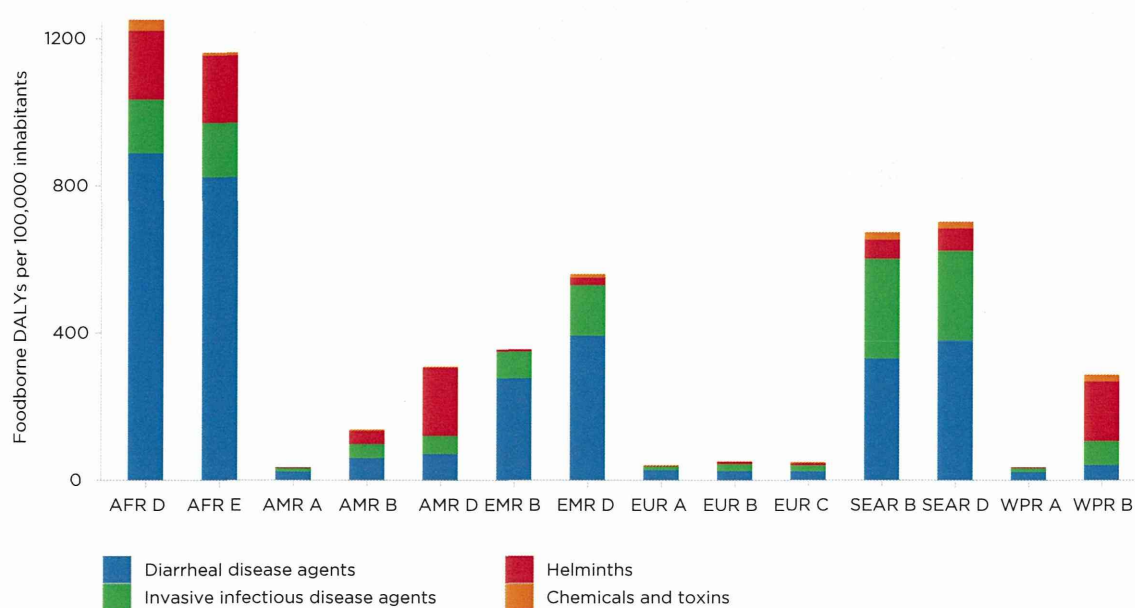


HAZARD	AFR D	AFR E	AMR A	AMR B	AMR D	EMR B	EMR D	EUR A	EUR B	EUR C	SEAR B	SEAR D	WPR A	WPR B
Invasive infectious disease agents	146 (46-342)	147 (55-343)	10 (6-14)	38 (16-76)	49 (19-144)	73 (32-148)	137 (38-334)	10 (7-15)	19 (9-61)	16 (10-29)	272 (71-721)	244 (38-623)	10 (5-132)	65 (19-145)
Viruses	27 (4-77)	18 (3-55)	0.5 (0.07-2)	1 (0.1-4)	2 (0.2-7)	2 (0.2-5)	32 (2-102)	0.8 (0.03-2)	1 (0.2-3)	1 (0.3-4)	5 (0.6-15)	58 (6-182)	1 (0.07-3)	5 (0.3-17)
Hepatitis A virus	27 (4-77)	18 (3-55)	0.5 (0.07-2)	1 (0.1-4)	2 (0.2-7)	2 (0.2-5)	32 (2-102)	0.8 (0.03-2)	1 (0.2-3)	1 (0.3-4)	5 (0.6-15)	58 (6-182)	1 (0.07-3)	5 (0.3-17)
Bacteria	93 (31-259)	104 (40-277)	4 (2-7)	16 (4-47)	19 (5-65)	50 (16-121)	82 (22-241)	3 (3-5)	8 (3-39)	5 (3-10)	251 (59-696)	165 (27-490)	3 (1-126)	50 (12-124)
<i>Brucella</i> spp.	2 (0.2-53)	0.3 (0.007-18)	0.07 (0.02-0.6)	1 (0.3-16)	2 (0.2-38)	23 (3-83)	4 (0.6-68)	0.3 (0.07-1)	4 (0.7-35)	0.8 (0.07-6)	0.8 (0.004-112)	0.7 (0.003-92)	0.6 (0.02-125)	0.6 (0.09-9)
<i>Listeria monocytogenes</i>	1 (0-21)	1 (0-21)	3 (2-5)	2 (0.2-17)	1 (0-21)	1 (0-21)	1 (0-21)	3 (2-4)	0.3 (0.2-0.8)	0.6 (0.3-2)	1 (0-21)	1 (0-21)	1 (0.7-2)	1 (1-4)
<i>Mycobacterium bovis</i>	25 (15-39)	34 (21-48)	0.03 (0.01-0.06)	0.4 (0.2-0.8)	2 (0.8-4)	1 (0.5-3)	13 (6-25)	0.08 (0.06-0.1)	0.6 (0.5-1)	3 (2-5)	11 (4-27)	14 (6-27)	0.1 (0.08-0.2)	3 (1-5)
<i>Salmonella</i> Paratyphi A	11 (0-39)	12 (0-43)	0.1 (0-0.4)	2 (0-6)	2 (0.006-7)	3 (0-12)	10 (0-36)	0.02 (0-0.1)	0.3 (0-2)	0.01 (0-0.06)	42 (7-120)	26 (0.6-80)	0.1 (0-0.5)	8 (1-22)
<i>Salmonella</i> Typhi	47 (0-169)	52 (0-187)	0.4 (0-2)	7 (0-27)	8 (0.03-29)	14 (0-51)	45 (0-158)	0.09 (0-0.6)	2 (0-9)	0.04 (0-0.3)	184 (32-522)	113 (3-347)	0.6 (0-2)	36 (6-95)
Protozoa	21 (8-41)	20 (9-37)	5 (2-8)	20 (9-33)	27 (10-84)	20 (10-35)	18 (9-31)	6 (3-9)	10 (5-23)	10 (5-18)	13 (6-22)	9 (2-19)	5 (3-8)	9 (4-14)
<i>Toxoplasma gondii</i>	21 (8-41)	20 (9-37)	5 (2-8)	20 (9-33)	27 (10-84)	20 (10-35)	18 (9-31)	6 (3-9)	10 (5-23)	10 (5-18)	13 (6-22)	9 (2-19)	5 (3-8)	9 (4-14)
Helminths	186 (125-308)	184 (141-240)	1 (0.9-4)	36 (27-134)	185 (149-229)	5 (2-15)	21 (12-40)	0.4 (0.2-1)	6 (3-27)	6 (4-15)	52 (42-64)	60 (45-80)	2 (1-3)	162 (131-202)
Cestodes	172 (112-289)	178 (136-235)	0.4 (0.3-0.6)	25 (19-34)	71 (53-95)	1 (0.2-10)	0.7 (0.1-19)	0.2 (0.05-0.5)	4 (2-25)	4 (2-12)	3 (2-5)	46 (34-61)	0.03 (0.007-0.8)	45 (25-65)
<i>Echinococcus granulosus</i>	0.4 (0.06-21)	0.8 (0.2-16)	0.01 (0.002-0.03)	0.3 (0.02-5)	2 (0.4-8)	0.9 (0.2-10)	0.6 (0.1-19)	0.1 (0.02-0.4)	2 (0.5-6)	0.5 (0.09-1)	0.001 (0-0.1)	0.8 (0.2-3)	0.02 (0.001-0.8)	0.3 (0.08-0.9)
<i>Echinococcus multilocularis</i>	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.03 (0.005-0.06)	0.005 (0-0.05)	0.03 (0.008-0.06)	2 (0.5-21)	2 (0.5-11)	0 (0-0)	0.007 (0-0.04)	0.008 (0.001-0.02)	18 (0-37)
<i>Taenia solium</i>	170 (110-283)	176 (134-229)	0.4 (0.3-0.6)	25 (19-32)	69 (51-91)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.9 (0.6-2)	3 (2-5)	45 (33-60)	0 (0-0)	27 (20-35)
Nematodes	13 (2-28)	5 (1-11)	0.6 (0.3-0.9)	11 (3-106)	12 (3-24)	3 (1-7)	13 (4-20)	0.04 (0.02-0.07)	1 (0.3-2)	1 (0.4-2)	8 (2-15)	13 (4-26)	0.004 (0.001-0.007)	11 (3-22)
<i>Ascaris</i> spp.	13 (2-28)	5 (1-11)	0.6 (0.3-0.9)	11 (3-106)	12 (3-24)	3 (1-7)	13 (4-20)	0 (0-0)	1 (0.3-2)	1 (0.3-2)	8 (2-15)	13 (4-26)	0 (0-0)	11 (3-22)
<i>Trichinella</i> spp.	0.001 (0-0.002)	0.001 (0-0.002)	0.009 (0.005-0.01)	0.009 (0.005-0.01)	0.009 (0.005-0.01)	0 (0-0)	0 (0-0)	0.04 (0.02-0.07)	0.04 (0.02-0.07)	0.04 (0.02-0.07)	0 (0-0.001)	0 (0-0.001)	0.004 (0.001-0.007)	0.004 (0.001-0.007)

