Report No. 67497-NI

Republic of Nicaragua
Country Environmental Analysis

Environmental Health in Nicaragua

Key Environmental Challenges – Study 1

June 29, 2010

Environmentally and Socially Sustainable Development Department
Latin America and the Caribbean Region

Document of the World Bank

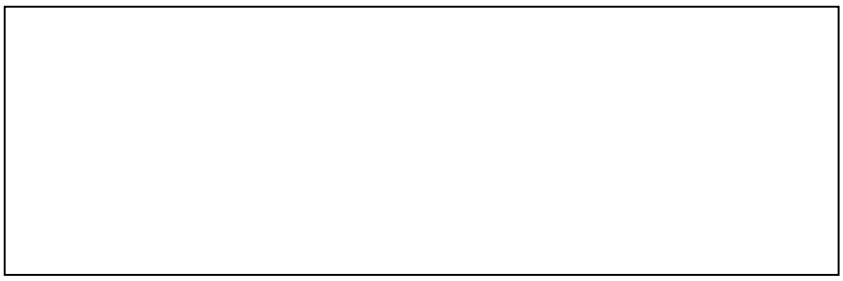
Final Version

CURRENCY EQUIVALENTS

Currency Unit = Nicaraguan Córdoba (NIO)
US $1 = 20.96

FISCAL YEAR

January 1 – December 31



Abbreviations and Acronyms

ARI	Acute respiratory infections
CEA	Country Environmental Analysis
COI	Cost of Illness
COPD	Chronic obstructive pulmonary disease
DALYs	Disability adjusted life years
EHS	Environmental Health Safeguards
ENACAL	*Empresa Nicaragüense de Acueductos y Alcantarillados Sanitarios* (Nicaraguan National Water Utility Company)
ENDESA	*Encuesta Nacional de Demografía y Salud* (National Survey on Demographics and Health)
GDP	Gross domestic product
GoN	Government of Nicaragua
HCA	Human Capital Approach
IAP	Indoor air pollution
LPG	Liquefied petroleum gas
MARENA	*Ministerio de Ambiente y Recursos Naturales* (Ministry of Environment and Natural Resources)
MINSA	*Ministerio de Salud* Ministry of Health
MDGs	Millennium Development Goals
NGO	Nongovernmental organization
NIO	Nicaraguan Córdoba
NO_2	Nitrogen dioxide
PM_{10}	Particulate matter less than 10 microns in size
$PM_{2.5}$	Particulate matter less than 2.5 microns in size
TSP	Total suspended particles
UNDP	United Nations Development Programme
VSL	Value of Statistical Life
WHO	World Health Organization
WSH	Water Sanitation and Hygiene
WSSH	Water Supply Sanitation and Hygiene
WSP	Water Sanitation Program

Table of Contents

Executive Summary iii

I. Overview 1

II. Water, Sanitation, and Hygiene 4

III. Indoor Air Pollution 13

IV. Urban Air Pollution 17

V. Conclusions 20

References 21

Tables

Table ES 1: Aggregate Environmental Health Costs for Nicaragua iv
Table I.1: Aggregate Environmental Health Costs for Nicaragua 1
Table I.2: Annual Cost of Environmental Damage – Low and High Estimates 2
Table II.1: Estimated Annual Health Effects from Water, Sanitation, Hygiene 5
Table II.2: Estimated Annual Cost of Diarrheal Illness 5
Table II.3: Baseline Data for Estimation of Costs Due to Water Boiling 6
Table II.4: Estimated Annual Household Avertive Expenditures 7
Table II.5: Costs and Benefits of Reductions in Diarrheal Morbidity and Mortality 9
Table II.6: Benefits and Costs of a Hand-Washing Program (Rural and Urban) 9
Table II.7: Benefits and Costs of a Rural Drinking Water Boiling Program 10
Table III.1: Estimated Annual Health Effects of Indoor Air Pollution 13
Table III.2: Estimated Annual Costs (million NIO) of Indoor Air Pollution in Nicaragua 14
Table III.3: Interventions 15
Table III.4: Benefits and Costs of Indoor Air Pollution Control in Nicaragua 15
Table IV.1: Measured Average Annual Concentration of Pollutants in Managua 17
Table IV.2: Estimated Health Impact of Urban Air Pollution 18
Table IV.3: Estimated Annual Cost of Health Impacts (Million NIO) 18

Figures

Figure ES 1: Costs of Environmental Degradation iv
Figure ES 2: Ranking of Interventions to Reduce WSSH Cost in Nicaragua vii
Figure ES 3: Ranking of Interventions for IAP Cost Reduction in Nicaragua viii
Figure I.1: The Burden of Mortality Related to Environmental Causes 2
Figure I.2: Health Cost of Environmental Damage in Selected Central American Countries 3
Figure II.1: Annual Costs of Inadequate Water, Sanitation and Hygiene (Million NIO) 7
Figure II.2: Ranking of Interventions to Reduce WSSH Costs in Nicaragua 12
Figure III.1: Ranking of Interventions for IAP Cost Reduction in Nicaragua 16

Acknowledgements

This study on Environmental Health for the Nicaragua Programmatic AAA has been prepared with overall coordination by Irina Klytchnikova (Economist) and Juan Carlos Belausteguigoitia (Lead Environmental Economist) and was written by Elena Strukova (Consultant, LCSEN) and Anjali Acharya (Sr. Environmental Specialist, LCSEN) with inputs from Francisco Carranza (Water Sanitation Specialist, WSP), Nelson Antonio Medina Rocha (WSP Coordinator for Nicaragua) and Gerardo Sánchez (Environmental Speacialist (JPA), LCSEN). The team would like to thank Yewande Awe (Sr. Environmental Engineer, ENV) and Ernesto Sánchez-Triana (Lead Environmental Specialist, SASDI) for their comments on this study. Assistance by Santiago Sandoval, Linda Castillo and editing by Janice Molina are gratefully acknowledged. The study was carried out under the overall guidance of Laura Frigenti (Country Director), Karin Kemper (Sector Manager since December 2009), Laura Tlaiye (Sector Manager until November 2009), Gregor Wolf (Sector Leader), Joseph Owen (Country Manager), and the guidance of the Steering Committee for the study, composed of high-level decision makers in Nicaragua. Financial support by the Governments of the Netherlands through the Bank Netherlands Partnership Program (BNPP) is gratefully acknowledged.

In order to provide country-specific estimates, workshops were held with the Technical Working Group which was set up to provide inputs to, and comment on, this environmental health analysis. In addition, workshops and other meetings were held with key officials from MARENA and MINSA, as well as other key stakeholders; their assistance with data and information has been critical for this report. The authors would like to thank MARENA Vice Minister Roberto Araquistain, MINSA Vice Minister Nora Orozco, Messrs. Jesús Marín Ruíz and Boanerges Castro (MINSA), members of the Steering Committee for the Study, composed of high-level decision makers, and the inter-institutional Technical Working Group, composed of technical experts, for their overall support for, and guidance of, this analysis.

Executive Summary

1. Globally, an estimated 24 percent of the disease burden (healthy life years lost) and an estimated 23 percent of all deaths (premature mortality) are attributable to environmental risks (WHO 2006). The burden of disease is unequally shared, with the children and the poor being particularly affected. Among children between the ages 0 and 14, the proportion of deaths attributable to environmental risks—such as poor water and sanitation, indoor air pollution and vector-borne diseases—is estimated to be as high as 36 percent (WHO 2006).

2. In its 2009–2011 Updated National Human Development Plan (NHDP), the Government of Nicaragua (GoN) has placed strong emphasis on preventive health measures and on addressing the root causes of ill health. The Plan has identified a series of measures to help Nicaragua achieve the MDG targets on child mortality and the environment. Recognizing the crucial role of improving the urban and rural populations' access to improved water and sanitation services, the GoN has also set ambitious targets to expand the provision of those services. This strategy has been reflected in the investment plans for the water supply and sanitation sector. The NHDP states the targets to expand access to public water supply in rural areas from 56 percent in 2007 to 64 percent by 2011, and to expand rural sanitation from 73 percent to 81 percemt (including all types of sanitation and including unimproved latrines). In urban areas, the targets are to increase access to public water supply from 72 to 86 percent, and to sanitation from 36 to 48 percent over the same period. In the area of air quality management, the GoN is preparing guidelines for an air quality policy, to be adopted in the future. The findings and recommendations of this study are directly relevant to the GoN's efforts to address the environmental causes of diseases.

3. In Nicaragua, poor access to water and sanitation, high use of fuelwood for cooking in rural areas, and growing vehicular use in urban areas are resulting in environmental health risks, especially in children under five years of age. The Government of Nicaragua requested the World Bank to undertake a study to answer two fundamental sets of questions on environment-related health problems in Nicaragua. The *first set* helps to demonstrate the significance of environment-related health problems: (a) How much disease and how many deaths are attributable to environmental risks? (b) Which subgroups bear the highest burden of disease? (c) What are the economic costs of the health impact of these environmental risks? The *second set* refers to the appropriate choice of interventions that the GoN can undertake to reduce these environmental risks to human health: (a) Which interventions are the most cost-effective?

4. Using established methodology recommended by the World Health Organization and others, this study attempts to provide information and raise awareness about the importance of environmental health interventions in addressing health, specifically child health, issues in developing countries such as Nicaragua. This study concentrates on three main environmental health risk factors: inadequate water supply and sanitation, indoor air pollution and urban air pollution. Recognizing the importance of using country-specific

data, this analysis has explicitly included data and figures provided by the Ministry of Environment and Natural Resources (MARENA) and by the Ministry of Health (MINSA).

5. The preparation of this analysis was launched by a consultation workshop, which was attended by representatives of MARENA, MINSA, academia, nongovernmental organizations and donor agencies. Drafts of the analysis were shared with the Technical Working Group that was created to review the findings, and comments were elicited. In June 2009, the Bank team organized a targeted one-day training course for selected staff in the Ministry of Health, aimed at building local capacity to carry out this analysis. The draft report with results of the study were shared with MINSA, MARENA and high-level decision makers from other agencies in March 2010, and the feedback received during these consultations has been incorporated in this version.

6. Several key messages have emerged from the process of putting together this study: (i) environmental health risks impose a significant burden on Nicaragua's economy, amounting to 2.6 billion NIO or 2.4 percent of the country's GDP, and result in premature deaths and infections, especially in children under five; (ii) cost-effective interventions to address these environmental health risks exist and should be prioritized in Nicaragua; (iii) country-specific health and environmental data are somewhat limited, especially in the case of air quality, and data collection and monitoring need to be further strengthened; and (iii) the capacity of MARENA and MINSA staff to conduct environmental health costing analysis needs to be strengthened through proper training.

Assessing the Economic Burden of Environmental Health Risks

7. Environmental health costs represent a significant burden on Nicaragua's economy. While progress is being made on interventions to address environmental risks, much more attention and resources need to be invested in water supply coverage, improved sanitation coverage, and proper waste disposal. Indoor air quality, especially in rural areas where biomass is used for cooking, and outdoor air quality, especially in urban areas such as Managua, are growing and important concerns. These environmental health risks are especially important for the most vulnerable subgroups of Nicaragua's population, including children under age five, women, the elderly and the poor. This study follows a methodology validated around the world for conducting analyses of the health burden of environmental degradation (Box ES 1).

Box ES 1. Estimation of environmental health costs

The analyses to assess the health impacts and subsequent costs attributed to risks from urban air pollution, poor water and sanitation, and indoor air pollution are based on World Health Organization (WHO) standard methodologies and on international research.

Water, sanitation and hygiene: Data on Nicaragua's population and on diarrheal mortality and prevalence in children under five are used to estimate the mortality and illness attributed to poor water and sanitation (WHO estimates that about 90 percent of diarrheal illness is attributable to inadequate water sanitation and hygiene). Estimates are made also for adult morbidity. Costs associated with this risk factor include expenses to treat diarrheal illness, such as doctor fees, laboratory tests, drugs and bed charges when

hospitalization is needed. Other costs include lost productivity when adults fall sick and stay home from work, or when primary caregivers have to take care of sick children (and potentially lose wages).

