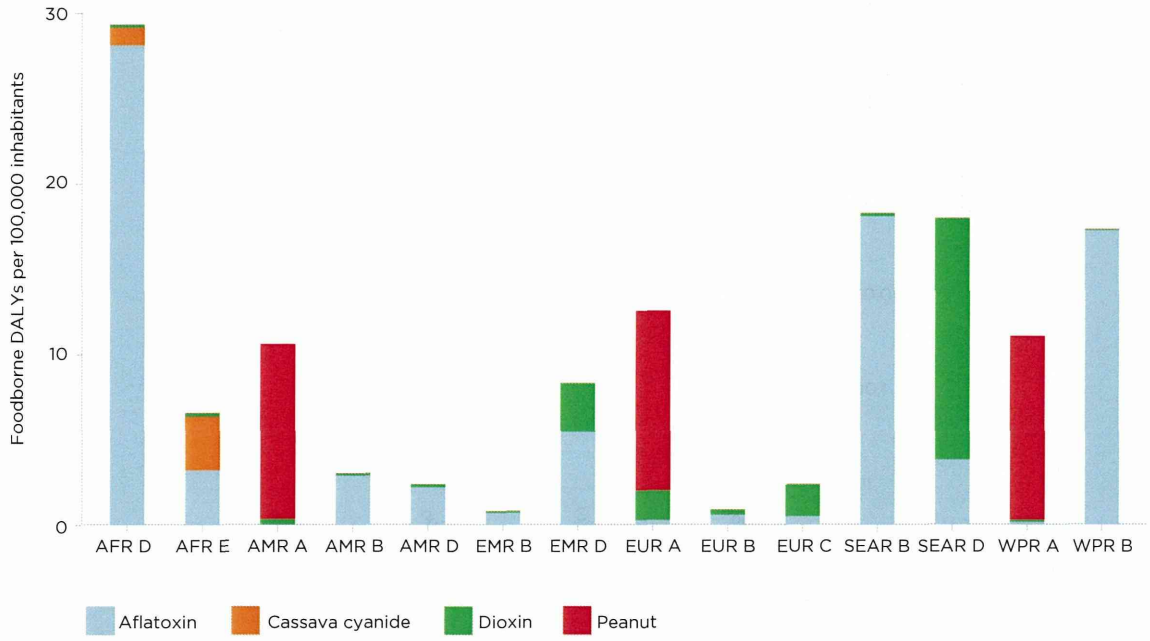
5.5 DALY Estimates: Chemicals

The analyses presented here show that four selected chemicals already have a substantial impact on the foodborne burden of disease, particularly in low- and middle-income countries. Just these four agents are estimated to be associated with 339 000 illnesses (95% UI 186 000–1 239 000); 20 000 deaths (95% UI 8 000–52 000); and 1 012 000 DALYs (95% UI 562 000–2 822 000) in 2010. These should be considered the "tip of the iceberg" in terms of foodborne chemicals and their impact on the global burden of disease. For peanut allergens, we were unable to estimate a burden for low- and middle-income countries due to data gaps. We also had to use an approximate disability weight, as there are data only on quality of life of patients with food allergy [102] and no specific data are available for peanut allergy.

The estimated number of incident cases, deaths and DALYs for each of the diseases associated with chemicals is given in Table A8.6 in Appendix 8. The chemical associated with the most number of illnesses is dioxin; however, no deaths have been reported from the presence of dioxin in the food supply. The chemical associated with the greatest number of DALYs is aflatoxin. The DALY estimates for aflatoxin and dioxin have the least uncertainty; more uncertainty is associated with the DALY estimates for peanut allergen and cyanide in cassava. The annual incidence, mortality, and DALY rate of each chemical-associated disease per 100 000 population for each of the regions is reported in Table A8.7 in Appendix 8. Peanut allergy is not reported in Table A8.7 in Appendix 8 because burden was estimated only for AMR A (United States of America, Canada and Cuba), EUR A (primarily countries in Western Europe), and WPR A (Australia, Brunei Darussalam, Japan and New Zealand) subregions. Burden estimates for cyanide in cassava are provided only for the African region (AFR) and assumed to be zero for other regions.

