WPS6219

Policy Research Working Paper 6219

An Analysis of Physical and Monetary Losses of Environmental Health and Natural Resources in India

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The World Bank
South Asia Region
Disaster Risk Management and Climate Change
October 2012

Abstract

This study provides estimates of social and financial costs of environmental damage in India from three pollution damage categories: (i) urban air pollution; (ii) inadequate water supply, poor sanitation, and hygiene; and (iii) indoor air pollution. It also provides estimates based on three natural resource damage categories: (i) agricultural damage from soil salinity, water logging, and soil erosion; (ii) rangeland degradation; and (iii) deforestation. The estimates are based on a combination of Indian data from secondary sources and on the transfer of unit costs of pollution from a range of national and international studies. The study estimates the total cost of environmental degradation in India at about 3.75 trillion rupees (US$80 billion) annually, equivalent to 5.7 percent of gross domestic product in 2009, which is the reference year for most of the damage estimates. Of this total, outdoor air pollution accounts for 1.1 trillion rupees, followed by the cost of indoor air pollution at 0.9 trillion rupees, croplands degradation cost at 0.7 trillion rupees, inadequate water supply and sanitation cost at around at 0.5 trillion rupees, pasture degradation cost at 0.4 trillion rupees, and forest degradation cost at 0.1 trillion rupees.

This paper is a product of the Disaster Risk Management and Climate Change, South Asia Region. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at mmani@worldbank.org.

Produced by the Research Support Team

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JEL codes: C68, O44, O53, Q43, Q52
Key words: India, Environmental Degradation, Pollution Control, Environment and Health, Economic Growth and Environment

Sector Board: Environment

[1] This paper is part of a collaborative effort between the World Bank and the Ministry of Environment and Forests (MoEF). Authors extend special gratitude to Mr. Hem Pande (Joint Secretary, MoEF), and his team for support and guidance throughout the study. The team gratefully acknowledges the contribution of Gaurav Joshi for his excellent help and support on the data front. The team also acknowledges Dan Biller, Charles Cormier, Giovanna Prennushi, and Michael Toman for carefully reviewing and providing expert guidance to the team at crucial stages. The financial support of UK's Department for International Development (DFID) is gratefully acknowledged.

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I Introduction

Economic growth is universally recognized as a prerequisite for development. A strong momentum in investment reflecting rising productivity, healthy corporate profits, and robust exports has fueled a buoyant economic growth exceeding 7% a year in India for almost a decade. Economic growth has increased employment opportunities and allowed millions to emerge from poverty.[3]

Economic expansion is also often accompanied by rising demands on the already scarce and often degraded natural resources (soils, fossil fuels, water and forests) and the increasing pollution footprint will negatively impact human health and growth prospects. In India's case, a remarkable growth record has been clouded by a degrading environment and growing scarcity of natural resources. Mirroring the size and diversity of its economy, environmental risks are wide ranging and are driven by both poverty and prosperity. Environmental sustainability could become the next major economic challenge as India surges along its growth trajectory.

This study provides estimates of social and financial costs of environmental damage in India from three pollution damage categories: (i) urban air pollution, (ii) inadequate water supply, poor sanitation and hygiene, (iii) indoor air pollution; and three natural resource damage categories: (i) agricultural damage from soil salinity, water logging and soil erosion, (ii) rangeland degradation, and (iii) deforestation. The estimates are based on a combination of Indian data from secondary sources and on the transfer of unit costs of pollution from a range of national and international studies (a process known as benefit transfer). Data limitations have prevented estimation of degradation costs at the national level for coastal zones, municipal waste disposal and inadequate industrial and hospital waste management. Furthermore the estimates provided do not account for loss of non-use values (i.e. values people have for natural resources even when they do not use them).

Methodology for Valuation of Environmental Damage

The quantification and monetary valuation of environmental damage involves many scientific disciplines including environmental, physical, biological and health sciences, 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 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 provide some guidance for the allocation of public and private resources across diverse sectors in the course of socio-economic development.

Environmental damage means physical damages that have an origin in the physical environment. Thus, damages to health from air or water pollution are included as well as damages from

[3] Source:Indiastat

deforestation. The term cost means the opportunity cost to society, i.e., what is given up or lost, by taking a course of action. When goods traded in markets are damaged, prices and knowledge of consumer preferences for the damaged goods (embodied in the demand function) and production information (embodied in the supply function) provide the necessary information for computing social costs. Estimating social costs from reduced productivity of agricultural land due to erosion, salinity or other forms of land degradation is a good example. However, many damages from environmental causes are to "goods," such as health, that are not traded in markets. In these cases, economists have devised a number of methods for estimating social costs based on derived preferences from observable or hypothetical behavior and choices.

One example is the value of time lost to illness or provision of care for ill family members. If the person who is ill or who is providing care for someone who is ill does not otherwise has a job the financial cost of time losses is zero. However, even in such a case the person is normally engaged in activities that are valuable for the family and time losses reduce the amount of time available for these activities. Thus, there is a social cost of time losses to the family. In an economic costing exercise 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 he or she chose to work for income. In summary, social costs are preferred over financial costs because social costs capture the cost and reduced welfare to society as a whole. All costs are estimated as flow values (annual losses).

Unfortunately, information needed to estimate social costs for some categories is often lacking, particularly in developing countries, such as India. In such cases one has the option of relying on financial costs, which generally do not capture all the social costs. In this study, financial costs have been used for a significant part of the analysis, but with social costs being reported wherever these could be obtained or estimated. In general these financial costs are likely to underestimate social costs.

II Cost of Environmental Degradation

This section provides a summary of estimated social and financial costs of environmental damage. A discussion of each environmental category is provided in the following sections.

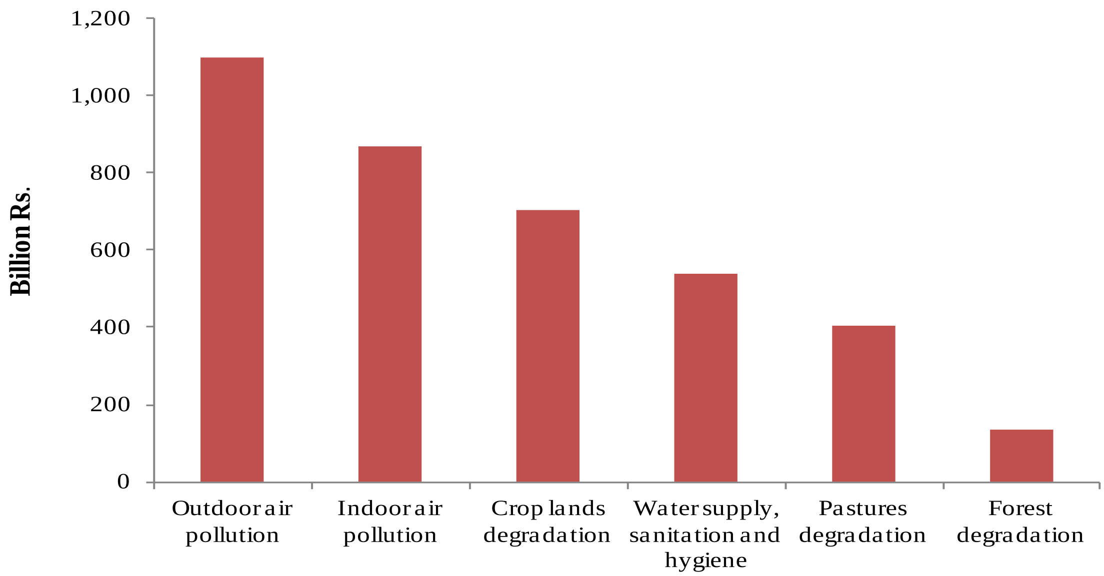
Environmental pollution, degradation of natural resources, natural disasters and inadequate environmental services, such as improved water supply and sanitation, impose costs to society in the form of ill health, lost income, and increased poverty and vulnerability. This section provides overall estimates of social and economic costs of such damages, referring, as much as possible, to damages for 2009. In some cases, however, the figures may be based on damages in an earlier year if that was the latest information available (see later sections for details).

The results are summarized in Figures 2.1 and 2.2 and in Table 2.1. Total damages amount to about Rs. 3.75 trillion (US$80 billion) equivalent to 5.7 percent of GDP. Of this total, outdoor air pollution accounts for the highest share at 1.7 percent (figure 2.1) followed by the cost of indoor air pollution at 1.3 percent; croplands degradation cost at just over one percent; inadequate water supply, sanitation and hygiene (WSH) cost at around at 0.8 percent; pastures degradation cost at 0.6 percent, and forest degradation cost at 0.2 percent. The individual damages are shown as shares of the total in Figure 2.2. Outdoor air pollution accounts for 29 percent, followed by indoor air pollution (23 percent), cropland degradation (19 percent), water supply and sanitation (14 percent), pasture (11 percent), and forest degradation (about 4 percent).

In addition India has experienced some damages from natural disasters (floods, landslides, tropical cyclones, and storms). These are, however, not included in the above figures as they are not the result of anthropogenic factors, although such factors can exacerbate their impacts. Over the period 1953-2009 damages from natural disasters were estimated at Rs. 150 billion a year on average (in constant 2009 prices) and took the form of loss of life and injury, losses to livestock and crops and losses to property and infrastructure.

