Annex 4 A

Health Costs of Environmental Damage

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I. INTRODUCTION

This report provides estimates of the costs of environmental health risks in Honduras from (i) urban air pollution (PM), (ii) inadequate potable water supply, sanitation and hygiene, and (iii) indoor air pollution. These are the three areas of environmental health risks that most likely represent the largest burden on the health of the Honduran population. Due to data constraints, only a limited number of diseases (and health endpoints) from these environmental risk factors have been considered. For example, the cost of water pollution is only captured in terms of diarrheal illness, while other costs relating to the potential impacts on health of water contaminated with heavy metals and chemicals are not estimated.

The monetary valuation of environmental damages, and the quantification of environmental damage, involves many scientific disciplines including environmental, physical and biological, health sciences and epidemiology, and environmental 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, and consequent environmental health risks. Results from these new analyses are useful to policy makers and stakeholders who are involved in setting environmental objectives and priorities. When expressed in monetary terms, these results can be instrumental in the allocation of public and private resources across diverse socio-economic development goals.

Different types of costs relating to environmental health effects are included in this report. Economic costs include reduced productivity from ill health and medical treatment cost; while other costs are associated with reduced well-being and quality of life. The latter include an unclean environment, pain and suffering from ill health and disability, and reduced quality and quantity of leisure time from illness.

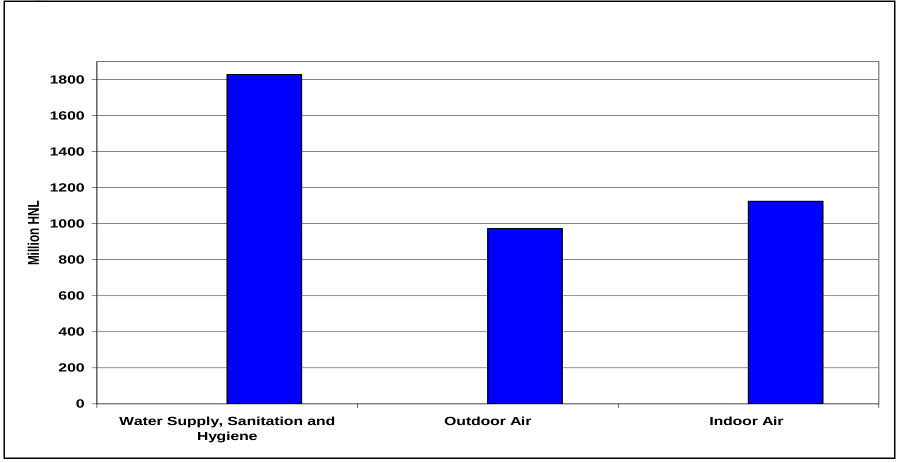
When estimating the cost of environmental damage, a distinction should be made between financial and economic costs. Economic costs are preferred (where feasible) as they capture the cost and reduced welfare to society as a whole. Financial costs of health services, on the other hand, include only what an individual pays –which may be substantially less than the full (unsubsidized) cost of providing these services. Another example illustrating the difference relates to the time lost to illness or care-giving for sick family members. If the person who is sick, or the caregiver does not earn an income, the financial costs of time losses is zero. However, if that person is normally engaged in activities that are valuable for the family, then the time losses represent an economic cost in terms of reduced quality or quantity of these activities, or of reduced time available for leisure activities. In economics and welfare analysis, this (non-market) economic cost is normally valued at the opportunity cost of time, i.e. the salary, or a fraction of the salary that the individual could have potentially earned.

II. ANNUAL COST OF ENVIRONMENTAL HEALTH EFFECTS

National Cost

The mean estimated annual cost associated with environmental health risks in Honduras totals nearly 4 billion L. per year (US $0.2 billion) (see Figure 2.1). The highest costs are from inadequate water supply, sanitation and hygiene –amounting to 1,830 million L (ranging from 1420-2240 million L), or 46% of the total. Next are the costs from indoor air pollution amounting to 1,125 million L (ranging from 770-1480 million L), or 29% of the total). And finally, the costs from urban (outdoor) air pollution total 970 million L (ranging from 280-1660 million L), or 25% of the total[1].

Figure 2.1: Annual Cost of Environmental Health Effects (Million L. per year)



Per capita are based on the population's exposure to environmental health risks. Improper hygiene practices, and to some extent inadequate potable water supply and sanitation –which affect most of the population —has an annual cost of nearly 950 L. per person per year. Estimated costs of urban air pollution (PM) –only considered for populations in cities with more than 100 thousand inhabitants –amount to nearly 500 L. per person per

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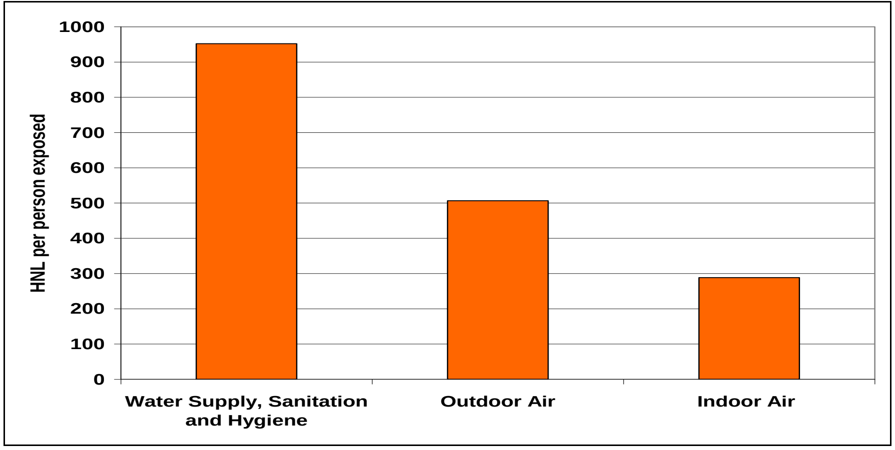
[1] A "low" and "high" estimate of annual cost is presented in Table 2.1. The range for water supply, sanitation and hygiene is from uncertainties of diarrheal child mortality rate. The range for urban outdoor air pollution is mainly from the use of two valuation techniques to estimate the social cost of premature mortality. The range for indoor air pollution is mainly from uncertainty of exposure level to indoor smoke from solid fuels, and thus a range was applied for the level of health risk.

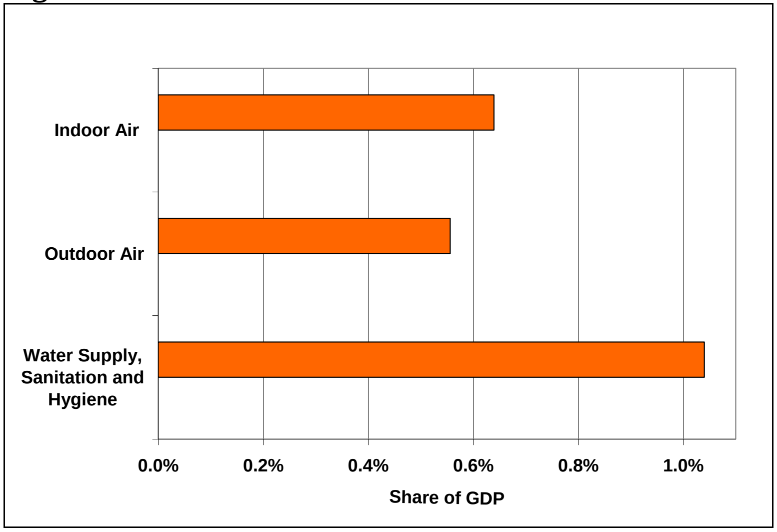
year. Indoor air pollution from solid fuels –which mostly impacts the rural population –has an estimated cost of 300 L. per person per year.