Figure 20 provides the DALYs per 100 000 inhabitants by global region. The regions with the highest burden per 100 000 inhabitants are the subregions in SEAR, WPR and AFR. The American Region (AMR), Eastern Mediterranean Region (EMR), and European Region (EUR) have the lowest DALYs per 100 000. Aflatoxin is the largest contributor to the burden in AFR and WPR. Dioxin makes the largest contribution in SEAR. Figure 21 contrasts the proportion of DALYs due to YLL and YLD for each of the four chemicals. Virtually all of the DALYs for aflatoxin and most of the DALYs for cyanide in cassava are due to YLL, whereas most of the DALYs for peanut allergen and all of the DALYs for dioxin are due to YLD. Figure 22 shows the uncertainty around the DALY estimates for each of the four chemicals. The chemical with the least uncertainty and the greatest number of DALYs is aflatoxin.

Figure 20. The relative contribution to the DALY incidence by each of four chemicals for each of the WHO Regions.



Notes: Peanut allergy burden was estimated only for the AMR A (United States of America, Canada and Cuba); EUR A (primarily countries in western Europe); and WPR A (Australia, Brunei Darussalam, Japan and New Zealand) subregions. Burden estimates for cyanide in cassava are provided only for the African region (AFR), and assumed to be zero for other regions.

Figure 21. The relative contributions from YLLs and YLDs for each of four chemicals.

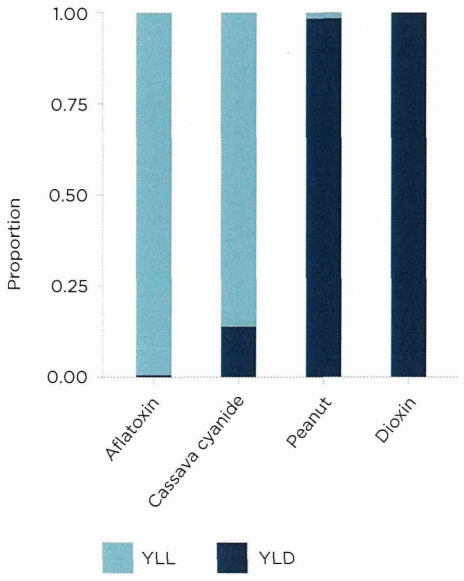
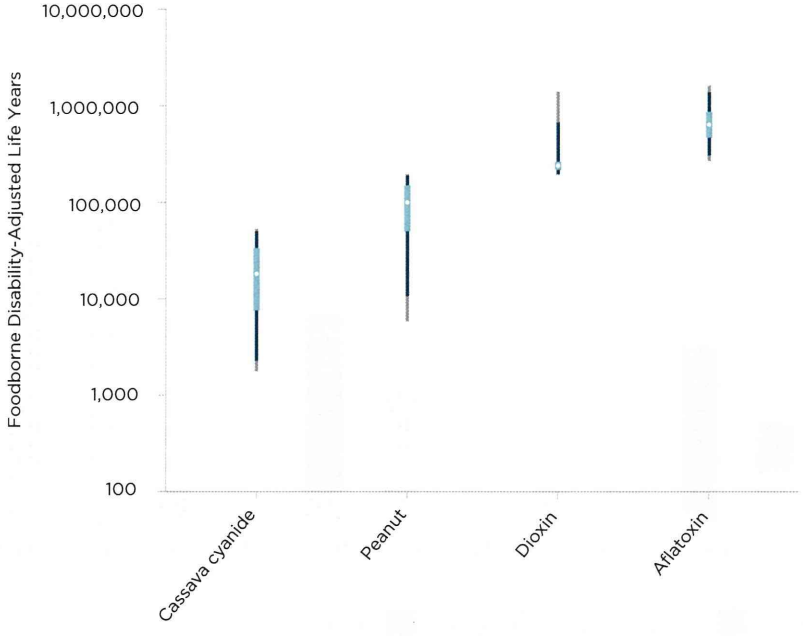


