Hygiene and Health in Developing Countries:

Defining Priorities-

A Cost-Benefit Assessment

By

Bjorn Larsen

Economist/Consultant
Environment and Health[1]

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[1] The author is an independent consultant, and previously Environmental Economist at the World Bank.

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The author can be contacted at: Email: BJ_LA @ hotmail.com; Tel.: (1- 703) 216-6285 in Washington, D.C., United States.

FOREWORD

One of the greatest failures of the last fifty years has been the failure to lay the foundation stones of public health in the developing world – hygiene, sanitation and water supply. Despite significant progress during the last two decades, the demographic and environmental health scenario continues to be a cause of serious concern in the developing countries of South East Asia and Sub-Saharan Africa. The traditional problems of water and air-borne infections combine with malnutrition and poor environmental sanitation to form a vicious cycle, which is increasing the burden of diseases beyond the capacity of the existing health infrastructure and jeopardizing the productivity of society. Today, while the urban population of these countries faces the development and environmental degradation, concurrently the rural & peri-urban population continues to suffer lack of sanitation and safe drinking water, malnutrition and ecological insecurity.

The per capita disease burden in developing countries is more than two times higher than the same in the high-income countries. Infectious diseases alone explain more than 50% of the difference. A major share of the infectious disease burden could be related to water, sanitation and hygiene. There are 2.2 million diarrhoeal death and 4 billion cases of diarrhoea per year along with intestinal worms infection, which affect about 500 million people, and schistosomiasis affecting 200 million people and 6 million are blind from the trachoma (WHO/UNICEF 2000).

Considering the central role of water, sanitation and hygiene education in preventing infectious diseases, UN Decade of Water Supply & Sanitation was launched during the eighties. Though substantial investment were made in the developing countries for improving community water supply & sanitation, the health benefits were not commensurate with the investments made and the agenda remains unfinished. One of the fundamental weakness of the programme undertaken by various developing countries was the propensity to give priority to water supply over sanitation and sanitation over hygiene. Improved hygiene, keeping faecal matter away from hands, food and water in the domestic environment is a factor of equal importance if not more.

Given the present situation in SEAR and Sub-Saharan African countries in respect of water, sanitation and hygiene at home, community water supply alone can go only part of the way in achieving the basic objective of improving the health status of the community. It would largely depend on the implementation of an integrated strategy aimed at improving water quality and availability, and sanitation, along with improving hygiene practice at home through changes in attitudes and higher levels of health education. Almost all water-borne, water based and water-washed diseases are spread through exposure of food and drinking water to human faeces. Hence, the rate of infection and cross-infection could be reduced by safe disposal of waste, as well as, home hygiene practices, safety and quality of food and drinking water and availability of adequate quantity of water for personnel hygiene. Unfortunately, however, whenever public health concerns are expressed in developing countries, they generally relate settings and services such as municipal services, hospitals and environmental sanitation

etc. There is reluctance to acknowledge the home as a setting of equal importance along with public institutions in the chain of disease transmission through the community. What is needed is that persons responsible for promoting home hygiene and the managers of community hygiene must act in unison to optimize return from their efforts to promote public health. It may not be out of place to mention that promotion of hygiene behaviour in the domestic setting is possibly the most cost-effective among all preventive public health measures, in the context of developing country situations today.

The present study, which was sponsored by IFH and funded by UNILEVER, indicates that promotion of hygiene education and change of hygiene behaviour could prevent the death of a child at only a fraction of the cost that is involved in large community water supply and sanitation programme. A programme of hygiene promotion at home that targets high-risk house holds without adequate access to safe water & sanitation could prevent 1 million child death per year in the developing countries at 0.15% of their current health expenditure. Such studies could be useful tools of advocacy for the health professionals as well as policy plannars.

IFH is committed to provide knowledge based and evidence based advocacy materials to the Government and community organizations of the developing countries. We would like to compliment and congratulate Mr Bjorn Larsen for undertaking this pioneering scientific study. Such studies are complex and conclusions are often subjected to many questions? But we are sure, that the substantive message of the document is clear and convincing and will be extremely useful for developing a cost-effective strategy for preventing sickness and death from infectious diseases in the developing countries.

Prof. K.J. Nath
Member, IFH, Scientific Advisory Board
Regional Coordinator for SEAR Countries

Prof Sally Bloomfield
Chairperson, IFH Scientific Advisory Board

SUMMARY

The per capita disease burden in developing countries – as measured by years of life lost due to illness, injuries and early death – is more than two times higher than in high-income countries. Infectious diseases alone explain more than 50% of this difference. In total, infectious diseases account for as much as 30 percent of the disease burden in the developing world, and averages more than 10 times higher per capita than in the high-income countries.

About one-quarter of the infectious disease burden in developing countries may be related to water, sanitation, and hygiene. There are 2.2 million diarrhoeal deaths and 4 billion cases of diarrhoea per year, intestinal worms infect about 500 million people, 200 million people have schistosomiasis, and 6 million are blind from trachoma (WHO/Unicef 2000).

Children suffer disproportionately from infectious diseases in developing countries. It is estimated in this report, from a cross-country analysis of 84 developing countries, that the death of 4 million children might be prevented each year by reaching 100% child immunization rates (currently 80%), eradicate female illiteracy (currently 22% for the age group 15-24), and reaching 100% of the populations with potable water supply (currently 78%) and 100% with safe sanitation (currently 52%). This is estimated to reduce child mortality by almost 50% in India and Sub-Saharan Africa.

A cost-effectiveness analysis indicates that a hygiene education programme can prevent the death of child at only a fraction of the cost of water supply and sanitation in most developing regions of the world. A programme that targets "high risk" households (i.e., which have children under the age of five, do not have access to safe sanitation *and* have illiterate mothers) is estimated to prevent 0.6-1.1 million child deaths per year. This is estimated to cost on the order of 0.15% of total health expenditures in the developing world.

There are plenty of examples of low-income developing countries that have achieved substantial reductions in child mortality and infectious diseases, such as Nicaragua, Sri Lanka, Vietnam and Uzbekistan. This suggests that protection of health in developing countries is not only an issue of affordability but also an issue of government and citizen priority to achieve equity in health performance.

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I. Introduction.

Developing countries have achieved substantial improvements in health status over the past several decades. Ahmad et al (2000) provides an analysis of country-specific and regional trends in child mortality. Despite the improvements, infectious diseases are still among the leading causes of child mortality and overall disease burden in several parts of the world. The objective of this paper is to provide quantitative estimates of the cost-effectiveness of some interventions for the control and prevention of some of these diseases, in particular in relation to the role of hygiene improvements and child mortality. Using country level data for more than 80 developing countries, the paper provides an analysis of several child mortality determinants and their relative importance in reducing mortality. Unit costs of interventions are then applied to provide estimates of cost-effectiveness of child mortality reduction.

Many factors have been identified in the research literature as contributors to the decline in child mortality, including increased child vaccination, water and sanitation improvements, and increased use of oral rehydration therapy (ORT). Victora et al (2000) discuss the successes of ORT since its large-scale introduction in the early 1980s, and provide a review of several country case studies. While ORT is found to be a cost-effective strategy to reduce child mortality in an environment with high diarrheal disease incidence (Varley et al 1998), the motivation for focusing on hygiene improvement in this paper is to assess the cost-effectiveness of a disease preventive intervention.

