

ENVIRONMENTAL HEALTH AND CHILD SURVIVAL IN NEPAL:  
Health Equity, Cost-Effectiveness, and Priority-Setting

by  
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## OVERALL ABSTRACT

Children in the developing world continue to face an onslaught of disease and death from largely preventable factors. These children are especially susceptible to poor environmental conditions, which put them at risk of developing illnesses in early life. In many developing countries, programs to improve child health have typically focused on improved feeding practices, micronutrient supplementation, national immunization campaigns, and measures to strengthen health systems (improving the availability of drugs, ensuring better treatment of cases, and hiring more trained personnel).

However, with continued exposure to contaminated water, inadequate sanitation, smoke and dust, and mosquitoes, children in developing countries are still falling sick, imposing a sustained and heavy burden on the health system. Recognizing the environment's contribution to overall child survival, there is an urgent need to broaden the spectrum of interventions beyond the health sector. Yet, environmental health interventions (which are defined as those aimed at environmental risks such as inadequate water and sanitation, and indoor air pollution) remain relatively neglected in the process of devising and implementing child survival intervention packages in most developing countries. In this thesis, only environmental health risks associated with sanitation coverage is addressed.

In developing countries like Nepal, sanitation coverage (defined as access to improved sanitary facilities)—an important contributor to child health – has been overlooked (JMP 2012). Politically, attention to provide access to water, especially piped water, has received much more attention, and strategies to expand access to water have often focused on urban areas. This neglect of sanitation becomes even more stark when one looks at it through the lens of health equity – with lower socioeconomic sections (as measured by wealth quintiles) of the population being disproportionately impacted. This dissertation, through three related papers, employs different types of analyses to investigate the importance and relevance of

including environmental health interventions such as sanitation to address child health.

These three papers focus on Nepal – where poor environmental conditions and malnutrition together continue to threaten child survival and development. The first paper highlights how expanding sanitation coverage may have the potential to differentially impact the poor, and may contribute to reducing health inequities across wealth quintiles in Nepal. The second paper investigates if cost-effectiveness of environmental health interventions to address diarrhea in children under five years old in Nepal varies across wealth quintiles. The third paper studies how environmental health interventions are prioritized among child health interventions by public health decision-makers in Nepal.

The **first** paper involves an estimation of the lives saved under two scale-up scenarios for improved sanitation in Nepal at the national level and across the 5 wealth quintiles using the Lives Saved Tool (LiST). This paper attempts to demonstrate the differential impact on child mortality and diarrheal incidence of scaling up sanitation coverage across wealth quintiles, through the use of the LiST model. The results suggest that many more lives of children under five are saved when sanitation scale-up is targeted to the lowest quintiles. It is important to note that welfare improvements made by sanitation clearly may go beyond child mortality; providing a healthier environment to children is likely to not only affect their short-term, but also their long-term physical and mental development, labor-force productivity, and lifetime earnings (Alderman et al 2006; Grantham-McGregor et al 2007; Lorntz et al 2006; Maluccio, Hoddinott, and Behrman 2006).

The **second** paper estimates how cost-effectiveness of sanitation scale-up may vary across wealth quintiles in Nepal. Results suggest that incremental cost-effectiveness ratios (ICERs) associated with scaling up sanitation are relatively low across all wealth quintiles in Nepal, and may be comparable to other child health interventions such as vaccines. Between the equal scale-up and pro-poor scale-up scenarios, there are no real differences in the ICERs for each quintile. This

demonstrates that for Nepal, from a cost-effectiveness (efficiency) perspective, there is no advantage of a pro-poor scale-up approach (however, for equity reasons, this may still be valid). A sensitivity analysis showed that while the scaling up of sanitation can be cost-effective, the degree of cost-effectiveness is sensitive to the intervention costs, diarrhea incidence, and effectiveness ratios. The absence of information/ research on differences in sanitation effectiveness across wealth quintiles, as well as the poor information of sanitation costs disaggregated by wealth quintile and type of technology, limits the interpretation of these results.

The first two papers present the equity and efficiency (cost-effectiveness) perspective when looking at scaling up sanitation. In health systems around the world policymakers share the common concern on how to find the right balance between these objectives. Ultimately, decisions on such programs to address child health involve prioritization of interventions across health and non-health sectors. The **third** paper uses a multi-criteria decision making approach to better understand how environmental health interventions might be prioritized relative to other interventions relevant for child health in Nepal. For this a discrete choice experiment survey was conducted in Kathmandu, with responses received from forty-six sanitation and public health decision-makers. This explorative analysis suggested that non-health benefits may be relevant in priority setting in child health while including a larger range of relevant criteria for priority setting. Environmental health interventions (both water and sanitation – which help reduce diarrheal incidence, as well as rural clean energy solutions –which help reduce incidence of acute respiratory infections) may be ranked as the highest priority in the context of child health in Nepal.

Together, these papers help investigate the attractiveness and potential for the inclusion of environmental health interventions within the scope of broader child health programs in developing countries like Nepal. More generally, this thesis illustrates the potential benefits of building on and extending various existing tools and methodologies to a range of environmental health interventions which lie

outside the health sector. It also specifically applies these methodologies at a disaggregated level (by wealth quintiles) to explore the differences across the socioeconomic sub-groups.

There are still need for more customized and country-specific research needed on intervention effectiveness and costs, including specifically in programmatic settings to gather evidence on scalability and sustainability. Uncertainty in several parameters and the lack of data at a disaggregated level limit the generalizability of the findings. But the economics of sanitation –from an equity-efficiency perspective –as shown in this thesis can help to inform the policy dialog on scaling up sanitation for better child health. This is an important step towards addressing the unfinished health agenda among the most vulnerable groups—children less than five years of age and in poorer households, who are disproportionately exposed to and affected by health risks from environmental hazards.

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## LIST OF ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
ARI	Acute respiratory infection
CBS	Central Bureau of Statistics
C-E	Cost-effectiveness
CEA	Cost-effectiveness analysis
CER	Cost-effectiveness ratio
CHERG	Child Health Epidemiology Reference Group
CI	Composite index
CMH	Commission on Macroeconomics and Health
DALY	Disability Adjusted Life Years
DCE	Discrete choice experiment
DHS	Demographic and Health Survey
FY	Fiscal year
GDP	Gross domestic production
GNI	Gross national income
ICER	Incremental cost-effectiveness ratios
IMCI	Integrated Management of Childhood Illness
JMP	Joint Monitoring Program
LE	Life expectancy
LiST	Lives Saved Tool
MCDA	Multi-criteria decision analysis
MDGs	Millennium Development Goals
MICS	Multiple Indicator Cluster Surveys
O&M	Operations and maintenance
ORS	Oral rehydration solution
ORT	Oral rehydration therapy
PAL	Practical Approach to Lung health
QALY	Quality Adjusted Life years
SD	Standard Deviation
SoPHEN	Society of Public Health and Environment, Nepal
TFR	Total Fertility Rate
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
VIP	Ventilated improved pit
WSH	Water, sanitation and hygiene
WHO	World Health Organization
WHO-CHOICE	WHO (CHOosing Interventions that are Cost-Effective)
WSS	Water supply and sanitation
WTP	Willingness to pay

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# Chapter 1: Environmental Health and Child Survival

# Chapter 1: Environmental Health and Child Survival

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## 1.1 Introduction

1. Interest in environmental health has mounted in recent years, spurred by concern that the most vulnerable groups—including children less than five years of age—are disproportionately exposed to and affected by health risks from environmental hazards. Typically, these environmental hazards are defined as risks from inadequate water supply and sanitation, poor hygiene practices, and indoor air pollution from unimproved stoves. More than 40 percent of the global burden of disease attributed to environmental factors falls on children below five years of age, who account for only about 10 percent of the world's population (WHO 2007b; Prüss-Üstün and Corvalán 2006).

### *Poor environmental health and malnutrition co-exist*

2. In large, populous areas in South Asia and Sub-Saharan Africa, where environmental health problems are especially severe, malnutrition in young children is also rampant (Ezzati, Vander Hoorn, et al 2004; Ezzati, Rodgers, and others 2004). Malnutrition is an important contributor to child mortality. As many as 1 in 6 children were estimated to be underweight in developing countries (UNICEF et al 2013).

3. Children in the developing world continue to face an onslaught of disease and death from largely preventable factors. These children are especially susceptible to

poor environmental conditions, which put them at risk of developing illness in early life. Each year, at least 3 million children under the age of five die due to environment-related diseases (WHO 2009). Acute respiratory infections annually kill an estimated 2 million children under the age of five (WHO 2009). As much as 60 percent of acute respiratory infections worldwide are related to environmental conditions (WHO 2009). Diarrheal diseases claim the lives of nearly 1.5 million children every year (WHO 2009). Eighty to 90 percent of these diarrhea cases are related to environmental conditions, in particular, contaminated water and inadequate sanitation (WHO 2009). In more recent estimates, globally, an estimated 6.6 million children died (12 deaths every minute) in 2012, mostly from preventable diseases. Pneumonia, diarrhea and malaria together killed roughly 2.2 million children under age five in 2012, accounting for a third of all under-five deaths (UNICEF et al 2013).

4. Malnutrition and environmental infections are inextricably linked (Black et al 1984, Checkley 2003; Scrimshaw 2003; Prüss-Üstün and Corvalán 2006; WHO 2007b); however, over time, these links have been forgotten or neglected by policy-makers in their formulation of strategies aimed at child survival and development (Acharya and Paunio 2008). Persistent malnutrition and rampant environmental health problems are contributing to the widespread failure among developing countries to meet their commitments toward the Millennium Development Goals (MDGs), including not only the goal to halve poverty and hunger (MDG 1), but also the potential to halve maternal and child mortality (MDGs 4 and 5), to achieve universal primary education (MDG 2), to promote gender equality (MDG 3), and to

combat malaria and confront the HIV/AIDS pandemic (MDG 6) by 2015. With the MDG targets coming up next year, there is clear indications that many developing countries will fail to meet their targets for sanitation.

*Role of environmental health in child survival*

5. In many developing countries, programs to improve child health have focused on improved feeding practices, micronutrient supplementation, national immunization campaigns, and measures to strengthen health systems (improving the availability of drugs, ensuring better treatment of cases, and hiring more trained personnel). However, with continued exposure to contaminated water, inadequate sanitation, smoke and dust, and mosquitoes, children in developing countries are still falling sick, imposing a sustained and heavy burden on the health system. Recognizing the environment's contribution to malnutrition and overall child survival, there is an urgent need to broaden the spectrum of interventions beyond the health sector.

6. Yet, environmental health interventions remain neglected in the process of devising and implementing child survival interventions in most developing countries. This thesis, through three related papers, employs different types of analyses to highlight the importance, demonstrate the relevance, and support the inclusion of environmental health interventions in addressing child health. These three papers focus on Nepal – where poor environmental conditions and malnutrition together continue to threaten child survival and development. The first paper (Chapter 3) highlights how expanding sanitation coverage has the potential to



differentially impact the poor, and contributes to reducing health inequities across wealth quintiles in Nepal. The second paper (Chapter 4) looks at how cost-effectiveness of environmental health interventions to address diarrhea in children under five in Nepal varies across wealth quintiles. The third paper (Chapter 5) studies how environmental health interventions are prioritized among child health interventions by health sector decision-makers in Nepal. From a public health perspective, this thesis investigates the potential for including and prioritizing environmental health interventions within the scope of broader child health programs in developing countries such as Nepal. From a methodological perspective, this thesis contributes to adapting and extending recently developed methodologies to the relatively under-researched field of environmental health interventions in the context of child health.

## **1.2 Country Context**

7. Renowned for the Himalayas, Nepal is rich in its geographic, natural, and cultural diversity. Nepal is divided into three broad geographic areas: the mountain region, the hill region, and the Terai region. Moving from east to west, the three regions lie parallel as continuous ecological belts, and are bisected by the country's river system. Nepal is a relatively small country, measuring roughly 650 kilometers long by 200 kilometers wide, with a total land mass of 147,181 square kilometers (World Bank 2008).

8. Nepal has a population of 26.5 million, with a population growth rate of 1.35 percent per year (CBS 2012). Despite some progress in poverty reduction in recent

years, Nepal remains one of the poorest countries in the world, with a Human Development Index of 0.463, placing it 157th out of 187 countries listed in the United Nations Development Programme's Human Development Report 2013 (UNDP 2013). Over 30 per cent of Nepalese people live on less than US\$14 per person, per month, according to the national living standards survey conducted in 2010-2011 (NLSS 2011). While the overall poverty rate for Nepal is 25 per cent, this figure increases to 45 per cent in the Mid-Western region and 46 per cent in the Far-Western region (NLSS 2011).

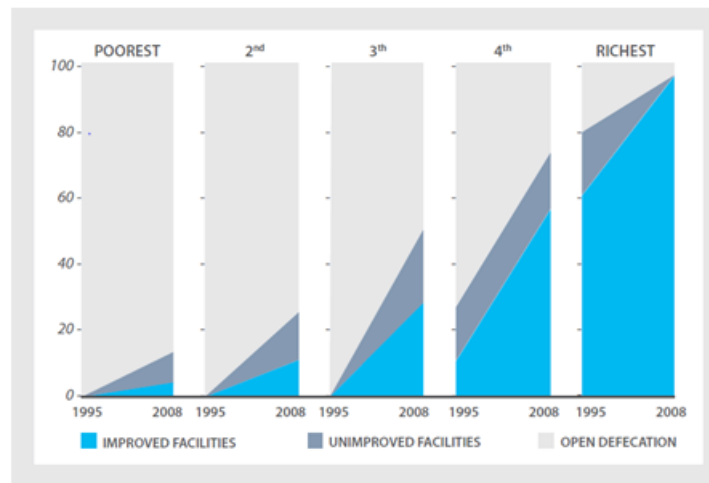
9. About 80 per cent of Nepal's people live in rural areas and depend on subsistence farming for their livelihoods (DHS 2011). Household food insecurity and poor nutrition are major concerns in these areas, where about half of children under five years of age are undernourished (DHS 2011). Most rural households have little or no access to primary health care, education, safe drinking water, sanitation or other basic services. Environmental health issues are a major concern in Nepal – with poor coverage of water and sanitation and high use of solid fuels for cooking in rural areas. The resulting incidences of diarrheal diseases (and its consequent impact on malnutrition) as well as of acute respiratory infections (from indoor air pollution) are major threats to child health.

10. Life expectancy has increased to 68 years, but is still lower than in neighboring South Asian countries (World Bank 2014). Life expectancy for women is lower than for men due to high maternal mortality. Progress in improving the health and wellbeing of children is being made, although the rate of improvement

appears to have diminished. The under 5 mortality rate had dropped significantly from 91 per 1000 in 2001 to 61 per 1000 in 2006, but then only a smaller reduction to 54 per 1000 in 2011 (DHS 2006; DHS 2011). Despite overall gains in child mortality over the last decade, malnutrition remains a major concern with over forty percent of children under five suffering from moderate to severe stunting and nearly 29% from moderate to severe underweight (DHS 2011). The poorest quintile have more than twice as many children that are stunted, and more than four times as many children who are underweight, than in the richest quintile (DHS 2011). More rural children are stunted (42 percent) than urban children (27 percent) (DHS 2011). While there has been some improvement in the nutritional status of children, malnutrition remains substantial.

11. Nepal has the poorest sanitation coverage in South Asia. Thirty-six percent of households still use a bush or open field for defecation, but this is an improvement over 2006, when one in two households had no toilet facility (DHS 2011). Nearly two in five households have improved toilet facilities (DHS 2011). Rural households are more likely than urban households not to have a toilet facility (40 percent versus 9 percent) (DHS 2011). Apart from the rural-urban differential, there is also a wide variance in coverage by region. The far-western region, for example, has the lowest percentage coverage of overall sanitary services.

**Figure 1.1: Sanitation in Nepal across wealth quintiles, 1995 and 2008**



*Source: UNICEF 2013*

12. A divide between the high-income and poor emerges when sanitation coverage is mapped against the poverty quintiles. Figure 1.1 shows that, over the 13-year period, 1995-2008, there has been little change in improved sanitation facilities for the two poorest quintiles. For example, only 4 percent of population in the bottom quintile benefited from an improvement in sanitation facilities. In the second poorest quintile, only 11 percent of the population witnessed an improvement in sanitation facilities (UNICEF 2013). Access to improved sanitation facilities for the third and fourth quintile stands higher at 29 percent and 57 percent, respectively (UNICEF 2013). On the other hand, the richest quintile recorded the most progress, with 97 percent of the population having access to improved sanitation facilities (UNICEF 2013). Given the extent of open defecation among the poor, there clearly is a serious lack of toilets and other sanitation facilities (UNICEF 2013).

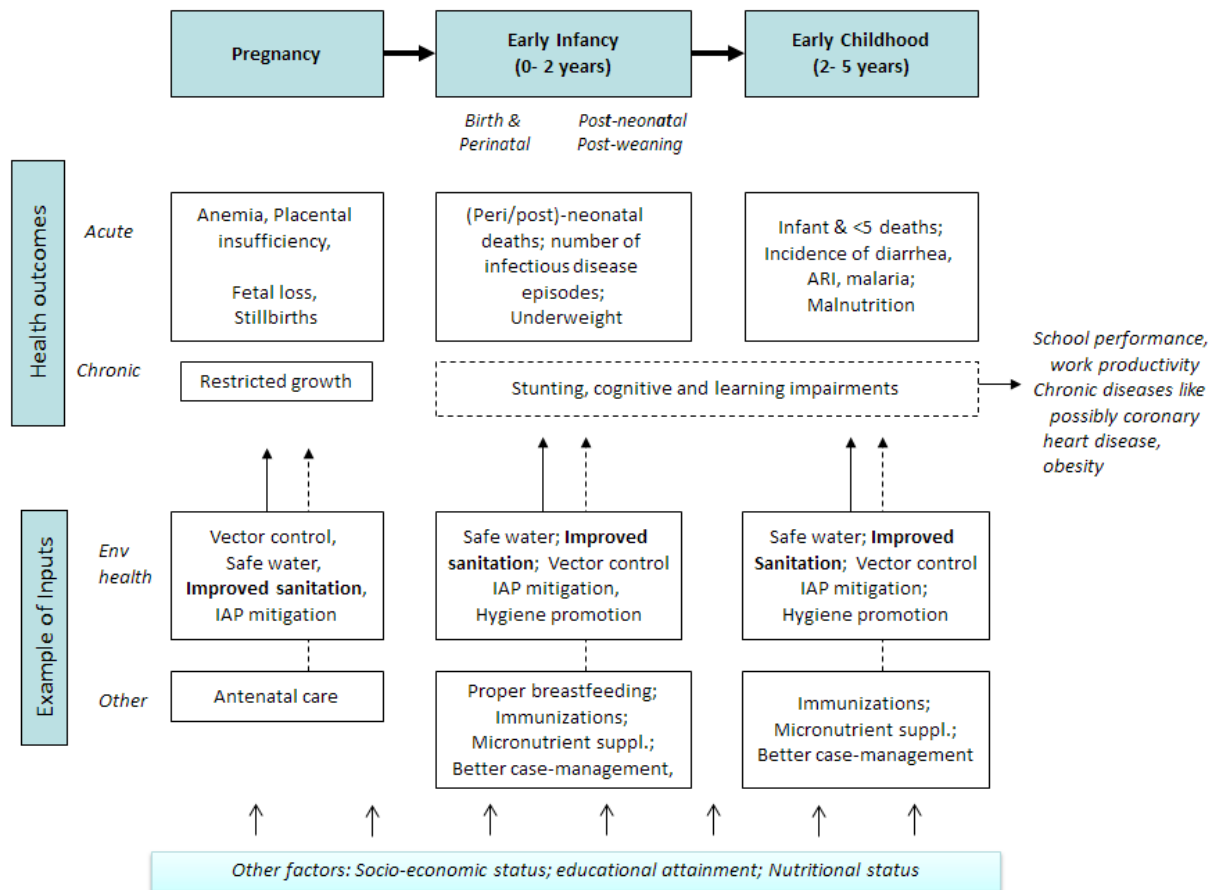
13. In Nepal, the use of biomass fuels such as wood, dung, agricultural waste, and charcoal as cooking and heating fuel is the principle cause of indoor air pollution,

especially in the rural areas. About 66% of the population still uses firewood and straw for cooking (DHS 2011). Most kitchens do not have chimneys or hoods for smoke exhaust. Use of low efficiency cooking stoves in poorly ventilated kitchens cause severe indoor air pollution which contains particulate matters, carbon monoxide, nitrous oxides, sulfur oxides (more with coal), formaldehyde, and polycyclic organic matter including carcinogens. Acute respiratory infections (ARI), chronic obstructive pulmonary disease, and tuberculosis are the three most common diseases associated with indoor air pollution in Nepal. Women and young children are the most vulnerable to indoor air pollution from smoky kitchens.

### **1.3 Conceptual Framework for Environmental Health**

14. Environmental health factors—at both the household and the community levels— play a critical role in a child’s survival and growth (see Figure 1.2). In the life cycle of a child, from the womb to the age of about two years, environmental health interventions—such as access to water and sanitation, proper hygiene practices, proper vector control, and the use of cleaner fuels for cooking and heating—are especially critical for preventing growth faltering in the fetus and infant, which has consequences for a child’s subsequent health. These impacts on a child’s growth have also been seen to result in cognition and learning problems as well as chronic diseases later in life (Guerrant et al 1999; Niehaus et al 2002; Patrick et al 2005; Lorntz et al 2006; Dangour et al 2013).

**Figure 1.2: Environmental health in the child's lifecycle**



Source: Adapted from Acharya and Paunio 2008

## Environmental health in the child's lifecycle

15. During pregnancy, the mother's own nutritional status and exposure to infections have an important effect on the fetus (Fishman et al 2004). In addition to experiencing micronutrient deficiencies, pregnant women in developing countries are exposed to numerous environmental risks. Malaria thrives in areas with poor drainage and stagnant water; while areas with bad sanitation provide prime conditions for hookworm infections (Hotez et al 2006). In many developing countries, and especially among the poor, malaria and hookworm infections coexist—both synergistically affecting the health of the pregnant woman and her

unborn child (Watson-Jones et al 2007). There is also some evidence of the effect of indoor air pollution in terms of low birth weight and perinatal mortality (WHO 2000).

16. Several studies that looked at the impact of infections on child growth have shown that exposure to environmental health risks in early infancy leads to permanent growth faltering, lowered immunity, and increased mortality (Martorell 1995; Stephensen 1999; Moore et al 2001; Checkley et al 2003). Averting repeated disease episodes, especially in the first two years of life—the “window of opportunity”—prevents the more permanent and devastating wasting and stunting, which have longer-term implications for a child’s health and prognosis (World Bank 2006).

17. Breastfeeding is considered an effective means of protecting infants from diarrheal diseases (Dai and Walker 1999; VanDerslice, Popkin, and Briscoe 1994). Reducing the level of environmental contamination similarly reduces the risk of diarrhea (VanDerslice, Popkin, and Briscoe 1994). Good sanitation practices (such as proper disposal of excreta, improving water supplies, and hand washing and personal hygiene) protect infants by creating barriers to keep pathogens out of their environment (VanDerslice, Popkin, and Briscoe 1994). The protective effect provided by good-quality drinking water and improved community sanitation is greatest for non-breastfed infants and completely weaned infants (VanDerslice, Popkin, and Briscoe 1994).

18. In early childhood (two to five years of age), the growth-faltering effects of repeated disease episodes are considered largely reversible, in contrast to the irreversibility of such effects in early infancy (Checkley 2003; Scrimshaw 2003). Still, the environmental risk factors associated with poor access to water, improper sanitation, and bad household and community hygiene remain a threat—especially given the child’s increased mobility (walking) and associated ever-increasing peri-household activities (Cairncross et al 1996). At the household level, hand-washing practices, proper disposal of children’s feces, and safe storage of milk and weaning foods are critical activities to cut diarrheal transmission. In addition, community action and control of the public domain can be seen as an important step to enable improved household and personal hygienic practices (the private domain).

19. More recently, research articles have pointed to tropical enteropathy as a primary causal pathway from poor sanitation and hygiene to under-nutrition (not diarrhea) (Humphrey 2009; McKay et al 2010; Korpe and Petri 2012; Lin et al 2013). Tropical enteropathy is caused by fecal bacteria ingested in large quantities by young children living in conditions of poor sanitation and hygiene; and the provision of toilets and promotion of handwashing after fecal contact could reduce or prevent tropical enteropathy and its adverse effects on growth. If this is the case, researchers argue, previous studies have underestimated the contribution of sanitation and hygiene to growth because the effect was modelled entirely through diarrhea (Humphrey 2009).



20. *Longer term impacts:* Beyond the acute effects, the cognitive function in children—reflecting an ability to learn—is affected by environmental and health-related factors (Berkman et al 2002). Risk factors that interfere with cognition are especially important in the first two years of a child’s life, which marks a period of rapid growth and development (Berkman et al 2002). In early childhood, diseases attributed to environmental factors, such as diarrhea and helminth infections, also have the potential to affect a child’s later cognitive functions (Guerrant et al 1999; Niehaus et al 2002; Patrick et al 2005; Lorntz et al 2006). Over the past several years, studies have begun to investigate the impact of diarrheal illness and helminth infections during early childhood on verbal fluency, cognitive function, and school performance (Guerrant et al 1999; Walker et al 2007).

### **Environmental health complements health sector interventions**

21. Current child survival strategies in developing countries, such as Nepal, focus mostly on treatment. Primary prevention from a health sector perspective comprises of vaccinations, micronutrient supplementation, promotion of breastfeeding, and measures to decrease low birth weight, including birth spacing (Murphy, Stanton, and Galbraith 1997). All these strategies are intended to increase the ability of the host to resist or reduce infection after exposure has occurred, but they do not attempt to reduce exposure to the environmental determinants of ill health, which constitute another aspect of primary prevention (Acharya and Paunio 2008)

22. In integrated child survival programs limitations relating to compliance (e.g. uptake and use of ORS), and growing resistance to drugs (e.g. helminth treatment, malaria chemotherapy) call for better primary prevention of environmental risks. In childbirth and infant care programs, hygienic and clean delivery practices, along with the availability of adequate quantities of water and proper sanitation facilities becomes critical. Poor breastfeeding practices and inadequate sanitation have pernicious synergistic effects (Habicht et al 1988) –conversely, programs to improve sanitation can complement campaigns to improve breastfeeding practices. Vitamin A and zinc supplementation programs are being touted as successful and cost-effective interventions in many developing countries; however, evidence also shows that the burden of infections (such as diarrhea and ARI) often constrains the effectiveness of these supplementation programs (Hadi et al 1999; West 2003; Hadi, Dibley, and West 2004). Again, environmental health interventions rolled out side-by-side with such programs can play a complementary role in improving child survival and development (Sepúlveda et al 2006).