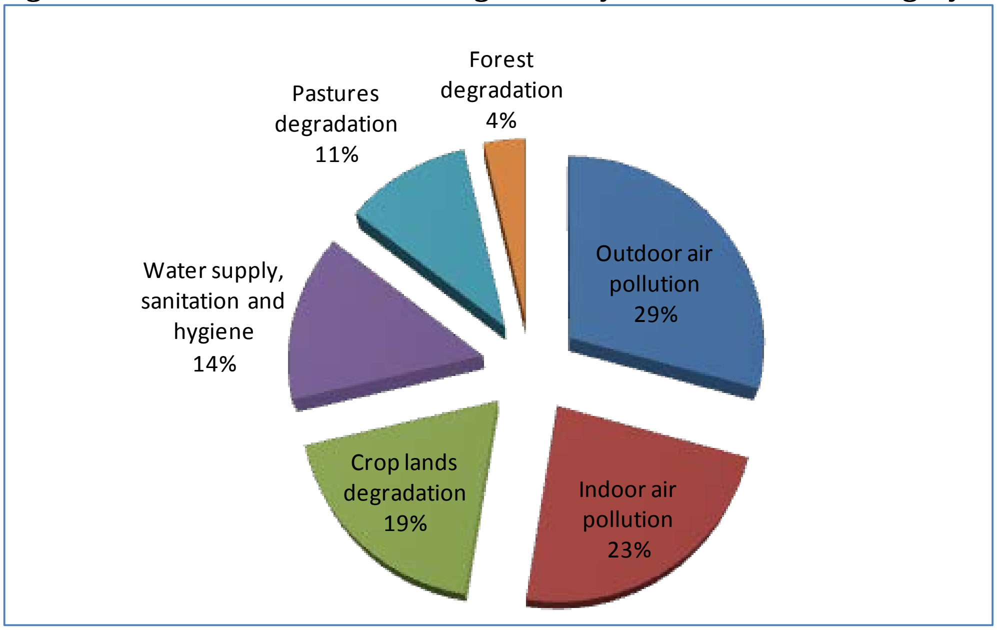
Similarly, while India has been phasing out lead in gasoline since 2001 there are a number of other sources that are not controlled. This is probably due to the fact that some gasoline is still produced with lead due the presence of lead in pipes, drinking water, soils, food, paints, and other products. Lead exposure could result in substantial mortality from diseases associated with high blood pressure among adults and IQ reduction and Mild Mental Retardation. While some studies have suggested high levels of lead among urban population (both children and adults) in there is great uncertainty about current BLL in the urban population as a whole (and the rural population). It is therefore necessary to undertake new studies of BLL in children and adults to provide a more accurate estimate of health effects and their costs taking into account the gradual lead phase-out in India.

Figure 2.1: Annual Cost of Environmental Damage (Billion Rs.)



Source: Staff estimates.

Figure 2.2: Relative share of Damage Cost by Environmental Category



Source: Staff estimates.

In addition to the mid-point values, "low" and "high" estimates of annual costs are presented in Table 2.1. The "low" and "high" range estimates differ considerably across the categories because of the uncertainties related to economic valuation procedure or uncertainties about exposure to specific hazards. The urban air pollution estimate range is mainly affected by the social cost of mortality which is derived by applying two different valuation techniques (Section III.1). The range for indoor air pollution arises mainly from the uncertainty of exposure level to indoor smoke and from the use of fuel wood (Section V). In the case of agricultural soil degradation, the range is associated with uncertainty of yield losses from salinity (Section VI.1). The range for water supply, sanitation and hygiene is in large part associated with uncertainties regarding estimates of diarrheal child mortality and morbidity (Section IV). The range for deforestation is associated with the uncertainty of the use benefits of forest (Section VII). If we take the lower bound of the estimates, the figures are about 45 percent of the mean values (or 2.6 percent of GDP), while if we take the upper bound they are 64 percent higher than the mean (or about 8.9 percent of GDP)[4].

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

	"Low"	**Mid-point Estimate**	"High"	Midpoint Estimate as percent of Total Cost of Environmental Damage
Environmental Categories				
Outdoor air pollution	170	**1,100**	2,080	29%

[4] Adding up of lower or higher bounds reflects only differences in calculation, and not actual changes in losses, associated with environmental degradation . A midpoint estimate presents an average of low and high estimates, the range is related to both uncertainties of valuation method and uncertainties of exposure to specific hazards.

Indoor air pollution	305	**870**	1,425	23%
Crop lands degradation	480	**703**	910	19%
Water supply, sanitation and hygiene	475	**540**	610	14%
Pastures degradation	210	**405**	600	11%
Forest degradation	70	**133**	196	4%
TOTAL ANNUAL COST (billion R's/yr.)	1,710	**3,751**	5,821	1
Total as percent of GDP in 2009	2.60%	**5.70%**	8.84%	

Note: Staff estimates are rounded to the nearest ten.

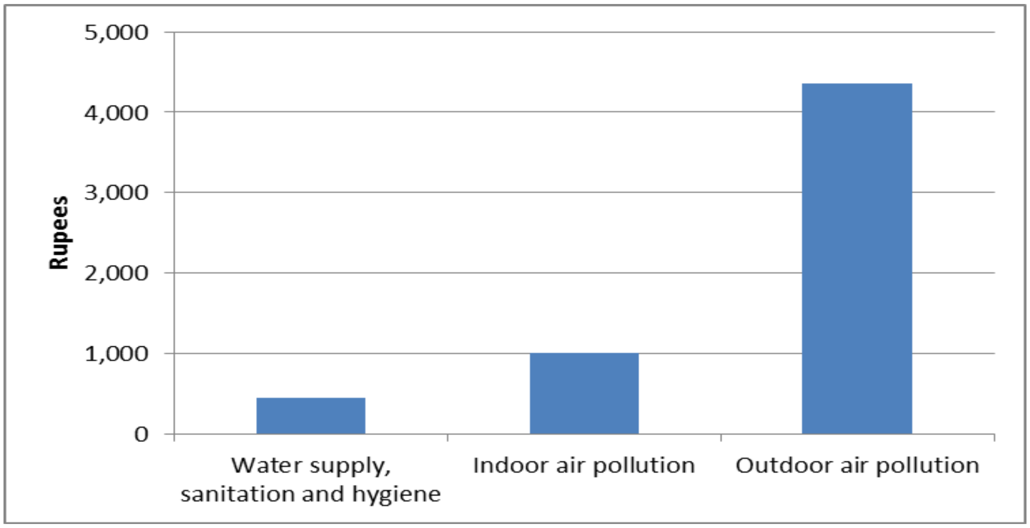
Health Related Damages among selected populations in India

The damages associated with environmental health are estimated for different groups of the population. This mainly reflects differences in terms of who is affected by the different pollutants but also the availability of data. The outdoor air pollution losses were estimated for the inhabitants of cities with a population of over 100 thousand (due to data limitations); inadequate water supply, sanitation and hygiene costs were estimated for the whole population of India; and indoor air pollution costs were estimated for the households that use solid fuel for cooking (about 75 percent of all households). These differences in coverage should be borne in mind when comparing across the different environmental burdens. In particular coverage for outdoor air pollution is less complete than the others and thus the figures for that category are underestimated.

The higher costs for outdoor/indoor air pollution (other than lead exposure) are primarily driven by an elevated exposure of the urban and rural population to particulate matter pollution that results in a substantial cardiopulmonary and COPD mortality load among adults. As noted the rural population has only been assessed for indoor air pollution.

Figure 2.3 gives estimates of damage per person within the different exposed populations used to construct the figures in Table 2.1. We note that a significant part of the health burden, especially from water supply, sanitation and hygiene is borne by children under 5 (Figure 2.4). These figures would suggest that about 23 percent of all under-5 mortality can be associated with indoor air pollution and inadequate water supply, sanitation and hygiene, and 2 percent of adult mortality with outdoor air pollution.

Figure 2.3: Annual Environmental Health Losses per Person of the Exposed Population

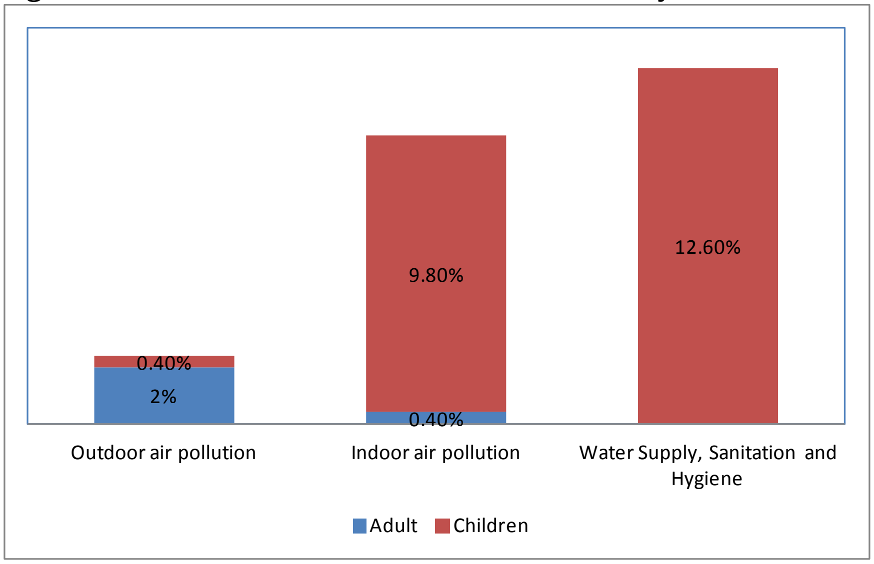


Source: Staff estimates.

