

Estimating child mortality and non-fatal outcomes  
of diarrheal diseases by etiology in 2010

Stephanie Y. Ahn

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Committee:  
Rafael Lozano  
Christopher JL Murray  
Haidong Wang

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University of Washington

**Abstract**

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Stephanie Y. Ahn

Chair of the Supervisor Committee:

Professor Rafael Lozano

Department of Global Health

*Background*

In spite of a large burden of diarrhea in children, surprisingly very little is known about the cause-composition of the main pathogenic agents of diarrhea. This uncertainty around the burden of diarrhea by etiology is problematic, especially in light of the pathogen-specific siloed interventions which are characteristic of current public health programs. It is thus critical to bridge this knowledge gap and identify the key pathogens, along with their distribution, that can cause diarrheal diseases in children in order to accurately assess health priorities. This study is the first to systematically review the literature on the cause composition of several pathogenic agents of diarrhea in children under 5 years of age.

*Methods and Findings*

We searched the literature for published studies on the proportion of diarrheal stools identified with pathogens from our comprehensive list of diarrheal etiologies. We used DisMod 3, a meta-regression tool, to estimate the proportion of diarrhea due to a given etiology for inpatient and outpatient cases of diarrheal disease in children under 5 in 2010.

Of the 690,000 (95% UI: 520,000-820,000) deaths due to diarrheal diseases in children 2010, 18% (95% UI: 7.0%-36%) or 113,000 (95% UI: 44,000-228,000) deaths were caused by rotavirus. EPEC and ETEC

comprised almost 13% of all deaths due to diarrhea in children, ranging from 11% of all diarrheal deaths in Sub-Saharan Africa, East and Sub-Saharan Africa, West to 18% in Central Europe. Other diarrheal diseases consistently represent the largest proportion of diarrheal deaths in children globally at 40% with 267,000 (95% UI: 109,000-515,000) deaths in 2010.

We predicted 1.9 billion (95% UI: 937 million-3.3 billion) incident cases of diarrheal diseases in children in 2010. Cryptosporidiosis caused about 10%, or 208 million (95% UI: 89 million-410 million cases) of the global number of incident diarrheal cases. Rotavirus and EPEC caused 11% and 13% of incident diarrheal cases worldwide, respectively, with 229 million cases (95% UI: 123 million- 386 million cases) and 534 million cases (95% UI: 75million- 534 million cases). Other diarrheal diseases contributed the greatest proportion of all incident cases of diarrhea with 41% or 721 million cases (95% UI: 435million-1.1 billion cases).

### *Conclusions*

The overwhelming proportion of both diarrhea mortality and morbidity caused by other diarrheal diseases highlights just how little is truly known about the etiology of diarrhea in children. Despite our best attempts to identify diarrheal pathogens that are most prevalent, we were still only able to attribute about 60% of all diarrheal deaths and cases in ages under 5 to specific pathogens. The uncertainty surrounding the pathogenic agents that cause the most cases and deaths due to diarrhea is significant. Not only are more studies on the burden of a wide array of diarrheal pathogens in all regions of the world desperately needed, but also better detection methods and surveillance of diarrhea by etiology must be created.

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## Dedication

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## Introduction

Despite major progress in reducing the child mortality rate during the past three decades, diarrheal diseases remain one of the leading causes of mortality and morbidity around the world among children under the age of 5. In the 2004 update of the Global Burden of Disease, diarrheal diseases had the second largest burden of disability-adjusted life years (DALYs) globally across all ages and ranked 3<sup>rd</sup> among ages 0 to 14 in low-income countries.[1] Recent studies show that the burden of diarrheal diseases remains significant as the second leading cause of death among children, with 1.336 million deaths globally in 2008, and a proportionate mortality greater than 25% in children in regions of the world where the majority of child deaths occur.[2][3]

In spite of the large burden of diarrhea in children, surprisingly very little is known about the cause-composition of the main pathogenic agents of diarrhea. For the pathogens that have been studied in more depth—rotavirus, for example-- estimates of their contribution to the burden of diarrheal diseases are often advocacy-driven and not considered within the distribution of other diarrhea-associated pathogens. This uncertainty around the burden of diarrhea by pathogenic agent is problematic, especially in light of the pathogen-specific siloed interventions which are characteristic of current public health programs.[4] It is thus critical to bridge this knowledge gap and identify the key pathogens, along with their distribution, that can cause diarrheal diseases in order to accurately assess health priorities.

There are several reasons why this gap in knowledge about the burden of specific pathogens of diarrhea exists. First and foremost, data on the incidence and mortality due to diarrhea by etiology are scarce. The conventional approach to measuring the burden of diarrheal diseases uses the paradigm of the International Classification of Diseases, now in its 10<sup>th</sup> revision (ICD). The ICD classifies diarrheal diseases

by pathogenic agent within 9 broad categories<sup>1</sup>, representing a range of bacterial, parasitic, and viral diarrheal etiologies. The 9 broad categories and the specific pathogens that fall within each group are shown in Table 1. In theory, the ICD provides a robust framework within which to clinically diagnose diarrhea based on origin. In practice however, classifying diarrheal diseases based on pathogenic agent rather than on symptom complex, for example, is difficult for health practitioners to execute, as identifying the etiology of diarrhea usually requires laboratory tests on stool samples or blood. Such diagnostic tests are particularly difficult to do in resource-limited settings. Furthermore, the very usefulness of identifying the pathogenic agent of diarrhea is questionable, as the etiological origin of a diarrheal episode is usually not relevant or necessary in the treatment of complications from the disease. What follows is a very detailed framework of disease classification which has little practical application in the understanding of the burden of diarrhea as evidenced in the dearth of data available for diarrhea by etiology. Even in countries like the United States, with complete coverage of vital registration, deaths due to diarrhea tend not to be classified at the pathogen-specific level of the ICD. For instance, of the 67,000 deaths due to diarrheal diseases between 1980 and 2010 in the United States across all ages, only 3% were recorded at the pathogen-specific level of detail of the ICD while 97% were categorized as “other diarrheal diseases”. [5]

To further complicate matters, vital registration data in general are rare in the regions of the world that have the highest burden of diarrhea. In countries without civil registration systems, verbal autopsies are increasingly being used to estimate cause-specific mortality. Although verbal autopsies are an exciting solution to fill gaps in cause of death data around the world, their usefulness in understanding the distribution of pathogens that cause diarrheal deaths is very limited; assigning a cause of death due to diarrhea at the etiological-level is near impossible using only interviews of the next of kin of the

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<sup>1</sup> We estimate the burden of typhoid and paratyphoid fevers separately from our analysis of diarrheal diseases, though it is included in the broader category of intestinal infectious diseases within the ICD-10.

deceased due to the need for laboratory confirmation of the presence of pathogens. In the absence of vital registration data for many of the regions of the world with high mortality, the utility of the highly detailed, pathogen-specific paradigm of the ICD is debatable and merits further discussion and thought by public health practitioners.

Data on the incidence of diarrhea are often no more helpful. Hospital admissions records are often used to help estimate the incidence of severe cases of disease. Very few diagnoses for diarrheal diseases in hospital, however, are made at the level of pathogen-specific detail of the ICD. For example, the Database of Hospital Discharges for Morbidity in Public Institutions, a nationally-representative hospital admissions database for Mexico, reports 300,000 hospital admissions due to diarrheal diseases between 2000 and 2009, with 83% coded to the residual category of the ICD-10 of “other diarrheal diseases”.<sup>[6][7]</sup> Similarly, in the United States National Hospital Discharge Survey, 72% of hospital admissions due to diarrhea between 1979 and 2006 were diagnosed without a specific etiology. Alternate sources of data, such as from systematic reviews, are required to accurately assess the burden of diarrheal diseases by etiology.

To our knowledge, there are no global or regional estimates of diarrheal mortality and morbidity due to a comprehensive list of pathogens in children under the age of 5. Previous reviews have either focused on the burden of only single diarrheal pathogens, or the prevalence of groups of pathogens within select countries or regions.<sup>[8][9][10]</sup> As part of a larger effort for the Global Burden of Diseases, Injuries, and Risk Factors 2010 (GBD 2010) Study, we attempt to estimate the number of diarrheal deaths by 10 etiological categories and 187 countries in children under the age of 5 in 2010. We also aim to estimate the number of incident cases of diarrheal diseases by pathogen in 2010 across 21 GBD regions.

## Methods

The estimation of mortality and non-fatal outcomes due to diarrheal diseases in general is described elsewhere.[11][12] In summary, we used the Cause of Death Ensemble Model (CODEm) to estimate the number of diarrheal deaths from 1980 to 2010 in 187 countries, 2 sexes, and 20 age groups. Ages under 5 were divided into early neonatal (0-6 days), late neonatal (7-28 days), post neonatal (1-11 months), and 1 to 4 years. CODEm explores a large variety of possible models to estimate trends in causes of death. Possible models are identified using a covariate selection algorithm that yields many plausible combinations of covariates which are then run through four model classes. The model classes include mixed effects linear models and spatiotemporal GPR models for cause fractions and death rates. All models for each cause of death are then assessed using out-of-sample predictive validity and combined into an ensemble with optimal out-of-sample predictive performance.[13]

To estimate non-fatal health outcomes for diarrheal diseases, we used DisMod 3, a Bayesian meta-regression tool used to generate consistent estimates of disease prevalence, incidence, and remission. We compiled data from published literature provided by the Global Burden of Diseases Diarrheal Diseases Expert Group, surveys, CODEm, and hospital admissions records to develop a database of diarrheal diseases prevalence, incidence, and excess mortality. We then used DisMod 3 to produce estimates of prevalence and incidence of diarrheal diseases by region, age, and sex for 1990, 2005, and 2010.

In order to estimate pathogen-specific burden, we split diarrheal diseases into 10 etiological categories which are listed below with their corresponding ICD 10th revision codes. All diarrheal pathogens were selected by the Global Burden of Disease Core Team for estimation due to their large contribution to the overall burden of diarrheal diseases and for their potential for prevention and vaccine development.[14]

- 1) Cholera (A00)

- 2) Other salmonella infections (A02)
- 3) Shigellosis (A03)
- 4) Enteropathogenic Escherichia coli infection (EPEC) (A04.0)
- 5) Enterotoxigenic Escherichia coli infection (ETEC) (A04.1)
- 6) Campylobacter enteritis (A04.5)
- 7) Amoebiasis (A06)
- 8) Cryptosporidiosis (A07.2)
- 9) Rotaviral enteritis (A08.0)
- 10) Other diarrheal diseases (A04 [except A04.0, A04.1, A04.5], A07-A09 [except A07.2, A08.0])

#### Data used

As mentioned previously, conventional sources of data, such as vital registration data, hospital records, and verbal autopsies, could not be used to estimate the burden of diarrhea by pathogen. To obtain data on the proportion of diarrhea caused by each specific etiological agent, we first searched PubMed for the most recent meta-analyses published on each pathogen or group of pathogens. We used “[etiology]” as the key word and filtered based on the MeSH terms “review”, “systematic review”, and “meta-analyses”. We limited the date range to studies published between 1980 and 2012. We found systematic reviews for cholera, shigellosis, rotavirus, and 1 study on a group of pathogens, and included their references in our database.[8][9][10][15][16] We included all studies from these sources except for those that did not fit our inclusion criteria. We excluded: case-control studies that did not include data for controls; studies that provided no raw data, only estimates; studies that did not include the proportion of diarrhea cases with positive laboratory tests for at least one pathogen; studies that were conducted for less than 12 months to avoid effects of seasonality; studies that only reported data for HIV-positive patients; and studies that looked at diarrhea in travelers. Due to the paucity of regional data for a given etiology, we included subnational studies in our database, but excluded studies in

whose populations were experiencing outbreaks of diarrhea due to a pathogen (such as cholera epidemics). We also obtained unpublished data on the fraction of diarrheal cases by etiology from a large community cohort study in Pakistan and national surveillance reports for rotavirus from the WHO. Table 2 shows the number of studies used by etiology and GBD region. In total, we included 148 studies between the years 1975 to 2010 in our database for all 7 of the GBD super regions and 20 of the 21 GBD regions. 111 studies had data on rotavirus, the largest for any one pathogen. We included data from inpatient, outpatient, case-control, and community-based studies.