23. A major reason for intersectoral (health and non-health) collaboration is the high prevalence of co-morbidity in sick children. For poorer sections of the population, inadequate access to health services is further compounded by poor environmental conditions. Even as governments strengthen health systems and expand coverage of health interventions, there is a growing recognition for them to also invest in expanding coverage of environmental health interventions such as sanitation (Acharya and Paunio 2008).

## **1.4 Research Aims and Thesis Structure**

24. The overall objective of this thesis is to provide the required evidence of how environmental health interventions should, and can be, included in packages of child survival interventions in developing countries. This thesis is structured as follows: this opening chapter provides the background and conceptual framework for looking at environmental health in the context of child survival.

25. Expanding coverage of environmental health interventions (such as sanitation) is known to differentially impact child mortality and morbidity across the wealth quintiles. Such interventions have the potential to help reduce health inequities across wealth quintiles. Chapter 2 details data sources and main models used in this thesis. Chapter 3 (which presents Paper 1) highlights this “health-equity potential” of targeting sanitation interventions to the poorest sections of the Nepali population. Building on this, Chapter 4 (which presents Paper 2) provides the cost and impact estimates relating to scaling up sanitation –and demonstrates the relative cost-effectiveness (the costs per unit of outcomes such as diarrhea cases or deaths) of sanitation interventions targeted to poorest sections of the population in Nepal in a comparison to others. In making decisions on choosing child health interventions, decision-makers typically have to consider several different criteria, including both health-equity and intervention cost-effectiveness. Chapter 5 (which presents Paper 3) describes how to understand the priorities accorded to environmental health interventions (such as sanitation) amongst decision-makers in Nepal. This priority-setting (defined as the policy choices leading to the

distribution of goods and services among programs or people) exercise will help inform if environmental health interventions may be included as part of the government program addressing child health issues in Nepal. In conclusion, Chapter 6 brings together the main messages, discusses the methodological findings and limitations, offers policy recommendations for countries like Nepal, and suggests topics and areas for future methodological and applied research efforts.

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## Chapter 2: Data Sources and Models Used

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### 2.1 Overview

26. This dissertation comprises of three related papers, which include several sources of data. The main data source for Chapters 3 and 4 (Papers 1 and 2) is the Nepal Demographic and Health Survey, conducted in 2011. Additional data sources are included in the Lives Saved Tool model used in Chapter 3, and which are elaborated on in this chapter. For Chapter 5 (Paper 3), primary data was collected through a discrete choice experiment conducted in Kathmandu, Nepal. Each source of data is described in further detail below, including its design, sampling methods, and data quality assurance methods.

### 2.2 Data Sources for Chapters 3 and 4

27. **Demographic and Health Survey:** The data for this paper was derived from the 2011 Nepal Demographic and Health Survey (DHS) –which was the fourth nationally representative comprehensive survey conducted as part of the worldwide DHS project in the country. The sample was designed to yield representative information for most indicators for the country as a whole, for urban and rural areas, for the three ecological zones (mountain, hill, and *terai*), and for each of the 13 domains obtained by cross-classifying the three ecological zones and the five development regions (Eastern, Central, Western, Mid-western, and Far-western). The primary objective of the 2011 DHS was to provide estimates with an

acceptable level of precision for important population characteristics such as fertility, and selected health indicators and infant mortality.

28. *Sampling frame:* While the next census was planned for 2011, the sampling frame from which to draw the sample for the 2011 DHS was not going to be available in time for the fielding of the 2011 DHS, and it would have to rely on the 2001 Census. However, the decade long gap between the 2001 Census and the fielding of the 2011 DHS was addressed by conducting a partial updating of the 2001 census frame through a quick count of dwellings at the first level by taking into consideration a large sample (about five times larger than the sample required for each of the 13 domains). This sample at the first level was selected with equal probability. The results of the quick count of dwellings served as the actual sample frame for the 2011 DHS sample design. The sample for the 2011 DHS is selected from this updated frame with probability proportional to the number of updated dwellings. Weights were calculated for each stage of the selection probability and the final weight is the product of each of the compound weights.

29. In Nepal, for the census purpose each district, as well as each of the other administrative units, was sub-divided into wards in the rural areas and sub-wards in urban areas. Thus, an enumeration area (EA) is defined as a ward in the rural areas and a sub-ward in the urban areas. Following the quick count, the 2011 DHS sample was selected using a stratified two-stage cluster design. In each domain (region), the number of allocated EAs was selected with probability proportional to size (with household size updated from the quick count). If a selected EA is large,

say more than 300 households, a segmentation process was recommended to be done, with only one segment chosen with equal probability, among all segments and a complete household listing process implemented in the selected segment. For all other selected EAs a complete household listing operation was carried out and households were selected to achieve a self-weighted sampling fraction within each EA.

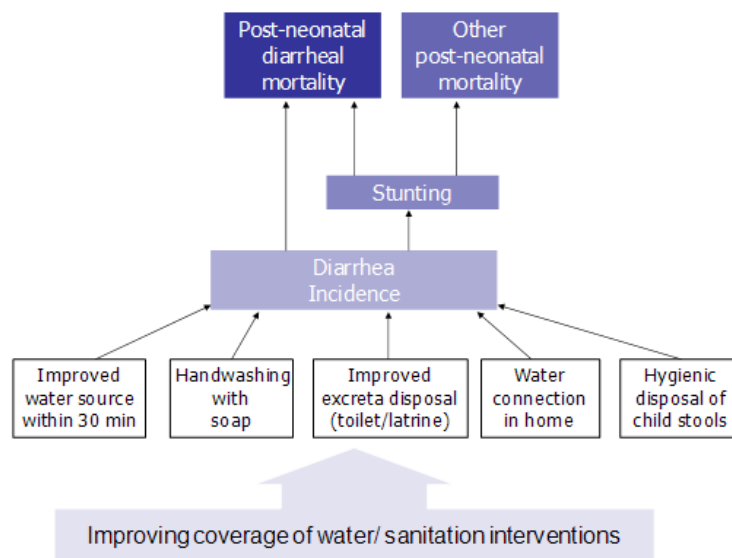
30. *Questionnaires:* Three questionnaires were administered in the 2011 DHS: the Household Questionnaire, the Woman's Questionnaire, and the Man's Questionnaire, which were translated from English into the three main local languages—Nepali, Maithali, and Bhojpuri—and back translated into English. The Household Questionnaire was used to list all of the usual members and visitors in the selected households. The Woman's Questionnaire was used to collect information from women age 15-49. The Man's Questionnaire was administered to all men age 15-49 living in every second household in the 2011 DHS.

31. From the sampling frame, a total of 289 clusters were selected throughout the 13 sub-regions. Data collection was carried out by 16 field teams, each consisting of three female interviewers, one male interviewer, and a male supervisor. A total of 11,353 households were selected, out of which 10,888 were found to be occupied during data collection. Interviews were completed for 10,826 of these existing households, yielding a response rate of 99 percent.

### 2.3 Sources of Data in Lives Saved Tool (LiST)

32. LiST is a partial cohort model which follows children through five age bands from birth to five years of age. Mortality rates and causes of death are described for neonates (under 1 month of age), children 1-59 months of age, and women giving birth. From this, the model determines the number of deaths by cause each year (DeCormier et al 2011).

**Figure 2.1: Conceptual LiST Framework for lives saved from water supply and sanitation interventions**



33. The LiST includes several intervention scenarios that can be combined (see Figure 2.1) which act through direct reduction of diarrhea deaths. They also reduce diarrheal incidence, which in turn has an effect on stunting, which has an effect on malaria, measles, diarrheal and pneumonia deaths. This paper is specifically focused on the issue of sanitation, and only the indicator relating to improved excreta disposal (sanitation) coverage for Nepal has been modeled.



34. *Adjustment of effect sizes of water and sanitation interventions* : In LiST, the five water and sanitation interventions all have both direct and indirect effects on mortality. Each WASH intervention directly reduces diarrheal mortality, but also has indirect effects on mortality from reduced diarrheal incidence. Therefore when one increases coverage of sanitation, for example, it not only has a direct impact in reducing diarrhea mortality, but also an indirect reduction in other cause mortality via the indirect impact on diarrheal incidence and stunting.

**Table 2.1: Effects of water supply and sanitation on diarrheal mortality and incidence**

Intervention	Published	<i>Effects used in LiST</i>		
	Severe Morbidity	Diarrheal Mortality	Diarrheal Incidence	Total % reduction in Diarrheal Mortality
Improved water	0.17* (0.07-0.17)	0.17	0.17	17.85
Household water connection	0.69**	0.69	0.627	70.23
Improved sanitation	0.36* (0.23-0.49)	0.36	0.36	37.37
Handwashing with soap	0.48* (0.42-0.48)	0.48	0.48	49.46
Hygienic disposal of child stools	0.20***	0.20	0.20	20.97

Source: \*Cairncross et al, 2010; \*\*Cairncross and Valdmanis 2006; \*\*\*Presented at CHERG June 2008 by S. Cairncross.

35. The reviews of the impact of WASH interventions on diarrhea mortality were estimates of the impact on severe morbidity (Fewtrell et al 2005; Cairncross and Valdmanis 2006; Clasen et al 2007; Clasen et al 2010; Cairncross et al, 2010). However, since the impact of WASH interventions on diarrheal incidence is also known, there is likely an effect of these interventions on diarrheal morbidity and stunting. Without direct evidence, we apply the same effectiveness sizes for both diarrheal mortality and incidence. This means that the total impact of each of the water and sanitation interventions may be greater than the direct impact.

**Table 2.2: Key parameters in LiST and sources of baseline information**

Parameter	Source
<b><i>Health Status Indicators</i></b>	
Neonatal, infant and under five mortality rate	United Nations Estimates
Distribution of neonatal and post-neonatal deaths by cause	CHERG
Whether or not the population of interest is Vitamin A deficient and/or zinc deficient	CHERG
Percent of women exposed to falciparum	Guerra et al.
Percent of newborns with IUGR	DHS, MICS, UNICEF, WHO
Percent of children severely wasted by age	DHS, MICS, WHO ( <a href="http://www.who.int/nutgrowthdb/database/en">http://www.who.int/nutgrowthdb/database/en</a> )
Percent of children stunted by age	DHS, MICS, WHO ( <a href="http://www.who.int/nutgrowthdb/database/en">http://www.who.int/nutgrowthdb/database/en</a> )
Incidence of diarrhea by age	Boschi et al.
Percent of pregnancies ending with spontaneous abortion	WHO
Percentage of the population living below the poverty line	Human Development Report, UNDP
<b><i>Intervention Effectiveness</i></b>	
Effectiveness of each intervention against each cause of death	CHERG
Affected fraction (fraction of deaths from a specific cause potentially addressed by each intervention)	CHERG
Effectiveness of nutrition-related interventions against IUGR, stunting, wasting and diarrhea incidence	CHERG
Effectiveness of breastfeeding promotion on breastfeeding practices	CHERG
<b><i>Coverage</i></b>	
Current coverage of each intervention	DHS, MICS, UNICEF, WHO, JMP

Source: LiST 2014

## **2.4 Data Collection for Chapter 5 (Paper 3)**

36. The DCE survey was administered to a group of sanitation and public health professionals and policy makers during a meeting of the Society of Public Health and Environment Nepal (SoPHEN) in Kathmandu in March 2013. The meeting included around 75 persons who were water, sanitation and public health professionals, several of whom were policy makers within departments in the Nepal government.

37. Before the administration of the survey, we familiarized the respondents with DCE by working through a number of examples. The questionnaire was prepared in English as all the participants at the meeting were fluent in the language. Completed questionnaires were submitted by 46 respondents, resulting in a response rate was just over 60 percent. Completed surveys were collected, and results compiled as per methodology articulated in Chapter 5.

38. *Key messages:* Two of the three papers in this thesis rely on DHS data for Nepal. What comes out clearly in the discussion of Chapters 3 and 4, is that the range of uncertainties for all the relevant indicators are especially important in drawing conclusions about the equity or cost-effectiveness of scaling up sanitation across wealth quintiles in Nepal. Standard errors from the DHS surveys are used in the sensitivity analyses for both papers.

39. Data limitations also constrain the conclusions drawn in Chapters 3 and 4. The virtual absence of disaggregated (by wealth quintile) data on sanitation costs and effectiveness calls for additional research so as to better inform the targeting of government sanitation scale-up programs in countries like Nepal.

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# Chapter 3: Estimating the Child Health Equity Potential of Improved Sanitation in Nepal (Paper 1)

## Abstract

**Background:** Access to improved sanitation plays an important role in child health through its impact on diarrheal mortality and malnutrition. Inequities in sanitation coverage translate into health inequities across socio-economic groups. This paper presents the differential impact on child mortality of expanding sanitation coverage across wealth quintiles in Nepal.

**Methods:** Data from the 2011 Nepal Demographic and Health Survey was used to derive health and intervention indicators across wealth quintiles by creating asset indices. Using the Lives Saved Tool (LiST), we estimated the lives saved under two scale-up scenarios for improved sanitation in Nepal across the wealth quintiles. The two sanitation scale-up scenarios included: equal effects across all quintiles, and a pro-poor scenario, which focused on scale-up in the three lower quintiles to reach the Millennium Development Goal (MDG) of 53 percent.

**Results:** If sanitation were scaled up at the national level to the MDG target in Nepal, a total of 485 lives would be averted. Concentration indices show diarrheal differentials across wealth quintiles to be flat. For an equal, proportional scale-up in sanitation coverage across the five quintiles, a total of 517 lives (range: 290-837) would be saved (about 15% of estimated 3400 diarrhea deaths in children under five). A pro-poor program with higher levels of sanitation scale-up in the lower three quintiles can save as many as 799 (range: 527-1078) child lives (23% of estimated under five diarrhea deaths).

**Conclusions:** Overlapping confidence intervals (using high-low values) in the equal scale-up scenario point to no significant difference in the child lives saved; while in the pro-poor scale-up, the difference is significant. Pro-poor policies for scaling-up sanitation coverage likely result in a higher number of lives saved due to reduced child diarrheal mortality.

# Chapter 3: Estimating the child health equity potential of improved sanitation in Nepal<sup>1</sup>

In collaboration with Ingrid K. Friberg, Li Liu, and Qingfeng Li

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## 3.1 Introduction

40. In developing countries like Nepal, sanitation coverage –an important contributor to child health – has been very much overlooked (WHO 2011).

Politically, attention to provide access to water, especially piped water, has received much more attention, and strategies to expand access to water have often focused on urban areas. This neglect of sanitation becomes even more stark when one looks at it through the lens of health equity – with lower socio-economic sections (as measured by wealth quintiles) of the population being disproportionately impacted. Knowing how health impacts from expanding sanitation coverage vary across wealth quintiles is critical input to government decision making. This chapter looks specifically at the health equity potential of sanitation interventions across wealth quintiles in Nepal.

41. Over the last decade, there has been an increased attention to health equity analyses describing the distributional impact of interventions (Wagstaff 2000; Wagstaff 2002; Gwatkin 2000; Leon 2001). These studies have aimed to analyze the

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<sup>1</sup> Anjali Acharya conceived the idea for the paper, performed the main analyses and is the lead author. Dr. Ingrid Friberg provided technical guidance on the use of LiST, contributed to the writing, and provided overall quality control. Dr. Qingfeng Li reanalyzed the raw Nepal 2011 DHS data into wealth quintiles. Dr. Li Liu recalculated data relating to cause of death by wealth quintile for Nepal, for the post-neonatal age group. A similar earlier paper, which used DHS 2006 data, was published as an article as part of BMC Public Health Volume 13 Supplement 3, 2013: *The Lives Saved Tool in 2013: new capabilities and applications*.



extent to which interventions reach and benefit disadvantaged groups, such as the poor, certain ethnicities, or otherwise vulnerable populations (Wagstaff 2002). Poor children are consistently found to be more likely to be exposed to health risks, and they have less resistance to disease because of malnutrition and other hazards typical in poor communities (Victora et al 2003). Compounding these inequities is reduced access to preventive and curative interventions (Victora et al 2003).

*“The term ‘inequity’ has a moral and ethical dimension. It refers to differences which are unnecessary and avoidable but, in addition, are also considered unfair and unjust.”*  
- Whitehead, 1991

39. Furthermore, recent papers have demonstrated that successive interventions are applied to the same population sub-groups, while the children in other sub-groups of populations consistently miss out, leading to a trend towards increasing inequity in child survival (Mulholland et al 2008; Moser 2005). Co-coverage analyses show an inequitable clustering of interventions at the level of the child raises the possibility that the introduction of new technologies might primarily benefit children who are already covered by existing interventions (Victora 2005). This “inverse equity” in many countries implies that children who are most likely to fall sick are least likely to receive child health interventions (Victora 2005; Victora et al 2000). Inequity patterns within countries are also found to be remarkably persistent over time, with only gradual changes from top inequity (disproportionately smaller gap for the wealthiest) in countries with coverage gaps exceeding 40% (Countdown et al 2008).

40. There is a growing recognition of the importance of addressing the underlying determinants of health, and that much of the work to redress health inequities lies beyond the health sector (WHO 2008a; Claeson and Waldman 2000; Marmot 2005). According to the report by the Commission on the Social Determinants of Health, "*Water-borne diseases are not caused by a lack of antibiotics but by dirty water, and by the political, social, and economic forces that fail to make clean water available to all...*" (WHO 2008a). Evidence has also shown that contextual factors including environmental characteristics such as water supply and sanitation may confound the delivery of a health sector intervention and its potential health impact (Victora 2005).

41. Given its critical role in child health, inequities in access to environmental services (e.g. sanitation) then translate into health inequities across socio-economic groups. However, very few studies have looked at how scaling up such interventions differentially impacts different socio-economic groups. A study of the impact of improved water and sanitation in Stockholm from 1878 to 1925 showed a decline in overall mortality and of diarrhea mortality and a leveling out of socioeconomic differences in child mortality due to diarrheal diseases (Burström et al 2005). Another paper used comparative risk assessment modeling to estimate the reduction in child mortality as a result of improving child nutrition and providing clean water, sanitation, and fuels (Gakidou et al 2007). A study in Cameroon showed that improved household (water, sanitation and cooking fuel) and community environment had positive effects on a child's nutritional status (Pongou et al 2006).

42. Other research has provided evidence of increasing inequities in child health in developing countries, even as coverage of related interventions is expanding. Investigations of co-coverage of interventions to address child mortality reveal an “inverse” equity – which states that any new intervention will be adopted or received first by the wealthier classes, leading to increased inequities, before it is received by the poor (Victora et al 2005). Environmental health interventions (such as sanitation coverage) are closely associated with socio-economic status.

43. According to the 2011 Millennium Development Goals Report, the world is far from meeting the sanitation target –with almost two thirds of the people who practice open sanitation residing in Southern Asia (WHO 2012). Rural populations are at a disadvantage when it comes to improved sanitation. Inequalities are clearly most stark in South Asia, where an urban resident is 2.2 times more likely to use an improved sanitation facility than a rural resident (WHO 2012). For three countries in South Asia, an analysis of trends over the period 1995-2008 shows that improvements in sanitation have disproportionately benefited the wealthy (WHO 2012). Sanitation coverage for the bottom two quintiles of households has barely increased, and four out of five people in the poorest 40 percent continue to practice open defecation (WHO 2012).

44. Given this, governments in South Asian countries, like Nepal, need to invest in expanding sanitation coverage – especially in the poorest households. Over the last few decades, Nepal has made significant improvements in access to safe water. The use of an improved water source for drinking water increased nationally from

80 percent in 2006 to 89 percent in 2011 (DHS 2006, DHS 2011). Households in urban areas have greater access to an improved source of drinking water than households in rural areas (93 percent versus 88 percent), but the urban-rural gap has narrowed in the last five years (DHS 2011). The majority of households (82 percent) do not treat drinking water, and rural households are particularly likely not to do so (87 percent, compared to 54 percent of urban households) (DHS 2011). However, improvements in sanitation continue to lag considerably behind improvements made in increasing access to safe water (DHS 2011). In 2006, 36 percent used improved sanitation facilities, and this figure barely rose to 38 percent (DHS 2006, DHS 2011).

### *Conceptual framework*

45. Given the vast differential in sanitation coverage between the wealth quintiles, there is potential for health improvements by investing in pro-poor sanitation in countries such as Nepal. In this paper, we modelled the impacts of scaling up sanitation coverage on child mortality and diarrheal incidence, disaggregated by wealth quintile. For this, we choose the Lives Saved Tool (LiST) model version 5.07 because its target populations are identical to those in this analysis, and the paper's intervention (i.e. improved sanitation) is represented (LiST 2014)

46. In addition, the model has been shown to provide accurate predictions of neonatal and child mortality associated with intervention scale-up in diverse geographical settings (Amouzou et al 2010). The paper found that the modeled

estimates of mortality within wealth quintiles fell within the 95% confidence intervals of measured mortality (in the Bangladesh Demographic and Health Survey) for both neonatal and post-neonatal mortality (Amouzou et al 2010). Another paper used the LiST model to estimate the potential lives saved from scaling up a number of diarrhea interventions at the national level for 68 countries – demonstrating the potential for reducing diarrheal deaths (Walker et al 2011).

47. This paper focuses specifically on sanitation coverage and looks at the population disaggregated by wealth quintile. Nepal is a good example as it continues to have the poorest sanitation coverage in South Asia and stark inequalities in coverage across wealth quintiles (DHS 2011). In addition, Nepal's recent verbal autopsy linked to the DHS made the mortality estimates by wealth quintile more precise. Equity in achieving the MDG targets is important, not only because the poorest households are least able to invest in their own facilities, but also because they have the most to gain due to their heightened vulnerability to adverse health outcome (Hutton 2012).

48. The aim of this paper is to explore the potential of increasing improved sanitation coverage to differentially impact child mortality and morbidity, specifically to investigate the differential impact by wealth quintile of expanding coverage of sanitation on child mortality and diarrheal incidence in children. An earlier analysis of this paper used Nepal 2006 DHS data, which was published in BMC Public Health (Acharya et al 2013).

49. This is the first application of the LiST model to assess the impacts of increasing sanitation coverage on child health disaggregated across wealth quintiles, and can be replicated for other developing countries to inform policy dialog and contribute to government investment strategies.

### **3.2 Health equity measures**

50. The most common measures for health equity are the concentration index and wealth quintiles. Both these measures can be calculated using any measure of socioeconomic status (SES) –such as the creation of wealth indices –that allows the population of interest to be ranked from highest to lowest (O'Donnell et al 2008).

51. *Wealth quintiles* rank the cumulative distribution of any population-based measure of health by a measure of SES. It represents dividing the population into five groups that represent 20% (each) of the population, ranging from the poorest 20% of the population up to those in the wealthiest 20%. By convention, quintile 1 (q1) is the poorest section of the population and quintile 5 (q5) is the richest. Researchers and decision-makers have examined health outcomes by wealth quintiles in reports such as the Demographic and Health Surveys, and to monitor progress towards the MDGs. Combining health outcomes (such as diarrheal mortality in children under five) with wealth quintiles shows how outcomes range over different socioeconomic groups. As a result of such analyses, researchers and decision-makers can gain insight into the impact of interventions (such as scaling up sanitation coverage) in each quintile and helps to improve targeting in future interventions.

52. There has been considerable debate about the composition of asset indices, and the use of principle component analysis to determine the weights. Index variables that were directly associated with child health outcomes (e.g. sanitation facility or source of water) increased inequality among households (Houweling et al 2003; Lindelow 2006). Therefore, there is some potential for some overestimation of inequality among the households in Nepal, if sanitation is included in the asset index in this analysis as well as used as an independent variable. For this reason, the asset index for this paper did not include sanitation amongst the asset index, and quintiles were calculated based on this revised index.

53. *Concentration Index:* Another commonly used measure to assess health equity is the concentration index, which uses one summary value to capture the extent of socioeconomic inequality in a health outcome. The concentration index ranges from -1 to 1, based on a concentration curve that orders the population by SES on the x-axis and plots the cumulative percentage of a health outcome on the y-axis. With zero signifying perfect equality, a negative value represents the health outcome's concentration among the poor; a positive value denotes concentration among the wealthy. As the concentration index moves further away from zero, either positively or negatively, there is greater inequity in the health outcome. The concentration index offers advantages as a metric of health equity because it is statistically comparable across time periods and geographic regions.

54. For this analysis, we calculated the concentration index from the concentration curve, which was generated by ranking the population by asset score

on the x-axis and plotting the cumulative percentage of the outcome variable of interest on the y-axis. This calculation used the STATA command GLCURVE. The concentration index, is equal to twice the area between the curve and the line of equality ( $x = y$ ), or  $2\text{cov}(y_i, x_i)/\mu_y$ , where  $x_i$  is the fractional rank of the  $i^{\text{th}}$  individual.

55. *Inequalities in Child Health:* Overall, some changes in child health are observed for infant mortality and under-five mortality between 2006 and 2011 (Table 3.1) at the national level. The infant mortality rate declined from 48 (40-56) per 1,000 live births in 2006, to 46 (39-53) per 1,000 in 2011. The under-five mortality rate decreased 61 (52-70) per 1,000 in 2006 to 54 (46-62) per 1,000 in 2011. Children's nutritional status also changed over the decade. In 2011, 41 (38-43) percent of under-five children were stunted compared with 49 (47-52) percent in 2006. The percentage of children who were wasted decreased from 12.6 (11-14) in 2006 to 11 (9-13) in 2011. The change in the average prevalence of diarrhea increased from 12 (11-13) percent in 2006 to almost 14 (12-15) percent in 2011, but this has been attributed partly to the timing of the surveys (DHS 2011). The uncertainty ranges reveal that, at the national level, almost none of these changes in overall were significant (as confidence intervals are shown to be overlapping). There appears to be a statistically significant decline in children under five, implying an improvement in nutritional status.

56. Within quintiles, however, we see that changes between 2006 and 2011 in infant mortality, under five mortality and stunting were significant for the lowest three quintiles (q1, q2, q3).



