The environmental burden of diarrhea in young children attributable to inadequate sanitation in Brazil

T. C. M. Sousa, C. Barcellos, A. F. Oliveira, J. Schramm and L. Garbayo

ABSTRACT

The Global Burden of Disease is the official metrics of World Health Organization in use to support public health evidence-based decision-making. It has been systematically used to assess environmental risk factors such as unsafe Water, Sanitation and Hygiene (WASH), as part of the measurement of Environmental Burden (EB). This article reports on the first study in Brazil that estimates the EB attributable to unsafe WASH associated with diarrhea for children under five years old for the country and macro-regions for 1998. The EB of diarrhea for this subgroup was estimated using the population attributable fraction (PAF) method for four scenarios of exposition to unsafe WASH. Results of PAF were multiplied by the EB obtained from the 1998 Brazilian GDB Study. The regions with higher EB for children below five years old were north and northeast, both predominantly rural. The EB attributable to unsafe WASH was 15% in 1998. The estimation of the EB of diarrhea contributes to the re-assessment of Brazil's attainment of the Millennium Development Goals (MDG) in both health and environmental dimensions. Results obtained indicated that the country's precarious conditions of WASH in rural areas are below the goals of MDG, as well as in impoverished urban areas.

Key words | Brazil, diarrhea, environmental burden of disease, Millennium Development Goals, unsafe sanitation

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INTRODUCTION

In the year 2000 the United Nations launched the Millennium Development Goals (MDG), as a wide platform to overhaul world development, end extreme poverty and its nefarious effects upon the world's population (UN 2000). The Millennium Declaration identified eight crucial developmental goals to be met by member countries by 2015: (1) eradicate extreme poverty and hunger; (2) achieve universal primary education; (3) promote gender equality and empowering women; (4) reduce child mortality rates; (5) improve maternal health; (6) combat HIV/AIDS, malaria, and other diseases; (7) ensure environmental sustainability; (8) develop a global partnership for development. Two of these goals – Goals IV, to reduce child mortality, and VII, to promote environmental sustainability – are strongly intertwined and can be shown to be directly associated with the risk factors of unsafe water, sanitation, and hygiene (WASH), and their effect on young children below five years old.

Different methodologies and health metrics have been adopted to assess the progress in the direction of the attainment of the MDG. Considering its measurement for proper assessment and global comparability, Brazil has officially recommended the use of the Global Burden of Disease (GBD) methodology, in following with the World Health Organization metrics standard (Ministry of Health 2006). The Environmental Burden of Disease (EBD) (WHO 2000), as part of the GBD, is a related metrics that may help to quantify the strength of connections between environmental factors and health disparities and inequities.

doi: 10.2166/washdev.2014.129

THE GLOBAL AND THE EBD

The World Health Organization has estimated the GBD for different diseases and illnesses around the world and regions since the nineties. The GBD uses the DALY (disability adjusted life years) as its main summary measure of population health, integrating both data on mortality and on morbidity. It is composed of two parts: the YLL (years of life lost), years of life lost due to premature death, and the YLD (years lived with disability).

In 2008, the WHO (2008) presented the GBD for 102 major diseases. According to this report, environmental risk factors contributed to disease burden in 85 of the diseases studied. The strength of some of these associations generated a clear platform for better understanding, promoting and preventing environmental health. Yet, even prior to the report, and in line with it, Pruss & Corvalan (2006) were able to show that diarrhea is the disease with the largest environmental contribution. Their work suggested that about 94% of the diarrhea burden of disease attributable to environment is associated with risk factors such as living with unsafe WASH. The authors called the GBD attributable to environmental risk factors, the EBD.

EBD IN BRAZIL

This article focuses on the EBD and estimates the environmental burden of diarrhea attributable to sanitation problems for Brazil and its macro-regions, considering sanitation conditions for the Brazilian population in 2000, focusing on its burden on children less than five years of age. The diversity of sanitation conditions was classified according to a set of scenarios that reflected different configurations of water supply, sewage systems coverage, and hygiene conditions. The scenarios selected were so chosen to consider in the study the different means of pathogen transmission and low sanitary conditions, according to Pruss *et al.* (2002).

By using the EBD, we aim at bringing into sharp focus the regional inequalities and inequities regarding the connections between environmental health and children's diarrhea in Brazil and at providing data to the monitoring of the MDG. The assessment of the environmental burden of diarrhea attributable to unsafe WASH in Brazil is also justified by the association of this specific risk factor with identified precarious development conditions. The largest burdens attributable to sanitation were identified in the poorest regions of the world, with a strong positive association with the development level of the countries (Pruss & Corvalan 2006). The environmental burden of diarrhea attributable to inadequate sanitation allows for the evaluation of the impact of this risk factor on the quality of life of populations and of a country's development. For this reason, it has been calculated in different countries and population groups, assisting in the identification of investment priorities. However, these realities can vary greatly due to the different historical and environmental context in which the relationship between health and sanitation occurs (Heller 1997). Thus, the adaptation of calculation parameters closer to local realities, in their historical and environmental contexts is a necessary step for adding needed accuracy to the overall estimation task.

