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Hygiene and health in developing countries: defining priorities through cost – benefit assessments

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Presented here are the four preliminary conclusions in the assessment of health and hygiene in developing countries: (a) child mortality, and disease burden associated with hygiene, water and sanitation in the developing and the developed regions of the world, has declined substantially in the past two decades, but substantial inter-regional and cross-country differences persist; (b) while child mortality and disease burdens decline with higher income levels, a substantial number of countries have been performing far better in reducing child mortality and disease burdens than their income levels would indicate, suggesting that active policy and investment interventions can yield significant health improvements without necessarily jeopardising economic growth; (c) despite the evidence of the role of water and sanitation services in reducing mortality and morbidity, service coverage at the country level has not increased as much as one may have expected in the past decade, in part because of the substantial resource requirements; (d) the paper will provide some new perspectives and evidence on the cost-effectiveness of interventions to reduce the disease burden of poor water and sanitation services and inadequate hygiene practices, in particular with regard to economic evaluation and in reference to hygiene programmes.

Keywords: Health; hygiene; developing countries; disease burden; cost-effectiveness; sanitation; child mortality; diarrhoeal disease.

Introduction

Developing countries have achieved substantial improvements in infectious disease control and child mortality rates over the past several decades (Ahmad *et al.* 2000). However, infectious diseases are still among the leading causes of child mortality and overall disease burden in several parts of the world. For instance, diarrhoeal diseases and lower respiratory infections continue 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,[1] and Sub-Saharan Africa.[2] In the developing world as a whole, the infectious disease burden is more than ten times higher per capita than in the high-income countries (World Bank 2001b).

The objective of this paper is to provide quantitative estimates of the potential health benefits and cost-effectiveness of hygiene education programmes and hygiene improvements for the control and prevention of infectious diseases in relation to child mortality.[3] Using country level data for more than 80 developing countries, the paper provides an analysis of the relative importance of hygiene, water, sanitation, literacy, and child immunisation in reducing child

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mortality. Unit costs of interventions are then applied to provide estimates of cost-effectiveness of child mortality reduction.

Pruss *et al*. (2002) estimate the global burden of diarrhoeal disease at around 2.2 million deaths (of whom 90% are children) associated with lack of safe water, sanitation and hygiene by applying relative risk factors. About 1 million of these deaths are estimated to be hygiene related. In terms of specific hygiene interventions, Curtis (2002) reports an average reduction of 40% in diarrhoeal diseases from handwashing based on a review of fifteen studies. The reduction in severe diarrhoea was 44%, which suggests that good handwashing practices in developing countries can significantly reduce child mortality. Studies have also specifically analysed child mortality. Esrey *et al*. (1991) have found from their review of 144 studies that the median reduction in child mortality from improved water and sanitation was 55%. Esrey and Habicht (1988) report from a study in Malaysia that maternal literacy reduces child mortality by about 50% in the absence of adequate sanitation, and by 40% if piped water is present.

Many of the above studies have focused on the role of one or two specific interventions or factors in controlling and preventing infectious diseases and/or reducing child mortality. A study by Rutstein (2000), however, presents a multivariate regression analysis of infant and child mortality in developing countries using Demographic and Health Survey (DHS) data from 56 countries from 1986 to 1998. The study finds a significant relationship between mortality variables and piped water supply, flush toilets, maternal education, access to electricity, medical services, oral rehydration therapy (ORT), vaccination, dirt floors in household dwellings, fertility rates and malnutrition.

This study uses country level data from 1999/2000 for 84 countries accounting for 95% of the population in the developing world. A regional overview of child mortality rates and select determinants included in this paper is presented in Table 1.[4] Data for several other determinants of child mortality are not available for all countries, and a quantification of the relative importance of each determinant therefore remains difficult. For instance, there are very limited and no consistent cross-country data available for important determinants of respiratory child mortality. This implies a serious data gap as respiratory infections are the cause of millions of deaths of children annually. Some data constraints also apply to the frequency of use of ORT, widely perceived as a major contributor to reduced child mortality rates since large-scale introduction in the early 1980s (Victora *et al*. 2000).