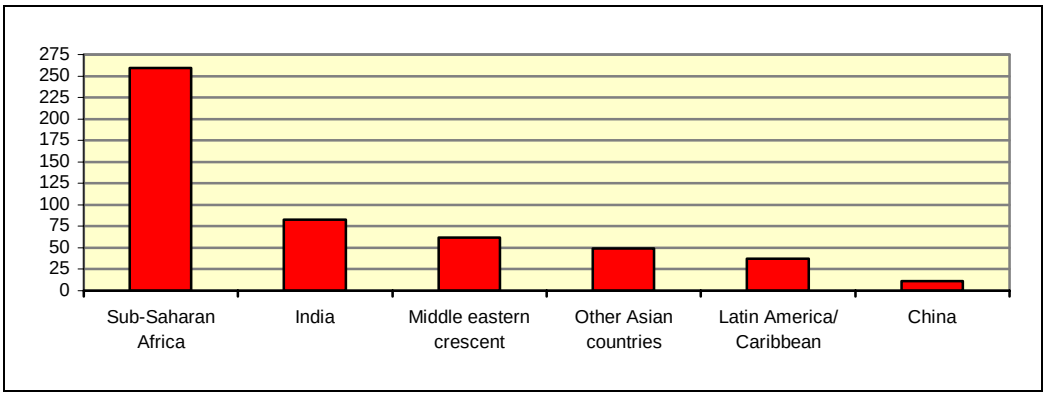
A regional overview of the infectious disease burden is presented in section II. Section III provides a review of some of the research literature on determinants of child mortality and the role of various interventions in controlling and preventing infectious diseases. A cross-country analysis of child mortality determinants and data are presented in Section IV and V. Potential health benefits, in terms of reduced child mortality rates, of various interventions are estimated in Section VI. Section VII and VIII present estimates of unit costs and cost-effectiveness of the interventions. Total intervention costs are estimated in Section IX, and child mortality rates in relation to GDP per capita is discussed in Section X. Section XI provides a summary and conclusions.

II. The Infectious Disease Burden.

The per capita burden of disease - as measured by years of life lost due to illness, injuries, and early death – is more than two times higher in the developing countries of the world than in the high-income countries. Infectious diseases alone explain more than 50% of this difference. For instance, diarrheal diseases and lower respiratory infections have continued to date to be among the two or three leading contributors to the overall

disease burden in India, the region of other Asian countries (excluding China), the Middle eastern crescent[2], and Sub-Saharan Africa. In total, infectious diseases account for as much as 30 percent of the disease burden in the developing world, and averages more than 10 times higher per capita than in the high-income countries. The infectious disease burden per capita in year 2000 is presented in Figure 2.1 as DALYs per 1000 persons, and the overall burden associated with water, sanitation and hygiene is presented in Box 2.1.[3]

Figure 2.1: Infectious Diseases in Year 2000 - DALYs per 1000 persons



Source: Calculated based on Global Burden of Disease data published by the World Bank.

Box 2.1: Select Infectious Diseases in Developing Countries

Diarrhoea	4 billion cases per year. 2.2 million deaths.
Intestinal nematode infections	Infect about about 500 million people.
Schistosomiasis	About 200 million are infected. 20 million suffer severe consequences.
Trachoma	About 6 million are blind from trachoma

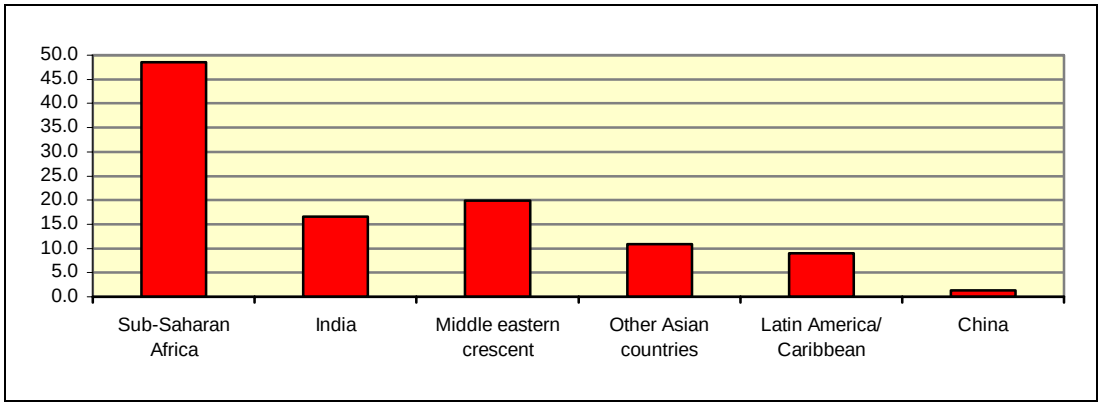
Source: Global Water Supply and Sanitation Assessment 2000 Report, Unicef/WHO.

[2] North Africa and Middle East to Pakistan.

[3] Disability Adjusted Life Year (DALY) is a measure of a year of life lost due to premature death, and illness and injuries weighted by severity and duration.

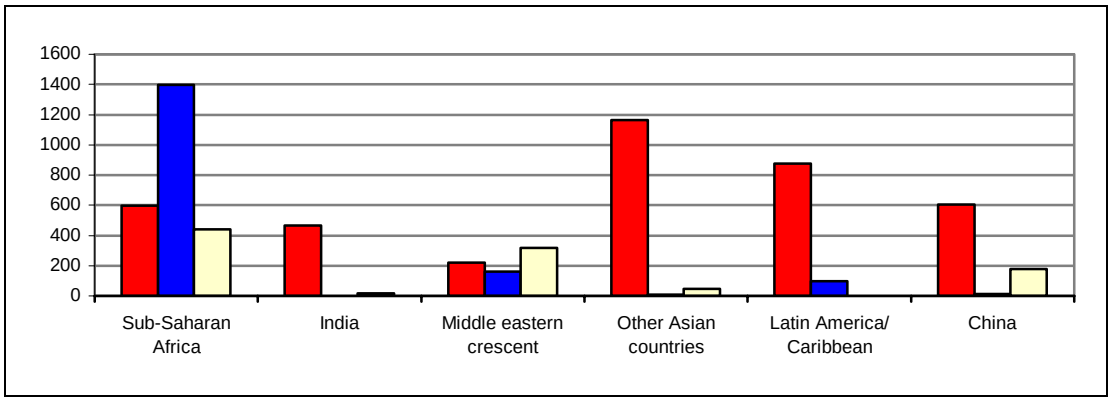
Figure 2.2 and 2.3 present the regional distribution of DALYs per capita for diarrhoeal diseases, intestinal worm infections, schistosomiasis, and trachoma. The per capita disease burden of these diseases does not always follow the pattern of total infectious diseases per capita in Figure 2.1. For diarrhoeal diseases the burden per capita is higher in the Middle eastern crescent than in India, and the per capita regional burden of intestinal worm infections bear no resemblance to the distribution of the diarrhoeal and infectious disease burden.

Figure 2.2: Diarrhoeal Diseases in Year 2000 - DALYs per 1000 persons



Source: Calculated based on Global Burden of Disease data published by the World Bank.

Figure 2.3: Intestinal worm Infections, Schistosomiasis, and Trachoma
(Year 2000 - DALYs per 1 million persons)

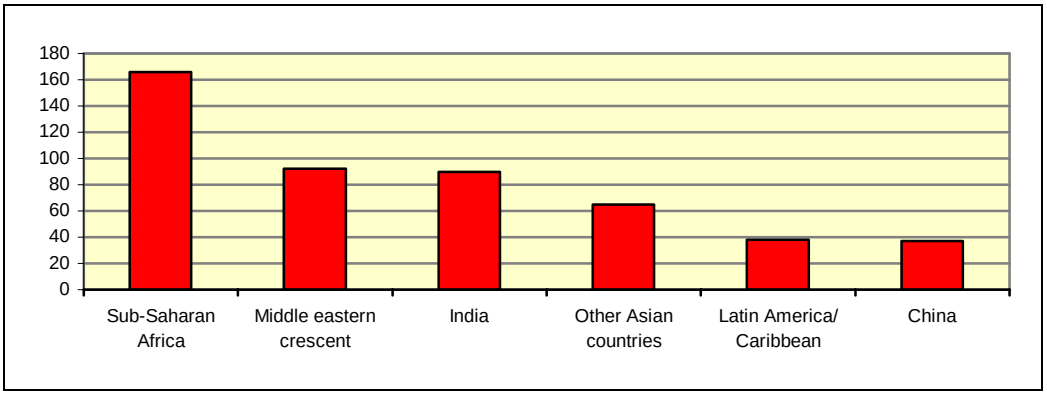


Note: Bars in the chart from left to right are: Intestinal worm infections; Schistosomiasis, and Trachoma.

Source: Calculated based on Global Burden of Disease data published by the World Bank.

Children bear a disproportionate burden of infectious diseases related to water, sanitation, and hygiene. This is reflected in high child mortality rates in most developing countries as seen in Figure 2.4.

Figure 2.4: Child Mortality Rates by Region in Year 1999/2000
(deaths per 1000 births)



Source: Based on country child mortality rates (under 5 years) in World Development Indicators, World Bank.

