

Review Paper

Undernutrition's blind spot: a review of fecally transmitted infections in India

Robert Chambers and Gregor von Medeazza

ABSTRACT

With relevance to India and more widely, this review article examines links between fecally transmitted infections (FTIs) and undernutrition, presents a new framework for understanding the relative nutritional significance of FTIs, and draws practical implications for professionalisation, professionals and research. In India, despite many efforts and programmes to get more and better food into children, stunting has been obstinately resistant, India remaining with about one-third of the undernourished children in the world. Recent research has found strong correlations between open defecation and stunting. This paper reviews published and emerging evidence to explore these correlations through a focus on FTIs. The nutritional significance of FTIs, and so of water, sanitation and hygiene, has been a professional 'blind spot'. Among FTIs, the visibility, measurability, relative manageability, and lethal potential of diarrhoeas have diverted attention from more continuous and often subclinical conditions of many other FTIs including environmental enteropathy, other intestinal infections, and parasites. Diarrhoeas are only the visible tip of the FTI iceberg. Access to sanitation in India is sharply skewed against the poor. India's proportion of the world's open defecation has risen to 60%. Safe sanitation and hygienic behaviour have become more vital than ever for reducing stunting more effectively.

Key words | fecally transmitted infections, India, open defecation, sanitation, stunting, undernutrition

Robert Chambers (corresponding author)

Gregor von Medeazza
Institute of Development Studies,
University of Sussex,
Brighton,
BN1 9RE,
UK
and
UNICEF Guinea-Bissau,
United Nations Building – PO Box 464,
1034 Bissau-Codex,
Guinea-Bissau
E-mail: r.chambers@ids.ac.uk

UNDERNUTRITION IN INDIA: THE SCALE AND PERSISTENCE OF STUNTING

The unacceptable effects of undernutrition in India – including suffering and diminished quality of life, inhibited physical growth, impaired immune response, impeded cognitive development, lower school attendance and performance, constrained livelihoods and earning power, and losses to the wider economy – are so many and so multiple that they are easy to underestimate (see section 'Economic losses from fecally transmitted infections [FTIs]' below). Such avoidable human suffering is intolerable. The former Prime Minister Manmohan Singh's 2008 remark has been fittingly much quoted, that undernutrition is 'a curse that we must remove' (from Prime Minister Manmohan Singh's 2008 address to the nation on the occasion of

the 62nd Independence Day: www.hindustantimes.com/India-news/NewDelhi/Malnutrition-a-curse-that-must-be-removed/Article1-331313.aspx, retrieved 17 March 2013).

In the 1990s, 52% of children in India were stunted ('stunting' refers to the reduced growth rate in human development [low height for age], and is an indicator of chronic undernutrition), compared with 40% in sub-Saharan Africa, 34% in China and 18% in Sri Lanka (UNICEF 2013). As per the latest reliable available National level estimates for India, in 2005–2006 48% of children under five years of age were stunted and 43% were underweight (NFHS-3 2007). The proportion of children who were severely undernourished was also high, with 24% according to height-for-age

and 16% according to weight-for-age. Wasting is also serious and affected 20% of children under five years of age (NFHS-3 2007) ('wasted' refers to the process by which a debilitating disease causes muscle and fat tissue to 'waste' away (weight for height), and is regarded as acute undernutrition). Recent data for 100 districts in nine states selected from the bottom of a child development index, and so likely to be worst cases, found that 59% of children under five in those states were stunted, and of these about half were severely stunted (Naandi Foundation 2012).

The persistence of wasting and stunting despite feeding programmes and other interventions has been widely regarded as a 'puzzle' (Deaton & Dreze 2009). Part of the puzzle has been 'the Asian enigma', that children in India are shorter on average than children in Africa who are poorer on average (Ramalingaswami *et al.* 1996). Research by Spears (2012a), based on 140 Demographic and Health Surveys (DHS), has found that open defecation accounts for much of the excess stunting in India. Children in better off households living in areas with open defecation are also affected even when they have access to sanitation.