### Analytic Strategy

Figure 1 shows the analytical strategy we used to estimate the burden of diarrheal diseases by etiology. We estimated the proportion of diarrheal diseases due to each diarrheal pathogen using DisMod 3, a Bayesian meta-regression tool which is built on an age-integrating mixed-effects negative-binomial model. While DisMod 3 also includes a compartmental model of process to produce consistent estimates for epidemiological parameters of disease, we used it without the compartmental model to estimate pathogen-specific prevalence only. Another capacity of DisMod 3 is to include both country-level covariates to account for variation across countries and study-level covariates to account for systematic variation across different data types and sources. DisMod 3 predicts for the reference category, which is set by the user, for study-level covariates.[17]

It has been reported that studies that only examine a single pathogen can overestimate the prevalence of a particular pathogen, as study sites are more likely to be selected based on known prevalence of the given etiology.[16] In order to account for the potential bias due to the number of pathogens for which a stool was tested, we included a study-level covariate for the number of pathogens for which a study tested each stool sample. The number of pathogens tested by study ranged from a single pathogen to over 20 pathogens. We binned the number of pathogens tested into 1 pathogen tested, 2 to 8

pathogens tested, and greater than 9 pathogens tested, which grouped a similar number of observations per binned category. We set the reference category to 2 to 8 pathogens tested, as every etiology had data which fell into this respective bin.

In order to adjust for severe versus all cases of diarrhea, we created another study-level covariate indicating whether the study population were inpatient cases of diarrhea or outpatient/community-based cases. We assumed hospitalized cases of diarrhea to be severe cases, whereas outpatient or community-based cases were deemed to be representative of all cases of diarrheal diseases. As DisMod 3 creates estimates for all ages between 0 and 100, we used the linear spline to represent the age specific rates with knots at ages 0, 3, 10, 40, 70, and 100, but only used the estimates for ages under 5. The reference category was set for all cases of diarrhea.

As regional data were scarce, we included log-transformed lag-distributed income, a proxy for GDP, as a country-level covariate to account for regional differences in the composition of diarrheal etiologies. We excluded this covariate for EPEC, ETEC, and cholera as there was no evident relationship between the proportion of diarrhea cases caused by the aforementioned pathogens and a country's income in separate analyses. In the case of cholera, we created a country-level covariate that was the mean number of reported cases to the WHO Cholera Surveillance system across available country-years divided by the national population in 2010. Despite the significant amount of missingness in the WHO Cholera Surveillance Case Reports, we believed that using this crude rate would still adequately inform the model of regional patterns in the levels of cholera incidence.[10] We also included the proportion of a country's population with access to improved sanitation sources in the cholera model. For rotavirus, we included a country-level indicator variable for whether or not the rotavirus vaccine had been introduced into the national immunization program as of 2011.

We rescaled the proportion of diarrheal diseases due to cholera after modeling in DisMod 3 to account for the fact that cholera is endemic in only a few regions around the world. We assumed countries and regions that only reported imported cases of cholera or in which non-imported cholera cases were very intermittent and rare according to the WHO Cholera Surveillance Reports to be cholera-free, and set the fraction of cholera deaths and cases in the relevant regions to zero.

Lastly, as all the data available were for both sexes combined and as there is little evidence of any epidemiological differences in the cause composition of diarrheal etiologies in males and females, we set the fixed effect on sex to zero.

We modeled the etiological category of other diarrheal diseases separately in a non-DisMod environment as the pathogens included in this residual category differed by study and were not comparable. In order to obtain the proportion of other diarrheal diseases, we summed the proportion of all 9 specific pathogens by study. We then subtracted the summed proportion of pathogen-specific diarrhea to get the proportion of the remainder category. We created an indicator variable for whether or not each study reported the proportion of diarrhea for each of the 9 pathogen-specific etiologies. We also included 2 studies that reported on the proportion of all 9 pathogens in our cause list and thus whose residual category represented the “true” proportion of other diarrheal diseases. We ran a linear regression on the logit-transformed proportion of other diarrheal diseases with dummy variables on year, GBD super region, and age groups under 5 /over5. We also included the pathogen-specific indicator variables described above for whether a given study had reported the proportion of a given etiology. We took 1000 draws of the cause fraction assuming a normal distribution to generate uncertainty, and predicted for the proportion of other diarrheal diseases assuming that all 9 specific diarrheal pathogens were present.

After obtaining the region-age-sex-specific proportion of diarrhea due to each etiology, we scaled the cause-specific fractions to fit them within the entire category of diarrheal diseases. We then took 1000 draws of the proportions to estimate uncertainty by etiology, and then applied the scaled draws for severe cases to the total number of deaths due to diarrheal diseases. We also applied this process to the etiology-specific proportions of all diarrhea cases in the estimation of non-fatal outcomes.

## Results

### Deaths and Cases of Diarrheal Diseases

Since 1980, there has been a steep decline in the number of deaths due to diarrheal disease in ages under 5 as shown in Figure 2. In 1980, we estimated 3.5 million (95% uncertainty interval (UI): 2.9 million-4.4 million) diarrheal deaths in children globally, with the highest burden in South Asia, Sub-Saharan Africa West, Sub-Saharan Africa East, and Southeast Asia. In 2010, we predicted 690,000 (95% UI: 520,000-820,000) deaths globally--a 3% annual decline in child diarrheal deaths during the past 30 years. This immense progress in reducing child mortality due to diarrheal diseases has not been shared equally across the world, however. South Asia, Sub-Saharan Africa West, and Sub-Saharan Africa East continue to have the highest burden of diarrheal deaths in children: these 3 regions combined comprised 75% of all child diarrheal deaths in 2010.

The incidence of diarrheal diseases in children has not seen the same decline as that in diarrheal deaths. Table 3 shows the number of incident cases of diarrheal diseases in 2010 by GBD region in children under 5. We predicted 1.9 billion (95% UI: 937 million-3.3 billion) incident cases of diarrheal diseases in children in 2010, a global incidence rate of 2.8 (95% UI: 1.4-5.4) diarrheal episodes per child-year. In 1990, we estimated 2.1 billion (95% UI: 1.0 billion-3.9 billion) incident diarrheal cases with a global incidence rate of 3.2 (95% UI: 1.6-6.1) episodes per child-year. Between 1990 and 2010, there was only a 0.6% annual decline in the incidence rate of diarrheal diseases. We see a similar pattern of a concentration of cases of diarrhea in a select number of regions as in diarrheal deaths over time, though with a slight shift in the regional composition of the burden of diarrheal incidence. In 1990, South Asia, East Asia, and Southeast Asia constituted over 50% of all diarrheal episodes in children. The burden of incident cases has shifted more towards Sub-Saharan Africa in recent years, with South Asia, Sub-Saharan Africa West, and Sub-Saharan Africa East comprising about half of incident diarrheal cases in 2010.

## Deaths by Etiology

Table 4 shows the number of deaths under 5 due to each diarrheal etiology by country in 2010. The proportion of diarrheal deaths in children due to a given pathogen ranged widely, from below 5% for cholera and shigellosis to over 40% for the residual category of other diarrheal pathogens worldwide.

Figure 3 illustrates the cause composition of diarrheal diseases by region for the same age group in 2010. We estimated that globally, rotavirus caused 113,000 (95% UI: 44,000-228,000) or 18% (95% UI: 7.0%-36%) of all deaths due to diarrhea in children in 2010. National estimates of rotavirus deaths ranged from 25,500 (95% UI: 9,700-51,500) in India to 0 in several countries in Western Europe in the same year. The proportion of rotavirus-related diarrheal deaths ranged from 12% to 30%; the proportion was highest in Western Europe and lowest in Sub-Saharan Africa, Southern. We believe our results to be in line with the prevailing belief that as countries develop and infrastructural improvements to water and sanitation sources become more common across countries, diarrhea caused by bacterial agents decreases and diarrhea caused by viral agents increases.[15] About 37% of these rotavirus-related deaths occurred in the 37 countries that are eligible to receive support for the rotavirus vaccine from GAVI as of September 2011. In the 24 countries where the rotavirus vaccine has already been included in national immunization programs as of 2011, rotavirus caused only 3% of all rotavirus-associated deaths in children in 2010. 6 countries account for more than half of all rotavirus deaths in children: India, Nigeria, the Democratic Republic of Congo, Pakistan, Indonesia, and Niger.

There were 58,000 (95% UI: 18,000-133,000) deaths due to EPEC and 31,000 (95% UI: 10,000-70,000) deaths due to ETEC globally in children under 5 in 2010. Together, EPEC and ETEC comprised almost 13% of all deaths due to diarrhea in children, ranging from 11% of all diarrheal deaths in Sub-Saharan Africa, East and Sub-Saharan Africa, West to 18% in Central Europe. The proportion of all diarrheal deaths due to EPEC and ETEC was consistently higher in developed regions of the world.

We predicted that cholera caused 34,000 (95% UI: 10,000-86,000) or 3% of all diarrheal deaths in children in 2010. The burden was highest in Sub-Saharan Africa, West and Sub-Saharan Africa, East, where cholera is endemic, with almost 50% of all cholera-related deaths occurring in Niger, Chad, Burkina Faso, Ethiopia, Malawi, and Sudan. The cholera-endemic regions of South Asia, Sub-Saharan Africa, West, and Sub-Saharan Africa, East constituted 84% of cholera-associated deaths in children worldwide.

Other diarrheal diseases consistently represent the largest proportion of diarrheal deaths in children globally at 40% with 267,000 (95% UI: 109,000-515,000) deaths in 2010. The proportion of other diarrheal deaths due to pathogens in the residual category ranged from 27% in North Africa/Middle East to 44% in South Asia and Latin America, Central. Interestingly, the proportion of diarrheal deaths caused by other pathogens not included in our cause list was still high in more developed regions such as Asia Pacific, High Income and North America, High Income. For example, 40% of all deaths due to diarrhea were due to other diarrheal diseases in Japan; 36% of diarrheal deaths were due to pathogens in this residual category in the United States. The large relative size of the proportion of other diarrheal diseases leads us to conclude that there are other diarrheal pathogens that are the cause of many diarrheal deaths in children under 5 that were not included in our cause list.

#### Non-Fatal Outcomes by Etiology

Table 5 lists the number of incident cases by etiological category and region in 2010. Cryptosporidiosis caused about 10%, or 208 million (95% UI: 89 million-410 million cases) of the global number of incident diarrheal cases. Rotavirus and EPEC caused 11% and 13% of incident diarrheal cases worldwide, respectively, with 229 million cases (95% UI: 123 million- 386 million cases) and 534 million cases (95% UI: 75million- 534 million cases). Other diarrheal diseases contributed the greatest proportion of all incident cases of diarrhea with 41% or 721 million cases (95% UI: 435million-1.1 billion cases).

Figure 4 shows the regional cause composition of incident cases in children under 5 in 2010. We estimated that the number of cases of rotavirus-associated diarrhea ranged from 403,000 cases (95% UI: 202000-713000) in Oceania to 58 million in South Asia in 2010. The regional trends of rotavirus, however, show a different story when discussed in terms of proportions rather than numbers. Rotavirus constituted 15% of all incident cases of diarrhea in 2010 in the GBD High-Income super region, the highest proportion across all super regions. The Sub-Saharan African, Latin American/Caribbean, and South Asian super regions had the lowest proportion of diarrheal cases due to rotavirus at around 11% in all super regions.

We estimated a total of 500 million incident cases of diarrhea in the South Asia super region in children under 5, about 26% of diarrheal episodes worldwide. The residual category of other diarrheal diseases caused the highest proportion of diarrheal episodes in South Asia at 44%, followed by rotavirus and EPEC, both contributing 12% of the total number of incident diarrheal cases. This same trend of a high proportion of other diarrheal diseases and cryptosporidiosis causing incident cases of diarrhea can be seen in Sub-Saharan Africa as well. The residual category constituted 39% of all diarrheal episodes, with cryptosporidiosis causing 14% in Sub-Saharan Africa. Rotavirus and EPEC each were the cause of about 11% of non-fatal diarrhea in the super region.

Similar to diarrheal deaths, the residual category of other diarrheal diseases contributed the highest proportion of cases of diarrhea across all other pathogens. The proportion of other diarrheal diseases ranged from 29% in North Africa/Middle East to 44% in Asia, South. High-income regions still had high proportions of other diarrheal diseases as well, with 37% in North America, High Income and 40% in Asia Pacific, High Income, suggesting that there are other pathogens not included in our cause list that have a large burden in all regions of the world.

## Discussion

Our estimation of deaths and morbidity by a select number of pathogenic agents of diarrhea is the first attempt to estimate the global burden for a comprehensive list of diarrheal subtypes for children under 5. Rotavirus and other diarrheal pathogens constituted the largest and most significant proportion of deaths due to diarrhea globally, accounting for 58% of all diarrheal deaths in children under 5 years of age. For non-fatal outcomes, other diarrheal diseases contributed the highest proportion of diarrheal cases at 41%, followed by rotavirus at 11%. Clearly, substantial uncertainty surrounding the main causes of diarrhea in children remains.

