Quantifying the burden of disease associated with inadequate provision of water and sanitation in selected sub-Saharan refugee camps

Aidan A. Cronin, Dinesh Shrestha, Paul Spiegel, Fiona Gore and Heiko Hering

ABSTRACT

A WHO methodology is used for the first time to estimate the burden of disease directly associated with incomplete water and sanitation provision in refugee camps in sub-Saharan African countries. In refugee camps of seven countries, containing just fewer than 1 million people in 2005, there were 132,000 cases of diarrhoea and over 280,000 reported cases of malaria attributable to incomplete water and sanitation provision. In the period from 2005 to 2007 1,400 deaths were estimated to be directly attributable to incomplete water and sanitation alone in refugee camps in Ethiopia, Kenya and Tanzania. A comparison with national morbidity estimates from WHO shows that although diarrhoea estimates in the camps are often higher, mortality estimates are generally much lower, which may reflect on more ready access to medical aid within refugee camps. Despite the many limitations, these estimates highlight the burden of disease connected to incomplete water and sanitation provision in refugee settings and can assist resource managers to identify camps requiring specific interventions. Additionally the results reinforce the importance of increasing dialogue between the water, sanitation and health sectors and underline the fact that efforts to reduce refugee morbidity would be greatly enhanced by strengthening water and sanitation provision.

Key words | burden of disease, DALYs, refugee, water and sanitation

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INTRODUCTION

Improving water, sanitation and hygiene has the potential to prevent at least 9.1% of the disease burden (in disability-adjusted life years, DALYs) or 6.3% of all deaths globally (Prüss-Ustün *et al.* 2008). Other studies estimate an even higher mortality burden (e.g. Kosek *et al.* 2003). Recent World Health Organisation (WHO) estimates for children (0–14 years) put the annual global diarrhoeal death toll at over 1.8 million, far in excess of the toll for tuberculosis (81,000), malaria (844,000) and HIV/AIDS (302,000) put together (WHO 2008*a*). In addition, it has been estimated that 50% (range 39–61%) of the malnutrition (i.e. undernutrition) disease burden alone is attributable to the environment, mainly as a result of incomplete or substandard water and sanitation provision (Prüss-Ustün & Corvalan 2006, 2007). It is clear that the level of mortality linked to incomplete water and sanitation coverage is still not appreciated widely enough, underlining a need for increased efforts in estimating and documenting the real impact on human health caused by incomplete or substandard water and sanitation services, including hygiene. Indeed Boschi-Pinto *et al.* (2008) clearly state that this lack of systems to generate such quality data is one of the major barriers internationally to reducing under-five mortality.

Recent work by WHO has begun to address this gap by producing a methodology for quantifying the health impact associated with incomplete water supply and sanitation coverage at both national and sub-national level (Fewtrell *et al.* 2007). The methodology was used to estimate mortality, as well as morbidity, in terms of disability-adjusted life years (DALYs) on a country-by-country basis. However, such calculations at national level do not always reflect the complete population residing in a country (e.g. for climate change calculations in Campbell-Lendrum & Woodruff 2007) or the most marginalised or vulnerable communities may not always be fully captured. Such groups not covered by the official statistics may also include dwellers in unrecognised slum areas or economic migrants and almost certainly persons displaced by conflict or persecution such as refugees.

A recent review by Cronin *et al.* (2008) documented the current standard of water and sanitation provision in refugee camps managed by the United Nations High Commissioner for Refugees (UNHCR) and highlighted the links between the gaps in these services and high morbidity principally related to diarrhoea, malaria and malnutrition. This paper attempts to estimate the burden of disease due to incomplete water and sanitation provision during 2005 in refugee camps in seven sub-Saharan African countries using the WHO methodology (Fewtrell *et al.* 2007). The results are then compared with national-level corresponding statistics from WHO. Three countries, Ethiopia, Tanzania and Kenya, where a functioning UNHCR Health Information System is available, were focused on to undertake additional detailed analyses for 2006 and 2007.

METHODOLOGY

Several different UNHCR data sets from the period 2005–2007 were used. Data on water and sanitation services, collected by UNHCR's principal global monitoring tool, known as the Standards and Indicators Initiative (UNHCR 2006a), covers refugees in UNHCR-managed camp settings only. This global monitoring tool compares average annual data (i.e. one value per camp) and, in 2005, it was completed for 93 camps located in 24 countries, with a total combined population of about 1.8 million. In these

settings, UNHCR's partners directly implement water, sanitation and health activities with support and monitoring by UNHCR offices in the field. The partners are also responsible for collecting much of the data on the ground. Health data (reported cases of malaria and diarrhoea) were compiled from the UNHCR health coordinators' annual reports and the UNHCR Health Information System, where functioning. The health coordinators' annual reports cover 20 countries consisting of 90 camps with a combined population of approximately 3 million refugees. Population subsets were complemented with statistics from the UNHCR Annual Statistics Report (UNHCR 2006b).