Figure 2.2: Estimated Cost of Environmental Health Effects per Person Exposed (L. per Year)



The mean estimated annual costs associated with the three main environmental health risks in Honduras totals 2.2 percent of the country's GDP (see Figure 2.3)[2] –with costs from inadequate water supply, sanitation and hygiene accounting for 1.0 percent; and costs from indoor air pollution and urban air pollution each accounting for about 0.6 percent of the GDP.

Figure 2.3: Annual Cost of Environmental Health Effects (% of GDP)



Note: % of GDP in 2006.

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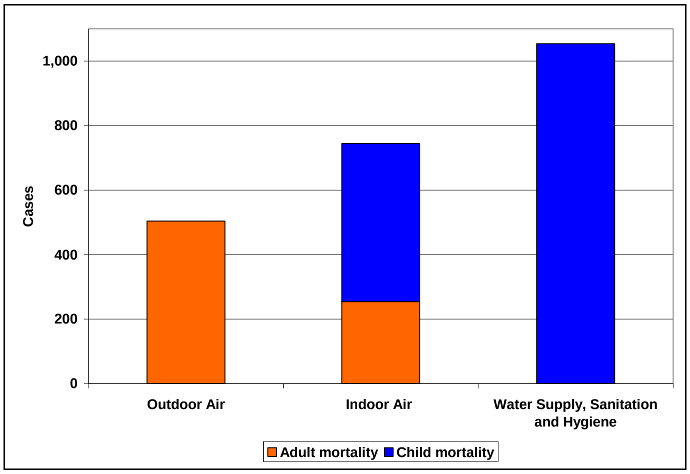
[2] Using GDP in 2004.

The annual costs of environmental health risks are distributed unevenly across the Honduran population –differing by age group (affecting children versus adults), and by location (affecting rural versus urban populations).

By age : Due to their differential exposures and higher susceptibilities to infections, children are disproportionately impacted by environmental health risks. Overall, 50% of annual costs represented health risks to children under five. In terms of specific environmental risk factors, about 22 percent of under-5 child mortality is attributed to inadequate water supply, sanitation and hygiene and indoor air pollution, while about 3 percent of adult mortality is attributed to outdoor and indoor air pollution (see Figure 2.5).

Figure 2.5: The Burden of Mortality Related To Environmental Causes

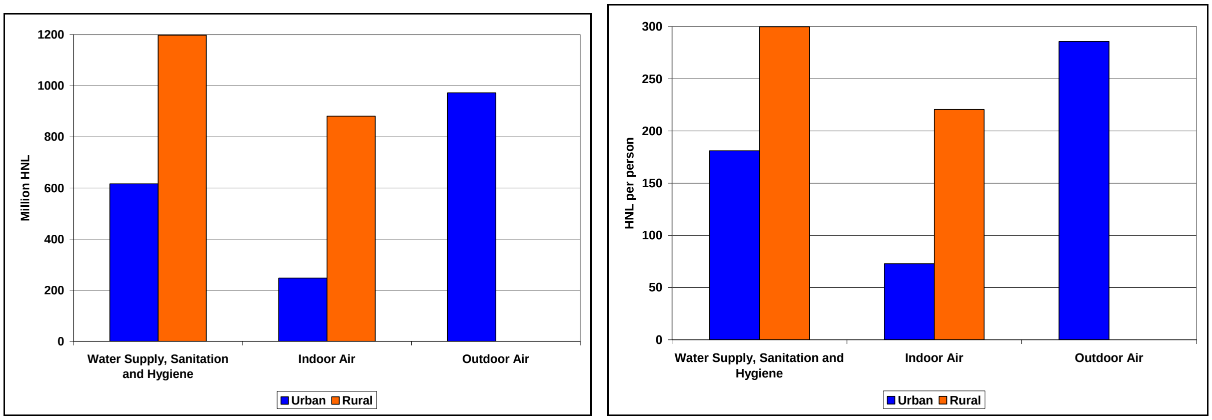


By location: In Honduras, the annual costs of environmental health effects are estimated to be about 2100 million L in urban areas, and around 1800 million L in rural areas. Given the distribution of population between urban and rural areas (46 and 54 percent, respectively), this translates into a slightly higher per capita basis in rural areas, although time value in rural areas is substantially lower. For health effects from inadequate water supply, sanitation and hygiene, and indoor air pollution the rural cost is substantially higher than the urban cost. This is mainly because of higher child mortality and morbidity in rural areas, and a substantially higher children population share in rural areas (children bear a disproportionate burden of health effects from these risk factors).

Rural populations in Honduras face a disproportionate burden of environmental cost for the rural population from water, sanitation and hygiene, and indoor air pollution (see

Figure 2.7). The cost per capita from indoor air pollution attributed health effects is about 3 times higher in rural areas than in urban areas. It is 65 percent higher for water, sanitation and hygiene related health effects. This is an important concern because the rural population is generally much poorer than the urban population and therefore in a worse position to cope with ill health.

Figure 2.6-2.7: Urban-Rural Annual Costs of Health Effects –Total and Per Capita

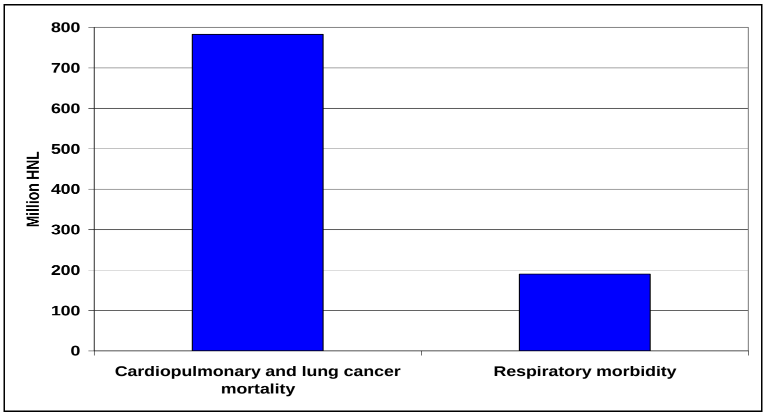


The disproportionate health burden on the rural population is to a large extent associated with higher child mortality from diarrheal illness from inadequate water supply, sanitation and hygiene, and from respiratory illness from indoor air pollution. These issues are discussed in more detail in sections IV and V.

III. URBAN AIR POLLUTION

The mean estimated annual cost of PM urban air pollution in Honduras –based on particulate matter (PM) exposure only –is estimated at about 972 Million L. or about 0.7 percent of the country's GDP in 2006. Of this cost, about 80 percent is associated with mortality, and 20 percent with morbidity (Figure 3.1). Measured in terms of DALYs, mortality represents 42 percent and morbidity 58 percent.

Figure 3.1: Annual Costs of Urban Air Pollution (Million L.)