Regression analysis

Using natural-log data for 84 countries, the following OLS regression equation was estimated:

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

The variables in the regression equation are defined as follows: CM = under-5 child mortality rate (deaths per 1000 live births); W = percentage of population with access to an improved water source; S = percentage of population with access to safe sanitation; L = percentage of females in age group 15–24 years who are literate; I = percentage of children receiving immunisation; H = percentage of adults in age group 15–49 who have HIV; and D = dummy variables (value 0 or 1).

Estimated coefficients (β), with *t*-statistics in parenthesis, are presented in Table 2. They represent the percentage change in child mortality rate associated with a 1% change in a given explanatory variable. All coefficients, except for immunisation in regression (2), are statistically

Table 1. Regional 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 in 2000 (% of total population)	88%	75%	78%	85%	83%	54%
Access to sanitation in 2000 (% of total population)	31%	38%	66%	78%	76%	54%
Female illiteracy in 2000 (% of 15–24 year olds)	35%	4%	20%	6%	31%	27%
Measles immunisation 1996–97 (% of infants < 12 months)	81%	96%	90%	87%	79%	55%

Source: Calculated based on data from World Development Indicators (World Bank) and Global Water Supply and Sanitation Assessment 2000 Report (WHO/Unicef).

Table 2. Regression estimates

	% Change in child mortality (under 5 years) associated with a 1% change in a given variable	
	Regressions	
Explanatory variables:	*(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)
Immunisation (% 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).

significant at 95%, and the explanatory power of the variables is relatively high with adjusted R^2 at 0.78 and 0.86. 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):

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

Subscript 0 denotes the state of a variable prior to an intervention, and subscript 1 denotes the state after an intervention. If for instance 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 on the coefficients (β) in equation (1).[5]

Potential health benefits

Estimated annual preventable child deaths are presented in Table 3. The estimates are based on the estimated coefficients in regression (2) in Table 2 and equation (2). Although the coefficient for immunisation in regression (2) is not statistically significant it is included in the analysis. WHO reports an estimated 780,000 and 310,000 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. Joint implementation of all four interventions is estimated to prevent about 4 million deaths yearly. It should be noted that the sum of estimates (1) through (4) in Table 3 is higher than deaths prevented in (6). This is because of the interdependence of variables in equation (2). The cross-regional differences in reductions are because of the different coverage rates of water and sanitation, and female literacy and child immunisation rates.

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. They include, therefore, perhaps most importantly, adequate handwashing, domestic cleaning, and removal of contamination in the outdoor environment, particularly where children are present.

Table 3. Estimated preventable child deaths[a] (thousands per year)

	India	*China*	*Other Asian countries*	*Middle Eastern Crescent*	*Sub-Saharan Africa*	*Latin America/ Caribbean*	*Total*
(1) Increase child immunisation to 100%	110	5	30	85	525	15	770
(2) Increase female literacy to 100% (age 15–24 years)	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 immunisation *and* female literacy *and* water *and* sanitation to 100%	1,030	215	330	495	1,910	70	4,050
(7) Percent reduction in child mortality rate based on (6)	46%	30%	28%	32%	48%	16%	

Source: Estimates are from statistical regression analysis of 84 countries by the author.[a]The current rates for the developing world are 80% for immunisation, 78% female literacy, 78% for water, and 52% for sanitation.

Varley *et al*. (1998) present estimates of the health benefits of improved hygiene based on a review of 65 studies. They cite a range of 10–30% reduction in diarrhoeal incidence/morbidity. Similarly, Esrey *et al*. (1991) cite a range of 20–40%, and Curtis (2002) reports a mean reduction of 44% in cases of severe diarrhoea from good handwashing practices. 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. The latter suggests 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%.

Based on the findings by Esrey and Habicht, a hygiene programme is evaluated in this study that targets households with illiterate mothers that have children under the age of 5 years, and that do not have access to safe sanitation facilities. A second motivation for this choice is that sanitation coverage is lower than water supply coverage in all regions, except in Sub-Saharan Africa where they are about the same (Table 1).