Seven countries in sub-Saharan Africa were selected according to the availability of data necessary to carry out the quantification of the burden of disease calculations, including health clinic case data on diarrhoea, malaria and other health impacts, crude and under-five mortality, as well as details on demography and water and sanitation coverage. The countries included in this analysis were Ethiopia, Kenya, Tanzania, Zambia, Sierra Leone, the Democratic Republic of the Congo (DRC) and the Republic of the Congo (RoC) with a cumulative total of just fewer than 1 million refugees in 2005 (Table 1). These populations are each made up of several distinct camps in each country but for this study camp data were consolidated at country level to allow a comparison of the burden of disease among refugees with the national population presented in Fewtrell *et al.* (2007).

Detailed trends in the estimates were produced for the years 2006 and 2007 for Ethiopia, Kenya and Tanzania. These three countries were chosen as they formed the basis for the initial roll-out of UNHCR's new Health Information System and contained relatively stable refugee communities that have moved beyond the initial emergency phase for morbidity and mortality thresholds outlined in UNHCR (2006a).

The WHO methodology for estimating the burden of disease related to the incomplete water and sanitation coverage (Fewtrell *et al.* 2007) was employed to analyse the data from the refugee camps. Essentially it uses methods developed for estimating the global burden of disease caused by exposure to unsafe water, sanitation and hygiene and the systematic literature review of the association between water resources development and vector-borne

Table 1 | Data from 2005 with related water and sanitation information (UNHCR 2006b). The attributable fraction (AF) of diarrhoea cases relating to poor water and sanitation coverage was calculated using the % of the population with access to improved water (Estimated water % column) and sanitation (Estimated sanitation % column) coverage, derived as per Table 3

Country	No. of camps	Population	Water l/person/day	Estimated water %	Sanitation persons per latrine	Estimated sanitation %	AF diarrhoea
Ethiopia	7	108,254	11	50	27	25	0.90
Kenya	2	224,785	17	50	20	50	0.89
Tanzania	10	425,000	17	50	6	90	0.86
Zambia	2	46,728	18	50	6	90	0.86
Sierra Leone	9	55,000	20	50	10	50	0.89
DRC	6	43,927	20	50	12	50	0.88
RoC	3	57,734	8	10	48	10	0.90

diseases. A total of 11 diseases or injuries are listed in the WHO methodology and estimates were made for each national population for the latest data which was available at the time (i.e. 2002). The focus of this study was on the three most critical water-related disease burdens (i.e. diarrhoea, malnutrition and malaria).

For diarrhoea, the methodology matches exposure scenarios and uses the associated relative risk for each proportion of the population coverage statistics in order to work out the overall attributable fraction (AF) for that population. The WHO methodology concludes that in situations where less than 98% of the population have access to basic sanitation the diarrhoea AF ranges between 86% and 91%; the relationship between the water and sanitation indicator sets and AF are shown in Figure 1, demonstrating the greater importance of sanitation access in the relationship. For malnutrition, population-attributable fractions are derived from the assessed exposure and from the relative risk estimates of disease and death associated with malnutrition (Blössner & de Onis 2005). The fraction of malaria attributable to water and sanitation was estimated on the basis of expert judgement and literature reviews. These three diseases constitute the vast majority of morbidity and mortality connected to poor water and sanitation services in the seven case study countries according to the national burden of disease estimates presented in Fewtrell *et al.* (2007). The WHO methodology acknowledges that there are significant sources of uncertainty in the calculation of exposure risks and in data compilation underlining the difficulties associated with estimating the burden of disease linked with the inadequate provision of water and sanitation in refugee camps and using locally/nationally collected data.

In this respect, some modifications in approach were needed in order to be able to use the UNHCR data and suit the needs of the current study. The first of these was to relate the UNHCR indicators of level of provision of water and sanitation services (i.e. using the indicators litres per person per day and persons per latrine, respectively) to the WHO approach requiring the percentage of the population with access to improved water supply and basic sanitation (see Table 2 for definitions). Household level surveys in refugee camps helped in this respect. Such surveys demonstrate the limitations of using annual average indicators that do not reveal spatial or temporal variations in water and sanitation service provision (Cronin *et al.* 2008). Hence, an approximate relationship was drawn up (Table 3). Table 2 stipulates that only non-shared (i.e. private) sanitation facilities are considered improved; this definition was followed for camps where all latrines were shared and Table 3 was used where a mixture of family and shared latrines were employed. The AFs of diarrhoeal disease related to water and sanitation was then estimated using Fewtrell *et al.* (2007) and the results presented in Table 1. The burden of disease in DALYs associated with diarrhoea only was estimated using the method of Murray & Lopez (1996) and Fishman *et al.* (2004).