Environmental Damages and the Poor

While this study does not address the impacts of the losses estimated above on poor households (that is something that should be undertaken as a separate study) one can comment on how the poor are affected by the environmental damages. First the losses related to water and sanitation and hygiene are likely to be concentrated among the poor who most often do not have access to piped water or sanitation. Second the rural population is more affected by the water and indoor air pollution-related damages than the urban population. For the urban population the distribution of impacts by income class is less certain. Some studies indicate that urban ambient air quality does affect the poor more than the rich (Garg, 2011) but the present study has not been able to confirm this point. In overall terms, however, it is very likely the case that the poorer urban population suffers more both from urban air pollution and inadequate water supply, sanitation and hygiene and in general it is the poor who are included in all major cost categories (those who live in big cities and use solid fuel for cooking).

Figure 2.4: Estimated Share of Annual Mortality from Different Sources in India



Source: Staff estimates.

Other Categories of Damages

Cropland damages arise from the decline the value of crops due to soil erosion, water logging, salinity and overgrazing. We derive a range of estimates due to uncertainty of crop and pasture profitability as well as the uncertainty of the level of degradation.

Forest degradation has arisen in India from unsustainable logging practices in some regions, and general over-exploitation of forest resources. Although the country has gained about 7 percent in overall forest cover between 1990 and 2010 there has also been a notable degradation in some forests. It is this that results in losses of ecosystem services including carbon sequestration, provision of timber and non-timber forest products, recreational and cultural use of forests and prevention of soil erosion. The losses are valued using a range of techniques, which are subject to considerable uncertainty arising from the estimates of forest productivity and methods of obtaining values for the non-marketed services.

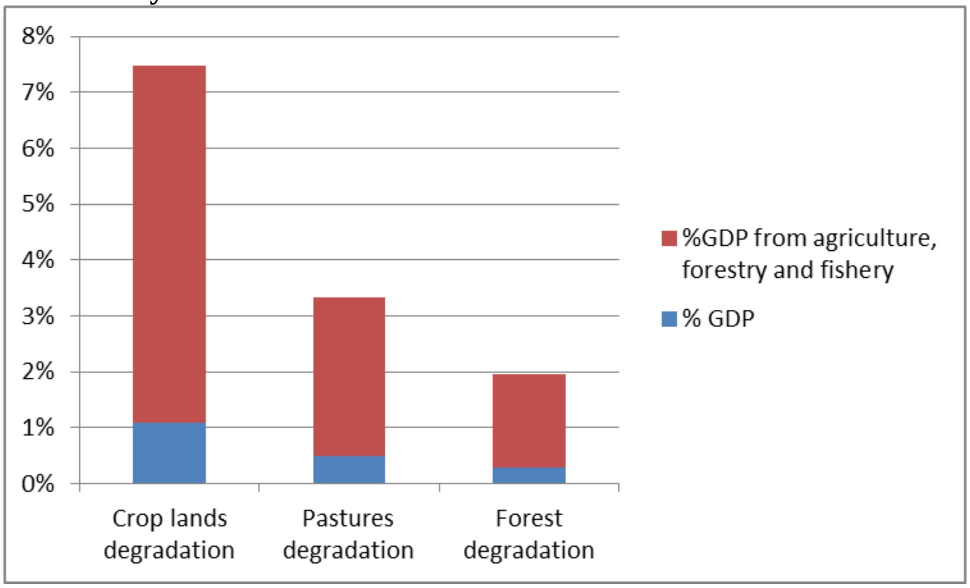
Finally impacts of changes in fisheries were examined but it was not possible to value these in monetary terms due to gaps in the data.

Another way of looking at the role of environmental resources is in terms of the "GDP of the poor"[5]. Natural resources degradation is more significant when compared with their income. One measure of the growth potential for the poor is in the share of GDP generated in agriculture, forestry and fishery, which made up about 17 percent of GDP in 2010. To be sure not all the GDP in these sectors goes to the poor but a more significant part of it does than for some other sectors. Figure 2.5 summarizes potential impact of natural resource degradation losses on the

[5] Gundimeda & Sukhdev (2008) introduced a concept GDP of the poor that includes GDP only from agriculture, forestry and fishery, since these sectors reflect growth potential for most of the rural, predominantly poor Indian making up 72 percent of the total. The importance of these sectors for the poor is also discussed in World Bank (2006).

GDP and GDP of the poor (i.e. GDP in agriculture, forestry and fishery). In total these losses are amount to about 2 percent of GDP and 11 percent "GDP of the poor" (GDP in Agriculture, Fishery and Forestry) in India. It should be noted that while this being an interesting concept, this could also be underestimation of impact of environmental damage suffered by the poor as much of the health damage from pollution in urban areas is also predominantly borne by the urban poor.

Figure 2.5: Natural Resource Losses Compared to GDP and GDP in Agriculture, Forestry and Fishery in 2009.



Source: Staff estimates.

Comparison with other Countries

The cost of environmental degradation in India is roughly comparable with other countries with similar income level (Figure 2.6). Studies of the cost of environmental degradation were conducted using a similar methodology in Pakistan, a low income country, and several low and lower-middle income countries in Asia, Africa and Latin America. They show that monetary value of increased morbidity, mortality and natural resources degradation typically amounts to 4 to 10 per cent of GDP, compared to 5.7 percent of GDP in India[6].

The situation also looks consistent across different countries if one compares only the health costs of outdoor air pollution (Figure 2.7). In all the selected countries these vary between 1.1 to 2.5 percent of GDP. In India the health cost of outdoor air pollution is estimated at about 1.7 percent of GDP. The high cost of outdoor air pollution-related mortality in urban areas is the main driver of environmental health costs. A World Bank study on China (2007), later cited in China 2030 (World Bank, 2012), applied a methodology for outdoor air pollution valuation similar to the one utilized in this study.

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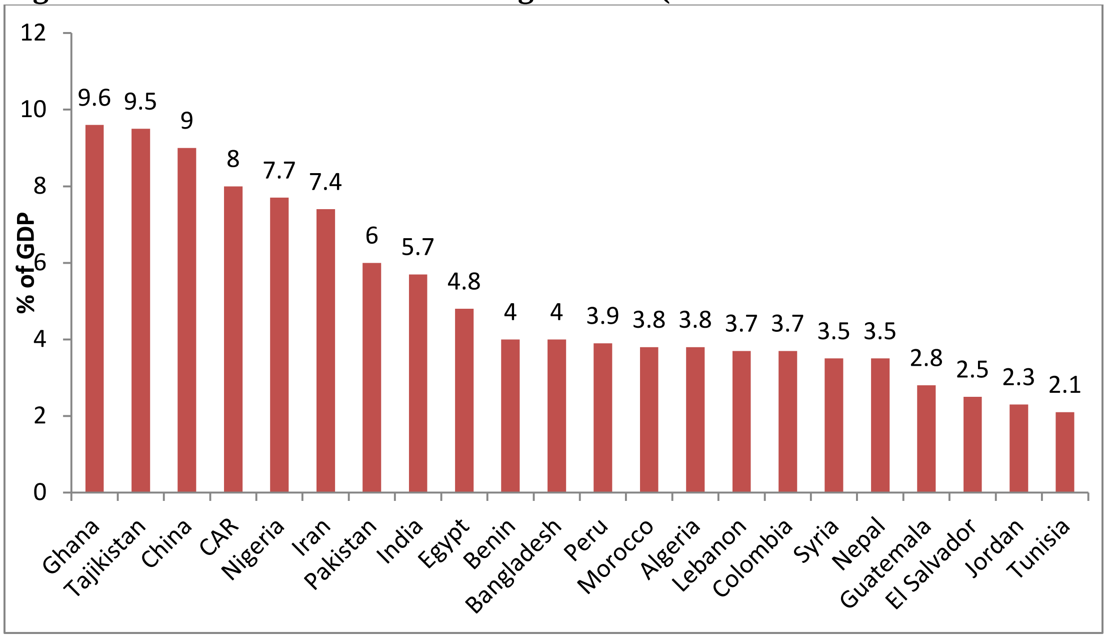
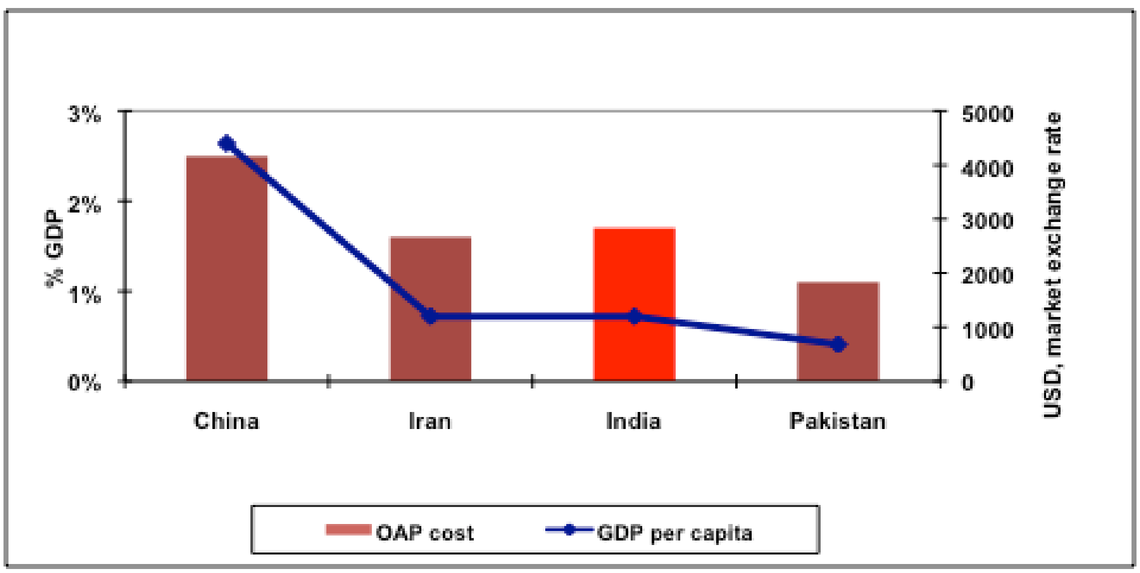
[6] The environmental media included in the analysis include outdoor/indoor air pollution, inadequate water supply, sanitation and hygiene and natural resource degradation (soils salinity/erosion, pastures degradation, deforestation and forest degradation, fishery loss). Losses from natural disasters were included in CED study in Peru and in Iran.