Yet sanitation and hygiene have been a blind spot for many professionals concerned with child undernutrition. This parallels the pervasive shift in psychology from the pre-occupation of Freud and early psychoanalysts with the anal to the current striking focus, almost tunnel vision if the metaphor can be permitted, on the oral. According to Haslam in 'Psychology in the Bathroom' (2012) there are numerous journals dedicated to the study of eating and drinking and thousands of articles and many journals that explore the symptoms, causes and treatments of eating disorders such as anorexia nervosa and bulimia nervosa, but no psychological scientific journals devoted to the elimination of food and its disorders. Similarly, recent journal articles and books concerned with hunger and nutrition repeatedly focus on quantity and quality of food, feeding programmes, micronutrients and issues of governance, rights and justice, often to the total or near-total neglect of sanitation, hygiene and FTIs, or only a passing reference (e.g. Paul *et al.* 2011). In this nutrition literature the relationships between sanitation, hygiene and FTIs have only recently begun to be brought to notice in a sustained way (see reviews in Humphrey 2009; Bartram & Cairncross 2010; Spears 2012a, 2012b; Spears *et al.* 2013; Dangour *et al.*

2013; Chambers & von Medeazza 2013; Loevinsohn *et al.* 2014 and Prüss-Üstün *et al.* 2014). For many nutritionists, though, the strong links of FTIs with stunting are still a blind spot: the mouth remains visible and attractive, and the anus hidden, as in daily life.

Against this background, we have three purposes in this review article: to examine how open defecation, lack of sanitation and hygiene, and FTIs contribute to stunting; to shed light on why this has been a blind spot; and to point to practical implications for professionalism, professionals and research.

METHODOLOGY USED FOR THE REVIEW

Much of the evidence for this article comes from what the body of literature examined covers and concludes, and what it does not cover.

A literature review was carried out to identify relevant evidence related to the impact of water, sanitation and hygiene (WASH) interventions on reducing diarrhoeal diseases and other FTIs and through them on reducing undernutrition. We use the term FTIs to avoid the reductionist exclusions of 'fecal-oral', which overlook parasite pathways through the skin (as with hookworm and schistosomiasis).

FTIs include but are not limited to the diarrhoeas (such as cholera, shigellosis, rotavirus, cryptosporidiosis, and campylobacter), intestinal parasites (such as giardia, amoebiasis, ascariis, hookworm, trichuris and tapeworms), environmental enteropathy (EE) and other conditions such as Hepatitis A, B and E, typhoid fever, liverfluke, poliomyelitis and other enteroviruses, neurocysticercosis, schistosomiasis, trachoma, and other zoonoses. More details and references on the FTIs are given below.

Between June 2012 and May 2014, a key-word search was carried out of English-language published studies in the past 10 years in international peer reviewed journals and United Nations publications. Some earlier work was included where it could shed historical light on the 'blind spot'. Around 250 papers and sources were reviewed. About a third of these are referred to in this article. The authors also hand searched reference lists of key articles for additional relevant material. Internal UNICEF literature reviews offering an overview of the topics related to WASH

and Nutrition were also consulted. For broader coverage, the search was extended to other resources, including grey literature and conference proceedings.

Publications and websites were consulted and/or colleagues contacted from the following organizations (in alphabetic order): Centers for Disease Control, Children Without Worms, DFID, Food and Agriculture Organization (FAO), IRC International Water and Sanitation Centre, Institute for Development Studies (University of Sussex, UK), International Centre for Diarrhoeal Disease Research, London School of Hygiene and Tropical Medicine, Public-Private Partnership for Handwashing with Soap, Stockholm International Water Institute, UNICEF, USAID, Water Aid, WEDEC (Loughborough University, UK), World Bank, World Bank Water and Sanitation Programme (WSP), WHO. We contacted subject experts and study authors, who provided additional information and further relevant references.

Throughout we looked for gaps and inconsistencies in the reviewed body of knowledge. In the light of recent research, we focused particularly on the 'blind spot' of links between open defecation and undernutrition. Recent research and the literature review also informed our development of the conceptual framework of the 5As, presented towards the end of this paper, to contribute to cross-disciplinary recognition of the significance of FTIs and the identification of gaps for research.