There is substantial research evidence from around the world that urban (outdoor) 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 (2005). Among the various air pollutants, particulate matter (PM), [3] and especially particulates of less than 10 microns in diameter (PM 10) or smaller has shown the strongest association with these health endpoints. 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. Other gaseous pollutants (SO_2, NOx, CO, and ozone) are generally not thought to be as damaging to health as fine particulates. However, SO_2 and NOx may have indirect health consequences because they can react with other substances in the atmosphere to form particulates.

This report focuses on the health effects from fine particulates (PM10 and PM2.5). There are three main steps to quantifying the health impacts from air pollution. *First*, the

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[3] Also called suspended particulates.

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.

Urban air pollution costs were estimated for Tegucigalpa and for the other cities in Honduras (San Pedro Sula, La Ceiba, Choloma, and El Progreso) with a population of over 100,000. The urban population exposed to air pollution was estimated at 2 million or 53 percent of total urban population in Honduras (BCH, 2007).

The PM_{10} annual average standard in Honduras corresponds to the standard established by US EPA (50 ug/m3). However, based on latest studies WHO advises that there is no threshold in PM_{10} pollution, even lower levels could correspond to pretty substantial health impact if a lot of population is exposed. For the purposes of regulation WHO is constantly lowering PM_{10} annual average standard. In 2005 air quality guideline for PM10 annual average concentration was established at 20 ug/m3[4]. California EPA established 20 ug/m3 also.

While PM_{10} is usually monitored, the proportion of even finer particulate matter ($PM_{2.5}$) needs to be estimated. Typically, the ratio of $PM_{2.5}$ in PM_{10} varies from 0.15 up to 0.96 for different pollution sources (See Table 3.1). For Tegucigalpa and other cities, the conservative estimate of 0.5 recommended by WHO is applied in this report, but the ratio may potentially be higher due to a high transportation fleet growth (5 percent annual growth, responsible for 70 percent of total air pollution, EIA estimate for all Central American countries, http://www.eia.doe.gov/emeu/cabs/centamenv.html).

Table 3.1: Emission Sources: Ratio of PM $_{2.5}$ and PM $_{10}$

	$PM_{2.5}/PM_{10}$ 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

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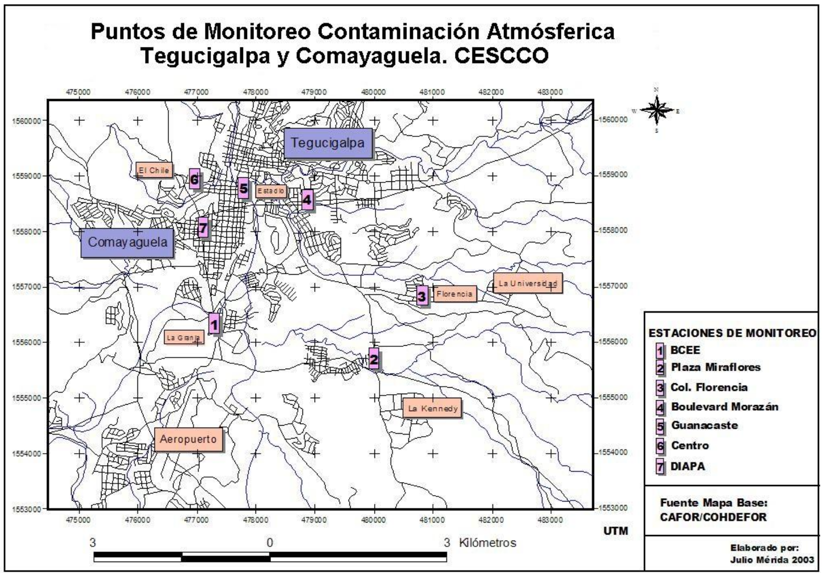
[4] http://www.euro.who.int/Document/E90038.pdf

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: Larson, 2004b

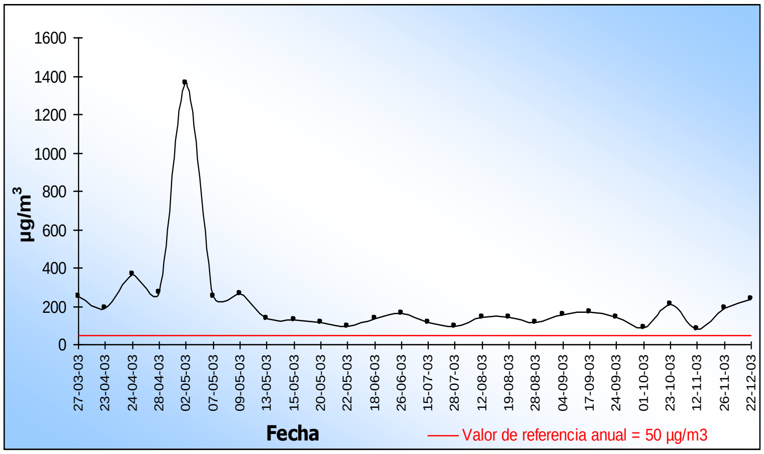
In the metropolitan area of Tegucigalpa there are 7 air quality monitoring stations, two of which measure PM_{10} (Figure 2). Figure 3.3 shows the levels of PM_{10} at the Colonia Florencia in 2003.

Figure 3.2: Monitoring Stations in Tegucigalpa



Source: http://www.cescco.gob.hn/Contenido/CalAire/2003.htm

Figure 3.3: PM_{10} concentrations in Tegucigalpa (Colonia Florencia), Jan-Dec 2003 (ug/m3)



Source: http://www.cescco.gob.hn/Contenido/CalAire/2003.htm

Results from these monitoring stations show that the annual average PM_{10} standard was exceeded in this area in 2002-2003 (see http://www.cescco.gob.hn/Contenido/CalAire/2003.htm). With only some stations measuring PM_{10} concentrations, accuracy of these results is a concern. The accuracy of health data is also a concern – with high uncertainty about the quality of data on mortality causes in Honduras. Underreporting also compounds the issue, with only about 50 percent of total deaths being registered with corresponding mortality causes (http://www.paho.org/English/DD/AIS/cp_340.htm).

Annual average PM_{10} levels in other cities (San Pedro Sula, La Ceiba, Choloma, and El Progreso) were assigned to these cities based on World Bank modeling of PM_{10} concentrations.[5] $PM_{2.5}$ concentrations were estimated from PM_{10} concentrations using proposed by WHO (2004) default ratio $PM_{2.5}$ / PM_{10}=0.5.

Dose Response Coefficients

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 of 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.

While the mortality effects are based on $PM_{2.5}$, the morbidity effects assessed in most worldwide studies are based on PM_{10}. Accordingly, dose response coefficients from Ostro (1994) and Abbey et al (1995) have been applied for morbidity effects. 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 3.2.

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[5] www.worldbank.org/nipr/Atrium/mapping.html.url.

Table 3.2: 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 mortality coefficient; Ostro (1994) and Abbey et al (1995) for morbidity coefficients.

In order to apply the mortality coefficient in Table 3.2 to estimate mortality from urban air pollution in Honduras, baseline data on total annual cardiopulmonary and lung cancer deaths are required. We applied WHO estimation for Honduras, that 30 percent of all deaths in the country have cardiopulmonary origins (http://www.who.int/whosis/en/).