Brazil's public health historical context, with the implementation of the universal health care system in the last decades, has been generating social advances, such as the increase in the coverage of sanitation facilities (Figure 1). Yet, such advances have not been distributed homogeneously across the country, but followed a large variation linked to distinct levels of urbanization and economic development between its regions. The Brazilian Institute for Geography and Statistics (IBGE) compiled data for present sewage systems (2011) show that only the

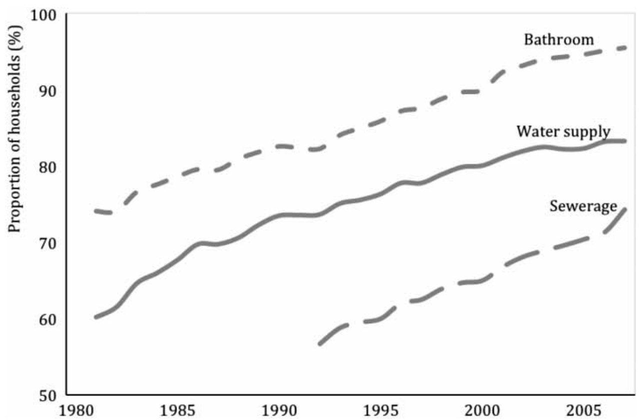

Figure 1 | Proportion of households with access to bathrooms, water supply systems, and sewage system in Brazil between 1980 and 2008.

southeast region, which is the most urbanized and has the highest Human Development Index in the country, had over half of the population with access to the public sewage system in 2008. The same is true for water supply. In contrast, in the north and northeast of the country, which are more rural and less developed regions of Brazil, the population with access to public sewage in 2008 was 35% and with access to water supply was 53%.

These regional disparities in sanitation conditions which the Brazilian population are submitted to, can be utilized as a methodological approach for the evaluation of the exposure to risk situations and their association with the incidence of diarrhea in the country. As the environmental burden of diarrhea is analyzed, the position of sanitation in investment priorities can be better identified, considering a more accurate different sanitation and socioeconomic conditions in Brazil.

Although the year of 2000 was used as a reference year in this study, due to the availability of Brazil's census data, as well as of epidemiological data, recent trends regarding increasing water supply and sewage systems can be observed since then. According to the National Home Sample Research from 2008, conducted by the Brazilian Institute of Geography and Statistics Foundation (IBGE 2011), 83% of the Brazilian population had access to the public water supply system and 75% have access to the public sewage system or septic tanks, considered to be safe forms of sanitation. This increase of coverage has been slow, but it is presented as a strong tendency.

According to Pruss *et al*. (2002), the lack of water is linked to inadequate personal, domestic, and agricultural hygiene, including person-to-person transmission of fecal–oral pathogens, food-borne transmission of fecal–oral pathogens and use of contaminated water for irrigation or cleaning. In this sense, in particular, to have a bathroom facility in the home represents a necessary condition but not a sufficient one for assuring hygiene (Eisenberg *et al*. 2007). Yet, such condition, when present, allows for the separation between water used in the preparation of food, and water used for bathing, excrete elimination, and hand washing, thereby contributing avoiding systematic contamination within the household.

From Figure 1 it is noted that the recent increase of the presence of bathrooms in households is almost reaching universalization. In this study, the presence of bathrooms has been used as a proxy of hygiene conditions of the population. In many developing countries there are frequently low levels of coverage of public water and sewage systems, accompanied by the absence of bathrooms in households. This difficult scenario can amplify disease risks among family members, mainly where community transmission, i.e., due to river water, public spaces and food contamination is high (Eisenberg *et al*. 2007). In Brazil, however, the relative availability of water and nearly universal bathroom presence in households make this scenario an unlikely risk hypothesis (Figure 1).