III. Determinants of Infectious Disease Burden and Child Mortality.

This section provides a brief review of some of the studies of the determinants of infectious disease burden and child mortality in developing countries, with a focus on infectious diseases related to water, sanitation and hygiene, and a broader set of determinants of child mortality.

A large number of studies have analyzed differences in infectious disease incidence and prevalence, and child mortality across households, communities, countries and regions of the world, and attempted to identify key determinants of such differences. Many of these studies are based on observed differences in health status, while others are controlled studies that have assessed the effects of particular interventions in households and communities.

Of the total infectious disease burden in the developing world, about one-quarter may be related to water, sanitation and hygiene. Pruss et al (2002) estimate the global burden of diarrheal disease at around 2.2 million deaths (of which 90% among children) associated with lack of safe water, sanitation and hygiene. About 1 million of these deaths are estimated to be hygiene related. To estimate the disease burden, the authors applied relative risk factors from the literature in relation to water and sanitation coverage and hygiene levels by geographic region.

Esrey et al (1991), a study often referenced in the literature, analyzed 144 studies to examine the impact of improved water supply and sanitation facilities on various infectious diseases, and found a median reduction in morbidity of 25-30 percent. The median reduction in morbidity associated with improved hygiene was somewhat above 30 percent.

In terms of specific hygiene interventions, Curtis (2002) reported an average reduction of 40 percent in diarrheal diseases from hand washing, based on a review of 15 studies. The reduction in severe diarrhea was 44 percent, which suggests that good hand washing practices in developing countries can significantly reduce child mortality.

Studies have also specifically analyzed child mortality. Esrey et al (1991) find in their review that the median reduction in child mortality from improved water and sanitation was 55 percent. Shi (1999) provides econometric estimates of the impact of potable water and sewerage connection on child mortality using a data set for about 90 cities around the world. The estimates indicate that child mortality rates fall by 8.3/1000 for every 10 percentage points increase in urban population with access to potable water connection, and by 4.7/1000 for every 10 percentage points increase in access to sewerage connection.

Esrey and Habicht (1988) reports from a study in Malaysia that maternal literacy reduces child mortality by about 50 percent in the absence of adequate sanitation, but only by 5 percent in the presence of good sanitation facilities. Literacy is also found to reduce child mortality by 40 percent if piped water is present, suggesting that literate mothers take better advantage of water availability for hygiene purposes to protect child health.

Findings from the Demographic and Health Surveys seem to further confirm the role of literacy in child mortality reduction. Results presented in Filmer and Pritchett (1997) from 44 country surveys from 1987-95 in all developing country regions indicate that child mortality is 26 percent lower in households with mothers with primary schooling compared to no schooling, and an additional 36 percent lower in households with mothers with secondary schooling compared to primary schooling.

Rutstein (2000) provides a multivariate regression analysis of infant and child mortality in developing countries using Demographic and Health Survey data from 56 countries from 1986-98. The study finds a significant relationship between mortality variables and piped water supply, flush toilet, maternal education, access to electricity, medical services, oral rehydration therapy (ORT), vaccination, dirt floor in household dwelling, fertility rates, and malnutrition.

While most of the above studies have focused on specific interventions or the role of specific factors in controlling and preventing infectious diseases and/or reducing child mortality, the study by Rutstein (2000) provides a broader assessment of the determinants of child mortality across countries at various stages of socio-economic development. A similar approach is taken in this paper in order to estimate the relative importance of key

determinants of child mortality, and provide estimates of the cost-effectiveness of some interventions including hygiene programmes.

IV. Methodology and Data

The objective of the analysis in this paper is to assess the potential role and health benefits of hygiene education programmes and hygiene improvements in the prevention of infectious diseases, as well as the cost of such programmes in comparison to other interventions such as water and sanitation investments. As quantitative information on country-level infectious disease morbidity is rather limited, the analysis concentrates exclusively on child mortality.

The determinants of child mortality differ across countries and regions, and some may be indigenous to particular regions or sub-regions such as malaria. Nevertheless, many important determinants are shared by most, if not all developing countries such as potable water quantity and quality, sanitation facilities, hygiene levels, child immunization, female literacy, basic health care services, housing conditions (overcrowding, insects etc.), and availability and affordability of medical treatment.

Data for all determinants are not available for most countries, thus a quantification of the relative importance of each determinant remains difficult. For instance, there is very limited and no consistent data set available for important determinants of respiratory child mortality, which implies a serious data gap as respiratory infections are the cause of millions of deaths of children annually. However, a substantial number of research studies have demonstrated the importance of key determinants of child mortality for which data are available – access to an improved water source, safe sanitation, child immunization, female literacy, and HIV prevalence.

Data used in this paper on access to water and sanitation is from the recent publication, Global Water Supply and Sanitation Assessment 2000 Report (WHO/ Unicef 2000). Data on child mortality, child immunization, female literacy, and HIV prevalence are from World Bank publications. Key regional averages and data for India and China are presented in Table 4.1.

According to Table 4.1, Sub-Saharan Africa (SSA) is performing poorly on all fronts. Child mortality is more than four times higher than in Latin America/Carribean (LAC) and China. The high mortality rate in the Middle Eastern Crescent (MEC) is largely due to Afghanistan, Iraq, Pakistan, Sudan and Yemen. The percentage of the population with access to an improved water source does not display great variations across regions except for SSA. The situation with regard to sanitation is different. The coverage rate in India and China is only one-half the rate in the other regions except SSA. It is also worth noting the very low female illiteracy rates in China and LAC as compared

to especially India, the MEC and SSA. Measles immunization rates at the regional level do not display such large variations with the exception of SSA[4].

Table 4.1: Child Mortality and Select Determinants

	India	China	Other Asian countries	Latin America/ Caribbean	Middle Eastern Crescent	Sub-Saharan Africa
Child mortality – under 5 (per 1000 live births) in 1999	90	37	65	38	92	166
Access to improved water source (% of total population)						
1990	78%	71%	71%	80%	79%	48%
2000	88%	75%	78%	85%	83%	54%
Access to sanitation (% of total population)						
1990	21%	29%	57%	73%	65%	51%
2000	31%	38%	66%	78%	76%	54%
Female illiteracy (% of 15-24 year olds)						
1990	46%	8%	24%	9%	44%	39%
2000	35%	4%	20%	6%	31%	27%
Measles immunization (% of infants <12 months)						
1987-88	50%	70%	43%	61%	61%	41%
1996-97	81%	96%	90%	87%	79%	55%

Source: World Development Indicators (World Bank); and Global Water Supply and Sanitation Assessment 2000 Report (WHO/Unicef).

V. Regression Analysis.

A multivariate OLS regression analysis for 84 countries, representing 95% of the population in the developing world, was undertaken as a step in assessing the potential role and health benefits of various interventions in reducing child mortality. Using natural-log data, the following OLS regression equation was estimated:

$$\ln(CM) = \alpha + \beta_1 \ln(W) + \beta_2 \ln(S) + \beta_3 \ln(L) + \beta_4 \ln(I) + \beta_5 \ln(H) + \beta_6 D + \varepsilon \ldots (1)$$

The variables in the regression equation are defined as follows:

CM = under-5 child mortality rate (deaths per 1000 live births);
W = percentage of the population with access to an improved water source;

[4] Measles immunization rates are available for more countries than rates for full immunization. However, alternative immunization rates are highly correlated (for instance, correlation coefficient=0.92 between DPT and measles immunization rates). Measles immunization rates are used in this study to capture the role of immunization in preventing child mortality.

S = percentage of the population with access to safe sanitation;
L = percentage of females in the age group 15-24 that are literate;
I = percentage of children receiving immunization;
H = percentage of adults in the age group 15-49 that have HIV; and
D = dummy variables (value 0 or 1).

Estimated coefficients (β) with t-statistics in parenthesis are presented in Table 5.1, and represent the percentage change in child mortality associated with a one percent change in a given explanatory variable. The regression equation was estimated with and without regional dummy variables for Sub-Saharan Africa (SSA) and high mortality countries in the Middle Eastern Crescent (MEC) and Asia Pacific (ASP) regions. The explanatory power of the variables is relatively high, with adjusted R^2 at 0.78 and 0.86. The coefficients and t-statistics for the regional dummy variables suggest that child mortality rates in SSA and the high mortality countries of MEC and ASP are significantly higher than can be explained by the explanatory variables.

