
DROUGHTS	0%	0%	3%	0%	0%
FIRES, BUILDINGS	1%	2%	0%	8%	0%
FIRES, FOREST	0%	0%	1%	0%	0%
AVALANCHES	3%	1%	1%	4%	2%
EARTHQUAKES	63%	76%	13%	56%	32%
CONTAMINATION	0%	4%	0%	0%	0%
OTHER	6%	2%	1%	0%	1%
TOTAL	100%	100%	100%	100%	100%

Note: Includes the Armenia earthquake.

Table 7.3 presents the distribution of disaster impacts across types of disasters. The distribution is based on data for the five most recent years (1999-2003). Earthquakes and landslides are causing the most deaths. Storms are among the leading causes of damages to houses, but not in terms of destruction of houses. Floods and earthquakes are having the largest impact in terms of total number of people affected and houses destroyed and damaged.

Table 7.4: Number of People Affected (annual average 1997-2003)

	Number of People Affected	% of National Total	% of Department Population
CHOCO	63523	14%	15%
BOLIVAR	52619	12%	3%
CESAR	42494	10%	4%
MAGDALENA	36393	8%	3%
ANTIOQUIA	29031	7%	1%
SUCRE	26459	6%	3%
CORDOBA	20289	5%	2%
NARIÑO	19563	4%	1%
BOYACA	14327	3%	1%
ATLANTICO	13830	3%	1%
SANTANDER	13135	3%	1%
CAUCA	12331	3%	1%
VALLE	11196	3%	0%
TOLIMA	8823	2%	1%
HUILA	7974	2%	1%
AMAZONAS	7711	2%	10%
PUTUMAYO	7194	2%	2%
RISARALDA	6743	2%	1%
ARAUCA	6158	1%	2%
META	6125	1%	1%
GUAJIRA	4820	1%	1%
QUINDIO	4800	1%	1%
NORTE DE SANTANDER	4278	1%	0%
CAQUETA	4264	1%	1%
CUNDINAMARCA	3306	1%	0%
CALDAS	3237	1%	0%
CASANARE	3084	1%	1%
GUAVIARE	2426	1%	2%
GUAINIA	2324	1%	6%
VICHADA	1124	0%	1%
VAUPES	109	0%	0%
SAN ANDRES	19	0%	0%
All Colombia	439709	100%	1%

Note: Does not include the Armenia earthquake.

Table 7.4 presents the total number of people affected by natural disasters in each department, reflecting an annual average for the period 1997-2003. The Armenia earthquake is not included in order to provide a perspective on the geographic distribution of frequently or annually occurring disasters.

About 62 percent of all people affected are concentrated in 7 departments in the northern part and north-east Pacific part of Colombia, while only having 29 percent of the country's population. In these departments, an average of 2-4 percent of the population is affected annually by disasters, in contrast to well below 1 percent in the rest of the country. As much as 15 percent of the population was affected annually in Choco.

Cost of Natural Disasters.

There are no systematic and comprehensive estimates of the cost of damages from natural disasters, with the exception of the Armenia earthquake in 1999. According to CEPAL, the earthquake inflicted a cost of 2800 billion Pesos (US $ 1.8 billion at 1999 exchange rate), of which more than 70 percent was housing/building damages.[31]

The cost categories presented by CEPAL has in this report been adapted and applied to provide an order of magnitude of the annual cost of natural disasters.[32] The cost of annually occurring disasters is based on annual averages for the five-year period 1999-2003. This period was selected because of more detailed and comprehensive data available from the Department for Disaster Prevention and Attention at the Ministry of Interior and Justice.

Total estimated annual cost of natural disasters is presented in Table 7.5a-b. The cost of frequently or annually occurring disasters is presented in Table 7.5a. The largest cost is associated with damages to housing, infrastructure, and public buildings. A range in cost has been used for infrastructure and public buildings due to uncertainties of exact cost of damages.

Table 7.5b presents estimated annualized cost of major earthquakes. The cost estimates are based on the costs of the Armenia earthquake. The frequency of such an earthquake is highly uncertain. A range of 5-10 year frequency was applied in this report, and the total cost of a major earthquake is annualized. The "low" estimate represent a frequency of 10 years, and the "high" estimate a frequency of 5 years.