In Brazil and in Latin American countries, the urban population increasingly has had more access to water due to the expansion of the water supply systems – despite the fact that such access might be precarious, i.e., subject to eventual water contamination or shortage. However, such expansion of access has not been followed by the equal improvement of the sewage system and waste collection and treatment. Accordingly, a transition to a hybrid scenario that combines both the universalization of the access to water supply systems and a growing vulnerability of the surface and subterraneous sources of water due to its sewage contamination is observed many times. In this new hybrid scenario, there is a tendency to diminish the exposure to pathogens in normal situations regarding sanitation. On the other hand, in this hybrid scenario, conditions are given for the occurrence of localized outbreaks, with great magnitude in situations of disasters or of temporary collapse of these systems, as happened recently during the 2013 draught in the northeast region of Brazil, and in other situations in which there was distribution of contaminated water by the supply systems (Lee & Schwab 2005). These important scenarios defy capture by coverage indicators, classically used for the evaluation of sanitation conditions (Andreazzi *et al*. 2007). Rather, the issue of considering precisely the quality of water – rather than only its availability – in such hybrid scenarios becomes critical to understand the vulnerabilities in the expansion of the coverage of the supply systems of water and sewage, and the quality specificities regarding the investment in treatment of sewage, in the protection of water sources and in the correct destination and treatment of waste. The identification of critical exposure pathways of infections due to inadequate sanitation is an important task for informing sanitation interventions in the future (Eisenberg *et al*. 2007).

The use of the GBD metrics allows for the incorporation of the portion related to morbidity of diarrhea, taking into account the tendency of infant mortality rate (IMR) reduction and the control actions of diarrheal diseases developed by basic health services. Victora (2009) indicates the reduction of IMR due to diarrhea from 11.9 to 0.2 deaths per 1,000 live births, resulting in the reduction of 98.6% between 1980 and 2000. The author points to the increase of coverage of sanitation services and basic health care as two of the factors responsible for the reduction of the IMR, although the multiple causes associated with the incidence of diarrhea are also pointed out.

The elevated IMRs in some regions of Brazil compromise the targets assumed by the country when looking at objective IV, reduction of the mortality rate of children under five years of age by two-thirds between 1990 and 2015. This same report projects that Brazil should reach the targets set for the reduction of IMRs before the end of 2015. If we analyze the IMR separating the rural from urban areas of the country, however, we see that the gap between the current values of IMR and the proposed targets is greater in the more rural parts of Brazil, especially in the north and northeast regions. Regarding regional disparities, the United Nations Development Program indicates that the northeast regions presented the greatest reductions in IMRs in the last two decades in comparison with other regions of the country. However, according to recent data provided by the Ministry of Health of Brazil (DATASUS 2014), the north and northeast regions have not yet reached the lower IMR in Brazil as determined by the MDG target, which is 17.8 per 1,000 live births.

The methodology phase of the estimation of the GBD is particularly critical for its adaption to the Brazilian reality, since it is usually based on data collected in different contexts (Almeida *et al*. 2001). In the case of sanitation, many estimates are based on studies carried out in small villages in Africa or Asia where water supply and sewage systems are nonexistent (Heller 1997) and, therefore, the impact of small sanitation actions is overestimated. According to Lee & Schwab (2005), the main problems faced today by water supply systems in developing countries are linked to the vulnerability and intermittency of these systems, rather than coverage.

In this study we focused primarily on the national data available to estimate the environmental burden of diarrhea attributable to unsafe WASH, to approximate the results to the Brazilian reality, but we also worked on the possibility of identifying data that should be better collected and registered in information systems. In this sense, our study presents the first estimation of the GBD for this risk factor in Brazil, carried out entirely with Brazilian data.

METHODS

The environmental burden of diarrhea attributable to unsafe sanitation, water and hygiene was estimated using the population attributable fraction (PAF). The estimation of the PAF is carried out as a function of two parameters: the relative risk (RR) of the outcome in analysis and the prevalence of the risk factor in the studied population. Considering a risk factor with k categories of exposure, the etiological fraction for the ith category is calculated in the following way:

$$\mathrm{FPA} = \frac{p_i(RR_i - 1)}{\sum_{i=0}^{k} p_i(RR_i - 1) + 1},$$

where p_i is the prevalence of ith category of exposure to the risk factor and RR_i is the RR in relation to the reference exposure category.

The methodology proposed in the publication Methodology for Assessment of EBD (WHO 2000) and that proposed by Pruss *et al.* (2002) was followed for the estimation of the PAF in the context of the EBD. Both publications indicate the necessity to present the PAF attributable to environmental risk factors for distinct exposure scenarios according to regional/national management interests. The definition of the exposure scenarios in this study used the following criteria: (1) utilization of national prevalence data obtained from the census of 2000 (IBGE 2000); (2) the RR data of these scenarios also came from a publication that evaluated the incidence or prevalence of diarrhea in children in Brazil (Genser *et al*. 2008); and (3) the scenarios created present the relationships regarding the determination of fecal–oral transmission of pathogens, similar to the model suggested by Pruss *et al.* (2002). This model presents six exposure scenarios due to the lack of sanitary facilities in a degree of exposure, in which the first scenario there is no transmission of pathogens due to unsafe sanitation, water and hygiene and in the last one, there is no availability at all of sanitation facilities. The intermediate levels present combinations between the presence and absence of these facilities. In this way, a gradation of fecal–oral pathogen transmission is presented, where the first scenario has low probability of transmission and the following scenarios have a gradual increase of the exposure to this risk factor.