THE BLIND SPOT OF FECALLY TRANSMITTED INFECTIONS

The diarrhoeas: significance and fixation

Among FTIs the most attention has been given to the diarrhoeas. Nothing should detract from their seriousness. How diarrhoeal FTIs cause undernutrition is well known. Diarrhoeal episodes adversely affect the nutritional status of children: nutrients are evacuated; less is eaten during illness; and, as outlined above, absorption of nutrients is reduced (Ejemot *et al.* 2008) and energy diverted to producing antibodies to fight off pathogens. Each diarrhoeal episode reduces resistance to infections and impairs growth and development when repeated and prolonged

(Ejemot *et al.* 2008). In India, diarrhoeas are one of the major causes of deaths, causing the deaths of 212,000 children younger than five years in 2010, accounting directly for 12.6% of child deaths, significantly more than the worldwide average of 9.9% (Liu *et al.* 2012).

However, the relative significance of diarrhoeas needs to be qualified. The dramatic clinical manifestations of the diarrhoeas, their visibility, the ease with which they can be recorded and the fact that they can kill, have led to their receiving attention to the relative neglect of the other FTIs, many of which are to varying degrees subclinical and asymptomatic but continuously debilitating. Also, the rigour of much medical research demands measurement and statistics, to which diarrhoeas lend themselves, whereas subclinical FTIs are less visible, and are harder, more time-consuming and more expensive to measure. However, diarrhoea as morbidity reported through recall, though relatively straightforward to obtain, has been shown to be systematically unreliable (for India, see Das *et al.* 2012). Moreover, using diarrhoea as an indicator for health outcomes of sanitation does not take account of the causality of FTIs as a whole.

Innumerable examples could be cited of the focus on diarrhoeas to the neglect of other FTIs. Four can serve to illustrate. First, in its section on health and nutrition, the *Handbook of Development Economics* (Schultz & Strauss 2008) lists diarrhoeas twice and intestinal helminths once, but none of the other FTIs. Second, the 2008 *Lancet* Maternal and Child Undernutrition Series was modelled entirely through diarrhoea. Third, Jean Humphrey in her seminal *Lancet* article on tropical EE (Humphrey 2009), constrained no doubt by data availability, compared EE only with the diarrhoeas and not with other FTIs. Fourth, what is measurable and measured – the diarrhoeas – lends itself not only to research, analysis and funding, but also to institution building. There is a world-renowned International Centre for Diarrhoeal Disease Research (Bangladesh) (ICDDR(B)). There is no International Centre for FTI Research. It must be pointed out, however, that the ICDDR(B) conducts much research beyond the diarrhoeas.

The scale and significance of other FTIs

Infections with other continuously debilitating FTIs are widespread in India. WHO estimates, for instance, that in 2011

around 240 million children in India (of which 69 million were pre-school age and 171 million school age children) needed chemotherapy treatment for Soil-Transmitted Helminths (retrieved 21 December 2012 from http://www.who.int/neglected_diseases/preventive_chemotherapy/sth/en/index.html). Cairncross (1998) reported that ascaris could 'steal' as much as one-third of the nutritional intake a child receives through feeding (the amount stolen varies – ascaris infections tend to be heaviest in a few individuals (pers. comm. S. Cairncross 2012). The figure of one third is at the high end of the scale, not an average); hookworms are a major cause of anaemia; and trichuris results in chronic colitis in infants and stunting in children, with their effect on children so dramatic and long-lasting that mothers tend to consider the related diarrhoea a 'normal' condition (Cairncross 1998). While de-worming strategies result in significant improvements of children's nutritional status (Hall *et al.* 2008), de-worming needs to be repeated at least yearly, since reinfection rates are high after treatment (Norhayati *et al.* 1997). There are also dangers of a build-up of resistance.