Our estimation of rotavirus-related diarrheal mortality in children is significantly lower than a recent systematic review by Tate et al. Tate et al. predicted 453,000 rotavirus deaths globally in 2008, 4 times higher than our estimates for the same year, and attributed 37% of diarrheal deaths to rotavirus in children. The discrepancy between our numbers is partially due to differences in the total number of diarrheal deaths in children that were used, as Tate et al. used the WHO estimates of 1.3 million diarrheal deaths in 2008 as compared to our 690,000.[8] The total number of diarrheal deaths in children does not account for the over 2-fold difference in our estimations of the proportion of diarrheal deaths caused by rotavirus, however. We believe that previous studies have consistently overestimated the proportion of rotavirus-related diarrheal deaths, as they did not account for the bias in studies that only estimate the prevalence of a single diarrheal pathogen. It has been reported that the weighted mean of single pathogen studies are significantly higher than that of studies that investigate multiple pathogens, since single pathogen study sites are often chosen based on known prevalence of a particular pathogen and thus inflate their true occurrence.[16] Our modeling strategy took into account the potential bias caused by studies that only measured the prevalence of single pathogens by assigning study-level covariates for the number of pathogens tested. Although we predict that the proportion of

rotavirus-related deaths is still higher than for other pathogens at 17.6%, it is not as high as previous estimates.

In a recent systematic review of the global burden of cholera, Ali et al. estimated 1.3 million cases of cholera in children under 5 in endemic countries.[10] We predicted 33 million (95% UI: 13 million- 74 million) cases in the same 51 cholera-endemic countries of Ali et al.'s study for children under 5.<sup>2</sup> The discrepancy between our estimates and those of Ali et al. are significant but can be explained by several differences in our analytic strategy. Firstly, we assumed that the entire population of a country was susceptible to cholera in our calculation of incidence, whereas Ali et al. applied the proportion of a country's population with access to improved sanitation sources to derive the population-at-risk. Accordingly, across the 51 cholera-endemic countries listed by Ali et al., only 57% of the population was at risk of contracting cholera. We believe Ali et al.'s assumption that the population-at-risk is only people without access to improved sanitation sources underestimates the true population-at-risk, as cholera is not only a disease that is spread through improper sanitation and water sources, but is also food-borne or passed from person-to-person contact.[18] Secondly, Ali et al. applied incidence rates of cholera as reported by the Diseases of the Most Impoverished (DOMI) cholera surveillance programs in India, Indonesia, and Mozambique, and applied the rates directly to the population-at-risk calculated as detailed above based on WHO mortality stratum. Extrapolating the incidence of cholera from 3 research sites across regions is questionable, as the research settings may not be representative of other areas of the world. In contrast, we took the regional *proportion* of all diarrhea caused by cholera, and applied this fraction of inpatient cases to the total number of deaths due to diarrheal diseases overall and the outpatient fraction to the total number of cases of diarrheal diseases. Our approach thus includes a holistic, comprehensive picture of the burden of cholera relative to other diarrheal pathogens within the

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<sup>2</sup> Ali et al. divide Sudan into Sudan and Southern Sudan. In order to make their estimates comparable with ours, we have combined Ali et al.'s estimates for Sudan and Southern Sudan.

total number of deaths and cases due to the overall category of diarrheal diseases. Lastly, the number of countries for which we are estimating the burden of cholera differs markedly between that of Ali et al. In their recent systematic review, the authors measured the burden of cholera in 69 countries, 51 of which were endemic and 18 of which were non-endemic. In comparison, we estimated the burden of cholera in 187 countries, 118 which we categorized as endemic and 69 which we classified as non-endemic. Despite the difference in the absolute numbers due to cholera globally, both Ali et al.'s and our estimates show that about 50% of cholera deaths and cases occur in children under 5.

Our study shows that EPEC, ETEC, cryptosporidiosis, and campylobacter are of increasing concern related to both diarrhea mortality and morbidity. Together, these 4 pathogens comprised 39% of diarrheal episodes and 28% of diarrheal-associated deaths in 2010. The high proportion of diarrheal deaths and cases related to the combination of these parasitic and bacterial pathogens is interesting to consider within the preliminary results of attributable burden of diarrheal diseases due risk factors for the GBD 2010 Study. The GBD 2010 estimated that child and maternal undernutrition caused 72%<sup>3</sup> of deaths due to diarrhea in ages under 5 in 2010, and 72.5% of diarrhea-associated DALYs. Sub-optimal breastfeeding, defined as non-exclusive breastfeeding under 6 months of age or no breastfeeding between 6 to 24 months of age, had a large attributable burden as well, responsible for 42% (95% CI: 26%-58%) of diarrheal deaths and 41% (95% CI: 24%-57%) of diarrhea-associated DALYs. Unimproved water and sanitation sources had a much lower attributable burden of diarrhea, causing 22% of diarrheal-associated DALYs and 23% of diarrheal deaths in children in 2010.[19] These results from GBD 2010 challenge the prevailing theory that unimproved water and sanitation sources are the main risk factors for diarrheal diseases. Although increasing access to improved water and sanitation in low-income countries is undeniably important, especially considering its relationship with other infectious

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<sup>3</sup> The uncertainty around the point estimates of for undernutrition and unimproved water and sanitation sources attributable burden for diarrheal diseases is still being finalized.

diseases, it may be more cost-effective and prudent to invest resources in encouraging mothers to adequately breastfeed their children and provide micronutrient supplements to children in order to decrease susceptibility to bacterial and parasitic diarrheal pathogens. These strategies also seem particularly relevant in light of the fact that the proportion of EPEC and campylobacter-associated diarrhea is still significant in low- and middle-income countries with high coverage of improved water and sanitation sources.

The overwhelming proportion of both diarrhea mortality and morbidity caused by other diarrheal diseases highlights just how little is truly known about the etiology of diarrhea in children. Despite our best attempts to identify diarrheal pathogens that are most prevalent, we were still only able to attribute about 60% of all diarrheal deaths and cases in ages under 5 to specific pathogens. Pathogens for which we did not estimate the burden but appeared frequently in studies during our initial cull of data included giardia lamblia, norovirus, and adenovirus, among others. It is likely that no one etiology not included in our cause list can explain the remaining 40% of diarrheal diseases. It is also possible that key diarrheal pathogens are not studied as frequently due to complicated and costly diagnostic techniques. Needless to say, the uncertainty surrounding the pathogenic agents that cause the most cases and deaths due to diarrhea is significant. Not only are more studies on the burden of a wide array of diarrheal pathogens in all regions of the world desperately needed, but also better detection methods and surveillance of diarrhea by etiology must be created.

Recent studies, including GBD 2010, have shown an immense decline in the number of diarrheal deaths since 1980. Deaths due to diarrhea in children have decreased in large part due to improvements in water and sanitation, the advent of oral rehydration therapy (ORT), increased coverage of vaccinations such as measles and DTP3, and the diminishing prevalence of malnutrition worldwide. This trend of huge reductions in diarrhea-associated mortality has not been seen in terms of the overall incidence of

diarrhea in children; incidence rates have stayed stubbornly constant over the past 2 decades and diarrhea continues to remain a significant cause of morbidity among children, especially in low-income countries. It must be noted that many of the public health programs and innovations that contributed to the steep decline in diarrhea-associated mortality in children were broad interventions either aimed at addressing general risk factors for child mortality-- such as micronutrient supplementation for malnutrition—or, targeted non-pathogen-specific complications of diarrheal diseases, such as ORT to treat dehydration.[20][21] In contrast, efforts to decrease the incidence of diarrheal diseases have tended to be pathogen-specific, such as the scale up of the rotavirus and cholera vaccines and the development of vaccines for ETEC and amoebiasis. Is targeting specific pathogens an appropriate and effective strategy to decrease the incidence of diarrhea? Or, should a more holistic approach to illness due to infectious disease in general be taken, such as was done to decrease deaths due to diarrhea? In order for the current pathogen-centric focus of interventions aimed at decreasing diarrheal diseases to be as cost-effective as possible, further research into the true burden of diarrhea by a comprehensive list of pathogenic agents must be done.

#### Limitations

There should be careful consideration of certain issues when interpreting our estimates. The scarcity of data used in the estimation of the burden of each diarrheal etiology is an additional, and major, limitation of our study. This is of particular concern when generalizing our results across region and time as there are likely variations in exposures and risk factors for each pathogenic agent by region and across years. Extrapolating our mostly subnational data to national or regional results can be problematic for the same aforementioned reasons; furthermore the characteristics of subnational populations can be inherently different from that of the country or region as a whole. We tried to compensate for the scarcity of available data by borrowing strength across space and time in both the

mortality and morbidity estimation processes. However, further studies on the etiology of diarrhea across regions and over time, particularly in low-income settings, are critically needed.

Additionally, very few studies reported on the co-occurrence of multiple pathogens in a single stool. We were thus unable to control for the role of multiple infections and assumed all data as isolated proportions. We did attempt to adjust for studies that may have been biased due to the examination of only single pathogens by including study-level covariates for the number of pathogens tested within our models. Currently, there are efforts to estimate the burden of diarrheal diseases by a comprehensive list of pathogenic agents using a case-control study design with non-diarrheal controls by the Global Enterics Multi-Center Study. It is our hope that these efforts will bring further innovations in quantitative methodology and diagnostic capability for dealing with this issue of multiple attributions and adjustment for co-infections.

We also recognize that the presence of a given pathogen in a stool sample does not necessarily indicate causal attribution, especially if co-infections exist. Asymptomatic carriers of many of the pathogenic agents that cause diarrhea add a layer of complexity, as it is possible that the presence of certain pathogens are similarly prevalent in stools of non-diarrheal patients. Even with the use of the most advanced diagnostic technology, causal attribution of diarrhea to a specific pathogen is extremely difficult. Thus, it is important to evaluate our results relative to the contribution and presence of other pathogens in patients with diarrheal diseases.

Considering the large uncertainty that still surrounds the burden of diarrheal diseases by pathogenic agent, the field of global health must reassess its approach and mentality towards the estimation of diarrheal disease burden by etiology. We must first reconcile the inherent tension that exists between current pathogen-specific interventions for diarrheal diseases framed within the ICD paradigm and our ability to accurately assess the true burden by etiology. Given the current global economic recession and

decreasing funds for global health aid, public health practitioners are forced to look towards the most cost-effective interventions that can ideally decrease the burden of a wide variety of illnesses. Without sound empirical evidence to support the prioritization of certain diarrheal pathogens over others in health policy, there are threats of unwise decisions about resource allocation. The uncertainty surrounding the burden of diarrhea by pathogenic agents brings into question the very basis of using the ICD framework to understand and measure diarrheal disease burden.

This study is the first to systematically review the literature on the cause composition of several pathogenic agents of diarrhea in children under 5 years of age. We attempted to illuminate the causal distribution of diarrheal etiologies in terms of both mortality and morbidity across regions. Despite the many limitations of our study, we propose our analytical strategy as one approach to more accurately and comprehensively estimate the relative burden of several key diarrhea-associated pathogens. We hope that our estimates help to fill the gap between the uncertainty surrounding pathogen-specific diarrheal disease burden and the setting of health priorities. We also hope our initial efforts will stimulate further research and dialogue around the etiologies of diarrhea, the innovation of more effective and targeted interventions for diarrheal diseases, and the eventual elimination of diarrheal diseases as a major cause of death and illness in children around the world.