For malaria, experts have estimated AFs for six regions of the world reflecting regional averages. Local variations can prove to be considerable, and the regional estimates can therefore not substitute for national or even sub-regional studies. However, due to lack of more detailed, localised
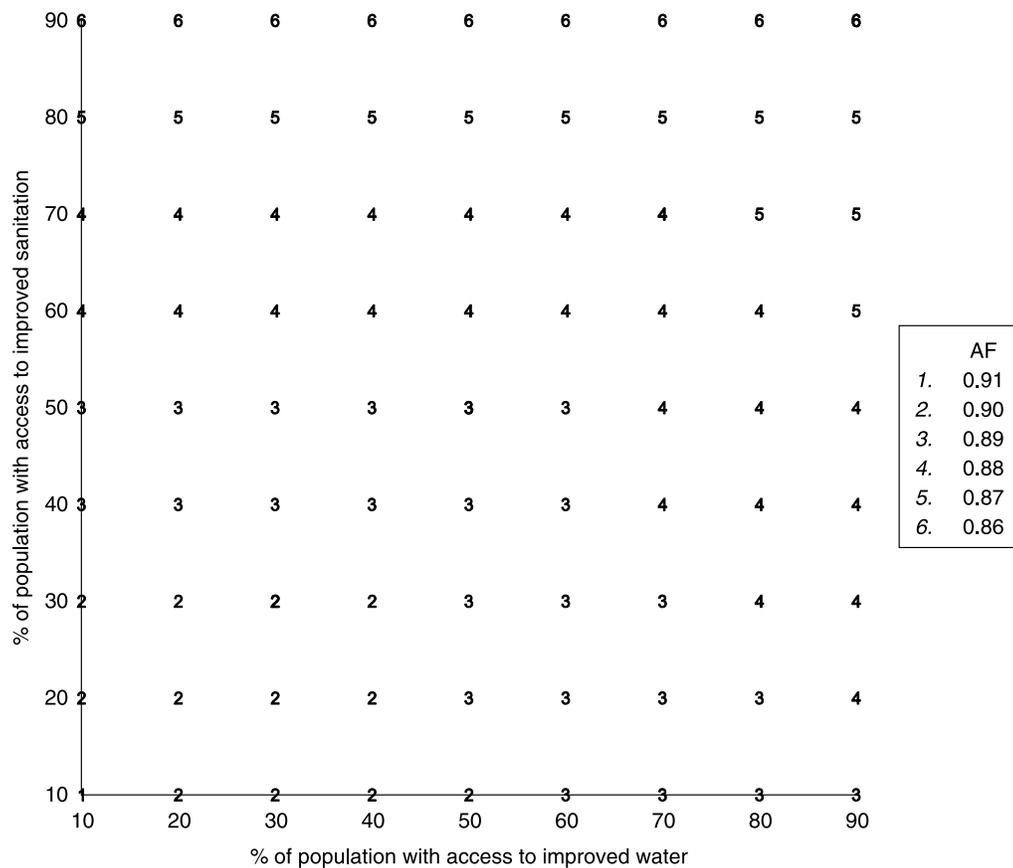
Figure 1 | Variation in the attributable fraction (AF) of diarrhoeal disease (in the range of 0.86 to 0.91) associated with varying levels of populations with access to improved water and improved sanitation coverage, both ranging between 10% and 90%. The numbers in the graph are related to the AF value in the adjoining box.

study information, a mean malaria AF of 42% was taken for the sub-Saharan African region (from Fewtrell et al. 2007, Table 8); this reflects the best estimate of the proportion of malaria morbidity and mortality directly related to inadequate water and sanitation service provision.