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[31] A presentation by Juan Carlos Echeverry (formerly at DNP) provides a summary of these estimates.

[32] Figures have also been adjusted for inflation to the year 2003.

In total, the annual cost of frequently occurring disasters and major earthquakes is estimated at 1330-2175 billion Pesos.

Table 7.5a: Estimated Annual Cost of Natural Disasters (except Major Earthquakes)

	Estimated Annual Cost (Billion Pesos)	
	"Low"	**"High"**
Deaths	25	35
Injured Persons	4	5
Missing Persons	6	10
Houses Destroyed	85	85
Houses Damaged	265	265
Lost/damaged furniture, equipment, and other losses per house	150	150
Roads, Bridges Damaged	180	360
Water Sypply and Sewage Systems Affected	55	105
Health Centers Affected	55	110
Schools, Education Centers, Community Centers Affected	60	120
TOTAL COST	885	1245

Table 7.5b: Estimated Annualized Cost of Major Earthquakes

	Estimated Annual Cost (Billion Pesos)	
	"Low"	**"High"**
Deaths	20	60
Injured Persons	10	35
Missing Persons	12	33
Houses Destroyed	70	140
Houses Damaged	45	85
Public Buildings damaged or destroyed	115	230
Lost/damaged furniture, equipment, and other losses per house	50	100
Other losses related to housing and buildings	15	30
Roads, Bridges Damaged	10	20
Water Sypply and Sewage Systems Affected	5	10
Health Centers Affected	10	20
Schools, Education Centers, Community Centers Affected	30	60
Energy sector	5	10
Commerce, Industry, Services	45	90
Miscellaneous	3	7
TOTAL COST	445	930

Unit costs of disaster impacts are presented in Table 7.6. These estimates are derived from the cost estimates of the Armenia earthquake presented by DNP (Echeverry) as discussed above. It should however be recognized that there is uncertainty as to the accuracy of applying these unit costs to disasters such as floods, storms and landslides. However, an improvement in the estimates would require a comprehensive assessment of the cost of damages across Colombia.

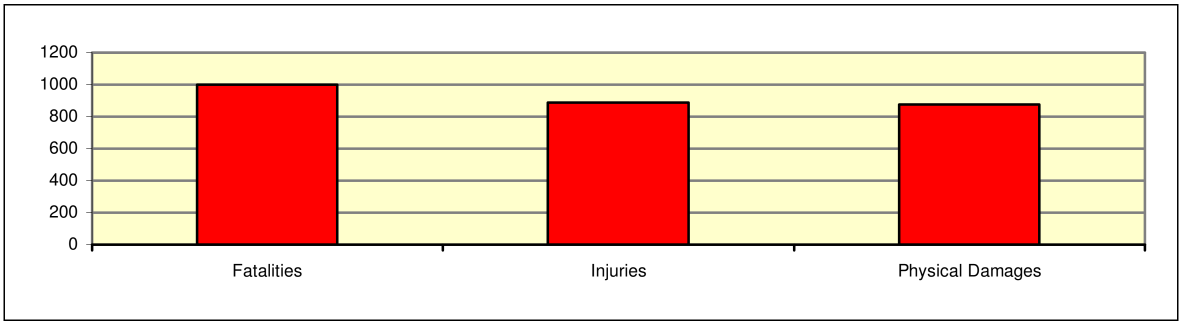
Table 7.6: Unit Costs Applied to Frequently Occurring Disasters

	Estimated Unit Cost (million Pesos) In year 2003
Destruction of Houses	33.2
Damages to Houses	16.8
Lost/damaged furniture, equipment, and other losses per house	8.1
Roads, Bridges Damaged	1 990
Water Sypply and Sewage Systems Affected	1 300
Health Centers Affected	13 650
Schools, Education Centers, Community Centers Affected	1 065

VIII. ROAD ACCIDENTS

The estimated mean annual cost of road accidents is presented in Figure 8.1, totaling 2770 billion Pesos. This estimate includes fatalities, injuries and physical damages to vehicles and other private and public property. Cost of fatalities represent about 36 percent of total cost, injuries about 32 percent of the cost, and physical damages about 32 percent.