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## Illustration and figures

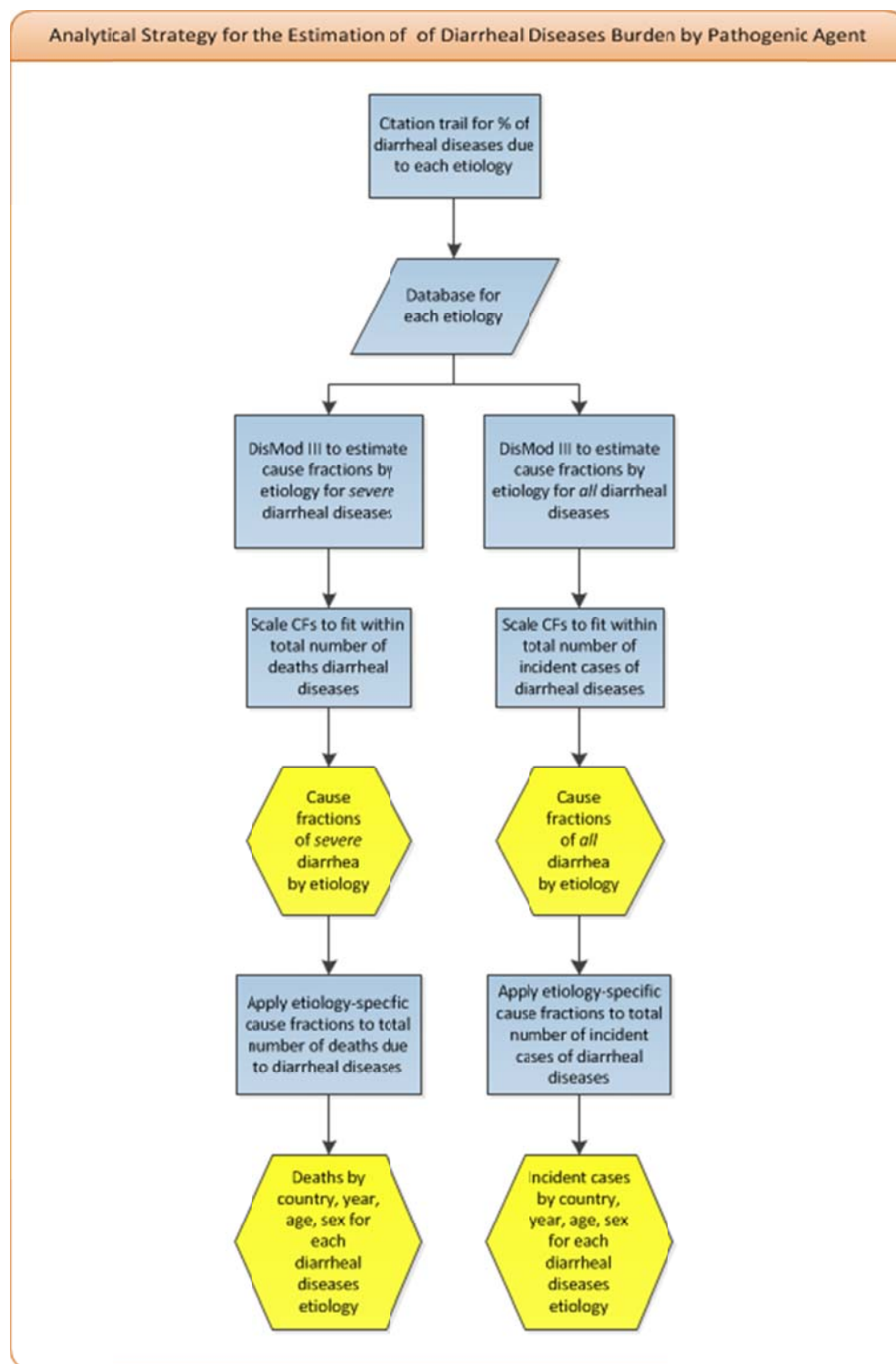


Figure 1: Analytical strategy for the estimation of the burden of diarrheal diseases by pathogenic agent

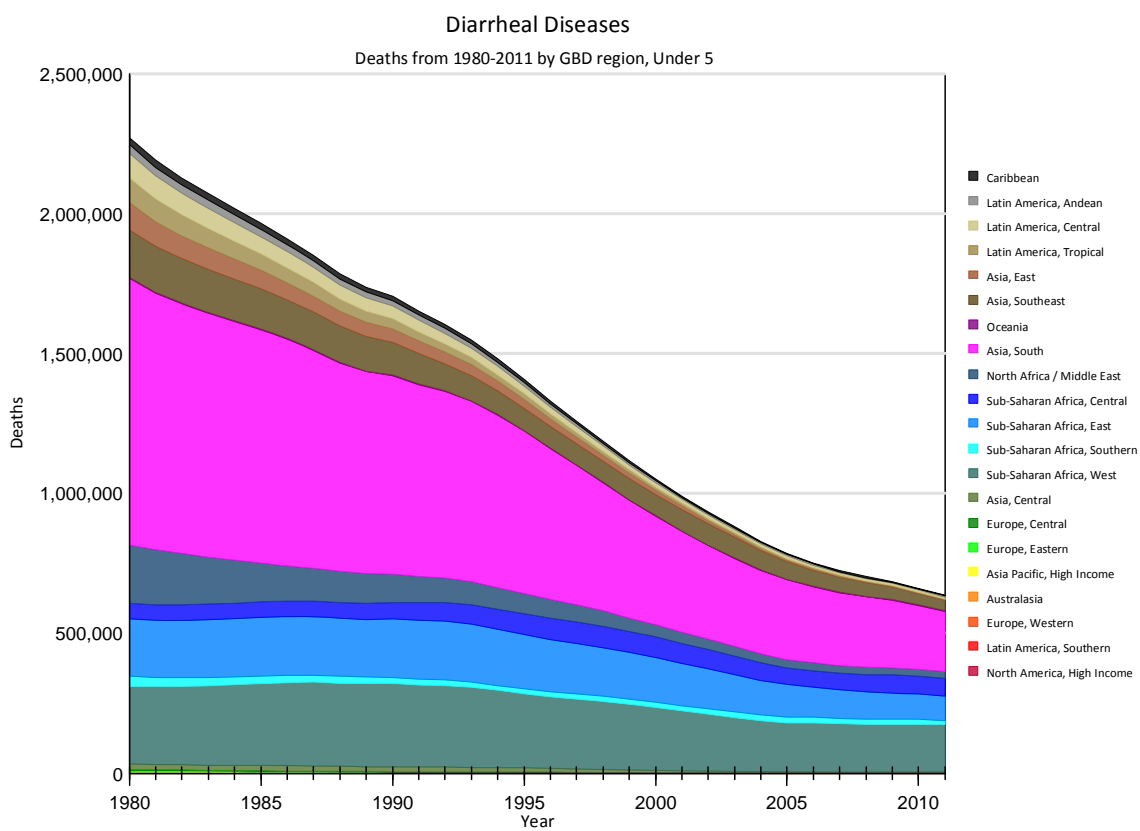


Figure 2: Global deaths due to diarrheal diseases from 1980 to 2010 by GBD region in ages under 5

Etiologic Cause Composition by Region, severe cases 2010  
Under 5

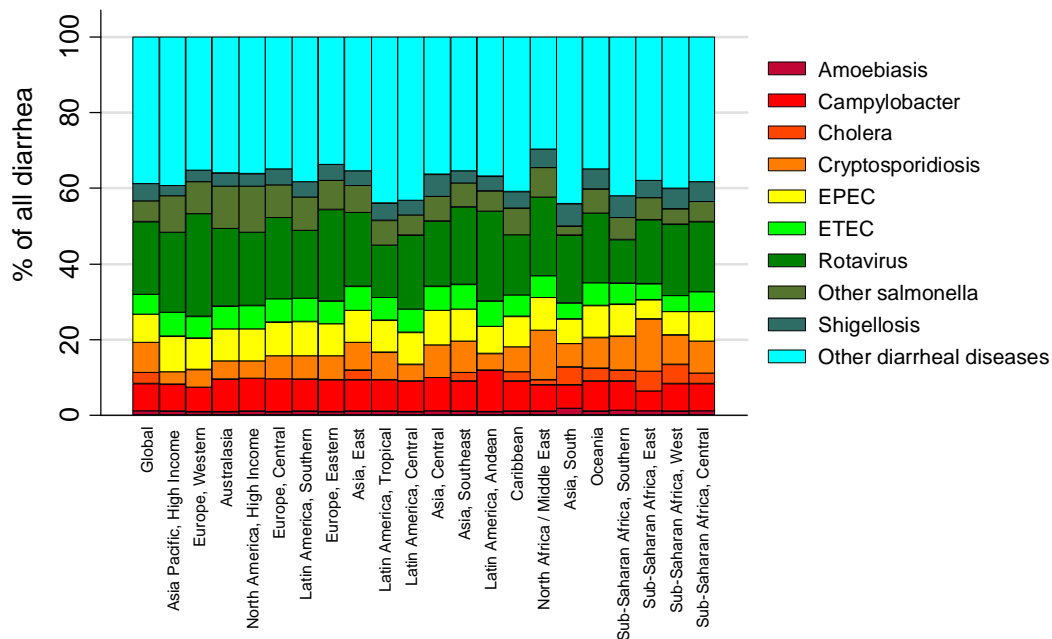


Figure 3: Regional cause composition of severe cases of diarrheal diseases by etiology in children under 5 in 2010

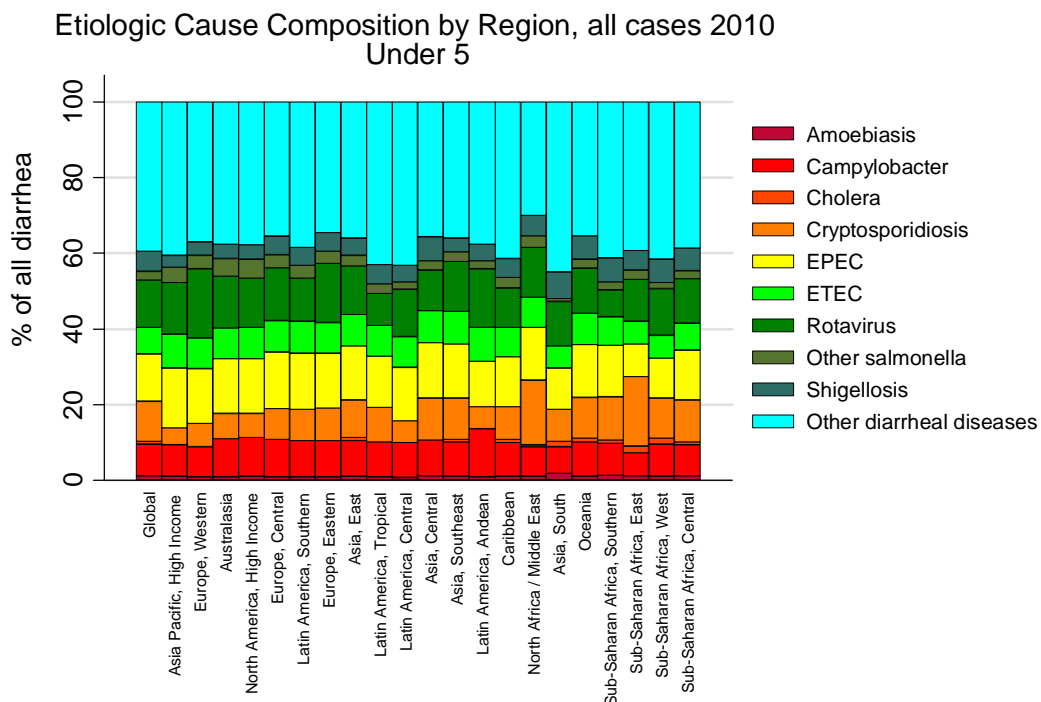


Figure 4: Regional cause composition of all cases of diarrheal diseases by etiology in children under 5 in 2010

## Tables

Table 1: ICD-10<sup>th</sup> revision codes for diarrheal diseases

ICD-10 Code	Etiological Category of Diarrheal Diseases
<b>A00</b>	<b>Cholera</b>
A00.0	Cholera due to <i>Vibrio cholerae</i> 01, biovar cholerae
A00.1	Cholera due to <i>Vibrio cholerae</i> 01, biovar eltor
A00.9	Cholera, unspecified
<b>A01</b>	<b>Typhoid and paratyphoid fevers*</b>
<b>A02</b>	<b>Other Salmonella infections</b>
A02.0	Salmonella enteritis
A02.1	Salmonella sepsis
A02.2	Localized salmonella infections
A02.8	Other specified salmonella infections
A02.9	Salmonella infection, unspecified
<b>A03</b>	<b>Shigellosis</b>
A03.0	Shigellosis due to shigella dysenteriae
A03.1	Shigellosis due to <i>Shigella flexneri</i>
A03.2	Shigellosis due to <i>Shigella boydii</i>
A03.3	Shigellosis due to <i>Shigella sonnei</i>
A03.8	Other shigellosis
A03.9	Shigellosis, unspecified
<b>A04</b>	<b>Other bacterial intestinal infections</b>
A04.0	Enteropathogenic <i>Escherichia coli</i> infection
A04.1	Enterotoxigenic <i>Escherichia coli</i> infection
A04.2	Enteroinvasive <i>Escherichia coli</i> infection
A04.3	Enterohaemorrhagic <i>Escherichia coli</i> infection
A04.4	Other intestinal <i>Escherichia coli</i> infections
A04.5	<i>Campylobacter</i> enteritis
A04.6	Enteritis due to <i>Yersinia enterocolitica</i>
A04.7	Enterocolitis due to <i>Clostridium difficile</i>
A04.8	Other specified bacterial intestinal infections
A04.9	Bacterial intestinal infection, unspecified
<b>A05</b>	<b>Other bacterial foodborne intoxications</b>
A05.0	Foodborne staphylococcal intoxication
A05.1	Botulism
A05.2	Foodborne <i>Clostridium perfringens</i> intoxication
A05.3	Foodborne <i>Vibrio parahaemolyticus</i> intoxication
A05.4	Foodborne <i>Bacillus cereus</i> intoxication
A05.8	Other specified bacterial foodborne intoxications
A05.9	Bacterial foodborne intoxication, unspecified

Table 1: (continued)

<b>A06</b>	<b>Amoebiasis</b>
A06.0	Acute amoebic dysentery
A06.1	Chronic intestinal amoebiasis
A06.2	Amoebic nondysenteric colitis
A06.3	Amoeboma of intestine
A06.4	Amoebic liver abscess
A06.5	Amoebic lung abscess
A06.6	Amoebic brain abscess
A06.7	Cutaneous amoebiasis
A06.8	Amoebic infection of other sites
A06.9	Amoebiasis, unspecified
<b>A07</b>	<b>Other protozoal intestinal disease</b>
A07.0	Balantidiasis
A07.1	Giardiasis (lambliasis)
A07.2	Cryptosporidiosis
A07.3	Isosporiasis
A07.8	Other specified protozoal intestinal diseases
A07.9	Protozoal intestinal disease, unspecified
<b>A08</b>	<b>Viral and other specified intestinal infections</b>
A08.0	Rotaviral enteritis
A08.1	Acute gastroenteropathy due to Norwalk agent
A08.2	Adenoviral enteritis
A08.3	Other viral enteritis
A08.4	Viral intestinal infection, unspecified
A08.5	Other specified intestinal infections
<b>A09</b>	<b>Diarrhea and gastroenteritis of presumed infectious origin</b>
A09.0	Other and unspecified gastroenteritis of infectious origin
A09.9	Gastroenteritis and colitis of unspecified origin
* Typhoid and paratyphoid fevers were estimated separately.	