An attempt was made to add to the estimate the links with malnutrition, defined in this context as undernutrition, which affects mainly children under five years of age, in low-income and middle-income countries because of repeated diarrhoea and nematode infections (Fewtrell et al. 2007). The other main childhood diseases linked to malnutrition include acute respiratory infections, perinatal diseases, measles and malaria (Rice et al. 2000; Black et al. 2003; Caulfield et al. 2004), making malnutrition one of the most important risk factors to child health globally (Fishman et al. 2004). A total of 54% of all deaths among children are believed to be associated with malnutrition

(Blössner & de Onis 2005; Fewtrell et al. 2007; WHO 2008b). Global estimates, reported by Fishman et al. (2004), conclude that over 3.5 million children die annually (based on data from 2002) as a result of malnutrition. In order to estimate the disease burden from malnutrition for child mortality, population attributable fractions (PAFs) were derived from the exposure data and from the relative risk estimates for death associated with malnutrition using the methodology outlined by Blössner & de Onis (2005). The relative risk estimates used for diarrhoea, malaria, measles, acute respiratory infections and other infectious diseases are based on a meta-analysis that was part of a global comparative risk assessment project for generic settings conducted by WHO and its partners (Blössner & de Onis 2005). Data relating to the number of deaths for Ethiopia, Kenya and Tanzania were extracted from UNHCR's Health Information System reports for 2006 and 2007.

Table 2 | Definitions of improved and unimproved water sources and sanitation facilities (from WHO/UNICEF 2006)

Status	Drinking water sources	Sanitation facilities
Improved	Piped water into dwelling, plot or yard	Flush or pour-flush to piped sewer system, septic tank or pit latrine
	Public tap or standpipe	Ventilated improved pit latrine
	Tubewell/borehole	Pit latrine with slab
	Protected dug well	Composting toilet
	Protected spring	
	Rainwater collection	
Unimproved	Unprotected dug well	Flush or pour-flush to elsewhere
	Unprotected spring	Pit latrine without slab or open pit
	Cart with small tank/drum	Bucket
	Bottled water	Hanging toilet or hanging latrine
	Tanker truck	No facilities or bush or field
	Surface water (rivers, canals etc.)	

The total mortality burden linked to malnutrition was estimated by multiplying the AFs by the total cause-specific mortality rate (i.e. diarrhoeal disease, malaria, measles, lower respiratory infections, other infections diseases, excluding AIDS and protein-energy malnutrition) for children under five years of age. It is estimated that 50% of the burden from childhood malnutrition can be attributed to water, sanitation and hygiene (Fewtrell *et al.* 2007; WHO 2008b) and so the obtained results were halved to obtain estimates for the water and sanitation-related malnutrition. To avoid double-counting, only the infectious diseases not directly caused by water and sanitation for which data was available were taken into account in these estimates. Data relating to underweight estimates (% < −2 standard deviations for weight-for-age) based on WHO standards were obtained from the WHO Global Database on Child Growth and Malnutrition (de Onis & Blössner

2003; WHO 2006) as this information was not available from UNHCR's Health Information System. It is important to note that the direct effects of diarrhoea from water and sanitation have already been taken into account via the calculated diarrhoea AF and the malnutrition burden of disease presented here is unrelated to indirect diarrhoeal conditions (i.e. diarrhoea as a result of malnutrition).

RESULTS

Table 4 presents the total cases of reported morbidity during 2005 at health clinics in the refugee camps in each country linked to diarrhoea and malaria; the proportion of these cases related to water and sanitation is also presented. The diarrhoea proportion was estimated using the appropriate AF factors (Table 1). Using the direct estimation option in

Table 3 | Generalised relationship between the percentage of population with improved water and sanitation coverage matched to UNHCR's water and sanitation indicators for refugee populations

Litres per person per day	% of the population with access to improved water supply	Person/latrine	% of the population with access to improved sanitation
<10	10	0 to 9	90
11 to 20	50	10 to 20	50
21 to 30	70	21 to 30	25
>30	90	>30	10

Table 4 | Total cases of morbidity related to diarrhoea, malaria and malnutrition and the number of these cases related to water and sanitation for the refugee camps in the named countries for 2005

Country	Total cases of diarrhoea	Diarrhoea attributable to water and sanitation	Total cases malaria	Malaria* attributable to water and sanitation	Burden of water and sanitation disease cases/person/year	DALYS due to diarrhoea in the camps	Diarrhoea DALYs /1,000 capita per year
Ethiopia	15,925	14,333	49,130	20,635	0.32	7,068	65
Kenya	47,340	42,132	200,283	84,119	0.56	7,621	34
Tanzania	41,239	35,465	232,050	97,461	0.31	19,544	46
Zambia	3,062	2,633	50,550	21,231	0.51	1,957	42
Sierra Leone	25,431	22,634	82,579	34,683	1.04	2,023	37
DRC	8,024	7,061	32,571	13,680	0.47	1,897	43
RoC	8,700	7,830	23,805	9,998	0.31	3,154	55

*Malaria figures contain both confirmed and suspected cases.

the WHO methodology, DALYs associated with diarrhoea were estimated for the seven study countries (Table 4). These values document the level of ill-health related to poor water and sanitation provision and further comparisons are possible by calculating water and sanitation-related clinic consultations. Sierra Leone shows the highest rate of clinical consultations with an average of over one consultation per person per year; Ethiopia, Tanzania and RoC are all under one-third of this value. Kenya shows the lowest DALY burden per capita with 34 years lost per 1,000 persons while Ethiopia is almost twice this value at 65 years lost per 1,000 persons.