HAZARD	AFR D	AFR E	AMR A	AMR B	AMR D	EMR B	EMR D	EUR A	EUR B	EUR C	SEAR B	SEAR D	WPR A	WPR B
Trematodes	0.06 (0.02-0.2)	0.02 (0.008-0.07)	0.2 (0.04-3)	0.1 (0.04-0.5)	101 (74-135)	0.3 (0.2-0.5)	7 (4-10)	0.2 (0.05-0.6)	0.2 (0.05-0.6)	1 (0.8-1)	40 (32-50)	0.7 (0.2-2)	2 (1-2)	106 (85-131)
<i>Clonorchis sinensis</i>	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.04 (0.03-0.04)	0.01 (0.003-0.04)	0.04 (0.01-0.2)	0.05 (0.01-0.2)	31 (26-38)
<i>Fasciola</i> spp.	0.02 (0.008-0.07)	0.01 (0.005-0.04)	0.04 (0.001-2)	0.04 (0.02-0.1)	46 (27-75)	0.2 (0.1-0.3)	7 (4-10)	0.07 (0.02-0.2)	0.06 (0.02-0.2)	0.04 (0.01-0.1)	0.02 (0.008-0.05)	0.05 (0.02-0.1)	0.07 (0.01-0.4)	0.9 (0.1-8)
Intestinal flukes*	0.01 (0.005-0.04)	0 (0-0)	0.1 (0.04-0.5)	0.06 (0.02-0.2)	0 (0-0)	0.06 (0.02-0.2)	0.08 (0.03-0.2)	0.03 (0.009-0.09)	0.05 (0.02-0.2)	0.09 (0.03-0.2)	0.2 (0.1-0.5)	0.1 (0.03-0.4)	1 (0.9-2)	9 (7-11)
<i>Opisthorchis</i> spp.	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.07 (0.02-0.3)	0.05 (0.01-0.3)	0.9 (0.6-1)	40 (32-50)	0.4 (0.1-1)	0 (0-0)	3 (2-4)
<i>Paragonimus</i> spp.	0.03 (0.008-0.08)	0.008 (0.002-0.02)	0.04 (0.004-0.6)	0.04 (0.01-0.1)	53 (38-73)	0 (0-0)	0.02 (0.008-0.07)	0 (0-0)	0 (0-0)	0.03 (0.01-0.1)	0.05 (0.008-0.5)	0.06 (0.02-0.2)	0.05 (0.02-0.2)	60 (43-83)
Chemicals and toxins	30 (8-85)	7 (3-21)	0.4 (0.2-3)	3 (0.7-16)	2 (0.09-159)	0.8 (0.3-14)	9 (4-66)	2 (1-22)	0.9 (0.4-25)	2 (2-9)	20 (4-75)	18 (13-52)	0.3 (0.06-13)	18 (3-71)
Aflatoxin	28 (7-78)	3 (1-8)	0.04 (0.006-0.2)	3 (0.6-9)	2 (0.07-137)	0.7 (0.2-3)	5 (1-17)	0.3 (0.1-0.7)	0.6 (0.3-1)	0.5 (0.2-2)	18 (3-52)	4 (0.6-15)	0.2 (0.04-0.8)	17 (3-69)
Cassava cyanide	1 (0.1-3)	3 (0.3-9)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Dioxin	0.2 (0.05-6)	0.2 (0.09-9)	0.3 (0.1-3)	0.1 (0.03-11)	0.2 (0.01-23)	0.09 (0.004-11)	3 (2-56)	2 (1-22)	0.3 (0.09-24)	2 (1-8)	0.2 (0.005-45)	14 (12-40)	0.1 (0.02-12)	0.06 (0.006-5)