The RR data needed for the estimation of the PAF was extracted from the following databases: Latin American and Caribbean Health Sciences Literature, Virtual Health Library (BVS), and Medical Literature Analysis and Retrieval System Online (MedLine). The keywords used in the Boolean search were: sanitation, environmental sanitation, diarrhea, water quality, water supply, and environmental burden.

The selection of the publications was based on the following criteria: (1) diarrhea was an outcome evaluated by the study; (2) whether one of the following measures of association related to lack of sanitation facilities was presented: RR, odds ratio, prevalence ratio or PAF; (3) if the studies were representative specifically of the Brazilian population, based on the Brazilian population and on its territory. The selection of articles that focus on studying the Brazilian population warrants that the results obtained present more representatives and applicability, since they approximate them to the Brazilian sanitation reality.

After the determination of the PAF with the extracted data, this result was multiplied by the number of DALYs related to diarrhea in the population younger than five years of age, obtained through the GBD study, carried out in Brazil in 1998 (Gadelha *et al.* 2002). In this way, the final estimation of the environmental burden of diarrhea attributable to sanitation problems was obtained solely with Brazilian data.

RESULTS

The first search for articles resulted in the identification of 3,563 publications. This high number is due to the generality of some key words, such as sanitation and water, which make the restriction of the search to a smaller number of publications difficult. However, using the exclusionary criterion of location, three articles were found that presented RR and RP data associated with diarrhea in Brazilian populations. The RR data utilized in this study were obtained from Genser *et al.* (2008). The authors evaluated the effects of sanitation improvements on the prevalence of diarrhea in children between the ages of 0 and 36 months in the city of Salvador, Bahia, between 1997 and 1998. They investigated determinants of prevalence of diarrhea in two cohort studies conducted before and after the intervention (a large sanitation program, initiated in 1997, which implemented increasing the proportion of the population with an adequate sewer connection from 26 to 80%; details of the intervention are given elsewhere). Each study enrolled preschool children followed up for 8 months. For both cohorts, the following was calculated: relative, attributable, and mediated risks of diarrhea determinants. We utilized the RR before intervention, when the exposition to unsafe sanitation was studied.

In Genser *et al.*'s 2008 study, prevalence rates were estimated for four environmental variables: (1) sewage system coverage; (2) presence/absence of open-air sewage; (3) public water supply system coverage; and (4) presence, or lack of paved roads.

From the environmental variables used by Genser *et al.* (2008) the scenarios elaborated by Pruss *et al.* (2002) were reproduced, according to the transmission level of the pathogens. The reference variables were the coverage of the public sewage systems and public water supply. Four Brazilian scenarios were elaborated based on these exposure variables and the RRs were determined according to the estimations presented by Genser *et al.* (2008), as shown in Table 1. In order to define the RRs for the estimation of the environmental burden of diarrhea, the prevalence rates found by Genser *et al.* (2008) were used for each scenario. In this study, we took the ratio of prevalence rates as RRs, since prevalence is the product of incidence and duration, so in this case in which prevalence was obtained by punctual surveys, prevalence is equivalent to incidence.

The PAF was calculated for the age group of children under five for both sexes, for each scenario, and for each

Table 1 | Exposure criteria elaborated based on the estimation of environmental burden of diarrhea in children under five years old in Brazil and their respective RR according to Genser *et al.* (2008)

Scenarios	RR source	RR
Scenario I – Access to sewage systems and no access to water supply	The RR due to the absence of water supply presented by Genser *et al.* (2008)	1.75
Scenario II – Access to water supply and no access to sewage systems	The RR due to the absence of sewage systems presented by Genser *et al.* (2008)	1.09
Scenario III – No access to water supply and no access to sewage systems	The RR was calculated using the absolute data presented by Genser *et al.* (2008) for each exposure category and the parameter used was the estimated absence of water supply and sewage systems[a]	1.7
Scenario IV – Access to water supply and access to sewage systems	No health risk. Used as a reference for the other scenarios	1

[a]Source: National Households Sample Study of 2008 (IBGE 2010).

Brazilian region, based on the prevalence of these scenarios, as presented in Figure 2.