Indoor air pollution: Data on population using fuelwood for cooking in Nicaragua and on child mortality and prevalence of acute respiratory illnesses (ARIs) is used with odds ratios from international research evidence to estimate the premature deaths and cases of illness from ARIs in children and adults and chronic obstructive pulmonary disease (COPD) in adult women. For COPD mortality and morbidity incidence, WHO regional estimates are used in the absence of Nicaraguan data.

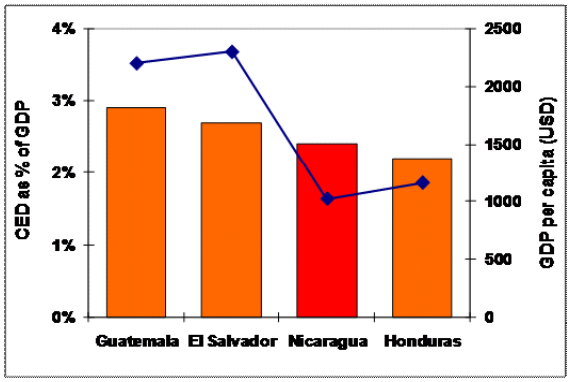
Urban air pollution: With Nicaraguan data on particulate matter and urban population figures, this analysis uses dose-response coefficients from international research evidence on long-term air pollution impacts on health to estimate the number of premature deaths and sickness attributed to urban air pollution. Using WHO methodologies, these health outcomes are then translated into disability adjusted life years (DALYs), and are also valued to arrive at cost estimates.

The cost of mortality for adults is based on the value of statistical life (VSL) as a high bound and the Human Capital Approach (HCA) as a low bound, while that for children is based on the HCA. In addition, treatment cost represents private sector (unsubsidized) health care services, while the value of time for adults (for lost work days due to sickness or caregiving) in Nicaragua is estimated at 75 percent of average hourly wages.

Source: Background report for this study (Strukova 2009).

8. Similar to other countries in Central America, the environmental health implications of poor water supply and sanitation and of indoor and urban air pollution dramatically impact Nicaragua's ability to achieve targets for reducing child mortality, improving maternal health, combating diseases, and other Millennium Development Goals (MDGs). Overall, the analysis carried out in this study shows that Nicaragua's economic costs associated with lack of water and sanitation and with indoor and urban air pollution amount to nearly 2.6 billion NIO, or 2.4 percent of the country's gross domestic product (GDP) (see table below). Among the three categories of environmental health risks, damages due to (i) inadequate water supply, sanitation and hygiene amounted to 0.92 billion NIO, or 0.9 percent of the country's GDP; (ii) indoor air pollution amounted to 870 million NIO, or 0.85 percent of GDP; and (iii) urban air pollution amounted to 780 million NIO, or 0.75 percent of the country's GDP.

Figure ES 1: Costs of Environmental Degradation



Source: CEA studies, World Bank 2005–2009.

Table ES 1: Aggregate Environmental Health Costs for Nicaragua

	NIO (billions)	Percent of GDP
Lack of water and sanitation	0.8–1.0	0.8–0.9
Indoor air pollution	0.8–0.9	0.7–0.9

Urban air pollution	0.3–1.2	0.3–1.2
Total	**1.9–3.1**	**1.8–3.0**

9. The costs of these environmental problems have been estimated in this report to help policy makers in Nicaragua appreciate the magnitude of these issues and better integrate environmental health considerations into economic development decision making. These costs include not only the medical costs of treatment and lost productivity due to sickness and caregiving, but also provide an estimate of the value of pain and suffering from premature death and disease. This analysis covers only a limited number of diseases attributed to the three environmental risk factors in question—inadequate water and sanitation, indoor air pollution, and urban air pollution—and therefore underestimates the economic burden these environmental risk factors place on Nicaragua. Furthermore, the study does not include the indirect impacts of poor water, sanitation and hygiene which are mediated through malnutrition.

10. Poor water quality, sanitation and hygiene: According to the latest WHO/UNICEF Joint Monitoring Program (JMP/2006), 90 percent of the urban population and 56 percent of the rural population in Nicaragua have access to improved sources of drinking water (piped water, public tap, borehole/tubewell, protected well, protected spring or rainwater). However, even in connected households, the quality of service is low (WSP 2008). In terms of sanitation, 56 percent of the urban population and 34 percent of the rural population have access to improved sanitation (are connected to public service or have a septic tank).[1] About 20 percent of urban and 30 percent of rural households disinfect drinking water (WSP 2008) in Nicaragua.

11. Applying an established methodology used by WHO and other international agencies and also used in this study, it is estimated that 240 children under age five in urban areas and 320 in rural areas die from diarrheal diseases attributed to poor water, sanitation and hygiene. Furthermore, among children under age five, more than a million annual cases of diarrhea in rural and urban areas, respectively, result from poor water, sanitation and hygiene. The estimated number of cases of diarrheal illness in children under age five is about 1.3 times higher in rural areas.[2]

12. The annual cost of diarrheal mortality and morbidity from inadequate water, sanitation and hygiene is estimated at 345 million NIO in urban areas and 455 million NIO in rural areas. The cost of morbidity includes the cost of illness (medical treatment, medicines

[1] These figures are comparable to the estimated shares of population in rural and urban areas with access to piped water and sanitation in all cases except for sanitation in rural areas (data from official Nicaraguan sources [ENACAL, FISE] and the 2009–2011 Updated National Human Development Plan). The figures for sanitation in rural areas are higher in the official statistics because all types of sanitation are included in these estimates, while this study excludes unimproved latrines.

[2] These estimates are made by assuming the under-age-five child mortality rate of 31 and 40 per 1,000 live births in urban and rural areas, respectively, based on 2006 data provided by the 2006–2007 ENDESA survey, which inquired about deaths of children under age five during the five-year period prior to the survey. The same source reports that for the ten-year period prior to the survey, the mortality rate for children under age five 35 and 47 per 1,000 live births in urban and rural areas.

and value of lost time). In addition, the cost of averting expenditures in Nicaragua—associated with the purchase of bottled water and disinfecting water through boiling or chlorination to avoid health risks—is estimated to range from 80 to 150 million NIO per year. The total estimated cost associated with inadequate water supply, sanitation and hygiene ranges from 830 million to 1 billion NIO per year, with a mean of 915 million NIO, amounting to 0.9 percent of the country's GDP.

13. ***Indoor air pollution****:* Acute respiratory infections (ARI) mainly affect women and children in rural areas in Nicaragua, where nine out of ten households (92 percent) burn fuelwood in inefficient stoves in poorly ventilated areas.[3] The vulnerable subgroups in the population include children under age five (ARI mortality and morbidity among children) and women over age 30 (COPD mortality and morbidity; ARI morbidity), because these subgroups are exposed to smoky kitchens.

14. Each year, an estimated 140 to 200 children under age five die from ARIs in rural areas, and an additional 40 to 70 children die in urban areas in Nicaragua. Among children under age five, more than half a million annual cases of acute respiratory infections in rural areas, and more than 200,000 cases in urban areas, can be linked to indoor air pollution. Among females over age 30, each year there are nearly 285,000 cases of indoor-air-pollution-related ARI morbidity in rural areas and nearly 162,000 cases in urban areas. Indoor air pollution also causes chronic obstructive pulmonary disease (COPD) in females over age 30: nearly 120 women die annually from COPD in urban and rural areas, and about 3,000 new cases of COPD can be attributed to indoor air pollution each year.

15. The total estimated annual cost of indoor air pollution ranges from 540 million 1.2 billion NIO with a mean cost of 870 million NIO. These costs accounted for about 0.8 percent of GDP in 2007. ARI in children represents the largest share (40 percent) of the costs. The rural poor are especially vulnerable and account for 56 percent of the total costs of indoor air pollution.

16. ***Urban air pollution:*** The total urban population exposed to air pollution was estimated to be about 1.95 million, or 62 percent of the total Nicaraguan population in 2007. Data relating to urban air quality concentrations are extremely limited and very dated. Furthermore, there is no emissions inventory, and very little city-specific data exist. Using the latest available data for 2001, adjusted using World Bank estimates, the annual average PM_{10} concentration for Managua was estimated at 67 $\mu g/m^3$, and in other Nicaraguan cities with populations over 100,000 at 43 $\mu g/m^3$. Urban air particulate pollution is estimated to cause around 420 premature deaths annually, although there is significant uncertainty about this estimate because of the limited data on emission levels and additional uncertainty in the estimation of mortality rates from illnesses related to urban air pollution in Nicaragua.[4] The number of new cases of chronic bronchitis is

[3] According to the 2006–2007 ENDESA survey, about 38 percent of households in urban and 92 percent in rural areas used fuelwood for cooking.

[4] An estimate of the annual incidence of chronic bronchitis (CB) is required in order to apply the dose response coefficients, which translate air pollution measures into the incidence of illness. In the absence of data on CB

estimated at about 520 per year. Annual hospitalizations due to pollution are estimated at close to 630, and emergency room visits/outpatient hospitalizations at 26,500 per year.

17. In estimating the costs of health impacts from particulate matter in Nicaragua, health conditions such as premature mortality, hospital admissions, restricted activity days, and emergency visits have been considered. In the absence of proper data on treatment costs, informed estimates have been provided by medical experts in Managua. The mean estimated annual cost of urban air pollution due to PM ranges from 305 million to 1.25 billion NIO, with a mean of about 780 million NIO. The low and high estimates are obtained by applying the HCA and the VSL approaches to the valuation of the costs of mortality, respectively. This represents about 0.7 percent of the country's GDP. Around 70 percent of the costs are due to mortality, and the remaining 30 percent are associated with morbidity.

---

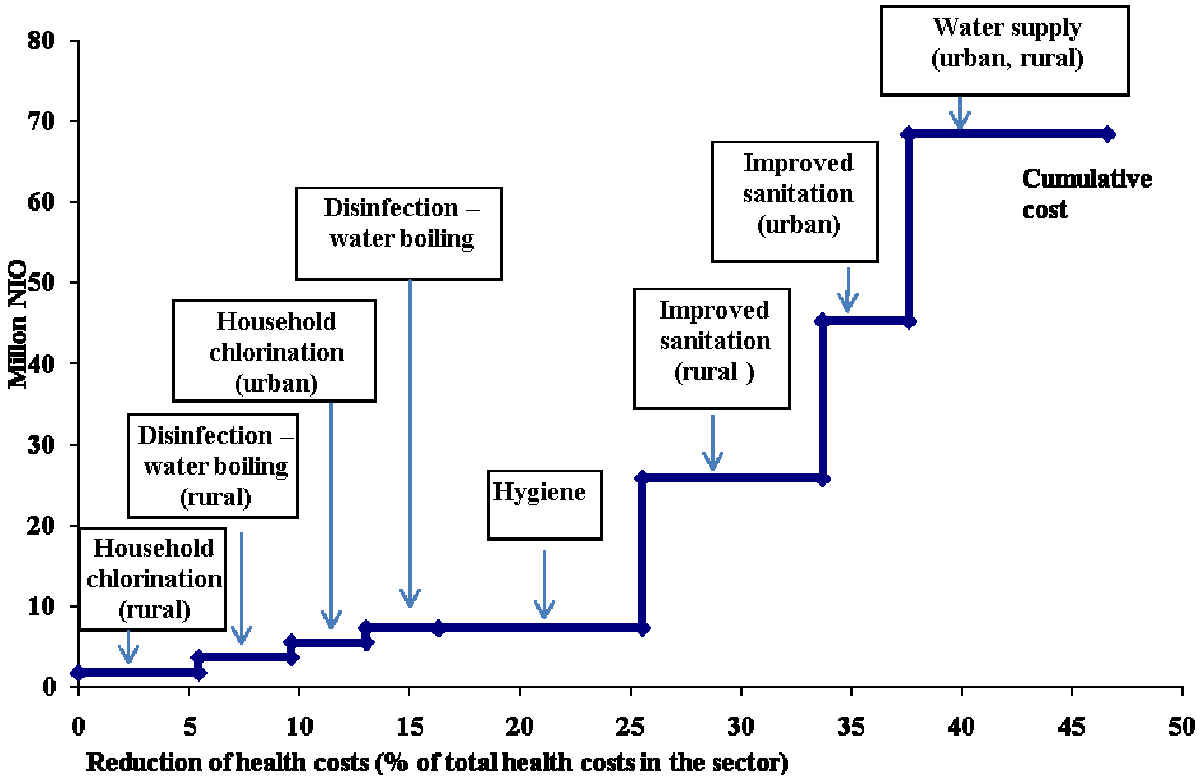
incidence for Nicaragua, this study has used the CB rate from WHO (2001) and Shibuya et al. (2001) for the AMRO D region of WHO, which includes Nicaragua. For details, see Annex A.