Table 2: Number of included studies by etiology and GBD region

GBD Region	Amoebiasis	Campylobacter	Cholera	Cryptosporidiosis	EPEC	ETEC	Rotavirus	Salmonella	Shigellosis
Asia Pacific, High Income	0	5	1	4	0	0	5	5	5
Asia, Central	0	0	0	0	0	0	18	0	0
Asia, East	0	0	0	0	0	0	4	0	1
Asia, South	20	22	30	21	6	26	33	13	34
Asia, Southeast	1	9	10	0	1	9	47	3	18
Australasia	0	0	0	0	0	0	0	0	0
Caribbean	0	0	0	0	0	0	4	0	0
Europe, Central	0	0	0	0	0	0	8	0	0
Europe, Eastern	0	0	0	0	0	0	21	0	0
Europe, Western	0	10	0	4	3	0	45	10	9
Latin America, Andean	0	4	2	3	1	2	7	2	4
Latin America, Central	4	3	0	10	1	5	14	4	7
Latin America, Southern	0	0	0	0	0	0	13	0	5
Latin America, Tropical	1	0	2	7	2	2	24	3	6
North Africa/Middle East	0	5	2	7	3	1	32	4	5
North America, High Income	0	2	0	0	0	2	2	2	2
Oceania	0	0	0	0	0	0	11	0	0
Sub-Saharan Africa, Central	0	0	0	0	0	0	1	0	0
Sub-Saharan Africa, East	1	1	2	5	2	2	15	1	3
Sub-Saharan Africa, Southern	1	1	1	1	1	1	16	1	1
Sub-Saharan Africa, West	2	1	0	3	5	7	8	6	8

Table 3: Number of incident cases of diarrheal diseases by GBD region in ages under 5, 2010

GBD Region	2010
Asia Pacific, High Income	18,000,000
Asia, Central	20,700,000
Asia, East	204,000,000
Asia, South	517,000,000
Asia, Southeast	123,000,000
Australasia	3,758,605
Caribbean	12,600,000
Europe, Central	9,704,687
Europe, Eastern	22,600,000
Europe, Western	45,900,000
Latin America, Andean	20,200,000
Latin America, Central	84,800,000
Latin America, Southern	12,400,000
Latin America, Tropical	51,400,000
North Africa / Middle East	166,000,000
North America, High Income	45,700,000
Oceania	3,387,773
Sub-Saharan Africa, Central	64,100,000
Sub-Saharan Africa, East	197,000,000
Sub-Saharan Africa, Southern	24,600,000
Sub-Saharan Africa, West	213,000,000
<b>Total</b>	<b>1,860,850,000</b>

Table 4: Number of diarrheal deaths in children under 5 by etiology and country in 2010

Country	2010									
	Amoebiasis	95% UI	Campylobacter	95% UI	Cholera	95% UI	Cryptosporidiosis	95% UI	EPEC	95% UI
Afghanistan	253	(41-860)	1,043	(332-2490)	531	(121-1466)	3,233	(1213-6964)	1,561	(507-3633)
Angola	42	(8-136)	652	(166-1747)	226	(46-661)	477	(122-1253)	743	(190-1939)
Albania	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-1)	0	(0-1)
Andorra	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
United Arab Emirates	0	(0-0)	1	(0-3)	0	(0-0)	1	(0-3)	1	(0-3)
Argentina	1	(0-4)	1	(5-34)	2	(0-6)	12	(4-28)	18	(6-42)
Armenia	0	(0-1)	1	(1-8)	0	(0-2)	3	(1-8)	4	(1-10)
Antigua and Barbuda	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Australia	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	0	(0-1)
Austria	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Azerbaijan	2	(0-5)	1	(5-49)	4	(0-16)	18	(5-46)	24	(6-59)
Burundi	71	(19-183)	1	(83-629)	248	(65-642)	791	(272-1716)	304	(95-700)
Belgium	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)
Benin	15	(3-45)	1	(30-320)	92	(20-264)	140	(38-351)	122	(31-320)
Burkina Faso	178	(53-438)	1	(417-2646)	1,465	(413-3696)	1,540	(574-3241)	1,235	(423-2728)
Bangladesh	161	(50-384)	1	(385-1875)	409	(149-879)	964	(399-1966)	1,090	(384-2354)
Bulgaria	0	(0-0)	1	(0-3)	0	(0-0)	1	(0-2)	1	(0-3)
Bahrain	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Bahamas	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Bosnia and Herzegovina	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	0	(0-1)
Belarus	0	(0-0)	1	(0-3)	0	(0-0)	1	(0-3)	1	(0-3)
Belize	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	1	(0-1)
Bolivia	15	(3-40)	1	(69-469)	17	(3-56)	101	(31-237)	172	(55-398)
Brazil	19	(4-54)	1	(91-585)	19	(3-61)	261	(95-561)	291	(102-649)
Barbados	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Brunei Darussalam	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Bhutan	0	(0-1)	1	(1-9)	1	(0-3)	3	(1-7)	4	(1-11)
Botswana	2	(0-6)	1	(8-70)	11	(2-32)	25	(7-60)	36	(11-86)
Central African Republic	27	(6-78)	1	(70-598)	105	(22-297)	282	(80-696)	305	(86-761)
Canada	0	(0-0)	1	(0-2)	0	(0-0)	0	(0-1)	1	(0-2)
Switzerland	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	1	(0-1)
Chile	0	(0-0)	1	(0-3)	0	(0-1)	1	(0-2)	1	(0-4)
China	17	(5-42)	1	(64-370)	60	(18-148)	172	(64-368)	205	(75-436)
Côte d'Ivoire	120	(31-308)	1	(342-2443)	780	(203-1972)	1,163	(394-2608)	1,114	(346-2550)
Cameroon	48	(11-141)	1	(122-1149)	337	(78-957)	456	(129-1139)	454	(119-1207)
Congo, the Democratic Republic of the	517	(117-1445)	1	(993-8227)	1,834	(415-5149)	4,787	(1450-11545)	4,303	(1207-10592)
Congo	4	(1-13)	1	(13-160)	24	(4-78)	42	(10-119)	64	(15-181)
Colombia	7	(2-18)	1	(29-180)	8	(1-28)	49	(16-112)	102	(34-228)
Comoros	1	(0-3)	1	(1-17)	3	(1-11)	13	(3-35)	6	(1-18)
Cape Verde	0	(0-1)	1	(1-7)	1	(0-2)	3	(1-7)	3	(1-7)
Costa Rica	0	(0-0)	1	(0-3)	0	(0-0)	1	(0-2)	1	(0-3)
Cuba	0	(0-0)	1	(0-2)	0	(0-1)	1	(0-1)	1	(0-2)
Cyprus	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Czech Republic	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Germany	0	(0-0)	1	(0-2)	0	(0-0)	1	(0-1)	1	(0-3)
Djibouti	1	(0-2)	1	(1-18)	1	(0-5)	11	(2-30)	7	(1-19)

Table 4: Number of diarrheal deaths in children under 5 by etiology and country in 2010 (continued)

Country	2010											
	Amoebiasis		Campylobacter		Cholera		Cryptosporidiosis		EPEC		95% UI	
Dominica	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Denmark	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Dominican Republic	2	(0-5)	1	(8-54)	7	(2-18)	18	(6-42)	28	(9-62)		
Algeria	3	(1-8)	1	(10-74)	6	(1-17)	49	(19-101)	44	(15-98)		
Ecuador	2	(1-5)	1	(14-67)	2	(0-5)	14	(6-29)	27	(11-55)		
Egypt	41	(9-112)	1	(159-814)	33	(4-120)	727	(341-1330)	583	(227-1154)		
Eritrea	19	(5-50)	1	(29-224)	83	(21-216)	247	(84-545)	105	(32-251)		
Spain	0	(0-0)	1	(0-2)	0	(0-0)	0	(0-1)	1	(0-2)		
Estonia	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Ethiopia	309	(79-819)	1	(486-3493)	1,991	(579-4966)	4,085	(1471-8725)	1,751	(557-4042)		
Finland	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Fiji	0	(0-1)	1	(1-7)	1	(0-2)	3	(1-6)	3	(1-8)		
France	0	(0-1)	1	(1-5)	0	(0-0)	1	(0-3)	3	(1-8)		
Micronesia, Federated States of	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Gabon	0	(0-1)	1	(2-21)	1	(0-5)	4	(1-11)	8	(2-22)		
United Kingdom	0	(0-0)	1	(0-3)	0	(0-0)	1	(0-2)	1	(0-4)		
Georgia	0	(0-0)	1	(0-4)	0	(0-1)	1	(0-4)	2	(0-5)		
Ghana	15	(4-39)	1	(34-265)	58	(14-158)	132	(43-307)	112	(34-264)		
Guinea	26	(6-72)	1	(53-450)	144	(34-395)	236	(70-548)	194	(54-487)		
Gambia	3	(1-10)	1	(8-67)	7	(1-21)	31	(10-74)	28	(8-68)		
Guinea-Bissau	10	(2-29)	1	(19-173)	34	(7-102)	91	(26-213)	73	(19-183)		
Equatorial Guinea	1	(0-4)	1	(2-45)	2	(0-7)	8	(1-28)	14	(3-48)		
Greece	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Grenada	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Guatemala	16	(5-39)	1	(56-331)	22	(4-70)	101	(36-222)	189	(65-409)		
Guyana	0	(0-1)	1	(1-9)	2	(0-6)	4	(1-9)	5	(1-10)		
Honduras	5	(1-14)	1	(13-104)	8	(1-31)	33	(9-80)	59	(17-136)		
Croatia	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Haiti	24	(5-71)	1	(52-396)	78	(14-238)	195	(63-442)	204	(66-450)		
Hungary	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Indonesia	192	(49-485)	1	(611-3989)	733	(211-1783)	2,105	(641-4363)	2,199	(664-4562)		
India	1,866	(546-4612)	1	(4536-26107)	9,516	(3255-21007)	11,789	(4336-24585)	15,001	(4689-33397)		
Ireland	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Iran, Islamic Republic of	3	(1-9)	1	(11-89)	9	(2-26)	52	(17-117)	51	(16-124)		
Iraq	15	(3-46)	1	(46-344)	22	(5-64)	285	(108-603)	211	(64-476)		
Iceland	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Israel	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	1	(0-1)		
Italy	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	0	(0-1)		
Jamaica	0	(0-1)	1	(1-14)	2	(0-5)	4	(1-10)	6	(1-15)		
Jordan	0	(0-1)	1	(1-8)	0	(0-1)	6	(2-13)	5	(2-11)		
Japan	0	(0-1)	1	(1-5)	0	(0-0)	1	(0-3)	3	(1-8)		
Kazakhstan	2	(0-5)	1	(8-64)	6	(1-22)	21	(7-51)	31	(10-70)		
Kenya	75	(17-201)	1	(155-1255)	403	(106-1055)	1,137	(386-2483)	581	(176-1376)		
Kyrgyzstan	4	(1-10)	1	(10-69)	10	(1-35)	37	(13-82)	38	(13-84)		
Cambodia	14	(3-39)	1	(31-225)	66	(14-191)	139	(42-330)	114	(35-271)		
Kiribati	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	0	(0-1)		

Table 4: Number of diarrheal deaths in children under 5 by etiology and country in 2010 (continued)