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.

An estimate of annual incidence of chronic bronchitis (CB) is also required. In the absence of CB incidence data for Honduras (or for specific cities), the rate for the WHO AMRO B region of which Honduras is part (WHO (2001) and Shibuya et al (2001)) is used.

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. The coefficients are expressed as cases per 100,000 in the absence of incidence data for Honduras.

The health effects of air pollution are converted to disability adjusted life years (DALYs) to facilitate a comparison to health effects from other risk factors. DALYs per 10 thousand cases of various health end-points are presented in Table 3.3.

Table 3.3: 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

Note: DALYs are calculated using a discount rate of 3% and full age weighting based on WHO tables. Estimates of DALYs for the morbidity end-points are from Larsen (2004a,b).

A measure of the welfare cost of morbidity is often based on the willingness-to-pay (WTP) to avoid or reduce 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 Oates 1992), and reflects the value that individuals place on avoiding pain and discomfort. With insufficient numbers of WTP studies from Honduras, the cost-of-illness (COI) approach (mainly medical cost and value of time losses) is used to proxy for the cost of pain and discomfort, with GDP per capita used to value DALYs.

To estimate the value of time for adults, economists commonly apply a range of 50-100 percent of wage rates. In this report, 75 percent of the estimated average urban wage in Honduras (230 L. per day[6]) has been applied for *both* income earning and non-income earning individuals. There are two reasons for applying the rate to non-income earning individuals. First, most non-income earning adult individuals provide household functions that have a value. Second, there is an opportunity cost to the time of non-income earning individuals, as they could choose to join the paid labor force.

There is very little information about the frequency of doctor visits, emergency visits and hospitalization for CB patients. Schulman et al (2001) and Niederman et al (1999) provide some information for the United States and Europe.[7] Figures derived from these studies have been applied to Honduras. 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.

To estimate the cost of a new case of CB, the medical cost and value of time losses have been discounted over a 20-year 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.

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[6] Estimated from GDP per capita, ratio of minimum wage in urban/rural areas and labor force participation ratio in Honduras. Also, see World Bank 2006, p. 74, table 5.

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

Table 3.4: Baseline Data for Cost Estimation

	Baseline	**Source:**
Cost Data for All Health End-Points:		
Cost of hospitalization (L. per day)	440	WHO estimates and per consultations with medical service providers, and health authorities
Cost of emergency visit (L.) - urban	300	
Cost of doctor visit (L.) (mainly private doctors) – urban	100	
Value of time lost to illness (US per day)	150	75% of urban wages in Honduras

Estimated Health Effects

Estimated annual health effects of ambient particulate outdoor air pollution in Honduras are presented in Table 3.5. There are an estimated 504 premature deaths, and 708 new cases of chronic bronchitis in Honduras every year. Annual hospitalizations due to pollution are estimated at 1,800, and emergency room visits/outpatient hospitalizations at 35 thousand per year. Cases of less severe health impacts are also presented in Table 3.5.

Table 3.5: Estimated Annual Health Effects of Urban Outdoor Air Pollution

Health end-points	**Total Cases**	**Total DALYs**
Premature mortality	504	3,777
Chronic bronchitis	708	1,558
Hospital admissions	1,800	29
Emergency room visits/Outpatient hospital visits	35,310	159
Restricted activity days	5,349,800	1,605
Lower respiratory illness in children	96,262	626
Respiratory symptoms	17,026,320	1,277
TOTAL		9,031

Estimated Cost of Health Effects

The total estimated annual costs associated with urban air pollution ranges between 259-1644 million L. (see Table 3.6). Mortality range relates to application of two different approaches to estimation of the value of mortality risk: lower estimate is obtained after application of HCA approach, higher estimate is based on the VSL and benefit transfer (explanation see section VI).

Table 3.6: Estimated Annual Cost of Health Impacts (Million L.)

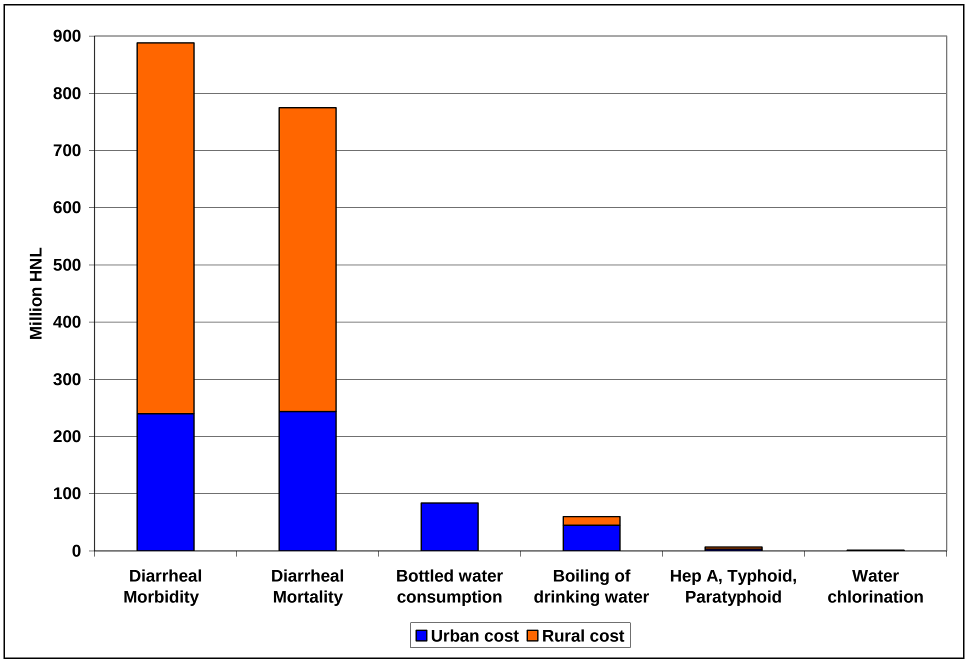
Health categories	**Total Annual Cost**	**Percent of Total Cost**
Mortality	90-1475	80%
Morbidity:		
Chronic bronchitis	3	0.4%
Hospital admissions	5	0.6%
Emergency room visits/Outpatient hospital visits	11	1.3%
Restricted activity days (adults)	144	15.0%
Lower respiratory illness in children	26	2.7%

Respiratory symptoms (adults)	0	0.0%
Total cost of Morbidity	190	20%
TOTAL COST (Mortality and Morbidity)	259-1644	100%

IV. WATER, SANITATION, AND HYGIENE

The estimated annual cost associated with inadequate water supply, sanitation and hygiene ranges from 1418-2238 million L per year, with a mean of 1828 Million L – equivalent to about 1 percent of GDP in 2006. These costs include those relating to mortality in children, morbidity in children and adults, and avertive expenditures (bottled water consumption, water chlorination, and water boiling) (see Figure 4.1). The estimated costs of under-5 child diarrheal mortality are about half of the costs of morbidity in children and adults. Child mortality is valued using the human capital approach (HCA).[8] The lower and upper bounds of estimated costs reflect an under-5 child diarrheal mortality of 12.6-21 percent of total under-5 child mortality (ENDESA 2005-2006, WHO). Urban costs account for 34 percent, while rural costs represent 66 percent of the total costs associated with inadequate water supply, sanitation and hygiene.