**Table 3.1: Health indicators for Nepal, by wealth quintiles**

Health indicators	Year	Wealth quintiles																				H/L ratio	CI	
		q1	Low	High	q2	Low	High	q3	Low	High	q4	Low	High	q5	Low	High	total	Low	High					
Infant mortality (per 1000 live births)	2006	71	63	79	62	54	70	70	62	78	51	43	59	40	32	48	48	40	56	1.78	1.65	1.97		
	2011	61	54	68	56	49	63	55	48	62	53	46	60	32	25	39	46	39	53	1.91	1.74	2.18		
Under-five mortality (per 1000 live births)	2006	98	89	107	83	74	92	91	82	100	63	54	72	47	38	56	61	52	70	2.09	1.91	2.35		
	2011	75	67	83	66	58	74	64	56	72	59	51	67	36	28	44	54	46	62	2.08	1.89	2.39		
Stunting among children under 5 (%)	2006	61.6	59.2	64.0	54.9	52.5	57.3	50.4	48.0	52.8	39.8	37.4	42.2	30.9	28.5	33.3	49.3	46.9	51.7	1.99	1.92	2.08		
	2011	56.0	53.2	58.8	45.7	42.9	48.5	34.5	31.7	37.3	30.5	27.7	33.3	25.8	23.0	28.6	40.5	37.7	43.3	2.17	2.06	2.31		
Wasting among children under 5 (%)	2006	11.5	10.3	12.7	15.2	14.0	16.4	15.2	14.0	16.4	12.8	11.6	14.0	7.0	5.8	8.2	13	11	14	1.64	1.55	1.78		
	2011	12.5	10.9	14.1	10.7	9.1	12.3	12.8	11.2	14.4	8.8	7.2	10.4	7.4	5.8	9.0	11	9.3	13	1.69	1.57	1.88		
Diarrhea among children under 5	2006	13.3	12.1	14.5	11.7	10.5	12.9	10.7	9.5	11.9	11.4	10.2	12.6	11.7	10.5	12.9	12	11	13	1.14	1.12	1.15		
	2011	12.6	11.2	14.0	14.4	13.0	15.8	16.9	15.5	18.3	12.8	11.4	14.2	11.9	10.5	13.3	14	12	15	1.06	1.05	1.07		

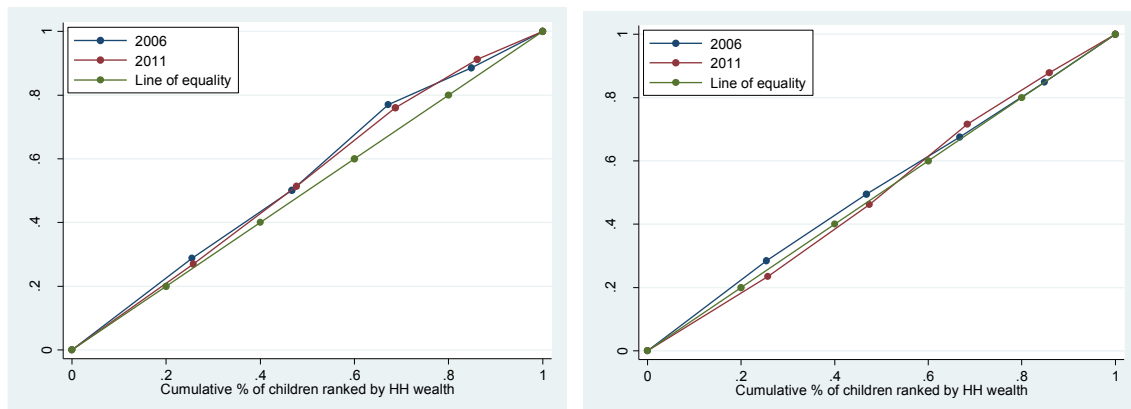
Source: Data from DHS 2011 and DHS 2006

57. Despite the absolute reductions in some health indicators among the poorest groups, a gap remains between the poorest and wealthiest quintiles in almost all indicators studied. Table 3.1 also shows the ratios of the poorest to the wealthiest for the two Nepal DHS surveys; the ratios for most of the indicators are greater than 1, indicating the presence of inequalities that favor the wealthy over the poor. The ratio was close to 1 for diarrhea in children under five years. Again, however, taking into account uncertainties (using standard errors from the DHS), we see that the difference in high/low ratios were not significant (confidence intervals overlap). It is important to note that the quintile ratio is based only on the information of the two extremes of wealth—the poorest and the wealthiest—and ignores the middle three groups. For this reason, we use the concentration indices along with concentration curves to assess the overall inequalities in health indicators and their changes among the population.

58. Most of the concentration curves for these health indicators lie above the line of equality, which implies inequality in all the indicators by household wealth, and the wealthy households have lower values of the outcomes than the poor households. The areas between the curve and the line of inequality appear greater for infant mortality and under-five mortality rate compared with the other health indicators. Trends in inequalities can be assessed by comparing concentration curves for a given health indicator at different time points. The inequality narrows if the curve moves towards the line of equality; otherwise, the inequality worsens. However, a visual inspection of a concentration curve in comparison with the 45-degree line or another concentration curve may give an impression of whether there

is dominance, obviously this inspection is not sufficient to conclude whether or not dominance is statistically significant (O' Donnell et al 2008).

**Figure 3.1: Concentration curves for children who died before 5<sup>th</sup> birthday; who had diarrhea recently**



59. The two curves for 2006 and 2011 for both under-five mortality and for diarrhea intersect each other in the middle, which introduces difficulty for assessing inequalities purely based on curves (see Figure 3.1). Concentration indices presented in the table below are used to quantify inequalities and is particularly useful when the concentration curves intersect or when the cross the line of equity. Concentration curves are estimated from survey (and therefore subject to sampling variability); we need to make inferences about dominance by computing calculating standard errors and 95% confidence intervals, in addition to their point estimate (O'Donnell et al 2008).

**Table 3.2: Concentration indices for diarrhea and under-five mortality for Nepal**

		concentration index	SE	Confidence interval (95%)	
				lower bound	upper bound
Diarrhea mortality	2006	-0.0323	0.0217	-0.075	0.0104
	2011	-0.0051	0.0196	-0.0436	0.0333
under five mortality	2006	-0.0850	0.0299	-0.1437	-0.0264
	2011	-0.0847	0.0334	-0.1504	-0.019

60. The concentration index for under-five mortality is negative at -0.08 (-0.15, -0.02) suggesting that poor children are disproportionately affected by ill health. However, there appears to be no temporal trend, with no statistical difference between 2006 and 2011. For diarrheal mortality, the concentration index is indifferent, indicating that diarrheal differentials across wealth quintiles are flat, i.e. poor children do not appear to be disproportionately dying of diarrhea. One criterion requires significant difference between ordinates at all quantile points to accept dominance and is consistent with the intersection union principle (O'Donnell et al 2008).

### 3.3 Methodology

#### *Study design*

61. We compared two strategic approaches to reducing under-5 mortality: one approach that we have labelled a mainstream approach to delivering services and the other, labelled as a pro-poor approach that prioritized operational strategies to reach the most deprived populations.

62. We estimated incremental costs incurred and reductions of deaths and stunting in children younger than 5 years of age resulting from implementation of effective preventive and curative interventions, as identified in the Lives Saved Tool (LiST), through the two proposed strategic approaches (table 1). Baseline was defined as the current situation. The simulation was modelled for the 5-year period of 2012 to 2016, coinciding with the years remaining to meet the MDGs.

### ***Data Sources***

63. National health surveys such as the Demographic and Health Surveys (DHS) and the Multiple Indicator Cluster Surveys (MICS) provide most of the data on current mortality rates, the prevalence of stunting and wasting, and the current coverage of interventions. Other health status indicators are drawn from WHO databases. Estimates of intervention effectiveness have been developed by the Child Health Epidemiology Reference Group (CHERG).

64. For this analysis, information has been derived from the 2011 Nepal Demographic and Health Survey –which provides current and reliable data on fertility and family planning, child mortality, children’s nutritional status, utilization of maternal and child health services, etc. This survey was designed to target a sample of 11,095 households and it was expected to interview a total of 13,200 women age 15-49 in the sample households and all men age 15-49 in a sub-sample of one in every two households selected for the woman’s interview (DHS 2011). Details on the sample framework, sample size, data sources and how original data were collected and analyzed are presented in chapter 2.

65. LiST is loaded with default baseline coverage values, measures of health status, levels of risk factors, population exposures and cause of death data for more than 80 countries, including Nepal (LiST 2014). The effectiveness of each of the diarrhea interventions incorporated into the LiST tool has been recently reviewed by CHERG (LiST 2014). For more details on the data within LiST, please refer to chapter 2.

### ***Variables used***

#### *Outcome variables*

66. Incidence of diarrhea: In line with most of the existing literature, the first dependent variable we use in our analysis is child diarrhea. Most DHS surveys (including the Nepal 2011 DHS) ask female respondents whether any of their children under the age of 5 had diarrhea over the two weeks preceding the interview. Diarrhea incidence is itself an intermediate outcome in LiST. It is affected by water and sanitation improvements, which include improved water source within 30 minutes, use of a water connection in the home, improved excreta disposal (latrine/toilet), hand washing and hygienic disposal of children's stools.

67. Child mortality (lives saved): LiST calculates the effects of health interventions on neonatal, child and maternal mortality. The key outputs for each type of mortality are the mortality rates (neonatal, infant, under five and maternal mortality rates), the number of deaths, the number of still births, the number of deaths by cause, the number of deaths averted, the number of deaths averted by cause, the number of deaths averted by intervention.

*Predictor variables*

68. Use of improved sanitary facility: The main explanatory variable of interest is the use of sanitation infrastructure. The classification of sanitation varies substantially across time and countries in the DHS surveys: some surveys focus on the distinction between private and public facilities, while others focus on the location (in or outside the house) or the exact type of the facility (e.g., ventilated vs. non-ventilated latrines)

69. In this analysis, the definition of improved sanitary facility from Nepal 2011 DHS report was adopted. Only non-shared facility could potentially be considered as improved sanitary facility. Specifically, the following toilet types were included: flush - to piped sewer system; flush - to septic tank; flush - to pit latrine; pit latrine - ventilated improved pit; pit latrine - with slab; and composting toilet. We collapsed them into 3 categories, since we are not primarily interested in identifying the more subtle differences between individual technologies (e.g. between ventilated and non-ventilated latrines), we choose a slightly more broad classification.

70. Stunting and wasting: The height-for-age index indicates linear growth retardation and cumulative growth deficits. Children whose height-for-age z-score is below minus two standard deviations (-2 SD) from the median of the reference population are considered short for their age (stunted) and chronically malnourished. Stunting reflects failure to receive adequate nutrition over a long period of time and is worsened by recurrent and chronic illness.

71. The weight-for-height index measures body mass in relation to body length and describes current nutritional status. Wasting represents failure to receive adequate nutrition in the period immediately preceding the survey and may be the result of inadequate food intake during a recent episode of illness, causing loss of weight and the onset of malnutrition. Children whose weight-for-height is below minus three standard deviations (-3 SD) from the median of the reference population are considered severely wasted. With age, height, and weight information from DHS data, the Z-score for each child under five years old was calculated using WHO Child Growth Standards.

**Table 3.3: Input table**

<i>QUINTILE</i>	<i>q1</i>	<i>q2</i>	<i>q3</i>	<i>q4</i>	<i>q5</i>
<b>Mortality rates</b>					
Neonatal mortality rate	37.0	40.0	39.0	37.0	19.0
Infant mortality rate	61.0	56.0	55.0	53.0	32.0
Under 5 mortality rate	75.0 (63-87)	66.0 (54-78)	64.0 (52-76)	59.0 (47-71)	36.0 (24-48)
<b>Sanitation Effectiveness</b>	0.36 (0.23-0.49)	0.36 (0.23-0.49)	0.36 (0.23-0.49)	0.36 (0.23-0.49)	0.36 (0.23-0.49)
<b>Cause of Death</b>					
Diarrhea	11.9	14.63	19.51	13.04	13.64
Injuries	4.76	7.32	9.76	13.04	9.09
Measles	0	0	2.44	0	0
Other	45.24	51.22	29.27	39.13	36.36
Pneumonia	38.1	26.83	39.02	34.78	40.91
<b>Incidence of diarrhea</b>					
<1 month	14.11	0.00	0.00	0.00	0.00
1-5 months	13.42	8.73	20.75	17.11	0.00
6-11 months	25.02	28.99	26.89	20.76	17.00
12-23 months	23.28	26.06	24.70	24.14	19.23
24-59 months	7.79	9.98	11.28	7.39	10.40
<b>Stunting (&lt;-2 Z scores)</b>					
< 1month	12.50	11.11	40.00	22.22	14.29
1-5 month	33.59	35.92	31.87	19.15	29.63
6-11 months	38.96	43.30	29.20	30.14	25.53
12-23 months	39.22	36.89	44.12	43.43	29.77
24-59 months	41.50	42.28	46.65	37.12	41.16
National	39.96	40.50	42.60	35.66	36.25



QUINTILE	q1	q2	q3	q4	q5
<b>Wasting (&lt;-3 Z scores)</b>					
< 1month	25.00	44.44	40.00	11.11	28.57
1-5 month	25.00	32.04	29.67	27.66	27.78
6-11 months	33.12	42.27	30.97	31.51	27.66
12-23 months	37.58	32.04	38.82	33.14	27.48
24-59 months	31.21	34.12	35.62	27.59	26.40
National	32.02	34.34	35.09	28.91	26.86
<b>Water, Sanitation, Hygiene Indicators (%)</b>					
Improved sanitary facility	12.9	25.4	38.4	53.3	61.6
Improved water within 30 min	85.2	87.7	84.3	87.7	79.5
Piped water into house/yard	9.6	19.5	21.8	22.6	42.8
Handwashing with soap	10.0	23.4	41.2	68.4	89.4
Hygienic disposal of child stools	19.6	26.3	33.8	57.5	84.7

*Sources: Author's calculations from DHS 2011 data set*

### ***Analysis methods***

72. To carry out the analyses, the Lives Saved Tool (LiST) is applied – specifically extending its application to sub-national levels – in order to estimate the lives saved from scaling up sanitation coverage across different wealth quintiles in Nepal. This required an adaptation of the model inputs to enable disaggregated information about child health and nutritional status, deaths by cause, and coverage of child health interventions, in addition to assumptions concerning the efficacy of those interventions.

### **Box 3.1: Lives Saved Tool**

Lives Saved Tool (LiST) is designed to enable international agencies and country planners to estimate the effect of increasing coverage of selected intervention combinations, such interventions for diarrhea, on mortality. LiST utilizes country-specific cause of death profiles and the effect of selected interventions on cause-specific mortality, and thus generates country-specific estimates of mortality reductions. This tool can project the future number or rate of child deaths, and can stratify that projection by cause of death and by specific child health intervention based upon changes in health intervention coverage. These projections then can be used to enhance knowledge of child survival options among policymakers and to build support for effective activities.

In brief, LiST uses current health status (mortality rates, nutritional deficiencies and population sizes) in combination with current health intervention coverage values (i.e. ORS, facility delivery rates) to predict changes in mortality based on changes in health intervention coverage over time linked by effect sizes. LiST applies prevention effectiveness information prior to treatments, having each intervention impact only the residual number of deaths available to “save” for that year, thus eliminating the potential for double counting.

*Source: Winfrey et al 2011; Fox et al 2011; Walker et al 2011.*

73. The LiST was applied to the five wealth quintiles, and with two different scenarios of intervention coverage scale-up to the MDG target of 53% for Nepal viz. equal scale-up across all quintiles; and pro-poor scale-up in bottom three quintiles. The following sections articulate the methodology used.

#### ***1. Adapting the LiST Model to a Subnational Level***

74. LiST supports program decision making by estimating the lives that can be saved by increasing coverage for proven maternal and child health interventions, alone or in combination, for user-defined populations and time frames (See Box 3.1). For this paper, LiST generates estimates of child deaths averted based on changes in improved sanitation coverage over time. Within this general description, the targeted sanitation intervention (improved sanitation coverage) has a direct impact

on diarrheal mortality reduction, as well as an indirect impact on multiple causes of mortality via a reduction in the rate of stunting. LiST applies the documented effectiveness for each intervention to the total diarrheal deaths possible among children under 5 for each given year.

75. *Sensitivity analyses* were used to show the range of additional child deaths averted under the scale-up scenarios. This paper focuses on univariate and scenario-based approaches. High-low scenarios considered uncertainty in values for key model parameters (under five mortality) as well as statistical uncertainty when estimating intervention effects (effectiveness of sanitation) (see Table 3.3).

76. National-level analyses considered high- and low-mortality scenarios due to uncertainty concerning the background of mortality rates. The high-low mortality scenario for children less than five years of age was based on United Nations Inter-agency Group for Child Mortality Estimation –which reported a mid-point estimate of 54, with a standard error of 6.03 ( UNICEF et al 2013). Using this, we estimated lives-saved (additional child deaths averted) based on the mid-point, and the upper and lower 95% CIs (42, 66) for effects of scaling up sanitation coverage, at the national level. We applied the same standard error to calculate the CIs for each of the wealth quintiles, and re-ran the LiST model to provide an uncertainty range of lives-saved estimates.

77. Another key variable that is associated with uncertainty is the effectiveness ratios for sanitation infrastructure. High-low scenarios were used, around the point

estimate of 0.36 from a meta-analysis review, with 95% CIs (0.23, 0.49) (Fewtrell et al 2004).

## ***2. Establishing Baseline Values for Cause of Death and Coverage of Interventions***

78. For this exercise, we adapted LiST to a sub-national level (by wealth quintile) for Nepal to project potential reductions in diarrhea mortality from scaling-up sanitation coverage. At the national level, we used standard country-level child mortality rates from the 2011 Nepal DHS.

79. We also used baseline intervention coverage values for sanitation from the available Nepal DHS 2011 data. Using the available 2011 Nepal DHS survey data, health indicators (wasting, stunting) and intervention coverage (improved sanitation) were disaggregated by wealth quintile through the use of an asset index to divide the population using principal components analysis (See Annex 2).

80. DHS surveys, such as the Nepal DHS, are based on multistage stratified probability sample design. This design is preferred over simple random sampling for frame development and for clustering interviews in order to reduce cost and increase efficiency. In addition to the stratum-level selection probability, the different response rates in different strata also require adjustments. Consequently sampling weight is needed to be accounted for to improve the representativeness of the sample data.

### *Baselines for mortality rates and cause of death*

81. Mortality rates by wealth quintile were available from the 2011 Nepal DHS.

The data showed that infant mortality rate in the lowest quintile was 1.9 times higher, and under five mortality rate was 2.1 times higher than in the richest quintile (DHS 2011, see Table 3.3).

82. The 2006 Nepal Demographic and Health Survey offered, for the first time in Nepal a verbal autopsy survey that presents data on the proportional distribution of causes of death among neonates, post-neonates, and children age 12-59 months (Nepal DHS 2006). Using this verbal autopsy data (there was no update to this in the 2011 DHS), the cause of death by wealth quintile for Nepal, for the post-neonatal age group (1-59 months) was recalculated. This data was then used as an input to the LiST model for cause of death in the 1-59 months age group; for the neonatal causes of death, default values were used (Black et al 2010)(see Table 3.4).

### *Baselines for other indicators*

83. Using standard methodology elaborated in the DHS for creating wealth quintiles (see Annex 2), other health indicators such as the incidence of diarrhea, wasting and stunting, and population coverage by age groups were estimated (DHS 2011). Diarrheal incidence showed differences across the wealth quintiles (see Table 3.5), with higher values in the middle quintiles.

84. In terms of malnutrition indicators of stunting and wasting, estimates show health inequities across the wealth quintiles. In addition to health indicators, for the

water and sanitation interventions covered in the LiST model, the relevant coverage data by wealth quintile for improved sanitary facilities, improved water within 30 minutes and piped water into household were calculated using standard methodology and raw DHS data (Table 3.7). Piped water access in the richest quintile is about 4.6 times higher than in the poorest quintile; while sanitation coverage was over 5 times higher. Related hygiene behavior – reported handwashing practices and disposal of children’s stools –was also recorded to be significantly higher in the richest quintiles.

85. In terms of curative interventions, data from the 2011 Nepal DHS on the use of ORS, antibiotics for dysentery and case management for pneumonia was also entered into the LiST model.

### ***3. Estimating Increased Coverage of Intervention***

86. The scale-up scenarios modeled assume a linear increase in sanitation coverage from the most recent data available (DHS 2011), through the year 2016. The first year of coverage scale-up was assumed to be 2012, and for a five year period. This allowed for the estimation of the total number of diarrheal deaths and deaths averted in Nepal for each year between 2012 and 2016. Two alternative scale-up scenarios for sanitation, representing varying focus on expanding coverage across the different wealth quintiles in the Nepalese population, were applied. Results are presented in Table 3.4.

(a) *Equal proportional increase*: Using the MDG target for sanitation for Nepal (53% nationally), increasing improved sanitation coverage equally in each of

the wealth quintiles to reach this target. Under this scenario, sanitation coverage for each quintile (q1-q5) was increased by 1.4 times, to reach the new national sanitation coverage of 53 percent (MDG target) by 2016.

(b) *Pro-poor expansion*: Focusing increases in sanitation coverage in the lower three quintiles up to the MDG national target (53%) in Nepal. Under this scenario, percentage increases in coverage were highest in q1 (4.5 times), then in q2 (2.3 times) and then q3 (1.5 times). Sanitation coverage in q4 and q5 were kept constant. To impart a degree of realism, increases in sanitation coverage were estimated such that for each quintile, the new coverage figure was lower than the new coverage in next highest quintile.

**Table 3.4: Scenarios for sanitation scale-up in Nepal (%)**

QUINTILE	q1	q2	q3	q4	q5
Current improved sanitation	12.9	25.4	38.4	53.3	61.6
Scenario (a): Equal increase	17.7	34.7	52.5	73.0	84.3
Scenario (b): Pro-poor increase (to 53%)	53.0	53.0	53.0	-	-

### 3.4 Results

87. From the two scenarios (equal scale-up and pro-poor scale-up) modeled using LiST, we were able to estimate the lives saved of children under five from diarrhea due to increases in sanitation coverage across various wealth quintiles (see Table 3.5). At the national level, if the sanitation coverage in Nepal were to reach the MDG target of 53 percent, it would result in averting approximately 485 deaths. Under the equal increase scenario, an estimated 517 (290- 837) lives would be

saved by 2016. In the pro-poor scenario, the LiST model estimated that nearly 800 (527-1078) lives would be saved due to increased sanitation coverage.

**Table 3.5: Output table: Additional lives saved from scaling-up sanitation**

Scenarios →		a. Equal scale-up				b. Pro-poor scale-up			
Uncertainty relating to Under Five Mortality									
Quintile	Current sanitation coverage %	New sanitation coverage %	Additional lives saved			New sanitation coverage %	Additional lives saved		
			Low	Base	High		Low	Base	High
q1	12.9	17.7	35	55	75	q1	293	451	608
q2	25.4	34.7	40	75	113	q2	116	220	334
q3	38.4	52.5	63	124	189	q3	65	128	194
q4	53.3	73.0	71	152	246	q4	0	0	0
q5	61.6	84.3	81	111	214	q5	0	0	0
Total			290	517	837		527	799	1078
Uncertainty relating to Effectiveness Ratio									
Quintile	Current sanitation coverage %	New sanitation coverage %	Additional lives saved			New sanitation coverage %	Additional lives saved		
			Low	Base	High		Low	Base	High
q1	12.9	17.7	42	55	67	q1	350	451	555
q2	25.4	34.7	56	75	95	q2	169	220	276
q3	38.4	52.5	97	124	155	q3	100	128	161
q4	53.3	73.0	115	152	197	q4	0	0	0
q5	61.6	84.3	75	111	154	q5	0	0	0
Total			385	517	668	273.9	619	799	992

Note: \*Under pro-poor scale-up scenarios, it was assumed that there was no scale-up in the upper two quintiles.

88. *Sensitivity Analysis:* With the high-low values for under five mortality, the LiST tool was run to recalculate the lives saved from scaling up sanitation. From Table 3.10 (which presents pro-poor scale-up to MDG of 53%), the lives saved for q1 ranges from 293 to 608, with a point estimate of 451. Similar uncertainty ranges were constructed for other quintiles, under the different scenarios. Importantly, in the pro-poor scale-up scenarios, it was assumed that there would be no scale-up in the top two quintiles (q4 and q5). There was considerable overlap in the confidence



intervals across quintiles under the equal scale-up scenario and some overlap under the pro-poor scale-up scenario. Undertaking a 2-sample t-test, we find that the differences for not significant in the equal scale-up scenario (at the  $p < .05$  level); but it still statistically significant for the pro-poor scale-up scenario.

89. Similarly, sensitivity analysis was also undertaken for the effectiveness ratio for sanitation (0.36), using high-low bounds from the research literature and meta-analysis (0.23, 0.49). For the poorest quintile, the lives saved were estimated at 451, with 95% CIs (350, 555); while for the middle quintile, 128 additional child lives were averted, with 95% CIs (100, 161). In this case, we find no overlap in the uncertainty ranges across quintiles under the pro-poor scale-up scenario, showing that the differences across the quintiles are significant (at 95% confidence levels). In the equal scale-up scenario, there was some overlap requiring the need for a 2-sample t-test. Results show that these latter differences for not significant (at the  $p < .05$  level).

### **3.5 Discussion**

90. If sanitation coverage in Nepal had been scaled up from 2012 to 2016 to reach the MDG target of 53 percent, it would have resulted in averting approximately 485 deaths. However, this aggregate figure does not contribute to helping the government of Nepal in strategizing on which sub-populations to target by increased sanitation coverage. An analysis of alternative scenarios of sanitation scale-up across the various quintiles would help the Nepalese government with better targeting strategies.

91. There are approximately 3400 diarrheal deaths in children under five in Nepal (UNICEF 2015; DHS 2011). The equal scale-up scenario shows no difference in the child lives saved as compared to the baseline, while in the pro-poor scale-up, these differences are significant. The LiST model estimates that there could be 799 (range 527 -1078) fewer diarrheal deaths in Nepal by 2016 if sanitation scale-up was appropriately targeted to poorest households where environmental health conditions are the worst. This represents a 23 percent (range:15-32%) of the estimated diarrheal deaths in children under-five years of age

92. It is important to note that benefits from increased sanitation clearly go beyond child mortality; providing a healthier environment to children is likely to affect not only their short-term condition, but may affect also their long-term physical and mental development, labor-force productivity, and lifetime earnings (Guerrant et al 1999; Niehaus et al 2002; Patrick et al 2005; Lorntz et al 2006; Walker et al 2007). Therefore, this chapter's estimates of the lives saved from expanding sanitation represent an underestimate of the full benefits that such interventions have for child health and overall population health. Providing better water and cleaner environments will not only benefit children, but also the rest of society both in terms of health and overall living standards (Fink et al 2011). Repeated diarrheal episodes contribute to malnutrition (stunting) in children under five –some of which is irreversible (Scrimshaw 2003).

93. This sub-national application of the LiST model shows a decline in diarrheal incidence especially under the pro-poor scenario when sanitation expansion was

targeted to the lowest quintile – demonstrating the potential for lower rates of malnutrition and subsequent longer term health impacts. These results suggest that LiST can be a useful tool for policymakers to prioritize and target sanitation coverage to the lowest quintiles for maximal effect on diarrheal mortality and incidence in children under five years of age, at least in South Asia.

94. There were several study limitations. *First*, this analysis of health impacts of expanding sanitation coverage on different socioeconomic groups involves the use of asset indices to create wealth quintiles. There has been considerable debate about the composition of asset indices, and the use of principle component analysis to determine the weights. Index variables that were directly associated with child health outcomes (e.g. sanitation facility or source of water) increased inequality among households (Houweling et al 2003; Lindelow 2006). While this analysis excluded the sanitation asset from the index, changes in the composition of the asset index influence the degree of inequality.