Table 5.1: Regression Estimates

Explanatory variables:	**% Change in Child Mortality (under 5)** associated with a 1 % change in a given variable	
	Regressions	
	(1)	(2)
Access to improved water source (% of population)	-0.41 (-2.30)	-0.31 (-2.10)
Access to safe sanitation (% of population)	-0.28 (-2.29)	-0.25 (-2.44)
Female literacy in age group 15-24 (%)	-0.83 (5.15)	-0.53 (3.80)
Immunization (% of children)	-0.38 (-2.07)	-0.24 (-1.50)
HIV prevalence (% of adults 15-49 years)	0.09 (4.43)	0.08 (3.24)
Dummy – SSA region		0.58 (4.84)
Dummy – High mortality countries in MEC region		0.60 (4.07)
Dummy - High mortality countries in ASP region		0.51 (3.82)
Adjusted R^2	0.78	0.86

SSA=Sub-Saharan Africa; MEC=Middle eastern crescent; ASP=Asia and Pacific (except China and India).

Several observations can be made from Table 5.1. The coefficients from regression (1), i.e., without regional dummies, are all statistically significant at 95 percent. With regional dummies in regression (2) the values of most of the coefficients are substantially lower (only somewhat lower for sanitation and HIV), and immunization is statistically insignificant. One possible reason for immunization being insignificant in equation (2) might be that immunization rates are correlated with omitted variables that might be region specific to SSA and the high child mortality countries in MEC and ASP. As the regional dummy variables are all statistically significant, the estimated coefficients in regression (2) are applied in the analysis in the following sections.

To estimate the impact on child mortality rates (CM) of a change in any of the variables on the right hand side in equation (1), the following equation is derived from equation (1):

$$CM_1 = CM_0(W_1/W_0)^{\beta 1}(S_1/S_0)^{\beta 2}(L_1/L_0)^{\beta 3}(I_1/I_0)^{\beta 4}(H_1/H_0)^{\beta 5} \ldots (2)$$

Subscript 0 denotes the state of a variable prior to an intervention, and subscript 1 denotes the state after an intervention. So for instance if sanitation coverage rate in a country is raised from S_0 to S_1, equation (2) predicts that child mortality declines from CM_0 to CM_1 based the coefficients (β) in equation (1).[5]

It should be noted that equation (2) portrays interdependence between the interventions in relation to child mortality. This means that if two interventions are implemented jointly, the magnitude of benefit in terms of reduced child mortality is less than the sum of benefits of implementing one or the other intervention. This is consistent with results from other studies. For instance, reductions in child mortality associated with provision of safe sanitation facilities is likely to be larger if mothers are illiterate or if plentiful water is unavailable. Similarly, an increase in water quantity might be less effective in reducing child mortality if safe sanitation facilities are available. Esrey and Habicht (1988) provide a discussion and empirical evidence of some of these issues. Equation (2) also postulates interdependence between immunization and water, sanitation and literacy. A reason for this is that risk of mortality from childhood diseases (such as measles) is likely to be less if child health is not already impaired by waterborne infectious diseases.

VI. Potential Health Benefits of Interventions.

In this section, estimates of potential health benefits of increased immunization, increased female literacy, and increased access to water and sanitation are carried out in a first stage, and improved hygiene through a hygiene education programme in a second stage.

The first stage involves the following four specific interventions to reduce annual child deaths in developing countries:

(a) Increase child immunization to 100%;
(b) Increase female literacy (age 15-24) to 100% through general education;
(c) Provide safe and plentiful water to 100% of the population; and
(d) Provide safe sanitation facilities to 100% of the population.[6]

Estimated annual preventable child deaths for each of the interventions, if implemented separately, are presented in Table 6.1 based on the estimated coefficients in regression (2) in Table 5.1 and equation (2). Full coverage provision of sanitation is estimated to prevent 1.5 million child deaths per year, followed by 1.5 million from eradicating female illiteracy, about 1 million from safe water, and more than 750

[5] The coefficients represent constant elasticities. Predicted change in child mortality by the derivative of equation (1) would therefore be overstated.
[6] The current rates for the developing world are 80% for immunization, 78% female literacy, 78% for water, and 52% for sanitation.

thousand from full child immunization coverage. Although the coefficient for immunization in regression (2) is not statistically significant it is included in the analysis here and the cost effectiveness analysis. It is included primarily because WHO reporting of estimates of about 780 thousand and 310 thousand deaths a year worldwide due to measles and tetanus, respectively (WHO 2001).

Implemented jointly, full water and sanitation coverage is estimated to prevent almost 2.5 million child deaths a year, while joint implementation of all four interventions is estimated to prevent about 4 million deaths a year. It should be noted that the sum of estimates (1) through (4) in Table 6.1 is higher than deaths prevented in (6) because of the interdependence discussed in section V in relation to equation (2).

Almost half of estimated preventable deaths are in Sub-Saharan Africa, followed by about one-quarter in India. In percentage terms, the largest estimated reductions from joint implementation of all four interventions are also in Sub-Saharan Africa and India (Table 6.2), with reductions of close to 50 percent. The lowest reductions are in Latin America and the Caribbean. The cross-regional differences in reductions are because of the different coverage rates of water and sanitation, female literacy, and child immunization (Table 4.1).

Table 6.1: Estimated Preventable Child Deaths
(thousands per year)

	India	China	Other Asian countries	Middle eastern crescent	Sub-Saharan Africa	Latin America/ Caribbean	Total
(1) Increase child immunization to 100%	110	5	30	85	525	15	770
(2) Increase female literacy to 100% (age 15-24)	460	15	135	280	615	15	1,520
(3) Provide safe water to 100% of the population	90	60	90	90	700	20	1,050
(4) Provide safe sanitation to 100% of the population	570	150	115	105	565	25	1,530
(5) Provide safe water *and* sanitation to 100% of the population	635	200	195	185	1,165	45	2,425
(6) Increase immunization *and* female literacy *and* water *and* sanitation to 100%	1,030	215	330	495	1,910	70	4,050

Source: Estimates are from statistical regression analysis of 84 countries by the author.

Table 6.2: Predicted Change in Child Mortality Rates by Region

Year 1999-2000	India	China	Other Asian countries	Latin America/ Caribbean	Middle eastern crescent	Sub-Saharan Africa
Child mortality rate (deaths per 1000 births)	90	37	65	38	92	166
Predicted child mortality rate (deaths per 1000 births)*	49	26	47	32	63	86
Predicted percentage reduction in child mortality	46%	30%	28%	16%	32%	48%

*Predicted child mortality rates are based on the implementation of immunization, hygiene education, and water and sanitation investments

The remainder of this section provides a discussion and estimates of the potential benefits of improved hygiene. Hygiene refers to a procedure or system of procedures or activities used to reduce microbial contamination on environmental sites and surfaces in order to prevent the transmission of infectious disease (IFH 2001). Thus hygiene involves personal, domestic and community hygiene. In a developing country context, good hygiene practices might be particularly important in the presence of poor sanitary conditions, and includes, perhaps most importantly, adequate hand washing, domestic cleaning, and removal of contamination in the outdoor environment, particularly where children are present.

Varley et. al. (1998) present estimates of the health benefits of improved hygiene based on a review of 65 studies, and cites a range of 10-30 % reduction in diarrhoeal incidence/morbidity. Similarly, Esrey et. al. (1991) cites a range of 20-40%., and Curtis (2002) reports a mean reduction of 44% in cases of severe diarrhea from good hand washing practices (see section III).

However, studies of the potential role of hygiene in reducing child mortality are very limited in number. Esrey and Habicht (1988) present the results of a study in Malaysia that assesses the impact on child mortality of literate vs. illiterate mothers under various conditions of water supply and sanitation. The results suggest that literacy reduces child mortality by about 50% in the absence of adequate sanitation (but only by 5% in the presence of good sanitation facilities). Literacy is also found to reduce child mortality by 40% if piped water is present, suggesting that literate mothers take better advantage of water availability to protect their children. If no piped water is available the findings indicate that literacy reduces child mortality by 20%.