As can be seen in Figure 2, the number of people living in scenario I is negligible, meaning, there is no exposure to a scenario in which there is access to sewage systems but not to water. Yet, when looking at scenarios II and III, the north region shows the higher value of exposure to unsafe SWH, with a prevalence of 45.6% for scenario II and 54.4% for scenario III. The next highest exposure prevalence was identified in the northeast region, followed by the central-west and south, with lowest prevalence in the southeast region.

The PAF was estimated for scenarios I, II, and III based on prevalence and RR data (Figure 3).

Finally, the PAF was then multiplied by the total DALYs of diarrhea in children under five. The data regarding the total DALYs to Brazil and macro-regions related to diarrhea and intestinal infections were obtained by the Brazilian GBD study that used the reference year of 1998 (Gadelha *et al.* 2002).

Table 2 presents the DALY rates for diarrhea per 1,000 inhabitants related to diarrhea and intestinal infections in children under five years of age for both sexes in Brazil and macro-regions.

It can be observed that the northeast region is responsible for the largest part of the environmental burden of diarrhea attributable to unsafe SWH, followed by the north region. In relation to the selected exposure scenarios, the simultaneous lack of access to water supply and sewage systems produces the largest portion of burden attributable to sanitation problems. Even though it is the predominating scenario in Brazil, access to water supply with no access to sewage is not the scenario that represents the largest burden of disease. These results are consistent with the pathogens transmission model presented by Pruss *et al.* (2002), which

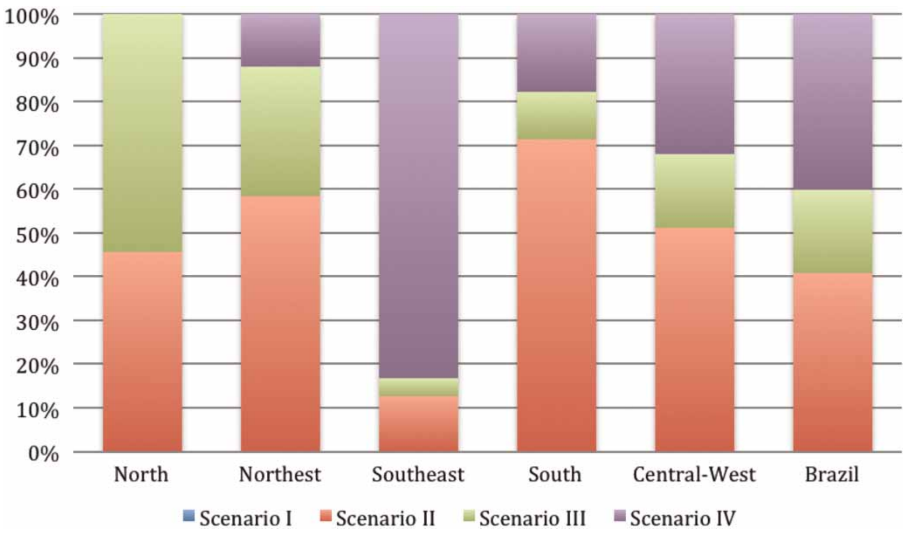

Figure 2 | Estimation of the exposure prevalence of the Brazilian population under five years of age exposed to unsafe SWH, according to macro-regions.

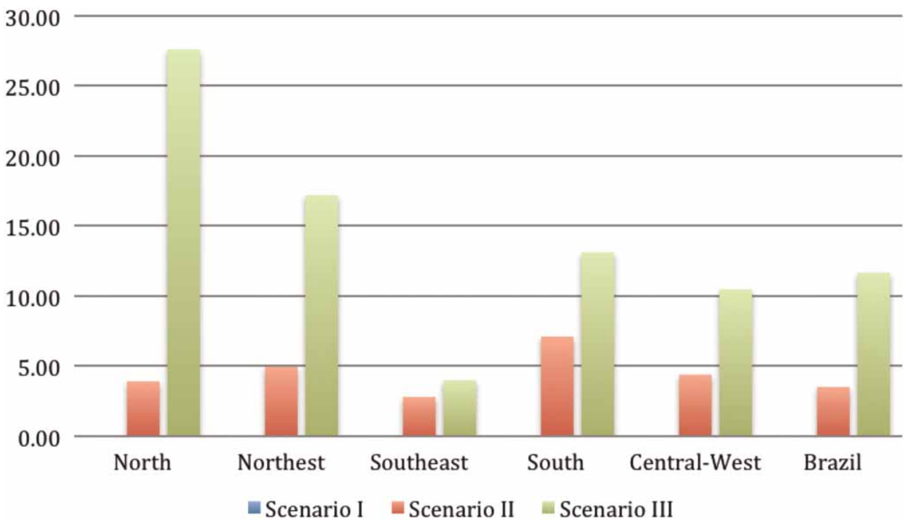

Figure 3 | PAF (%) for unsafe SWH for scenarios I, II, and III for Brazil and macro-regions in 2000.