95. *Second*, we did not consider statistical uncertainty associated with all parameter estimates from the demographic and health survey data. As these uncertainties are the same in all scenarios, this is not likely to lead to a systematic impact on mortality scenarios. We carried out a sensitivity analysis on key parameters viz. under five mortality and sanitation effectiveness relative risk, using high-low values to indicate the order of magnitude of the uncertainty ranges for the study results.

96. *Third*, this analysis only considers scaling up sanitation coverage, with other diarrhea-related interventions (both health and non-health) remaining constant in the period 2012-2015. Corresponding increases in other interventions such as access to improved water sources and piped water, handwashing practices, and increased ORS use may likely result in a greater reduction in health inequities between the poorest and the richest subgroups in Nepal.

97. *Fourth*, when considering sanitation scale-up, Nepal can look towards starting with a health equity baseline based on the MDGs. But ultimately, success in achieving positive health outcomes requires that interventions like sanitation scale-up be tailored to the country's unique sociocultural dynamics. To augment the data and analysis described here, standard behavioral and social science methods are needed to investigate the role of culture, norms, hygiene practices etc. Multivariate quantitative analysis and qualitative studies will help clarify causal pathways that cause certain groups to be more impacted.

98. *Fifth*, the LiST model is currently structured for analysis at the country-level, and is not disaggregated to produce results for sub-populations. However, as this paper investigates the impact of sanitation (as a selected environmental health intervention) on different socio-economic groups in Nepal, a number of estimations and assumptions are made for parameters by wealth quintiles. For e.g. the effectiveness ratios (relative risk) for sanitation may vary across wealth quintiles – assumptions made on these adjustments will contribute to the uncertainty of the exercise.

99. *Last*, while convergence of findings from multiple data sources and methods promises good internal validity, generalization of these results disaggregated to the quintile level requires evidence of external validity which is currently lacking. This paper uses the LiST model to estimate lives saved from saving up sanitation across wealth quintiles. The results in this paper are likely valid in countries with similar or larger gradients across wealth quintiles for the related health indicators (e.g. diarrheal mortality, under five mortality) and sanitation indicators (e.g. sanitation coverage).

100. Sustained progress in improving child health outcomes can be made if the prevention and treatment of diarrhea becomes an international priority among governments in developing countries like Nepal. Increasing sanitation coverage in countries in South Asia, where sanitation lags far behind other environmental services, is critical, and requires inputs and leadership from, and coordination among, health, environment and infrastructure ministries. Coordinating especially the targeting of sanitation interventions to vulnerable population subgroups (such as the poorest quintile) is especially important to get the maximum health benefits in terms of reduced child morbidity and mortality due to diarrhea. Such analysis disaggregated to the level of wealth quintiles is critical for program planners, funders, and policy and decision makers in developing countries like Nepal to better understand the potential impact on mortality when investing in diarrhea prevention at different wealth quintiles of the population.

101. Nepal has been unable to achieve the MDG national target of 53 percent sanitation coverage by 2015. Looking ahead, the government and policy makers can take advantage of models such as LiST to build momentum towards expanding sanitation coverage, even while appropriately targeting non-health sector interventions such as improved water and sanitation hand-in-hand with other health sector interventions for addressing diarrhea (such as ORS use, vitamin A supplementation etc.). Working across sectoral ministries to improve health outcomes through interventions in both the health sector as well as other sectors will be critical in ensuring success in addressing child mortality in Nepal.

102. The costing of the alternative scenarios is discussed in the next chapter; but clearly resource considerations often constrain the rolling out of sanitation interventions in low income countries like Nepal. In a budget-constrained world, it becomes even more important to appropriately target these interventions to communities where the largest reductions in diarrheal mortality can take place, and to counter the tendency for co-coverage of many health and environmental interventions in richer households.

## Annex 1: Methodology for creating wealth quintiles

This annex details the methodology for creating of wealth quintiles for this paper.

### Wealth quintiles

The wealth index used in this survey is a measure that has been used in many DHS and other country level surveys to indicate inequalities in household characteristics, in the use of health and other services, and in health outcomes (Rutstein et al., 2000). It serves as an indicator of level of wealth that is consistent with expenditure and income measures (Rutstein, 1999). The index was constructed using household asset data via a principal components analysis.

The standard approach to constructing an asset index is to define it as the weighted sum of household assets (and other characteristics), where the weights are derived from principal components analysis (Filmer and Pritchett 1998). Principal components analysis seeks to describe the variation of a set of multivariate data in terms of a set of uncorrelated linear combination of the original variables, where each consecutive linear combination is derived so as to explain as much as possible of the variation in the original data, while being uncorrelated with other linear combinations (Lindelow 2006). The asset index for individual  $i$  is defined as the first principal component:

$$A_i = \sum_k \left[ f_k \frac{(a_{ik} - \bar{a}_k)}{s_k} \right]$$

where  $a_{ik}$  is the value of asset  $k$  for household  $i$ ,  $\bar{a}_k$  is the sample mean, and  $s_k$  is the sample standard deviation.

In its current form, which takes better account of urban-rural differences in scores and indicators of wealth, the wealth index is created in three steps. In the first step, a subset of indicators common to urban and rural areas is used to create wealth scores for households in both areas (DHS 2011). Categorical variables to be used are transformed into separate dichotomous (0, 1) indicators. These indicators and those that are continuous are then examined using a principal components analysis to produce a common factor score for each household (DHS 2011). In the second step, separate factor scores are produced for households in urban and rural areas using area-specific indicators (DHS 2011). The third step combines the separate area-specific factor scores to produce a nationally applicable combined wealth index by adjusting area-specific scores through a regression on the common factor scores (DHS 2011)

This three-step procedure permits greater adaptability of the wealth index in both urban and rural areas. The resulting combined wealth index has a mean of zero and a standard deviation of one (DHS 2011). Once the index is computed, national-level wealth quintiles (from lowest to highest) are obtained by assigning the household score to each de jure household member, ranking each person in the population by his or her score, and then dividing the ranking into five equal categories, each comprising 20 percent of the population (DHS 2011)



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## Chapter 4: Cost-Effectiveness of Scaling-Up Sanitation across Wealth Quintiles in Nepal (Paper 2)



## Abstract

**Background:** Previous studies have shown water, sanitation and hygiene interventions to be cost-effective for addressing diarrheal deaths and disease in children under five. Within a country, there are differences in the outcomes (reduction in health burden associated with sanitation scale-up) and costs (difference in sanitation-related costs at the household level), by socioeconomic status. This paper examines how cost-effectiveness of sanitation scale-up may vary across wealth quintiles in Nepal.

**Methods:** Across the wealth quintiles, we estimated the incremental cost-effectiveness ratios (ICERs) from scaling up improved sanitation under two scenarios –an equal scale-up and a pro-poor scale-up. Raw data from the most recent 2011 Nepal Demographic and Health Survey (DHS) was used to estimate health and sanitation coverage indicators across wealth quintiles (through the creation of asset indices). For outcomes, DALYs were estimated to capture premature mortality and morbidity from diarrhea in children under five. For costs, sanitation hardware costs (infrastructure, maintenance) and cost-offsets (averted household treatment costs) were included. Multivariate sensitivity analyses using @Risk (v.6) was carried out at wealth quintile level to test the robustness of the results to uncertainty in parameters (costs, effectiveness, discount rates).

**Results:** The results show that incremental cost-effectiveness ratios (ICERs) associated with scaling up sanitation are relatively low across all wealth quintiles in Nepal. In an equal scale-up of sanitation (where sanitation coverage in each quintile was increased by the same factor), ICERs do not vary widely, ranging from 5.82 (4.22, 7.64) in the poorest quintile to 7.30 (1.96, 13.34) in the richest quintile. In the pro-poor scale-up of sanitation, where sanitation coverage was concentrated in the lowest three quintiles, the ICERs show no distinct trend, and range from 7.78 (5.83-9.98) in the poorest quintile to a high of 10.04 (6.68-13.90) in the second quintile.

The ICER confidence intervals across quintiles overlap considerably, pointing to no significant differences between the two scale-up scenarios. Sanitation costs are found to have the largest influence on the ICERs.

**Conclusions:** Given the uncertainties relating to sanitation costs and effectiveness ratios across wealth quintiles, there appears to be no significant differences in the cost-effectiveness results for the sanitation scale-up and the two scenarios. From this analysis, we can conclude that from a cost-effectiveness (efficiency) perspective, both equal scale-up and pro-poor scale-up of sanitation coverage can be attractive options for Nepal. However, from an equity perspective, the pro-poor scale-up of sanitation remains important because of its benefits in terms of lives saved.

# Chapter 4: Cost-Effectiveness of Scaling-Up Sanitation across Wealth Quintiles in Nepal<sup>2</sup>

*In collaboration with Andrew Mirelman and Louis Niessen*

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## 4.1 Introduction

103. In many developing countries, government programs to improve child health have focused on safe delivery, improved feeding practices, micronutrient supplementation, national immunization campaigns, and measures to strengthen health systems (such as improving the availability of drugs, ensuring better treatment of cases, and hiring more trained personnel). However, with continued exposure to contaminated water, inadequate sanitation, smoke and dust, and mosquitoes, children in developing countries are still falling sick, imposing a sustained and heavy burden on the health system.

104. Poor environmental conditions and infectious diseases are highly associated geographically and take their heaviest tolls on children under five years of age in Sub-Saharan Africa, South Asia, and certain countries in the other sub-regions (Ezzati et al 2003; Ezzati et al 2004; recent). Infections and malnutrition operate in a vicious cycle to affect child health. Though the effect of malnutrition on disease is generally recognized, the role of infections in the worsening of nutritional status has

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<sup>2</sup> Anjali Acharya conceived the idea for the paper and is the sole author. Andrew Mirelman supported the adaptation of the Excel based model to the context of this paper, and double-checked the model inputs. Dr. Louis Niessen provided guidance as well as quality assurance for the analysis (especially the @Risk add-in) and paper.

been relatively neglected. Furthermore, in their agenda to reduce child mortality and improve child health, governments in developing countries like Nepal are paying little attention to addressing environmental risk factors.

105. The previous chapter showed the health-equity potential for scaled-up sanitation coverage; with many more lives saved of children under five when such interventions were targeted at the lowest quintiles. Even with such evidence, governments in countries like Nepal have to identify and prioritize interventions with a limited budget envelope –which then requires an evaluation of the cost-effectiveness (CE) of different child health interventions.

106. While there is considerable literature on the cost-effectiveness of health sector interventions, there is less research to provide governments with information the cost-effectiveness of environmental health interventions, such as sanitation, and its effects of health outcomes such as diarrhea. This often contributes to the failure of health ministries to consider the costs and benefits of such interventions in setting policy. This becomes even more important when considering the targeting of vulnerable subgroups of the populations, like the lowest quintiles. This chapter looks at the evidence base for the cost-effectiveness of sanitation interventions, and attempts to provide a disaggregation of CE estimates across wealth quintiles in Nepal.

107. Early attempts at cost-effectiveness analyses of water supply and sanitation interventions, which included hardware costs, found such interventions (though desirable) to be relatively cost-ineffective. Others excluded the hardware costs of

such interventions arguing that these are not properly borne by the health sector (Varley et al 1998). In its 2002 World Health Report, the WHO assessed the cost-effectiveness of interventions to increase coverage of water and sanitation services, concluding that the most cost-effective strategy was the provision of a water disinfection capacity at the point of use (WHO 2002). Adding basic low technology water and sanitation was also found to be either very cost-effective or cost-effective in most settings. The report also stated that interventions targeting improving hand washing practices would also likely prove to be cost-effective (WHO 2002).

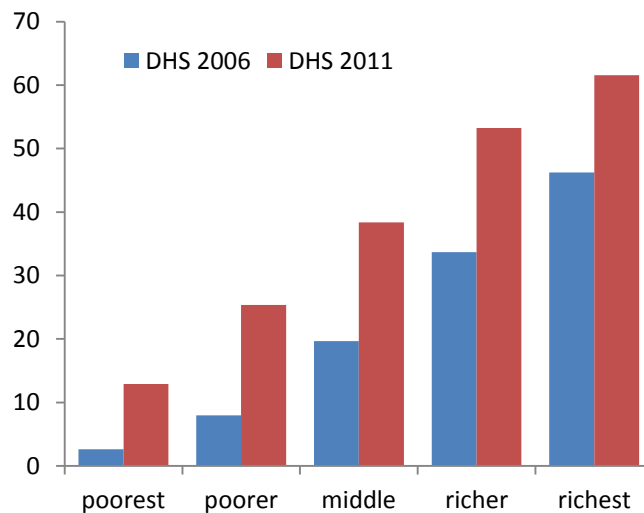
108. Water, sanitation and hygiene interventions have also been shown to be highly cost-effective investments. Under the Disease Control Priorities Project, Cairncross et al. compiled cost-effectiveness estimates for water, sanitation and hygiene, using evidence from studies and reviews (Cairncross et al 2006). The cost-effectiveness of promoting sanitation and hygiene (US\$11.15 and US\$3.35, respectively, per DALY) compares favorably with cost-effectiveness of promoting oral rehydration therapy (estimated at US\$23/DALY), the principal other measure available to prevent diarrhea mortality. In yet another paper, a cost-effectiveness analysis revealed that a hygiene education program can prevent the death of child at only a fraction of the cost of water supply and sanitation in the developing regions of the world (Larsen 2004). An analysis of the cost effectiveness ratio of a number of interventions against diarrheal disease shows that water, sanitation and health (WSH) interventions have low costs per DALY compared to vaccination interventions, or treatment, such as oral rehydration, once diarrhea has been contracted (Jamison et al 2006). Yet another review of household-based water

quality interventions found household-based chlorination to be the most cost-effective where resources are limited; while household filtration yielded additional health gains at higher budget levels (Clasen et al 2006).

109. Over the last few years, there has been an increase in the interest in exploring intra-country health inequalities, across the spatial (rural-urban) and socio-economic (wealth quintiles), related to environmental health interventions. Recent articles have focused on estimating the environmental health burden at sub-national levels, as well as exploring ways to estimate household costs (Rheingans et al 2012a; Rheingans et al 2012b) and other program costs associated with sanitation / water coverage (UNDP 2006, Hutton et al 2014).

110. A recent study reports the model-based analyses on the distribution of sanitation-related health burden by wealth quintile; and the distribution of health benefits for targeting different wealth quintile groups, for 10 low-income countries<sup>1</sup> in sub-Saharan Africa and South Asia (Rheingans et al 2012c). The paper concluded that, for the 10 countries assessed, the health burden associated with poor sanitation is distributed highly inequitably with children in the poorest quintile bearing up to 20 times the burden of those in the richest quintile (Rheingans et al 2012c). It also stated that although the study did not directly consider the relative costs of targeting the poorest households, reaching these households may yield substantially higher health benefits and greater economic returns (Rheingans et al 2012c).

**Figure 4.1: Sanitation coverage across wealth quintiles (%)**



*Source: DHS 2006, DHS 2011*

111. There is a need to contextualize existing regional estimates of cost, effectiveness and cost-effectiveness to the setting in which the information will be used, since many factors may alter the actual cost-effectiveness of a given intervention across settings. These include the costs related to sanitation: the availability, mix and quality of inputs into the sanitation hardware; local prices, especially labor costs etc. Likewise on the effectiveness side, there is a need for contextualization, at the wealth quintile level. For example, effectiveness estimates used in CEA are often based on efficacy data taken from experimental and context-specific trials, and mostly at the aggregate level. Across different wealth quintiles, due to specific living conditions, levels of congestion, community sanitation and hygiene practices etc., the effectiveness of sanitation interventions is likely to vary (potentially lower effectiveness in the poorer quintiles but possibly with higher absolute improvements).

112. This paper estimates the outcomes (reduction in health burden associated with sanitation scale-up) and costs (difference in sanitation-related costs at the household level) to examine how cost-effectiveness may vary across wealth quintiles in developing countries such as Nepal.

## **4.2 Methodology**

113. Earlier studies on Nepal have looked at an economic analysis of environmental health costs attributed to poor water and sanitation, indoor air pollution and urban air pollution. A World Bank analysis showed that Nepal's economic costs associated with poor water/ sanitation constituted 1.2% of the country's GDP (World Bank 2008). If malnutrition-mediated effects had been considered, this figure would be even higher –further highlighting the importance of considering environmental health issues such as sanitation in the context of child health programs.

114. To further make the case for expanding environmental health interventions such as sanitation, it becomes important to look at their cost-effectiveness, when compared to other child health interventions. But even more importantly and related to implementation, it is important to look at how this economic measure may vary across sub-groups of the population in countries like Nepal. This paper has looked at estimating the relative cost-effectiveness of sanitation interventions across wealth quintiles in Nepal –to see if targeting the lowest quintiles makes even more economic sense in terms of health outcomes achieved.



### ***CEA Framework***

115. This section articulates the perspective of the study, the analytic methods, the outcomes etc. which affect the interpretation and usefulness of the results (Haddix et al 2003). The following paragraphs elaborate on different elements of the conceptual framework for this study, to help explain the methodology and analysis chosen.

116. *Audience:* The primary audience for this study is decision-makers in Nepal; the exercise will help raise awareness for them to consider the incorporation of environmental health interventions (such as sanitation) within the context of the broader child survival program. Equally, this study targets donor organizations and international institutions (such as the World Bank, UNICEF and the World Health Organization) that finance and support child health programs.

117. *Perspective:* It is important to specify the perspective from which the analysis will be carried out. Costs that will be considered differ depending on the particular perspective, be it the Ministry of Health, or the household. Typically for such an analysis, and for purposes of this paper, costs are measured from the perspective of society as a whole, regardless of who pays for them. This includes opportunity costs (e.g. costs associated with productivity losses). Non-health benefits associated with interventions such as sanitation are important to consider, even while difficult to quantify and to include. These latter include benefits relating to convenience, privacy, dignity etc. that are also associated with having access to improved sanitation.

118. *Cost-effectiveness* is defined as a measure of the cost of a particular intervention (e.g. sanitation) and its effectiveness with respect to a certain health outcome (e.g. the prevention of diarrheal disease) (Varley and Travid 1998; WHO 2000; Murray et al 2000; Tan Torres Edejer 2003; Kapiriri et al 2004; Drummond et al 2005; Evans et al 2005; Evans et al 2005b; Laxminarayanan et al 2006).

Effectiveness requires measure and an assessment of health outcomes i.e. of the fatal (diarrheal deaths) and non-fatal health outcomes (diarrheal morbidity) that occur when an intervention (e.g. sanitation) is introduced (Cairncross and Valdmanis 2006; Clasen et al 2006; Clasen et al 2007; Clasen et al 2010; Cairncross et al 2010). Such analyses help extend the knowledge base in global population health by improving understanding of the implications of investing in interventions options.

119. The previous chapter of this thesis explores the potential of sanitation interventions to differentially impact child mortality in Nepal across wealth quintiles. This paper further contributes to environmental health research by examining the cost-effectiveness across wealth quintiles to identify possible variations which might help inform government strategy on sanitation/ hygiene investments in countries like Nepal.

### ***Methods of Analysis of Costs and Benefits***

#### *Data sources*

120. This analysis uses secondary data sources for Nepal to estimate the costs and effectiveness of selected environmental health interventions. For population and

health data, key sources have included the latest Nepal Demographic and Health Survey (DHS 2011), the Nepal Living Standards Survey 2010/11 (NLSS 2011), UNICEF's report on the State of the World's Children (UNICEF 2015), and the World Bank's World Development Indicators (World Bank 2014). Data on costs related to sanitation infrastructure was from recent research papers estimating sanitation costs, as well as household treatment costs (Hutton and Haller 2004; Rodriguez et al 2012; Nguyen et al 2012; Hutton et al 2012; UNDP 2006; Rheingans 2012a; Rheingans et al 2012b; Hutton et al 2014).

### ***Study design***

121. We compared two sanitation scale-up approaches to reducing diarrheal mortality and morbidity in children under-five years of age. One approach that we have labelled an “equal scale-up” approach to increasing sanitation coverage equally across all wealth quintiles. The other, labelled as a “pro-poor scale-up” approach that prioritized scaling up sanitation to reach the most deprived populations (i.e. the lowest quintiles).

122. We estimated incremental costs incurred and reductions of deaths and illness in children younger than 5 years of age resulting from implementation of scaling up sanitation through the two proposed strategic approaches. Baseline was defined as the situation as of 2012. The simulation was undertaken for the 5-year period between 2012 and 2016 –using the latest data from the 2011 Nepal DHS, and with the period roughly coinciding with the years remaining to meet the MDGs.

123. Sensitivity analyses are used to address uncertainty in cost-effectiveness evaluations with regard to estimates of effectiveness, the course of illness, and costs. Recent CEA papers have employed the probabilistic sensitivity analysis (using a Monte-Carlo simulation) to test the robustness of the results to parameter uncertainty (for costs, effectiveness ratios etc.) in cost-effectiveness calculations (Whang et al 1999; O'Hagen et al 2007). For this paper, high-low value distributions were computed for key scenario parameters in a Monte Carlo simulation (using @Risk software add-in for Excel) enabling multivariate sensitivity analysis at the wealth quintile level (@Risk 2013).

### ***Variables***

124. Improved sanitary facility: The classification of sanitation varies substantially across time and countries in the DHS surveys: some surveys focus on the distinction between private and public facilities, while others focus on the location (in or outside the house) or the exact type of the facility (e.g., ventilated vs. non-ventilated latrines).

125. In this analysis, the definition of improved sanitary facility from Nepal 2011 DHS report was adopted. Only non-shared facility could potentially be considered as improved sanitary facility. Specifically, the following toilet types were included: flush - to piped sewer system; flush - to septic tank; flush - to pit latrine; pit latrine - ventilated improved pit; pit latrine - with slab; and composting toilet. We collapsed them into 3 categories, since we are not primarily interested in identifying the more

subtle differences between individual technologies (e.g. between ventilated and non-ventilated latrines), we choose a slightly more broad classification.

- Open defecation
- Simple/ traditional pit
- Ventilated improved pit/ Composting/ Flush to pit latrine
- Flush to Septic tank/ Sewers

126. Incidence of diarrhea: In line with most of the existing literature, the first dependent variable we use in our analysis is child diarrhea. Most DHS surveys (including the Nepal 2011 DHS) ask female respondents whether any of their children under the age of 5 had diarrhea over the two weeks preceding the interview.

127. Disability-adjusted Life Years (DALYs): The disability adjusted life year (DALY) is a summary measure of population health combining information on mortality and non-fatal health outcomes into a single measure. It represents the population loss of years of full health due to disease and its consequences. For cost-effectiveness analysis (as opposed to burden of disease calculations), the calculation of DALYs require subtracting the years of premature mortality without an intervention from the estimated years with it (the years of life gained) (Evans et al 2005). DALYs include both premature mortality as well as morbidity associated with diarrhea, and this serves as the denominator of the cost-effectiveness ratio. Data inputs required for calculating DALYs were gathered from systematic household surveys such as the Demographic and Health Surveys (DHS). For the

effect size of scaling up sanitation, we used estimates based on existing literature and research findings.

128. Costs: For this paper, the costs are meant to capture changes in resource use associated with an intervention (in this case, sanitation) –which can be divided broadly into patient (household) costs and program costs. Household level costs for sanitation will include costs of the technology plus other inputs (such as soap, additional water). Program level costs include all resources required to establish and maintain an intervention: administration, publicity, training, and delivery of supplies (Evans et al 2005). It is important to note that the benefits of improving access to safe water and sanitation accrue mainly to households and individuals (Hutton et al 2007). And unlike the typical health sector interventions, sanitation-related program costs such as personnel and infrastructure are fixed costs which do not change with the number of patients or size of the target population (Hutton et al 2007). The CEA omits the inclusion of program costs since the focus is on increased coverage at household level (personal) preventative interventions associated with sanitation. Additionally, household-level costs associated with the specific sanitation option (different technologies as one moves up the sanitation ladder) are included.

**Table 4.1: Input Table**

<i>Quintile</i>	<i>Q1 (Cls)</i>	<i>Q2 (Cls)</i>	<i>Q3 (Cls)</i>	<i>Q4 (Cls)</i>	<i>Q5 (Cls)</i>
<b><i>Age-groups</i></b>					
0-4	14.6	12.4	11.8	9.6	7.9
0-4	16.6	13.2	11.5	10.6	10.2
5-9	15.5	14.3	13.5	13.0	11.6
15-19	8.9	10.6	11.6	11.3	10.0
20-24	5.3	6.8	8.8	10.1	9.7
25-29	5.4	6.4	7.2	7.9	8.8
30-34	5.1	5.2	5.4	6.0	8.9
35-39	5.1	5.2	5.3	6.0	7.7
40-44	4.2	4.6	4.7	5.0	5.4
45-49	3.4	3.6	4.1	4.2	4.6
50-54	4.0	4.6	4.1	5.0	4.4
55-59	3.0	3.6	3.6	3.6	3.3
60-64	3.3	3.4	2.7	2.5	2.4
65-69	2.0	2.1	2.3	2.4	1.9
70-74	1.6	2.0	1.7	1.3	1.1
75-79	1.3	1.0	1.1	0.8	1.0
80+	0.8	1.1	0.7	0.8	1.3
<b><i>Health indicators</i></b>					
Diarrhea incidence	12.71 (11.3-14.1)	14.55 (13.2-16.0)	16.92 (15.5-18.3)	12.9 (11.5-14.3)	11.96 (10.6-13.4)
Diarrhea specific mortality	0.119	0.146	0.195	0.130	0.136
Diarrheal CFR	0.07	0.07	0.07	0.07	0.07
Duration of disease	0.010 (0.005-0.015)	0.010 (0.005-0.015)	0.010 (0.005-0.015)	0.010 (0.005-0.015)	0.010 (0.005-0.015)
<b><i>Sanitation options</i></b>					
Open defecation	71.2	47.1	33.6	11.0	0.5
Simple/ traditional pit latrine	15.9	27.4	28.1	35.7	37.9
VIP/composting	10.4	14.7	19.5	15.0	3.0
Flush to septic tank/ sewers	2.5	10.7	18.9	38.3	58.6
<b>Baseline Costs</b>	\$20.4	\$45.5	\$66.0	\$104.6	\$136.6
<b>Sanitation effectiveness</b>	0.36 (0.23-0.49)	0.36 (0.23-0.49)	0.36 (0.23-0.49)	0.36 (0.23-0.49)	0.36 (0.23-0.49)
<b>Discount rate -health (%)</b>	3(1.5-4)	3(1.5-4)	3(1.5-4)	3(1.5-4)	3(1.5-4)
<b>Monetary discount rate</b>	3(1.5-4)	3(1.5-4)	3(1.5-4)	3(1.5-4)	3(1.5-4)

129. Discount rate: Discounting adjusts for the time value of money (i. e., a dollar one possesses now is worth more than a dollar that one will receive in two years, since it could have been invested and earned interest in the intervening period). While acknowledging the debate on the use of discount rates, WHO-CHOICE guidance recommends that DALYs accruing in the future to an intervention today are traditionally discounted at 3%.