A similar estimate of the impact of literacy in relation to sanitation can be provided in this study based on the derivates of equation (1), the estimated coefficients from regression (2) presented in Table 5.1 and the regional data in Table 4.1 (see Annex A1). In the situation of not having access to safe sanitation, the predicted reduction in child mortality from female literacy ranges from 36% to 47% (Table 6.3), which is close to the findings of Esrey and Habicht (1988) in Malaysia. The differences in predicted mortality rates and percentage reductions across regions are due to the different levels of water supply coverage, immunization rates, and other factors affecting child mortality.

Table 6.3: Child mortality Reductions from Literacy

	India	China	Other Asian countries	Middle eastern crescent	Sub-Saharan Africa	Latin America/ Caribbean
Predicted child mortality rate if no sanitation and illiterate	173	71	125	176	318	73
Predicted child mortality rate if no sanitation and literate	89	45	72	94	175	46
Predicted reduction in child mortality rate from literacy	48%	36%	42%	47%	45%	37%

Source: Estimated by author.

Based on the findings by Esrey and Habicht, and that sanitation coverage is lower than water supply coverage in all regions, except in Sub-Saharan Africa where they are about the same (see Table 4.1), a hygiene programme is evaluated that targets households with illiterate mothers that have children under the age of five, and that do not have access to safe sanitation facilities. The total number of such households is conservatively estimated at 30 million, of which one-half are in India and one-quarter in Sub-Saharan Africa. This constitutes about 3% of all households in the developing world, and more than 7% of all households in India and Sub-Saharan Africa (Table 6.4).

While Esrey and Habicht finds that literacy reduces child mortality by 50% in the absence of safe sanitation facilities (relatively similar to the findings in this study), it is not clear if improvements in hygiene would reduce child mortality by more or less than 50%. On the one hand, literate mothers may intervene more effectively in the case of an infectious disease. However, hygiene education may be more effective than literacy in preventing disease and child mortality.

Given the uncertainties as to the effectiveness of hygiene improvement in reducing child mortality, a "high" and "low" case is developed here to estimate preventable child deaths. The "high" case applies the predicted percentage reductions in Table 6.2, and the "low" case is a uniform 25% reduction in child mortality. Both cases are applied to households with illiterate mothers with children under the age of five and no access to safe sanitation facilities.

The results of "high" and "low" case are presented in Table 6.4, indicating that an estimated 0.6-1.1 million deaths of children can be prevented each year by improvements in hygiene in the developing world (see Annex A1). The vast majority of estimated preventable deaths are in India and Sub-Saharan Africa. This is because of the relatively high female illiteracy rates *and* the high proportion of the population without safe sanitation.

Table 6.4: Hygiene Improvement – Estimated Preventable Child Deaths
(thousands per year)

	India	China	Other Asian countries	Middle eastern crescent	Sub-Saharan Africa	Latin America/ Caribbean	Total
Targeted Number of Households (millions)	15.3	1.6	2.8	3.2	7.0	0.4	30.3
Percent of all households	7.5%	0.4%	1.8%	2.9%	7.3%	0.3%	1.8%
Percent of all households with children under age five	24.2%	2.5%	6.8%	7.4%	12.4%	1.3%	10.6%
Child deaths averted per year ("high" reduction case)	510	12	59	105	439	4	1,130
Child deaths averted per year ("low" reduction case)	264	8	35	57	245	3	612

Source: Estimates by the author. Details of estimates are in Annex A1.

VII. Unit Costs of Interventions.

In order to undertake a cost-effectiveness analysis of child mortality reduction, intervention costs are needed. Such costs have to be annualized in order to be comparable to annual preventable deaths, and are not readily available at the country or regional level. Thus annualized costs are estimated in this section. They should be considered orders of magnitude rather than exact figures. However, as seen in the next section, the ranking of cost-effective interventions is relatively insensitive to changes in cost estimates.

Unit cost estimates of interventions are summarized in Table 7.1. Cost of water supply and sanitation is based on construction cost per person, for various types of service levels, as presented in the Global Water Supply and Sanitation Assessment 2000 Report (WHO/Unicef 2000) for Asia, Africa and Latin America and the Caribbean. Construction costs for Asia have been applied to China and India, and the average for Asia and Africa has been applied to the Middle Eastern Crescent. Rural and urban construction costs have been calculated taking into account cost differentials across types of services, and then weighted by regional water and sanitation coverage rates to arrive at the costs presented in Table 7.1, annualized at 10 percent discount rate over 20 years (see Annex A2 for details).[7]

Cost of immunization per child is based on estimates presented in Abt Associates Inc (2001) and Khan and Yoder 1998. The costs are for full immunization and reflect personnel, vaccines, other recurrent, and capital costs. In Table 7.1, regional costs are based on US $20 for Sub-Saharan Africa (low end of three country estimates in Abt Associates Inc) and adjusted by purchasing power parity GDP per capita differentials

[7] A discount rate of 10 percent has been applied to reflect the opportunity cost of capital investment. A lower discount rate would reduce annualized cost. Annualized cost changes minimally if discount period is increased to 30 years.

across the regions as an approximation for labor cost differentials.[8] Cost of education per student per year is based on national education expenditure data and population age distributions (World Bank 2001a), and is presented in Table 7.1. In the cost-effectiveness analysis in the next section nine years of schooling have been assumed necessary to reap the full health benefits of literacy. The nine-year cost of education per student has been annualized over 10 years to reflect the child bearing period of a typical woman in a developing country and to be consistent with the data used in the assessment, i.e., females in the age group of 15-24 (not presented in Table 7.1).

Cost of hygiene improvement includes private costs of a minimum amount of additional water consumption and hygiene products (soap, detergent etc.), and the cost of a hygiene education programme. Total estimated hygiene improvement cost per household per year is presented in Table 7.1. Estimated cost is based on regional average cost of water supply as reported in WHO/Unicef (2000), cost of a hygiene education programme as reported in Varley et al (1998), and author's estimate of hygiene product costs. As average regional costs are not available for hygiene programmes and products, the costs have been adjusted across regions by purchasing power parity GDP per capita differentials (the non-tradable fraction of cost). Details of the estimated costs are in Annex A2.

Table 7.1: Cost Estimates of Interventions (US $)

	China	India	Other Asian countries	Middle Eastern Crescent	Sub-Saharan Africa	Latin America/ Caribbean
Water supply (annualized costs per person)	5	6	5	6	4	9
Sanitation (annualized costs per person	8	8	8	10	10	14
Immunization (cost per child)	35	25	30	35	20	60
Female education (cost per year per student)	120	80	110	200	85	800
Hygiene improvement (cost per household per year)	12	13	13	17	17	21

Source: Estimated by author. Figures are rounded to the nearest dollar for water, sanitation, immunization and hygiene, and to the nearest five dollars for education.

VIII. Cost-Effectiveness Analysis.

Section VI presented the estimated potential for preventing child deaths in the developing regions of the world by an increase in provision of safe water and sanitation, immunization, female literacy, and improved hygiene. Based on these estimates, and the costs presented in section VII, this section provides estimates of the cost of preventing the death of children from each of these interventions.

[8] Only personnel cost (about 60% of total cost) is adjusted by purchasing power parity GDP per capita differentials.

Estimated cost of preventing the death of a child is presented in Table 8.1.[9] These estimates are orders of magnitude, and will vary from country to country within each region. Nevertheless, the estimates indicate a distinct ranking of the cost-effectiveness of the interventions, and three important observations may be presented:

(1) Hygiene improvement (including programme and private cost) is estimated to be the lowest cost option followed by child immunization;
(2) The cost of female literacy is comparable to the cost of water supply and/or sanitation in most of the regions, except Latin America and the Caribbean; and
(3) The cost of any substantial reductions in child deaths is significantly higher in China and Latin America/Caribbean because of the relatively low child mortality rates already achieved (and vs. for Sub-Saharan Africa).

Table 8.1: Cost of Preventing the Death of a Child (US $)

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

Source: Estimates are from analysis by the author. Cost of water, sanitation, and literacy per death averted is rounded to the nearest one thousand dollars, and cost of immunization and hygiene improvement to the nearest one hundred dollars.