Figure 8.1: Estimated Annual Costs of Road Accidents (Billion Pesos)



A total of 190 thousand road accidents were registered in 2002, and there were almost 43 thousand personal injuries and more than 6 thousand fatalities.[33] The total number of accidents increased steadily from the 1980s to 2001, with an almost doubling between 1990 and 2001. There was however a 20 percent decline in the number of accidents from 2001 to 2002. The number of personal injuries peaked in 1998 after an almost tripling from 1990. Injuries in 2002 were 20 percent lower than in 1998. The number of fatalities peaked in 1995, after a more than doubling from 1990. Fatalities in 2003 were 30 percent lower than in 1995.

About 18 percent of all road accident fatalities were among people older than 60 years of age, although they only constitute 7 percent of the population in Colombia. While there has been a significant reduction in fatalities in all other age groups since 1997, there has been no reduction among people over 60 years. The decline has also been minimal among 45-59 year olds. Almost 40 percent of all deaths are pedestrians, and 25 percent are motorcyclists and cyclists.

Published estimates by the National University of Colombia of the cost of road accidents, as reported by Fondo de Prevencion Vial, have been applied in this report. While

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[33] Fatalities declined to about 5500 in 2003. Figures on total accidents and personal injuries are not yet available for 2003.

the published estimates were based on the human capital approach (HCA) to estimate the cost of fatalities, a "low" to "high" range was applied in this report using HCA and value of statistical life (VSL) in order to be consistent and comparable to the estimated environmental costs for other categories. Total estimated annual costs are presented in Table 8.1.

Table 8.1: Estimated Annual Cost of Road Accidents

	Total Annual Cost (Billion Pesos)	
	"Low"	**"High"**
Total annual cost of fatalities (adults 20+ years)	390	1310
Total annual cost of fatalities (children <20 years)	155	155
Total annual cost of injuries	890	890
Total annual cost of accidents (physical damage)	875	875
TOTAL ANNUAL COST	2310	3230

Estimated unit costs of road accidents are presented in Table 8.2. These costs have been applied to total accidents, injuries and fatalities to estimate the costs presented in Table 8.1. The low end of the cost per fatality for adults is based on the HCA, with an average age of 43 years at time of death for adults (the average age is from accident statistics). The high end is based on VSL. The cost of fatality of children is based on the HCA, with an average age of 13 years at time of death (from accident statistics). The costs per injury and accident (physical damages) are based on figures reported by Fondo de Prevencion Vial, based on the study by National University of Colombia.

Table 8.2: Estimated Unit Costs of Road Accidents

	Unit Costs (Million Pesos)
Cost per fatality (adults 20+ years)	85 -290
Cost per fatality (children < 20 years)	153
Average cost per injury (million Pesos)	20.8
Average cost per accident (million Pesos)	4.6

IX. DEFORESTATION

Forest cover in Colombia is estimated to have been 92 percent before large-scale human settlements (WRI 2003). Today, forest cover is about 45 percent of total land area. While this is still above the world average of 30 percent, forest cover in Colombia is distributed extremely unevenly across the country.[34]

The cost of deforestation is very difficult to estimate. Some of these costs are already included in the cost of natural disasters, as deforestation is believed to contribute to increased frequency and severity of flooding and landslides. Deforestation is likely also contributing to the agricultural land erosion problems in many parts of Colombia. It is also associated with impacts on water resources quality. However, it is practically very difficult to identify and isolate the cost of deforestation at the national level. In what follows are some perspectives on the historic processes of deforestation.

About two-third of remaining forest area is located in the six Departments in the south-eastern part of Colombia east of the mountain chains.[35] These Departments represent one-third of total land area, and have less than 2.5 percent of the total population of the country. Forest cover in these Departments averages almost 85 percent.

The four remaining Departments east of the mountain chains (and north of the other six Departments), with 3 percent of the country's population, have now only an average of 17 percent forest cover left.[36] This represents 8 percent of Colombia's forest area. Of the remaining forest area, 18 percent of total is located in four of the coastal Departments[37], and Bolivar and Antioquia. Forest cover in these six Departments averages 42 percent.