130. *Sensitivity Analysis*: Using @Risk add-in to Excel, the following sensitivities have been tested: the discount rate for health benefits (life years gained due to reduction of diarrheal deaths) and the monetary discount rate, the assumed maximum lifespan for under-fives, as is used in the DALY calculation, the effectiveness of sanitation across wealth quintiles, and the costs for sanitation technology, and diarrhea incidence. Following standard protocols, we assumed different types of distribution for each indicator. The full table is presented below:

**Table 4.2: Distributions, ranges and sources of key indicators**

Indicator	Type of Distribution	Range	Sources
Sanitation effectiveness	Normal	2.78 ( $\pm 0.5$ )	Fewtrell et al 2005; Clasen et al 2007; Clasen et al 2010
Diarrhea incidence	Normal	Point estimate $\pm 0.7$	DHS 2011
Duration of disease	Uniform	0.010 (0.005- 0.015)	Various sources
Intervention costs	Lognormal	Point estimate $\pm 10\%$	Estimated from Hutton et al 2014; other sources
Discount rate	Uniform	3% (1.5%-4%)	WHO CHOICE



## ***Analysis Approach***

131. Country life tables for Nepal were developed and used to calculate the effect on child survival. This Excel-based method is comparable to that of WHO-CHOICE and has been used for analysis in other studies (Niessen et al 2009). We use the Nepal-specific demographic life tables to estimate the expected population-level effects and total costs of the selected environmental health interventions (sanitation coverage), over a period of ten years, taking a household perspective. Existing life tables are used again to estimate the effect of the expected reductions in mortality in children under age five, and disaggregated by wealth quintile, over a ten year period. These analyses was done in the following steps:

### ***1. Defining a demographic-epidemiologic diarrheal model.***

132. The country-level model describes the basic epidemiology of childhood diarrhea in Nepal in terms of incidence, case-fatality ratio, overall neonatal and age-specific mortality rates, all of which are disaggregated by wealth quintile. This is intended to flesh out the differences in parameters across the population sub-groups from the poorest to the richest. Table 4.1 shows how diarrheal incidence and diarrhea-specific mortality vary across wealth quintiles. It is important to note that the DHS data shows that diarrhea incidence does not seem to vary much across the wealth quintiles in Nepal. In addition, calculations of diarrhea-specific mortality also reveal a small difference between the poorest and richest quintiles.

## ***2. Selecting national demographic data for year of study.***

133. This includes the estimated Nepali population in absolute figures, by age, observed births and disaggregated by wealth quintile. Data from the Nepal DHS 2011 was used to disaggregate the population by age group and by wealth quintile. From Table 4.1, we see that the percentage of under-five population ranges from over 16 percent in the lowest quintile to 10 percent in the highest quintile.

## ***3. Constructing baseline dynamic population by age and wealth quintile***

134. These estimates reflect current UN population figures and epidemiologic rates and agree with future United Nations demographic scenarios. The estimates are used to compute the baseline burden of disease expressed in Disability Adjusted Life Years, DALYs, the number of life years lost because of death as compared to an upper lifespan limit (taken as 68 years for Nepal) and the number of life years lost because of morbidity during the diarrheal episodes.

## ***4. Estimating effectiveness of sanitation across wealth quintiles***

135. This will repeat the analysis under step 3 with changes to one or more key epidemiological parameters (e.g. mortality rate) as a result of sanitation intervention effectiveness. Effectiveness data for the selected intervention (in this case, sanitation) will be taken from various systematic reviews of such interventions and meta-analyses (Fewtrell et al 2004; Clasen 2007; Clasen 2010) and provide a measure of the effectiveness of these interventions to prevent diarrhea in children under five.

136. A Cochrane Collaboration review examined trials of interventions to improve the safe disposal of human feces to prevent diarrhea (Clasen et al 2010). In low-income settings like Nepal, this mainly consists of introducing or expanding the number and use of latrines and other facilities to contain or dispose of feces. This includes steps to reduce open defecation by constructing basic sanitation in accordance with the MDG target (Clasen et al 2010).

137. While sanitation interventions are known to have a protective effect in terms of child health, the type and quality of the sanitation infrastructure constructed, and the manner of its use makes a difference (Gunther and Fink 2010). Another paper found strongly protective effects of high quality toilet facilities for child mortality risks, as well as for risks of episodes of diarrhea and stunting (Fink et al 2011). Children living in a household with high quality toilets (viz. flush toilets) were found to have 23% lower mortality risk, a 13 percent lower risk of child diarrhea, and a 27 percent lower risk of mild or severe stunting, than that of children living in households with no toilet facility (Fink et al 2011).

138. A recent systematic review showed that inadequate water and sanitation are associated with considerable risks of diarrheal disease and that there are notable differences in illness reduction according to the type of improved water and sanitation implemented (Wolf et al 2014). The review evidence that sewer interventions are associated with a greater reduction in diarrhea than basic household sanitation. Sanitation interventions in previous analyses have been shown to reduce diarrhea by 30–40% (Waddington et al. 2009; Cairncross et al.

2010), with a larger effect observed for sewer connection (Norman et al. 2010) (see Figure 4.2). Pooled estimates show that sewerage systems typically reduce diarrhea incidence by about 30%, or perhaps as much as 60% when starting sanitation conditions are very poor (Wolf et al 2014). For purposes of this paper, the sanitation effectiveness ratio used is 2.78 (relative risk=0.36).

### ***5. Estimating intervention costs.***

139. Intervention costs for selected sanitation and hygiene interventions are divided broadly into patient (household) costs and program costs. Household level costs for selected environmental health interventions (such as sanitation) will include costs of inputs, such as infrastructure. Also included will be cost offsets (savings) that would accrue to households in terms of direct costs averted due to reduced levels of disease (such as for medicines, outpatient visits, inpatient stays etc.) (Clasen et al 2007). As mentioned earlier, program level costs have been omitted since the focus is on household level (personal) preventative interventions associated with sanitation.

Overall costs = intervention costs - averted household treatment costs

140. Intervention costs include initial capital costs plus operations and maintenance over a 10 year period (assumed life of the infrastructure). The Nepal DHS 2011 data does not disaggregate the sanitation technology per wealth quintile, so the analysis includes the same effectiveness estimates across quintiles. The table below shows the percentage of the respective sanitation option, within each quintile (based on information from the 2011 DHS). The data shows that open defecation

remains high in the bottom three quintiles; as much as 71 percent of the lowest quintile has no sanitation facility. At the other extreme, about 58 percent of the richest quintile use flushing systems that include septic tank/ sewer systems, relatively more frequently as compared to less than 3 percent in the bottom quintile (see Table 4.3).

141. The next step is to factor in the respective (typical) costs associated with each of these sanitation options. This paper applies unit price estimates based on global and regional figures as well as other country research papers (Hutton and Haller 2004; Rodriguez et al 2012; Nguyen et al 2012; Hutton et al 2012; UNDP 2006; Hutton et al 2014) (see Table 4.3). There are no sanitation costs available at the disaggregated wealth quintile level, which limits the analysis and its interpretation. A recent paper gives some estimates of sanitation costs across different types of sanitation technology in Southeast Asia (Hutton et al 2014). Using those costs, as well as previous estimates, we have assumed the sanitation costs in Nepal to vary by 10 percent (Hutton et al 2014).

**Table 4.3: Costs by sanitation option**

<b>Modality</b>	<b>Simple pit latrine</b>	<b>VIP latrine/pour flush</b>	<b>Septic tanks/sewer</b>
Investment cost US\$ per capita	39	70	160
Lifecycle cost US\$ per capita	0.10	0.14	0.38
Maintenance cost US\$ per capita	4.88	6.21	9.75
	~ \$45	~\$80	~\$200

*Source: Hutton and Haller 2004; UNDP 2006*

142. Given the costs per sanitation option, and with the estimated percentage of sanitation options per wealth quintile, we can calculate the baseline costs for

sanitation technology (household costs) per capita, per quintile. The table below shows sanitation costs per capita ranging from just over \$20 per capita for the poorest quintile to \$137 per capita for the richest quintile (see Table 4.4). These estimates take into account the relative proportion of different types of sanitation options within each wealth quintile.

**Table 4.4: Sanitation costs per capita by quintile (US\$)**

	Q1	Q2	Q3	Q4	Q5
Open defecation	-	-	-	-	-
Simple/ traditional pit latrine	7.15	12.33	12.63	16.06	17.07
Ventilated improved pit/composting	8.35	11.74	15.56	11.99	2.40
Flush to pit latrine/ septic tank/ sewers	4.94	21.38	37.82	76.56	117.12
<b>Total Sanitation costs</b>	<b>20.44</b>	<b>45.45</b>	<b>66.01</b>	<b>104.62</b>	<b>136.59</b>

*Household treatment and potentially averted costs*

143. With diarrhea being a major cause of mortality in countries like Nepal, they also have an important economic impact on households of affected children (Rheingans et al 2012a; Rheingans et al 2012b). These economic costs include the costs of medication and costs related to hospitalization, as well as other out-of-pocket expenses like transportation and lost time from work. These are considered cost-offsets as they are the averted costs when interventions like sanitation help to reduce diarrheal disease in children. As this paper adopts a household perspective, these averted costs are subtracted from the overall costs of sanitation to get the numerator for the CEA. Another paper has estimated household costs associated with childhood diarrhea in 3 South Asian countries (Rheingans et al 2012a).

144. Household treatment costs included direct medical costs, direct nonmedical costs, indirect medical costs, and total costs per child for utilizing healthcare services to treat a given case of diarrhea, converted to US dollars (Rheingans et al

2012a; Rheingans et al 2012b). Direct medical costs were either informal or formal expenditures, with the former representing care provided by a local healer or pharmacists and the latter combining both outpatient and inpatient care (Rheingans et al 2012a; Rheingans et al 2012b). Outpatient facilities were primarily health centers and private doctors' offices, while inpatient facilities were primarily public district hospitals (Rheingans et al 2012a; Rheingans et al 2012b).

***6. Calculating incremental total population-level environmental health intervention costs and population effectiveness in DALYs for Nepal.***

145. The costs of increase in sanitation coverage for each wealth quintile will be ascertained to identify the range of ICERs at different levels of socioeconomic (and health) status. To determine whether an intervention is cost-effective, this paper uses the criteria suggested by the Commission on Macroeconomics and Health viz. interventions that avert one DALY for less than average per capita income for a given country or region are considered very cost-effective; interventions that cost less than three times average per capita income per DALY averted are still considered cost-effective and those that exceed this level are considered not cost-effective (WHO Commission on Macroeconomics and Health 2001).

146. We estimate the sanitation effectiveness time frame to be 10 years starting in 2011. After that, the new population cohorts resume pre-intervention status. Hence, the calculations include the extra life-years lived by additional surviving children beyond the 10-year period. We estimate total health effects over an analytic horizon

of 100 years to include all life-years gained beyond the 10-year time frame, among all survivors.

147. Since the type of sanitation infrastructure makes a difference in the level of impact on disease burden, this paper estimated the type of scale-up that would be realistic in countries like Nepal. For this analysis, we have assumed that any household using open defecation will move to pit latrines; and those with pit latrines (unimproved sanitation technologies) would get an improved latrine (VIP/ composting/ pit with slab). A more ambitious scenario (not considered for this paper), would aim at upgrading sanitation access to the highest possible standard – meaning any household not already having a toilet connected to a septic tank or sewage system will be provided with such access.

148. The third chapter, which looked at the equity dimension of sanitation on health, explored different levels of scale-up which are used in this paper (Table 4.5).

- (i) *Equal scale-up*: Using the MDG target for sanitation for Nepal (53% nationally), increasing improved sanitation coverage equally in each of the wealth quintiles to reach this target; and
- (ii) *Pro-poor scale-up*: Increasing improved sanitation coverage starting from the lowest quintile to the MDG national target (53%) in Nepal. Under this scenario, we have focused on increasing sanitation coverage in the lowest three quintiles, and no change in the top two quintiles.



**Table 4.5: Scale-up of sanitation in Nepal under two scenarios**

Quintile → Sanitation option%	Q1	Q2	Q3	Q4	Q5
<b>1. Equal scale-up*</b>					
Open defecation	0.0	0.0	0.0	0.0	0.0
Simple/ traditional pit latrine	85.7	65.3	47.5	0.0	0.0
VIP/composting/pit with slab	14.3	20.1	26.6	47.5	19.8
Flush to septic tank/ sewers	0.0	14.6	25.9	52.4	80.2
	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>
<b>2. Pro-poor scale-up*</b>					
Open defecation	0.0	0.0	0.0	11.0	0.5
Simple/ traditional pit latrine	57.1	47.0	47.0	35.7	37.9
VIP/composting/pit with slab	42.9	30.7	26.9	15.0	3.0
Flush to septic tank/ sewers	0.0	22.3	26.1	38.3	58.6
	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

Notes: \*Under these scenarios, the same scale-up factors used as in Chapter 3.

### 4.3 Results

149. This section presents the results of the cost-effectiveness analyses for scaling up sanitation interventions across wealth quintiles in Nepal, in terms of DALYs saved, additional costs (sanitation costs less averted medical costs) involved and the incremental cost-effectiveness ratios (ICERs) across the wealth quintiles. These ICERs are calculated under the two scenarios of equal scale-up and pro-poor scale-up to add the cost-effectiveness dimension to Chapter 2 on health equity from sanitation across wealth quintiles. This analysis also takes into account uncertainties in the effectiveness of sanitation interventions across wealth quintiles, as well as uncertainties in cost estimates (sanitation costs) at the household level. The results of multivariate sensitivity analyses for all quintiles (for equal scale-up scenario), and for the lowest three quintiles (for the pro-poor scale-up scenario) are presented in tornado graphs. These tornado graphs indicate the most sensitive parameters which influence the ICERs.

150. Costs: From this analysis, we see that the per capita costs under the equal scale-up scenario ranged from \$50-\$176 across the wealth quintiles, and under the pro-poor scale-up scenario, ranged from \$60 to \$137 (see Table 4.6). The sanitation intervention technology is assumed to vary across the wealth quintiles -which explain the movement up the sanitation “ladder” typically the gradient from poorer to richer households in Nepal (and other settings). The sanitation intervention costs are the costs over a ten year period (assumed as the life of the relevant intervention) and discounted over that same period, with a discount rate of 3% (varying 1.5% - 4%) in the sensitivity analyses. These costs take into account both capital costs, as well as operations and maintenance costs over the 10 year period.

**Table 4.6: Sanitation costs per capita under two scale-up scenarios**

<b>Equal Scale-Up</b>	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>	<b>Q5</b>
Open defecation	-	-	-	-	-
Simple pit latrine	38.57	29.37	21.36	-	-
VIP/composting/pit with slab	11.43	16.08	21.32	38.00	15.84
Flush to septic tank/ sewers	-	29.28	51.80	104.85	160.39
<b>Costs, per capita</b>	<b>\$50.00</b>	<b>\$74.73</b>	<b>\$94.47</b>	<b>\$142.85</b>	<b>\$176.23</b>

<b>Pro-poor Scale-Up</b>	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>	<b>Q5</b>
Open defecation	-	-	-	-	-
Simple pit latrine	25.71	21.15	21.15	16.06	17.07
VIP/composting/pit with slab	34.30	24.53	21.50	11.99	2.40
Flush to septic tank/ sewers	-	44.66	52.24	76.56	117.12
<b>Costs, per capita</b>	<b>\$60.00</b>	<b>\$90.35</b>	<b>\$94.89</b>	<b>\$104.62</b>	<b>\$136.59</b>

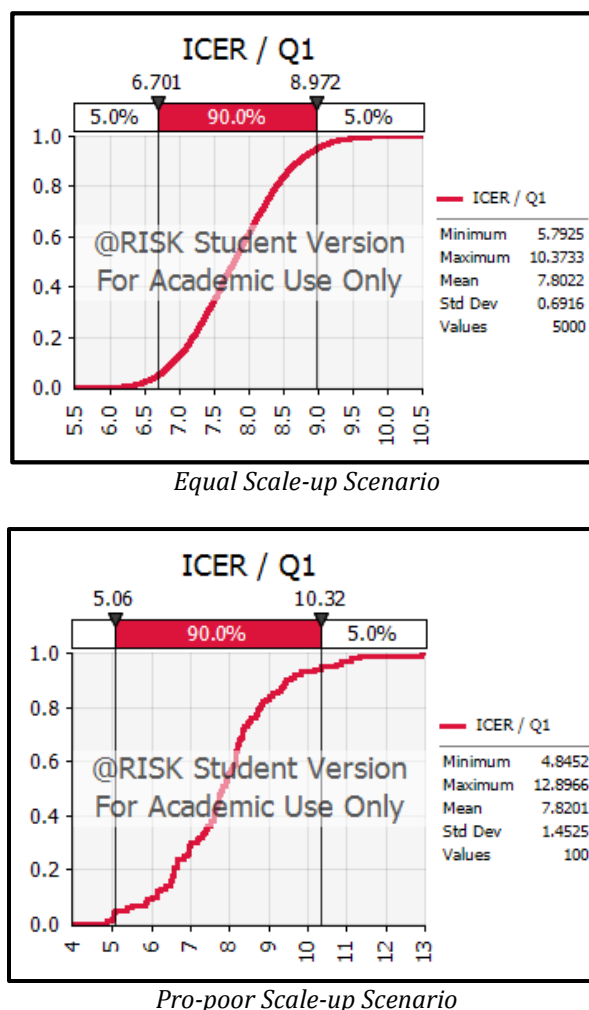
151. The household treatment costs also vary across the wealth quintiles, using different assumptions and estimates relating to costs of treatment (Rheingans et al 2012a; Rheingans et al 2012b). These represent averted costs (savings) at the household level, and are subtracted from the sanitation costs to get the net costs. Differences in the rate of ORS use and the percentage of the sub-population taking

the child to hospital for treatment across the wealth quintiles contributes to these cost differences.

152. *Outcomes*: One can observe that the number of potential DALYs saved varies across the wealth quintiles in Nepal, especially due to the number of children under five in each quintile. The lowest quintiles typically have the largest numbers of under-fives population as compared to the highest. This demographic pattern, however, does not fully explain this result. Overall under-five mortality is also higher in the poorest quintiles, which means the potential to save DALYs, relatively, is also higher.

153. Results from the cost-effectiveness analyses for scale-up of sanitation in terms of terms of DALYs retrieved, additional sanitation costs involved and the incremental cost-effectiveness ratios (ICERs) for each wealth quintile are presented, accounting for uncertainties in the effectiveness of the sanitation interventions as well as uncertainties in cost estimates. Acceptability curve graphs plot the probability that the ICERs is favorably cost-effective (i.e. has a cost-effectiveness ratio below the societal willingness to pay threshold). The acceptability curves for the ICERs in each of the two sanitation scale-up scenarios for the lowest quintile (Q1) are shown in Figure 4.2, using probabilistic analyses, presenting the probability (y-axis) of a particular ICER value (x-axis).

**Figure 4.2: Incremental cost-effectiveness ratio acceptability curves for the lowest quintile, by scenario**



154. In looking at sanitation scale-up, we have computed two different scenarios – of equal scale-up across all wealth quintiles, and of pro-poor scale-up focused on the lower quintiles –mirroring two of the scenarios considered in Chapter 3 (on health equity). For the equal scale-up scenario, the ICERS do not vary very much ranging from 5.82 (4.22, 7.64) in Q1 to 7.30 (1.96, 13.34) in Q5 (see Table 4.7 below).

**Table 4.7: Incremental cost-effectiveness ratios for scaling up sanitation**

	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>	<b>Q4</b>	<b>Q5</b>
<b>Equal Scale-up</b>	5.82 (4.22-7.64)	6.66 (3.92-9.81)	7.33 (3.30-11.97)	7.67 (2.99-13.01)	7.30 (1.96-13.34)
<b>Pro-Poor Scale-up</b>	7.78 (5.83-9.98)	10.04 (6.68-13.90)	7.59 (3.52-12.27)	n/a	n/a

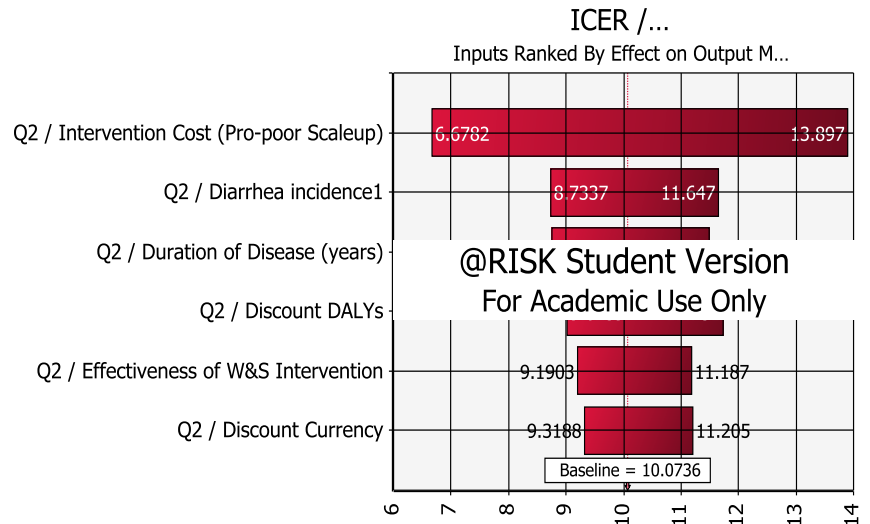
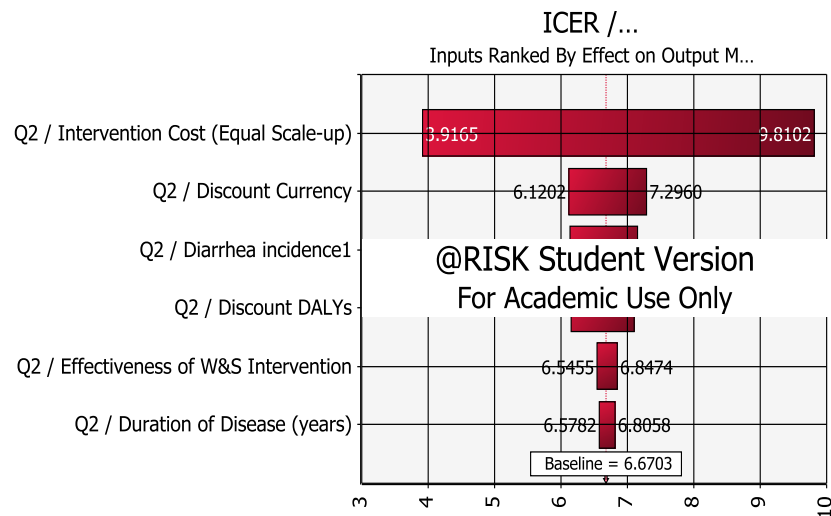
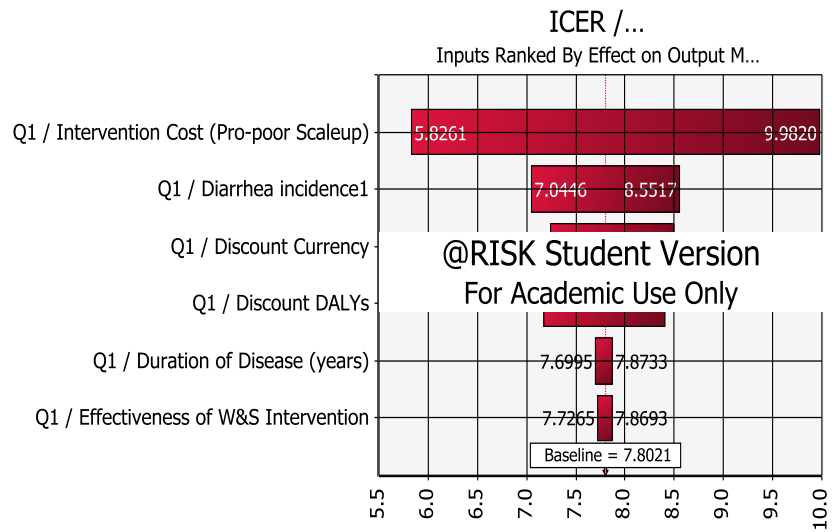
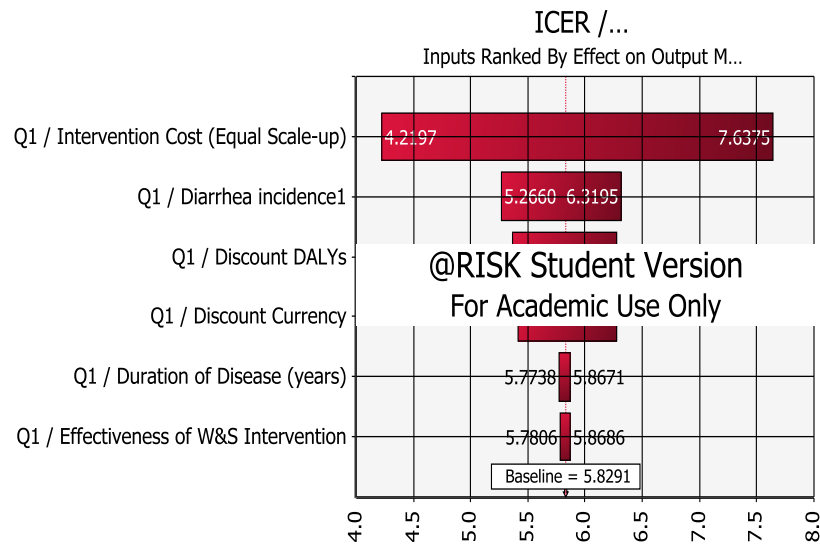
155. For the pro-poor scenario, the results show a wider spread of ICERs – which is 7.78 (5.83, 9.98) for the lowest quintile, 10.04 (6.68, 13.90) in q2, and 7.59 (3.52, 12.27) in q3. The sensitivity analysis shows that the confidence intervals for the ICERs overlap considerably –indicating that the ICERs are not significantly different across the wealth quintiles in either scenario.

156. Overall, the cost-effectiveness ratios for scaling up sanitation across the wealth quintiles in Nepal is found to be low, and comparable to other alternatives in child survival such as vaccines (which are typically lower than ten dollars per DALY). Also, the ICERs across all quintiles and under both scale-up scenarios are below the national GDP of Nepal, which is the cost-effectiveness reference threshold set by WHO (WHO Commission on Macroeconomics and Health 2001).

#### *Sensitivity analysis*

157. In the sensitivity analysis, for both the equal scale-up and pro-poor scale-up scenarios for the lowest quintile (Figure 4.4), the figure shows larger influence of the intervention costs, diarrhea incidence, effectiveness ratio, discount DALYs and discount DALYs. Annex 3 shows all the ICERs for the quintiles.

**Figure 4.4: Incremental cost-effectiveness ratios for lowest two quintiles, by scenario**



## 4.4 Discussion

158. This study shows that for Nepal, with observed high inequalities in general health status and in the access to environmental services, the scaling up of sanitation across all quintiles is an attractive option for addressing child health, when considering efficiency in the allocation of resources. Even so, the estimates and analyses in this paper do not point to any significant differences in cost-effectiveness cross wealth quintiles.