Prioritizing Interventions through Cost-benefit Analyses

18. Recognizing the importance of setting priorities, subsequent follow-up work included cost-benefit analyses of various environmental health interventions to address inadequate water sanitation and hygiene, and indoor air pollution. These analyses would help the government determine the most cost-effective interventions to implement in terms of addressing key environmental health risks in Nicaragua.

19. *Water, sanitation, hygiene*: Interventions related to improving the quality and quantity of water supply, improving access to improved sanitation, and programs encouraging better hygiene practices (including hand washing) have potential health benefits. For Nicaragua, this study estimated the cost-benefit ratios for improvements in water supply and sanitation, hand-washing programs, and drinking water disinfection programs (both boiling and chlorination). The height of each segment of the cumulative cost curve equals the unit cost of an intervention per one percentage point reduction of health damages; the total area below each segment is equal to the total cost of this intervention. Although several of these interventions have significant time-savings benefits, only health benefits were considered in this study. Several assumptions were also made relating to the sustainability of these programs from a behavioral perspective.

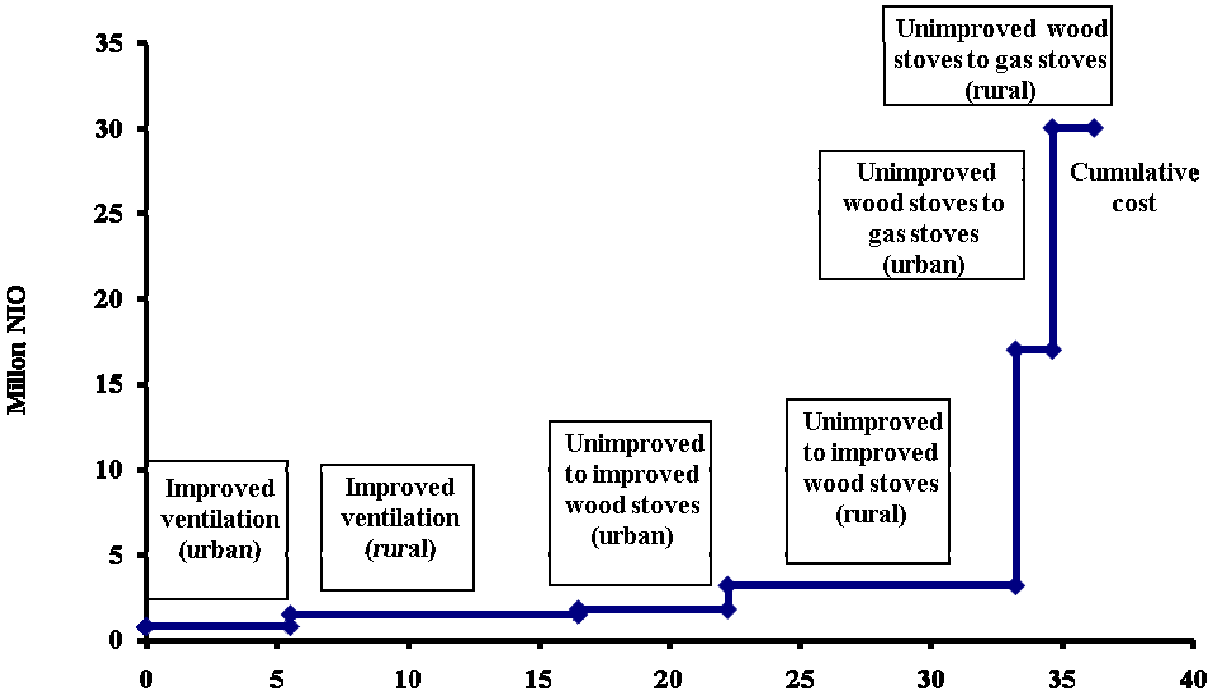
Figure ES 2: Ranking of Interventions to Reduce WSSH Cost in Nicaragua



20. Findings from this analysis revealed that in terms of water, sanitation and hygiene interventions, highest priority should be given to drinking water disinfection and hand-washing programs (in rural and urban areas) because they had the lowest cost-benefit ratios.

21. *Indoor air pollution*: Interventions are available to reduce indoor air pollution and associated health effects. These interventions typically include addressing (a) source of pollution, including moving from traditional stoves to improved stoves, and switching to cleaner fuels such as LPG; (b) the living environment, such as chimneys and smoke hoods (with flues); and (c) user behavior, such as keeping young children away from smoke. For Nicaragua, cost-benefit ratios were only estimated for interventions related to moving from unimproved to improved stoves, better ventilation, and switching to cleaner fuels.

Figure ES 3: Ranking of Interventions for IAP Cost Reduction in Nicaragua



22. The analysis for Nicaragua recommends shifting households with unimproved stoves to improved ones, and improving ventilation. The relative attractiveness of other interventions (such as from unimproved stoves to LPG or from improved stoves to LPG) is much more uncertain and depends substantively on the costs and benefits used.

23. *Urban air pollution*: For urban air pollution, a similar cost-benefit analysis was not carried out because the paucity of air quality data is a significant constraint to prioritizing interventions to reduce urban air pollution in Nicaragua. The study recommends the development of an emissions inventory to identify the main sources of air pollution in Managua and León. Furthermore, the study recommends as a priority the development of an air quality monitoring system for Managua and León so as to monitor emissions in the main urban areas. Work recently initiated by the World Bank to develop an emissions inventory for Managua and León will contribute to the identification of relevant interventions to reduce urban air pollution in Nicaragua.

I. Overview

24. Environmental pollution and inadequate environmental services, such as improved water supply and sanitation, impose significant costs to Nicaragua's economy in the form of ill health, lost income, and increased poverty and vulnerability. While progress is being made on interventions to address environmental risks, much more attention and resources need to be invested in water supply coverage and in improved sanitation coverage. Indoor air quality, especially in rural areas where biomass is used for cooking, and outdoor air quality, especially in urban areas such as Managua, are growing concerns. These environmental health risks are especially important for the most vulnerable subgroups of Nicaraguan population, including children under age five, women, the elderly and the poor. This section provides overall estimates of the health costs of environmental pollution in Nicaragua.

25. In its 2009–2011 Updated National Human Development Plan (NHDP), the Government of Nicaragua (GoN) has placed strong emphasis on preventive health measures and on addressing the root causes of ill health. The Plan has identified a series of measures to help Nicaragua achieve the MDG targets on child mortality and the environment. Recognizing the crucial role of improving the urban and rural populations' access to improved water and sanitation services, the GoN has also set ambitious targets to expand the provision of these services. This strategy has been reflected in the investment plans for the water supply and sanitation sector. The NHDP states the targets to expand access to public water supply in rural areas from 56 percent in 2007 to 64 percent by 2011, and to expand rural sanitation from 73 to 81 percent (including all types of sanitation and unimproved latrines). In urban areas, the targets are to increase access to public water supply from 72 to 86 percent, and to sanitation from 36 to 48 percent over the same period. In the area of air quality management, the GoN is preparing guidelines for an air quality policy, to be adopted in the future. The findings and recommendations of this study are directly relevant to the GoN's efforts to address the environmental causes of diseases.

26. As the evidence shows, the environmental health implications of poor water supply and sanitation and of indoor and urban air pollution dramatically impact Nicaragua's ability to achieve targets for reducing child mortality, improving maternal health, combating diseases, and other Millennium Development Goals (MDGs). Overall, the analysis shows that Nicaragua's economic costs associated with lack of water and sanitation and with indoor and urban air pollution amount to nearly 2.6 billion NIO, or 2.4 percent of the country's gross domestic product (GDP) (see Table I.1). Among the three categories of environmental health risks, (i) damages due to inadequate water supply, sanitation and hygiene amounted to 0.92 billion NIO, or 0.9 percent of the country's GDP; (ii) indoor air pollution amounted to 870 million NIO, or 0.85 percent of GDP; and (iii) urban outdoor air pollution amounted to 780 million NIO, or 0.75 percent of the country's GDP.

Table I.1: Aggregate Environmental Health Costs for Nicaragua

	NIO (billion)	Percent of GDP
Lack of water and sanitation	0.8–1.0	0.8–0.9
Indoor air pollution	0.8–0.9	0.7–0.9
Urban air pollution	0.3–1.2	0.3–1.2
Total	**1.9–3.1**	**1.8–3.1**

27. In addition to the mean estimates, "low" and "high" estimates of annual costs are presented in Table I.2. The range for water supply, sanitation and hygiene is in large part associated with uncertainties regarding estimates of diarrheal child mortality and morbidity. In the case of urban air pollution, two different valuation techniques for estimating the social cost of mortality have been applied; these yielded the "low" and "high" estimates. The range for indoor air pollution is mainly from the uncertainty about the level of exposure to indoor smoke from the use of fuelwood, and thus a range has been applied for the level of health risk.

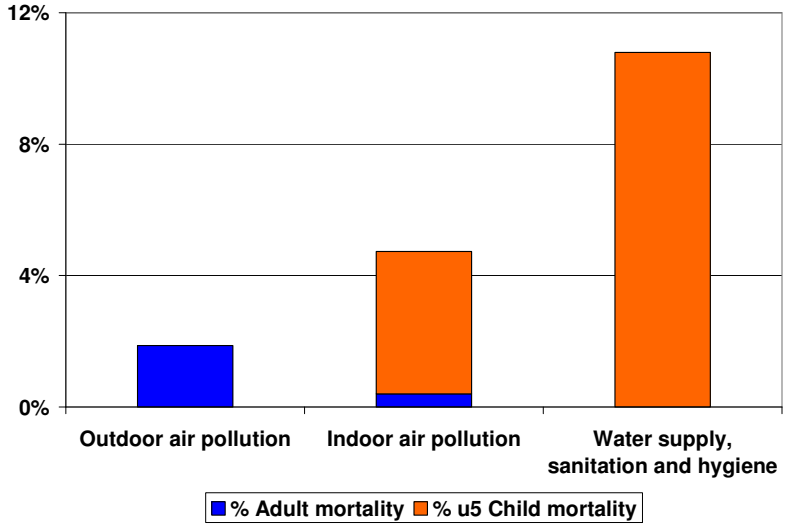
Table I.2: Annual Cost of Environmental Damage – Low and High Estimates (million NIO per year)

	"Low"	Mean Estimate	"High"
Environmental Categories			
Water supply, sanitation and hygiene	832	917	1,001
Indoor air pollution	772	872	972
Outdoor air pollution	309	779	1,249
Total costs	1,913	2,568	3,222
Costs as percent of GDP in 2007	1.8%	2.4%	3.1%

28. *Distributional impacts:* The costs of damages associated with environmental health are distributed unevenly across the population. Losses due to outdoor air pollution were estimated for the inhabitants of the cities with populations over 100,000; costs of inadequate water supply, sanitation and hygiene were estimated for the entire population of Nicaragua; indoor air pollution costs were estimated for households that use solid fuel for cooking (about 60 percent of households). Outdoor urban air pollution has the highest cost on a per-person basis, followed by damages due to indoor air pollution. Among the estimated cost items, inadequate water supply and sanitation has the lowest cost per capita.