Notes: * Includes selected species of the families Echinostomatidae, Fasciolidae, Gymnophallidae, Heterophyidae, Nanophyidae, Neodiplostomidae and Plagiorchiidae (depending on data availability).

Figure 12. The global burden of foodborne disease (DALYS per 100 000 population) by hazard groups and by subregion, 2010.



The relative contribution of mortality (measured as YLL) and morbidity (measured as YLD) to the total burden of disease varied widely between hazards (Figure 13). For 18 foodborne hazards, more than 75% of the total burden was due to premature mortality (red columns in Figure 13). These mainly include hazards leading to diseases with known high case-fatality ratios (non-typhoidal *S. enterica*, EPEC, ETEC, *Shigella* spp.

and *V. cholerae*, *Listeria monocytogenes*, *Salmonella* Typhi and *Salmonella* Paratyphi, *Echinococcus multilocularis* and aflatoxin). At the other extreme, more than 75% of the total burden due to morbidity (blue columns in Figure 2) were accounted for by seven foodborne hazards, of which four (*Giardia* spp., *Fasciola* spp., intestinal flukes, and dioxin) were not assumed to cause fatal illnesses.

Figure 13. Relative contribution of Years of Life Lost due to premature mortality (YLL) and Years Lived with Disability (YLD) to the global burden of 31 hazards in food, 2010.

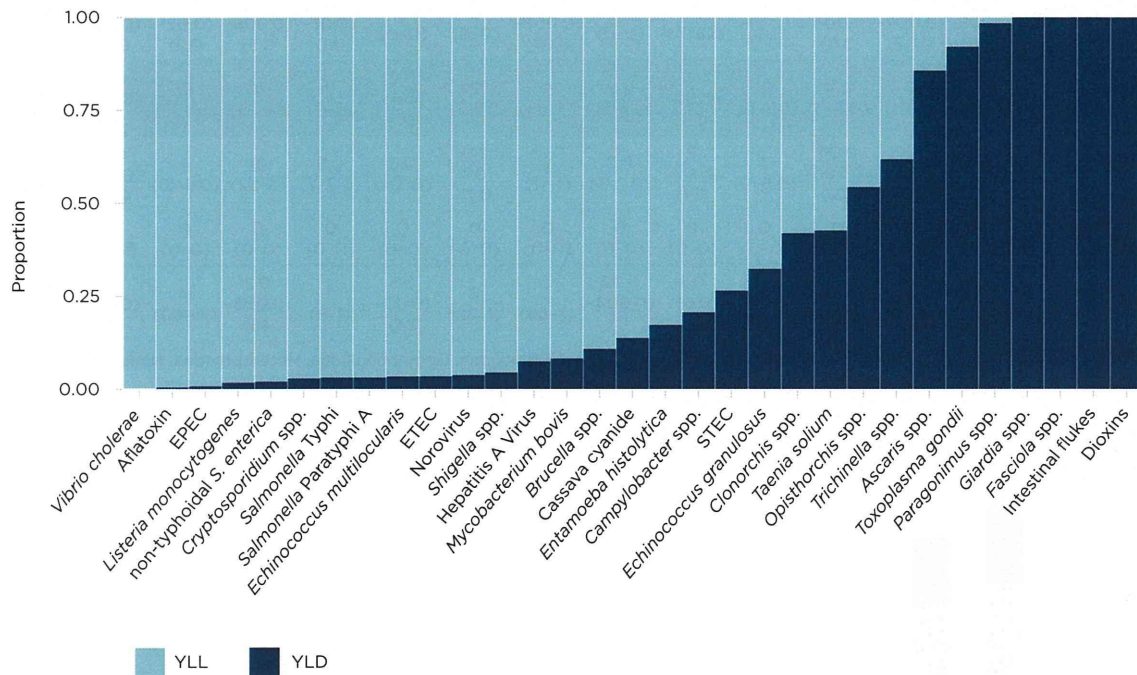
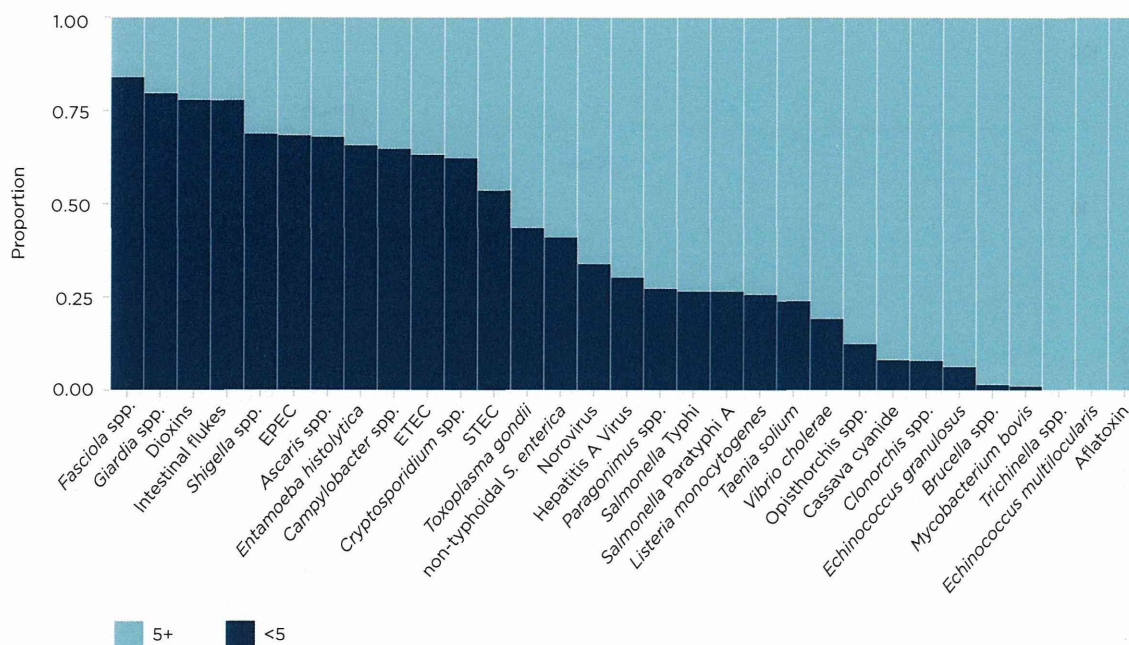