Figure 2.6: Cost of Environmental Degradation (Health and Natural Resources Damages)



Source: Bank (2012): Green Growth: Path to Sustainable Development.

Figure 2.7: Health Cost Attributed to Outdoor Air pollution



Source: Islamic Republic Of Iran: Cost Assessment Of Environmental Degradation, World Bank, 2005; Ghana Country Environmental Analysis, World Bank, 2006; Pakistan: Country Strategic Environmental Assessment, World Bank, Volume II, 2007: World Bank, 2007. Cost Of Pollution In China. Economic Estimates Of Physical Damages World Bank.

III Urban Air Pollution

3.1 Particulate Matter

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), Ostro et al. (2004). The air pollutant that has shown the strongest association with these health endpoints is particulate matter and other secondary particles with similar characteristics of less than 10 microns in diameter (PM10)[7]. Research in the United States in the 1990s and most recently by Pope et al (2002) provides strong evidence that it is particulates of less than 2.5 microns (PM2.5) that have the largest health effects. Other 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 secondary particulates. In particular, the evidence implicates sulfates formed from SO2, but is much less certain about nitrates, formed from NOx.

The focus of this study therefore is the health effects of all fine particulates (PM10 and PM2.5). This requires data on who is exposed, the health impacts of that exposure and the value attached to those impacts.

Given data limitations we can only estimate impacts for the urban populations and in fact only for a part of that population. Only major cities have TSP and PM10 monitoring data. In this study we focus on cities with a population of 100,000 and above only. Since the baseline population is from the 2001 census there are many cities that have achieved a population of 100,000 since 2001 and have not been included in the study. This can be updated in the future. .

Pollution data for all cities, where available, was taken from the Central Pollution Control Board's (CPCB) Environmental Data Bank website for the year 2008. Health damage estimates for PM10 were calculated based on observations for the year 2008. The study included 96 cities with monitoring stations and 223 cities with no monitoring stations (254 million people in total). The population for 96 cities with monitoring stations amounts to 186 million, or about 16% of the country's population. In addition there are about 225 cities with an average population of 69 million for which there are no data on PM concentrations. Since excluding them from the estimation of health impacts would be a serious omission, annual average PM10 levels were assigned to these cities based on scaling up of the World Bank modeling PM10 concentrations (taken from the World Bank Internal Research Database), using an average factor for the major cities.

The age distribution of the urban population was estimated using urban population parameters from the 2001 India Census. PM10 were transformed into PM2.5 to obtain values for the latter using a ratio of 0.5 based on evidence from India (CPCB, 2011). This ratio reflects the mean of the PM2.5/PM10 ratio for large Indian cities reported in this paper

[7] Also called total suspended particulates or TSP.

Based on the current status of worldwide research, the risk ratios, or concentration-response coefficients from Pope et al (2002) were considered likely to be the best available evidence of the mortality effects of ambient particulate pollution (PM 2.5).

Damages due to anthropogenic factors are measured from a baseline PM2.5 concentration, which we set equal to 7.5 ug/m3 (as in WHO (2002). This is considered to be the level one would find in the natural environment. A log-linear function for estimating cardiopulmonary mortality associated with outdoor air pollution was applied.

The morbidity effects assessed in most worldwide studies are based on PM10. Concentration-response coefficients from Ostro (1994, 1998) and Abbey et al (1995) have been applied to estimate these effects. Ostro (1994) reviews worldwide studies and based on that Ostro (1998) estimates concentration-response coefficient for restricted activity days, and Abbey et al (1995) provides estimates of chronic bronchitis associated with particulates (PM10). A linear function for estimating morbidity end-points associated with outdoor air pollution was applied. The mortality and morbidity coefficients are presented in Table 3.1 based on these estimates.

Table 3.1 Urban Air Pollution Concentration-Response Coefficients

Annual Health Effect	Concentration-response Coefficient	Per 1 ug/m^3 annual average ambient concentration of:
Long term mortality (% change in cardiopulmonary and lung cancer mortality)	0.8% *	PM 2.5
Acute mortality children under five (% change in ARI deaths)	0.166%	PM10
Chronic bronchitis (% change in annual incidence)	0.9%	PM10
Respiratory hospital admissions (per 100,000 population)	1.2	PM10
Emergency room visits (per 100,000 population)	24	PM10
Restricted activity days (% change in annual incidence)	0.475%	PM10
Lower respiratory illness in children (per 100,000 children)	169	PM10
Respiratory symptoms (per 100,000 adults)	18,300	PM10

*Mid-range coefficient from Pope et al (2002) reflecting a linear function of relative risk. In the analysis however, we used a log-linear

Source: Pope et al (2002), Ostro (2004) for the mortality coefficients. Ostro (1994, 1998) and Abbey et al (1995) for the morbidity coefficients.

The health effects of air pollution can be converted to disability adjusted life years (DALYs) to facilitate a comparison with health effects from other environmental risk factors. DALYs per 10 thousand cases of various health end-points are presented in Table 3.2.

Table 3.2: DALYs for Different Health Endpoints

Health Effect	DALYs lost per 10,000 cases
Mortality adults	75,000
Mortality children under 5	340,000
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.

Urban air particulate pollution is estimated to cause around 109,000 premature deaths among adults and 7,500 deaths among children under 5 annually. Adult mortality estimated above is consistent with Cropper et al's (2012) estimate of the annual mortality associated with coal electricity generation in India (about 60,000 people calculated as about 650 deaths per year with 92 coal burning power plants in India). Electricity generation is responsible for a fraction of PM pollution analyzed in this study[8]. Estimated new cases of chronic bronchitis are about 48,000 per year. Annual hospitalizations due to pollution are estimated at close to 370 thousand and emergency room visits/outpatient hospitalizations at 7,300 thousand per year. Cases of less severe health impacts are also presented in the Table. In terms of annual DALYs lost mortality accounts for an estimated 60 percent, chronic bronchitis around 5 percent, restricted activity days (RADs) for 7 percent, and respiratory symptoms for 25 percent.

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Table 3.3: Estimated Health Impact of Urban Air Pollution

Health end-points	Total Cases	Total DALYs
Premature mortality adults	109,340	820,049
Mortality children under 5	7,513	255,431
Chronic bronchitis	48,483	106,663
Hospital admissions	372,331	5,957
Emergency room visits/Outpatient hospital visits	7,303,897	32,868
Restricted activity days	1,231,020,030	369,306
Lower respiratory illness in children	16,255,360	105,660
Respiratory symptoms	3,917,855,052	293,839
TOTAL		1,989,773

Source: Staff estimates.

The estimated annual cost of urban air pollution health effects is presented in Table 3.4. The cost of mortality is based on the human capital approach (HCA) as a lower bound and the value of statistical life (VSL) as an upper bound for adults and HCA for children (see Annex I).

[8] Cropper et al (2012) analyses direct emissions from coal burning power plants and applied annual average intake PM2.5 fractions. Ambient concentrations of PM2.5 are analyzed in this report.