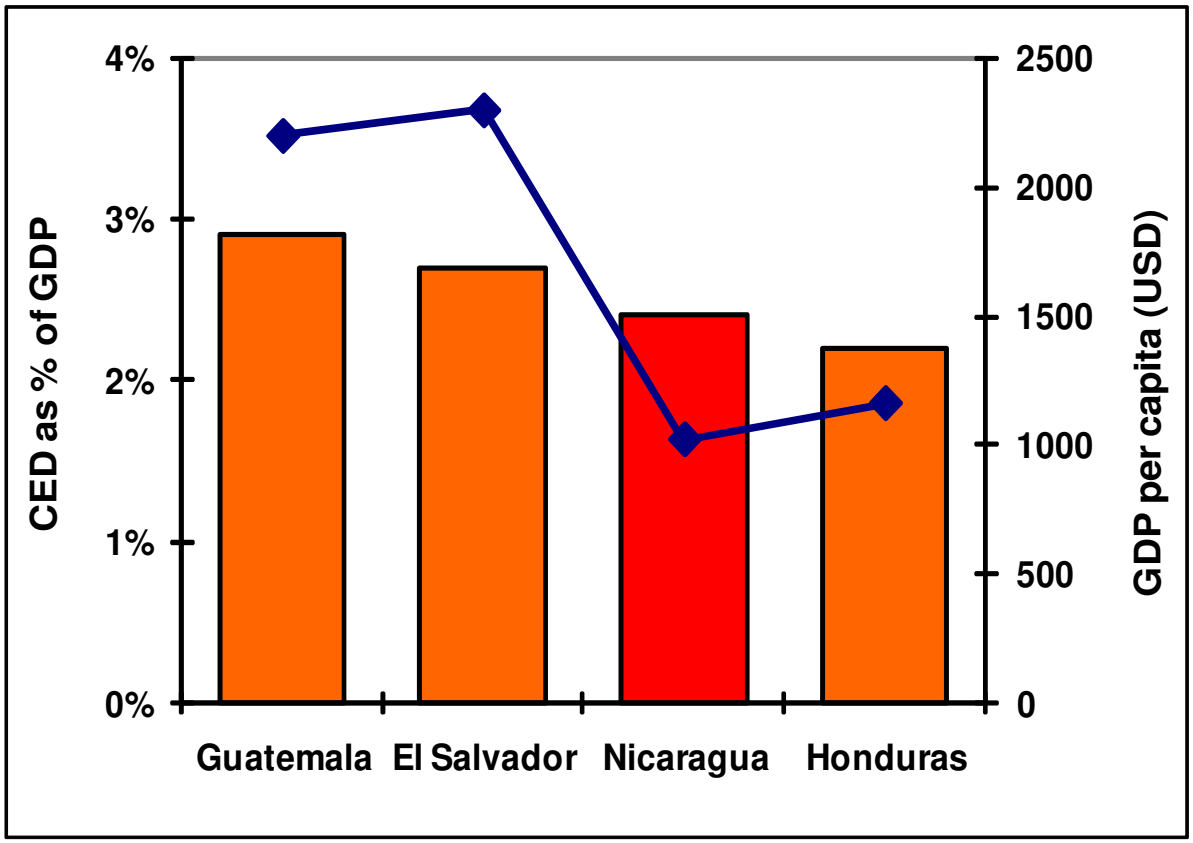
29. *Vulnerable subgroups:* About 2 percent of adult mortality is attributed to outdoor and indoor air pollution, and about 15 percent of under-age-five child mortality is attributed to inadequate water supply, sanitation and hygiene and to indoor air pollution. Figure 1.1 presents the burden of mortality related to environmental causes as a percent of total mortality among adults and children under age five in Nicaragua.

Figure I.1: The Burden of Mortality Related to Environmental Causes



30. *Central American Context:* The cost of environmental degradation in Nicaragua is comparable with other countries at similar income levels. In all the selected countries in Central America, these costs range from two to three percent of the respective country's GDP. In Nicaragua, the health cost of environmental damage—including costs of inadequate water, sanitation and hygiene, and costs of indoor and outdoor air pollution—amounts to 1.8–3.1 percent of the country's GDP.

Figure I.2: Health Cost of Environmental Damage in Selected Central American Countries



Source: CEA studies, World Bank 2005–2009.

31. The cost of environmental damage is equivalent to the benefits that society would enjoy if environmental quality were improved to a condition with no environmental risks to health, no negative impacts on productive assets from environmental degradation, and no damages to health, infrastructure and housing from natural disasters. The estimates of damage costs presented above can therefore be used as a starting point to evaluate the benefits of interventions to improve environmental quality and reduce environmental damage.

32. From a socioeconomic point of view, the well-being of society will improve if interventions that provide greater benefits than costs are implemented. A cost-benefit analysis would provide a sense of prioritization among various interventions. In terms of water supply, sanitation and hygiene, a cost-benefit analysis would involve looking at various interventions such as hand washing, drinking water disinfection, improved sanitation and water supply options, etc. Similarly, for indoor air pollution a cost-benefit analysis would consider alternative scenarios of indoor cooking that include the use of improved or unimproved stoves, and the use of solid or clean fuel (LPG). For outdoor air pollution, this analysis would assess the costs and benefits of various particulate matter (PM) emissions control options in urban areas. However, the identification of appropriate

interventions is constrained by the lack of air quality monitoring data and the absence of an emissions inventory in Nicaragua.

33. In the following sections, this study provides estimates for the costs associated with environmental health risks from inadequate water, sanitation and hygiene, and from indoor and urban air pollution. Therefore, in order to help the GoN prioritize among available interventions, this study also attempts to undertake cost-benefit analyses for each of these environmental health risks in the context of Nicaragua.

II. Water, Sanitation, and Hygiene

34. According to the latest WHO/UNICEF Joint Monitoring Program (JMP/2006), 90 percent of the urban population and 56 percent of the rural population in Nicaragua have access to improved sources of drinking water (piped water, public tap, borehole/tubewell, protected well, protected spring or rainwater). However, even in connected households, the quality of service is low (WSP 2008). In terms of sanitation, 56 percent of the urban population and 34 percent of the rural population have access to improved sanitation (are connected to public service or have a septic tank).

35. Inadequate quantity and quality of potable water supply, sanitation facilities and practices, and hygiene conditions are associated with various illnesses both in adults and children. The major health effects of inadequate water quality and quantity, sanitation facilities and practices, and hygiene are diarrheal morbidity and mortality.[5] WHO estimates that about 90 percent of diarrheal illness is attributable to these factors (WHO 2002). While diarrheal illness is generally not as serious as some other waterborne illnesses, it is more common and affects a larger number of people.

36. *Health impacts:* The estimation for diarrheal mortality in Nicaragua is based on total child mortality. Nicaragua has relatively high child mortality in general, although the estimates are quite uncertain. According to the latest demographic and health survey (*Encuesta Nicaragüense de Demografía y Salud, ENDESA*), mortality among children under age five is 35 per 1,000 live births, using the 2006 child mortality rate as the starting point in the estimation (ENDESA 2006–2007). A similar estimate of child mortality in 1998 was 51 deaths for 1,000 live births (ENDESA 1998). The main reason for the uncertainty and year-to-year variation in the estimates is that not all births are registered (Alarcón, Robles 2007).

37. The estimated health effects from inadequate water, sanitation and hygiene are based on background health data, taking into account the WHO estimate that 88 percent of diarrheal illness in Nicaragua is attributable to water, sanitation and hygiene.[6] The percent of diarrheal cases among children under age five is estimated from ENDESA 2006–2007, and in the age group older than age five it is estimated from the *Encuesta de*

[5] Hygiene refers to personal hygiene (such as hand washing), domestic hygiene and food hygiene.
[6] Estimated applying methodology presented in Fewtrell et al., 2007.

Hogares sobre Medición del Nivel de Vida, EMNV (2005).[7] The same method was applied to estimate treated cases because only the percentage of treated cases among children under age five was available from ENDESA 2006–2007.

38. Each year, an estimated 240 children under age five in urban areas and 320 in rural areas die from diarrheal diseases attributed to poor water, sanitation and hygiene. Furthermore, among children under age five, more than a million annual cases of diarrhea in rural and urban areas, respectively, result from poor water, sanitation and hygiene. The estimated number of cases of diarrheal illness in children under age five is about 1.3 times higher in rural areas.

39. Although the rural population in Nicaragua comprises about 44 percent of the total population, the estimated number of cases of diarrheal child mortality is about 40 percent higher there because the share of children in the population as well as the diarrheal prevalence are also substantially higher in rural areas. The larger share of children in the rural population, lower public awareness of the health benefits of drinking boiled water, and poorer access to energy are also determinants of higher diarrheal illness in rural children.

Table II.1: Estimated Annual Health Effects from Water, Sanitation, Hygiene

	Urban cases	**Rural cases**
Children (under age five – increased mortality	240	320
Children (under age five) – increased morbidity	1,000,000	1,200,000
Population over age five – increased morbidity	700,000	650,000

40. *Economic costs:* Inadequate access to water and sanitation leads to premature deaths and disease, which in turn impose costs on Nicaragua's economy. These costs include the expenses incurred to treat illness from diseases attributed to poor water and sanitation, doctor fees, laboratory tests, drugs, and bed charges when hospitalization is needed. Other costs include lost productivity when adults fall sick and stay home from work, or when primary caregivers have to take care of sick children (and potentially lose wages). Furthermore, the pain and suffering from premature death and illness can also be valued by calculating the burden of disease in disability adjusted life years (DALYs)[8] and by costing these DALYs at GDP per capita.

[7] EMNV (2005) reports significantly lower diarrheal prevalence among people over 5 in comparison with other AMRO D countries. This lower diarrheal prevalence among people over 5 explains relatively low estimates of WSSH losses on Nicaragua. WHO GBD (2004) predicts higher rates of diarrheal illness in AMRO D than those reported in EMNV (2005).

[8] The Disability Adjusted Life Year (DALY) is a health gap measure that extends the concept of years of life lost due to premature death to include equivalent years of healthy life lost due to poor health or disability. DALYs for a disease or health condition are calculated as the sum of the years of life lost due to premature mortality (YLL) in the population and the years lost due to disability (YLD) for incident cases of the health condition.

41. The annual cost of diarrheal mortality and morbidity from inadequate water, sanitation and hygiene is estimated at 345 million NIO in urban areas and 455 million NIO in rural areas (Table II.2). The cost of diarrheal child mortality is based on the Human Capital Approach (HCA) discussed in Annex A. The cost of morbidity includes the cost of illness (medical treatment, medicines, and value of lost time). About 50 percent of these costs are associated with the value of time lost to illness (including care giving), and 50 percent are from cost of treatment and medicines.

Table II.2: Estimated Annual Cost of Diarrheal Illness (million NIO)

	Urban	**Rural**
Mortality: Children under age 5	135	185
Morbidity: Children under age 5, population over age 5	210	270
Total Annual Costs	**345**	**455**

42. *Avertive Expenditures:* In the presence of perceived health risks, people often take averting measures to avoid these risks. If people perceive there is a risk of illness from the municipal water supply or from other sources of water supply that they use, some of them are likely to purchase bottled water for drinking purposes, boil their water, filter or chlorinate it. These averting expenditures associated with the purchase of bottled water and boiling the water account for the costs of health risks.