Country	2010									
	Amoebiasis	95% UI	Campylobacter	95% UI	Cholera	95% UI	Cryptosporidiosis	95% UI	EPEC	95% UI
Korea, Republic of	0	(0-0)	1	(0-2)	0	(0-0)	1	(0-2)	1	(0-3)
Kuwait	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	0	(0-1)
Lao People's Democratic Republic	15	(3-42)	1	(28-280)	47	(9-136)	149	(37-377)	129	(31-330)
Lebanon	0	(0-0)	1	(0-4)	0	(0-0)	2	(0-5)	2	(0-6)
Liberia	47	(10-136)	1	(84-650)	129	(28-361)	413	(137-946)	303	(86-700)
Libyan Arab Jamahiriya	0	(0-1)	1	(1-12)	0	(0-2)	6	(2-16)	6	(2-17)
Saint Lucia	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Sri Lanka	1	(0-2)	1	(2-15)	1	(0-3)	6	(2-16)	7	(2-17)
Lesotho	19	(4-53)	1	(32-234)	92	(20-257)	164	(54-363)	142	(45-314)
Lithuania	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Luxembourg	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Latvia	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Morocco	5	(1-16)	1	(13-108)	14	(3-38)	84	(30-189)	65	(21-152)
Moldova	0	(0-0)	1	(0-2)	0	(0-0)	1	(0-3)	1	(0-3)
Madagascar	75	(19-195)	1	(131-1001)	414	(117-1049)	1,040	(359-2251)	479	(148-1122)
Maldives	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Mexico	9	(3-24)	1	(56-305)	17	(3-55)	73	(27-161)	180	(66-378)
Marshall Islands	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	0	(0-1)
Macedonia, the Former Yugoslav Republic of	0	(0-0)	1	(0-3)	0	(0-0)	1	(0-3)	1	(0-4)
Mali	64	(12-186)	1	(96-1134)	378	(78-1129)	552	(138-1459)	443	(99-1224)
Malta	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Myanmar	175	(43-490)	1	(326-1702)	247	(81-580)	1,465	(562-2968)	1,010	(376-2074)
Montenegro	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Mongolia	0	(0-1)	1	(0-5)	0	(0-1)	2	(0-5)	2	(1-6)
Mozambique	83	(21-219)	1	(130-956)	376	(103-981)	1,146	(395-2455)	474	(151-1092)
Mauritania	10	(3-25)	1	(27-187)	49	(13-137)	89	(30-201)	82	(25-194)
Mauritius	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	0	(0-1)
Malawi	73	(18-187)	1	(114-864)	477	(128-1166)	989	(341-2113)	422	(126-980)
Malaysia	0	(0-0)	1	(1-5)	0	(0-1)	2	(1-4)	2	(1-6)
Namibia	6	(2-15)	1	(18-128)	30	(7-83)	60	(20-135)	74	(23-161)
Niger	336	(98-824)	1	(682-3968)	2,373	(710-5866)	2,693	(1058-5496)	1,932	(676-4192)
Nigeria	524	(132-1384)	1	(1283-9995)	3,150	(799-8562)	4,581	(1483-10504)	4,095	(1161-9896)
Nicaragua	4	(1-12)	1	(9-76)	7	(1-24)	26	(8-62)	44	(13-104)
Netherlands	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)
Norway	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Nepal	114	(35-280)	1	(228-1101)	324	(103-769)	661	(272-1265)	714	(237-1522)
New Zealand	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Oman	0	(0-0)	1	(0-1)	0	(0-0)	1	(0-1)	1	(0-1)
Pakistan	547	(166-1322)	1	(1546-7544)	1,466	(521-3262)	3,474	(1455-6939)	4,586	(1601-9859)
Panama	0	(0-1)	1	(2-12)	1	(0-3)	3	(1-7)	7	(2-15)
Peru	3	(1-7)	1	(15-101)	3	(1-10)	18	(6-41)	34	(11-76)
Philippines	32	(7-83)	1	(75-619)	65	(15-164)	313	(76-708)	317	(77-727)
Papua New Guinea	10	(2-31)	1	(25-273)	49	(10-140)	110	(27-295)	123	(30-332)
Poland	0	(0-0)	1	(0-2)	0	(0-0)	1	(0-2)	1	(0-3)
Korea, Democratic People's Republic of	2	(0-6)	1	(2-37)	2	(0-7)	13	(2-43)	14	(2-44)
Portugal	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)

Table 4: Number of diarrheal deaths in children under 5 by etiology and country in 2010 (continued)

Country	2010											
	Amoebiasis	95% UI	Campylobacter	95% UI	Cholera	95% UI	Cryptosporidiosis	95% UI	EPEC	95% UI		
Paraguay	2	(0-5)	1	(6-37)	1	(0-5)	20	(7-44)	19	(7-42)		
Occupied Palestinian Territory	0	(0-1)	1	(1-4)	0	(0-1)	4	(1-8)	2	(1-6)		
Qatar	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Romania	0	(0-1)	1	(1-9)	0	(0-0)	3	(1-8)	5	(2-11)		
Russian Federation	3	(1-9)	1	(15-96)	0	(0-0)	33	(11-77)	50	(16-108)		
Rwanda	19	(5-52)	1	(32-274)	100	(26-260)	272	(92-618)	125	(36-312)		
Saudi Arabia	1	(0-3)	1	(4-36)	2	(0-5)	16	(5-38)	19	(6-47)		
Sudan	92	(20-265)	1	(173-1629)	753	(189-1994)	1,299	(386-3075)	707	(180-1801)		
Senegal	53	(15-133)	1	(134-964)	191	(49-516)	476	(162-1023)	431	(136-985)		
Singapore	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Solomon Islands	0	(0-1)	1	(1-7)	1	(0-2)	3	(1-7)	3	(1-8)		
Sierra Leone	22	(5-60)	1	(41-353)	104	(24-289)	191	(60-448)	150	(41-383)		
El Salvador	1	(0-3)	1	(4-26)	2	(0-8)	8	(3-18)	15	(5-33)		
Somalia	97	(27-242)	1	(163-1134)	302	(85-745)	1,284	(471-2593)	560	(184-1233)		
Serbia	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	0	(0-1)		
Sao Tome and Principe	0	(0-1)	1	(0-5)	1	(0-3)	2	(1-5)	2	(0-5)		
Suriname	0	(0-0)	1	(0-2)	0	(0-0)	1	(0-1)	1	(0-2)		
Slovakia	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)		
Slovenia	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Sweden	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-1)		
Swaziland	6	(1-17)	1	(18-139)	35	(8-99)	67	(20-160)	79	(24-179)		
Seychelles	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Syrian Arab Republic	0	(0-1)	1	(1-9)	1	(0-2)	7	(2-16)	5	(2-13)		
Chad	204	(59-501)	1	(499-3227)	1,814	(474-4561)	1,822	(618-3845)	1,517	(484-3316)		
Togo	27	(7-71)	1	(50-413)	90	(22-253)	229	(71-547)	180	(50-447)		
Thailand	1	(0-3)	1	(5-34)	2	(1-6)	14	(4-33)	16	(5-38)		
Tajikistan	11	(3-32)	1	(28-208)	8	(1-31)	111	(36-248)	113	(37-254)		
Turkmenistan	3	(1-10)	1	(10-97)	3	(0-11)	36	(9-92)	46	(12-115)		
Timor-Leste	4	(1-10)	1	(9-69)	10	(2-32)	40	(12-90)	36	(11-79)		
Tonga	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)		
Trinidad and Tobago	0	(0-0)	1	(0-2)	0	(0-0)	0	(0-1)	1	(0-2)		
Tunisia	1	(0-4)	1	(3-32)	2	(0-6)	19	(5-47)	17	(4-45)		
Turkey	3	(0-8)	1	(12-82)	7	(2-19)	49	(18-111)	49	(16-113)		
Taiwan	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-1)	0	(0-1)		
Tanzania, United Republic of	60	(15-168)	1	(110-857)	378	(98-996)	877	(298-1947)	411	(126-989)		
Uganda	47	(11-130)	1	(75-696)	192	(44-553)	693	(223-1590)	307	(87-756)		
Ukraine	1	(0-3)	1	(4-27)	0	(0-0)	10	(3-24)	14	(4-32)		
Uruguay	0	(0-0)	1	(0-3)	0	(0-0)	1	(0-3)	2	(0-4)		
United States	1	(0-4)	1	(4-25)	0	(0-0)	6	(2-16)	13	(4-30)		
Uzbekistan	4	(1-11)	1	(8-85)	13	(1-49)	37	(10-101)	38	(10-106)		
Saint Vincent and the Grenadines	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Venezuela	4	(1-12)	1	(21-141)	5	(1-18)	33	(11-76)	77	(26-172)		
Viet Nam	6	(1-16)	1	(13-99)	20	(5-54)	55	(16-138)	46	(13-114)		
Vanuatu	0	(0-0)	1	(0-3)	0	(0-0)	1	(0-3)	1	(0-4)		
Samoa	0	(0-0)	1	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Yemen	152	(21-504)	1	(325-2611)	576	(99-1718)	2,692	(852-5638)	1,745	(485-3996)		

Table 4: Number of diarrheal deaths in children under 5 by etiology and country in 2010 (continued)

Country	2010									
	Amoebiasis	95% UI	Campylobacter	95% UI	Cholera	95% UI	Cryptosporidiosis	95% UI	EPEC	95% UI
South Africa	74	(19-189)	1	(340-1916)	327	(98-797)	848	(306-1815)	1,199	(460-2471)
Zambia	51	(13-136)	1	(106-773)	190	(52-494)	757	(274-1595)	364	(117-840)
Zimbabwe	79	(14-245)	1	(75-648)	120	(30-325)	536	(166-1213)	371	(108-864)
Country	2010									
	ETEC	95% UI	Rotavirus	95% UI	Salmonella	95% UI	Shigellosis	95% UI	Other	95% UI
Afghanistan	815	(250-2008)	2,705	(1091-5559)	550	(157-1461)	1,018	(351-2300)	4,367	(1793-9089)
Angola	391	(102-1027)	1,474	(473-3541)	578	(142-1578)	264	(67-716)	2,930	(985-6674)
Albania	0	(0-1)	1	(0-2)	0	(0-1)	0	(0-0)	1	(0-3)
Andorra	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
United Arab Emirates	1	(0-2)	2	(0-6)	1	(0-4)	0	(0-1)	3	(1-8)
Argentina	9	(3-23)	26	(11-55)	11	(3-27)	5	(2-13)	59	(26-123)
Armenia	2	(1-5)	6	(2-13)	2	(1-5)	2	(1-4)	13	(5-26)
Antigua and Barbuda	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)
Australia	0	(0-1)	1	(0-2)	0	(0-1)	0	(0-0)	2	(0-4)
Austria	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-0)	1	(0-1)
Azerbaijan	12	(3-31)	34	(12-76)	12	(3-32)	9	(3-24)	70	(25-154)
Burundi	206	(70-460)	757	(284-1538)	172	(51-410)	267	(87-605)	1,810	(700-3629)
Belgium	0	(0-1)	1	(0-3)	0	(0-1)	0	(0-0)	1	(0-3)
Benin	67	(18-174)	286	(86-677)	54	(13-149)	80	(21-201)	636	(202-1449)
Burkina Faso	678	(247-1439)	2,879	(1250-5575)	505	(164-1221)	875	(317-1872)	6,548	(3040-11955)
Bangladesh	511	(195-1093)	1,488	(653-2871)	218	(73-500)	785	(313-1619)	4,949	(2307-8947)
Bulgaria	1	(0-2)	2	(1-5)	1	(0-2)	0	(0-1)	3	(1-8)
Bahrain	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)
Bahamas	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-1)
Bosnia and Herzegovina	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	1	(0-2)
Belarus	1	(0-2)	3	(1-6)	1	(0-2)	1	(0-1)	4	(2-9)
Belize	0	(0-1)	1	(0-2)	0	(0-1)	0	(0-1)	2	(1-5)
Bolivia	108	(36-245)	390	(146-802)	64	(18-160)	80	(27-177)	677	(262-1329)
Brazil	166	(58-375)	367	(167-689)	131	(39-315)	111	(39-250)	1,179	(567-2124)
Barbados	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-1)
Brunei Darussalam	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)
Bhutan	2	(0-5)	6	(1-15)	1	(0-3)	2	(0-5)	16	(5-43)
Botswana	18	(5-44)	50	(17-109)	20	(5-50)	14	(4-34)	141	(51-287)
Central African Republic	162	(46-389)	562	(188-1243)	146	(38-371)	151	(42-380)	1,223	(448-2523)
Canada	0	(0-1)	2	(0-4)	1	(0-2)	0	(0-1)	3	(1-7)
Switzerland	0	(0-1)	2	(1-4)	1	(0-1)	0	(0-0)	2	(1-4)
Chile	1	(0-2)	2	(1-5)	1	(0-2)	0	(0-1)	4	(1-10)
China	114	(43-247)	373	(177-691)	111	(39-251)	84	(30-189)	693	(336-1248)
Côte d'Ivoire	576	(190-1299)	2,516	(1001-5028)	491	(144-1188)	651	(220-1439)	5,482	(2384-10507)
Cameroon	244	(70-606)	1,086	(355-2496)	227	(59-624)	265	(76-677)	2,354	(792-5275)
Congo, the Democratic Republic of the	2,320	(691-5750)	8,092	(2879-17338)	1,645	(467-4170)	2,547	(718-6231)	17,470	(6350-35605)
Congo	33	(8-95)	125	(36-317)	47	(11-134)	23	(5-67)	249	(77-620)
Colombia	62	(22-139)	172	(71-345)	45	(15-105)	37	(13-84)	437	(194-835)
Comoros	4	(1-11)	16	(4-39)	4	(1-13)	4	(1-11)	33	(8-82)
Cape Verde	1	(0-4)	6	(2-14)	1	(0-3)	1	(0-4)	12	(4-29)
Costa Rica	1	(0-2)	2	(1-5)	1	(0-2)	0	(0-1)	6	(2-12)