159. Previous papers have shown that the exposure levels and overall sanitation risk of children in poor households is manifold those in the richest quintile (Rheingans 2012). One paper looking across 10 countries reported that children in the poorest households may bear up to 20 times the sanitation-related health burden compared to children in the richest households (Rheingans et al 2012c). A number of factors place the poorest children at greatest risk of mortality.

160. The poorest children are more likely to be in households with no sanitation facilities, more likely to be in households that share facilities, and (in most countries) are more likely to be in communities with high densities of people without sanitation (Rheingans et al 2012c). Children from the poorest households also have an increased susceptibility to fatal diarrhea as they are more likely to be undernourished and without access to ORT or vitamin A and zinc supplementation. Chapter 3 of this thesis also shows how scaling-up sanitation interventions (under two different scenarios) both offer high impacts in terms of lives saved of children under five years of age.

161. Our analysis has several limitations. *First*, we recognize that there are many factors that influence the epidemiology of this linkage, including overall exposure levels, and susceptibility of children, health care availability (for severe diarrhea cases), and treatment results for diarrheal episodes (both ORS and hospital care). These factors will vary by across wealth quintiles within a country. This paper looks specifically at scaling up sanitation coverage and its expected impact on child health across wealth quintiles, and does not take into account potential changes in other variables.

162. *Second*, while the biological association between diarrhea and exposure to human feces is well established, there is limited epidemiological evidence of the effectiveness of different types of sanitation interventions to prevent disease (Esrey et al 1985; Esrey and Habicht 1986; Clasen 2010). We were unable to find any estimates showing a possible range of sanitation effectiveness across different sections of the population, or associated with different types of sanitation technology.

163. *Third*, there is relative paucity of data relating to sanitation technology costs. The cost of achieving complete coverage with any intervention (such as sanitation coverage) will clearly differ between the wealthiest and the poorest quintile. However, there is little information available on the determinants of these costs in each quintile (and disaggregated by sanitation technology, or options) or the actual differences in cost of implementation. Some values (e.g. household treatment costs)



have been made from the limited data available, for other countries similar to Nepal (Rheingans et al 2012c).

164. *Fourth*, as with any modelling exercise, caution should be taken not to over-interpret the findings, in view of these uncertainties. We also recognize that the two sanitation scale-up approaches compared are not necessarily realistic nor are mutually exclusive in practice. Reality often lies between these approaches –with some pro-poor targeting of sanitation scale-up, with also an emphasis on urban areas. Yet the broader significance of the results of our analysis lies in the suggestion that much greater impetus needs to be given to prioritizing sanitation scale-up to the lowest quintiles.

165. This economic evaluation estimates if cost-effectiveness varies when there are potentially differences in intervention (sanitation) effectiveness across wealth quintiles, as well as in the range of intervention costs. The analysis shows us that where existing levels of sanitation coverage are relatively low and the diarrheal burden is relatively high (i.e. in the lower quintile), the scaling up of sanitation is cost-effective; but that the degree of cost-effectiveness is sensitive to the intervention costs. The absence of information/ research on differences in sanitation effectiveness across wealth quintiles limits the analyses in this paper.

166. The choice of a suitable approach that can differentiate health effects between different improvements in sanitation technology relative to the baseline is crucial for meaningful estimates. However, the evidence, from well-conducted intervention studies assessing universal use of effective sanitation, is still very

limited (Wolf et al 2014). Most other observed uncertainties, observed in the study, are caused by the lack of specific data on the costs relating to the interventions (which sanitation technology, for example) as well as the (averted) household treatment costs.

167. This paper shows that for countries like Nepal—with a high inequality in access to sanitation, and in the burden of diarrheal diseases –the scaling up of sanitation at the lowest quintiles can be an attractive option, from the efficiency perspective and even given the uncertainties in the economic analysis. It is important to note that an effective sanitation intervention is defined as one that reduces disease (i.e., is efficacious) and also one that people use (i.e., they comply) (Enger et al 2013). So, even while moving people up the sanitation ladder to more efficacious technology options, the ultimate impacts on health burdens also depends on the proper use of these sanitation options (cleanliness, handwashing etc.).

168. The evident benefits of improved sanitation, and the relative cost-effectiveness of such interventions across all quintiles in Nepal, make a renewed thinking about investments in such projects. It is important to note, however, that decision-making does not solely depend on cost-effectiveness. In the broad picture, countries like Nepal will also have to weigh the total health equity impact and the efficiency findings in more elaborate approaches, considering competing preventative inventions for child health such as vaccines to arrive at rational decision making (Baltussen et al. 2005, 2006; Mirelman et al. 2012).

169. Even while this paper does not point to any preference for a pro-poor scale-up of sanitation from a cost-effectiveness perspective, there may still be equity-based reasons for considering this option. Recent checklists provide equity criteria that are relevant to health care priority setting and are not adequately considered by cost-effectiveness analysis (Norheim et al 2014).

170. Ultimately, decisions on programs to address child health involve prioritization of interventions across health (e.g. vaccinations, micronutrient supplementation) as well as non-health (e.g. convenience, sanitation, hand-washing) sectors. Understanding how such decisions are made, and estimating the likelihood of environmental health interventions (such as sanitation) being prioritized for child health, is important –and the topic of the next chapter in this thesis.

## Annex 2: Using @ Risk for Multivariate Sensitivity Analysis

Risk Analysis is any method — qualitative and/or quantitative — to assess the impacts of risk on decision situations. The goal of any of these methods is to help the decision-maker choose a course of action, to enable a better understanding of the possible outcomes that could occur. For our paper, this would help decision-makers in Nepal understand better how to target communities for sanitation scale-up, taking into account the cost-effectiveness across wealth quintiles

@RISK uses “simulation” to combine all the uncertainties we have identified in our models for sanitation scale-up in Nepal. Instead of using a single point estimate for a variable, using @Risk, we are able to include its full range of possible values and some measure of likelihood of occurrence for each possible value (@Risk 2013)

For this paper, we use @RISK (v. 6) to take into account uncertainties relating to several variables that feed into the calculation of cost-effectiveness ratios from scaling up sanitation in Nepal. In general, the techniques in a risk analysis using @Risk encompass the following steps:

**1. Developing a Model** — by defining your problem or situation in Excel worksheet format. For this paper, we are modelling the cost-effectiveness of scaling up sanitation under two different scenarios, and across the wealth quintiles.

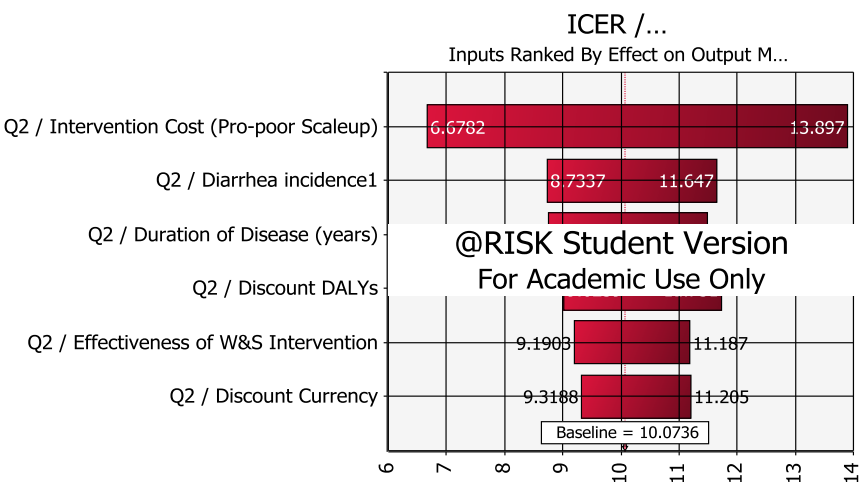
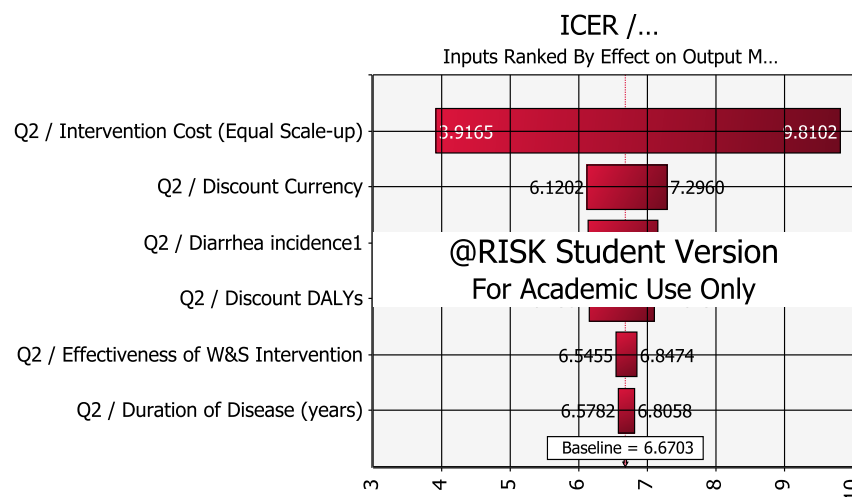
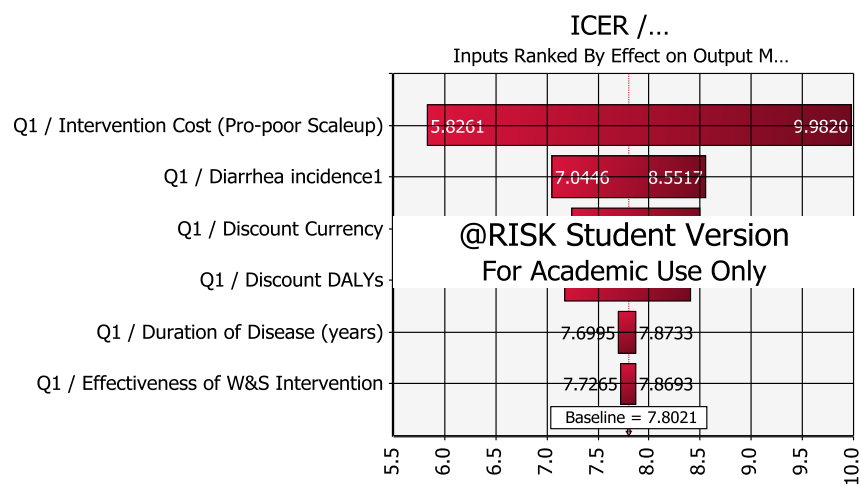
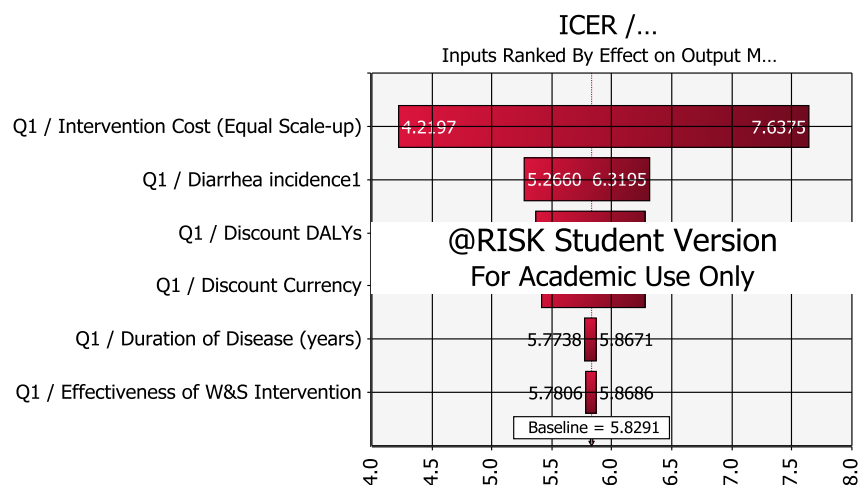
**2. Identifying Uncertainty** — in variables in your Excel worksheet and specifying their possible values with probability distributions, and identifying the uncertain worksheet results you want analyzed

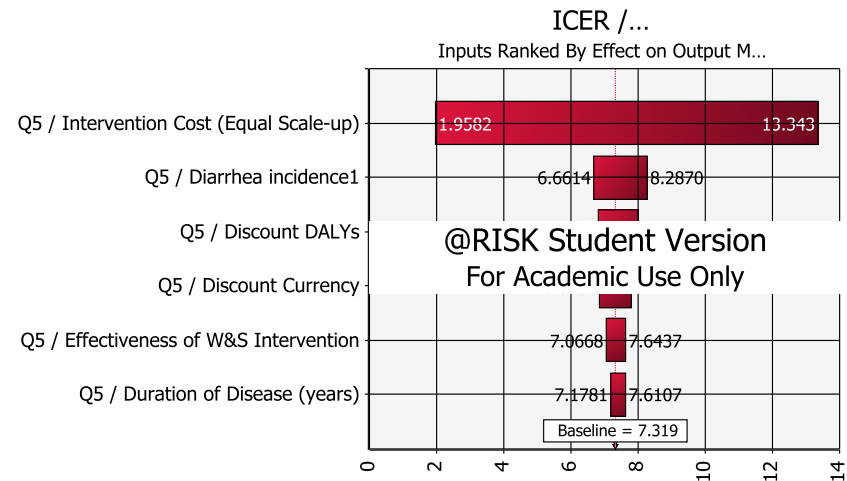
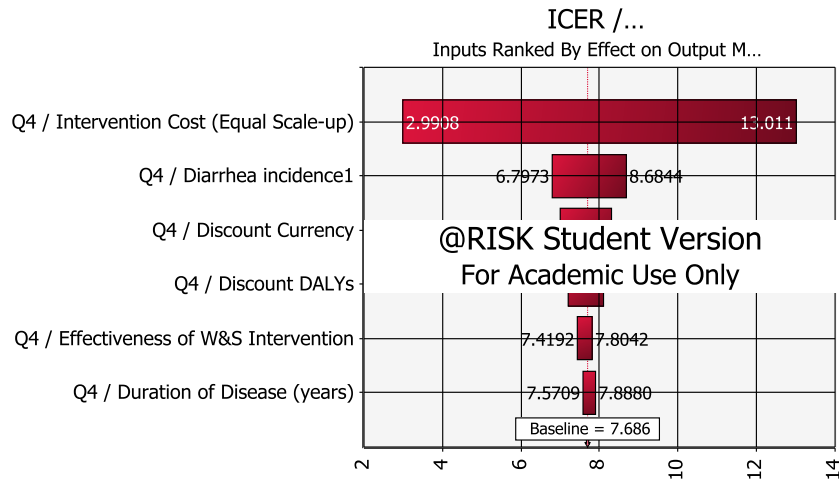
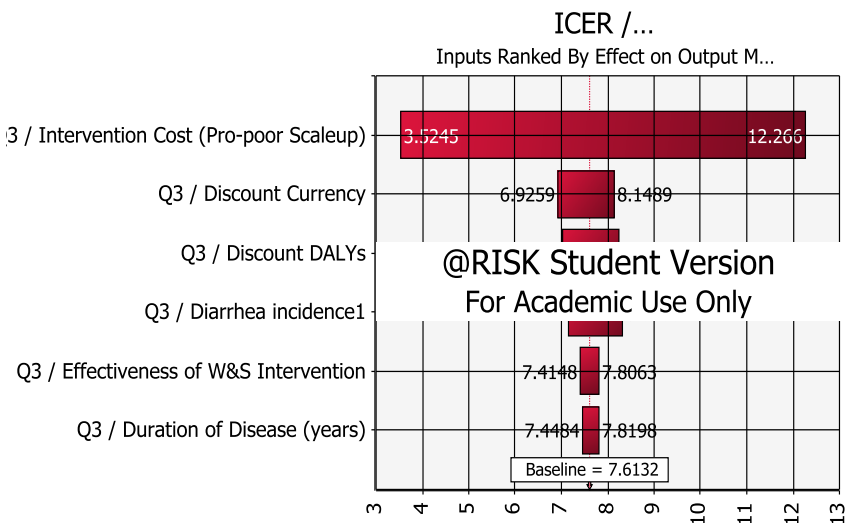
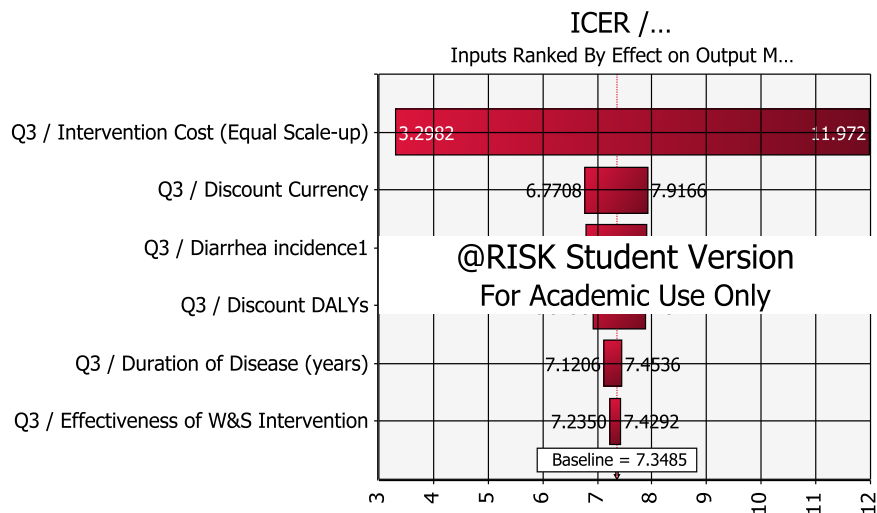
In this paper, we varied the intervention costs, diarrhea incidence, the effectiveness values, the discount rate and duration of disease. Following standard protocols, we assumed different types of distribution for each indicator.

Indicator	Type of Distribution
Sanitation Effectiveness	Normal
Duration of disease	Uniform
Intervention costs	Lognormal
Discount rate	Uniform

**3. Analyzing the Model with Simulation** — to determine the range and probabilities of all possible outcomes for the results of your worksheet. Using @Risk functions, we present tornado graphs to indicate which indicators have the most influence on the incremental cost-effectiveness ratios (ICERs).

### Annex 3: Effects of inputs on incremental cost-effectiveness ratios, by quintile and scenario





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Chapter 5: Environmental Health in Priority  
Setting for Child Health in Nepal  
(Paper 3)

## **Abstract**

**Background:** Addressing child health requires the implementation of interventions from both health sector (vaccinations, micronutrient supplementation) and non-health sector (such as sanitation, hand washing). Multi-criteria decision analysis is applied to better understand how environmental health interventions might be prioritized relative to other interventions relevant for child health in Nepal.

**Methods:** A total of forty-six sanitation and public health decision makers from Nepal participated in a discrete choice experiment, weighting the relative value of six policy criteria. The criteria were cost-effectiveness, impact on poverty reduction, severity of disease, number of potential beneficiaries, health benefits, and individual/community non-health benefits. We used multivariate logistic regression with selection as dependent variable to derive odds ratios for each criterion. Next, we constructed a composite league table - based on the sum score for the probability of selection - to rank fourteen potential interventions addressing child health in Nepal. These interventions included both within the health sector and non-health sector (such as water, sanitation, hand washing, improved cook stoves).

**Results:** The group considered non-health benefits, impact on poverty reduction, and number of beneficiaries as the most important criteria in decision making. Given these preferences, environmental health interventions were ranked to be the highest priority.

**Conclusions:** The findings emphasize other societal (non-health) benefits and equity impact as important policy criteria. This has important implications for choosing priority interventions for child health. Environmental health interventions may have an important role in addressing child health in developing countries like Nepal. Further research using sub-group analysis, repeating the experiment over time and in other countries with different socioeconomic settings and organizational contexts would help to extend the generalizability of these findings.

# Chapter 5: Environmental Health in Priority Setting for Child Health in Nepal<sup>3</sup>

*In collaboration with Thierry Defechereux and Louis Niessen*

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## 5.1 Introduction

171. The previous two chapters have looked at scaling up sanitation interventions in terms of (i) their potential to reduce health inequities between wealth quintiles, and (ii) their relative cost-effectiveness across wealth quintiles. The criteria of health-equity and cost-effectiveness are two of several taken into account by decision makers in countries like Nepal when deciding on, and prioritizing, various interventions for addressing child health. To further extend the investigation of environmental health interventions (such as sanitation) in the context of child health, one needs to look at how they stack up against typical health sector interventions. This chapter looks at how environmental health features in priority-setting of child health interventions in Nepal, through an exercise in multi-criteria decision analysis.

172. Multi-criteria decision analysis (MCDA) is widely and routinely used in the environmental sciences, e.g. to structure remedial decisions at contaminated sites in environmental sciences (Kiker et al 2005). MCDA has also been applied in

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<sup>3</sup> Anjali Acharya conceived the idea for the paper and is the lead author. Dr. Thierry Defechereux contributed to the DCE survey design and administration at the Nepal workshop, and helped with the data analysis. Dr. Louis Niessen provided guidance as well as quality assurance for the analysis and paper. The authors are very grateful to Binay Shah for facilitating our participation at the meeting for the Society of Public Health and Environment, Nepal (SoPHEN), where the DCE was administered. Thanks also to the various sanitation and public health practitioners who participated in this survey

agricultural, energy, and marketing sciences to help people effectively analyze multiple streams of dissimilar information (Baltussen et al 2006). The analysis establishes preferences between various options in the context of an explicit set of objectives identified, and with measurable criteria to assess the extent to which these objectives have been achieved. MCDA offers a number of ways of aggregating the data on individual criteria to provide indicators of the overall performance of options.

### ***Priority setting in the health sector***

173. More recently, the last few years has seen an emergence of MCDA as an instrument for priority setting in the health sector. Decisions on health sector interventions are complex, and are often chosen based on multiple criteria (Baltussen and Niessen 2006). With an inability to process multiple criteria simultaneously, policymakers often resort to selecting interventions on a subjective basis or based on political motivations.

174. Multi-criteria decision analysis offers a way to help gauge the health priorities of decision makers in a country. Five main sets of criteria play a role in choosing health interventions. These include (i) maximizing general population health; (ii) distribution of health, with high priorities given to interventions targeting vulnerable populations; (iii) specific societal preferences, such as for acute care in life-threatening circumstances; (iv) budgetary and practical constraints; and (v) political motivations (Baltussen and Niessen 2006). Over the past decades, several approaches to priority setting have been developed, including evidence-

based medicine, burden of disease analyses, cost-effectiveness analyses, and equity analyses.

175. Baltussen et al. (in 2006 and 2007) carried out explorative research to prioritize health interventions in Ghana and Nepal using discrete choice experiments (DCE). In Ghana, criteria were identified through a series of group discussions with policy makers, and included 'cost-effectiveness', 'poverty reduction', 'age', 'severity of illness', 'budget impact' and 'burden of disease' (Baltussen et al 2006). The relative weights of the various criteria were estimated through the use of DCEs, with a large number of policy makers. Analysis of the options showed that policy makers give high value to interventions that are cost-effective, reduce poverty, target the young, or target severe diseases (Baltussen et al 2006).

176. In Nepal, the use of DCE within an MCDA framework was used to support current policy making in the country on the implementation of the Practical Approach to Lung health (PAL) program (Baltussen et al 2007). Analysis of options chosen by respondents revealed that age of target group is the most important criterion, followed by individual health benefits, severity of disease, cost-effectiveness and number of potential beneficiaries. In the composite league table, the PAL program ranks 13th; this rank would be 27th if on the basis of cost-effectiveness alone (Baltussen et al 2007; Mirelman et al 2012).

177. The application of MCDA to case studies in Ghana and Nepal show that this methodology, while country specific, is robust in terms of determining the priorities

accorded to different types of health interventions in a country. These applications show that conducting a discrete choice experiment in a developing country context can involve issues not encountered in developed countries (Mangham et al 2009). The selection of attributes is key, while pre-testing the questionnaire is also likely to be particularly important (Mangham et al 2009).

### ***Priority-setting in environmental health***

178. Environmental health interventions play an important role in child survival and development. Yet very few studies that look at prioritization of interventions that address health outcomes include non-health sector interventions such as water supply, sanitation and hygiene interventions. In the Nepal study, child health interventions on the curative side included zinc and vitamin A supplementation, zinc fortification, and case management for pneumonia and diarrhea (ORT); and on the preventive side, only measles vaccinations (Baltussen et al 2007). In the Ghana study, however, improved water supply and sanitation technologies were included, but not hygiene interventions (such as handwashing programs) nor improved cook stove programs (which help to reduce indoor air pollution, and consequently acute respiratory infections in children) (Baltussen et al 2006). In the under-researched field of environmental health, the need for priority-setting will be critical towards helping developing country governments incorporate such interventions within the larger child health agenda.

179. In making decisions on choosing child health interventions, decision-makers typically have to consider several different criteria (including but not limited to

cost-effectiveness and health equity potential). Studies using multi-criteria decision analysis used in Nepal, Uganda and other countries to help decision-makers prioritize among health sector interventions have proven to be useful. A similar (but broader) analysis is now being proposed to look at child health interventions, including selected environmental health interventions.

180. The aim of this paper is to measure the relative importance of multiple criteria, and consequently to assess how selected environmental health interventions are prioritized among other child health interventions by key decision-makers in Nepal.

## **5.2 Methodology**

181. To carry out this analysis we investigated the priority given to environmental health interventions in water and sanitation, and rural energy (improved cook stoves) in addressing child health within the broader range of child health programs. For this paper, we used the typical criteria employed in DCE techniques for the health sector, viz. cost-effectiveness, number of beneficiaries, impact on poverty reduction, size of individual health benefits, and severity of disease. We also included an additional measure to capture community-level benefits which are common for environmental health interventions. We then administered a survey using the discrete choice experiment technique to identify priorities accorded to various child health (including environmental health) interventions.

### Box 5.1: Methods used for priority-setting in health

Limited resources coupled with unlimited demand for healthcare mean that decisions have to be made regarding the allocation of scarce resources across competing interventions. Ryan et al 2001 carried out a systematic literature review to identify methods for eliciting public views.

A number of quantitative techniques have been widely used in healthcare. These include simple ranking exercises, rating exercises, satisfaction surveys and methods for estimating quality weights within the QALY paradigm (visual analogue, standard gamble, time trade-off). Conjoint analysis (ranking, rating and discrete choices) and WTP are being developed within the context of healthcare. Of the qualitative techniques, one-to-one interviews and focus groups have been widely used in many different fields and more recently in healthcare, with a current focus on their uses in priority setting. Other methods such as citizens' juries are relatively new, having been recently developed in the context of decision-making.

With a rising number of empirical studies using more comprehensive priority-setting in the health sector in developing countries, a recent review (Youngkong et al 2009) describes the methodological approaches of several (18) of these studies.