Several stages of analysis are involved in estimating the potential reduction in child mortality from improved hygiene in the targeted households. First, child mortality rates are estimated for households with illiterate mothers and no sanitation by applying the derivates of equation (1), the estimated coefficients from regression (2), and the regional data in Table 1. The results are presented in (3) in Table 4. Second, child mortality rate reductions from maternal literacy are estimated by the same procedure as in the first stage. Estimated rate reductions are presented in (4) in Table 4 and range from 36% to 47%. This is close to the findings of Esrey and Habicht (1988) in Malaysia. The differences across regions in Table 4 are due to the different levels of water supply coverage, immunisation rates, and other factors affecting child mortality.

It is not clear, however, if improvements in hygiene would reduce child mortality by more or less than maternal literacy. On the one hand, literate mothers may intervene more effectively in the case of an infectious disease. On the other hand, 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 (4) in Table 4, and the 'low' case is a uniform 25% reduction in child mortality as presented in (5) in Table 5.

In estimating preventable child deaths from improved hygiene, both the 'high' and 'low' case are applied to households with illiterate mothers with children under the age of 5 years and no access to safe sanitation facilities. The total number of such households is conservatively estimated at 30 million, of which half are in India and one-quarter in Sub-Saharan Africa (see (1) in Table 4). 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 4).[6] 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 because these characteristics tend to be correlated (correlation coefficient = 0.68 for the sample of 84 countries included in this study). In this case, the number of households and preventable deaths are underestimated. The number of children under the age of 5 years in households without sanitation and with illiterate mothers as presented in (2) in Table 4 is calculated based on (1) in Table 4 and total fertility rates, assuming an average of 2 years between child births.

Table 4. Hygiene improvement – estimated preventable child deaths

Illiterate and no sanitation and children under 5 years	*China*	*India*	*Other Asian Countries*	*Middle Eastern Crescent*	*Sub-Saharan Africa*	*Latin America/ Caribbean*
(1) Targeted number of households (millions)	1.6	15.3	2.8	3.2	7.0	0.4
(2) Number of children under 5 years (millions) in targeted households	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) Reduction in child mortality (%) 'high case'	36%	48%	42%	47%	45%	37%
(5) Reduction in child mortality (%) 'low case'	25%	25%	25%	25%	25%	25%
(6) Child deaths prevented per year (thousands) 'high case'	12	510	59	105	439	4
(7) Child deaths prevented per year (thousands) 'low case'	8	264	35	57	245	3

The results of 'high' and 'low' case are presented in (6) and (7) in Table 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. 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.

Unit costs of interventions

Annualised unit cost estimates of interventions are summarised in Table 5. They should be considered orders of magnitude rather than exact figures. Cost of water supply and sanitation is based on construction cost per person for various types of service levels presented in (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 their regional prevalence. These have then been annualised at 10% discount rate over 20 years and weighted by regional rural and urban water and sanitation coverage rates to arrive at the costs presented in Table 5.[7]

Cost of immunisation per child is based on estimates presented in Abt Associates Inc. (2001) and Khan and Yoder 1998. The costs are for full immunisation and reflect personnel, vaccines, other recurrent and capital costs. In Table 5 regional costs are based on US$20 for Sub-Saharan Africa (low end of three country estimates in Abt Associates Inc (2001)) and adjusted by purchasing power parity GDP per capita differentials across the regions as an approximation for labour cost differentials.[8] Cost of education per student per year is based on national education expenditure data and population age distributions (World Bank 2001a). In the cost-effectiveness analysis in the next section 9 years of schooling have been assumed necessary to reap the full health benefits of literacy. The 9-year cost of education per student

Table 5. Cost estimates of interventions (US$)

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

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

has been annualised over 10 years to reflect the typical child-bearing period of a 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 years.