Figure 8.1 presents the cost of preventing a child death as weighted averages for the developing world, based on the estimates in Table 8.1. The average cost of preventing a death by increasing child immunization is around US $1,000, which implies a cost per DALY averted of almost US $30. The cost in Sub-Saharan Africa is as low as

[9] Estimated cost per death averted is based on a marginal change in female literacy rates, coverage rates of water, sanitation, and immunization, and number of households targeted by a hygiene education programme by applying the first order derivate of equation (1).

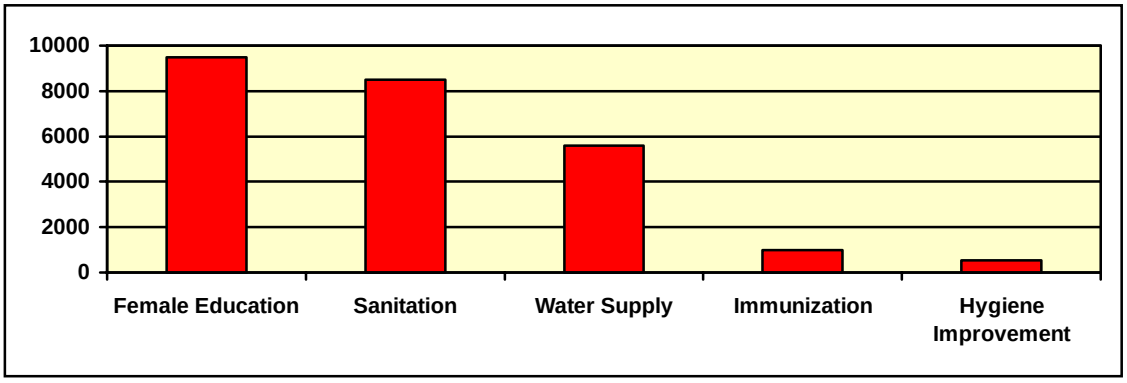
US $10 per DALY averted.[10] These estimates are consistent with findings presented in Jamison et al (1993).

The weighted average cost of preventing a death by hygiene improvement in the developing world is estimated at around US $500, or US $15 per DALY averted[11]. This is only one-third of the estimated cost by Varley et al (1998) of hygiene improvements for households without water and sanitation, even though Varley et al do not include the private cost of hygiene improvement. However, estimates in Varley et al are relatively similar to the "low" case estimates in Table 8.1 for Asia and Middle Eastern Crescent.

Varley et al (1998) report that the cost of water and sanitation per death averted presented in Walsh and Warren (1979) is around US $10,000 in 1996 prices. This is very similar to the developing world average estimate presented in Figure 8.1. However, as seen in Table 8.1 the cost per death averted of water and sanitation is only US $1,000-3,000 in Sub-Saharan Africa.

As regards female literacy the literature review undertaking during this study did not reveal any estimates of the cost effectiveness of female literacy in reducing child mortality.

Figure 8.1: Cost of Preventing a Child Death (US$-developing world average)



Source: Estimated by author as weighted average costs based on Table 8.1.

The largest uncertainties regarding the intervention costs, and thus the cost-effectiveness analysis, are the cost of literacy and the private cost of hygiene improvement. The cost of literacy is based on nine years of schooling. If, however, five years of schooling is sufficient to reap the full health benefits of literacy, the cost per death averted would be almost one-half of the figures presented in Table 8.1 and Figure 8.1. In this case, female literacy would be more cost effective than water and sanitation in most regions except Latin America and the Caribbean.

[10] The death of child under the age of five represents close to 35 disability adjusted years (DALYs), because of the age weighting and discounting of future life years.
[11] The weighted average cost for hygiene improvement is almost exclusively (85%) determined by the cost for India and SSA as most of the benefits are estimated to come from there.

As regards private cost of hygiene improvement it is possible that the cost of water for hygiene purposes is underestimated. The targeted households are those that do not have sanitation and have illiterate mothers. It is very possible that many of these households do not have improved water supply and rely either on vended water or spend excessive time on water collection. If water prices are four times higher than applied in the above cost-effectiveness analysis (i.e., US $0.8 instead of US $0.2 per cubic meter), the total cost of hygiene improvement would double. In this case the cost per death averted would increase to an average of US $1,000 and be very similar to the cost-effectiveness of immunization.

It should also be said that while provision of water and sanitation, and education for female literacy may be more expensive than other options to prevent infectious diseases, there are other benefits of these interventions that are valued by recipients and society. Thus the result of the analysis in this section does not suggest that these interventions should be ignored. On the contrary, the results presented here suggest that the relevant authorities of water and sanitation services and education should take account of the significant health benefits associated with these interventions.

IX. Programme Cost.

The estimated total costs of interventions per year are presented in Table 9.1. The cost of water and sanitation is annual cost for a 10-year programme to reach 100% coverage rates. With no surprise the cost of sanitation is substantially higher than the cost of water because of the generally lower sanitation coverage rates, and somewhat higher unit costs.

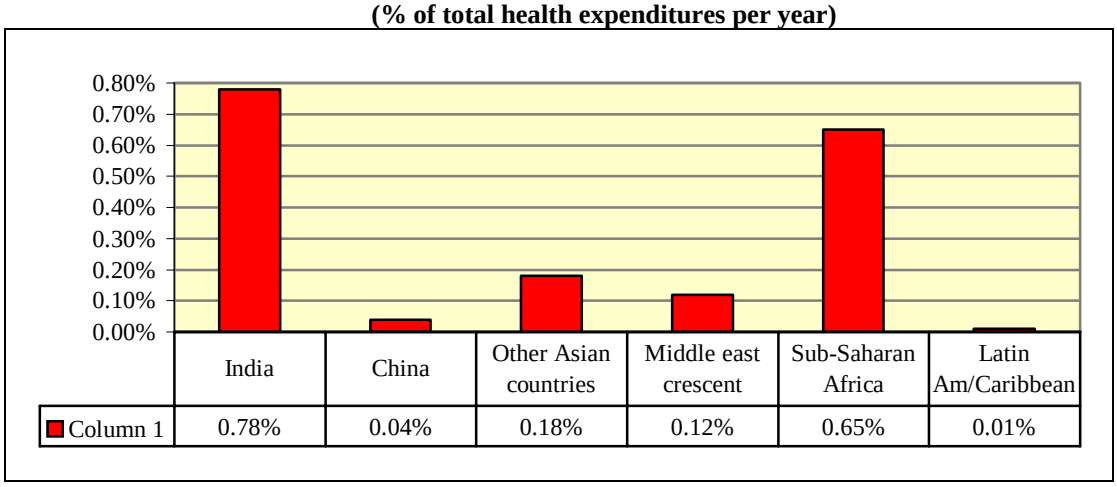
Table 9.1: Annual Cost of Interventions
(US $ millions)

	India	China	Other Asian countries	Middle eastern crescent	Sub-Saharan Africa	Latin America/ Caribbean
Provide safe water to 100% of the population	600	1,400	750	500	1,000	600
Provide safe sanitation to 100% of the population	4,800	5,600	1,700	1,200	2,400	1,400
Increase immunization to 100% of all children	120	30	50	130	220	80
Female literacy to 100%	3,200	400	1,800	4,700	2,500	2,400
Hygiene improvement for “high risk” households	200	20	40	60	120	10

Source: Estimates by author. Cost of water and sanitation provision is annual cost for a 10-year programme to reach 100% coverage rates. Cost of water, sanitation and literacy is rounded to nearest one hundred million dollars. Cost of immunization and hygiene improvement is rounded to nearest ten million dollars. Cost of hygiene improvement includes cost of hygiene programme and private cost of hygiene improvement.

To place the cost of hygiene improvement (hygiene programme and private cost) in some perspective, Figure 9.1 presents the annual cost of the programme as a percentage of total (government and private sector) health expenditures. The cost reaches 0.6-0.8% of health expenditures in Sub-Saharan Africa and India because of the larger number of households with female illiteracy and without sanitation than in the other regions.

Figure 9.1 : Cost of Hygiene Improvement
(% of total health expenditures per year)



Source: Estimates by author.

X. Infectious Disease Prevention and Income

A remaining issue to discuss is the affordability of developing countries to implement a comprehensive programme, as presented here, to prevent infectious diseases. There are two dimensions to this issue. First, countries can choose to be selective in order to benefit from low-cost (cost-effective) interventions first, such as immunization and hygiene education programmes. Second, there are plenty of examples of lower-income countries that have achieved substantial reductions in infectious diseases and child mortality, suggesting that the issue has less to do with affordability but rather with government willingness and a priority to achieve equity in health performance among its citizens.