Figure 14. Age-distribution of disability adjusted life years for 31 hazards contributing to the global burden of foodborne disease, 2010.

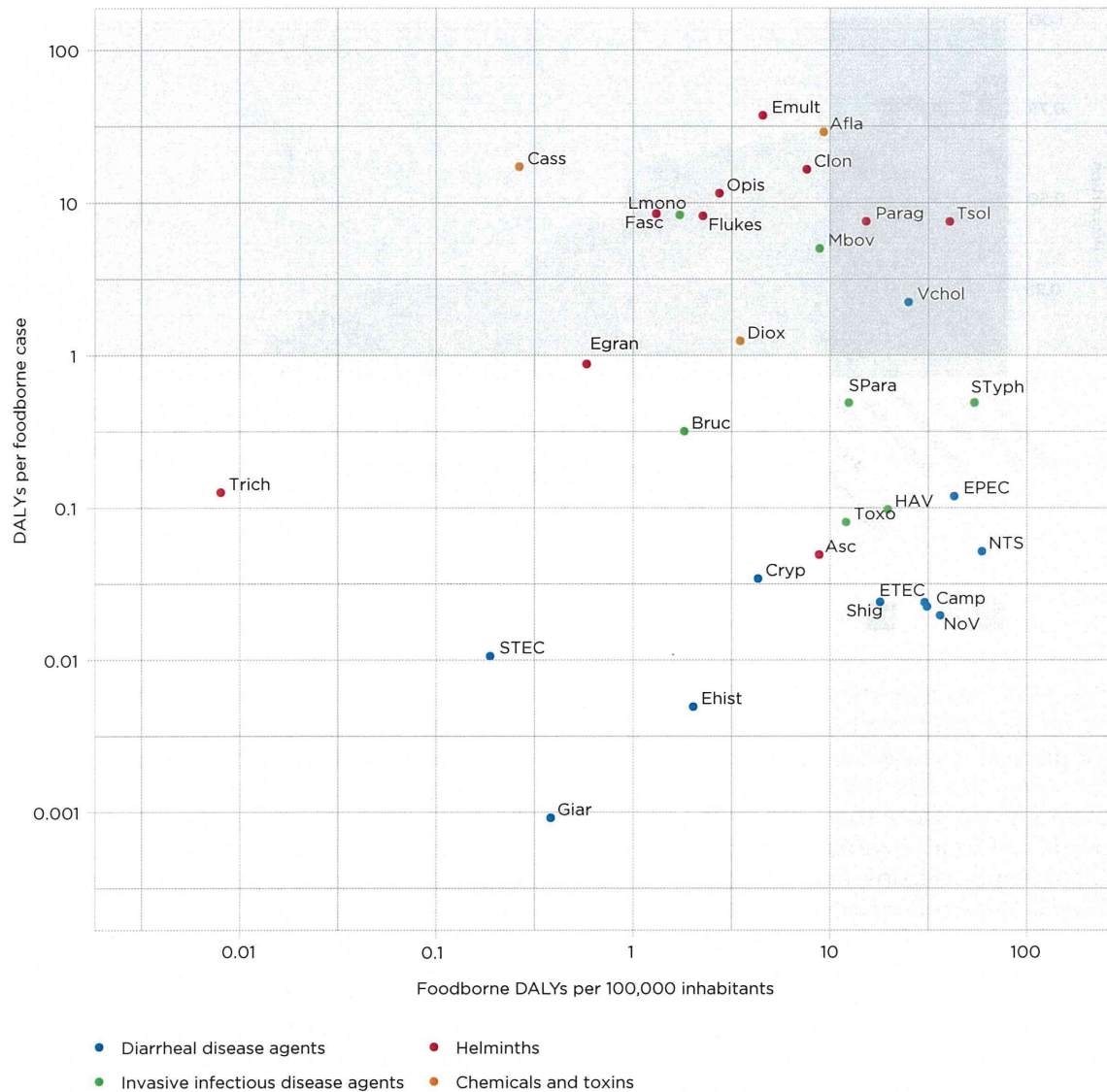


The FERG studies show that children under five years old bear 40% of the foodborne disease burden (including, for some hazards, the life-long burden of sequelae). More than 75% of the burden of four hazards (*Fasciola* spp., *Giardia* spp., dioxins, and intestinal flukes) occurred among children under five (Figure 14). Prenatal infections accounted for 21% of the burden of *L. monocytogenes* and for 32% of the burden of *Toxoplasma gondii*. By contrast, more than 75% of the burden of 11 hazards occurred among people over five years old.