Estimated total cost of hygiene improvement per household per year is presented in Table 5. The estimate includes private cost of a minimum amount of additional water consumption of 10 litres per person per day for improved hygiene purposes, private cost of hygiene products (soap, detergent etc.), and the cost of a hygiene education programme. Cost of water (US$0.2–0.3 per m^3) per household per year is based on regional average cost of water supply as reported in WHO/Unicef (2000) and average regional household size estimated based on total fertility rates (World Bank 2001a). Average regional costs of hygiene products and cost of a hygiene education programme per household per year are, however, not readily available. These costs have, therefore, been adjusted across regions relative to Sub-Saharan Africa by purchasing power parity GDP per capita differentials (the non-tradable fraction of cost) based on hygiene product costs of US$ 1.00 per person per year (author's estimate), and hygiene programme cost of US$3.00 per household per year (Varley *et al.* 1998).

Cost-effectiveness analysis

Estimated cost of preventing the death of a child is presented in Table 6.[9] These estimates are orders of magnitude and will vary across countries 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 immunisation;
(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.

The developing world weighted average cost of preventing a death by increasing child immunisation is around US$1,000. This implies a cost per DALY averted of almost US$30. The cost in Sub-Saharan Africa is as low as US$10 per DALY averted.[10] These estimates are consistent with findings presented in Jamison *et al.* (1993).

Table 6. 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 immunisation	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 immunisation and hygiene improvement to the nearest one hundred dollars.

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 they do not include the private cost of hygiene improvement. However, estimates in Varley *et al*. (1998) are relatively similar to the 'low' case estimates in Table 6 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 as estimated here, but substantially higher than the US$1,000 – 3,000 in Sub-Saharan Africa (Table 6). 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.

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 9 years of schooling. If, however, 5 years of schooling are 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 6. In this case, female literacy would be more cost effective than water and sanitation in most regions except Latin America and the Caribbean.

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$0.80 instead of US$0.20 per cubic metre) 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 immunisation.

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.

Conclusions

Children suffer disproportionately from infectious diseases in developing countries. It is estimated here that the death of 4 million children can be prevented each year by reaching a 100% child immunisation rate, reaching 100% of the populations with potable water supply safe sanitation, and eradicating female illiteracy.[12]

The potential benefit of improved hygiene for reducing child mortality was also analysed. A cost-effectiveness analysis revealed that hygiene improvements 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 hygiene education programme that reaches households with children under the age of 5 years, with illiterate mothers, and without safe sanitation, i.e., at least 30 million households worldwide, is estimated to prevent about 0.6 – 1 million deaths per year.

One important shortcoming of the analysis presented in this paper is the absence of assessing the cost-effectiveness of ORT. ORT is considered a cost-effective strategy to reduce child mortality in an environment with high diarrhoeal disease incidence (Varley *et al.* 1998). However, the data requirement for such an assessment within the framework presented here was beyond the scope of this study. An area of future research would involve assessing the cost-effectiveness of ORT and hygiene improvement within a framework such as in this study that explicitly accounts for differences in child mortality rates, levels of other child mortality determinants, and unit costs of interventions across regions and countries. Such an analysis would allow for a comparison of two apparently low-cost interventions – ORT with the objective of controlling the health consequences of an illness, and hygiene improvement with the objective of preventing an illness.

Notes

1 North Africa and Middle East to and including Pakistan.

2 The disease burden is measured as lost Disability Adjusted Life Years (DALYs), i.e., years of life lost due to premature death, and illness and injuries weighted by severity and duration.

3 In terms of life years lost, children bear a disproportionate burden of infectious diseases. Child mortality rates are therefore the focus of this paper.

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

5 The coefficients represent constant elasticities. Predicted change in child mortality by the derivative of equation (1) would therefore be overstated.

6 The number of such households is estimated based on sanitation coverage rates, illiteracy rates and estimated number of households with children under the age of 5 years. Households with children under 5 years are estimated based on fertility rates.

7 A discount rate of 10% has been applied to reflect the opportunity cost of capital investment. A lower discount rate would reduce annualised cost. Annualised cost changes minimally if discount period is increased to 30 years.

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

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

[10] The death of child under the age of 5 years 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.

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

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