Figure 4.1: Annual Costs by Category (Million L.)



Diarrheal Illness

Water, sanitation and hygiene factors also influence child mortality. Esrey et al (1991) found 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 levels are 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 (DHS) around the world 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 DHS 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), vaccinations, 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.

WHO (2002b) reports that 90 percent of diarrheal illness in developing countries is from substandard potable water supply, sanitation and hygiene practices. This is elaborated in Pruss et al (2002).

Baseline Health Data

Honduras has achieved substantial reductions in child morality and diarrheal child mortality. Data from ENDESA 2005-2006, and WHO estimates (http://www.who.int/quantifying_ehimpacts/national/countryprofile/mapwsh/en/index.html) indicate that 12.6-21 percent of child mortality was due to intestinal diseases. It is very difficult to identify diarrheal morbidity as a substantial share of cases are not treated (or do not require treatment at health facilities), and are therefore never recorded. Additionally,

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[8] See Chapter VI for details.

diarrheal cases treated by private doctors or clinics are often not reported to public health authorities. Household surveys, therefore, provide the most reliable estimates of total cases of diarrheal illness –but only record diarrheal illness in children. Moreover, these surveys only reflect diarrheal prevalence only 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 Demographic and Health Survey (ENDESA 2005-2006) reports a diarrheal prevalence (preceding two weeks) rate of 17.2 percent in rural areas and 13.3 percent in urban areas among children under five years of age. This rate is used to estimate annual diarrheal cases per child under-5, and then total annual diarrheal 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 the annual cases of per child.[9]

Household survey data in Honduras does not provide information on diarrheal illness in the population above 5 years of age. International evidence indicates that diarrheal incidence in children under-5 is on the order of 5 times higher than the incidence in the population over 5 years of age (Larsen 2004a,b).

These estimates of annual diarrheal cases are translated into DALYs per cases of diarrheal illness, which are then used to estimate the number of DALYs lost to inadequate water supply, sanitation and hygiene (see table 4.1). The disability weight for diarrheal morbidity is 0.119 for children under-5 and 0.086 for the rest of the population, and the duration of illness is assumed to be the same (i.e., 4 days). The DALYs per 100 thousand cases of diarrheal illness are much higher for the population over 5 years of age due to age weighting –which attaches a low weight to young children and a higher weight to adults that corresponds to physical and mental development stages.[10] For diarrheal child mortality the number of DALYs is 34. This reflects an annual discount rate of 3 percent of life years lost.

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[9] The average duration of diarrheal illness is assumed to be 4 days. This implies that the two-week prevalence captures about a quarter of the diarrheal prevalence in the week prior to and a quarter in the week after the two-week prevalence period. The 2-week prevalence rate is therefore multiplied by 52/2.5 and not 52/2.

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

Table 4.1: Baseline Data for Estimating Health Effects

	Urban	**Rural**	**Source:**
Under-5 child mortality rate in 2004 (per 1000 live births)	29	43	ENDESA 2005-2006
Diarrheal 2-week Prevalence in Children under 5 years	13.3%	17.2%	ENDESA 2005-2006
Estimated annual diarrheal cases per child under 5 years	2.3	3.4	Estimated from ENDESA 2005-2006
Estimated annual diarrheal cases per person (> 5 years)	0.5	0.6	Estimated from a combination of ENDESA 2005-2006 and international experience
Percent of diarrheal cases attributable to inadequate water supply, sanitation and hygiene	90%	90 %	WHO (2002b)
DALYs per 100 thousand cases of diarrhea in children under 5	40	40	Estimated from WHO tables using age weighting and an average duration of illness of 4 days, and age weighting and 3 percent discount rate for mortality
DALYs per 100 thousand cases of diarrhea in persons >5 years	130	130	
DALYs per case of diarrheal mortality in children under 5	34	34	

Estimated Health Impacts from Inadequate Water, Sanitation and Hygiene.

WHO estimates that 90 percent of diarrheal illness is attributable to inadequate water, sanitation and hygiene. Using this figure, there are an estimated 1050 premature deaths, and about 3 million additional cases of diarrhea in children under five attributed to poor water sanitation and hygiene (see table 4.2). Although the overall rural population share in Honduras is about 55 percent, the share of children is substantially higher than in urban areas. This explains the 15 percent higher diarrheal child mortality, as well as the twice as high estimated diarrheal cases in rural areas than in urban areas.

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

	Cases		
	Urban	Rural	**Total**
Children (under the age of 5 years) – increased mortality	330	720	1,050
Children (under the age of 5 years) – increased morbidity	1,050,000	2,000,000	3,050,000
Population over 5 years of age – increased morbidity	1,400,500	2,100,000	3,500,500

DALYs from diarrheal illness (mortality and morbidity) is presented in Table 4.3, based on the data in Tables 4.1-4.2. About 75 percent of the DALYs are from diarrheal child mortality.

Table 4.3: Estimated DALYs from Diarrheal Mortality and Morbidity

	Estimated Annual DALYs		
	Urban	Rural	% of Total DALYs
Children (under the age of 5 years) – increased mortality	11,300	24,500	85%
Children (under the age of 5 years) – increased morbidity	370	700	3%

Population over 5 years of age – increased morbidity	1,700	3,500	12%
TOTAL	13,370	28,700	100%

Estimated Cost of Health Impacts.

The annual costs of diarrheal mortality and morbidity attributed to inadequate water, sanitation and hygiene are estimated at 480 million L. in urban areas and 1105 million L. in rural areas (see Table 4.4). The cost of diarrheal child mortality –based on the human capital approach (HCA) –is estimated at about 775 million L. The cost of morbidity –which includes the cost of illness (medical treatment, medicines, and value of lost time) –is estimated at 810 million L. About 70 percent of these costs are associated with the value of time lost to illness (including care giving), and 30 percent are from cost of treatment and medicines.

Table 4.4: Estimated Annual Cost of Diarrheal Illness (Million L.)

	Estimated Annual Cost		**Total**
	Urban	**Rural**	
Mortality: Children under age 5	245	530	775
Morbidity: Children under age 5, population over age 5	235	575	810
TOTAL ANNUAL COST	480	1105	1,585

Baseline data for the cost estimates of morbidity are presented in Table 4.5. Percent of diarrheal cases for the population over 5 years treated at medical facilities is extrapolated from percent of treated children (ENDESA 2005-2006) and international experience (Larsen 2004a,b). Costs of medical services reflect the costs of private health care, which are a better indication of the true (unsubsidized) economic costs of health services. As in the case for urban air pollution costs, the value of time for adults is estimated using 75 percent of urban and rural average wages in Honduras.[11]

Table 4.5: Baseline Data for Cost Estimation

	Urban	**Rural**	**Source:**
Percent of diarrheal cases treated at medical facilities (children < 5 years)	49%	45%	ENDESA 2005-2006
Percent of diarrheal cases treated with ORS (children < 5 years)	69%	65%	ENDESA 2005-2006
Percent of diarrheal cases (children < 5 years) treated with use of pharmacy	24%	18%	ENDESA 2005-2006
Percent of diarrheal cases treated at medical facilities (population > 5 years) and with medicines	29%	35%	Estimated from a combination ENDESA 2005-2006 and international experience

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[11] 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.