The remaining 17 Departments, including Bogota, have only 10 percent of the country's forest area (averaging 18 percent forest cover), but two-thirds of the country's population. About 60 percent of agricultural cropped land is located here, on 23 percent of total land area. Rural population density is close to 25 per km^2, compared to about 2 per km^2 in the ten Departments east of the mountains.

A regression analysis was conducted to shed some light on the long-term historic process of forest losses in Colombia. The analysis is based on data for each Department on

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[34] The following discussion and analysis is based on forest cover data from IDEAM 2002.

[35] In alphabetical order: Amazonas, Caqueta, Guainia, Guaviare, Putumayo, and Vaupes.

[36] In alphabetical order: Arauca, Casanare, Meta, and Vichada.

[37] Cauca, Choco, Cordoba, and Narino.

hectares of forest area (1996), total land area, land area under cultivation (1991), and estimates of rural population (2002). The results are presented in Table 9.1. As expected, the coefficient for land area is highly significant, implying that larger Departments in general have larger forest area (although not necessarily higher forest cover). The coefficient for land under cultivation indicates that a one-hectare increase in cultivation is associated with 4.1 hectares of loss in forest area. Similarly, forest loss associated with a one-person increase in rural population is 1.5 hectares. An intercept dummy was included for the five most northern Departments east of the mountains.[38] These Departments now have forest cover that is substantially lower than rural population and land under cultivation would indicate.

Table 9.1: Regression Analysis of Forest Cover (Ha)

	Coefficient	t-statistics
Land area (km^2)	87.7	18.2
Land under cultivation (ha)	-4.1	-2.6
Rural population	-1.5	-2.6
Dummy	-2594237	-6.7
Constant	214755	0.8
R^2	0.94	

The coefficients in Table 9.1 were then applied to calculate (predict) the forest area for each Department that one would expect based the variables in the regression equation. The difference between actual and predicted forest areas is particularly large in five Departments. In total, the forest areas in these five Departments are more than 18 million hectares less than expected by their size of rural population and land under cultivation, clearly indicating additional forces of deforestation. Atlantico, Boyaca, La Guajira, Magdalena, Norte de Santander, and Santander also have significantly less forest than expected. In contrast, some Departments have a larger forest area than expected by rural population size and land area under cultivation. Most notably, Bolivar has close to 50 percent forest cover, versus an expected cover of 30 percent.

While Colombia on average has a relatively high forest cover, some parts of the country is quite deforested. The relatively deforested areas are large sections east of the

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[38] Arauca, Casanare, Guainia, Meta, and Vichada.

mountains, and parts of the country with the highest population shares. In the latter parts, 7 Departments have less than about 10 percent forest cover.

Land under cultivation and the size of rural populations seem to explain a substantial part of the variations in forest cover across Departments. It is however clear that other factors have contributed substantially to forest losses in some parts of the country.

X. VALUATION OF MORTALITY

Two distinct methods of valuation of mortality are commonly used by economists to estimate the social cost of premature death, i.e., the human capital approach (HCA) and the concept of value of statistical life (VSL). The first method was dominant in the past but has increasingly been replaced by the VSL approach in the last couple of decades.

In this report, the HCA has been applied as a lower bound and VSL as a higher bound in estimating the cost of adult mortality. For child mortality, the HCA has been applied.

Human Capital Approach.

The HCA is based on the economic contribution of an individual to society over the lifetime of the individual. Death involves an economic loss that is approximated by the loss of all future income of the individual. Future income is discounted to reflect its value at the time of death. The discount rate commonly applied is the rate of time preference. Thus the social cost of mortality, according to the HCA, is the discounted future income of an individual at the time of death. If the risk of death, or mortality risk, is evenly distributed across income groups, average expected future income is applied to calculate the social cost of death. Mathematically, the present value of future income is expressed as follows:

$$PV_0(I) = \sum_{i=k}^{i=n} I_0(1+g)^i/(1+r)^i \qquad (1)$$

where PV_0 (I) is present value of income (I) in year 0 (year of death), g is annual growth in real income, and r is the discount rate (rate of time preference). As can be seen from (1), the equation allows for income to start from year k, and ending in year n. In the case of children, we may have $i \in \{20,\ldots,65\}$, assuming the lifetime income on average starts at age 20 and ends at retirement at age 65. An annual growth of real income of 2 percent, and a discount rate of 3 percent have been applied to Colombia in this report.