The cost-of-illness (COI) approach (mainly medical cost and value of time losses) was applied to obtain an estimate of the morbidity cost (see cost of morbidity in Table 3.4).

To summarize, the mean estimated annual cost of PM urban air pollution totals 1,103 billion Rs. or 1.7 percent of GDP in 2009. About 90 percent of the cost is associated with mortality, and 10 percent with morbidity (Table 3.4). Measured in terms of Disability Adjusted Life Years (DALYs)[9] about 54 percent of the cost is associated with mortality and 46 percent with morbidity (Table 3.3).

Table 3.4: Estimated Annual Cost of Health Impacts (Billion Rs.)

Health categories	Total Annual Cost*	Percent of Total Cost*
		(Mean)
Mortality		
Adults	1,018	92.2%
Children under 5	13	1.2%
Morbidity:		
Chronic bronchitis	1	0.1%
Hospital admissions	3	0.3%
Emergency room visits/Outpatient hospital visits	8	0.7%
Restricted activity days (adults)	46	4.2%
Lower respiratory illness in children	14	1.3%
Total cost of Morbidity	72	9%
TOTAL COST (Mortality and Morbidity)	1,103	100 %

* Percentages are rounded to nearest percent.
Source: Staff estimates.

3.2 Lead Exposure

The problem of lead pollution used to be quite serious in India. A number of Indian studies report on a mean level in blood (BLL) at about 10 ug/dL a level that the U.S. Center for Disease Control considers requiring urgent action (see for example http://www.cdc.gov/nceh/lead/faq/about.htm). Health effects are quite uncertain at blood levels of 5-10 ug/dl.

The main pathways for lead exposure in India are the following[10]:

i. Food traces of lead are found in almost all food. Airborne lead falls onto crops or soil and is absorbed by plants.

[9] The sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability (www.who.int).
[10] Source: Toxics Link Handout on Lead (http://www.toxicslink.org)

ii. Air: lead in environment comes from industrial emissions, smelters and refineries
iii. Dust and soil: dust and soils can be significant sources of lead exposure, especially for young children. Lead in soil can come from the air or from erosion of lead bearing rocks and may be carried indoors as dust.
iv. Water: lead can enter the water supply from lead solder in the plumbing or lead pipes in the house.
v. Paint: most indoor and outdoor paints contain substantial amounts of lead. Most paint companies in large cities have eliminated lead from their products, although lead in paints might still be prevalent in rural areas.
vi. Inexpensive, horizontal PVC mini blinds.
vii. Leaded crystal is widely used for serving beverages. When the crystal comes in contact with the beverages, especially acidic beverages such as port, wine and fruit juices, some lead dissolves into the liquid.
viii. Lead fumes are released when waste oil, colored newsprint, battery casings or wood covered with lead paint are burned.

Thus, while India has been phasing out lead in gasoline since 2001 there are a number of other sources that are not still controlled. Therefore it will be quite some time until the lead phase-out policy brings significant results. Roy et al (2009) in a special study about lead phase out report that measured lead blood levels are still high in the Indian population.

Some of the studies of BLL in India date back to 2003 and the average BLL do not reflect the recent phase-out program of lead in gasoline. While there is great uncertainty about how much BLL will decline due to the on-going lead phase-out program, international experience indicates that a program over a five-year period could lead to a 40 percent reduction in BLL under a complete phase out.

As there is great uncertainty about current BLL in the urban population as a whole (and the rural population), it is necessary to undertake new studies of BLL in children and adults to provide a more accurate estimate of health effects and their costs taking into account the gradual lead phase-out in India.

IV Water Supply, Sanitation and Hygiene

The main health impacts of unclean water and poor hygiene are diarrheal diseases, typhoid and paratyphoid. In addition there are costs in the form of averting expenditures to reduce health risk. Diarrheal and related illness contributes the dominating share of the health cost. We consider these in turn.

4.1 Diarrheal Diseases, Typhoid and Paratyphoid

WHO has proposed a rigorous methodology[11] that links the access to improved water supply, safe sanitation, and hygiene to diarrheal illnesses (mortality and morbidity of children under 5) and other population morbidity based on an extended meta-analysis of peer reviewed

[11] Fewtrell, L. and J. Colford Jr. (2004).

publications,. About 88 % of diarrheal cases globally are attributed to water, sanitation and hygiene (Pruss-Ustun et al, 2004). This is a conservative approach where malnutrition impact on early childhood diseases is omitted. If considered, this additional indirect impact would approximately double the mortality attributed to water supply, sanitation and hygiene (WSH) (World Bank, 2010). However, a major part of these losses are in the form of acute respiratory mortality that was accounted for in the indoor air pollution section. To avoid double counting and be on a conservative side we considered only direct impact of inadequate water supply, sanitation and hygiene (WSH).

Mortality for children under 5 and diarrheal-based child mortality are high in India. Baseline health data for estimating the health impacts of inadequate water supply, sanitation and hygiene are presented in Table 4.1. The Office of the Registrar General (2004) indicates that 14 percent of child mortality was due to intestinal diseases. A baseline diarrheal mortality rate of 14 percent of under-5 child mortality is thus used for diarrheal mortality estimation.

For diarrheal morbidity, however, it is very difficult or practically impossible to identify all cases of diarrhea. The main reason is that substantial numbers of cases are not treated or do not require treatment at health facilities, and are therefore never recorded. A second reason is that cases treated by private doctors or clinics are often not reported to public health authorities. Household surveys therefore 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.

In spite of all these difficulties a reasonable estimate has been made of the number of cases and prevalence of diarrhea in the population, along with the number of DALYs per 100,000 cases of diarrhea. The figures summarized in Table 4.1.

Table 4.1: Baseline Data for Estimating Health Impacts

	Baseline	**Source:**
Under-5 child mortality rate in 2006	52-82	NFHS-3
Diarrheal mortality in children under 5 years (% of child mortality)	14 %	Office of Registrar General (2004)
Diarrheal 2-week Prevalence in Children under 5 years	8.9-9%	NFHS-3
Estimated annual diarrheal cases per child under 5 years	1.85-1.87	Estimated from NFHS-3
Estimated annual diarrheal cases per person (> 5 years)	0.37-0.56	International experience (Krupnick et al, 2006)
Hospitalization rate (% of all diarrheal cases) –children under 5 years	0.15%	NSS (2004)
Hospitalization rate (% of all diarrheal cases) –children under 5 years	0.3-0.6 %	
Percent of diarrheal cases attributable to inadequate water supply, sanitation and hygiene	90 %	WHO (2002b)
DALYs per 100 thousand cases of diarrhea in children under 5	70	Estimated from WHO tables
DALYs per 100 thousand cases of diarrhea in persons >5 years	100-130	

DALYs per 100 thousand cases of typhoid in persons under 5 and over 5	190-820	
DALYs per case of diarrheal and typhoid mortality in children over 5 and under 5	32-34	

Table 4.2 presents the estimated health impacts from inadequate water, sanitation and hygiene, based on the parameters given in Table 4.1, including the assumption (from WHO) that 88 percent of diarrheal illness is attributable to water, sanitation and hygiene. The table also provides estimates of DALYs lost to waterborne diseases. About 60 percent of the DALYs are from diarrheal child mortality. Typhoid/paratyphoid deaths add another 20 percent of DALY.

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

	Cases		Estimated Annual DALYS		% of Total DALYS
	Urban	Rural	Urban	Rural	
Children (under the age of 5 years) – increased mortality (Thousand)	41	198	1,384	6,714	87-93
Children (under the age of 5 years) – increased morbidity (Thousand)	57,831	178,898	20	63	1
Population over 5 years of age – increased morbidity (Thousand)	149,836	344,183	177	406	11-6
Typhoid/paratyphoid mortality (Thousand)	0.57		19		0
Typhoid/paratyphoid morbidity (Thousand)	1,150		8		0

Source: Staff estimates.

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The estimated costs associated with the impacts identified above are given in Table 4.3. The hypothetical value from which the estimates are based relies on the WHO methodology which uses conditions in developed countries as the benchmark. The incidence rates for these illnesses are close to zero in those countries (0.3 per person/year as in Fewtrell and Colford, 2004).

The total cost is Rs. 490 billion. The cost of mortality is based on the human capital approach (HCA) for children under 5. The cost of morbidity includes the cost of illness (medical treatment, medicines, and value of lost time) and value of lost DALYs estimated at GDP per capita. We used GDP per capita as a proxy for WTP for one additional year of life, expressed in DALYs.

Table 4.3 Estimated Health Impacts from Inadequate Water, Sanitation, Hygiene

	Estimated Annual Cost Rs. Bn.		
	Urban	**Rural**	**Total**
Mortality			
Children under age 5 diarrheal mortality	50	227	277
Children under age 5 typhoid			0.3
Persons over 5 typhoid			0.5
Morbidity			

Diarrheal morbidity	105	103	208
Typhoid morbidity[12]			3.3
TOTAL ANNUAL COST	155	330	489.1

Source: Staff estimates.