Figure 15 presents a scatterplot of the burden at individual level (DALYs per case, a measure for disease severity) and the burden at population level (foodborne DALYs per 100,000 population, also accounting for disease

incidence), including uncertainty intervals. On the basis of this plot, hazards were divided by two criteria with arbitrary cut-offs as indicated by grey-shaded areas in the Figure. *V. cholerae*, *T. solium* and *Paragonimus* spp. were in the H/H category. All other diarrheal disease agents were in the H/L category, except STEC, *E. histolytica* and *Giardia* spp. (L/L). The L/L category further included *Trichinella* spp. The L/H category contained agents that are of relatively low global impact but have a high impact on affected individuals. These included different parasites, particularly *E. multilocularis*, the invasive bacteria *Brucella* spp., *L. monocytogenes* and *M. bovis*. In subregions where the burden is higher than the global average, these agents are of specific relevance to policy makers.

Figure 15. Scatterplot of the global burden of foodborne disease per 100 000 population and per incident case.



Abbreviations: NoV = Norovirus; Camp = *Campylobacter* spp.; EPEC = Enteropathogenic *Escherichia coli*; ETEC = Enterotoxigenic *E. coli*; STEC = Shiga toxin-producing *E. coli*; NTS = non-typhoidal *Salmonella enterica*; Shig = *Shigella* spp.; Vchol = *Vibrio cholerae*; Ehist = *Entamoeba histolytica*; Cryp = *Cryptosporidium* spp.; Giar = *Giardia* spp.; HAV = Hepatitis A virus; Bruc = *Brucella* spp.; Lmono = *Listeria monocytogenes*; Mbov = *Mycobacterium bovis*; SPara = *Salmonella* Paratyphi A; STyph = *Salmonella* Typhi; Toxo = *Toxoplasma gondii*; Egran = *Echinococcus granulosus*; Emult = *E. multilocularis*; Tsol = *Taenia solium*; Asc = *Ascaris* spp.; Trich = *Trichinella* spp.; Clon = *Clonorchis sinensis*; Fasc = *Fasciola* spp.; Flukes = Intestinal flukes; Opis = *Opisthorchis* spp.; Parag = *Paragonimus* spp.; Diox = Dioxin; Afla = Aflatoxin.

5.3 DALY Estimates: Enteric diseases

It was estimated that the 22 diseases in the enteric disease study caused 2.0 billion (95% UI 1.5–3.0 billion) illnesses in 2010, 39% of which (95% UI 26–53%) were in children <5 years of age. Among the 1.9 billion cases of diarrhoeal diseases, norovirus was responsible for 684 million illnesses– the largest number of cases for any pathogen (Table A8.1 in Appendix 8). The pathogens resulting in the next largest number of cases were ETEC, *Shigella* spp., *Giardia* spp., *Campylobacter* spp. and non-typhoidal *Salmonella* spp. *Campylobacter* spp. cases included almost 32 000 GBS cases. There were also 2.48 million STEC cases, which included 3610 with HUS and 253 with ESRD. Among the extra-intestinal diseases, the pathogens resulting in the most infections were hepatitis A virus, *S. Typhi* and *S. Paratyphi* A. *Brucella* spp. resulted in 0.83 million illnesses, which included almost 333 000 chronic infections and 83 300 episodes of orchitis. *L. monocytogenes* resulted in 14 200 illnesses which included 7830 cases of septicaemia, 3920 cases of meningitis, and 666 cases with neurological sequelae.

Overall, 29% (95% UI 23–36%) of all 22 diseases were estimated to be transmitted by contaminated food, equating to 582 million (95% UI 400–922 million) foodborne cases in 2010; of which 38% (95% UI 24–53%) in children <5 years of age. The pathogens resulting in the most foodborne cases were norovirus, *Campylobacter* spp., ETEC, non-typhoidal *Salmonella* spp., and *Shigella* spp. A high proportion of foodborne infections caused by *V. cholerae*, *S. Typhi*, and *S. Paratyphi* A occurred in the African region (Table A8.2 in Appendix 8). A high

proportion of foodborne infections caused by EPEC, *Cryptosporidium* spp. and *Campylobacter* spp. occurred among children <5 years of age (Table A8.3 in Appendix 8) Among the 11 diarrhoeal diseases, the rate ratio of foodborne cases occurring among children <5 years of age compared with those >5 years of age was 6.44 (95% UI 3.15–12.46).

It was estimated that the 22 diseases in the enteric diseases study caused 1.09 million (95% UI 0.89–1.37 million) deaths in 2010, of which 34% (95% UI 29–38%) in children <5 years of age. Among the diarrhoeal diseases, norovirus was responsible for the most deaths. Other diarrhoeal pathogens responsible for large numbers of deaths were EPEC, *V. cholerae* and *Shigella* spp. The 37 600 deaths attributed to *Campylobacter* spp. included 1310 deaths from GBS. Among the extra-intestinal enteric diseases, the pathogens resulting in the most deaths were *S. Typhi*, hepatitis A virus, iNTS and *S. Paratyphi* A.

Overall, the 22 diseases in the enteric diseases study resulted in 351 000 (95% UI 240 000–524 000) deaths due to contaminated food in 2010; with 33% (95% UI 27–40%) in children <5 years of age. The enteric pathogens resulting in the most foodborne deaths were *S. Typhi*, EPEC, norovirus, iNTS, non-typhoidal *Salmonella* spp. and hepatitis A. The mortality rates of foodborne diseases were consistently highest in the African subregions, followed by the South Eastern Asian subregions (Table A8.2 in Appendix 8) Among the 11 diarrhoeal diseases due to contaminated food, the rate ratio of deaths in children <5 years of age compared with those >5 years of age was 8.37 (95% UI 5.90–11.4). For all 22 diseases, the rate ratio of deaths in children <5 years of age compared with those >5 years of age was 4.85 (95% UI 3.54–6.59).

It was estimated that the 22 diseases in the enteric diseases study caused 78.7 million (95% UI 65.0–97.7 million) DALYs in 2010, of which 43% (95% UI 38–48%) in children <5 years of age. The pathogens resulting in the most DALYs were norovirus, *S. Typhi*, EPEC, *V. cholerae*, ETEC, and hepatitis A (Table A8.1 in Appendix 8).