Several important issues are often raised regarding the HCA. The first issue is regarding the application of this valuation approach to individuals that do not participate in the economy, i.e., to individuals not having an income, such as the elderly, family members taking care of the home, and children. One may think of an extension of the HCA that recognizes the value of non-paid household work at the same rate as the average income earner, or at a rate equal to the cost of hiring a household helper. In this case, the HCA can be applied to the death of non-income earners and children (whether or not children will become income earners or take care of the home during their adult life). In the case of the elderly, the HCA would not assign an economic value to old individuals that have either retired from the workforce or do not make significant contributions to household work. This obviously a serious shortcoming of the HCA approach.

The second issue regarding the HCA is that the social cost of mortality is limited to the economic contribution of an individual, or value of household work if the individual takes care of the home. Alternative approaches to the valuation of mortality, or social cost of mortality, have therefore been developed and increasingly been applied in the past couple of decades. These approaches employ a concept or measure called VSL, which nowadays is much more widely used in public policy than the HCA approach.

The estimated cost of mortality in Colombia based on HCA is presented in Table 10.1. Average annual income is approximated by GDP per capita, corresponding to around 17500 Pesos per working day. The estimates are from equation (1).

Table 10.1: Cost of Mortality (per Death) using HCA

	Average Number of Years Lost	Million Pesos
Adults:		
Mortality from Urban Air Pollution	7.5	33
Mortality from Road Accidents	22	85
Mortality from Indoor Air Pollution	6	26
Mortality from Natural Disasters	37*	135
Children:		
Mortality from Diarrheal Illness and Indoor Air Pollution	65	135
Mortality from Road Accidents	52	153

* This is an average for all individuals. Age specific data on mortality from natural disasters were not obtained. It should be noted that this does not significantly affect the estimated cost of natural disasters because most of the cost is associated with physical damages.

Value of Statistical Life.

While the HCA involves valuation of the death of an individual, VOSL is based on valuation of mortality risk. Everyone in society is constantly facing a certain risk of dying. Examples of such risks are occupational fatality risk, risk of traffic accident fatality, and environmental mortality risks. It has been observed that individuals adjust their behavior and decisions in relation to such risks. For instance, individuals demand a higher wage (a wage premium) for a job that involves a higher than average occupational risk of fatal accident, individuals may purchase safety equipment to reduce the risk of death, and/or individuals and families may be willing to pay a premium or higher rent for properties (land and buildings) in a cleaner and less polluted neighborhood or city.

Through the observation of individuals' choices and willingness to pay for reducing mortality risk (or minimum amounts that individuals require to accept a higher mortality risk), it is possible to measure or estimate the value to society of reducing mortality risk, or, equivalently, measure the social cost of a particular mortality risk. For instance, it may be observed that a certain health hazard has a mortality risk of a magnitude of 1/10 000. This means that one individual dies every year (on average) for every 10 000 individuals. If each individual on average is willing to pay 30 thousand Pesos per year for eliminating this mortality risk, then every 10 000 individuals are collectively willing to pay 300 million Pesos per year. This amount is the VSL. Mathematically it can be expressed as follows:

$$VSL = WTP_{Ave} * 1/R \qquad (2)$$

where WTP_{Ave} is the average willingness-to-pay (Pesos per year) per individual for a mortality risk reduction of magnitude R. In the illustration above, R=1/10 000 (or R=0.0001) and WTP_{Ave}= 30 000 Pesos. Thus, if 10 individuals die each year from the health risk illustrated above, the cost to society is 10* VSL = 10*300 million Pesos = 3 billion Pesos .

Estimating VSL

The main approaches to estimating VSL are through revealed preferences and stated preferences. Most of the studies of revealed preferences are hedonic wage studies, which estimate labor market wage differentials associated with differences in occupational mortality risk. Most of the stated preference studies rely on contingent valuation methods (CVM), which in various forms ask individuals about their willingness-to-pay (WTP) for mortality risk reduction.