Table 2 | Environmental burden of diarrhea attributable to inadequate sanitation for Brazil and macro-regions (DALY/1,000 inhabitants)

Scenarios	North	Northeast	Southeast	South	Central-west	Brazil
Access to water supply and no access to sewage systems	1.9	16.4	0.5	1.2	0.6	16.1
No access to water supply and no access to sewage systems	13.5	56.5	1.3	1.4	1.4	53.3
Total	15.4	72.9	1.9	2.5	1.9	69.4

indicates that the exposure to this risk factor – and, consequently to the transmission of pathogens – is increased when the sanitation facilities, sewage systems, and water supply, are lacking.

DISCUSSION

Among the methodological assumptions made in order to structure and circumscribe the scope of this study, we highlighted the choices of only one illness for estimating the environmental burden of diarrhea and one age range in the study model.

These choices represent only a part of the sicknesses associated with inadequate sanitation, and may underestimate the impact of the lack of sanitation facilities more broadly.

Some methodological aspects of environmental burden of diarrhea attributable to this risk factor deserve specific considerations. The estimation of exposure prevalence to the different scenarios of access to sanitation provided a basis for estimating the attributable environmental burden of diarrhea. This estimation, based on census data of water and sewage coverage, showed that the majority of the Brazilian population has access to public water supply, but little access to public sewage systems. This situation is revealed by the absence of the population exposed to scenario I, where there is access to public sewage systems but there is no access to public water supply.

According to the last Brazilian census (IBGE 2011), in 2010, 55% of the Brazilian municipalities had access to a sewage system. Nevertheless, when observing the number of municipalities that had access to a treated sewage system, this number goes down to only 29% of the population. The disparity between regions also remains the same: in 2010, 95% of the southeast region already had access to a sewage system, but only 48% had access to sewage treatment, while in the north region these numbers were 13.3% and 8%, respectively. Thus, the estimation that considers only the access dimension to the sewage system tends to underestimate the exposure impact to sewage without treatment in the transmission of diseases. Accordingly, although positive changes have been made in the access to sanitation structures in the last decades, resulting overall in a larger coverage (Figure 3, IBGE 2000, 2011) there is still an important fraction of the diarrhea burden that can be attributable to the inadequate sanitation in Brazil's rural areas, mainly in the northern (Amazon) and northeast regions. This study has shown that the exposure scenarios to risk situations in Brazil have a strong regional gradient. Besides the social and climatic differences between regions, the coverage of these services is strongly associated with the level of urbanization. In the urban areas of south and central regions, water contamination and water shortage can be important factors in the determination of the diarrhea burden, mainly during emergencies, extreme climate events, and disasters.

Nevertheless, children also have diarrhea for other causes. This happens because diarrhea presents several exposure pathways and the intervention in one of these pathways by means of sanitation procedures does not guarantee the elimination of disease (Briscoe 1984). In fact, diarrhea incidence, measured by the mean number of episodes per individual per year, may be equally high in continents such as Africa, Americas and Europe, but with different impacts on health conditions due to the severity of episodes, which is influenced by the nutritional status, access to health services, and household conditions (Fischer *et al.* 2012), which affect more intensively the burden of disease than the mere incidence.

Not surprisingly, scenario III, characterized by the absence of both sanitation facilities (water supply and sewage systems) corresponded to the largest attributable burden on the health of the Brazilian population. As the most resource-deprived scenario, it implies a greater health risk, according to the pathogen transmission fecal–oral model. The predominance of scenario III in the exposure prevalence in the north and northeast regions correlated positively with limited coverage of sewage systems found in the Atlas of Sanitation of Brazil (IBGE 2011). The Atlas shows that only 13% of the municipalities in the north region and 45% of the northeast region have access to the public sewage system. This positive correlation found between scenario III and the limited coverage found in the Atlas of Sanitation of Brazil suggests that the greatest lack of sanitation infrastructure increases the risk of diarrhea in comparison to other regions, as shown in Figure 2. Due to its seriousness, scenario III should be the priority in public policy actions.

It is important to point out that the calculation of the environmental burden of diarrhea encompasses a fundamental underestimation, since national morbidity data for this condition are lacking. In our study, the total number of DALYs due to diarrhea based on national data is mainly composed of mortality from diarrhea (86%), in comparison to only 14% of morbidity. The lack of diarrhea morbidity data comes from low registration associated with that condition, and absence of population studies. Indeed, this lack of morbidity data is an obvious obstacle to better understand and create a knowledge basis for the control of this illness. Furthermore, in considering the Brazilian epidemiological transition, the reference to the morbidity of diarrhea should be a fundamental component for improving the understanding of Brazilian infant health.