In terms of *respondents*, 11 studies included more than one type of stakeholder (with policymakers being most often included). In terms of *approaches to identify criteria*, 10 studies organized group discussions or held interviews. Eight studies identified criteria from a literature review. In terms of *identified criteria*, cost-effectiveness was the most common important criterion considered (in 12 of the 17 studies that identified criteria), followed by severity of disease (6/17). Other criteria included burden of disease, age of target group, poverty reduction, effectiveness / benefit of treatment and health effects.

In terms of *eliciting preferences for those criteria*, a wide range of approaches were used. Eight studies relied solely on qualitative approaches viz. semi-structured interviews, group discussions and key informant interviews. Another three studies relied solely on quantitative approaches, viz discrete-choice experiments (DCE) and questionnaires involving a rating scale. Four studies combined qualitative and quantitative techniques. Makundi et al. (2007) employed individual rating and group discussions with a balance sheet to test a model of combining evidence and public values in priority-setting. Ottersen et al. (2008), Madi et al. (2007) and Kafiriri et al. (2004) used group discussions, questionnaires with rating questions to explore preferences regarding cost-effectiveness and severity of disease.

*Source: Ryan et al 2001; Ryan et al 2001b; Youngkong et al 2009.*



## ***Study Design***

182. For this paper, a multi-criteria decision analysis (MCDA) involved using a discrete choice experiment technique which was administered to a group of stakeholders in Nepal. In a DCE, respondents choose their preferred option from sets of scenarios, each consisting of a bundle of attributes that describe the scenario in question, with each attribute varying over a range of levels. The attributes are constant in each scenario, but the levels that describe each attribute may vary across scenarios. Analysis of the options chosen by respondents in each scenario reveals the extent to which each attribute is important to the decision at hand. In the context of this paper, these scenarios refer to child health interventions, and attributes to criteria for priority setting.

183. *Criteria and definitions.* The criteria will be chosen based on a review of priority-setting criteria used in previous such exercises in the health sector (in Uganda, Ghana, Nepal), as well as additional options to capture attribute of non-health sector interventions and for their relevance to the issue of child health in Nepal. Overlapping criteria will be combined into a single criterion (for e.g. costs of treatment, effectiveness of treatment, and cost-effectiveness of treatment are combined in a single criterion 'cost-effectiveness'). The DCE includes only a limited number of criteria (six) in order to avoid informational overload for the respondents. The criteria (see Table 5.1) were selected to ensure completeness, feasibility, and mutual independence.

- a. *Cost-effectiveness*: Many decision-makers choose to prioritize on the basis of cost-effectiveness, as this would generate the largest health gains at population level for the available budget. Interventions were defined as cost-effective when the cost per disability adjusted life year (DALY) is less than three times the gross national income (GNI) per capita, according to the Commission on Macroeconomics and Health.
- b. *Impact on Poverty Reduction*: People's concern for fairness or equity may guide them to choose interventions that particularly help the more disadvantaged populations. This criterion is especially relevant in developing countries where there are insufficient methods for transferring wealth from the relatively rich to the poor.
- c. *Severity of disease*: In this criterion, interventions that would treat disease with life expectancy of 2 or more years are considered as not severe, while those that treat disease with less than 2Y of LE are considered as severe.
- d. *Health benefits*: Key stakeholders in Nepal would have to choose between interventions which would provide a small health benefit to children (less than 5 years of healthy life per individual) or a large health benefit (> 5 healthy years).
- e. *Individual/ community non-health benefits*: This new criteria serves to capture benefits of interventions that have individual as well as broader community non-health benefits such as privacy, convenience, dignity etc. These benefits are often considered significant when making choices.

- f. *Number of potential beneficiaries*: Finally, decision-makers may favor interventions often have to choose between interventions that target many beneficiaries (>100,000) as opposed to fewer beneficiaries.

**Table 5.1: Criteria and levels**

<b>Attribute</b>	<b>Levels</b>	
Cost-effectiveness (C-E)	Not C-E	C-E
Impact on poverty reduction	Neutral	Positive
Severity of disease	Not severe	Severe
Individual health benefits	Small	Large
<b>Individual/ Community non-health benefits</b>	<b>Small</b>	<b>Large</b>
Number of potential beneficiaries	Few	Many

184. On the basis of the various criteria measured at two levels, a relatively large number of unique scenarios were generated under a full factorial experimental design in DCE. However, to avoid informational overload, we applied a fractional factorial design which included a much smaller subset of scenarios that allow for estimation of all main effects. Each of these scenarios was paired to its mirror image to retrieve the maximum information from each choice. Our fractional factorial design included a subset of 32 scenarios paired in 16 sets of choices. An example of a pair of scenarios is given in Figure 5.1.

**Figure 5.1: Pair of scenarios**

PROGRAM A	Criteria	PROGRAM B
Not severe Health expectancy => 2Y	Severity of disease	Severe Health expectancy <2Y
Few < 100.000	Number of potential beneficiaries	Many >100.000
Small < 5 healthy years	Individual health benefits	Large > 5 healthy Years
Small	Individual/community Non- health benefits	Large
Neutral	Impact on poverty reduction	Positive
Not Cost effective cost/DALY >3 GDP/cap	Cost-effectiveness	Cost Effective Cost/DALY <3 GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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185. The DCE consists of this set of discrete choices. It measures preferences between intervention options by counting the extent to which specified objectives are preferred most. We used conditional logistic regression model in STATA (StatCorps 2011) to analyze all the response data. The independent variables (the defined policy criteria) are categorical with two levels and the dependent variable is the preferred choice i.e. the selected scenario. The weighing results are presented as regression coefficients. These indicate the size of the effect of a criterion on the selection probability of an intervention which fulfills the criterion. Finally, the calculated sum weight over all criteria for each intervention leads to ranking of the options in a composite league table based on the probability of selection.

### ***Data sources***

186. A discrete choice experiment (DCE) survey was administered during a workshop held for the Society of Public Health and Environment Nepal (SoPHEN) in

Kathmandu and was completed by 46 water, sanitation and public health decision-makers. Before the administration of the survey, we familiarized the respondents with DCE by working through a number of examples before they embarked on the survey. Further details on data collection are in Chapter 2. Limited data on demographics was requested as part of the questionnaire to allow for sub-group analysis. However, the lower response rate of just over 60 percent did not permit for any sub-group analysis.

### ***Analysis***

187. All levels for criteria were qualitative and data are dichotomous choice ('1' represents the option being chosen, '0' where not chosen). As the respondents provide multiple observations, a random effects logistic regression model, which accounts for random within-respondent effects, was used to analyze the responses. The results are presented as regression coefficients, average marginal effects and relative contributions. *Regression coefficients* indicate the sign of the effect of a variable on the probability of selection of an intervention. A positive sign for a particular level implies a positive impact on the probability of choosing interventions with that level. *Average marginal effects* can be quantitatively interpreted and reflects the change in probability of selection of an intervention following a change in a single variable. For example, a marginal effect of 0.443 for poverty reduction will mean that interventions that reduce poverty have a 44% higher probability of being selected than interventions that do not, other things being equal.

188. *Composite league table.* On the basis of the DCE results, we computed a composite index that represents the relative priority of each intervention as a function of their characteristics. *First*, we considered the regression coefficients of the particular levels of all criteria as weights in the priority setting process. These weights relate to the probability of choosing an intervention with that level. Its absolute values denote the relative importance of particular levels of a criterion in comparison to other levels of all other criteria.

189. *Second*, we considered a set of 14 health sector and non-health sector interventions (see Annex 5) relating specifically to child health and mapped their characteristics on the levels of the various criteria. Individual environmental health interventions for child health were also included within a broader list of child health interventions including ORS for diarrhea, case management of pneumonia, zinc supplementation, measles vaccination, zinc fortification, and vitamin A supplementation. The interventions considered reflect strategies to reduce risks to child health in Nepal, and represent an important part of the burden of disease for the country. To denote levels of the various criteria, each intervention was mapped with '1's and '0's : cost-effectiveness ('1'=cost-effective, '0'=not cost-effective), equity potential ('1'=positive, '0'=neutral). Several of these interventions overlapped with those found in the Baltussen 2006 paper on DCE in Nepal for lung health program. To ensure consistency, these interventions were given the same mapping (i.e. same allocations of 0s and 1s) are those in the previous analysis.

190. *Third*, we defined a “composite index” (CI) that represents the relative priority of each intervention as a function of their characteristics, based on the criteria weights. The “probability of selection” is estimated for each intervention using the regression model and a rank ordering of all intervention on the basis of this composite index results in a composite league table.

**Our main effect model uses the following form:**

$$\text{Logit } (P) = \text{Ln } (P/1 - P) = \beta_0 + \beta_1 V_1 + \beta_2 V_2 + \dots + \varepsilon \quad (1)$$

191.  $P$  is the probability of an intervention to be selected as the most qualifying intervention based on the joint inclusion of all relevant criteria and their relative weights. The  $\beta_0$  is the constant term or intercept; the  $\beta_i$  are the indexed coefficients for each the criteria included in the model, while  $\varepsilon$  is the unobservable error term.  $V$  has the value of ‘1’ in case the criterion is present and ‘0’ when it is absent. The use of this linear additive utility model is based on the assumption of mutual independence of the criteria selected.

192. Computation of the CI involves several steps. The set of child health interventions to be prioritized has to be mapped in which way they fit the selected six criteria. This fit is indicated by ‘1’ or ‘0’ to denote levels of the various criteria, so that the matrix will indicate, e.g. for cost-effectiveness ‘1’ when the intervention is CE and ‘0’ if it is not. To illustrate computation, in the matrix in Annex 1, Water and Low technology sanitation (WSH-LowT) intervention is rated as ‘0’ for Disease severity criteria that is “no severe”, ‘1’ as providing significant individual benefit, ‘1’

as the intervention has non-health benefits, '1' as the intervention is cost effective....etc.

193. When the mapping for all criteria is completed, the CI is calculated, for all interventions, based on the main effect additive utility model (formula 1), so that WSH-LowT will have as

$$\text{CI: } 0*0.0276 + 1*0.4066 + 0*0.1893 + 1*0.4696 + 1*0.4435 + 0*0.3382 = 1.658046$$

194. The selection probability for each child health intervention is calculated, based on the general equation:  $P = \text{EXP}(\text{CI}) / 1 + \text{EXP}(\text{CI})$ , the exponential (EXP) function returns e raised to the n<sup>th</sup> power, where e = 2.71828183. The selection probability for WSH-LowT is computed as:

$$e^{1.658} / 1 + e^{1.658} \text{ or } 2.71^{1.658} / 1 + (2.71^{1.658}) = 0.84$$

195. The research proposal was submitted for ethical approval to the Institutional Review Board (IRB) at the Johns Hopkins Bloomberg School of Public Health, and has been waived from requiring formal ethics approval.

### 5.3 Results

196. The survey was completed by 46 respondents at the workshop held in Kathmandu. Table 5.2 shows the results of the random effects regression model. A positive sign for a particular level implies a positive impact on the probability of choosing interventions with that level. As mentioned, the absolute values of the regression coefficients indicate their relative importance in priority setting, in that



respect, the number of potential beneficiaries, non-health benefits and addressing poverty reduction were seen to be the most important criteria.

**Table 5.2: Results from the logistics regression model**

<i>CRITERIA</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>P-value</i>
Severity of disease	.0275716	.1144223	0.810
<b>Number of potential beneficiaries</b>	.4066057	.1098404	<b>0.000</b>
Individual health benefits	.1892946	.1180803	0.109
<b>Individual/ community non-health benefits</b>	<b>.4696303</b>	<b>.1201286</b>	<b>0.000</b>
<b>Impact on poverty reduction</b>	.4435550	.1139139	<b>0.000</b>
Cost-effectiveness	.3382548	.1168590	0.004

197. From the results, three coefficients showed to be significant and their signs had the expected direction. The interventions with the highest priority were found to the environmental health interventions – ranking at #1 were WSH-disinfection at source and WSH- handwashing promotion; while ranking next were improved WSS (low tech) and improved cook stoves. Those receiving the lowest ranking are interventions regarding immunizations (measles and pneumococcal).

## 5.4 Discussion

198. The composite league table identifies high priority interventions related to child health in Nepal, as well as those which are of lower priority –based on a different and more differentiated rank ordering of interventions compared to one based on pure efficiency ratings. More specifically, this exercise revealed the significantly higher priority accorded to various environmental health interventions (for water and sanitation as well as rural energy) in the context of child health in Nepal. This has implications for the implementation of sanitation programs, hand washing campaigns, and improved cook stove (rural energy) programs that are

ongoing and can be planned to contribute to the overall goal of improving child survival and development.

199. This explorative analysis suggests that non-health benefits may be relevant in priority setting in child health while including a larger range of relevant criteria for priority setting. Taking into account additional societal criteria changes the rank order of priority interventions, due to the increase in overall societal value i.e. non-health benefits. This multi-criteria approach, which includes other societal criteria, can be an important step forward to rational priority setting in low-income countries and raise the awareness of the importance of environmental health interventions in addressing child health.

200. For ascertaining the priority accorded to different environmental health interventions in the context of child health, this paper adopts the discrete choice experiment model used in previous research papers in the health sector (Baltussen et al 2006; Baltussen et al 2007). There are some limitations associated with the DCE, as identified in previous papers. For example, the attributes chosen for the DCE are defined at two levels only, which may not fully capture the respondents' preferences. Also, the research design ignores potential interaction effects between different criteria – however, in this paper the interactions between the selected criteria are expected to be relatively small.

201. While the methodological approach used to identify how environmental health interventions are prioritized, is applicable to other developing countries – the results are very country-specific, which limits the generalizability of this analysis. Its

application to another country would require the identification of priority setting criteria as relevant to that country, including the conduct of DCE, to arrive at a country-specific rank ordering of interventions. The criteria chosen that are relevant for child health in Nepal are inherently subjective and therefore may differ from those in other developing countries; as may the weights attached by decision-makers in different countries. Importantly also, child health interventions (including environmental health interventions) may have very different characteristics in different countries.

202. This study has elicited the preferences of group of decision makers in Nepal, on the assumption that these represent the preferences of the country as a whole. However, the DCE survey carried out in Nepal was administered to decision makers who primarily work on water, sanitation and public health in Nepal. Given this profile, it is likely the reason for the much higher “weight” apportioned to non-health benefits –which is one of the main advantages that environmental health interventions have over the “health sector” interventions. The weighting judgments required for making choices between the scenarios express critical value tradeoffs on part of the participants, and may also be biased by their professional training and background. To facilitate a further discussion, the DCE should be carried out with a different profile of decision-makers (for e.g. where more health systems representatives participated), and carry out a sub-group analysis to identify possible differences in the ranking, and therefore in the results.

203. Another issue is the question of consistency of these rankings over time. As countries like Nepal focus on scaling up sanitation, and move up the development path, the weights and rankings assigned to these criteria may change. Carrying out the discrete choice experiment to similar sub-groups after a gap of some years might help to inform if these rankings stay consistent over time, or are influenced by the changes over time (and therefore the priorities) in the socioeconomic status, global influences or population health concerns.

204. This priority setting process was not embedded in the organizational context of the MOH in Nepal, and hence its relevance and usefulness for policymaking is likely to be limited. Importantly, the inclusion of environmental health interventions such as sanitation, requires the collaboration between ministries of health, and infrastructure (for sanitation coverage), and this is often extremely weak in developing countries like Nepal. Future research could investigate other institutional models for sanitation to ascertain how the organization context might in the implementation, subsequent to the priority-setting process. In Nepal, for example, the health and sanitation reside in two different ministries; in Vietnam, on the other hand, the Ministry of Health includes a department for Environmental Sanitation.

205. Current child health strategies in developing countries mostly adopt a more treatment-oriented perspective, relying on case-management and focusing primarily on reducing mortality. With this analysis, there is more evidence to support the inclusion of preventative interventions that serve to reduce

environmental risks, among the menu of traditional child health interventions. This is the first application of the DCE which specifically includes the “non-health benefits” criteria, and extends the analysis by looking at interventions outside the health sector that may have additional, and often qualitative, benefits. Given this potential new research agenda, it would be important to repeat the analysis in other developing countries, with different socioeconomic settings, as well as different organizational arrangements for addressing sanitation.

#### Annex 4: Composite League Table for Priority Setting in Child Survival, Nepal

Code	Interventions	severity	nbenefic	indbenf	nonh benf	poverty	ceff	Comp Index	Select Prob	Rank
WSH-Dis	WSH: Disinfection at point of use	0	1	1	1	1	1	1.847340	0.8638145	1
WSH-Hand	WSH: Hygiene promotion: handwashing	0	1	1	1	1	1	1.847340	0.8638145	1
WSH-LowT	WSH: Improved WSS, low tech.	0	1	0	1	1	1	1.658046	0.8399755	3
RE-Cook	Rural Energy: improved cookstoves	0	1	0	1	1	1	1.658046	0.8399755	3
CH-Pneu	Childhood health: case mgmt of pneumonia	1	1	1	0	1	1	1.405282	0.8030207	5
CH-Dia	Childhood health: ORT for diarrhea	0	1	1	0	1	1	1.377710	0.7986230	6
CH-VitAS	Childhood health: vitA suppl	0	1	1	0	1	1	1.377710	0.7986230	6
CH-ZnS	Childhood health: Zn supplementation	0	1	1	0	1	1	1.377710	0.7986230	6
WSH-HighT	WSH: Improved WSS, high tech.	0	1	0	1	1	0	1.319791	0.7891469	9
CH-VitAF	Childhood health: vitA for. of staple food	0	1	0	0	1	1	1.188416	0.7664576	10
CH-ZnF	Childhood health: Zn fort. of staple food	0	1	0	0	1	1	1.188416	0.7664576	10
CH-Cfeed	Childhood health: improved compl. feeding	0	1	0	0	1	0	0.850161	0.7006009	12
IM-Meas	Immunizations: measles vaccination	1	1	0	0	0	0	0.434177	0.6068707	13
IM-Pneu	Immunizations: pneumococcal vaccination	1	1	0	0	0	0	0.434177	0.6068707	13

## Annex 5: Questionnaire for the Discrete Choice Experiment in Nepal

### DEMOGRAPHICS

1. What is your job?
2. Place of work?
3. Are you a male or female?
4. What is your age ?
5. How many Years of practice do you have in your job ?
6. Work in Kathmandu or Provinces ?

### QUESTION 1.

PROGRAM A	Criteria	PROGRAM B
Not severe Health expectancy $\Rightarrow$ 2Y	Severity of disease	Severe Health expectancy $<$ 2Y
Few $<$ 100.000	Number of potential beneficiaries	Many $>$ 100.000
Small $<$ 5 healthy years	Individual health benefits	Large $>$ 5 healthy Years
Small	Individual/community Non- health benefits	Large
Neutral	Impact on poverty reduction	Positive
Not Cost effective cost/DALY $>$ 3 GDP/cap	Cost-effectiveness	Cost Effective Cost/DALY $<$ 3 GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund **program A** ☐ I would prefer to fund **program B** ☐

### QUESTION 2.

PROGRAM A	Criteria	PROGRAM B
Severe Health expectancy $<$ 2Y	Severity of disease	Not Severe Health expectancy $\Rightarrow$ 2Y
Few $<$ 100.000	Number of potential beneficiaries	Many $>$ 100.000
Small $<$ 5 healthy years	Individual health benefits	Large $>$ 5 healthy Years
Small	Individual/community Non- health benefits	Large
Positive	Impact on poverty reduction	Neutral
Not Cost effective cost/DALY $<$ 3 GDP/cap	Cost-effectiveness	Cost Effective Cost/DALY $>$ 3 GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund **program A** ☐ I would prefer to fund **program B** ☐

### QUESTION 3.

PROGRAM A	Criteria	PROGRAM B
Not Severe Health expectancy =>2Y	Severity of disease	Severe Health expectancy <2Y
Many > 100.000	Number of potential beneficiaries	Few < 100.000
Small < 5 healthy years	Individual health benefits	Large > 5 healthy Years
Small	Individual/community Non- health benefits	Large
Positive	Impact on poverty reduction	Neutral
Cost effective cost/DALY <3 GDP/cap	Cost-effectiveness	Not Cost Effective Cost/DALY >3 GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund **program A** ☐ I would prefer to fund **program B** ☒

### QUESTION 4.

PROGRAM A	Criteria	PROGRAM B
Severe Health expectancy < 2Y	Severity of disease	Not Severe Health expectancy =>2Y
Many > 100.000	Number of potential beneficiaries	Few < 100.000
Small < 5 healthy years	Individual health benefits	Large > 5 healthy Years
Small	Individual/community Non- health benefits	Large
Neutral	Impact on poverty reduction	Positive
Cost effective cost/DALY <3 GDP/cap	Cost-effectiveness	Not Cost Effective Cost/DALY >3 GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund **program A** ☒ I would prefer to fund **program B** ☐



### QUESTION 5.

PROGRAM A	Criteria	PROGRAM B
Not Severe Health expectancy => 2Y	Severity of disease	Severe Health expectancy <2Y
Few < 100.000	Number of potential beneficiaries	Many > 100.000
Large > 5 healthy years	Individual health benefits	Small < 5 healthy Years
Large	Individual/community Non- health benefits	Small
Positive	Impact on poverty reduction	Neutral
Cost effective cost/DALY <3 GDP/cap	Cost-effectiveness	Not Cost Effective Cost/DALY >3 GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 6.

PROGRAM A	Criteria	PROGRAM B
Severe Health expectancy < 2Y	Severity of disease	Not Severe Health expectancy= >2Y
Few < 100.000	Number of potential beneficiaries	Many > 100.000
Small < 5 healthy years	Individual health benefits	Large > 5 healthy Years
Large	Individual/community Non- health benefits	Small
Neutral	Impact on poverty reduction	Positive
Cost effective cost/DALY <3 GDP/cap	Cost-effectiveness	Not Cost Effective Cost/DALY >3 GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 7.

PROGRAM A	Criteria	PROGRAM B
Not Severe Health expectancy $\geq 2Y$	Severity of disease	Severe Health expectancy $< 2Y$
Many $> 100.000$	Number of potential beneficiaries	Few $< 100.000$
Small $< 5$ healthy years	Individual health benefits	Large $> 5$ healthy Years
Large	Individual/community Non- health benefits	Small
Neutral	Impact on poverty reduction	Positive
Not Cost effective cost/DALY $> 3$ GDP/cap	Cost-effectiveness	Cost Effective Cost/DALY $< 3$ GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 8.

PROGRAM A	Criteria	PROGRAM B
Severe Health expectancy $< 2Y$	Severity of disease	Not Severe Health expectancy $\geq 2Y$
Many $> 100.000$	Number of potential beneficiaries	Few $< 100.000$
Small $< 5$ healthy years	Individual health benefits	Large $> 5$ healthy Years
Large	Individual/community Non- health benefits	Small
Positive	Impact on poverty reduction	Neutral
Not Cost effective cost/DALY $> 3$ GDP/cap	Cost-effectiveness	Cost Effective Cost/DALY $< 3$ GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 9.

PROGRAM A	Criteria	PROGRAM B
Not Severe Health expectancy $\geq 2Y$	Severity of disease	Severe Health expectancy $< 2Y$
Few $< 100.000$	Number of potential beneficiaries	Many $> 100.000$
Small $< 5$ healthy years	Individual health benefits	Large $> 5$ healthy Years
Large	Individual/community Non- health benefits	Small
Neutral	Impact on poverty reduction	Positive
Cost effective cost/DALY $< 3$ GDP/cap	Cost-effectiveness	Not Cost Effective Cost/DALY $> 3$ GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 10.

PROGRAM A	Criteria	PROGRAM B
Severe Health expectancy $< 2Y$	Severity of disease	Not Severe Health expectancy $\geq 2Y$
Few $< 100.000$	Number of potential beneficiaries	Many $> 100.000$
Small $< 5$ healthy years	Individual health benefits	Large $> 5$ healthy Years
Large	Individual/community Non- health benefits	Small
Positive	Impact on poverty reduction	Neutral
Cost effective cost/DALY $< 3$ GDP/cap	Cost-effectiveness	Not Cost Effective Cost/DALY $> 3$ GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 11.

PROGRAM A	Criteria	PROGRAM B
Not Severe Health expectancy $\geq 2Y$	Severity of disease	Severe Health expectancy $< 2Y$
Many $> 100.000$	Number of potential beneficiaries	Few $< 100.000$
Large $> 5$ healthy years	Individual health benefits	Small $< 5$ healthy Years
Small	Individual/community Non- health benefits	Large
Positive	Impact on poverty reduction	Neutral
Not Cost effective cost/DALY $> 3$ GDP/cap	Cost-effectiveness	Cost Effective Cost/DALY $< 3$ GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 12.

PROGRAM A	Criteria	PROGRAM B
Severe Health expectancy $< 2Y$	Severity of disease	Not Severe Health expectancy $\geq 2Y$
Many $> 100.000$	Number of potential beneficiaries	Few $< 100.000$
Small $< 5$ healthy years	Individual health benefits	Large $> 5$ healthy Years
Large	Individual/community Non- health benefits	Small
Neutral	Impact on poverty reduction	Positive
Not Cost effective cost/DALY $> 3$ GDP/cap	Cost-effectiveness	Cost Effective Cost/DALY $< 3$ GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 13.

PROGRAM A	Criteria	PROGRAM B
Not Severe Health expectancy $\geq 2Y$	Severity of disease	Severe Health expectancy $< 2Y$
Few $< 100.000$	Number of potential beneficiaries	Many $> 100.000$
Large $> 5$ healthy years	Individual health benefits	Small $< 5$ healthy Years
Large	Individual/community Non- health benefits	Small
Positive	Impact on poverty reduction	Neutral
Not Cost effective cost/DALY $> 3$ GDP/cap	Cost-effectiveness	Cost Effective Cost/DALY $< 3$ GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 14.

PROGRAM A	Criteria	PROGRAM B
Severe Health expectancy $< 2Y$	Severity of disease	Not Severe Health expectancy $\geq 2Y$
Few $< 100.000$	Number of potential beneficiaries	Many $> 100.000$
Large $> 5$ healthy years	Individual health benefits	Small $< 5$ healthy Years
Large	Individual/community Non- health benefits	Small
Neutral	Impact on poverty reduction	Positive
Not Cost effective cost/DALY $> 3$ GDP/cap	Cost-effectiveness	Cost Effective Cost/DALY $< 3$ GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 15.

PROGRAM A	Criteria	PROGRAM B
Not Severe Health expectancy $\geq 2Y$	Severity of disease	Severe Health expectancy $< 2Y$
Many $> 100.000$	Number of potential beneficiaries	Few $< 100.000$
Large $> 5$ healthy years	Individual health benefits	Small $< 5$ healthy Years
Large	Individual/community Non- health benefits	Small
Neutral	Impact on poverty reduction	Positive
Cost effective cost/DALY $< 3$ GDP/cap	Cost-effectiveness	Not Cost Effective Cost/DALY $> 3$ GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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### QUESTION 16.