Mrozek and Taylor (2002) provide a meta-analysis of VSL estimates from labor market studies from around the world. They identify a "best-practice" sample and control for industry characteristics other than occupational mortality risk that also affect inter-industry wage differentials. The study concludes that a range for VSL of US $1.5-2.5 million can be reasonably inferred from labor market studies when "best-practice" assumptions are invoked.

It should be noted that the VSL range inferred by Mrozek and Taylor is substantially lower than average VSL estimated in other meta-analysis studies. Some of these studies identify a mean VSL on the order of US $6 million. However, the contribution by Mrozek and Taylor to the meta-analysis literature is their careful assessment of a large sample of VSL estimates and inclusion of industry control variables to better assess wage differentials associated with mortality risk.

Benefit Transfer

There are no studies of VSL conducted in Colombia. This implies that values have to be transferred from studies in other countries. The overwhelming majority of VSL studies have been conducted in countries with substantially higher income level than in Colombia. VSL estimates from these countries must therefore be adjusted to Colombia.

One commonly used approach in benefit transfer is to apply income elasticities.[39] Viscusi and Aldi (2002) estimate an income elasticity of VSL in the range of 0.5-0.6 from a large sample of VSL studies. The range in income elasticity is however influenced by three unusually high estimates of VSL from labor market data from one state in India. Leaving out these three studies provides an income elasticity of about 0.80.

However, the most appropriate income elasticity to apply to middle-income countries, such as Colombia, remains uncertain. The reason for this is that the income level in Colombia falls far outside the range of income in the sample of countries from which the income elasticities of VSL is estimated in the empirical literature. A prudent approach might be to apply an elasticity of 1.0 in order to reduce the risk of overstating the cost of mortality in Colombia.

Table 10.2 presents the VSL for Colombia from benefit transfer based on the range of VSL reported by Mrozek and Taylor (2002) and an income elasticity of 1.0. These figures

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[39] The income elasticity is the percentage change in VSL per percentage change in income.

are substantially higher than the ones from the HCA, especially for urban air pollution and indoor air pollution adult mortality. A comparison is presented in Table 10.3.

Table 10.2: Estimated Value of Statistical Life in Colombia

	"High"	**"Low"**	**Source:**
Average VSL in high-income countries (million US $)	2.5	1.5	Mrozek and Taylor (2002)
Average GDP/capita in high-income countries (US $)	30 000	30 000	World Bank*
GDP per capita in Colombia (US $ in 2001)	1910	1910	World Bank
Income elasticity	1.0	1.0	
Estimated VSL in Colombia (million Pesos)**	365	220	Benefit transfer

* weighted average GDP per capita, based on the sample in Mrozek and Taylor (2002). ** Using an exchange rate of 2300 Pesos per US $ in 2001.

Table 10.3: A Comparison of HCA and VSL estimates applied to Colombia

	Ratio of VSL/HCA
Adults:	
Mortality from Urban Air Pollution	6.7 - 11
Mortality from Road Accidents	2.6 – 4.3
Mortality from Indoor Air Pollution	8.5 - 14
Mortality from Natural Disasters	1.6 – 2.7
Children:	
Mortality from Diarrheal Illness and Indoor Air Pollution	1.6 – 2.7
Mortality from Road Accidents	1.4 - 2.4

XI. COST OF REMEDIATION

This report has provided estimates of the annual cost of environmental damage for several categories of the environment, and indicated the areas with the highest national, urban and rural costs. However, it is important to assess the cost of remediation, i.e., the cost of actions to reduce the damage cost, and to estimate the benefits of such actions. This would assist in identifying cost-effective actions and in setting environmental priorities that provide positive net benefits to society.

An analysis of cost-effectiveness and cost-benefits will be undertaken by a study that is to follow this report. This section will only provide some relevant evidence from other studies for the environmental health categories assessed in this report (water, sanitation and hygiene, and urban air pollution) and some perspectives on costs and benefits of indoor air pollution reduction.

Water, Sanitation and Hygiene

Very few studies provide estimates of the cost-effectiveness of reducing diarrheal illness and/or diarrheal child mortality. While oral rehydration therapy (ORT) proved to be a very cost-effective intervention to reduce diarrheal child mortality, ORT does not prevent or reduce the incidence of diarrheal illness.