Countries that have performed particularly well include Nicaragua, Vietnam, Sri Lanka, and Uzbekistan among lower income countries, and Chile and Costa Rica among middle-income countries. Annex A.3 presents child mortality rates relative to child mortality rates that may be expected by countries' level of GDP per capita. This is presented for the sample of 84 countries used in the analysis in this report, except for a few countries for which GDP figures are not readily available.

Table 10.1 presents a summary of the table in the Annex. It suggests that child mortality rates in most of the Asian countries are lower than expected by their GDP per

capita, while the opposite is the case in Sub-Saharan Africa. This is worth a consideration given that GDP per capita for most of the Asian and Sub-Saharan countries are relatively similar. Based on the analysis in this report, part of the reason for the better performance in Asia is, on average, lower female illiteracy rates, and higher water, sanitation and immunization coverage rates than in Sub-Saharan Africa. But part of the reason is also the high HIV rates, malaria and other factors in the latter region.

Table 10.1: Child Mortality Rate Performance Relative to GDP per capita

Number of countries in each region:							
	China	India	Other Asian countries	Middle Eastern Crescent	Sub-Saharan Africa	Latin American/ Caribbean	Total
Lower than expected child mortality	1	1	9	8	10	13	42
Higher than expected child mortality	0	0	2	6	20	9	37

Source: See Annex A3.

XI. Summary and Conclusions

The disease burden per person in developing countries – as measured by years of life lost due to illness, injuries and early death – is more than two times higher than in high-income countries. Infectious diseases alone explain more than 50% of this difference. In total, infectious diseases account for as much as 30 percent of the disease burden in the developing world, and averages more than 10 times higher per person than in the high-income countries.

About one-quarter of the infectious disease burden in developing countries is related to water, sanitation, and hygiene. There are 2.2 million diarrhoeal deaths and 4 billion cases of diarrhoea per year, intestinal worms infect about 500 million people, 200 million people have schistosomiasis, and 6 million are blind from trachoma.

Children suffer disproportionately from infectious diseases in developing countries. It is estimated in this report, from a cross-country analysis of 84 developing countries, that the death of 4 million children can be prevented each year by reaching a 100% child immunization rate, reaching 100% of the populations with potable water supply safe sanitation, and eradicating female illiteracy[12]. This is estimated to reduce child mortality by close to 50% in India and Sub-Saharan Africa.

[12] The current rates for the developing world are 80% for immunization, 22% female illiteracy, 78% for water, and 52% for sanitation.

The potential benefit of improved hygiene for reducing child mortality was also analyzed. A cost-effectiveness analysis revealed that a hygiene education programme 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. A programme that reaches households with children under the age of five, with illiterate mothers, and without safe sanitation, i.e., about 30 million households worldwide, is estimated to prevent about 0.6-1 million deaths per year.

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ANNEX

A1. Estimating Preventable Child Deaths from Hygiene Improvement

A hygiene programme is evaluated that targets households with illiterate mothers that have children under the age of five, and that do not have access to safe sanitation facilities. The methodology and estimated reductions in annual child deaths is presented in Table A1.1.

While some of the data in Table A1.1 are from World Bank (2001a), most are estimated by author and will be explained in this section. Average household size and percentage of households with children under the age of five for each of the regions and India and China is estimated based on total fertility rates for each of the countries in the sample in this study. Fertility rates are from World Bank (2001a). The number of households in each region without sanitation, with children under the age of five, and illiterate mothers as presented in (1) in Table A1.1, is estimated based on the percentage of the population without sanitation and female illiteracy rates. It is assumed that female illiteracy is uniformly distributed across households with and without sanitation. It is likely, however, that households without sanitation have higher than average illiteracy rates as these characteristics tend to be correlated (correlation coefficient=0.68 for the sample of 84 countries included in this study). Similarly, households with these characteristics are very often poorer households that tend to have more than the average number of children. In this case, the number of households and preventable deaths are underestimated. The number of children under the age of five (in the households without sanitation and with illiterate mothers), as presented in (2) in the table, is calculated based on (1) and total fertility rates.

Child mortality rates in households without sanitation and with illiterate mothers are estimated based on the first order derivates of equation (1), the coefficients from regression (2) in Table 5.1, and the data in Table 4.1. A “high” and “low” case in terms of reductions in child mortality rates from the hygiene programme is presented in (5) and (6) in Table A1.1. The “high” case is the same as the predicted reduction in child mortality from literacy, based on the coefficients from regression (2), which is somewhat lower than reductions presented in Esrey and Habicht (1998). The “high” case would be an overestimate of the potential effectiveness of hygiene improvements if: (a) literacy is as effective as hygiene education in improving hygiene; and (b) literacy improves infectious disease intervention resulting from the lack of safe sanitation. The “low” case is half of the reductions from literacy reported by Esrey and Habicht. Based on (5) and (6), estimated annual preventable child deaths from hygiene education on the order of 0.6 to 1.1 million are presented in (7) and (8) in Table 4.1.

Table A1.1: Child Mortality Reductions from Hygiene Improvements

	China	India	Other Asian Countries	Middle Eastern Crescent	Sub-Saharan Africa	Latin America/ Caribbean
Population (millions)	1261	1016	718	616	619	515
Sanitation (% of population)	38	31	66	76	54	78
Illiteracy (% of females 15-24)	4	35	20	31	27	6
Crude birth rate (per 1000)	15	25	23	28	40	23
Average household size	3.5	5.0	4.5	5.5	6.5	4.5
Total number of households (millions)	360	203	160	112	95	114
Total annual births (millions)	18.9	25.4	16.5	17.2	24.8	11.8
Households with children u-5	18%	31%	26%	39%	59%	26%
Illiterate and No Sanitation and Children u-5						
(1) Number of households (millions)	1.6	15.3	2.8	3.2	7.0	0.4
(2) Number of children u-5 (millions)	2.3	30.7	5.6	6.4	15.4	0.8
(3) Child mortality rate (illiterate and no sanitation)	70.9	172.5	124.6	176.3	318.1	72.8
(4) Annual child deaths (000)	33	1058	140	226	978	11
(5) Reduction in child mortality (%) "high case"	36%	48%	42%	47%	45%	37%
(6) Reduction in child mortality (%) "low case"	25%	25%	25%	25%	25%	25%
(7) Child Deaths prevented per year (000) "high case"	12	510	59	105	439	4
(8) Child Deaths prevented per year (000) "low case"	8	264	35	57	245	3

Source: Estimated by author. Country population, sanitation, illiteracy, and crude birth rates are from World Bank (2001a).

A2. Cost of Interventions

Water supply and sanitation construction costs per person are presented in Tables A2.1-2, and are from the Global Water Supply and Sanitation Assessment 2000 Report (chapter 3). The costs represent regional averages and vary significantly across countries within each region, depending on local characteristics and input prices. The costs, as presented in Tables A2.1-2, are therefore rounded to the nearest 5 dollars in order not to give the impression of exactness.

Table A2.1:
Average Water Supply Construction Cost per Person 1990-2000(US $)

	Asia	Africa	Latin America/ Caribbean
Household connection	90	100	145
Standpost	65	30	40
Borehole	15	25	55
Dug well	20	20	50
Rainwater	35	50	35

Source: Global Water Supply and Sanitation Assessment 2000 Report. Costs are rounded to nearest 5 dollars.

Table A2.2:
Average Sanitation Construction Cost per Person 1990-2000 (US$)

	Asia	Africa	Latin America/ Caribbean
Sewer connection	155	120	160
Small bore sewer	60	50	110
Septic tank	105	115	160
Pour-flush systems	50	90	60
VIP	50	55	50
Simple pit latrine	25	40	60

Source: Global Water Supply and Sanitation Assessment 2000 Report. Costs are rounded to nearest 5 dollars.