The rates of foodborne DALYs per 100 000 population are shown by hazard and by subregion in Table A8.2 in Appendix 8.

It was estimated that the 22 diseases in the enteric diseases study resulted in 25.2 million (95% UI 17.5–37.0 million) DALYs due to contaminated food; 43% (95% UI 36–50%) in children <5 years of

age. Figure 17 shows the relative burden of foodborne enteric infections, if iNTS and non-typhoidal *Salmonella* spp. were grouped together. The pathogen resulting in the most foodborne DALYs was non-typhoidal *Salmonella* spp., if iNTS were included (4.07 million). Other pathogens resulting in substantial foodborne DALYs included: *S. Typhi*, EPEC, norovirus and *Campylobacter* spp. The rates of DALYs for foodborne diseases were highest in the African subregions. Overall, the 22 diseases transmitted by contaminated food resulted in 10.8 million (95% UI 7.59–15.3 million) DALYs in children <5 years of age, compared with 14.3 million (95% UI 9.42–22.5 million) DALYs in those >5 years of age.

Figure 16. The global burden of foodborne disease by subregion (DALYs per 100 000 population) caused by enteric hazards, 2010.

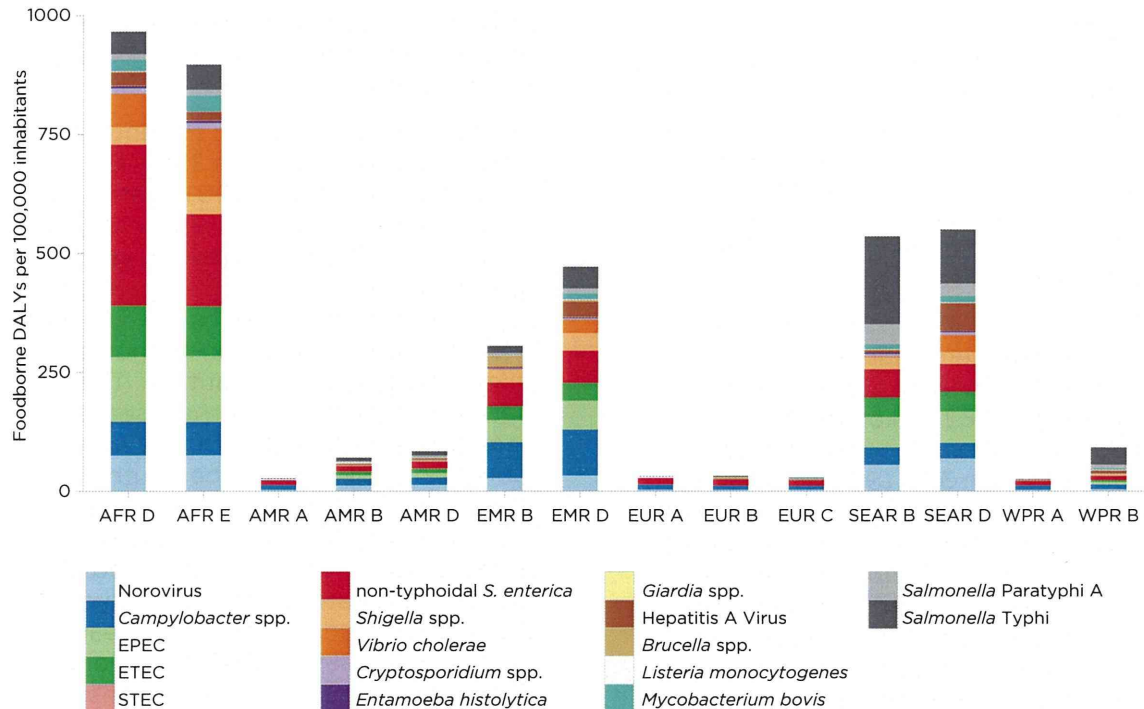
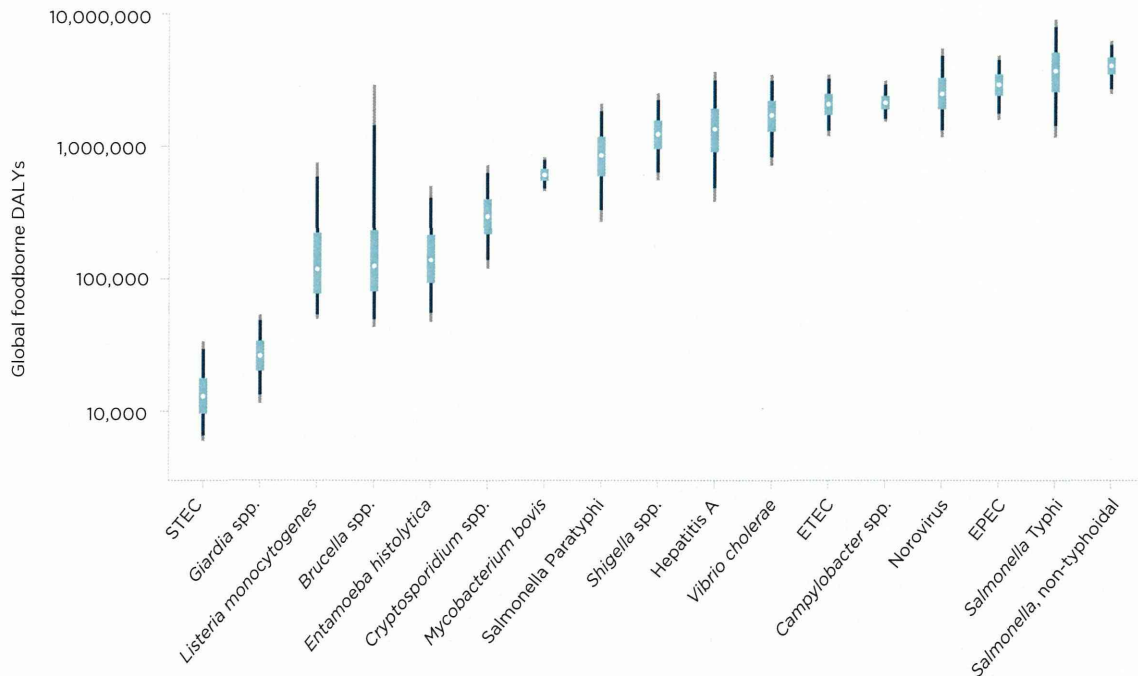


Figure 17. Disability Adjusted Life Years for each pathogen acquired from contaminated food ranked from lowest to highest with 95% Uncertainty Intervals, 2010.