Due to the low number of population studies found about RR associated with diarrheal conditions in each Brazilian macro-region, it was necessary to extrapolate the RR data obtained from one region to other regions and then to the country as a whole. For this reason, it was not possible to estimate the environmental burden of diarrhea with data from all the regions. The RR used in the PAF estimation was mainly obtained from one selected study of the Brazilian population (Genser *et al.* 2008). The absence of Brazilian population health longitudinal studies in all its regions suggests the urgent need to strongly incentivize the pursuit of population studies that consider the epidemiology of diarrhea in different regions in the country, as well as in rural and urban areas and in different situations of water supply and sewage system coverage. Another limitation of our study is in reference to the age range studies. While the environmental burden of diarrhea was estimated for children under five, data from Genser *et al.* (2008) used only children under the age of three.

Nevertheless, given that the estimation of the GBD has been used for the comparison of health conditions in different countries and regions, also the estimation of the environmental burden of diarrhea in Brazil can be utilized to compare the results obtained in similar calculations in other countries. In the systematic review carried out in our study, three other studies on GBD attributable to unsafe sanitation were found, with similar characteristics to our study in Brazil and with the same methodological orientation indicated by Pruss *et al.* (2002). The locations where these studies of GBD estimation were carried out were Cuba (Romero *et al.* 2010), South Africa (Lewin *et al.* 2007), and Europe (Valent *et al.* 2004). Yet, even if their methodological orientations were similar, some distinct aspects between these studies and the Brazilian study partly compromise the ability to compare the results. One important distinction is that the definition of exposure scenarios proposed in this study, as well as the RR data extracted from a Brazilian publication (Genser *et al.* 2008), produced results according to the specific comparison of Brazilian scenarios. This methodological step did not happen in other studies in the world that used the scenarios proposed by Pruss *et al.* (2002). They used RR data from the systematic review carried out by Pruss *et al.* (2002) as well, for the estimations of the GBD attributable to unsafe WASH. Pruss *et al.* considered primarily studies carried out in eight countries with sanitation conditions more precarious than in Brazil. These countries were: Burundi, Ghana, Togo, Uganda, Sri Lanka, Morocco, Bolivia, and Guatemala (Esrey *et al.* 1991). Accordingly, the figures obtained by Pruss *et al.* (2002) in relation to RR were understandably higher than those obtained in Brazil.

The difference of RR estimation is mainly due to the sanitary conditions between the countries studied by Esrey *et al.* (1991), and utilized by Pruss *et al.* (2002), and the differential sanitation conditions in Brazil. Although this comparison has limitations with virtue to the uncertainties aggregated to each study, we illustrated the distinct RR results when sewage structures are compared with different levels of unsafe sanitation. According to WHO's diagnostic (2000) regarding the world sanitation coverage, Togo presented, in 2000, only 34% of its population with access to sewage system, while Brazil had a coverage of 77%. The relevant difference between exposures to the risk factor in analysis both in Togo and Brazil is translated in different RRs. Such is the goal of this comparison between the RR used by Pruss *et al.* (2002) and the RR used in this study.

Comparatively, the worst scenario, the absence of public sewage systems and public water supply, resulted in an RR of 11 in the calculation adopted by Pruss *et al.* (2002), and in the estimation of EBD attributable to diarrhea in Brazil, the RR was equal to 1.7, using the results obtained by Genser *et al.* (2008), which accompanied the incidence of diarrhea in children under 36 months old living in the city of Salvador, Bahia.

Other differences found between the Brazilian study of the attributable GBD and the studies carried out in other regions of the world are: (1) the health outcomes considered in the studies and (2) the age ranges of the studies (Table 3).

The differences found between the studies that estimated the GBD attributable to unsafe sanitation make accurate comparisons between studies undeniably difficult. In order to minimize this problem, the refinement of the methodology utilized between different countries would be important so that a more reliable international comparison might be made.

The estimation of the environmental burden of diarrhea attributable to various exposure scenarios of the risk factor of unsafe WASH, allows not only for a more precise evaluation of the situation of Brazilian childhood health, but can be used for the achievement of the targets proposed for the world by the United Nations through the MDG.