For the purpose of the analysis in this paper, type of service costs need to be converted to urban and rural costs because the data on water and sanitation coverage rates are reported in terms of urban and rural. It should be noted that urban and rural costs depend on type of service. The costs presented in Table A2.3 reflect the most prevalent types of services in Asia, Africa, and Latin America/ Caribbean as reported in the Global Assessment report. Urban water supply cost is the cost of household connection, and rural water supply cost is the average cost of standpost and borehole in Table A2.1. Urban sanitation cost is the average cost of sewer connection and septic tank, and rural sanitation cost is the average cost of septic tanks, pour-flush systems, and pit latrines in Table A2.2. The costs are rounded to the nearest 5 dollars. Costs for China and India are assumed the same as the average for Asia, and costs for the Middle Eastern Crescent are assumed to be the average of costs in Asia and Africa.

Table A2.3:
Urban and Rural Construction Cost per Person 1990-2000(US $)

	China	India	Other Asian countries	Middle Eastern Crescent	Sub-Saharan Africa	Latin America/ Caribbean
Urban water supply	90	90	90	95	100	145
Rural water supply	40	40	40	35	25	50
Urban sanitation	130	130	130	125	120	160
Rural sanitation	60	60	60	70	80	95

Source: Calculated by author based on Tables A2.1-2, and rounded to nearest 5 dollars.

In order to calculate the cost of providing full coverage of water and sanitation the rural and urban coverage rates in Table A2.5 (and rural and urban population shares)

have been applied to the construction costs in Table A2.3, resulting in the weighted average construction costs presented in Table A2.4 (rounded to the nearest 5 dollars).

Table A2.4 also provides annualized construction costs, discounted at 10 percent over 20 years, which are applied in the estimation of cost effectiveness of interventions to reduce child mortality.

Table A2.4: Weighted Average Construction Costs (US $)

	China	India	Other Asian countries	Middle Eastern Crescent	Sub-Saharan Africa	Latin America/ Caribbean
Average construction cost per person						
Water supply	45	50	45	50	35	80
Sanitation	70	70	70	80	85	125
Annualized construction cost per person						
Water supply	5	6	5	6	4	9
Sanitation	8	8	8	10	10	14

Source: Calculated by author based on Tables A2.3 and A2.5.

Table A2.5: Urban and Rural Regional Coverage Rates

	China	India	Other Asian countries	Middle Eastern Crescent	Sub-Saharan Africa	Latin America/ Caribbean
Urban water	94%	92%	91%	92%	83%	93%
Rural water	66%	86%	72%	75%	40%	62%
Water (rural and urban)	75%	88%	78%	83%	54%	85%
Urban sanitation	68%	73%	86%	93%	82%	87%
Rural sanitation	24%	14%	56%	56%	41%	49%
Sanitation (rural and urban)	38%	31%	66%	76%	54%	78%

Source: Based on country data in Global Water Supply and Sanitation Assessment 2000 Report.

Hygiene improvement costs are presented in Table A2.6. They include both private costs of improvements and costs of a hygiene education programme. Additional water consumption in the amount of 10 liters per day per person has been used as a minimum for hygiene improvement purposes.[13] Cost of water is from WHO/Unicef (2000). Cost of additional hygiene products of US $1 per person per year has been used as a minimum. This is applied to Sub-Saharan Africa, and 25 percent of the cost is adjusted for the other regions by purchasing power parity GDP per capita differentials to reflect differences in costs of non-tradable inputs. The cost of a hygiene education programme has been set at US $3 per household per year (annualized) for Sub-Saharan Africa (see Varley et. al. 1998). Half of cost has been adjusted for the other regions in relation to their GDP per capita (at purchasing power parity) to reflect differences in costs

[13] Total cost of hygiene improvement would increase by 20-25 percent if minimum water requirement is 20 liters per person per day.

of labor and other non-tradable inputs of programme development and delivery. Total cost per household per year is rounded to the nearest dollar.

Table A2.6: Annual Cost Per Household of Improved Hygiene (US $)

	China	India	Other Asian countries	Middle Eastern Crescent	Sub-Saharan Africa	Latin America/ Caribbean
Increased water use (ltrs per person per day)	10	10	10	10	10	10
Cost of water per m^3	0.2	0.2	0.2	0.25	0.3	0.3
Cost of water per person per year	0.73	0.73	0.73	0.91	1.10	1.10
Cost of hygiene products per person per year	1.3	1.1	1.2	1.3	1.0	1.8
Average household size	3.5	5	4.5	5.5	6.5	4.5
Private cost per household per year (water and hygiene products)	7.2	9.2	8.7	12.4	13.6	13.1
Cost of hygiene programme per household per year	5.0	3.6	4.2	5.0	3.0	7.9
Total cost per household per year	12	13	13	17	17	21

Source: Estimated by the author.

A3. Child Mortality and Income

Table A3.1 presents the difference between actual child mortality rate and child mortality rate predicted by GDP per capita. Predicted child mortality is based on a regression analysis of child mortality and GDP per capita, and indicates the child mortality rate that would be expected at a particular level of GDP per capita.

Table A3.1: Child Mortality Rates and Income

	Child Mortality Rate (deaths per 1000 births in 1999-2000)	GDP per capita (US $ in year 2000)	Percent difference in Child Mortality Rate (actual vs. predicted by GDP per capita)*
Nicaragua	43	475	-61%
Chile	12	4,649	-60%
Costa Rica	14	4,315	-56%
Paraguay	27	1,397	-43%
Jamaica	24	2,631	-41%
Colombia	28	1,959	-36%
Panama	25	3,470	-31%
Ecuador	35	1,076	-28%
Uruguay	17	6,052	-24%
Trinidad and Tobago	20	5,444	-22%
Venezuela, RB	23	4,985	-18%
El Salvador	36	2,106	-17%
Honduras	46	915	-7%
Haiti	118	481	9%
Brazil	40	3,454	11%
Peru	48	2,100	11%
Dominican Republic	47	2,325	12%
Guatemala	52	1,672	14%
Guyana	76	831	52%
Mexico	36	5,864	54%
Argentina	22	7,709	62%
Bolivia	83	1,017	69%
Vietnam	42	399	-66%
Sri Lanka	19	847	-62%
Mongolia	73	407	-41%
Nepal	109	228	-32%
Bangladesh	89	369	-32%
Thailand	33	2,008	-25%
Philippines	41	995	-17%
Indonesia	52	728	-7%
Cambodia	143	267	-7%
Lao PDR	143	328	2%
Papua New Guinea	77	834	54%
China	37	856	-26%
India	90	472	-18%

*A negative percentage indicates that the child mortality rate is lower than expected by the country's GDP per capita. Expected child mortality rate by level of GDP per capita is based on a regression analysis of child mortality and GDP per capita.

Table A.4 (continued): Child Mortality Rates and Income

	Child Mortality Rate	GDP per capita	% difference in Child Mortality Rate*
Uzbekistan	29	548	-69%
Syrian Arab Republic	30	1,023	-39%
Jordan	31	1,707	-32%
Iran, Islamic Rep.	33	1,546	-29%
Sudan	109	376	-16%
Algeria	39	1,770	-13%
Yemen, Rep.	97	495	-8%
Lebanon	32	3,832	-6%
Pakistan	126	447	9%
Oman	24	6,263	13%
Egypt, Arab Rep.	54	1,541	17%
Turkey	45	3,061	18%
Morocco	62	1,162	29%
Saudi Arabia	25	6,756	34%
Eritrea	105	146	-41%
Mauritius	23	3,795	-33%
Ghana	109	282	-27%
Gambia, The	110	308	-24%
Congo, Dem. Rep.	161	109	-14%
Kenya	118	346	-14%
Ethiopia	166	98	-12%
Togo	143	274	-6%
Madagascar	149	259	-4%
Central African Republic	151	267	-1%
Tanzania	152	276	1%
Mauritania	142	350	5%
Nigeria	151	325	7%
Uganda	162	283	8%
Benin	145	360	9%
Senegal	124	459	10%
Chad	189	183	11%
Lesotho	141	424	17%
Rwanda	203	207	23%
Mozambique	203	216	24%
Guinea-Bissau	214	186	26%
Zambia	187	289	26%
Malawi	227	153	28%
Mali	223	216	36%
Zimbabwe	118	607	44%
Niger	252	172	46%
Cameroon	154	576	75%
South Africa	76	2,941	96%
Cote d'Ivoire	180	584	108%
Namibia	108	2,000	147%

*A negative percentage indicates that the child mortality rate is lower than expected by the country's GDP per capita.