PROGRAM A	Criteria	PROGRAM B
Severe Health expectancy $< 2Y$	Severity of disease	Not Severe Health expectancy $\geq 2Y$
Many $> 100.000$	Number of potential beneficiaries	Few $< 100.000$
Large $> 5$ healthy years	Individual health benefits	Small $< 5$ healthy Years
Large	Individual/community Non- health benefits	Small
Positive	Impact on poverty reduction	Neutral
Cost effective cost/DALY $< 3$ GDP/cap	Cost-effectiveness	Not Cost Effective Cost/DALY $> 3$ GDP/cap

In the hypothesis you have to decide funding for one of those 2 programs, whose characteristics (criteria) are detailed in columns A and B, which one would you choose?

I would prefer to fund <b>program A</b>	<input type="checkbox"/>	I would prefer to fund <b>program B</b>	<input type="checkbox"/>
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## Chapter 6: Conclusions, Policy Implications and Future Research

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206. This final chapter of the thesis is divided into four sections. The first section summarizes the main conclusions of the three chapters, their contribution to the research agenda, as well as the limitations. The second section considers the generalizability of the overall findings, taking into account the complex interplay between cost-effectiveness, efficiency and health equity, and consensus building through a priority setting lens. The third section provides the public health importance of this thesis, and related policy recommendations for decision-makers in developing countries like Nepal. And finally, the fourth section considers some future research priorities.

### **6.1 Main Findings and Research Contributions**

207. The main results from these three papers include the following:

- Scaling up sanitation can be cost-effective in countries like Nepal, and across all wealth quintiles because of relatively lower costs of sanitation technology used, and the higher disease burden averted. From an efficiency perspective, there is no significant difference between the two scenarios (equal or pro-poor) of scaling up sanitation.
- Pro-poor scale-up of sanitation coverage has the ability to save larger number of child lives. The Nepal analysis reveals that pro-poor scale-up of sanitation

coverage can save a total of nearly 800 (527-1078) child lives –compared to 517 (290- 837) lives in an equal scale-up across all wealth quintiles.

- In setting priorities for child health, policy-makers highly value community/ non-health benefits as well as equity-impact of interventions. In the Nepal DCE, amongst a set of 14 health sector and non-health sector interventions relating specifically to child health, environmental health interventions were ranked the highest.

208. In recent years, there have been several efforts to estimate the global burden of child mortality and identify the main causes, study the role of risk factors, assess the effectiveness of interventions, and to track the coverage of those interventions in developing countries (Black et al 2008; Bhutta et al 2008; Bhutta et al 2010). However, much of the economic evaluations and priority setting exercises have focused on various health sector interventions available to developing country governments to reduce child mortality and improve child survival. Environmental health interventions – such as water supply, sanitation, hygiene promotion, improved cook stoves etc. –have also been commonly neglected in government child health programs.

209. New tools, methodologies and frameworks such as LiST, CEA, and MCDA have been developed and/or used in recent years to aid in developing countries, like Nepal, choose and prioritize health sector interventions. The main strength of this thesis is in building on and extending these tools and methodologies to a range of child health interventions, such as sanitation, which lie outside the health sector. It

also specifically drills down these methodologies into wealth quintiles (Chapter 3 and 4) to explore the differences across the population and to inform the targeting of government programs on increasing sanitation coverage. The background and literature review presented in this thesis demonstrate the importance of environmental health interventions (such as water, sanitation, hygiene) in improving child health. With such interventions being under-researched in the context of child health, the potential for adapting these methodologies for environmental health also remains untapped.

210. Typically these tools and methodologies are applied at the national level; this thesis carries out analyses at a sub-national level as well, recognizing the disparities and differentials in various parameters within a country. Policymakers in countries like Nepal share a common concern on how to find the right balance between equity and efficiency objectives; this thesis contributes to that discussion, in the specific context of sanitation. In Chapter 3, the issue of health inequities related to sanitation coverage was disaggregated by wealth quintile, to demonstrate the differential impacts on child health in these sub-populations when sanitation coverage in increased. And, Chapter 4 investigates how the cost-effectiveness (efficiency) of environmental health interventions (such as sanitation) may vary across quintiles, helping to inform the targeting of government scale-up programs. This thesis represents a significant step towards evaluating environmental health interventions (such as sanitation) through the filter of typical criteria of equity and cost-effectiveness used in decision making in developing countries.

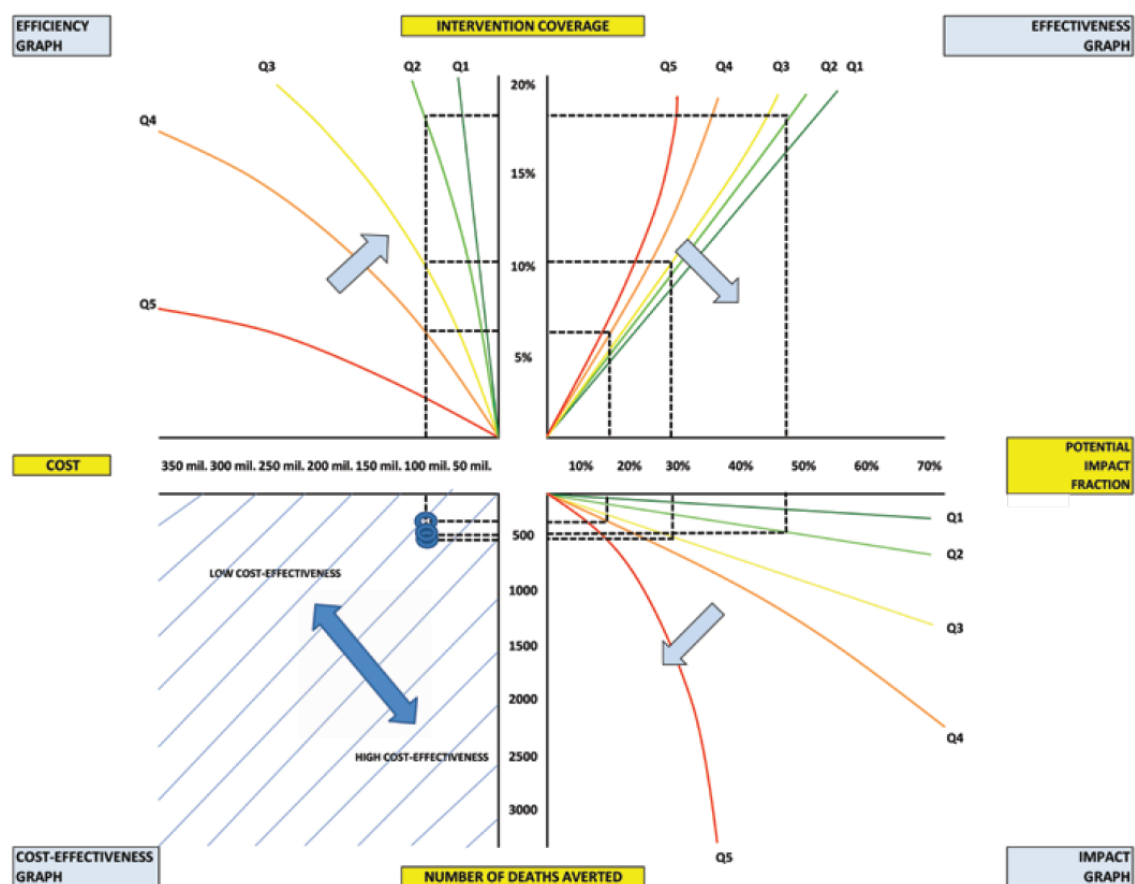
211. The three papers that form this thesis are of significant public health importance at various levels. They help demonstrate the attractiveness and potential for the inclusion of environmental health interventions within the scope of broader child health programs in developing countries. The next section shows how the result of these papers provides important information for how sanitation investments might be better planned, targeted and monitored; and to assist health decision-makers in developing countries prioritize environmental health interventions (such as sanitation) towards the poor.

## **6.2 Interplay of Criteria for Sanitation Interventions**

212. A recent paper looked at the complex interplay between cost-effectiveness and equity and proposes an interesting framework that exposes the nature of the links between the five key determinants that need to be taken into account when planning (Chopra et al 2012). The paper identifies the following key factors (i) efficiency of intervention scale-up (requires knowledge of differential increase in cost of intervention scale-up by equity strata in the population); (ii) effectiveness of intervention (requires understanding of differential effectiveness of interventions by equity strata in the population); (iii) the impact on mortality (requires knowledge of differential mortality levels by equity strata, and understanding the differences in cause composition of overall mortality in different equity strata); (iv) cost-effectiveness (compares the initial cost and the resulting impact on mortality); and (v) equity structure of the population (Chopra et al 2012).

213. An interesting application of this framework is in the context of environmental health interventions such as improved sanitation. In this thesis, the first paper looks at the health equity issues relating to improved sanitation in Nepal; while the second paper looks at the cost-effectiveness (efficiency) of such interventions across wealth quintiles. Efficiency aims to maximize population health given a certain budget, whereas equity, or fairness, aims to minimize differences in health among population groups, with special reference vulnerable populations such as children (Whitehead 1991). From these papers, new insights into the targeting and choice of environmental health interventions can be had.

**Figure 6.1: Interplay between cost-effectiveness and equitable impact**



Source: Chopra et al 2012

214. With an interplay of the key criteria in their particular context, policy makers in countries like Nepal need to decide, for example, whether the majority of the society would value improved equity or cost-effective mortality burden reduction (ie, more deaths averted per money invested, irrespective of the increasing inequity) as the more important goal (Chopra et al 2012). The final paper in this thesis looks at where environmental health interventions would rank among various child health interventions for policymakers.

215. Using this framework, and given the discussions in Chapter 3 and 4, we can pose some questions that would help demonstrate how these graphs would like for sanitation interventions in Nepal. Important to note that in this graphic (above), Q1 denotes the highest quintile and Q5 the lowest (opposite of the terminology used in this thesis).

a. **Efficiency Graph:** From an efficiency perspective, research would be needed into the scale-up factors for sanitation interventions across the wealth quintiles. This graph better represents scale-up of health sector interventions, where increases in program costs would be reflected as one scales up. However, in the context of sanitation, these are mostly household level costs –and sanitation technology at the lower end of the sanitation ladder is cheaper. So these quintiles efficiencies may be closer together.

b. **Effectiveness Graph:** Evidence from countries like Nepal show us that the effectiveness of the same intervention (such as sanitation) may differ substantially between Q1 and Q5. Some of this may be due to a different spectrum



of pathogens among the very poor (and more susceptible), and/ or later presentation with more severe symptoms because of barriers in access to care or differences in care-seeking behavior. Also the quality of sanitation coverage (or technology) will not be the same in all socio-economic strata. Poorer quality and sanitation options lower on the sanitation ladder may decrease the effectiveness of the intervention against diarrheal deaths and sickness. This may lead to a wider spread between Q1 and Q5 effectiveness.

c. **Impact Graph:** The “potential impact fraction” of an intervention like sanitation which targets diarrhea in reduction of the overall child mortality burden could be much larger in the poorest than in the wealthiest quintile despite lower quality of delivery in poor settings acting to reduce intervention effectiveness. With the differences in sanitation risks, and in the susceptibilities between the poorest and richest quintiles in Nepal, this graph may have a wide spread of lines –with considerably higher deaths averted in the poorest quintiles.

d. **Cost-effectiveness Graph:** Results from Chapter 4 show that the cost-effectiveness of the poorest quintiles are not significantly different from those of the richest quintiles.

216. The above discussion points out the importance of different criteria –health equity and cost-effectiveness –in the targeting and choice of sanitation interventions across wealth quintiles in Nepal. Chapter 5, brings these two criteria together, and includes other criteria to help understand how policy-makers in Nepal may choose

to prioritize environmental health interventions among a range of child health interventions.

217. These papers help in furthering the discussion on the role of sanitation in addressing child health –from a health-equity and cost-effectiveness perspective and taking into account its prioritization in decision-making. These results are broadly generalizable in other developing countries, like Nepal, where poor environmental conditions and high child mortality co-exist.

218. However, some cautionary notes are necessary. Estimating the health effects of sanitation is a difficult task, especially in developing country settings. Whatever the importance of sanitation, there are other variables that are also critical. These include water quality, hygienic practices of household members (hand-washing at critical times), the education of women involved in decision-making, and the nutritional level of the household (indicative of the ability to withstand health shocks). It is also important to note that sanitation (technology, quality, coverage and use) is highly country-specific, and especially at the level of sub-populations (such as wealth quintiles).

### **6.3 Policy Implications**

219. There is growing evidence that demonstrates the potential role of environmental health factors in child health, and the substantial burden and consequent economic costs associated with environmental health risks (Acharya and Paunio, 2008). However, the silo structure of implementing interventions has

meant that governments in developing countries roll out various child health programs along sectoral lines, and without any coordination. Health sector and health systems related interventions are considered separate from programs to improve water, sanitation and hygiene as well as rural energy programs, even though these all also contribute to child health.

220. From the results of the three papers in the thesis, the following points emerge for consideration at the policy level:

- ***Pro-poor policies for expanding sanitation coverage have the ability to save lives through reduced child diarrheal mortality.*** This would help protect these children and households most at risk, and to maximize the impact of sanitation investments more broadly (Rheingans et al 2012). Chapter 3 identifies the potential impacts on child health of scaling up sanitation coverage in different wealth quintiles – such information can help decision-makers formulate policies that expand sanitation coverage.
- ***Sanitation scale-up is cost-effective across all wealth quintiles –from the poorest households to the richest in Nepal.*** This is because of the relatively large sanitation-related disease burden that is reduced as a consequence, and the low costs of moving up the sanitation ladder. Chapter 4 develops two different scenarios of sanitation scale-up and shows both scenarios to be cost-effective. Because of its prevention-focus, environmental health interventions such as sanitation help to reduce the incidence of childhood infections such as diarrhea; also lessen the burden on the health systems in the country. Thus

reaching these households are likely to yield higher health (and non-health) benefits, representing a more efficient use of national resources.

- ***Environmental health interventions are likely to be ranked high by the involved country policy-makers***, as the criteria relating to individual/community non-health benefits is very valued in making decisions about interventions. Environmental health interventions (such as sanitation) bring not only health benefits but also other societal (non-health) benefits which have important implications for choosing priority interventions for child health. Chapter 5, through its focus on priority setting and the use of a multi-criteria decision analysis framework, helps to understand how decision-makers prioritize environmental health interventions for better child health outcomes. This calls for stronger efforts to develop collaborations between health sector professionals and those in other sectors to work together for better child health.

#### **6.4 Future Research Priorities**

221. Further research is needed to study the impacts of sanitation on health at the household and community levels, disaggregated to investigate different types of sanitation technologies, incentives for better coverage and uptake, and within sub-groups of the population. As developing countries like Nepal look to scaling up sanitation over the next few decades, billions of dollars would be better spent if there were an improved understanding of the varying levels of effectiveness associated with different sanitation technologies, the differences in costs (both for sanitation technology and household treatment), and the resulting impacts on

disease burden. These factors would also point specifically to the best strategy for targeting sanitation interventions (who, what, where, when).

222. As is often the case, however, this thesis also raises additional questions that were beyond the scope of the analyses presented here. This section identifies a range of issues that could be explored in future research work on these topics, and concludes with a call for additional research and analytical studies addressing sanitation, and other environmental health problems in developing countries –with the perspective of addressing child health. These include the following:

223. *Moving from Global to Country-Specific Studies:* There have been numerous global studies looking at estimating the disease burden of WSS interventions, and estimating the benefits and costs associated with improving sanitation coverage (Hutton and Haller 2004; Hutton and Haller 2007; Hutton 2008; Acharya and Paunio 2008; Hutton 2012; Fink et al 2011; Lim et al 2012; Pruess Usten et al 2014; Wolf et al 2014). As we think about addressing child survival at the country level, it becomes critical to understand and incorporate the local context, and situation-specific information and data relating to people (e.g. subgroup analysis of risk, susceptibility), technology (e.g. different sanitation options), costs (e.g. sanitation infrastructure and household treatment) and behavior (e.g. reflecting on sanitation use, handwashing etc.). National studies in countries like Nepal should be conducted within the context of national policy processes and decision-making for improving child health.

224. *Estimating Effectiveness of Different Technology:* Further research is needed into the health impacts of water supply and sanitation from different sub-types of technology and services, and coverage levels achieved. This would help estimate, for example, the additional health gains a community that has become open-defecation free, can receive compared to one that has high but incomplete coverage of latrines. Also to distinguish between the health improvements associated with shared latrines, compared to private latrines, in different spatial and socio-economic settings (Hutton 2012).

225. *Estimating Effectiveness of Sanitation Scale-up.* Presently, there is little understanding or evidence about the nature and scale of differences in effectiveness of health interventions in different equity strata (Chopra et al 2012). There is, therefore, a need for longer-term effectiveness studies in programmatic (not research driven) settings. Rigorous observational studies and project evaluations can also contribute valuable evidence on the scalability and sustainability of sanitation interventions. Differences in programmatic approaches to optimize the adoption and long-term utilization of sanitation should also be investigated.

226. *Calculating Costs of Sanitation and Household Treatment:* At the country level, it would be important to carry out research to get information about the investment costs (both capital and recurrent for O&M) related to the different types of sanitation options available. This would help identify the preferred technologies to invest in, from an economic perspective, given the different costs, maintenance requirements, uptake/use by the population, utilization capacity, and life span.

These analyses should be disaggregated at the wealth quintile level, as well as the rural-urban dimension, reflecting the differentials in costs.

227. *Expanding Scope beyond Diarrhea:* In these papers, only the impact of sanitation on diarrheal mortality and morbidity has been considered. Many other health effects (such as intestinal parasite infections, impaired nutritional status and possibly environmental enteropathy) associated with inadequate water and sanitation, should also be included (Korpe and Petri 2012; Dangour et al. 2013). Furthermore, these analyses should be extended to look at derivative effects whereby poor sanitation may reduce the effectiveness of other health interventions. For example, Humphrey et al. (2009) suggest that poor sanitation and hygiene may reduce the impact of nutrition interventions. Similarly, Madhi et al (2010) suggest that environmental enteric exposures may reduce the effectiveness of live oral vaccines such as that for rotavirus.

228. *Generalizing findings to other countries.* The methods used in the three papers in this thesis are broadly generalizable to other developing countries like Nepal, where income inequalities and environmental health risks (such as poor sanitation) co-exist. However, the generalizability of the results is constrained by the specific country context – from the scale of inequalities in access to services (like sanitation), to the local-level effectiveness of different types of sanitation interventions; and to the availability of localized costing data on sanitation and household treatment costs.

229. There are still gaps in the research agenda – with more customized and country-specific research needed on intervention effectiveness and costs, including specifically in programmatic settings to gather evidence on scalability and sustainability. Uncertainty in several parameters and the lack of data at a disaggregated level limit the interpretation of the findings. But the economics of sanitation –from an equity-efficiency perspective –as shown in this thesis can help to inform the policy dialog on scaling up sanitation for better child health.



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## CURRICULUM VITAE

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### CAREER SUMMARY

Eighteen years of international development experience, working on a range of environmental issues including environmental health, pollution management, biodiversity and protected areas, climate change, environmental policies, and forestry. Work experience in several countries in the Africa, Latin America, South Asia, and East Asia regions.

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### EDUCATION

**Johns Hopkins University, Bloomberg School of Public Health**, Baltimore, MD  
(ongoing)

PhD (*expected in May 2015*), Health Systems, Department of International Health

*Dissertation Title:* Environmental Health and Child Survival in Nepal: Health Equity, Cost-Effectiveness, and Priority Setting.

*Advisor:* Louis W. Niessen

*Courses* included epidemiology, international health reform, water sanitation, tropical environmental health, urban issues in developing countries, biostatistics.

**Duke University, School of the Environment**, Durham, NC (1992-1994)

Masters in Environmental Management (Resource and Environmental Economics)

*Master's thesis:* Deforestation in mainland S.E. Asia following the 1989 logging ban in Thailand.

*Courses* included advanced environmental economics, natural resource economics, tropical ecology, applied regression analysis, environmental law, etc.

**Delhi University, Faculty of Management Studies**, Delhi, India (1991-1992)

Graduate Studies in Management.

*Courses* included finance, business economics, accounting, marketing, HR mgmt.

**Delhi University, St. Stephen's College**, Delhi, India (1988-1991)

Bachelor of Arts (First Class with Honors) in Economics. *Minor in Mathematics.*

*Courses* included microeconomics, macroeconomics, development policy, monetary policy

## PROFESSIONAL EXPERIENCE

**The World Bank**, Washington D.C. (Oct. 1996- present)

### ***Senior Environmental Specialist***

Vietnam Country Office, East Asia and Pacific Region (*August 2012 - Present*)

- ♦ *Environment Cluster Leader*: Supervise the environment and climate change World Bank portfolio in Vietnam. Team lead for a project on climate resilience and sustainable livelihoods in the Mekong Delta. Environmental safeguards coordinator

Sustainable Development Dept, Latin America and Caribbean Region (*Oct 2007-July 2012*)

- ♦ *Operational work*: Worked on industrial pollution abatement projects and TA in Argentina and Uruguay. Worked with sector specialists to prepare environmental DPLs for Mexico and Peru. Led the supervision of a six-country protected areas project in the Eastern Caribbean.
- ♦ *Analytical work*: Responsible for the environmental health costing as part of the Honduras, Nicaragua, Bolivia and Panama Country Environmental Analyses. Supervised analysis on estimating the costs associated with environmental risks of inadequate water, sanitation; indoor/urban air pollution.
- ♦ *Safeguards*: Serve as environmental safeguards specialist for several sectoral (urban, protected areas, rural development, energy, disaster risk management) projects under preparation/supervision in Jamaica, Mexico, Nicaragua and the OECS. Environmental safeguards coordinator for the Caribbean.
- ♦ *Other*: Team lead for 2011 Env. Strategy background paper on “*Role of Environmental DPLs in Mainstreaming Sustainability*”. Contributing author to publication on *Urban Agriculture*. Peer reviewer for industrial pollution/brownfields projects in Vietnam, China, Turkey; biodiversity analytical work in Vietnam; environmental policy note for Sri Lanka, etc.

Environment Department (*May 1999-September 2007*)

- ♦ Core member of the *Env Health Program*, which aimed to strengthen environmental health content in the Bank’s infrastructure projects/TA. Team leader and lead author for analytical report *Environmental Health and Child Survival*; as well as Challenge Fund Award study on *Improving EH Outcomes in Slum Upgrading Projects*. Core team member for analytical studies on environmental health in Nepal, China, Vietnam.
- ♦ Provided substantive technical support to the preparation of national-level environmental reports in Thailand, the Philippines, Vietnam, and Lao PDR. Co-authored thematic *Environment Monitors* on water quality, air quality, and solid waste management. Routinely participated in missions to these countries, interacting and collaborating with senior government officials.

- ♦ Assisted in the preparation of the Bank's 2001 Environment Strategy, which includes a focus on protecting people's health from environmental risks and pollution. As part of the *Env Strategy Team*, reported on areas of progress, and gaps in implementation.

***Environmental Consultant (Oct. 1996- April 1999)***

Wrote a strategy paper for the Africa region, outlining key areas for building environmental capacity. Identified crucial issues in global forestry to re-examine the Bank's role in the forestry sector in the Asia.

**Worldwatch Institute, Washington D.C., *Researcher* (Aug. 1994- Sept. 1996)**

Research on tropical and boreal forests, biodiversity, and the impact of climate change. Authored articles on environmental trends and issues for "Vital Signs" and "World Watch" magazine. Contributed to research on China's environment, and freshwater ecosystems for chapters in "State of the World" (1995, 1996).

**World Resources Institute, Washington D.C., *Research Intern* (Summer 1993)**

Conducted extensive research on community forestry projects in Asia. Wrote paper on the need for economic incentives in Asian community forestry schemes.

**Center for International Development Research (Sept. 1992- May 1993)**

Duke University, Durham, NC, *Research Assistant*

Researched the role of self-governing institutions in forestry management in developing countries. Developed case studies of community forest management, included in *Communities and Sustainable Forestry in Developing Countries* (1994).

**Faculty Research, St. Stephens College, New Delhi, India, *Researcher* (Summer 1991)**

Surveyed two villages in Uttar Pradesh, as part of a project team to assess the impact of a central government employment scheme. Collected, and interpreted household data; identified shortcomings, and recommended improvements.

PUBLICATIONS

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**Teaching**

Guest Lecturer, Environmental Health and the Developing World. Johns Hopkins Bloomberg School of Public Health. 4<sup>th</sup> Term, 2007-2009. Led by Prof G. Jakab.

**Selected reports**

Acharya, A. (lead author, and team lead), *Environmental Health and Child Survival: Epidemiology, Economics, Experiences*, Environment and Development Series, Env Department, World Bank, September 2008.

Acharya, A., and M. Dyoulgerov, *Analytical and Advisory Activities in Environmental and Natural Resource Management*, Env. Strategy Paper, Env Department, World Bank, Sept. 2005.

- Acharya, A., "Section 9: Environment "in *Vietnam Delivering on its Promise: Development Report 2003*, World Bank, Nov. 2002.
- Acharya, A., and A. Abuyuan, *A Decade of Environmental Lending: A Review of the World Bank's Environment Portfolio during the 1990s*, Environment Strategy Paper No. 7. Environment Department, World Bank, Nov. 2002.
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- \_\_\_ "Forest Loss Continues," in *Vital Signs 1996*, Lester R. Brown et al. New York, NY: W.W. Norton & Company, 1996.
  - \_\_\_ "CFC Production Drop Continues," in *Vital Signs 1996*, Lester R. Brown et al. New York, NY: W.W. Norton & Company, 1996.
  - \_\_\_ "Aquaculture Production Rising," in *Vital Signs 1996*, Lester R. Brown et al. New York, NY: W.W. Norton & Company, 1996.
  - \_\_\_ "Small Islands: Awash in a Sea of Troubles," *World Watch*, Vol. 8, No. 6, Nov./Dec. 1995.

- \_\_\_ "El Niño: Fingerprint of Climate Change," World Watch, Vol. 8, No. 4, Jul./Aug. 1995.
- \_\_\_ "Tropical Forests Vanishing," in Vital Signs 1995, Lester R. Brown et al. New York, NY: W.W. Norton & Company, 1995.
- \_\_\_ "Plundering the Boreal Forests," World Watch, Vol. 8, No. 3, May/June 1995.
- \_\_\_ "Climate Change Affects the Northern Forests," World Watch, Vol. 8, No. 1, Jan./Feb. 1995.

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#### AWARDS AND HONORS

Proctor & Gamble Fellowship, Johns Hopkins School of Public Health, 2005.  
Dept. tuition scholarship, Johns Hopkins School of Public Health, 2005.  
Pew Scholarship, Duke University School of the Environment, 1992-93.  
Sixth in the university, Delhi University economics final examinations, 1991.

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#### COMPUTER SKILLS, CERTIFICATIONS, LANGUAGES

Extensive experience with Excel; Familiarity with Stata;  
Training in Intermediate GIS.  
English (native); Hindi (native); Spanish (Intermediate- Medium).