Table 5 presents morbidity (diarrhoea DALYs) and mortality (related to water and sanitation for diarrhoea, malaria and malnutrition) for national populations (2002) and for the total refugee camp populations in Ethiopia, Kenya and Tanzania (2005–2007). All indicators in Ethiopian refugee camps improve from 2005 to 2007, except water and sanitation-related malnutrition deaths in 2007. The average per capita diarrhoea DALYs in Ethiopian refugee camps are higher than the national averages in 2005 but have reduced to half the national average value by 2007; average diarrhoea deaths in the camps are much lower. Malaria deaths are also considerably lower in the camps than in national populations though there are differences in camp endemicity malaria values; as national refugee totals are being used to compare with national population values it is justified to combine the various transmission zones together.

Indicators in Kenyan refugee camps for 2005 are all above the equivalent national levels and the diarrhoea DALYs figures increase significantly from 2005 to 2006 though water and sanitation-related deaths per 1,000 capita fall from 2005 to 2007. Despite these falling trends, per capita ratios in Kenya for diarrhoea DALYs and malnutrition deaths linked to water and sanitation remain in excess of the national averages for 2007. Malaria deaths linked to water and sanitation fall significantly from 2006 to 2007 in Kenyan refugee camps.

All indicators in Tanzanian refugee camps improve over the period 2005 to 2007. Per capita ratios for diarrhoea DALYS are lower than national averages and malnutrition deaths linked to water and sanitation slightly above the national averages. As for the other two countries, diarrhoea deaths are significantly lower in the camps. Malaria deaths are also much lower in the camps than in national populations.

DISCUSSION

A comparison of refugee DALYs per 1,000 persons (for 2005) and national data (for 2002) is presented in Figure 2. Though different years and data collection scales are involved, it is interesting to compare displaced and national populations and it can be seen that Ethiopia, Kenya, Tanzania and RoC all have refugee DALYs greater than national values. By 2007, Ethiopia and Tanzania have

Table 5 | Diarrhoea DALYS and mortality, malaria mortality and child (<5) malnutrition mortality all attributable to incomplete water and sanitation provision in national populations (from Fewtrell *et al.* 2007) and refugee populations

		Ethiopia				Kenya				Tanzania			
		National 2002	Refugee camps 2005	Refugee camps 2006	Refugee camps 2007	National 2002	Refugee camps 2005	Refugee camps 2006	Refugee camps 2007	National 2002	Refugee camps 2005	Refugee camps 2006	Refugee camps 2007
Population		68.9×10^6	108,254	98,085	79,463	31.5×10^6	224,785	229,695	231,291	36.3×10^6	425,000	324,573	283,796
Diarrhoea DALYS	Total	2.1×10^6	7,068	2,798	1,163	818,000	7,621	21,244	9,242	1.06×10^6	19,544	6,847	7,243
	Per 1,000	30	65	29	15	26	34	92	40	29	46	21	26
Diarrhoea deaths	Total	63,200	4	2	2	24,600	179	86	36	31,900	29	18	16
	Per 1,000	0.92[*]	0.04	0.02	0.02	0.78	0.80	0.37	0.15	0.88[†]	0.07	0.05	0.05
Malaria deaths	Total	31,900	10	6	4	18,100	371	179	74	56,700	201	121	106
	Per 1,000	0.46	0.09	0.06	0.06	0.57	1.65	0.78	0.32	1.56	0.47	0.37	0.37
Malnutrition deaths in <5 year olds	Total	17,000	ID	1	2	1,400	ID	13	8	7,500	ID	23	19
	Per 1,000	0.25	ID	0.03	0.17	0.04	ID	0.32	0.24	0.21	ID	0.36	0.34