The most nutritionally significant FTI is probably EE (earlier known as tropical enteropathy). Though recognised earlier as 'tropical sprue' (Lindenbaum 1973) and intermittently reviewed (e.g. Fagundes-Neto *et al.* 1994), it has only come into prominence recently following the article in the *Lancet* by Humphrey (2009). EE is a subclinical condition linked with the ingestion of fecal bacteria. These damage the wall of the small intestine: villi are atrophied and their area reduced so that they can absorb less nutrients. This damage also results in gut hyperpermeability, evoking energy and protein consuming immune response to fight the infections. Studies of Gambian infants living in dirty conditions have found them to enter 'a near-continuous state of growth-suppressing immune response: dietary nutrients [are] repartitioned away [...] in favour of glucose oxidation and synthesis of acute-phase proteins and other immune mediators' (Humphrey 2009). EE is a continuous largely subclinical condition inhibiting growth. Lunn *et al.* (1991) found that an indicator of gut permeability (the lactulose to mannitol urinary excretion ratio which is associated with EE) explained 43% of growth in height. Recent studies have confirmed the association of inflammation and gut permeability with stunting. Kosek *et al.* (2013), after controlling for diarrhoeal disease, found a relationship between intestinal

inflammation and lineal growth failure. Lin *et al.* (2013) found fecal contamination associated with EE and growth faltering in rural Bangladesh, with a stunting prevalence 22% lower among children living in clean households and height gains largest with joint improvements in WASH. They concluded that their results were consistent with the hypothesis that environmental contamination causes growth faltering mediated through EE. Findings from a study in Zimbabwe suggest that an extensive enteropathy occurs during infancy and that stunting is characterised by chronic inflammation (Prendergast *et al.* 2014).

When all the FTIs are taken together, the diversity, extent and probable debilitating impact of non-diarrhoeal FTIs on nutritional status is striking. Yet it does not seem common practice to list or consider these FTIs together. EE, along with worm infestation and other subclinical FTIs reduce nutrient absorption, aggravate undernutrition and stunting and cognitive deficits; WHO (2005), for instance, estimated an average Intelligence Quotient (IQ) loss per worm infection of 3.75 points, amounting to a total IQ loss of 633 million points for the world's low-income countries. Combinations of EE with worms, giardia and other continuous infections may have interactive as well as cumulative effects on a child, damping down and reducing activity, play and learning, as well as affecting more measurable indicators of growth, and these are in addition to, as well as interacting with, the diarrhoeas.

FTIs can be understood to interact and combine also with undernutrition in a negative syndrome. FTIs adversely impact nutritional status. Undernutrition in its turn brings susceptibility to respiratory diseases and other infections (Fewtrell *et al.* 2007). Infectious diseases are the main killers of children under the age of five years in conditions like rural India. While not the 'primary' cause of these deaths, undernutrition has been considered the 'underlying' cause of about half of them (Schlaudecker *et al.* 2011).

The accumulation of evidence suggests that the total combined impact of non-diarrhoeal FTIs on stunting is far more than that of the diarrhoeas. The non-diarrhoeal FTIs are likely to have greater adverse effects on children's nutritional status, and so on morbidity and mortality, than was earlier generally recognized. Jean Humphrey has described the diarrhoeas as only the visible tip of a much larger subclinical iceberg (pers. comm., November 2011). From the literature reviewed, child mortality rates and height for age

(stunting) seem thus preferable to the incidence of diarrhoeas as composite outcome indicators.

THE NUTRITIONAL IMPACT OF LACK OF SANITATION AND HYGIENE

Positive evidence has accumulated that sanitation and hygiene prevent and reduce stunting. Esrey (1996) showed from a sample size of around 17,000 children collected from three continents that improvements in sanitation resulted in height increases ranging from 0.8 to 1.9 cm, larger than those found in many nutritional interventions. Research on the effects of toilets constructed in India's national Total Sanitation Campaign (TSC) (Spears 2012b) has found reduced stunting (0.2 SD), comparable with the average impact of other health and nutritional programmes. Outcomes of various meta-analyses show that the single practice of handwashing with soap can reduce the incidence of diarrhoea in children under five by 37–48% (Curtis & Cairncross 2003; Fewtrell *et al.* 2005; Ejemot *et al.* 2008; 3IE 2009; CHERG 2010), and that sanitation reduces diarrhoea risk by 32–36% (Fewtrell *et al.* 2005; 3IE 2009; CHERG 2010). Similar reductions can be expected with some of the other less easily measurable FTIs.