Figure 22. Disability Adjusted Life Years for each of four chemicals from contaminated food ranked, from lowest to highest, with 95% uncertainty intervals



Notes: The dot in the middle of each box represents the median, the box the 50% uncertainty interval, the dark bar the 95% uncertainty interval, and the light bar the 95% uncertainty interval.

DISCUSSION 6

DISCUSSION

This study estimates that 31 foodborne hazards resulted in 33 million DALYs in 2010, which shows the considerable public health impact of contaminated food. Importantly, children <5 years of age experienced 40% of the foodborne disease burden, despite representing only 9% of the global population. The study provides a substantial expansion of the available data on the public health impact of FBDs.

Several high-income countries have published national estimates of FBD. Estimates of food-related illnesses and deaths in the USA were estimated in the late 1990s [169] and updated to cover the period 2000–2008 [170, 171]. Similar studies are available from Australia [173], Canada [175], France [174] and the UK [172]. Some countries have extended this work to estimate DALYs, including Greece [177], the Netherlands [178], New Zealand [176] and the USA [179]. While the range of hazards covered in these studies differed from those in the FERG studies, the focus was on enteric diseases and a limited number of invasive and parasitic diseases. The FERG data, by contrast, cover numerous countries across the globe and provide a more complete picture of FBD.

Comparisons of the FERG estimate of the burden of FBD with other estimates, such as those of the Institute for Health Metrics and Evaluation's GBD 2010 study [81], must be made with care because of differences in the methodology and data used. For example, the GBD 2010 study used prevalence-based DALYS, whereas our study used incidence-based DALYs. As a consequence, the impact of sequelae such as Guillain-Barré syndrome (due to Campylobacter spp.), hemolytic uremic syndrome (due to Shiga toxin-producing E. coli) and invasive disease (due to non-typhoidal S. enterica) were attributed to the diarrheal disease agents in the FERG estimates whereas in the GBD 2010 study they were recorded in different disease categories. Furthermore, the GBD 2010 study used a different life table than FERG and more extensive mathematical modeling to account for data gaps, which smoothed the data considerably, resulting in narrower uncertainty intervals than in our study. The GBD 2010 and FERG studies used the same set of disability weights, but the FERG included some updates as recommended by WHO. Neither study applied time discounting or age-weighting in their baseline estimates.

The GBD 2010 study, which looked at all sources of disease, found that the key hazards and risk factors for disease burden were dietary risk factors (254 million DALYs), unimproved water and sanitation (211 million DALYs), HIV/AIDS (82 million DALYs), malaria (82 million DALYs), air pollution (76 million DALYs) and tuberculosis (49 million DALYs). Recently published findings from WHO[1] for 2012 were: HIV/AIDS (92million DALYs); malaria (55 million DALYs) and tuberculosis (44 million DALYs). Hence, the burden of FBD (33 million DALYs) is of a similar order of magnitude as the 'big three' infectious diseases (HIV/AIDS, malaria and tuberculosis) and air pollution, but clearly lower than the burden of dietary risk factors or unimproved water and sanitation.

The FERG estimate of 29,000 deaths due to foodborne transmission of invasive non-typhoidal *S. enterica* only included infections in non-HIV infected individuals. Ao et al. [180] estimated there were approximately 680,000 deaths due to invasive non-typhoidal salmonellosis in 2010. Of these, approximately 350,000 would be due to foodborne transmission, assuming 52% of all non-typhoidal

[1] http://apps.who.int/gho/data/node.main.DALYNUMWORLD?lang=en; accessed July 22, 2014

salmonellosis cases is transmitted by food [156]. Even though this high number of deaths among HIV infected people is not included in the FERG estimates of the burden of FBD, they would be preventable by food safety interventions.