Table 4: Number of diarrheal deaths in children under 5 by etiology and country in 2010 (continued)

Country	2010											
	ETEC	95% UI	Rotavirus	95% UI	Salmonella	95% UI	Shigellosis	95% UI	Other	95% UI		
Cuba	0	(0-1)	1	(1-3)	1	(0-1)	0	(0-1)	3	(1-7)		
Cyprus	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Czech Republic	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	1	(0-1)		
Germany	1	(0-2)	4	(2-8)	1	(0-2)	0	(0-1)	4	(2-9)		
Djibouti	4	(1-12)	17	(4-42)	6	(1-17)	4	(1-10)	35	(8-86)		
Dominica	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Denmark	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)		
Dominican Republic	15	(5-34)	45	(19-92)	17	(5-42)	10	(3-24)	109	(48-218)		
Algeria	22	(7-54)	80	(33-162)	27	(8-66)	17	(6-39)	119	(50-239)		
Ecuador	18	(7-36)	64	(30-118)	12	(4-28)	12	(5-24)	112	(56-197)		
Egypt	287	(105-610)	988	(508-1696)	311	(109-680)	245	(104-487)	1,536	(772-2592)		
Eritrea	69	(22-160)	265	(100-543)	69	(19-174)	80	(26-188)	601	(239-1200)		
Spain	1	(0-1)	3	(1-7)	1	(0-2)	0	(0-1)	3	(1-6)		
Estonia	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Ethiopia	1,102	(371-2546)	4,073	(1643-8210)	1,039	(306-2493)	1,291	(438-2916)	9,498	(4045-18345)		
Finland	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)		
Fiji	2	(1-4)	6	(2-12)	2	(1-5)	1	(0-3)	11	(5-22)		
France	2	(1-4)	11	(4-23)	3	(1-7)	1	(0-2)	11	(4-24)		
Micronesia, Federated States of	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)		
Gabon	4	(1-11)	16	(5-42)	8	(2-26)	2	(0-6)	29	(9-74)		
United Kingdom	1	(0-2)	5	(2-11)	1	(0-3)	0	(0-1)	5	(2-12)		
Georgia	1	(0-3)	3	(1-7)	1	(0-3)	1	(0-2)	5	(2-14)		
Ghana	59	(19-145)	262	(97-563)	46	(13-121)	73	(24-174)	569	(229-1177)		
Guinea	102	(31-244)	434	(150-974)	74	(20-195)	130	(40-310)	968	(367-2035)		
Gambia	15	(5-36)	64	(23-143)	12	(3-30)	18	(5-44)	140	(55-291)		
Guinea-Bissau	39	(11-98)	166	(54-369)	28	(7-74)	50	(14-128)	377	(132-802)		
Equatorial Guinea	8	(1-27)	30	(6-97)	16	(3-56)	5	(1-16)	57	(13-182)		
Greece	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)		
Grenada	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Guatemala	120	(45-246)	340	(151-640)	80	(29-172)	79	(30-168)	865	(411-1563)		
Guyana	3	(1-6)	7	(3-15)	2	(1-6)	2	(1-5)	19	(8-37)		
Honduras	35	(11-81)	95	(32-193)	21	(6-50)	24	(7-57)	247	(86-481)		
Croatia	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	1	(0-1)		
Haiti	110	(36-251)	308	(123-628)	82	(23-196)	102	(32-242)	814	(343-1548)		
Hungary	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	1	(0-1)		
Indonesia	1,377	(444-2917)	4,688	(1854-8154)	1,453	(419-3266)	1,023	(334-2186)	7,993	(3148-13813)		
India	7,104	(2496-15611)	25,502	(9732-51488)	3,887	(1184-9145)	8,755	(3080-19044)	70,465	(28269-135242)		
Ireland	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-0)	1	(0-1)		
Iran, Islamic Republic of	25	(7-62)	95	(37-209)	33	(9-81)	18	(6-43)	133	(51-290)		
Iraq	103	(31-261)	368	(145-755)	113	(32-276)	90	(31-200)	545	(221-1101)		
Iceland	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Israel	0	(0-1)	2	(1-3)	0	(0-1)	0	(0-0)	2	(1-4)		
Italy	0	(0-1)	1	(1-3)	0	(0-1)	0	(0-0)	2	(1-3)		
Jamaica	3	(1-9)	10	(3-24)	4	(1-11)	2	(1-6)	24	(8-56)		
Jordan	3	(1-6)	9	(4-18)	3	(1-7)	2	(1-5)	14	(6-28)		
Japan	2	(1-5)	7	(3-14)	3	(1-7)	1	(0-2)	13	(5-26)		

Table 4: Number of diarrheal deaths in children under 5 by etiology and country in 2010 (continued)

Country	2010											
	ETEC	95% UI	Rotavirus	95% UI	Salmonella	95% UI	Shigellosis	95% UI	Other	95% UI		
Kazakhstan	16	(5-39)	48	(21-99)	19	(6-46)	12	(4-28)	96	(42-194)		
Kenya	363	(115-848)	1,460	(557-3025)	441	(124-1117)	355	(111-838)	3,105	(1257-6209)		
Kyrgyzstan	20	(7-45)	53	(24-102)	16	(5-38)	19	(7-43)	119	(56-219)		
Cambodia	72	(21-174)	223	(82-471)	58	(15-150)	67	(21-162)	412	(155-845)		
Kiribati	0	(0-1)	1	(0-2)	0	(0-1)	0	(0-1)	2	(0-4)		
Korea, Republic of	1	(0-2)	2	(1-5)	1	(0-2)	0	(0-1)	4	(2-9)		
Kuwait	0	(0-1)	1	(0-2)	0	(0-1)	0	(0-0)	1	(0-3)		
Lao People's Democratic Republic	84	(21-213)	273	(85-607)	73	(17-195)	73	(19-193)	490	(150-1081)		
Lebanon	1	(0-3)	3	(1-10)	1	(0-4)	1	(0-2)	4	(1-15)		
Liberia	150	(48-346)	622	(231-1252)	87	(24-218)	216	(66-493)	1,392	(557-2600)		
Libyan Arab Jamahiriya	3	(1-8)	12	(3-30)	5	(1-14)	2	(1-5)	16	(5-42)		
Saint Lucia	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-1)		
Sri Lanka	4	(1-12)	14	(4-33)	5	(1-13)	3	(1-9)	26	(8-63)		
Lesotho	69	(22-155)	174	(69-335)	42	(13-103)	86	(28-196)	552	(227-1004)		
Lithuania	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Luxembourg	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Latvia	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-1)		
Morocco	32	(9-80)	112	(42-236)	32	(9-79)	29	(9-68)	171	(65-362)		
Moldova	1	(0-1)	2	(1-4)	0	(0-1)	1	(0-1)	4	(1-7)		
Madagascar	304	(101-682)	1,195	(466-2398)	329	(96-813)	327	(107-748)	2,647	(1068-5121)		
Maldives	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-1)		
Mexico	106	(42-223)	292	(135-525)	89	(31-193)	56	(21-121)	744	(380-1305)		
Marshall Islands	0	(0-0)	1	(0-1)	0	(0-1)	0	(0-0)	1	(0-3)		
Macedonia, the Former Yugoslav Republic of	1	(0-2)	2	(1-6)	1	(0-2)	1	(0-1)	4	(1-9)		
Mali	242	(55-649)	1,005	(272-2465)	177	(37-496)	309	(77-815)	2,317	(666-5523)		
Malta	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Myanmar	652	(247-1339)	1,968	(991-3355)	434	(150-966)	710	(274-1495)	3,796	(1928-6356)		
Montenegro	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Mongolia	1	(0-3)	3	(1-8)	1	(0-3)	1	(0-3)	6	(2-17)		
Mozambique	294	(99-646)	1,164	(473-2356)	285	(82-710)	345	(112-780)	2,546	(1104-4878)		
Mauritania	45	(15-101)	195	(76-402)	39	(12-92)	52	(17-119)	434	(178-861)		
Mauritius	0	(0-0)	1	(0-1)	0	(0-1)	0	(0-0)	1	(1-3)		
Malawi	267	(87-609)	1,058	(407-2180)	262	(74-662)	308	(100-736)	2,309	(960-4612)		
Malaysia	2	(1-4)	5	(2-10)	2	(1-6)	1	(0-2)	10	(4-20)		
Namibia	37	(12-83)	101	(39-196)	36	(11-84)	34	(11-76)	301	(121-552)		
Niger	1,085	(414-2210)	4,495	(2004-8224)	714	(240-1589)	1,529	(592-3148)	10,510	(5059-18182)		
Nigeria	2,303	(731-5464)	10,218	(3734-22408)	2,054	(578-5309)	2,679	(836-6467)	22,965	(8551-48604)		
Nicaragua	25	(8-58)	63	(24-132)	13	(4-32)	18	(6-43)	173	(72-332)		
Netherlands	0	(0-1)	1	(0-3)	0	(0-1)	0	(0-0)	1	(1-3)		
Norway	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)		
Nepal	334	(127-683)	1,098	(462-2026)	143	(48-316)	485	(188-981)	3,298	(1485-5620)		
New Zealand	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	1	(0-1)		
Oman	0	(0-1)	1	(0-3)	1	(0-1)	0	(0-0)	2	(1-4)		
Pakistan	2,129	(798-4370)	7,166	(3124-13594)	1,172	(386-2640)	2,633	(1037-5377)	21,146	(9710-37965)		
Panama	4	(1-9)	12	(5-24)	3	(1-7)	2	(1-6)	30	(13-58)		
Peru	23	(8-51)	94	(35-199)	15	(4-38)	15	(5-33)	142	(56-288)		

Table 4: Number of diarrheal deaths in children under 5 by etiology and country in 2010 (continued)