An authoritative WHO publication (Prüss-Üstün & Corvalán 2006), concluded that 'overall, 50% (39–61%) of the health burden of malnutrition was [...] attributable to the environment, and in particular to poor WASH. Another WHO publication has stated that 100% of all the annual worldwide cases of ascaris, trichuris and hookworm infestation are attributable to inadequate sanitation and hygiene (Prüss-Üstün *et al.* 2004). Fewtrell *et al.* (2007) concluded that improved sanitation, along with other WASH components, was essential for sustainable reduction in intestinal nematode infections, to which may be added other FTIs. In sum, for improving nutritional status, effective WASH interventions are vital (see e.g. Bhutta *et al.* 2008).

OPEN DEFECTION AND STUNTING

Recent studies have shown an association of height with sanitation and stunting with its lack and with open defecation

(Fink *et al.* 2011; Spears 2012a, 2012b; Hammer & Spears 2013; Ghosh *et al.* 2014). There are clear correlations between the countries around the world with the highest numbers of open defecators, the highest numbers of under five deaths and the largest proportions of stunted children: out of the 20 countries with the most open defecators, 17 have stunting rates of 35% or higher (WHO & UNICEF 2012; UNICEF 2012) (compiled by UNICEF New York based on the cited reference; see also 'A Promise Renewed' webportal www.apromiserenewed.org/) Similarly, as shown in Figure 1, a suggestive correlation can be found in India between open defecation and stunting: States (each represented by a bubble of size proportional to the State's population) with high open defecation rates on average also feature a higher percentage of stunted children.

This association has been found also comparing the height of children of the same socio-economic status in West Bengal and Bangladesh: in Bangladesh with much less open defecation, those children are taller (Ghosh *et al.* 2014). Research by Spears (2012a) has shown that open defecation is even more harmful where population density is high, conditions in which children (and adults) are more likely to be exposed to infections from feces. Comparing countries' DHS data he has found that while open defecation can account for 54% of cross-country variation in child height, open defecation per square kilometre can linearly account for 65%. India's widespread open defecation and high population density thus constitute a double threat, and combine to

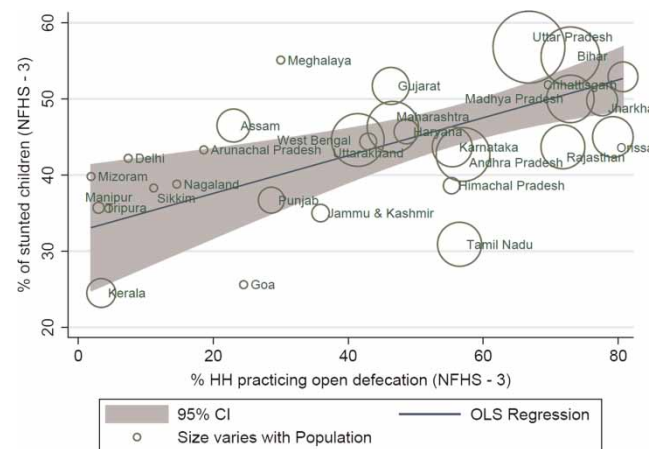


Figure 1 | The correlation in India between open defecation (% of households practising open defecation in a given State for both urban and rural) and stunting (below 2 SD). Data source: NFHS-3 (2007).