43. No reports were identified on the use of bottled water in Nicaragua. Bottled water use in Nicaragua was estimated at 23,000 m^3 (23 million liters) per year in 2004, with information on pricing and costs of production derived from Gómez 2008. According to surveys, nearly five to seven percent of urban households and one to three percent of rural households in Nicaragua boil their drinking water, either all the time or sometimes (WSP 2008). It is assumed that the average daily consumption of drinking water per person is 0.5 to 1.0 liters among households that use boiled water. The residential cost of energy is estimated based on data from experts, using the average stove efficiency for natural gas and wood fuel (see Annex A for details). Baseline data are presented in Table II.3. The annual cost of boiling water for these households is estimated at 20 million NIO per year.

Table II.3: Baseline Data for Estimation of Costs Due to Water Boiling

Indicator	Data	Notes
% of households that boil their drinking water	1–7%	WSP 2008
Average daily consumption of drinking water	0.5–1.0	Liters per person per day
% of households using electricity (urban-rural)	0.9–0.3%	ENDESA 2006–2007
% of households using LPG (urban-rural)	65.6–7.3%	
% of households using fuel wood (urban-rural)	30.9–91.4%	
% of households using coal (urban-rural)	0.9–0.1%	
Energy requirement for heating water (100% efficiency)	4,200	Joules/ltr/1 degree C
Average stove efficiency for heating water	25–50%	Varies by type of stove
Average time of boiling water (after reaching boiling point)	10	Minutes

41. About 20 percent of urban and 30 percent of rural households disinfect drinking water (WSP 2008) in Nicaragua. Chlorination is predominantly used to disinfect drinking water.[9] Braghetta (2006) cites the cost of chlorinating drinking water at the point of use in Nicaragua at US$10 per household per year. It is estimated that rural households spend 24 million NIO and urban households spend 15 million NIO annually for water chlorination. Data on filter use are sketchy. Although MINSA has a program for household filter distribution and about 80,000 filters are reported to have been distributed, there is no information on actual use. WSP (2008) estimates that about 5 percent of urban households use filters; this would translate into annual costs of about 7 million NIO.[10]

44. Total avertive expenditures for Nicaragua are estimated to range from 80 to 150 million NIO (Table II.4) per year. This represents about 10 to 17 percent of the total estimated annual cost associated with inadequate water supply, sanitation and hygiene.

Table II.4: Estimated Annual Household Avertive Expenditures

	Total Annual Cost (million NIO)	
	"Low"	"High"
Bottled water consumption	25	75

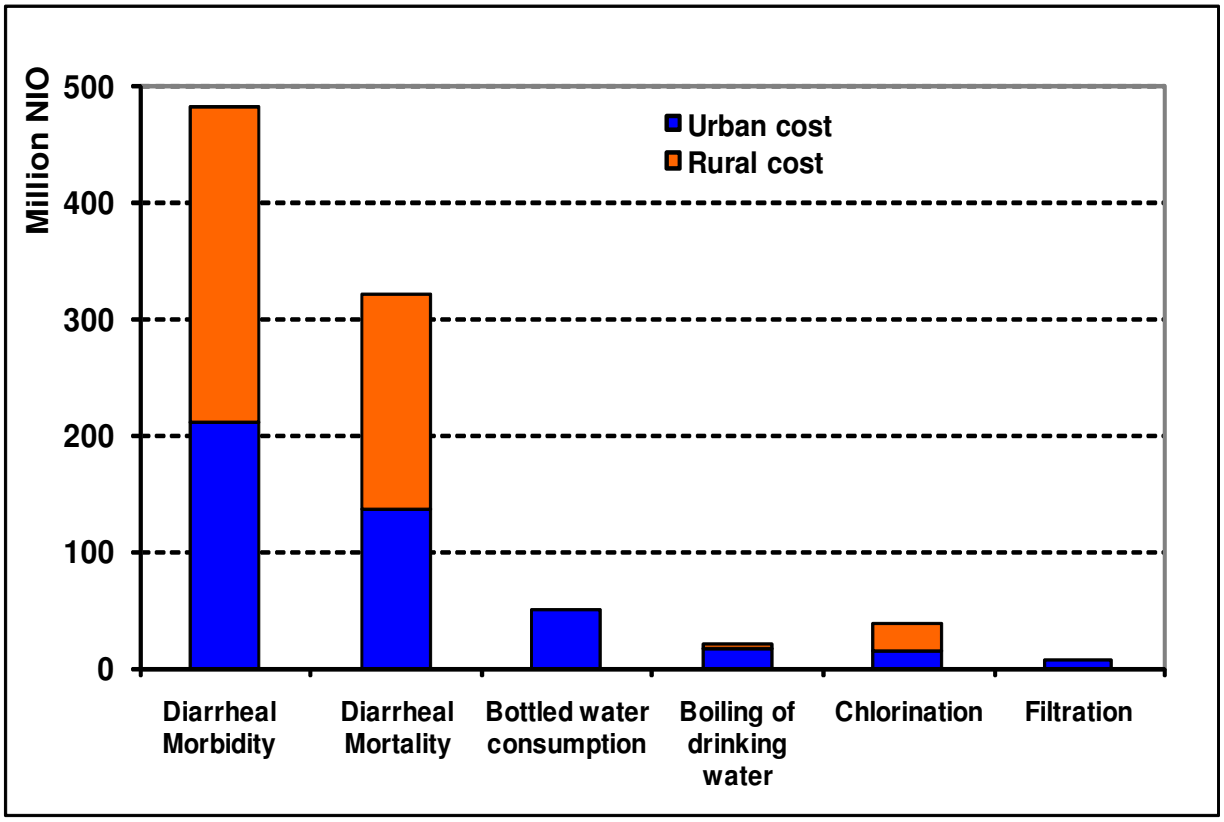
[9] WSP (2008) reports that 90 percent in rural areas and 55 to 60 percent in urban areas of those who disinfect choose to chlorinate water. However, other sources, such as Ramírez (2008), indicate that water filtration is a significant source of disinfected water in Nicaragua.

[10] Filter distribution and pricing data are from communications with B. Castro. MINSA, March 2009.

Boiling of drinking water	10	30
Chlorination	38	38
Filtration	7	7
Total annual cost	80	150

45. The total estimated cost associated with inadequate water supply, sanitation and hygiene ranges from 830 million to 1 billion NIO per year, with a mean of 915 million NIO (Figure II.1). The damages include health impacts, mortality and morbidity and averting expenditures which mostly include household boiling of drinking water. The cost of health impacts represents an estimated 87 percent, and avertive expenditures represent about 13 percent of total costs. While rural areas account for 52 percent of total cost, urban areas account for the remaining 48 percent.

Figure II.1: Annual Costs of Inadequate Water, Sanitation and Hygiene (million NIO)



46. Inadequate water and sanitation as well as poor hygiene contribute directly to health risks (diarrheal diseases), especially in children under age five. However, given the linkages among environmental health, malnutrition and disease, there are additional malnutrition-mediated (indirect) health impacts associated with inadequate water and sanitation provisions and with improper hygienic practices (Fewtrell, Prüss-Üstün et al. 2007). Furthermore, the consequences of malnutrition in children under age five, in terms of longer term cognition and learning impacts, can also be partly attributed to inadequate

water, sanitation and hygiene. Recent analyses in Ghana and Pakistan have shown that by adding these indirect impacts (both in the short term and long term), the health costs attributed to poor water, sanitation and hygiene nearly double (World Bank 2008). Estimating these additional impacts requires much more detailed analyses; it is recommended as follow-up work but has not been included within the scope of this study.

Water, Sanitation, and Hygiene Interventions

47. Interventions related to improving the quality and quantity of water supply, improving access to improved sanitation, and programs encouraging better hygiene practices (including hand washing) have potential health benefits. Based on studies from several countries around the world, estimates of the benefits associated with different interventions to reduce damage arising from unsafe water and sanitation have been developed (see Annex A for details). These international studies estimate the percentage reductions in the incidence of diarrheal morbidity and mortality following interventions to improve the infrastructure that provides drinking water or basic sanitation, or interventions that improve personal hygiene. The results are applied to available Nicaraguan health data and to estimates of the costs of providing such improvements in rural and urban areas of Nicaragua.

A. Cost-Benefit Analysis of Water and Sanitation Improvements

48. Providing piped water supply to all rural households is likely to be very expensive. A realistic objective might be to at least provide improved water supply (protected wells or boreholes) and sanitation facilities (improved pit latrines or pour-flush latrines). The aim of the infrastructure interventions is to improve water supply and sanitation, largely in rural areas. Two programs are analyzed: one that provides 1.5 million people with improved sanitation, and one that provides 1.2 million people with an improved water supply both in rural and urban areas.

49. The annualized investment costs per capita are estimated at about US$12–19 for improved sanitation and US$30–40 for improved water supply, using information about incremental service increase and corresponding investment needs from the *Estrategia Sectorial de Agua Potable y Saneamiento 2005.* This is based on a ten percent annual discount rate, an annual five percent for operation and maintenance (O&M) and five percent for promotion/water source protection costs, and US$6 in annual sewage costs.[11]

50. Benefits associated with improvements in water supply and sanitation include reductions in mortality and morbidity from diarrheal diseases (see Table II.5). Improved water supply is estimated to avert 200,000 diarrheal cases (and 40 child deaths) per year in rural areas, and 70,000 diarrheal cases (and 12 child deaths) per year in urban areas. Similarly, improvements in sanitation are estimated to avert 300,000 diarrheal cases (and 60 child deaths) per year in rural areas, and 100,000 diarrheal cases (and 17 child deaths) per year

[11] Per capita investment costs represent average costs in South America (WHO/UNICEF 2000).

in urban areas. Details on the assumptions and calculations can be found in Annex B. The morbidity costs, based on the costs of treatment and value of lost time, are US$8–14 per case of diarrhea. The mortality costs are calculated based on the Human Capital Approach (HCA).

Table II.5: Costs and Benefits of Reductions in Diarrheal Morbidity and Mortality

	Rural Areas		Urban Areas	
	Improved Sanitation Facilities	**Improved Water Supply**	**Improved Sanitation Facilities**	**Improved Water Supply**
Population (million) receiving improved sanitation	1.0		0.5	
Population (million) receiving improved water supply		0.9		0.2
% reduction in diarrheal illness /person (Fewtrell and Colford 2004)	32%	25%	32%	25%
Diarrheal cases (million) averted per year	0.3	0.2	0.1	0.07
Deaths in children averted per year	60	40	17	12
Annual Health Benefits of Improved Services (US$ million)	*4*	*3*	*2*	*1*
Annualized Costs of Service Provision (US$ million)	*12*	*24*	*9*	*10*
Benefit-Cost Ratio (health benefits only)	**0.35**	**0.1**	**0.2**	**0.1**
Marginal cost (million NIO per 1% reduction) in WSSH health cost	26	69	45	70

51. The analysis estimates that interventions (programs) that improve sanitation in Nicaragua will have a benefit-to-cost ratio greater than 1.0 when the time savings of improved water are included. For water supply programs, the benefit cost ratio is less than 1. For water supply/sanitation programs in urban areas, the costs are higher and the benefits are lower due to lower diarrheal mortality among children under age five and lower diarrheal prevalence. Marginal cost[12] would be higher than marginal benefits[13] (health damage reduction) for all four investment programs considered.

B. Benefit-Cost Analysis of Hygiene Improvements

52. In many studies, the single most effective hygiene intervention is found to be hand washing after defecation, before preparing meals, and before eating. For Nicaragua, this analysis estimates the benefits and costs of hand-washing programs in both rural and urban areas. The costs of improved hand-washing practices include (i) the costs of program preparation and implementation, and (ii) the private (household) costs associated with increased water and soap consumption. Benefits from a hand-washing program include the percentage reduction in diarrheal illness per child. These benefits are dependent on the effectiveness and sustainability of the hand-washing program in terms of behavioral change at the household and individual levels. Assumptions made, and details of methodology, can be found in Annex B.

Table II.6: Benefits and Costs of a Hand-Washing Program (Rural and Urban)

	Rural Households with Children Under Age 5	**Urban Households with Children Under Age 5**

[12] Approximated by average cost per one percent of WSSH cost reduction.
[13] Value of one percent of WSSH cost reduction, estimated at about 9 million NIO.