4.2 Averting Expenditures

In the presence of perceived health risks, individuals often take measures to avoid these risks. These are usually considered as a cost of the health risks of environmental burdens. If consumers perceive that the municipal water supply or the other sources of water supply they rely on are unsafe, they are likely to purchase bottled water for drinking purposes, or boil their water, or install water purification filters. The estimated costs of these options are given in Table 4.4. The assumed hypothetical level of expenditure here is zero (i.e. no avertive expenses would be incurred if the water supplied was safe). The total amount of avertive expenditures for India amount to about Rs. 55 Bn. a year.

Table 4.4: Estimated Total Annual Household Cost of Averting Expenditures

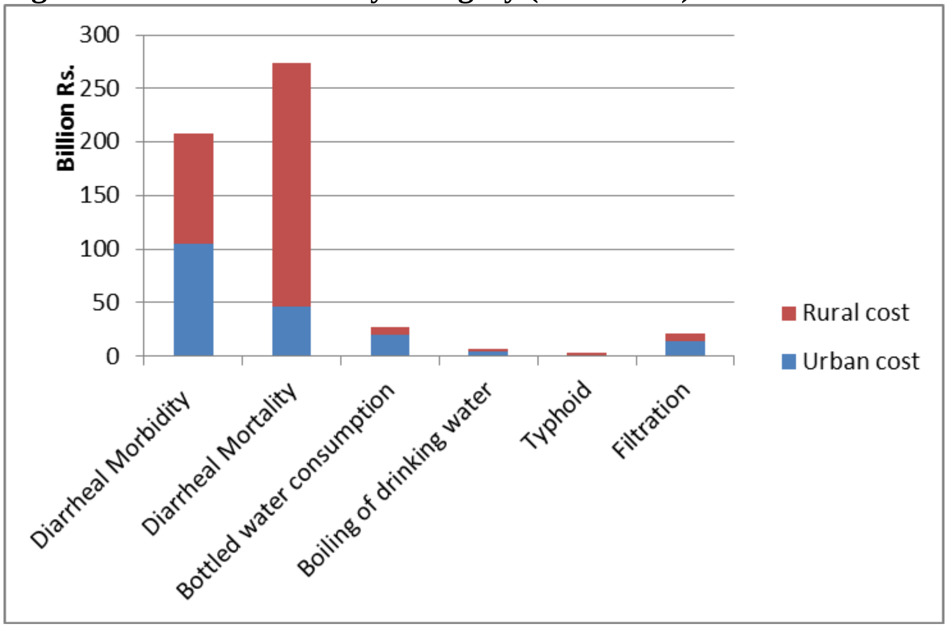
	Total Annual Cost (Billion Rs.)	
	Urban	**Rural**
Cost of bottled water consumption	20	7
Cost of household boiling drinking water	4	3
Cost of household filtering drinking water	14	7
Total annual cost	38	17

Source: Staff estimates.

In summary the estimated annual cost associated with inadequate water supply, sanitation and hygiene is presented in Figure 4.1, totaling 470-610 billion Rs. per year, with a mean of 540 billion Rs. The cost of health impacts represents an estimated 90 percent of total mean cost, with averting expenditures accounting for about 10 percent. Health impacts include both mortality and morbidity, and averting expenditures include bottled water consumption, and household boiling of drinking water. Annual costs by major category are presented on Figure 4.1.

[12] About 25 percent of estimated COI is from hospitalization and doctor visits, 70 percent is from time losses for the ill individuals and their caregivers during illness

Figure 4.1: Annual Costs by Category (Billion Rs.)



Source: Staff estimates.

V Indoor Air Pollution

WHO (2002b) estimates that 1.6 million people die each year globally due to indoor smoke from the use of traditional fuels in the home. The most common is incomplete combustion of fuels such as 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, 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.

The odds ratios in Table 5.1 have 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.[13] It is these population groups who suffer the most from indoor air pollution. This is because women spend much more of their time at home, and/or

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

more time while cooking (with little children at their side), than in comparison with older children and adult males, who spend more time outdoors.

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).

The NFHS-3 reports that 90 percent of rural and 32 percent of urban households use solid fuels for cooking in India. The national weighted average is about 71 percent.

To estimate the health effects of indoor air pollution from the odds ratios in Table 5.1, baseline data for ARI and COPD need to be established. These data are presented in Table 5.2, along with unit figures for disability adjusted life years (DALYs) lost to illness and mortality. The hypothetical level against which damages are calculates is a situation in which there is no exposure to indoor air pollution and the odds ratio is one.

Table 5.2: Baseline Data for Estimating Health Impacts

	Baseline		Source:
	Urban	Rural	
Female COPD mortality rate (% of total female deaths)	9.5%		WHO estimate for India, Shibuya et al (2001)
Female COPD incidence rate (per 100 thousand)	79		
ARI 2-week Prevalence in Children under 5 years	22%	22%	NFHS-3, 2006
Estimated annual cases of ARI per child under 5 years	1.0	1.0	Estimated from NFHS-3, 2006
Estimated annual cases of ARI per adult female (> 30 years)	0.4	0.5	Estimated from a combination of NFHS-3, 2006 and Krupnick et al, 2006
ARI mortality in children under 5 years (% of child mortality)	22%		Office of Registrar General (2004)
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	

The results of the estimation of health losses associated with indoor air pollution are presented in Table 5.3. Estimated cases of ARI child mortality and ARI morbidity (children and female adults) from indoor air pollution represent about 38-53 percent of total ARI in India. Similarly, the estimated cases of COPD mortality and morbidity represent about 46-72 percent of total estimated female COPD from all causes.

Table 5.3: Estimated Annual Health Impacts of Indoor Air Pollution (Thousands)

	Estimated Annual Cases (000)		Estimated Annual DALYs (000)	
	Urban	Rural	Urban	Rural
Acute Respiratory Illness (ARI):				
Children (under the age of 5 years) – increased mortality	19.5	166.4	662	5,660
Children (under the age of 5 years) – increased morbidity	7,570	47,925	12.5	79
Females (30 years and older) – increased morbidity	9,401	47,384	65.8	331.7
Chronic obstructive pulmonary disease (COPD):				
Adult females – increased mortality	7.5	53.4	74	363
Adult females – increased morbidity	39,000	202.5	127.7	455.6
Total Disability Adjusted Life Years (DALYs)-mortality and morbidity			942.4	6,889.3

Source: Staff estimates.

Table 5.3 also gives the DALYs lost to indoor air pollution. An estimated 8 million DALYs are lost each year. About 70-80 percent are from mortality and 20-30 percent are from morbidity.

The central estimated costs associated with the impacts identified above are given in Table 5.4. Briefly, the cost of mortality is based on the value of statistical life (VSL) estimated for India as a higher bound and HCA as a lower bound for adults and on HCA for children under 5. The cost of morbidity includes the cost of illness (medical treatment, value of lost time, etc) and value of DALYs estimated in GDP per capita.

To summarize, the total annual cost of indoor air pollution is estimated at Rs. 305-1425 billion, with a mean estimate of about Rs.865 billion (Table 5.4) or 1.3 percent of GDP in 2009. About 68 percent of this cost is associated with COPD, and 32 percent with ARI.[14] COPD and ARI mortality represents about 90 percent of the total cost, and morbidity about 10 percent (Figure 5.1).

Table 5.4: Estimated Annual Cost of Indoor Air Pollution

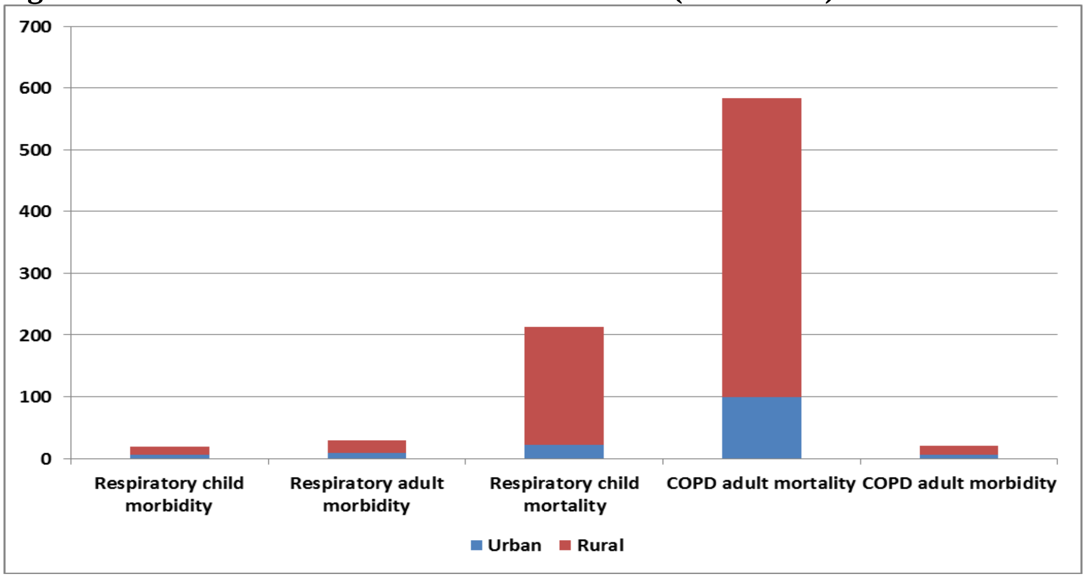
	Estimated Annual Cost (Billion Rs)	
	Urban	Rural
Acute Respiratory Illness (ARI):		
Children (under the age of 5 years) – increased mortality	20	190
Children (under the age of 5 years) – increased morbidity	5	15
Adult females – increased morbidity	10	20
Chronic obstructive pulmonary disease (COPD):		
Adult females – increased mortality	99	485
Adult females – increased morbidity	6	15
TOTAL	140	725

Source: Staff estimate.