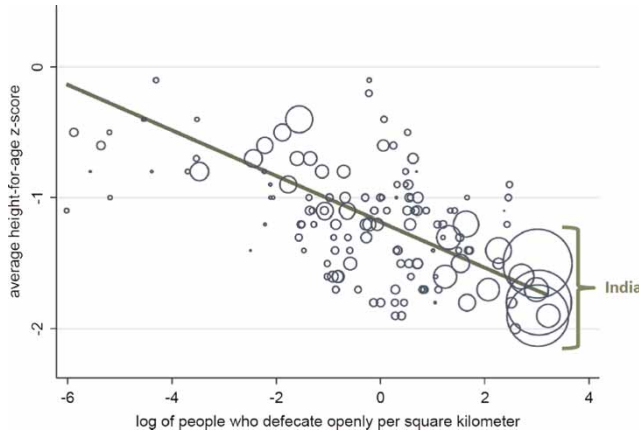


Figure 2 | Each circle represents a single DHS round, reflecting one country in one year. The visible linear trend shows that children are shorter, on average, in countries where they are exposed to more open defecation with higher population density. The circle sizes are proportional to population (Spears 2012a). It is difficult to conceive any more dramatic indication of the Indian crisis than the three large circles at the bottom right.

place its large population at the extreme end of the international distribution, as shown in Figure 2.

THE SYNDROME OF OPEN DEFECTION, POVERTY AND UNDERNUTRITION IN INDIA

In spite of the fact that 291 million people in India gained access to improved sanitation from 1990 to 2012, over 597 million still defecated in the open in 2012, according to the 2014 JMP update (WHO & UNICEF 2014). According to the 2001 and 2011 censuses, the total number of open defecators in India went down by 50.9 million in the intercensal

period, but the improvement in urban areas combined with the increased number of households masked the fact that the number of rural households without latrines actually ‘increased’ by 8.3 million (Hueso & Bell 2013) and average exposure to open defecation and so to FTIs increased (Spears 2014). India’s proportion of open defecators in the world has continued to rise: 51% of all the world’s open defecators were in India in 1990, 55% in 2000 and around 60% in 2012 (WHO & UNICEF 2014). The distribution of open defecation by wealth decile is sharply skewed in India, as shown for rural areas in Figure 3 below. The wealthiest 40% of Indians are 10 times more likely than the poorest 40% to use improved sanitation (Narayanan *et al.* 2011).

Despite the intended focus given by the national TSC during the period covered in Figure 3 to Below Poverty Line households, progress was negligible for the poorest in rural areas, while most gains were made by the better off. Urban open defecation is also overwhelmingly a phenomenon of the poorest.

The scale of undernutrition and open defecation relative to other countries is indicated in Figures 4 and 5, and their links with poverty in Figure 6.

India accounts for approximately one-third of the stunted children in the world, 60% of the open defecation in the world, and over one-third of those living on less than US \$1.25 a day. Figure 6 depicts some of the links existing between open defecation, poverty and undernutrition, which combine in to reinforce each other, some of which are as follows:

A1: Open defecation and lack of sanitation and hygiene cause and sustain poverty in many ways. The most obvious

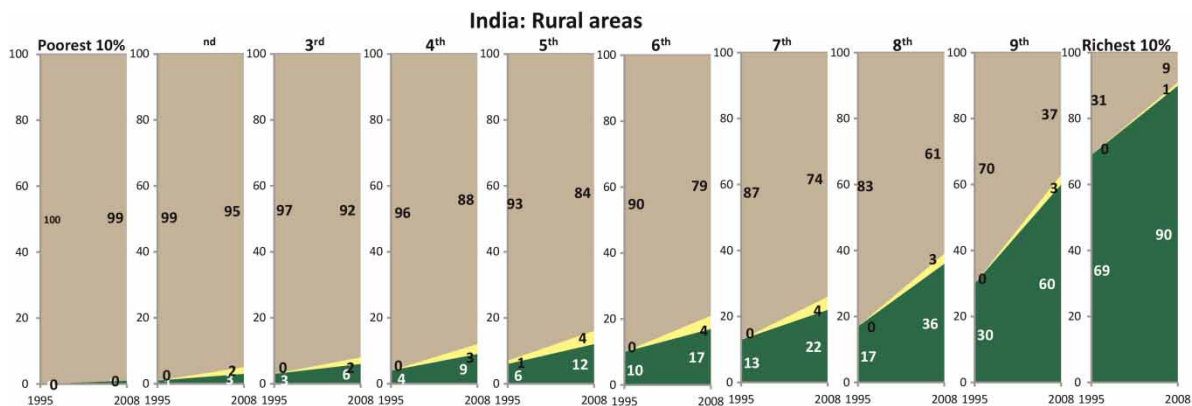


Figure 3 | Rural trends in sanitation by wealth decile in India. Sources: NFHS (1995, 2000, 2007), prepared by UNICEF Statistics and Monitoring Section, May 2010.