Country	2010											
	ETEC	95% UI	Rotavirus	95% UI	Salmonella	95% UI	Shigellosis	95% UI	Other	95% UI		
Philippines	213	(55-485)	589	(174-1173)	226	(54-535)	154	(43-350)	1,269	(374-2486)		
Papua New Guinea	69	(18-190)	218	(68-523)	61	(14-173)	60	(15-164)	409	(131-977)		
Poland	1	(0-1)	2	(1-5)	1	(0-2)	0	(0-1)	3	(1-8)		
Korea, Democratic People's Republic of	8	(1-25)	24	(4-73)	7	(1-21)	6	(1-19)	47	(8-137)		
Portugal	0	(0-1)	1	(0-3)	0	(0-1)	0	(0-0)	1	(0-3)		
Paraguay	12	(4-26)	27	(12-51)	8	(2-19)	9	(3-21)	84	(40-155)		
Occupied Palestinian Territory	1	(0-3)	4	(2-9)	1	(0-3)	1	(0-3)	7	(2-14)		
Qatar	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	0	(0-1)		
Romania	2	(1-6)	8	(4-17)	3	(1-6)	2	(1-4)	14	(6-27)		
Russian Federation	25	(9-60)	101	(46-195)	31	(9-78)	17	(5-40)	151	(68-291)		
Rwanda	79	(25-192)	307	(113-649)	83	(23-213)	86	(27-209)	680	(261-1434)		
Saudi Arabia	9	(3-24)	36	(13-79)	17	(5-42)	6	(2-14)	51	(19-112)		
Sudan	446	(131-1113)	1,731	(580-3975)	575	(147-1492)	429	(120-1055)	3,880	(1354-8505)		
Senegal	236	(79-527)	1,003	(384-2006)	203	(61-494)	278	(95-621)	2,279	(945-4359)		
Singapore	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-1)		
Solomon Islands	2	(1-5)	6	(2-12)	2	(0-4)	2	(0-4)	11	(4-23)		
Sierra Leone	79	(24-193)	329	(113-743)	53	(14-140)	106	(32-255)	749	(281-1592)		
El Salvador	9	(3-20)	24	(10-47)	6	(2-14)	5	(2-12)	63	(28-116)		
Somalia	359	(125-767)	1,383	(579-2623)	356	(109-817)	406	(148-881)	3,122	(1351-5740)		
Serbia	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-0)	1	(0-2)		
Sao Tome and Principe	1	(0-3)	4	(1-10)	1	(0-2)	1	(0-3)	9	(3-21)		
Suriname	0	(0-1)	1	(0-3)	1	(0-1)	0	(0-1)	3	(1-8)		
Slovakia	0	(0-0)	1	(0-1)	0	(0-0)	0	(0-0)	1	(0-2)		
Slovenia	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Sweden	0	(0-0)	1	(0-2)	0	(0-0)	0	(0-0)	1	(0-2)		
Swaziland	38	(11-96)	104	(38-217)	34	(10-86)	37	(11-89)	307	(119-628)		
Seychelles	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)		
Syrian Arab Republic	3	(1-7)	10	(4-23)	3	(1-8)	2	(1-6)	16	(6-34)		
Chad	836	(293-1796)	3,593	(1438-6830)	663	(205-1611)	1,049	(339-2338)	8,089	(3417-14586)		
Togo	98	(29-244)	423	(147-924)	69	(20-182)	129	(39-313)	950	(345-1994)		
Thailand	10	(3-24)	33	(13-68)	14	(4-33)	7	(2-17)	59	(24-118)		
Tajikistan	59	(19-138)	162	(66-322)	45	(13-109)	59	(19-136)	356	(148-680)		
Turkmenistan	24	(6-60)	69	(22-156)	24	(6-63)	20	(5-51)	144	(47-319)		
Timor-Leste	21	(7-49)	65	(27-123)	17	(5-42)	17	(5-38)	120	(49-225)		
Tonga	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	1	(0-2)		
Trinidad and Tobago	0	(0-1)	1	(0-3)	1	(0-1)	0	(0-1)	3	(1-6)		
Tunisia	9	(2-23)	30	(9-71)	10	(2-29)	7	(2-17)	46	(14-108)		
Turkey	24	(7-60)	93	(38-192)	33	(9-81)	17	(6-40)	127	(51-261)		
Taiwan	0	(0-1)	1	(0-3)	1	(0-1)	0	(0-0)	2	(0-4)		
Tanzania, United Republic of	255	(82-609)	1,018	(393-2121)	286	(80-726)	267	(86-636)	2,198	(912-4525)		
Uganda	193	(56-472)	757	(274-1678)	210	(52-569)	207	(61-517)	1,654	(643-3482)		
Ukraine	7	(2-17)	25	(10-51)	7	(2-18)	5	(2-13)	41	(17-83)		
Uruguay	1	(0-2)	2	(1-5)	1	(0-2)	0	(0-1)	5	(1-11)		
United States	7	(2-16)	23	(9-46)	11	(3-27)	4	(1-9)	42	(18-83)		
Uzbekistan	20	(5-55)	55	(17-137)	16	(4-43)	20	(5-55)	122	(39-304)		
Saint Vincent and the Grenadines	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-0)	0	(0-1)		

Table 4: Number of diarrheal deaths in children under 5 by etiology and country in 2010 (continued)

Country	2010											
	ETEC	95% UI	Rotavirus	95% UI	Salmonella	95% UI	Shigellosis	95% UI	Other	95% UI		
Venezuela	46	(16-103)	134	(54-260)	37	(12-86)	25	(9-58)	322	(141-613)		
Viet Nam	32	(10-79)	98	(35-221)	30	(9-77)	30	(9-74)	191	(69-418)		
Vanuatu	1	(0-2)	3	(1-6)	1	(0-2)	1	(0-1)	5	(2-10)		
Samoa	0	(0-0)	0	(0-1)	0	(0-0)	0	(0-0)	0	(0-2)		
Yemen	828	(219-1977)	2,897	(987-5830)	727	(170-1827)	832	(252-1830)	4,354	(1481-8658)		
South Africa	566	(210-1192)	1,404	(661-2491)	633	(220-1378)	471	(176-992)	4,574	(2346-7599)		
Zambia	232	(78-527)	931	(373-1912)	279	(83-659)	231	(77-522)	2,003	(862-3857)		
Zimbabwe	189	(56-440)	470	(164-996)	96	(26-248)	284	(84-667)	1,561	(559-3127)		

Table 5: Number of incident cases of diarrhea under 5 by etiology and GBD region for 2010

GBD Region	2010									
	Amoebiasis	95% UI	Campylobacter	95% UI	Cholera	95% UI	Cryptosporidiosis	95% UI	EPEC	95% UI
Asia Pacific, High Income	179,702	(16758-689259)	1,514,443	(461168-3624503)	0	(0-0)	859,591	(256934-2117018)	2,995,011	(934192-6508086)
Asia, Central	216,402	(45188-620492)	2,028,876	(656825-4734962)	0	(0-0)	2,337,015	(788173-5283854)	3,196,770	(966409-6961714)
Asia, East	1,906,279	(409611-5736687)	19,800,000	(6520304-45892887)	1,662,859	(385945-4801237)	20,900,000	(6721620-49129001)	31,300,000	(9501983-69856872)
Asia, South	8,375,782	(3055577-18642492)	35,500,000	(15377575-71604336)	7,162,825	(3268852-14528701)	42,900,000	(21939320-76906338)	57,800,000	(16917336-134708424)
Asia, Southeast	1,219,824	(293187-3427502)	11,300,000	(3860342-25799845)	926,640	(226713-2671598)	13,800,000	(4743594-30153499)	18,500,000	(5892740-39358018)
Australasia	32,161	(3546-121849)	387,037	(123585-873759)	0	(0-0)	254,556	(75872-623312)	570,565	(165462-1259701)
Caribbean	117,419	(18163-383314)	1,174,860	(377332-2674537)	102,980	(15807-368157)	1,140,577	(366077-2642669)	1,812,040	(565483-3852051)
Europe, Central	83,118	(14509-272638)	983,215	(322713-2213708)	0	(0-0)	822,748	(262148-1942628)	1,517,720	(466911-3264941)
Europe, Eastern	191,637	(36308-603259)	2,235,585	(728881-5361936)	0	(0-0)	2,020,542	(650802-4779495)	3,436,620	(1043867-7442789)
Europe, Western	386,855	(42584-1546377)	3,630,649	(1257310-8280161)	0	(0-0)	2,916,969	(933474-7114162)	6,926,039	(2173688-15377302)
Latin America, Andean	149,805	(35478-413576)	2,640,563	(1113442-4934838)	0	(0-0)	1,209,601	(467226-2591439)	2,552,508	(798487-5286440)
Latin America, Central	606,527	(130235-1753611)	8,043,264	(2732635-17653397)	0	(0-0)	4,914,974	(1850755-11101293)	12,500,000	(4048050-26104225)
Latin America, Southern	108,339	(18964-348323)	1,224,494	(384329-2845127)	0	(0-0)	1,052,072	(338763-2517059)	1,955,251	(585135-4264781)
Latin America, Tropical	426,834	(99617-1245786)	4,901,620	(1602480-10996645)	0	(0-0)	4,933,920	(1730025-10857528)	7,508,867	(2286750-16620119)
North Africa/Middle East	1,767,167	(288749-5810247)	14,800,000	(5701046-31025521)	796,199	(169624-2334457)	34,000,000	(16083026-60357826)	27,800,000	(9531159-56697586)
North America, High Income	445,009	(36701-1746104)	4,829,298	(1602130-10570497)	0	(0-0)	2,886,877	(900088-6867354)	6,861,767	(2286181-14759800)
Oceania	32,273	(6915-93596)	316,116	(102458-726370)	36,036	(8497-102198)	375,298	(119777-857586)	511,574	(144705-1175913)
Sub-Saharan Africa, Central	675,457	(130370-2056948)	5,363,732	(1701461-13049878)	573,574	(107281-1776066)	7,290,239	(2274653-17020335)	8,940,313	(2683917-19496074)
Sub-Saharan Africa, East	2,235,440	(632649-5772747)	12,200,000	(4059318-27634501)	3,397,865	(1001849-8904938)	37,400,000	(17792797-65018344)	17,800,000	(6182424-40368817)
Sub-Saharan Africa, Southern	301,374	(49736-1024138)	2,127,509	(716712-4789035)	211,874	(44710-629203)	2,872,300	(946921-6323933)	3,542,824	(1130003-7661414)
Sub-Saharan Africa, West	2,075,583	(547479-5467596)	18,400,000	(6029206-40630750)	3,617,801	(792924-10617784)	22,900,000	(9574676-46055550)	23,800,000	(7145342-53005921)
GBD Region	2010									
	ETEC	95% UI	Rotavirus	95% UI	Salmonella	95% UI	Shigellosis	95% UI	Other	95% UI
Asia Pacific, High Income	1,578,089	(564337-3488578)	2,501,678	(1194701-4564090)	680,968	(209076-1735011)	568,137	(180757-1402223)	7,146,628	(4042796-11765962)
Asia, Central	1,707,284	(584906-3848977)	2,208,451	(1166429-3831013)	502,206	(144354-1255807)	1,283,459	(439841-2937866)	7,193,004	(4015549-11700282)
Asia, East	16,800,000	(5900533-37966905)	26,000,000	(12809824-47569262)	5,509,065	(1644970-13985692)	8,883,820	(2890110-21282069)	71,500,000	(39356467-118415507)
Asia, South	29,200,000	(12051262-60043536)	58,000,000	(31539477-96600477)	4,212,874	(1493597-10026062)	32,800,000	(14464972-66241902)	219,000,000	(136533665-333269219)
Asia, Southeast	10,500,000	(3719375-23600134)	16,200,000	(9459344-26081046)	3,075,457	(933377-7514247)	4,242,643	(1780292-9139145)	43,200,000	(25124217-67579072)
Australasia	305,605	(109814-680413)	518,875	(233916-992401)	165,734	(46089-420756)	143,082	(44851-344600)	1,380,990	(762214-2247789)
Caribbean	964,795	(336897-2129144)	1,307,691	(644131-2319948)	335,602	(96486-832498)	606,977	(199888-1380304)	5,085,664	(3093992-7615315)
Europe, Central	801,076	(277268-1810745)	1,354,512	(634267-2536714)	322,305	(93431-810778)	467,152	(152321-1066188)	3,352,842	(1845784-5478461)
Europe, Eastern	1,807,641	(597032-4058659)	3,528,599	(1836426-6101893)	687,804	(204743-1782884)	1,083,900	(347217-2615665)	7,600,064	(4195938-12292054)
Europe, Western	3,663,343	(1332500-7876179)	8,752,422	(4818347-14570690)	1,533,129	(456341-3877574)	1,646,489	(599792-3709750)	16,400,000	(9422508-26418497)
Latin America, Andean	1,805,696	(796835-3433287)	3,139,406	(1649282-5337993)	410,532	(129288-1024785)	881,048	(369283-1727004)	7,393,447	(4517024-10909366)
Latin America, Central	6,945,554	(2527848-14850374)	10,500,000	(5780975-17124634)	1,748,607	(577145-4165078)	3,608,735	(1239539-8340558)	36,000,000	(22265660-52827278)
Latin America, Southern	1,038,191	(366803-2318939)	1,424,825	(740886-2445720)	410,308	(121140-1040193)	569,806	(192134-1335368)	4,644,442	(2648182-7383657)
Latin America, Tropical	4,065,195	(1415945-9185797)	4,326,807	(2357074-7367016)	1,218,930	(362273-3038690)	2,566,589	(856345-6090475)	21,500,000	(12980304-33490619)
North Africa/Middle East	14,200,000	(4883406-31770752)	24,500,000	(13651316-39539012)	5,442,822	(1806644-12818962)	9,979,587	(4040552-20335869)	53,700,000	(30336098-84052384)
North America, High Income	3,771,921	(1361819-8206169)	5,963,164	(3067073-10887350)	2,214,446	(663098-5427900)	1,773,070	(622271-3967604)	17,000,000	(9935921-26141619)
Oceania	273,095	(94464-611156)	402,847	(202259-712625)	79,524	(21662-207766)	202,649	(63074-485901)	1,158,360	(620836-1951810)
Sub-Saharan Africa, Central	4,456,516	(1529874-9977236)	7,587,375	(3540962-13879239)	1,338,690	(371146-3455077)	3,739,446	(1215023-8649037)	24,100,000	(14171381-36847378)
Sub-Saharan Africa, East	11,400,000	(4854168-23327269)	22,100,000	(12218897-36448145)	4,538,446	(1562118-10546894)	10,200,000	(4166647-21890393)	75,700,000	(48011831-110536243)
Sub-Saharan Africa, Southern	1,809,038	(648793-3914682)	1,751,119	(904986-3090694)	548,210	(162559-1358558)	1,523,141	(499281-3468709)	9,957,912	(5966838-14986026)
Sub-Saharan Africa, West	12,400,000	(4890222-25541727)	26,600,000	(14233426-44100963)	3,412,207	(1011116-8481491)	12,900,000	(4994386-27484857)	87,300,000	(55648057-123871419)