Note figure is on a logarithmic scale. The figure shows the median (white dot); Inter-Quartile Range = 50% UI = 25%/75% percentiles (thick black line); 90% UI = 5%/95% percentiles (thin black line); 95% UI = 2.5%/97.5% percentiles (thin grey line). Note, four foodborne intoxications due to *Clostridium botulinum*, *Cl. perfringens*, *S. aureus*, and *Bacillus cereus* due to a lack of data for global estimation. In addition, data for non-typhoidal *Salmonella enterica* infections and invasive non-typhoidal *S. enterica* have been combined.

5.4 DALY Estimates: Parasites

The parasitic diseases with the largest total number of symptomatic incident cases and symptomatic incident cases attributable to contaminated food in 2010 are acquired toxoplasmosis and ascariasis. The incidence in 2010 of each parasitic disease per 100 000 population by region are given in (Table A8.4 in Appendix 8). Also of note were the relatively few cases of human trichinellosis, with a global estimate of just 4400 cases and 4 deaths in 2010.

The number of DALYs associated with each parasite and the proportion of DALYs that were foodborne in 2010 are given in Table A8.5 in Appendix 8. In 2010 the burdens estimated to be

caused by cysticercosis were 2.79 million (95% UI 2.14–3.61 million) DALYs. Foodborne trematodiasis resulted in 2.02 million (95% UI 1.65–2.48 million) DALYs. Toxoplasmosis had a burden (congenital and acquired combined) of 1.68 million (95% UI 1.24–2.45 million) DALYs, with ascariasis also resulting in 1.32 million (95% UI 1.18–2.70 million) DALYs. Echinococcosis (alveolar and cystic combined), had a burden of approximately 871 000 DALYs (CE 184 000, 95% [UI 88 100–1.59 million] DALYs; AE 688 000, 95% [UI 409 000–1.1 million] DALYs). This gives a 2010 global burden of these 11 parasitic diseases of 8.78 million (95% UI 7.62–12.5 million) DALYs, of which 6.64 million (95% UI 5.61–8.41 million) DALYs were estimated

to be foodborne. Contaminated food may be responsible for 48% (95% UI 38–56%) of incident cases and approximately 76% (95% UI 65–81%) of DALYs (Table 1). Stillbirths were excluded, although in the case of congenital toxoplasmosis, if counted as deaths as an alternative scenario, this would result in 4470 (95% UI 969–12 400) additional deaths and hence an addition of approximately 411 000 (95% UI 89 100–1.14 million) YLLs. Of these, approximately 2180 (95% UI 470–6090) deaths and 200 000 (95% UI 43 200–560 000) YLLs would be foodborne.

The largest global incidence rate of DALYs was found in the Western Pacific and African subregions, with 156 (95% UI 127–193) and 208 (95% UI 159–283)

DALYs per 100 000, respectively, whereas the lowest was found in the European subregions, with 11 (95% UI 8–24) DALYs per 100 000 (Appendix 8 Table A8.4). However, the relative importance of the different parasitic infections varied across regions and this is clearly illustrated in Figure 18A. For example, the burden of opisthorchiosis is largely confined to SEAR subregion D, whilst cysticercosis is rarely seen in either EMR or EUR regions.

The absolute and relative foodborne burdens of these parasitic diseases, including the three enteric protozoa, are illustrated in Figure 18B. The relative proportion of the burden of each of the foodborne parasitic diseases contributed by YLLs and YLDs is illustrated in Figure 19.

Figure 18A. The relative contribution to the DALY incidence by each agent for each of the subregions. This includes enteric protozoa to complete the picture on foodborne parasitic diseases. However the detail is reported in the accompanying manuscript on foodborne enteric pathogens [168].

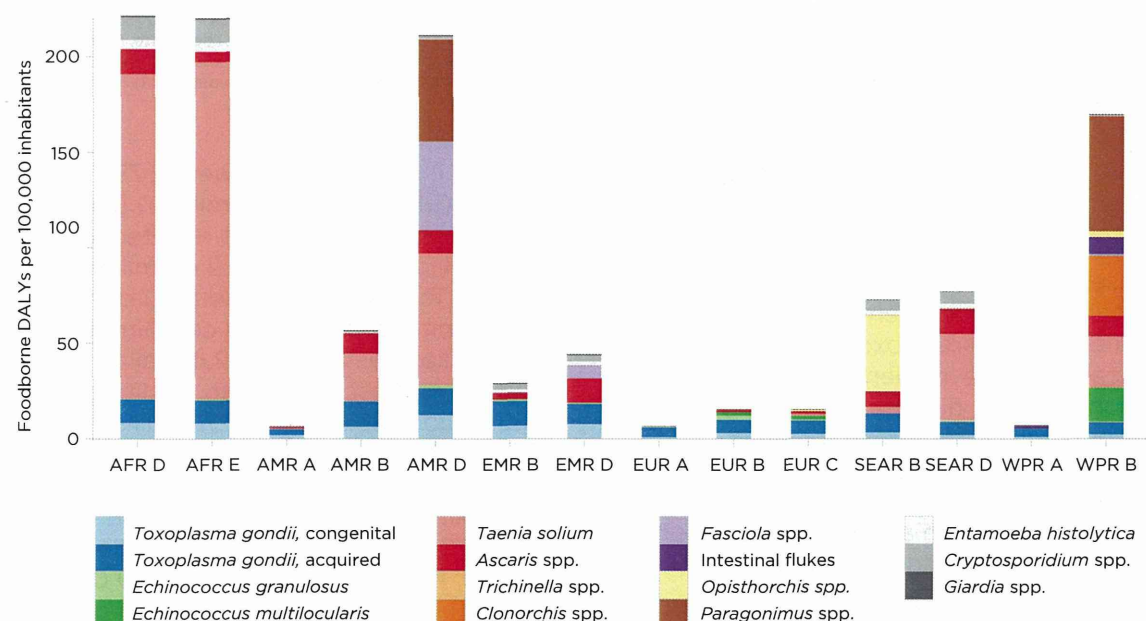


Figure 18B. Disability Adjusted Life Years for each parasite acquired from contaminated food ranked from lowest to highest with 95% Uncertainty Intervals, 2010. This includes enteric protozoa to complete the picture on foodborne parasitic diseases. However the detail is reported in the accompanying manuscript on foodborne enteric pathogens [168].