	Rural Households with Children Under Age 5			Urban Households with Children Under Age 5		
	Low	Med	High	Low	Med	High
Program target (million households)*	0.3	0.3	0.3	0.3	0.3	0.3
Program response (% of households with behavioral change)	10%	15%	20%	10%	15%	20%
Percent reduction in diarrheal illness per child (Fewtrell and Colford 2004)	45%	45%	45%	45%	45%	45%
Total program cost (US$ million)	0.1	0.4	1.7	0.1	0.4	1.6
Private costs of water and hygiene products per year (US$ million)	0.1	0.2	0.2	0.1	0.2	0.2
Total costs from hand-washing program	*0.2*	*0.6*	*1.9*	*0.2*	*0.6*	*1.8*
Cases of diarrheal illness averted per year (thousands)	30	45	60	30	50	60
Deaths in children averted per year	9	13	18	9	14	19
Total benefits from hand-washing program	*0.5*	*0.8*	*1.0*	*0.7*	*1.0*	*1.4*
Benefit-Cost Ratios						
LOW: If behavioral change lasts 1 year	2.2	1.4	0.6	2.9	1.9	0.8
MEDIUM: If behavioral change lasts 2 years**	3.0	**2.1**	1.0	3.9	**2.8**	1.3
HIGH: If behavioral change lasts 3 years**	3.4	2.6	1.3	4.5	3.4	1.7
Marginal cost for medium scenario (million NIO per 1% of WSSH health cost reduction)		10			7	

* There are about 0.6 million rural children under age five in Nicaragua. It is assumed there is one child under age five in each household (thus the program target is 0.6 million households). However, the estimated benefit-cost ratio is higher for households with more than one child under age five. There are about 0.4 million urban children under age five in Nicaragua. It is assumed there is one child under age five in each household (thus the program target is 0.4 million households). However, the estimated benefit-cost ratio is higher for households with more than one child under age five.** Benefits and costs in the second and third years are discounted at an annual rate of 10 percent.

53. In terms of the sustainability of the hand-washing programs, benefit-cost ratios are estimated for three scenarios of behavioral change (low, medium, high). The analysis estimates that the benefit-cost ratios for hand-washing programs in Nicaragua range from 4.5 in the "low" scenario to about 0.6 in the "high" scenario. These ratios are higher for the urban population since medical treatment costs and annual wages are higher in urban areas. Apart from children under age five, the general population over age five can also benefit from a hand-washing program. However, the benefit-cost ratios are found to be below one, primarily due to the substantially lower diarrheal incidence rates in the sub-population above age five.

C. Benefit-Cost Analysis of Drinking Water Disinfection

54. The benefit-cost analysis for drinking water disinfection interventions (boiling water, which is more common in Nicaragua, and chlorination programs) has also been estimated. There are no estimates of program costs to promote drinking water disinfection at point-of-use; therefore, the same costs as for hand-washing programs (and three scenarios of effectiveness ranging from 10 to 20 percent) have been applied. The program costs are estimated per household, while the private cost of boiling drinking water is estimated at US$5 per year for urban households using commercial fuels and about US$3 for rural households using fuelwood collected by household members. The cost of water chlorination is estimated at US$3 per household based on an average drinking water consumption of 0.75 liters per person per day (Lantagne et al. 2005).

Table II.7: Benefits and Costs of a Rural Drinking Water Boiling Program

	"Low"	"Medium"	"High"
Target population – rural population not practicing disinfection (millions)	1.5	1.5	1.5
Target households (millions)	0.3	0.3	0.3
Program response (% of households with behavioral change)	10%	15%	20%
Percent reduction in diarrheal illness per person (Fewtrell and Colford 2004)	47%	47%	47%
Program costs (US$ million)	0.1	0.3	1.4
Private costs of boiling drinking water per year (US$ million)*	0.3	0.4	0.5
Total costs of boiling drinking water	*0.4*	*0.7*	*1.9*
Cases of diarrheal illness averted per year (thousands)	45	65	90
Deaths in children averted per year	<15	<20	25
Total benefits from boiling drinking water (US$ million)	*0.7*	*1.1*	*1.5*
Benefit-Cost Ratios			
LOW: If behavioral change lasts 1 year	1.9	1.5	0.7
MEDIUM: If behavioral change lasts 2 years**	2.2	1.9	1.1
HIGH: If behavioral change lasts 3 years**	2.3	2.1	1.4
Marginal cost for medium scenario (million NIO per 1% of WSSH health cost reduction)		5	

* Estimated based on efficiency of LPG and wood stoves, cost of LPG, fuelwood collection time of 30 minutes per day and 10 percent of fuelwood used for water boiling, and per-person water consumption of 0.75 liter per day.
** Benefits and costs in the second and third years are discounted at an annual rate of 10 percent.

55. In rural areas of Nicaragua, disinfection programs are estimated to avert 110,000 to 220,000 cases of diarrhea and 25 to 50 deaths in children per year. The benefit-cost ratio for the central estimate in water boiling programs is 1.9 and for water chlorination 4.8, corresponding to a 15 percent program response rate with drinking water disinfection sustained for two years. Even for the "high" program cost, and with improved hand washing only sustained for one year, the benefit-cost ratio is 3.2. Benefit cost ratios are lower, but well above 1 in urban areas. In urban areas, the disinfection programs are estimated to avert 70,000 to 130,000 cases of diarrhea and 10 to 25 deaths in children per year. Drinking water chlorination programs in both rural and urban areas have high benefit-cost ratios, because associated private costs are low. Detailed tables for disinfection in urban areas, as well as for chlorination programs in both rural and urban areas, are in Annex B.

Summary Assessment of Interventions Relating to Water, Sanitation and Hygiene

56. As part of this analysis, interventions relating to sanitation and water supply, various forms of disinfection (boiling water and chlorination, as well as hand-washing programs) were examined. The results for these interventions can be summarized in terms of their contribution to reduced environmental damages and the costs per one percent of health damage reduction (marginal cost).

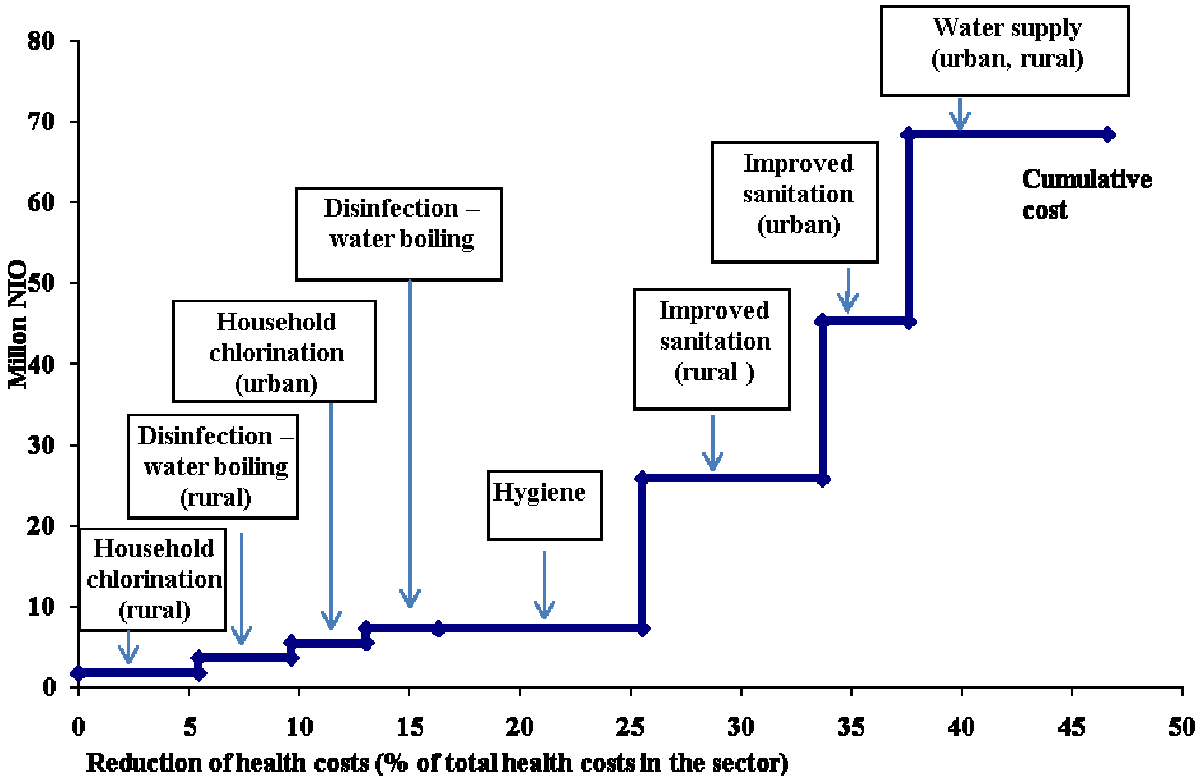
57. The length of each segment depicted in Figure II.2 represents percentage point reduction of health damage (morbidity, mortality) from the implementation of a corresponding intervention. The height of each segment of the cumulative cost curve equals the unit cost of an intervention per one percentage point reduction of health damages. The total area below each segment is equal to the total cost of this intervention. For example, the first intervention to reduce water pollution is chlorination of water at the point of use in rural areas. It is depicted by the first segment of Figure II.2. This intervention reduces five percent of total health damage associated with inadequate water supply, sanitation and

hygiene at the cost of 2 million NIO per one percentage point of this damage reduction. The total cost of this intervention is 10 million NIO. The segments are ranked in the order of increasing unit costs.

58. The disinfection and hygiene programs are estimated to have the greatest potential health benefits, but only if at least 20 percent of the population responds favorably to the program and improves hand-washing practices. Hygiene improvement and disinfection of drinking water at point of use have a substantial potential to reduce diarrheal illness and mortality. However, the challenge is to develop and deliver programs that induce sustained behavioral response at a large scale while containing program costs at an affordable level.

59. The benefit-cost ratios for hand washing and drinking water disinfection are based on behavioral change being sustained for two years. The ratios would be higher (lower) if, as a result of promotion programs, households sustain improved behavior for longer (less) than two years. This figure does not consider the possible interaction effects between different interventions (i.e., how the impacts of a first intervention affect those of a second intervention), because data constraints preclude a sound analysis of such effects.

Figure II.2: Ranking of Interventions to Reduce WSSH Costs in Nicaragua



Recommendations for Actions on Water, Sanitation, and Hygiene

60. From the analysis presented here, it is clear that in Nicaragua, most measures to improve the water supply and sanitation facilities in rural areas yield benefits in excess of costs under most assumptions. The programs are also justified because the benefits are concentrated primarily among the poor. The highest priority should be given to the drinking water disinfection and hand-washing programs in both rural and urban areas.

III. Indoor Air Pollution

61. About 2.4 billion people worldwide burn biomass (wood, crop residues, charcoal and dung) for cooking and heating. The smoke created from burning these fuels turns the kitchens of the world's poorest countries into death traps. Indoor air pollution from the burning of solid fuels kills over 1.6 million people, predominantly women and children, each year (World Bank 2002b). Smoke in the home is one of the world's leading child killers, claiming the lives of nearly one million children each year (ITDG 2004). The strongest links between indoor smoke and health are for lower respiratory infections, chronic obstructive pulmonary disease (COPD), and cancer of the respiratory system. Of all the respiratory diseases associated with indoor smoke, lower respiratory infections account for about 37.5 percent, COPD accounts for 22 COPD, and cancer of the respiratory system accounts for about 1.5 percent globally (WHO 2002b).