[14] Based on the mean estimated annual cost.

Taking another classification, respiratory child mortality is 77 percent of the cost, and adult female chronic obstructive pulmonary disease (COPD) mortality is 21 percent of the cost (Figure 5.1). Acute respiratory illness (ARI) in adult females and in children represents 2 percent of cost.

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



Source: Staff estimates.

VI Natural Resources: Land Degradation, Crop Production and Rangeland Degradation

Major categories of land degradation in India are similar to those in other Asian countries. They include: (1) water and wind soil erosion and in particular, irrigation-related land degradation, including secondary salinity, water logging and irrigation-related soil erosion, (2) pasture and range land degradation, and (3) degradation of forests and bushes and related loss of biodiversity. Land degradation eventually causes landslides and mudflows especially in the sensitive mountainous areas. Most affected by degradation is pasture land near villages as well as bush and tree vegetation. Common causes are ineffective land management and lack of alternate energy resources. Land degradation not only affects agricultural productivity, biodiversity and wildlife, but also increases the likelihood for natural hazards (World Bank, 2007).

Losses to croplands and rangelands include damages from soil salinity and water logging due to improper irrigation practices and human-induced soil erosion. In the absence of data on the annual increase in salinity and eroded croplands and rangelands, the annual loss of agricultural production (crop and rangeland fodder) is estimated based on accumulated degradation. This estimate may be more or less than the net present value (NPV) of annual production losses depending on the rate of annual increase in degradation. The losses are considered in this section and the next.

6.1 Soil Salinity and Water Logging

Soil salinity and water logging reduce the productivity of agricultural lands and, if a threshold salinity level is exceeded the land becomes unfit for cultivation. According to the conventional welfare economics, if agricultural markets are competitive, the economic costs of salinity would be measured as the losses in consumer surplus (consumer willingness to pay above market price) and producer surplus (profit) associated with the loss in productivity. These losses include direct losses through reduced yields as the land becomes saline or degraded. In practice, the calculations can be more complex as account needs to be taken of crop substitution to more saline-tolerant but less profitable crops and other indirect losses. Because of a lack of data, the losses here are approximated by the value of "lost" output related to the salinity, with some simple adjustment for changes in cropping patterns.

The estimated losses from saline soils were calculated under the assumption that such land is only used for wheat production (if it is used at all). This reflects the assumption that when soils are saline farmers will tend to plant crops that are more tolerant of this factor and wheat is such a crop, as opposed to pulses and rice. FAO estimates indicate a loss of yield of 5% for wheat per unit salinity (dS/m) for levels of salinity over 6 dS/m. Taking these values and applying them to lands under wheat is the basis of the estimated loss of output.

Table 6.1. Land degradation in India, million hectares (2002)

Degradation type	Degree of Degradation				
	Slight	Moderate	Strong	Extreme	Total
Water Erosion	27.3	111.6	5.4	4.6	148.9
a. Loss of topsoil	27.3	99.8	5.4	-	132.5
b. Terrain Deterioration	-	11.8	-	4.6	16.4
Wind Erosion	0.3	10.1	3.1	-	13.5
a. Loss of topsoil	0.3	5.5	0.4	-	6.2
b. Loss of topsoil/terrain deterioration	-	4.6	-	-	4.6
c. Terrain deformation/over blowing	-	-	2.7	-	2.7
Chemical Deterioration	6.5	7.3	-	-	13.8
a. Loss of nutrient	3.7	-	-	-	3.7
b. Salinization	2.8	7.3	-	-	10.1
Physical Deterioration	-	-	-	-	116.6
Waterlogging	6.4	5.2	-	-	11.6
Total (affected area)	36.8	137.9	8.5	4.6	187.8

Source: indiastat.com

The estimates indicate a net income from a hectare of land under wheat in 2009 as being in the range Rs 8,000-18,000 and total losses from salinity based on the above assumptions come out at between Rs. 0-10 billion in scenario 1 and between Rs. 3-13 billion in scenario 2[15].

[15] Information of the salinity level (slight, moderate, strong) was not available at the time of the study. 2 scenarios were considered to address this issue.

In addition to the losses we also have to account for losses from strongly saline lands that could not be cultivated at all. There are estimated to be about 13 million hectares of agricultural land that cannot be cultivated, either because they are waterlogged or because they are highly saline. If we assume half of this area is saline then annual net losses from land wasted due to salinity are about Rs. 60-135 billion Rs. In total therefore losses due to salinity amount to between Rs. 63 and Rs 148 billion. The middle of that range is 110 billion Rs. (0.17% of GDP in 2010).

The losses due to water logging are estimated in a similar way. Then annual production losses are about 20 billion Rs. or 0.03% of GDP in 2010.

The remaining waterlogged wasteland is estimated by Indiastat.com to be 7.5 million. ha. None of this is deemed to be cultivatable. Given that the loss in annual profits for paddy production on one hectare is in the range 15,000-24,000 Rs/ha The annual net losses from land wasted due to water logging are about 83-143 billion Rs. or 113 billion Rs. on average (0.2% of GDP in 2010).

6.2 Soil Erosion

In addition to soil salinity land degradation caused by wind and water erosion is substantial in India. Two major impacts of this erosion are sedimentation of dams and loss of nutrients in the soil.

Soil erosion contributes to sedimentation of dams in India. This in turn reduces the capacity of dams and thus irrigation capacity. We do not have reliable data on sedimentation of dams and reduction in the capacity of dams in India. Hence estimates of losses in crop production as a result of sedimentation could not be made.

As far as soil erosion and the loss of soil nutrients are concerned, this can be valued in terms of the costs of replacing the losses.

The estimated cost of soil nutrients (in terms of nitrogen, phosphorus and potassium) substitution is about 320-600 billion Rs. or 460 billion Rs. on average (0.7 % of GDP in 2010). Soil erosion is thus by far the most substantial problem of land degradation in India.

Adding up the three categories of losses arising from land degradation in India we get a total of 715 billion Rs. or 1.1 % of GDP in 2010 (Table 6.2). Another way to express the loss is as a percentage of GDP from agriculture, forestry and fishery, which are sources of income predominantly for the poor. Gundimeda and Sukhdev (2008) refer to this as the “GDP of the poor” and as a percent of that the loss is about 6.4%.

Table 6.2. Estimated Annual Cost of Crop Losses Due to Land Degradation

	Total Loss (billion Rs)			% of GDP	% GDP of the poor
	Low	Mean	High	2010	
Salinity losses	63	110	148	0.2%	1.1%
Waterlogged land losses	103	133	163	0.2%	1.2%
Erosion losses	320	460	600	0.7%	4.1%
Total Crop Land Degradation Losses	480	703	910	1.1%	6.4%

Source: Staff estimates.

6.3 Rangeland Degradation

Land use reported in India suggests that the main causes of rangeland degradation in India are irrational land use management practices leading to denudation of vegetation from rangelands which, exacerbated by intermittent droughts, has resulted in many pockets of desertification. According to land use data from Indiastat.com about 10 million hectares are classified as permanent pastures. At the same time, about 1.5 times more land, including that under miscellaneous tree crops and groves and cultivable waste land, is also used as pastures. There is a substantial share of degraded lands within all these land categories. Forest lands that are used as pastures are estimated in the next section to avoid double-counting. An estimated 60 percent of livestock grazes in the forest area (Kapur et al., 2010).

The loss in yield is valued in two ways. In the first method the reduction in fodder production is valued at the price of fodder. In the second method the loss of fodder is converted into a loss of livestock based on livestock feed requirements and a value is attached to the loss of livestock. In both cases the hypothetical value against which losses are calculated is one in which original productivity prevails.

The estimated annual cost of rangeland degradation for the two methods is summarized in Table 6.3. The mean of two estimates is 405 billion Rs at 0.6% of GDP in 2010 or 3.6% GDP of the poor.

Table 6.3. Annual Cost of Rangelands Degradation in India

	Billion RS.	% of GDP	% of GDP of the poor
Market value of fodder losses	400-800	0.6-1.2%	3.6-7.2%
Foregone livestock income from fodder losses	170-256	0.3-0.4%	1.5-0.2.3%
Mean cost	405	0.6%	3.6%

Source: Staff estimates.

VII Forest Degradation

The cost of deforestation and degradation of forests is the aggregate social loss associated with degraded or deforested lands. These losses include, in theory, a wide range of local, regional, national, and even global costs. Examples include direct losses of timber, fuel wood and non-timber products, recreation and tourism losses and indirect use losses (such as those associated with damages to ecosystem services, water supply and carbon sequestration), and non-use value loss associated with loss of forests. This section examines each of these categories of losses with the available data.