Larsen (2003) undertook a global cost-effectiveness analysis of interventions that reduce diarrheal illness and child mortality, and estimates the cost of preventing child mortality for four regions and two countries. This is presented in Table 11.1 Cost per death prevented in the region of Latin-America and the Caribbean (LAC) is substantially higher than in the other regions. This is because of the already lower child mortality in LAC and higher intervention costs than in the other regions. The latter is associated with higher labor costs and other costs of service provision.

In all regions and the two countries in Table 11.1, hygiene improvement is found to be the most cost-effective intervention of those considered in Larsen (2003). The same conclusion is reached by Varley et al (1998). It should however be recognized that the health benefits of water, sanitation and hygiene interventions are not independent of each other. As can be inferred from Esrey and Habicht (1988), hygiene awareness is likely to provide larger health benefits if plenty of water and opportunties for improved sanitary behaviour is available.

Another important aspect of the cost-effectiveness analysis by Larsen (2003) is that health benefits are limited to reduction in child mortality. As presented in this report, the cost of diarrheal morbidity has a high cost in Colombia. A complete cost-effectiveness analysis should therefore include diarrheal morbidity. While this is very data intensive at a regional level, it will need to be included in an analysis for Colombia.

Table 11.1: Cost of Preventing the Death of a Child (US $)

	India	China	Other Asian countries	Middle eastern crescent	Sub-Saharan Africa	Latin America/ Caribbean
Provide safe water supply	8,000	23,000	9,000	6,000	1,000	32,000
Provide safe sanitation facilities	5,000	23,000	13,000	11,000	3,000	57,000
Child immunization	1,000	4,000	1,800	1,300	300	5,700
Female literacy	5,000	25,000	11,000	12,000	3,000	150,000
Hygiene improvement ("high" mortality reduction case)	400	1,600	600	500	300	2,000
Hygiene improvement ("low" mortality reduction case)	700	2,300	1,000	1,000	500	2,900

Source: Reproduced from Larsen (2003).

Urban Air Pollution

This report assessed the cost of particulate pollution in terms of health effects. Some of the main sources of particulate pollution in urban areas in Colombia are traffic and industry. An analysis of cost-effectiveness and benefit-cost ratios of interventions to reduce particulate emissions requires a detailed emission inventory, emission coefficients from existing emission sources, as well as information about emission reductions from potential interventions. One potentially important source of particulate emissions in Colombia is the use of vehicle diesel. Diesel used in Colombia is often of high sulfur content that increases particulate emissions and makes modern diesel vehicle emission control technology ineffective.

Larsen (1997) provides estimates of cost and benefits of select interventions to reduce particulate emissions in Casablana, Morocco. The benefits are the value of health improvements. The estimated benefit-cost ratio of cleaner diesel for road transport is on the order of 3-3.5. An effective inspection and maintenance program for diesel buses provides an estimated benefit-cost ratio of 2-3, and a ratio of 1-2 for trucks used predominantly in urban areas. Particulate abatement technology for buses is also found to give higher benefits than cost, with a benefit-cost ratio on the order of 2-3.

The study also provides some assessment of particulate emission reductions from industry. For example, a reduction in sulpfur content in heavy fuel oil is estimated to give a benefit-cost ratio of 3-3.3.

Indoor Air Pollution

Use of natural gas and propane has steadily increased in Colombia, including in rural areas. This fuel substitution away from fuel wood is likely the long term solution to indoor air pollution from wood smoke. The mean estimated cost of health impacts of indoor air pollution presented in this report is equivalent to almost 300 thousand Pesos per household per year for those households using fuel wood. This amount is equivalent to the cost of seven bottles of propane (17.7 gl bottles) with an energy content equivalent to almost 10 kWh of electricity per day. Thus the health benefits of eliminating fuel wood would exceed the cost of substitution to propane if the household energy requirement is less than 10 kWh per day (for energy needs now met by fuel wood), not even counting the savings in fuel wood cost. For natural gas, the health benefits would exceed to cost for household energy requirement up to 20 kWh per day.

A more detailed assessment of fuel wood use, stove efficiency, and fuel wood cost will be undertaken in the forthcoming report on cost-effectiveness to estimate the benefit-cost ratio of fuel substitution.

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