62. *Rural energy use:* Indoor air pollution is associated with use of traditional fuels (mainly cotton stalks in Nicaragua). About 92 percent of the rural population and 32 percent of the urban population use solid fuel for cooking in Nicaragua (ENDESA 2006–2007). WHO (Desai et al. 2004) suggests using a ventilation coefficient of 0.25 for households that use improved stoves or have outside kitchens. The national survey of solid fuel use in Nicaragua (ENDL 2006–2007) estimates that kitchens are located outside the house in 50 percent of rural and 75 percent of urban households.

63. *Health effects:* Acute respiratory infections (ARIs) and COPD are the most common diseases associated with indoor air pollution in Nicaragua. The vulnerable subgroups in the population include children under age five (ARI mortality and morbidity among children) and women over age 30 (COPD mortality and morbidity; ARI morbidity), because these subgroups are exposed to smoky kitchens. The health estimates attributed to indoor air pollution are based on background health data on ARI and COPD prevalence, available from ENDESA 2006–2007 and international sources, taking into account odds ratios (see Annex A for details).

Table III.1: Estimated Annual Health Effects of Indoor Air Pollution

	Rural areas		**Urban Areas**	
	"Low"	"High"	"Low"	"High"
Mortality:				
Acute respiratory infections in children under age 5	140	200	40	70
Chronic obstructive pulmonary disease in women over age 30	45	70	20	50
Morbidity:				
Acute respiratory infections in children under age 5	586,900	1,049,800	208,000	627,200
Acute respiratory infections in women over age 30	284,800	412,700	161,800	273,900
Chronic obstructive pulmonary disease	1,280	2,060	530	1,160

64. Each year, an estimated 140 to 200 children under age five die from ARIs in rural areas, and an additional 40 to 70 children die in urban areas in Nicaragua. Among children under age five, more than half a million annual cases of acute respiratory infections in rural areas, and more than 200,000 cases in urban areas, can be linked to indoor air pollution. Among females over age 30, each year there are nearly 285,000 cases of indoor-air-pollution-related ARI morbidity in rural areas and nearly 162,000 cases in urban areas. Indoor air pollution also causes COPD in females over age 30: nearly 120 women die annually from COPD in urban and rural areas, and about 3,000 new cases of COPD can be attributed to indoor air pollution each year.

65. *Economic costs:* The total estimated annual cost of indoor air pollution ranges from 540 million to 1.2 billion NIO with a mean cost of 870 million NIO (Table III.2). These costs account for about 0.83 percent of GDP in 2007. ARI in children represents 40 percent of cost; respiratory child mortality represents 12 percent; COPD mortality in adult females

and ARI morbidity in adult females represent 11 and 12 percent of the total costs, respectively. The rural poor are especially vulnerable and account for 56 percent of the total costs of indoor air pollution.

Table III.2: Estimated Annual Costs (million NIO) of Indoor Air Pollution in Nicaragua

	"Low"	**"High"**
Acute Respiratory Illness (ARI):		
Children (under age 5) – increased mortality	104	157
Children (under age 5) – increased morbidity	249	558
Adult females – increased morbidity	158	248
Chronic obstructive pulmonary disease (COPD):		
Adult females – increased mortality	12	212
Adult females – increased morbidity	17	30
Total	**539**	**1205**

66. In order to estimate the cost of COPD mortality for adults, the Value of Statistical Life (VSL) is used as the upper bound and HCA as the lower bound (see Annex A for details on this methodology). In the case of children, HCA is used to estimate the cost of mortality. The cost of morbidity includes the cost of illness (medical treatment and value of time lost due to illness).

Indoor Air Pollution Interventions

67. A wide range of interventions are available to reduce indoor air pollution and associated health effects. These interventions can be classified according to the level at which they are effective: (a) interventions on the source of pollution, including moving from traditional stoves to improved stoves, and switching to cleaner fuels such as LPG; (b) interventions on the living environment, such as chimneys and smoke hoods (with flues); and (c) interventions on user behavior, such as keeping young children away from smoke. For purposes of this economic analysis for indoor air quality in Nicaragua, only those interventions relating to the source of pollution have been considered, that is, moving from unimproved to improved stoves, better ventilation, and switching to cleaner fuels.

68. Five intervention scenarios considered for Nicaragua represent stylized situations commonly found in most developing countries representing reduction of pollution loads from solid fuel use. However, actual pollution exposure can vary substantially in each scenario, and depends on additional factors such as household ventilation as well as other characteristics and household behavior.

Table III.3: Interventions

Scenarios:	*Description:*
From I (50% HH) to II	From unimproved stove inside to better ventilation

From I (50% HH) to III	From unimproved stove inside to improved stoves
From III to V	From improved stove to LPG
From IV to VI	From unimproved stove and LPG mix to LPG only
From V to VI	From improved stove and LPG mix to LPG only

Table III.4: Benefits and Costs of Indoor Air Pollution Control in Nicaragua

	Rural Areas			*Urban Areas*		
	Better ventilation from unimproved stove inside	Improved stoves from unimproved stoves inside	LPG from improved stove	Better ventilation from unimproved stove inside	Improved stoves from unimproved stoves inside	LPG from improved stove
Population receiving intervention (million)	0.5	0.5	0.07	0.1	0.1	0.03
ARI cases averted/year (thousand)	400	400	50	80	80	20
ARI deaths in children averted/year	36	36	5	10	10	<5
COPD cases averted per year	110	110	20	50	50	15
COPD deaths averted per year	10	10	<5	<10	<10	<5
Annual health benefits (million NIO)	*96*	*96*	*14*	*50*	*50*	*10*
Program cost (million NIO)	13	13	2	4	4	1
Annualized stove cost (million NIO)	3	22	4	1	6	2
Annual cost of LPG (million NIO)	0	0	40	0	0	20
Total annual costs (million NIO)	*18*	*37*	*47*	*5*	*10*	*23*
Benefit-cost ratio (health benefits only)*	**6.0**	**2.7**	**0.3**	**10.6**	**4.9**	**0.5**
Marginal cost (million NIO per 1% of IAP health cost reduction)	1.5	3.2	30	0.8	1.8	17

Note: *rounded off

69. In the benefit-cost analyses of selected interventions, improved ventilation and replacement of unimproved stoves with and improved ones in individual households are found to have substantially higher benefits than costs. The benefit-cost ratio is estimated at above 3 for all four of these interventions. The benefit-cost ratio is lower than 1 if there is switching to LPG due to high LPG prices. For households with improved stoves, the health benefits alone are not large enough to outweigh the cost of switching to LPG. Although promotion of improved stoves is a very attractive intervention, the merits of promoting LPG in individual rural households are uncertain. LPG prices would have to be reduced dramatically for the estimated benefits to exceed costs. Therefore, it appears that LPG will have a chance of success only in better-off households.

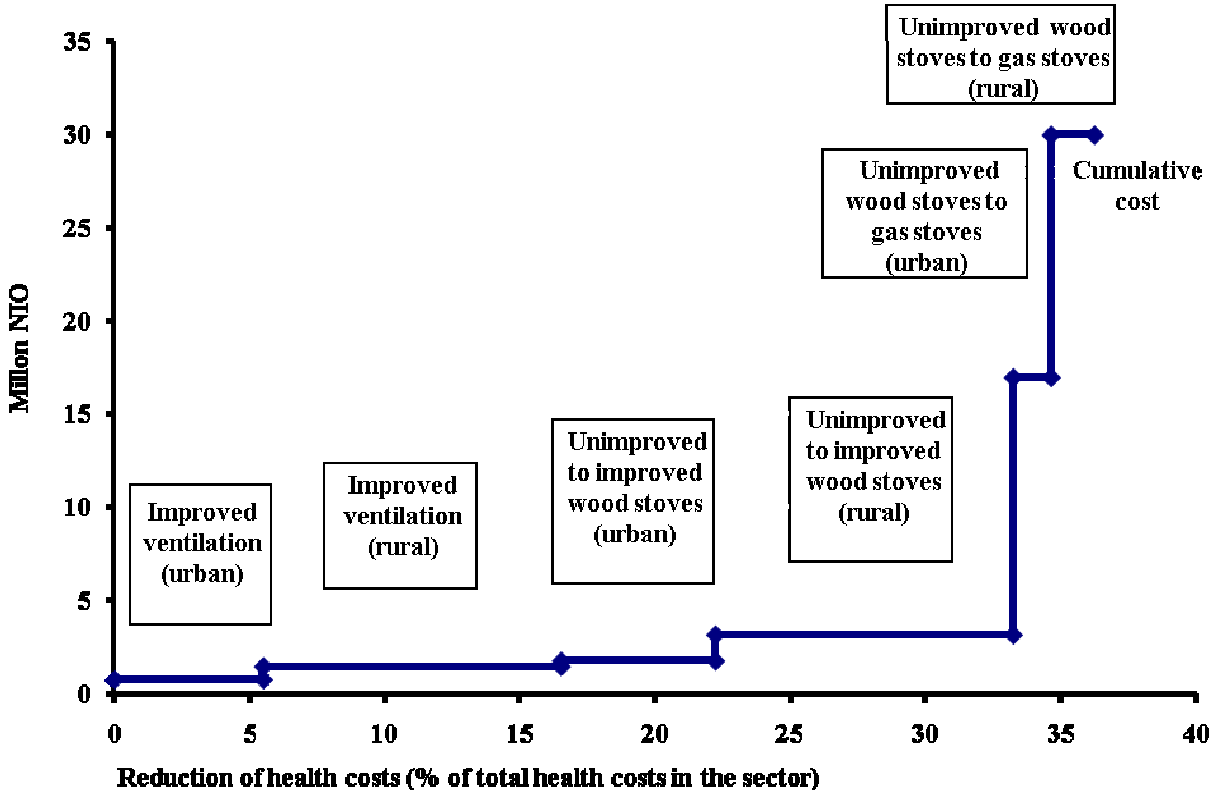
Summary Assessment of Interventions to Address Indoor Air Pollution

70. The range of interventions is summarized in terms of their contribution to reduced environmental damages and costs per one percent of health damage reduction (marginal cost)[14] (Figure III.1). Similar to the case of water pollution, the length of each segment depicted represents a percentage point reduction of health damage (morbidity, mortality) from the implementation of a corresponding intervention. The unit costs reflect only program costs and private household costs, without taking into account time and fuelwood savings.

[14] Approximated by the average cost to implement intervention per one per cent of IAP cost reduction.

71. Improved ventilation and household replacement of unimproved stoves with improved stoves results in the largest reduction in damages in rural areas. This is followed by households switching to LPG alone from improved stoves in urban and rural areas. Each of these measures contributes a smaller amount of reduction in environmental damages; marginal costs for these two interventions slightly exceed marginal benefits. In total, the first four interventions reduce the cost of health effects by about 37 percent per year. This reflects better ventilation and switching to improved stoves in 43 percent of rural households and in 8 percent of urban households, and switching to LPG from improved stoves in 3 percent of rural and 1 percent of urban households.

Figure III.1: Ranking of Interventions for IAP Cost Reduction in Nicaragua



Recommendations for Actions on Indoor Air Pollution

72. The analysis presented here recommends shifting households who have unimproved stoves to improved ones, and to improve ventilation. The relative attractiveness of other interventions (such as switching from unimproved stoves to LPG or from improved stoves to LPG) is much more uncertain and depends substantively on the costs and benefits used.

IV. Urban Air Pollution

73. *Air quality:* Managua, the capital of Nicaragua, has a population of about 1.2 million. It is located in the western part of Nicaragua on the southwestern shore of Lake Managua.

Urban (outdoor) air pollution is emerging as a major problem in Nicaragua's urban centers, particularly in Managua. Total urban population exposed to air pollution is about 1.95 million, or 62 percent of the total Nicaraguan population[15] in 2007. Data relating to urban air quality concentrations are extremely limited and very dated (last available in 2001). There is no emissions inventory, and very little city-specific data are available. Furthermore, the estimates relating to health effects from urban air pollution relate to only Managua and other cities with populations over 100,000. Although the urban population in other smaller cities in Nicaragua is also exposed to ambient air pollution, these cities were not included in the analysis due to the lack of monitoring data and estimated concentrations.