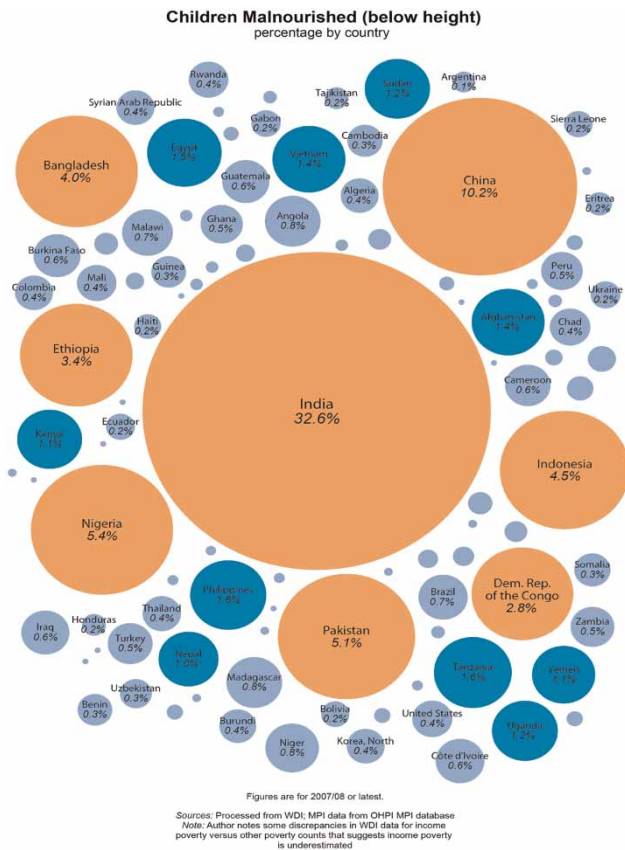


Figure 4 | Children stunted in India and other countries. Source: The Guardian| (UK newspaper, Tuesday 14 September 2010, posted by Jonathan Glennie www.guardian.co.uk/global-development/datablog/2010/sep/14/bottom-billion-poverty).

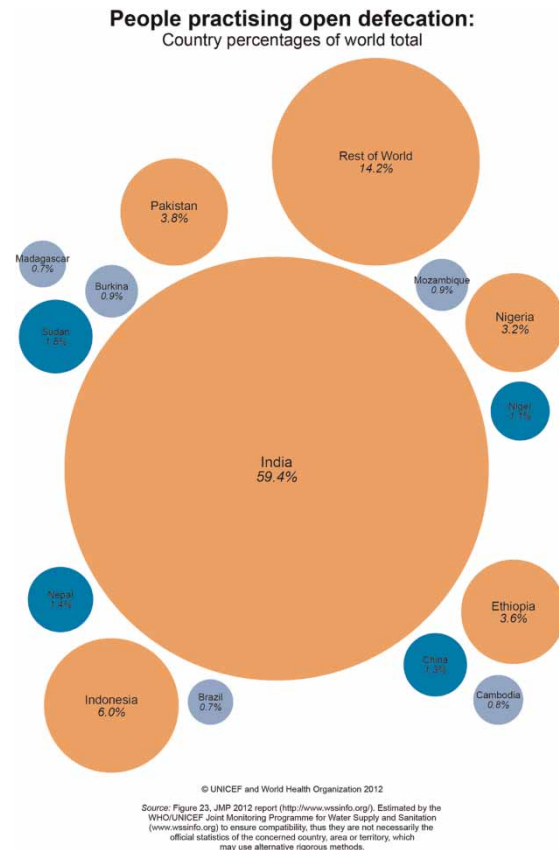


Figure 5 | People practising open defecation in India and other countries: Source: WHO & UNICEF (2012).

are through FTIs, their physically disabling effects reducing capacity to work and impoverishing through medical expenses (Krishna 2010). Other links include the many deprivations imposed on women having to defecate in darkness, constipation and others suffering from having to postpone urination and defecation, risks of assault, rape and abuse (EPW 2012), indignity, loss of time and sleep, and lack of privacy for menstrual hygiene.