Average Cost of health services (L. per visit)	100	100	Per consultations with pharmacies, medical service providers, health authorities
Average Cost of medicines for treatment of diarrhea (L.)	70	70	
Average cost of ORS per diarrheal case in children (L.)	35	35	
Average duration of diarrheal illness in children, adults (days)	4	4	Assumed
Caregiving per case of diarrhea in children (Hours per day)	2	2	Assumed
Lost time to illness per case of diarrhea in adults (Hours per day)	2	2	Assumed
Value of time for adults in care giving and sickness (L./hour)	22	16	75% of urban and rural wages
Percent of diarrheal cases attributable to inadequate water, sanitation and hygiene	90%	90 %	(WHO 2002b)

Hepatitis A, Typhoid and Paratyphoid

There are 3,088 recorded annual cases of hepatitis A in Honduras in 2004 (TRANS, 2005). Typhoid/paratyphoid cases are not available, and assumed to be at the same level as hepatitis A. Annual costs of these illnesses are estimated at 18 million L (see table 4.6). Over half (10 million L) of these costs are from hospitalization, while about 40 percent (8 million L) is associated with time losses for sick individuals and their care givers.

Table 4.6: Estimated Annual Cost of Hepatitis A and Typhoid/Paratyphoid

	Estimated Total Annual Cost (Million L.)
Cost of Hospitalization	8
Cost of Medication	0.6
Cost of time losses	10
Total Annual Cost	18

Averting Expenditures

People often take averting measures to avoid perceived health risks. For example, if people perceive a risk of illness from their local water supply sources, some of them are likely to purchase bottled water, while others may boil their water, or install water purification filters. These “avertive” costs need to be included in the total costs of health risks.

Bottled Water. There is no available data on annual average bottled water consumption in Honduras. Accordingly, data on bottled water consumption in Nicaragua and Mexico are adapted for Honduras by scaling down by the urban population and adjusting by GDP per capita ratio. The total annual cost of bottled water consumption is estimated to range between 10-155 million L –the lower bound represents a 25 percent mark-up of average factory price, while the upper bound represents an arithmetic average of retail prices for the most commonly sold quantities of bottles and containers. Average retail price was assumed about 2 L./liter.[12]

It is important to note that a portion of bottled water consumption is likely to related to life-style choice or convenience rather than perceptions of health risk. In the absence of data, no adjustment has been made to account for this, and therefore the estimated costs of bottled water consumption may be an overestimated.

Boiling of Water. Nearly 19 percent of urban households and 23 percent of rural households in Honduras boil their drinking water, either always or sometimes (ENDESA 2005-2006). The annual costs of boiling water for those households are estimated to range between 41-82 million L per year (see table 4.7).

The average daily consumption of drinking water per person is assumed to be 0.5-1.0 liters among households boiling water. Residential cost of energy is estimated using data from Honduran experts. The average stove efficiency is for natural gas and wood fuel.

Table 4.7: Baseline Data for Cost Estimation

	Data	Notes
Percentage of households that boil their drinking water	19-23 %	ENDESA 2005-2006
Average daily consumption of drinking water	0.5-1.0	Liters per person per day
Percent of households using electricity (urban-rural)	34-5%	ENDESA 2005-2006
Percent of households using LPG (urban-rural)	33-7%	
Percent of households using fuel wood (urban-rural)	20-86%	
Percent of households using kerosene (urban-rural)	13-2%	
Energy requirement of heating of water (100% efficiency)	4200	Joules/ltr/1 degree C
Average Stove efficiency for heating of water	25-50 %	Varies by type of stove
Average time of boiling water (after bringing to boiling point)	10	Minutes

Water chlorination. Nearly 21 percent of urban households and 23 percent of rural households in Honduras chlorinate their drinking water (ENDESA 2005-2006). Costs of water chlorination –provided by experts from Honduras –are 0.003 L. per liter of water. The annual costs of water chlorination for those households are estimated to be 1-2 million L per year.

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[12] The non-weighted average retail price would be an overestimate of the cost of bottled water consumption if consumers purchase more of the large bottles than the small bottles because the unit price (L./liter) is lower for the larger bottles. As sales information was not readily available, a factory price mark-up was used as a lower bound for weighted average cost of bottled water consumption.

The total household costs relating to avertive expenditures range from 52-239 million L. per year –representing 8 percent of the total estimated annual costs associated with inadequate water supply, sanitation and hygiene (see table 4.8).

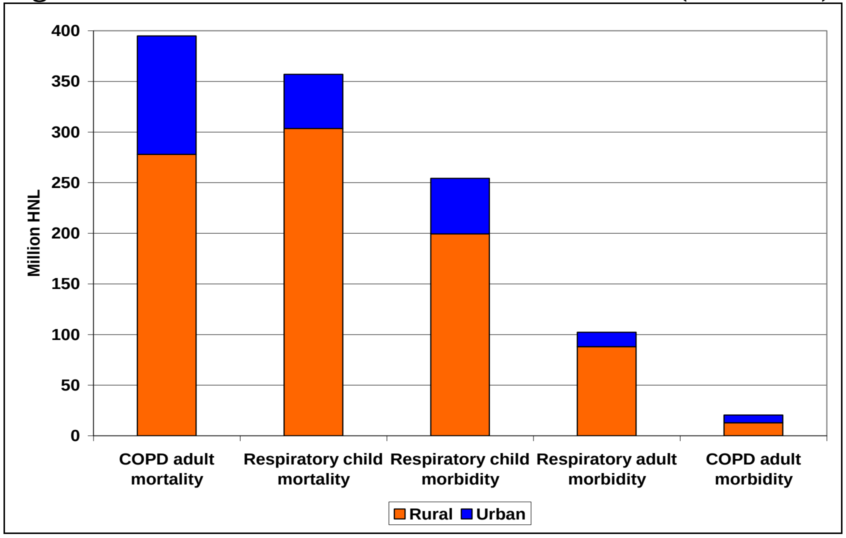
Table 4.8: Estimated Annual Household Cost of Averting Expenditures

	Estimated Annual Cost	
	"Low"	**"High"**
Cost of bottled water consumption	10	155
Cost of household boiling drinking water	41	82
Cost of household chlorination of drinking water	1	2
Total annual cost	**52**	**239**

V. INDOOR AIR POLLUTION

The mean estimated annual costs of health impacts from indoor air pollution in Honduras associated with the use of traditional fuels (mainly fuel wood) ranges from 770-1475 million L, with a mean of 1120 million L., equivalent to about 0.6 percent of the country's GDP in 2006. Chronic obstructive pulmonary disease (COPD) mortality in adult females accounts for 35 percent of the cost, while respiratory child mortality represents 32 percent (see figure 5.1). Acute respiratory infections (ARI) in children represent 23 percent of the cost, while COPD and ARI morbidity in adult females represents 11 percent of the cost. Rural population bears 78 percent of the total cost of indoor air pollution.

Figure 5.1: Annual Costs of Indoor Air Pollution (million L.)



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 from indoor air pollution. *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 such exposures 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 ENDESA 2005-2006 contains information on household use of traditional fuels for cooking. Around 20 percent of urban and 86 percent of rural households used fuel wood for cooking in 2005 ENDESA 2005-2006.

Health Risk Assessment.