74. MARENA provided the monitored data for annual average concentrations of major pollutants in Managua in 1995–2001. No monitoring of PM_{10} and TSP was conducted after 2001.

Table IV.1: Measured Average Annual Concentration of Pollutants in Managua (1996–2001)

	Units	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**Average**	**Standard**
NO_2	$\mu g/m^3$	40	34	31	34	22	23	31	40
Ozone	$\mu g/m^3$	88	71	75	119	42	23	70	60
PM_{10}	$\mu g/m^3$	66	67	62	52	65	70	64	50
TSP	$\mu g/m^3$	n/a	288	341	241	300	253	285	75

Source: MARENA 2009

75. *Vehicle growth*: However, since the number of vehicles nearly doubled in Nicaragua in 2000–2007 (Figueroa de la Vega 2009) and the transportation fleet is a major polluting source in the urban areas, annual average concentrations of PM_{10} have not decreased since 2001. Using the latest available monitoring data, and then adjusting them in relation to World Bank estimates, the annual average PM_{10} concentration for Managua was estimated at 67 $\mu g/m^3$; in other Nicaraguan cities with populations over 100,000 it was estimated at 43 $\mu g/m^3$.[16]

76. *Health impacts*: The most significant health impact of outdoor air pollution has been associated with particulate matter and, to a lesser extent, with ground-level ozone. Particles smaller than 10 microns in size (PM_{10}), and especially those smaller than 2.5 microns ($PM_{2.5}$), penetrate deep into human lungs and cause health impacts such as acute respiratory infection (both upper and lower respiratory tract infections), COPD (especially bronchitis), asthma attacks, cardiovascular disease and lung cancer. Certain population subgroups, such as the elderly, children, and individuals with existing respiratory or cardiovascular diseases, are at increased risk from exposure to particulate matter.

[15] Estimated from http://www.mongabay.com/igapo/2005_world_city_populations/Nicaragua.html, adjusted to 2007 by applying the urban population growth rate in Nicaragua from http://www.makingcitieswork.org/files/pdf/latin-am-carribean/Nicaragua.pdf for all cities with populations over 100,000.

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

77. The annual health effects of ambient particulate air pollution in Nicaragua are calculated using the information on applicable concentration-response coefficients that link annual average PM pollution with additional cardiopulmonary mortality and various morbidity end-points (for details of the methodology, see Annex A). Urban particulate air pollution is estimated to cause around 420 premature deaths annually. The number of new cases of chronic bronchitis is estimated at about 520 per year. Annual hospitalizations due to pollution are estimated at close to 630, and annual emergency room visits/outpatient hospitalizations at 26,500. Cases of less severe health impacts are also presented in Table IV.2. In terms of annual DALYs lost, mortality accounts for an estimated 45 percent, chronic bronchitis around 16 percent of the total, Restricted Activity Days (RADs) 20 percent, and respiratory symptoms 15 percent.

Table IV.2: Estimated Health Impact of Urban Air Pollution

Health end-points	**Total Cases**
Premature mortality	429
Chronic bronchitis	514
Hospital admissions	1,352
Emergency room visits/Outpatient hospital visits	26,518
Restricted activity days	4,478,531
Lower respiratory illness in children	58,749
Respiratory symptoms	14,253,413

78. *Economic costs:* Increasing air pollution in Nicaragua's urban areas, especially in Managua, is imposing a negative economic impact from premature deaths, illness, medical costs and lost productivity. Costs of health impacts from particulate matter have been assessed, and health conditions such as premature mortality, hospital admissions, restricted activity days, and emergency visits have been considered. In the absence of proper data on treatment costs, informed estimates have been provided by medical experts in Managua.

Table IV.3: Estimated Annual Cost of Health Impacts (Million NIO)

Health Categories	**Total Annual Cost**	**% of Total Cost (Mean)**
Mortality	55–1,000	68%
Morbidity:		
Chronic bronchitis	7	1%
Hospital admissions	6	1%

Emergency room visits/Outpatient hospital visits	15	2%
Restricted activity days (adults)	202	26%
Lower respiratory illness in children	20	3%
Respiratory symptoms (adults)	0	0%
Total costs of morbidity	250	32%
Total costs (mortality and morbidity)	305–1,250	100%

79. The mean estimated annual cost of urban air pollution due to PM ranges from 305 million to 1.25 billion NIO, with a mean of is about 780 million NIO. This represents about 0.7 percent of the country's GDP. Around 70 percent of the cost is due to mortality, and the remaining 30 percent is associated with morbidity (Table IV.3). The cost of mortality, based on the Human Capital Approach (HCA) and the Value of Statistical Life (VSL), ranges from 1 billion to 55 million NIO. The measure of the welfare cost of morbidity is often based on the willingness-to-pay (WTP) to avoid or reduce the risk of illness. It 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. However, there is an insufficient number of WTP studies from Central America. Thus, the Cost-of-Illness (COI) approach (mainly medical costs and value of time losses) has been applied to estimate morbidity (see Annex A).

Summary Assessment of Actions on Urban Air Pollution

80. Health effects of air pollution are a function of ambient air quality. Estimating the benefits of urban air pollution control therefore requires: (a) an emissions inventory, (b) a relationship between the inventory and ambient air quality, and (c) an estimate of emissions reductions from individual pollution control measures. Each of these three dimensions is complex, and estimates of the benefits and costs of control options therefore need to be accompanied by a careful sensitivity analysis of key parameters of the estimates. Because Nicaragua lacks an emissions inventory, it is difficult to conduct these related economic analyses.

81. At a general level, interventions to control primary and secondary particulate emissions from mobile sources can be broadly classified into: (a) market-based instruments, such as fuel pricing and taxation, vehicle taxation, and emission taxes; (b) vehicle technology standards and regulations, including in-fleet technology retrofitting, inspection and maintenance programs, as well as auto import regulations; (c) fuel quality improvements and fuel use regulations, such as low-sulfur diesel and conversion to compressed natural gas; and (d) traffic management and urban planning, including public transportation policies (Larsen 2005). Several of these measures may be potential options for the Government of Nicaragua to consider in light of worsening air quality in its cities.

Recommendations for Actions on Urban Air Pollution

82. Rapidly increasing urban populations and accompanying vehicle growth, coupled with inadequate regulations and monitoring, will impact the air quality in cities such as Managua unless appropriate actions are taken. The lack of adequate data on air quality in Nicaragua cities, and of subsequent analysis about the sources of urban pollution, constrain the analysis of potential interventions to address this issue.

83. An air quality indicator system should be established to monitor emissions in the main urban areas of Managua and León. Moreover, as part of improving the Nicaraguan air quality management system, a detailed and integrated emissions inventory for Managua and León should be developed. A World Bank analytical study (funded by TFESSD) is under way to carry out an emissions inventory for Managua and León. Results from this work will be very useful inputs to determine the specific kinds of interventions that can address urban air pollution.

V. Conclusions

84. Several key messages have emerged from the process of putting together this study and its results: (i) environmental health risks impose a significant burden on Nicaragua's economy, amounting to 2.6 billion NIO, or 2.4 percent of the country's GDP, and resulting in premature deaths and infections, especially in children under age five; (ii) cost-effective interventions to address these environmental health risks exist and should be prioritized in Nicaragua; (iii) country-specific health and environmental data are somewhat limited, especially in the case of air quality, and data collection and monitoring need to be further strengthened; and (iii) the capacity of MARENA and MINSA staff to carry out environmental health costing analyses needs to be strengthened through proper training.

85. Diarrheal and other waterborne diseases result from inadequate water, sanitation and hygiene in Nicaragua. The significant economic burden attributed to health costs from these diseases can be alleviated through various water, sanitation and hygiene interventions. For Nicaragua, water disinfection and hygiene programs are estimated to have the greatest potential health benefits, and it is recommended that the government invest in such programs, in both in rural and urban areas. However, infrastructure investments to expand access to water and sanitation are also extremely important, especially in rural Nicaragua, because they also provide significant non-health benefits (convenience, time-savings, etc.).

86. Interventions that aim to improve air quality through improved cookstoves, switching to cleaner fuels, and better ventilation can help reduce the incidence of respiratory diseases in Nicaragua, especially among women and young children. This analysis recommends that the GoN invest in improved cookstove programs, especially for the numerous rural households where unimproved stoves are currently being used. Switching to cleaner fuels (such as LPG) is also recommended; however, the GoN needs to review the relative costs of these fuels to ensure affordability.

87. Rapidly increasing urban populations and accompanying vehicle growth, coupled with inadequate regulations and monitoring, are continuing to impact the air quality in cities such as Managua. However, the lack of adequate data and the absence of an emissions inventory make it difficult to identify the appropriate interventions for improving urban air quality in Nicaragua. The analysis endorses the ongoing work to carry out an emissions inventory for Managua and León, and recommends that the GoN take a more integrated approach to air quality management.

88. Finally, discussions with the GoN and other stakeholders have provided feedback about the usefulness of such analyses in helping to identify the appropriate interventions to address environmental health risks and contribute to a healthier Nicaragua. As part of this study, the Bank team helped to build capacity within MINSA and MARENA to carry out such environmental health costing work in future exercises. Apart from the ongoing analytical work on developing an emissions inventory, the GoN has also expressed interest in a study that would estimate health costs associated with dengue and identify appropriate environmental management solutions for Nicaragua.

References

Alarcón, D., and Robles, M. (2007). The Challenges of Measuring Child Mortality when Birth Registration is Incomplete. Global Forum on Gender Statistics. Rome, Italy.

Braghetta, A. (2006) Drawing the Connection between Malnutrition and Lack of Safe Drinking Water in Guatemala. www.livingwatersfortheworld.org/docs/drawing-the-connection-en.doc

Encuesta de Hogares sobre Medición del Nivel de Vida, EMNV (2005). INIDE. Nicaragua

Encuesta Nacional de Leña, ENDL (2006–2007). Multiconsult & Cia. Ltda.

Encuesta Nicaragüense de Demografía y Salud, ENDESA 2006–2007, Nicaragua

Fewtrell, L. and J. Colford Jr. (2004). Water, Sanitation and Hygiene: Interventions and Diarrhoea – A systematic review and meta-analysis. HNP Discussion Paper. World Bank.

Fewtrell., L., Prüss-Üstün, A., Bos, R., Gore, F., Bartram, J. (2007) Quantifying the health impact at national and local levels in countries with incomplete water supply and sanitation coverage. Environmental Burden of Disease Series, No. 15. WHO. Geneva.

Gómez, O., (2008). Producción y distribución son dos gotas de agua envasada.

Larsen, B. (2005). *Cost of Environmental Damage: Analysis by Department.* Prepared for MAVDT, Colombia.

Ramírez, C. (2008). Informe Estudio de Mercado Filtros Caseros Sostenibles. World Bank. WSP. Managua, Nicaragua.

Strukova, E. (2009). *Nicaragua. Health Costs of Environmental Damage*. Working Paper. World Bank.

WHO (2002a). Global Burden of Disease 2002. The World Health Organization.

WHO (2002b). The World Health Report 2002. The World Health Organization.

WHO/UNICEF. (2008) Joint Monitoring Programme for Water Supply and Sanitation

(JMP). Progress on Drinking Water and Sanitation: Special Focus on Sanitation. UNICEF, New York and WHO, Geneva

World Bank (2002a). Egypt Cost Assessment of Environmental Degradation. Report No. 25175-EGT. Washington DC.

World Bank (2008) El estado del saneamiento en Nicaragua. Resultados de una evaluación en comunidades rurales, pequeñas localidades y zonas periurbanas. WSP-LAC.

World Bank (2009). World Development Indicators 2009. Washington DC.

WSP. (2008). El estado del saneamiento en Nicaragua. Resultados de una evaluación en comunidades rurales, pequeñas localidades y zonas periurbanas. World Bank.

www.worldbank.org/nipr/Atrium/mapping.html.url.