This study is subject to several limitations, notably due to uncertainties in the data limitations on burden estimates and attribution estimates. For most hazards (25 of the 31 studied), the 95% DALY uncertainty interval (UI) ranged from one-fourth to four times the median. The uncertainty was markedly greater for *E. multilocularis* (because of uncertainty in the attribution estimates), *E. granulosus* and *L. monocytogenes* (because of uncertainties in the imputation results). In low-income countries, where the burden is highest, data availability was generally most problematic. Furthermore, in these countries, the proportions of diseases transmitted by food, water and the environment are difficult to disentangle, as contaminated water may also result in contamination of foods. Due to these limitations, it was not possible to present reliable estimates at country level, and elected to present results at subregion level.

For some hazards (e.g. *M. bovis* and *E. multilocularis*, aflatoxin and dioxin), incident illness is related to past exposures due to long incubation times of disease. For such hazards, the estimated burden reflects exposure dating back to the average incubation period of the disease rather than current exposure. For some hazards (e.g. dioxins), the impact on the child depends on the lifelong exposure of the mother.

The FERG estimates of the FBD burden are probably conservative, i.e. underestimates rather than overestimates. Limited resources and data obliged us to focus on only a subset of more than 100 hazards of potential relevance [182]. In particular, we did not include burden estimates for several chemicals (arsenic, cadmium, lead and methylmercury), because methods for estimation of the fraction of illnesses attributed to foodborne exposure to these chemicals are not readily available. Even for the hazards we have studied, it was not always possible to include all relevant disease outcomes in our estimates of burden. For example, we did not include functional bowel disorders as potential outcomes for enteric infections [183]. Inclusion of these outcomes would likely considerably increase the burden of enteric infections [184].

Aflatoxin burden was estimated using a counterfactual approach, estimating population attributable fractions from exposure assessment estimates and cancer potency factors, and applying these to WHO estimates for incidence and mortality by hepatocellular carcinoma. Risk assessment, as used to assess the burden of dioxins [133] has been proposed as an alternative basis for estimating this particular burden, and would result in considerably higher estimates of the burden of aflatoxin [110]. Moreover, both aflatoxin and dioxin can cause other adverse health effects than the ones considered (e.g. diarrhoeal diseases [185] and aflatoxin as causes of malnutrition and stunting, dioxin and immune effects or cancer), for which data were not available to allow disease burden estimates.

A further limitation of this study is that DALYs do not quantify the full societal impact of FBD. The economic burden (cost-of-illness, losses in the agricultural and food sectors and trade impacts) is also an important factor to consider in national and international decision-making. Also, the process of food production can cause human diseases by mechanisms other than direct

transmission of pathogens through food. For example, animal husbandry is an important source of zoonotic disease agents that spread from pigs, poultry, cattle, etc., by direct contact or through the environment, and may also affect livestock health. It is increasingly necessary to consider holistically all aspects of food-related disease in a One Health Framework [186].

Despite its data gaps and assumptions, this study presents the first ever estimates of the global burden of FBD and should serve as an important resource to focus activities that will reduce this burden. A sustainable, multi-sectoral response is needed from governments and international organizations to reduce the visible and 'hidden' burden; this includes enforcement of food safety standards and effective surveillance networks at country, regional and global levels. This will require a concerted effort by all stakeholders in the food chain, from primary production to consumers. The diversity of foodborne hazards suggests the need for a multi-faceted strategy, with priorities tailored to each region. While national studies may further refine these priorities and are highly recommended, the current findings could already be a basis for developing strategies at the global, regional and national levels.