India's forest cover is about 21% of total land area (about 69 million hectares). Dense forest constitutes only 12% of total forest cover area (indiastat.com). Although forest cover area increased by 0.1% in 2007 (indiastat.com), the north-eastern mountainous states with the most dense forest, like Nagaland, Arunachal Pradesh, Tripura and Assam, continued to experience deforestation due to the widespread practice of shifting cultivation. This loss is especially damaging for hilly areas where destructive agricultural practices can result in total ecosystem destruction. Total annual deforested land averaged from 2006-2009 is at about 0.6 million hectares annually (indiastat.com).

Many sources reflect a substantial level of land degradation in India. Overexploitation of forest resources has led to the opening up of the canopy and an increase of shrub-covered areas. The degraded area grew from 19.5 to 24.4 million hectares in 2003 (3rd National Report on Implementation of UN Convention to Combat Desertification, 2003). From the figure of 2.4 million hectares and with annual forest deforestation assumed to be at the same level as in 2006-2009, the total degraded forest area in 2009 would be estimated at 28 million hectares.

The estimated losses from the degraded forests are based on the use values attached to the forest in their non-degraded state. Previous studies have estimated the use values for two categories: direct use value and indirect use value. Under direct use value they have included: (i) Timber, (ii) Non-timber forest products, (iii) Fodder, (iv) Eco-tourism and (v) Carbon sequestration. Under indirect use values they have covered (i) Soil erosion prevention and (ii) Water recharge. No estimate has been made of non-use values from forests, nor has any account been taken of biodiversity values (e.g. from bioprospecting) although these can be significant.

A summary of the values obtained, both in total and normalized in terms of Rs. per hectare are given in Table 7.1. The biggest source is carbon sequestration, followed by fodder and ecotourism.

In order to value the losses we assume that degraded forests provide between 20 and 80 percent for most of the direct use values but none of the indirect values since indirect values are only associated with dense forest functions. In the case of sequestered carbon a more precise figure is available: degraded forests are associated with 20% loss of total accumulated carbon (Gundimeda, 2001), reported in the range of 21-59 tC/hectare in India,[16] valued at a social cost of carbon USD20 per ton of CO2[17]. The losses are applied to 29 million hectares of degraded forest and about 0.6 million hectares of deforested lands.

[16] We assume that degraded land would continue to sequester carbon up to 80% of what it uptakes on non-degraded forest. Carbon issues are complicated and at the next stage they should be carefully studied in the context of geographical location and other specific factors. This study attempted to provide indicative country-wide estimates.

[17] The same CO2 price is applied in China 2030 (World Bank, 2012).

Table 7.1. Estimated annual use values per hectare of forest in India (Billion Rs. except where indicated)

	Low	High
Direct		
Timber	17.2	17.2
Non timber values	21.0	21.0
Fodder	94.4	188.8
Ecotourism	51.2	51.2
Carbon sequestration	266.8	339.5
Total direct	450.6	617.7
Per hectare, Rs.	6,471.3	8,871.2
Indirect		
Soil erosion	15.5	15.5
Water recharge	6.4	6.4
Total indirect	21.9	21.9
Per hectare, Rs.	314.5	314.5
Total use values	472.5	639.6
Total per hectare, Rs.	6,785.9	9,185.7

Source: Staff estimates applying secondary data from GAISP (2005-2006), FAO (2009), Gundimeda (2005), Haripriya (2001), Pearce et al (1999), 3rd National Report on Implementation of UN Convention to Combat Desertification (2003), World Bank (2006), World Bank (2012), data from indiastat.org and www.indg.in.

Based on these figures total annual losses from degraded forest land and annual deforestation losses are presented in Table 7.2. The resulting losses are in the range of 0.1-0.3% of GDP. We should note that this is very likely an underestimate of total losses as it excludes non-use values loss. Gundimeda (2005) estimates that the non-use and bioprospecting values of forests could be as much as 6-20 times greater than use values. Due to the high uncertain nature of this estimate we did not use it in this study.

Table 7.2. Estimation of annual forest value loss, Rs. per hectare, except where indicated

Losses	% loss	Low	High
Direct values			
Timber	80-100%	198	248
Non timber values	20-100%	60	301
Fodder	0%	1,356	2,712
Ecotourism	100%	51	51
Carbon sequestration	20%	766	975
Total direct		2,432	4,287
Average % loss		42%	53%
Total direct , Rs Bn.		60.5	106.7
Indirect values			

Soil erosion	0-100%	0	1,783
Water recharge	0-100%	0	765
Total indirect		0	2,548
Average % loss		0	100
Total indirect , bil Rs		0.0	63.4
Total degradation losses, Bill Rs		60.5	170.2
Total deforestation losses (20% carbon losses only) Bill Rs		9.14	25.47
Total		69.7	195.6
%GDP		0.11%	0.30%
% GDP for the poor		0.60%	1.68%

Source: Staff estimates applying secondary data from GAISP (2005-2006), Gundimeda (2005), Gundimeda (2001).

If related to the GDP of the poor that was about 17% of the total GDP in India in 2010, then losses in the forestry sector are at about 0.6-1.7%.

Annex I. Valuation of Premature Mortality

Two distinct methods of valuation of premature mortality are commonly used 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 involves estimating income losses from premature death and was dominant in the past. But because this measure is not based on individual preferences and for other conceptual problems, it has been overtaken by both stated and revealed preference approaches to estimating preferences for reducing mortality risks. The monetary value of these preferences, or willingness to pay, when divided by the relevant risk reduction yields the value of statistical life (VSL). Because HCA almost always underestimates the VSL, the HCA has been applied as a low estimate and VSL as a high estimate in estimating the cost of premature mortality.

A. 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 Ramsey discount rate. 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 $i \in \{16,\ldots,65\}$, assuming the lifetime income on average starts at age 16 and ends at retirement at age 65. The annual growth of real income is variable, and set at about 5 percent for the first 30 years and reducing to 2 percent over the next 35 years. The GDP per capita growth rate was computed in the CGE model for India (see World Bank forthcoming report "Economic Growth and Environmental Sustainability"). Since the real growth of GDP per capita is quite high, it should be accounted for in determining the social discount rate. We apply the Ramsey discount rate to real GDP per capita assuming an intertemporal coefficient of consumption equal to 1, as in Summers and Zeckhauser (2008). Then the average effective discount rate is set at about 1percent.

The most important practical issue raised regarding the HCA is 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 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 is a serious shortcoming of the HCA approach.

The estimated cost of mortality in India based on HCA is presented in Table A1.16. Average annual income is approximated by GDP per capita, corresponding to around 57 thousand Rs. per year. The estimates are from equation (1).

Table A1: Cost of Mortality (per Death) using HCA

	Average Number of Years Lost	Thousand Rs
Adults:		
Mortality from Urban Air Pollution	8	430
Mortality from Indoor Air Pollution	7	390
Mortality from Lead Exposure	8	430
Children:		
Mortality from Urban Air Pollution	65	1,148
Mortality from Indoor Air Pollution	65	1,148
Mortality from Diarrheal Illness, Typhoid , children under 5	65	1,148
Mortality from Diarrheal Illness, Typhoid , children under 19	55	1,863

B. Value of Statistical Life.

While the HCA involves valuation of the death of an individual, VSL is based on preferences for reducing mortality risk by a small amount. Everyone in society is constantly facing a certain risk of dying. Examples of such risks are occupational fatality risks, risks 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, 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 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 Rupees per year for eliminating this mortality risk, then every 10,000 individuals are collectively willing to pay 100 thousand Rupees 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 (Rupees 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 Rupees. Thus, if 10 individuals die each year from the health risk illustrated above, the cost to society is 10* VSL = 10*100 thousand Rupees = 1 million Rupees.

A number of VSL studies have been conducted in India. Table A2 presents a summary.

Table A2: Value of Statistical Life in India

Name of Study	**Method of Estimation**	**Value**	**Adjusted Value (2010)**	**Adjusted Value in $ (2010) using ` 47.5 = $1 exchange rate**
Shanmugam K.R. (1997	Compensating-wage differentials	` 12,084,000	` 18,932,020	$398,569
Simon et al. (1999)	Compensating-wage differentials	` 6,417,341 - ` 15,040642	` 16,197,563	$341,001
Bussolo and O'Connor (2001).	PPP and income elasticity Brandon (1995) estimate	$ 202,000 - $343,860, use the central value of $273,000	` 19,109,280	$402,301
Madheswaran (2007)	Compensating wage differentials	` 15,000,000	` 16,939,353	$356,618

Source: prepared by A. Sagar.

The average VSL from these comes out at about $375,000 (Rs. 17.8 million) and this figure was applied in the report. From Table 6.2 it can be seen that the ratio of VSL/HCA is about 16 times for children and 44 times for adults.

In this report we used the average of the VSL and HCA values for adults (i.e. $192,000 or Rs. 9.1 million). For children we do not use the VSL value at all as none of the VSL studies are for children. Hence we take only the HCA value of $24,168 or Rs. 1.148 million (Table 6.1). This conservative approach is also consistent with other costs of degradation studies that have been conducted.

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