ID, insufficient data available.
[*]The corresponding estimate from Boschi-Pinto *et al.* (2008) is 1.25.
[†]The corresponding estimate from Boschi-Pinto *et al.* (2008) is 0.69.
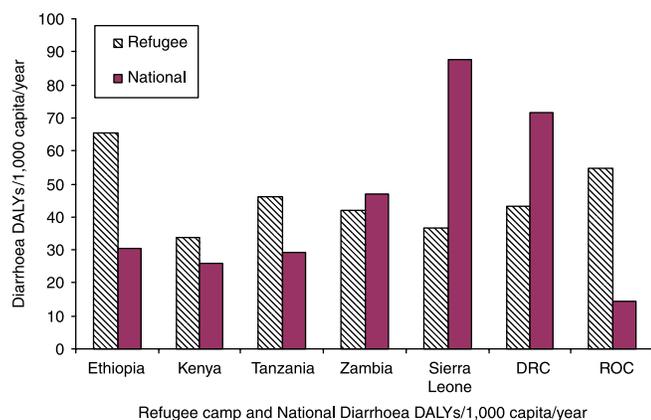
Figure 2 │ Comparison of the national population DALYs (estimated for data from 2002 by Fewtrell et al. 2007) and refugee camp DALYs associated with incomplete water and sanitation coverage during 2005.

refugee camp DALYs that are lower than the national equivalent values (Table 5). It is possible to calculate the ratio between diarrhoea DALYs and deaths due to diarrhoea using the data presented in Fewtrell et al. (2007). This use of the WHO methodology is quite useful to assess how the refugee camps compare with national data (Figure 3) although the data from the WHO methodology is only available for 2002 and the refugee data from 2005. This comparison shows that although all camps have diarrhoea DALYs in excess of the trend line, diarrhoea deaths are much lower than should be expected from the WHO methodology relationship line. This would suggest that, in general, medical care for diarrhoea patients may be more easily accessible in refugee camps with a stable operational environment than in national areas (i.e. camp cases are elevated due to higher transmission rates but the resulting impact in mortality is lower in camps as opposed to what may be expected if similar values were found in national populations where distances to medical care may be far
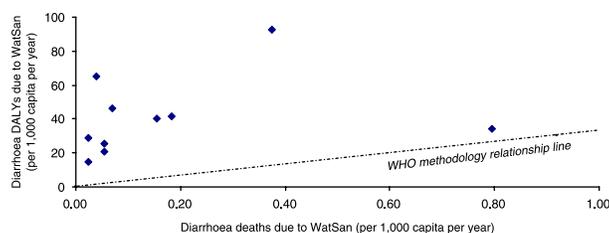

Figure 3 │ Relationship between per capita diarrhoea DALYs and deaths in refugee populations in Ethiopia, Tanzania, Kenya (2005–2007), DRC, Congo, Zambia and Sierra Leone (2005 only). The WHO Methodology line was calculated using the data presented in Fewtrell et al. (2007).

greater). However, mortality in refugee camps cannot be as well captured as in national populations for various reasons, including under-reporting of cases due to the fear of loss of rations for a family (Spiegel et al. 2001, 2002). Similarly, populations in the camps can be over-estimated for many reasons including the registration of persons living away from the camp and/or local persons in order to obtain food distribution and other camp services. In addition, the reported crude incidence rates in camps may sometimes be over-estimated as they can include locals coming to the refugee camp clinics for treatment but who are not registered in the camp.

The drop in Ethiopian refugee camp diarrhoea rates is likely to be linked to the fall in the overall refugee population totals as the relative ratio of refugee to medical staff has improved significantly over this period. Diarrhoea deaths are significantly lower in the camps than national averages, most probably reflecting easier access to clinics and oral rehydration salts in the camps. Malaria deaths are also much lower in the camps than in national populations though this is also due to the fact that significant numbers of refugees in Ethiopia are sited in areas with low transmission rates, such as in the Jijiga area near the Somali border.

The high values in Kenyan refugee camps for 2005 can be linked to a serious outbreak of cholera in Kakuma refugee camp which resulted in 17 fatalities (Cronin 2005). The diarrhoea DALYs figures for 2005/2006 can be linked to severe drought, large influxes from Somalia to the Dadaab refugee camps and large-scale flooding and high rates of diarrhoea transmission that occurred in 2006. The fall in water and sanitation-related deaths per 1,000 capita from 2005 to 2006 reflects strengthening of the health services and water supply though inadequate sanitation remains a serious issue (Cronin 2006). Lower diarrhoea deaths in the camps as compared with national populations most likely reflect easier access to clinical treatment and oral rehydration salts in the camps.

There are several possible factors to explain why malaria deaths linked to water and sanitation fell significantly from 2006 to 2007 in Kenyan refugee camps. In 2006, the introduction of artemisinin-based combination therapy (ACT) improved the effectiveness of malaria treatment. ACT is now the treatment of choice for uncomplicated malaria. For complicated malaria, the treatment protocol has also

been changed from quinine to artesunate which acts much faster because of its much higher reduction rate per parasite cycle. Also as ACT treatments are provided in short courses, compliance is much improved. The introduction of consistent diagnostic confirmation (microscopy or rapid diagnostic test) has also had a significant impact on the detection of malaria with earlier detection and quicker treatment initiation. Hence, a change in protocol resulting in prompt diagnosis and an efficacious treatment is reflected in decreased mortality due to malaria.