The diversity of foodborne hazards and regional differences in their importance suggest the need for consideration of these estimates at the national or even subnational level. As one of its aims, the FERG has fostered national studies of the burden of FBD, and pilot studies have been conducted in Albania, Japan, Thailand and Uganda. The tools and protocols developed by the FERG to support such national studies emphasize the collation of local data to validate its regional estimates, the consideration of local hazards that may not have been addressed at a global level, and the translation of burden estimates into food safety policy. The estimates developed by this WHO initiative will be invaluable for countries where local data gaps prevent the development of a full picture of FBD.

The considerable difference in the burden of foodborne disease between low- and high-income regions suggests that a major proportion of the current burden is avoidable. The WHO is working with governments and partners, including food producers, caterers and consumers, to reduce food contamination throughout the food chain, and particularly at the point of consumption, to levels at which the exposure to pathogens and contaminants does not pose significant risks for human health. There is, therefore, an urgent need to develop cost-effective food hygiene interventions that can be implemented in resource-poor settings. This research and development should be informed by estimates of the burden of specific food vehicles, taking all hazards into account.

General principles for strengthening food safety systems have been suggested by the WHO; they include integrating food safety into nutrition and food security policies and programs, and fostering closer collaboration between the various sectors involved (agriculture, human health, animal health, trade, tourism, etc.). The WHO recommends governments put in place risk-based food control systems and implement international food safety standards as established by the Codex Alimentarius Commission. Food handlers and consumers should handle and prepare food safely, practicing the WHO's 'Five Keys to Safer Food' and grow fruits and vegetables using the WHO's 'Five Keys to Growing Safer Fruits

and Vegetables' to decrease microbial contamination[2].

FBDs are closely linked to poverty in developing countries but they are also a global public health issue because growing international trade increases the risk of contamination in transported foods; also, migration and travel can expose populations to new hazards. Achievement of the internationally agreed Millennium Development Goals and the proposed Sustainable Development Goals, including the overarching goals of poverty reduction, achieving food security and ensuring healthy lives, will depend in part on successful reduction of the burden of FBD.

6.1 Attribution

In the attribution study, the results are presented of the first world-wide study on the contribution of contaminated food and other exposure routes to human disease caused by 18 major microbiological hazards and a chemical hazard. The study highlights the importance of the foodborne route of transmission for these hazards and– when combined with estimates of incidence, severity, duration and mortality– allows estimation of the burden of foodborne disease. Attempting to estimate foodborne transmission at the subregional level is an ambitious goal. However, this was vital given the geographically localized nature of exposure to many pathogens. The results are significant due to the global nature of the estimation, the number of experts participating, and the rigorous approach taken to assessing and including expert performance in the final estimates.

[2] http://www.who.int/campaigns/world-health-day/2015/en/

We were unable to identify epidemiological studies in the literature that delineate and quantify the importance of each transmission pathway as investigated in this study. This makes it difficult to formally validate the findings of the expert elicitation. Still, a discussion of summary findings in the context of other scientific knowledge may be of value.

The hazards can be grouped into several categories with respect to their major pathways. For *Campylobacter*, non-typhoidal *Salmonella*, STEC, *T. gondii*, and *E. multilocularis*, the foodborne route was considered the most important route in all subregions. These pathogens are all zoonotic and known to have one or more animal reservoirs. The zoonotic nature of these organisms is also reflected in experts' judgments by the identification of direct contact with animals as an important transmission route as well. Other pathogens with animal reservoirs include *E. granulosus* and *Brucella* spp., and here direct contact with animals was considered equally or more important than food as routes of transmission.

As described in the results section for several pathogens, there was a clear pattern that the experts considered the foodborne route less important in low- and middle-income subregions, where other routes (animal contact, water and soil) were believed to contribute relatively more in comparison with high-income subregions. This is consistent with data showing lower levels of access to improved water and sanitation in less developed regions compared with high-income countries. This ranking of subregions across different pathogens provides some confidence in the results, as the estimates were done independently and partly by different experts.