Table 3 | Summary of the differences between studies of EBD attributable to unsafe sanitation, water and hygiene

	Brazil	**Europe**	**Cuba**	**South Africa**
Age range	0–5	0–14	All	All
Disease/condition	Diarrhea	Diarrhea	Diarrhea	Diarrhea, intestinal parasites and schistosomiasis
RR	RR = 1.7/National Study (Genser *et al.* 2008)	RR = 11/International Study (Pruss *et al.* 2002)	RR = 11/International Study (Pruss *et al.* 2002)	RR = 11/International Study (Pruss *et al.* 2002)

The MDG's Goal VII is related to sustainable development and indicates the need to implement basic sanitation facilities for signatory countries. According to the Brazilian Institute of Statistics and Geography (IBGE 2011) there has been an increase in the sanitation coverage in Brazil (Figure 2), but – as we already discussed – it has not occurred in a homogeneous way. There has been a concentration of sewage systems in urban areas, to the detriment of less populated areas of the country where there is more exposure to this risk factor. In alignment with IBGE's data, the main difference in the results for the attributable burden of diarrhea in our study is due to the difference in sanitation infrastructure available. There is less structure in rural regions in comparison with the urban areas of the country, resulting in different exposures to sanitation problems for both populations. Another data point that strengthens this hypothesis is found in the monitoring of the MDG Report conducted by the Institute for Applied Economic Research (IPEA 2010), which confirms that the IMR in Brazil varies in relation to the state of urbanization.

In making these considerations, it can be then appreciated that the north and northeast regions present distinct vulnerabilities in comparison to the rest of the country in regards to the incidence and severity of diarrhea. Even though the IMR due to diarrhea has decreased in the last few years, there is a proportion of the Brazilian population, mainly rural, that still does not have access to basic sanitation facilities, and therefore is highly exposed to this risk factor. In addition, Victora (2009) points out that, despite the importance of vertical health actions, such as the distribution of oral rehydration and other measures to reduce the lethality of the disease, they do not alter diarrhea incidence. Rather, only the integration of such vertical health actions with horizontal ones, implemented by the public health system and other government sectors, can reach the goal of reducing mortality by diarrhea.

Further considering the need for the integration of public health actions and a national research agenda, Morel (2004) suggests that the agenda of the MDG should combine together with the need of developing a national research system aligned with Brazilian sanitation priorities, ultimately aiming at generating integrated social development, economic, and health policies. There are certainly ethical justifications for such integration as well. While considering the ethical dimension of such integration with the use of GBD methodology, Garbayo *et al.* (2011) suggested that the GBD metrics, when interpreted within the context of the right to health in the Brazilian Constitution of 1988, is ultimately constrained by egalitarian principles for driving public policy. Alignment of research and policy, as suggested by Morel, would thus depend on the proper consideration of distributive justice concerns in the Brazilian context, while evaluating equality of opportunities in health (Garbayo 2011). Thus, the debate over egalitarian dilemmas in the Brazilian health system, regarding prioritization of investment in public health policy-making and research priorities on the health of more vulnerable populations – such as children under five, who do not have access to safe sanitation, water and hygiene – also belongs to the ethical consideration of an ethics (and metrics) of research capable of supporting researchers to identify and make visible health and environmental disparities and further, provide data for the consideration of health equity and inequalities in the Brazilian context (Garbayo 2011, forthcoming).

CONCLUSIONS

Brazil lost 69,443 years of life in 1998 due to premature death or incapacity associated with diarrhea in children under five years of age. According to the obtained results, 15.2% of diarrhea in Brazil in this age range can be attributed to inadequate sanitation conditions. The regions with large DALYs estimates associated with the absence of sanitation facilities are mostly the north (31.5%) and northeast (22.2%), followed by the central-west (14.9%), south (13.1%), and southeast (4%). Scenario III, which indicates the lack of sewage systems and water supply, presents greater attributable DALYs in all of the regions.

The burden of disease metrics, with an EBD extension, is one more measurement tool to summarize population health in the context of the MDG (Morel 2004; Garbayo *et al.* 2011). The environmental risk factor sanitation is in accordance to indicator 13 of child mortality under five, according to Target 4, and in accordance to indicator 30, Target 11, Goal 7, regarding the improvement of sanitation for slum dwellers. The EBD measure assists in the generation, test, and validation of the sanitation information and public health interventions that should be considered in the context of the MDG.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Maria de Fatima Siliansky de Andreazzi and Dr. Joaquim Valente for their invaluable contributions. The first author also would like to thank the Brazilian National Council of Research (CNPq) and the Climate and Health Observatory (Observatório Clima e Saúde) for financial support; and the National School of Public Health/Fiocruz, and the University of Texas at El Paso for continued research support. Intellectual contribution by author: TS, CB, LG, AO, and JS designed the study; TS, CB, AO, and JS collected data. TS estimated the EBD attributable to unsafe sanitation, with support and/or revision from CB, LG, AO, and JS. TS, CB, and LG analyzed and interpreted data, discussed results, and wrote the manuscript.

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First received 15 October 2013; accepted in revised form 4 April 2014. Available online 9 May 2014