The Tanzanian per capita indicators are lower than the Kenyan equivalents but Ethiopia has, by 2007, the lowest water and sanitation-related morbidity and mortality in all categories. It is noteworthy that Ethiopia has significantly fewer refugees as well as smaller camp sizes than the other two countries.

Camp-based populations have easier access to utilities and services compared with the mostly rural, dispersed host populations nearby. For instance, for malaria, increased coverage of prevention interventions (insecticide treated nets, indoor residual spraying) are evident in camps. Furthermore, as in the case of HIV behavioural surveillance studies related to knowledge, attitudes and behaviours among refugees, there is evidence to show that refugees benefit from targeted awareness raising initiatives and other prevention activities (UNHCR 2008). In addition, the important role of community service and community health workers as well as social networking in refugee communities cannot be underestimated in following up on both health and water and sanitation issues in the community. However, access to water and sanitation is limited to what is provided to the refugees by aid agencies, whereas there may be other alternative sources and options for national communities. This is similar for food security where the deprivation of access to resources for food production and reduced purchasing power are major limitations for refugees to become self-sufficient in food provision.

Diarrhoea DALYs constitute a very large burden of the refugee morbidity. However, it is interesting to compare the number of malaria-related cases due to incomplete water and sanitation coverage (Table 4) and associated mortality (Table 5) to see the important burden of disease associated with malaria. In fact, the analyses show that water and sanitation-related malaria deaths are higher than diarrhoea

or malnutrition across each country each year. The fight against malaria has traditionally been health focused, but the figures here highlight the need for increased environmental management and effective interventions. Further, the figures underline the need for increased examination of the burden of disease associated with incomplete water and sanitation service provision with the findings forming the basis for targeted follow-up interventions. In short, these findings emphasise the importance of increased dialogue and collaboration across the water, sanitation and health sectors.

Bartram (2008) states 'Water is critically important for health. Yet it is typically low on the health agenda and the health system is often ill-equipped to engage effectively'. Similar arguments on the disengagement between health and sanitation have also been made: for example,

> The shamefully weak presence of the health sector in advocating for improved access to water and sanitation is incomprehensible and completely short-sighted … the global health community is standing aside, absolving itself of responsibility, and firmly passing the buck to the water and sanitation sectors (The Lancet 2008).

Such statements seem to be justified in the light of the data presented here. There is a need to undertake basic cost–benefit analyses in refugee settings for improved water and sanitation provision and to clearly state the benefits in terms of health and livelihoods. Arguments that refugee camps are temporary solutions and thus do not warrant such analyses cannot be justified given the lengthy periods many current refugee camps have been in existence. Indeed, the Human Development Report 2006 on the global state of water and sanitation commented on the impact of poor water and sanitation on health and suffering by stating 'often the reality is even more bleak than the statistics' (UNDP 2006), a point echoed by Carter & Danert (2003). Stronger links between health and water and sanitation can only be achieved once there is a greater awareness of the impact of resource gaps on the suffering related to poor water, sanitation, health and nutrition services, especially in protracted refugee situations.

There are several limitations to this study in addition to those already outlined. There are camp-wide inconsistencies in the quality of water and sanitation service

provision, which are not reflected in annual average values. The alignment of available water and sanitation indicators with the WHO methodology parameters (Table 3) resulted in approximations of the AF value estimates. AF values themselves are best estimates according to the WHO methodology which allows an upper and lower bound estimate of diarrhoea AF to be calculated. The percentage difference between upper and lower bounds and the best estimate was calculated for 52 water and sanitation percentage coverage combinations (Table 6) and shows upper and lower AFs can, on average, deviate from the best estimate in the order of 10%. The camp data inconsistencies are both spatial and temporal in nature and have been further described in Cronin *et al.* (2008). In addition, health statistics data are also provided at the camp level and thus do not reflect in-camp variations. AFs, particularly in the case of malaria, reflect regional estimates (Prüss-Ustün & Corvalan 2006) although there may well be wide local variations across the region. It is recommended that more detailed local study information is collected in order to improve future AF estimates.

Health centre statistics only reflect those who present themselves for assistance (i.e. passive surveillance). Active case finding was not undertaken and therefore the figures presented in Tables 4 and 5 do not fully capture the extent of the burden of these diseases. Independent case collaboration of patients who present themselves at health clinics is missing and quality control is limited, given the difficult working conditions and high workload placed on medical practitioners in refugee camps. This study deals with large populations and so cannot claim to be a controlled scientific study that can quantify the influences of variables. The other diseases listed in the WHO methodology (i.e. intestinal

nematode infections, schistosomiasis, trachoma, lymphatic filariasis, onchocerciasis, dengue, Japanese encephalitis and drowning) were not considered either because of their lack of occurrence in the camps or, more significantly, the unavailability of data for these diseases.