Desai et al (2004) provides a review of research studies around the world that have assessed the magnitude of health effects attributed to indoor air pollution from solid fuels. The odds ratios –which represent the risk of illness for those who are exposed to indoor air pollution compared to the risk for those who are not exposed –for acute respiratory infections (ARI) and chronic obstructive pulmonary disease (COPD) are presented in Table 5.1. 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 drawing on the review by Desai et al (2004), is presented below. These odds ratios have been applied to 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.[13] It is these population sub-groups that disproportionately suffer from indoor air pollution, as they traditionally spend much more of their time indoors and near the cook stoves than do older children and adult males.

Studies around the world have also found linkages between indoor air pollution from traditional fuels and an 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 fine particulates have the highest effect on mortality from

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[13] Although Desai et al (2004) present 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 Honduras associated with indoor air pollution is therefore likely to be minimal.

cardiopulmonary diseases. As indoor smoke from traditional fuels is high in fine particulates, the effect on these individuals with these diseases might be substantial. More research is however required to draw a definite conclusion about the linkage and magnitude of the effect.

Table 5.1: Health Risks of Indoor Air Pollution

	Odds Ratios (OR)	
	"Low"	"High"
Acute Respiratory Illness (ARI)	1.9	2.7
Chronic obstructive pulmonary disease (COPD)	2.3	4.8

Source: Desai et al (2004).

Baseline Health Data.

To estimate the health effects of indoor air pollution from the odds ratios, baseline data for ARI and COPD, and unit figures for disability adjusted life years (DALYs) lost to illness and mortality are required (table 5.2). Data on COPD mortality and especially morbidity incidence are not readily available for Honduras; therefore regional estimates from WHO (2001) and Shibuya et al (2001) for the AMRO B region are used instead.[14]

The national average two-week prevalence rate of ARI in children under 5 years from the ENDESA 2005-2006 was used to estimate total annual cases of ARI in children under-5. The procedure applied is to multiply the two-week prevalence rate by 52/3 to arrive at an approximation of the annual cases of ARI per child[15].

Household surveys in Honduras do not provide information on ARI in adults. Instead, data on cases of ARI from the National Institute of Health (INS) in Colombia is used to impute a value for Honduran adults. The Colombian database –which contains information only on ARI cases treated at health facilities –reveals that the ARI incidence in the population over 5 years is about 1/6th of the incidence in children under 5 years of age. In general, the percentage of ARI cases treated at health facilities is higher among young children than older children and adults, hence the incidence ratio of six (over 5 to under five years), as suggested from the INS database in Colombia is likely to be an overestimate. The annual cases of ARI per adult female (>30 years) in Honduras is therefore estimated in the range of 1/6th to (1/0.9)*1/6th of the annual cases per child under-5 (table 5.2).

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

[15] A factor of 52/3 is applied 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.

ARI mortality in children under 5 years is 17 percent of total estimated child mortality in Honduras (ENDESA 2005-2006). To estimate the number of DALYs lost from ARI and COPD attributed to indoor air pollution, a disability weight of 0.28 is used for ARI morbidity in children and adults, and duration of illness is assumed to be the same (i.e., 7 days). The DALYs per 100 thousand cases of ARI is found to be much higher for adults, due to the higher age weighting given to adults in the DALY methodology.[16] For child mortality from ARI, the number of DALYs lost is 34, reflecting an annual discount rate of 3 percent of life years lost.

Table 5.2: Baseline Data for Estimating Health Impacts

	Baseline		Source:
	Urban	**Rural**	
Female COPD mortality rate (% of total female deaths)	2.1-3.6 %	2.1-3.6 %	WHO (2002) and Shibuya et al (2001)
Female COPD incidence rate (per 100 thousand)	94	94	
ARI 2-week Prevalence in Children under 5 years	9.5%	12.8%	ENDESA 2005-2006
Estimated annual cases of ARI per child under 5 years	1.7	2.2	Estimated from ENDESA 2005-2006
Estimated annual cases of ARI per adult female (> 30 years)	0.3	0.4	Estimated from Columbia data, and ENDESA 2005-2006
ARI mortality in children under 5 years (% of child mortality)	17%	17%	ENDESA 2005-2006
DALYs per 100 thousand cases of ARI in children under 5	165	165	Estimated from WHO tables
DALYs per 100 thousand cases of ARI in female adults (>30)	700	700	
DALYs per case of ARI mortality in children under 5	34	34	
DALYs per case of COPD morbidity in adult females	2.25	2.25	
DALYs per case of COPD mortality in adult females	6	6	

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) for the AMRO B region. 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.[17] A discount rate of 3 percent is applied to both COPD morbidity and mortality.

Estimated Health Impacts

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

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

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

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

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:

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

where PP is the percentage of population exposed to fuel wood smoke (20 percent of urban and 86 percent of rural households according to ENDESA 2005-2006), and OR is the odds ratios (or relative risk ratios) presented in Table 5.1.

Estimated Health Impacts

Every year, between 365-480 children under the age of five die from ARI in rural areas, while an additional 55-90 children die in urban areas (see table 5.3). Also, among children under five more than half million annual cases of acute respiratory illness in rural areas and more than 100 thousand cases in urban areas could be linked to indoor air pollution. Indoor air pollution related annual ARI morbidity among females above thirty years old constitutes about two hundred cases in rural areas and close to thirty thousand cases in urban areas. Indoor air pollution also causes COPD in females over 30 years old. Up to 300 females die annually from COPD in urban and rural areas, also about 25 thousand new cases of COPD annually could be attributed to indoor air pollution. An estimated 25.5 thousand DALYs are lost each year due to indoor air pollution (mean estimate), of which about 70 percent is from mortality.

Table 5.3: Estimated Annual Health Effects of Indoor Air Pollution (Rural and Urban)

	Estimated Annual Rural Cases		Estimated Annual Urban Cases		Total	
	“Low”	“High”	“Low”	“High”	“Low”	“
Acute Respiratory Illness (ARI):						
Children (under the age of 5 years) – increased mortality	365	480	55	90	210	
Children (under the age of 5 years) – increased morbidity	535,000	729,000	95,000	158,000	315,000	44
Females (30 years and older) – increased morbidity	183,000	250,000	19,500	32,500	101,250	14
Chronic obstructive pulmonary disease (COPD):						
Adult females – increased mortality	145	210	50	100	100	
Adult females – increased morbidity	1050	1550	415	865	730	
Total Disability Adjusted Life Years (DALYs)-mortality and morbidity	17,400	24,000	3,400	6,150	10,400	1

Estimated Cost of Health Impacts

Total annual costs attributed to indoor air pollution in Honduras is estimated at 1130 million L. (Tables 5.5). Rural population bears 78 percent, and urban population 22 percent of the total cost of indoor air pollution. The cost of mortality for adults is based on the value of statistical life (VSL) as a high bound and HCA as a low bound, while that for children is based on the human capital approach. About 37 percent of the cost of morbidity –which includes the cost of illness (medical treatment, value of lost time, etc) –is associated with COPD, and 63 percent with ARI.[18] Mortality from COPD and ARI represents about 67 percent of the total cost, while morbidity accounts for the rest.