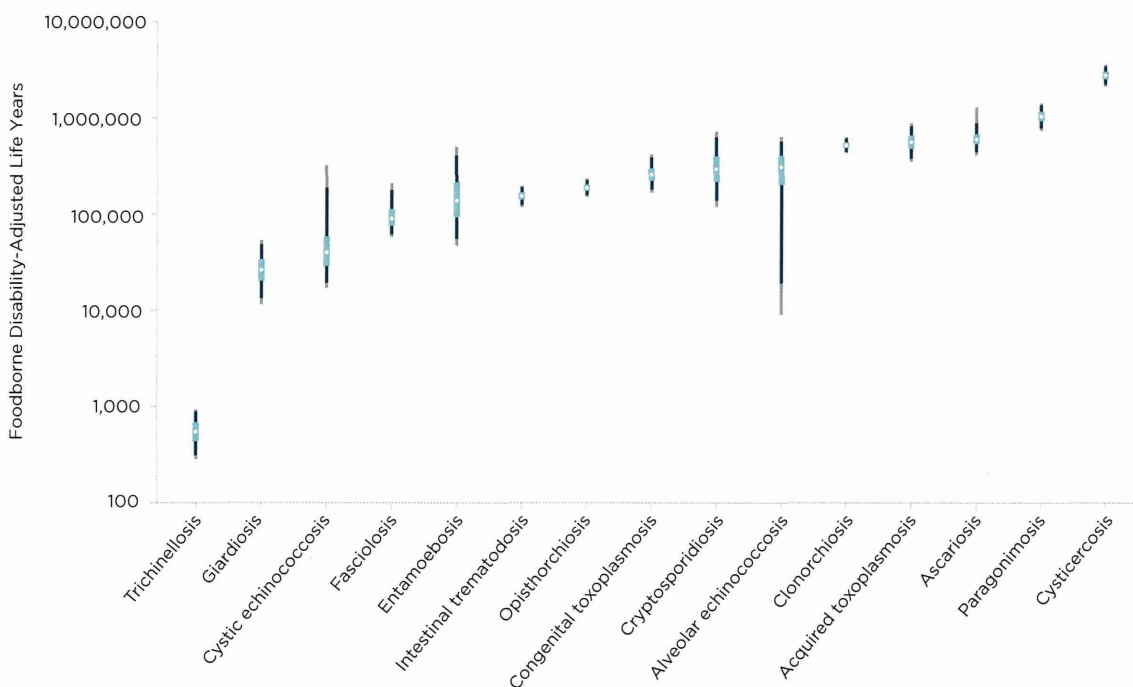
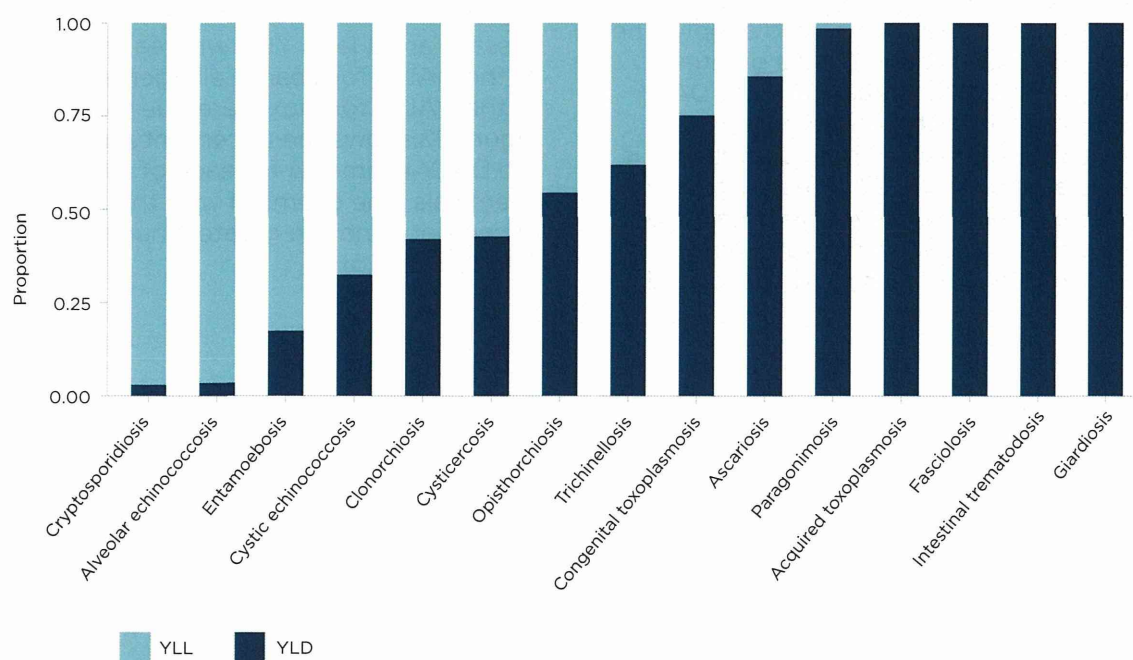


Figure 19. The relative proportion of the burden of each of the foodborne parasitic diseases contributed by YLLs and YLDs



RESULTS