There are also limitations to the estimates related to malnutrition in this study. The UNHCR's Health Information System data do not contain the exact cause of death due to all diseases and not in a format that would easily enable estimates of the associated malnutrition DALYs. Furthermore, information regarding malnutrition (i.e. underweight estimates) was obtained from the WHO Global Database on Child Growth and Malnutrition because this information was not available from UNHCR, thus introducing some level of uncertainty in the results. These estimates are based on national estimates and not camp-like situations. Nutrition survey data collected in refugee camps usually include wasting and severe wasting (i.e. weight-for-height), which typically reflects acute malnutrition (see SCN 2008) rather than data on prevalence of underweight (i.e. weight-for-age estimates) needed for the purpose of the current estimates (see WHO 2008*c*). Hence, there may be discrepancies in the exposure data and the relative risks applied. Although these estimates are likely to be conservative, they not only provide a first glimpse into the prevailing situation, but also provide an opportunity to identify data gaps to improve future data collection efforts and related processes in order to strengthen estimates of the burden of disease at local level and in refugee camps. The implications of comparing malnutrition data from different data sources make the interpretability more difficult and so it may be worthwhile in the future to consider such an indicator to be collected as part of a health information system.

The WHO methodology is principally targeted at national populations though it is applicable at regional or local levels, as has been attempted in this study. There are limitations in the definitions of improved and unimproved water and sanitation services; these often consider only the hardware aspects and may not take into account water quality or temporal variations in service. Care must be taken to ensure that the broad categories of supply do not fail to encompass discrimination in populations and vulnerability groups who may officially have access to

Table 6 | Percentage differences between lower and upper bound estimates and the best estimate calculations for AF diarrhoea calculated using the WHO methodology (Fewtrell *et al.* 2007) for a range of 52 different water and sanitation % coverage combinations

	% difference between lower and best AF estimates	% difference between upper and best AF estimates
N	52.0	52.0
Minimum	8.8	5.5
Maximum	12.8	9.3
Mean	10.7	7.5
Median	10.2	8.0

improved services but are unable to access them fully and so depend on higher risk strategies. Examples may be malfunctioning safe water sources with unprotected water bodies forming the alternative or non-use of toilets so that open defecation becomes the norm. It is also worth noting that the sensitivity of DALY estimates to crude mortality rates is significant, although in refugee camps it is not always easy to get accurate crude mortality rates for the reasons already outlined. In addition, care must be taken with output indicators, such as DALY estimates, as they can prove difficult to understand at the field level, as they cannot be easily compared with crude mortality rates or number of consultations.

Despite the many limitations, it was felt that this first quantification of the burden of water and sanitation-related disease in refugee camps was worthwhile, indeed essential, if we are to address such statements as 'there is a profound need for research to quantify the association between water availability and human suffering during crises' by Roberts (1998). It is hoped that, as data quality improves, future improved estimates will be undertaken.

CONCLUSIONS

The WHO methodology to estimate the environmental burden of disease associated with incomplete water and sanitation provision (Fewtrell et al. 2007) has proved to be a valuable tool to allow the first estimates of disease associated with incomplete water and sanitation service provision in refugee camps. Health data from 2005 for refugee camps in seven sub-Saharan countries was analysed; three of these countries were further examined for the period 2006 to 2007. During 2005, in these seven sub-Saharan countries with refugee camps containing approximately 1 million people, there were 132,000 cases of diarrhoea attributable to incomplete water and sanitation provision. Reported cases of malaria attributable to incomplete water and sanitation provision were in excess of 280,000. In the years 2005 to 2007, a figure of 1,400 deaths due to diarrhoea, malaria and malnutrition can be directly attributed to incomplete water and sanitation provision in the refugee camps of Ethiopia, Kenya and Tanzania. A comparison with national values suggests that

although diarrhoea estimates in the camps are often in excess of national values, mortality values are generally much lower, potentially because of the more ready access to medical care in the camps. The estimates of disease burden underline significant ill-health and associated social burden among the population, attributable to incomplete water and sanitation provision in refugee settings in Africa. Cross-comparisons of camps or countries, as presented here, can help resource managers to understand and compare among the various operations and identify those requiring additional expertise or resources specific to water and sanitation. Additionally the results suggest the need for increased dialogue and collaboration across the water and sanitation and health sectors.

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