Table 5.5: Estimated Annual Cost of Indoor Air Pollution in Honduras

	Estimated Annual Cost (Million L.)	
	"Low"	"High"
Acute Respiratory Illness (ARI):		
Children (under the age of 5 years) – increased mortality	300	415
Children (under the age of 5 years) – increased morbidity	210	300
Adult females – increased morbidity	80	120
Chronic obstructive pulmonary disease (COPD):		
Adult females – increased mortality	45	745
Adult females – increased morbidity	15	25
TOTAL	650	1605

Baseline data for the cost estimates of morbidity attributed to indoor air pollution are presented in Table 5.6. Treatment cost represents private sector (unsubsidized) health care services. As before, the value of time for adults in Honduras is estimated at 75 percent of average hourly wages. 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.

To estimate the cost of a new case of COPD, the medical cost and value of time losses have been discounted over a 20-year 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 5.6: Baseline Data for Cost Estimation in Rural and Urban Areas

	Rural	**Urban**	**Source**
Percent of ARI cases treated at medical facilities (children < 5 years)	49%	69%	ENDESA 2005-2006
Percentage of cases with use of pharmacy (children <5 years)	49%	62%	ENDESA 2005-2006
Cost of medicines for treatment of acute respiratory illness (population < 5 years) (L.)	70	70	Per consultations with pharmacies

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[18] Based on the mean estimated annual cost.

Percent of ARI cases treated at medical facilities (females > 30 years)	37%	40%	Estimated from a combination of the ENDESA 2005-2006 and international experience
Percent of COPD patients being hospitalized per year	1.5	1.5	Assumption based on Schulman et al (2001) and Niederman et al (1999)
Percent of COPD patients with an emergency doctor/hospital outpatient visits per year	15	15	
Average number of doctor visits per COPD patient per year	1	1	
Estimated lost workdays (including household work days) per year per COPD patient	2.6	2.6	Estimated based on frequency of doctor visits, emergency visits, and hospitalization
Cost of doctor visit (L. per visit)	100	100	Per consultations with pharmacies, medical service providers, and health authorities
Cost of hospitalization (L. per day)	440	440	
Cost of emergency visit (L. per visit)	300	300	
Average duration of ARI in days (children and adults)	7	7	Assumption
Hours per day of care giving per case of ARI in children	2	2	Assumption
Hours per day lost to illness per case of ARI in adults	3	3	Assumption
Value of time for adults (care giving and ill adults) – L./hour	16	66	75% of wages in Honduras
Average length of hospitalization for COPD (days)	10	10	Larsen (2004b)

VI. 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 value of statistical life (VSL). The first method has been dominant in the past, it is increasingly being replaced by the VSL approach in the last couple of decades.

In this report, the HCA has been applied to represent a lower bound and the VSL as a upper bound in estimating the cost of adult mortality. For child mortality, only the HCA has been applied. A brief discussion of the two approaches follows.

Human Capital Approach.

The HCA is based on the economic contribution of an individual to society over his/her lifetime. Premature death involves an economic loss that is approximated by the loss of all future income of the individual. This future income is discounted –at rate of time preference –to reflect its value at the time of death. According to the HCA, the social cost of mortality, is therefore 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 Honduras in this report.

Several important issues are often raised regarding the HCA. The first issue relates to the application of this valuation approach to individuals who do not participate in the economy, i.e., to individuals not earning an income, such as the elderly, family members taking care of the home, and children. The HCA 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 way, the HCA can be applied to the death of non-earning individuals 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 does not assign an economic value to those have either retired from the workforce or do not make significant contributions to household work. This obviously is a serious shortcoming of the HCA approach.

The second issue relates to the way HCA estimates the social cost of mortality –which is limited to the economic contribution of an individual, or the value of household work if the individual takes care of the home. Some have argued that most people value safety not out of concern for preserving current and future income levels, but rather primarily because they have an aversion to pain and suffering and death –which is not valued in the HCA. Alternative approaches to the valuation of mortality –such as the VSL –have therefore been developed and increasingly been applied in the past couple of decades.

The estimated cost of mortality in Honduras based on HCA is presented in Table 6.1. Average annual income is approximated by GDP per capita, corresponding to around 1260 L. per year. The estimates are from equation (1).

Table 8.1: Cost of Mortality (per Death) using HCA

	Average Number of Years Lost	**Thousand L.**
Adults:		
Mortality from Urban Air Pollution	7.5	178
Mortality from Indoor Air Pollution	6	143
Children:		
Mortality from Indoor Air Pollution	65	730
Mortality from Diarrheal Illness	65	730

Value of Statistical Life

While the HCA involves valuation of the death of an individual, VSL is based on valuation of mortality risk. Everyone in society is constantly facing a certain risk of dying. Examples of such risks relate to occupational fatalities, traffic accident fatalities, 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 accidents; or individuals may purchase safety equipment to reduce the risk of death; or individuals and their 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 will accept to bear a higher mortality risk), it is possible to estimate the value (social cost) to society of reducing mortality risk. For example, it may be observed that a certain health hazard has a mortality risk 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 10 L. per year for eliminating this mortality risk, then every 10 000 individuals are collectively willing to pay 100 thousand L. 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 (L. 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}= 10 L.. Thus, if 10 individuals die each year from the health risk illustrated above, the cost to society is 10* VSL = 10*100 thousand L. = 1 million L.

Estimating VSL

The two 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 lower estimate for VSL of USD 2 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. As a higher bound for VSL a mean estimate of VSL meta-analysis from Kochi et al (2006) of USD 5.4 million was applied. This is the latest meta-analysis utilizing an empirical Bayes pooling method to combine and compare estimates of the value of a statistical life (VSL). The data come from 40 selected studies published between 1974 and 2002, containing 197 VSL estimates.

Benefit Transfer

There are no studies of VSL conducted in Honduras, and therefore values have to be transferred from studies in other countries. Since the overwhelming majority of VSL studies have been conducted in countries with substantially higher income levels, their VSL estimates have to be adjusted for Honduras.

One commonly used approach in such a benefit transfer is to apply income elasticities.[19] 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.

The most appropriate income elasticity to apply to middle-income countries, such as Honduras, remains uncertain. The reason for this is that the income level in Honduras 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 Honduras.

Table 6.2 presents the VSL for Honduras from benefit transfer based on the range of VSL reported by Mrozek and Taylor (2002) as a lower bound, and Kochi et al (2006) as a higher bound, and an income elasticity of 1.0. These figures 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 6.3.

Table 6.2: Estimated Value of Statistical Life in Honduras

	"High"	**"Low"**	**Source:**
Average VSL in high-income countries (million US $)	5.4	2	Kochi et al (2006), Mrozek

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

			and Taylor (2002),
Average GDP/capita in high-income countries (US $)	30 000	30 000	World Bank*
GDP per capita in Honduras (US $ in 2004)	1260	1260	BCH 2007
Income elasticity	1.0	1.0	
Estimated VSL in Honduras (million L.)	4.3	1.6	Benefit transfer

* Weighted average GDP per capita, based on the sample in Mrozek and Taylor (2002).

Table 6.3: A Comparison of HCA and VSL estimates applied to Honduras

	Ratio of VSL/HCA
Adults mortality	18
Children mortality	4

From Table 6.3 it is easy to see that for adults, the ratio of VSL/HCA differs by about 4 to 18 times for different VSL estimations. Since mortality cost contributes about 60% of the total health cost of environmental damage, the approach selected for mortality valuation is the major factor influencing the overall results.

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