A2: Poverty sustains open defecation and unhygienic behaviour in many ways. Only a small minority of rural people in the bottom income groups have access to sanitation (see Figure 3).

B1: How poverty leads directly to undernutrition is well recognized, including lack of food, whether grown or purchased, poor diets, lack of micronutrients, lack of energy for work, unhealthy environments, and lack of safe drinking water.

B2: The link from undernutrition to poverty is also strong. Childhood undernutrition reduces adult economic productivity (Black *et al.* 2008). Undernutrition and anaemia in pregnant mothers lead to low birthweight children (Balarajan *et al.* 2013), whose subsequent undernutrition not only results in underweight, wasting and stunting but also slows and limits cognitive development. Repeated episodes of diarrhoea during early childhood have proven adverse impacts on cognitive development, and diarrhoea has been shown to be the best single predictor test of nonverbal intelligence scores and even school performance at 6–12 years of age (Dillingham & Guerrant 2004).

C: The link between open defecation and undernutrition and stunting is the major theme of this paper.

Though these links are almost self-evident, their combined impacts as a syndrome may be easy to

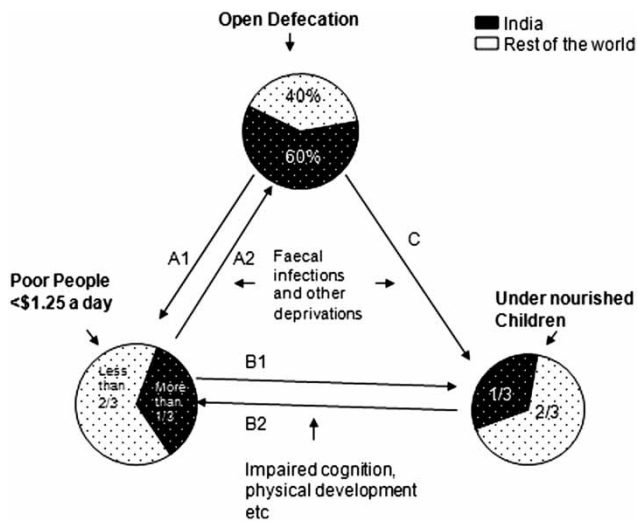


Figure 6 | Links between open defecation, poverty and undernutrition. Source: Original.

underestimate. Taken together each arrow has more force through the circularities of the syndrome than it would have on its own. FTIs stunt, not only directly but also through circular and indirect pathways.

ECONOMIC LOSSES FROM FTIS

The relative neglect of non-diarrhoeal FTIs affects assessments of the economic impact of sanitation and hygiene. In its Flagship Report ‘Economic Impacts of Inadequate Sanitation in India’ (WSP 2011) the WSP of the World Bank estimated that the total annual economic impact of inadequate sanitation in India in 2006 amounted to US \$48 per person or about 6.4% of the country’s GDP. As a proportion of GDP only Cambodia was higher, at 7.2%, while most African countries were in the much lower range of 1–2% (WSP 2011, 2012a, 2012b). Economic impact was calculated on the basis of impacts related to health, domestic water, access time, and tourism. The impact on poorer people was found to be disproportionate. The health costs took account of diarrhoeas and intestinal helminths.

However, six less visible and less measurable effects of lack of sanitation and hygiene were not taken into account. First are FTIs and related diseases, many of which may often be sub-clinical, like giardiasis, most liverfluke, some

hepatitis, tapeworms, some other zoonoses, and above all EE, which when added together and combined interactively can be expected to have much greater impact on undernutrition than the diarrhoeas. Menzies *et al.* (1999), for instance, found an association between lower GDP per capita and more severe EE. Second, the study states (WSP 2011: 83) that account was not taken of low birth weights, and the consequent poor prognoses for children. These low birth rates may often result from FTIs and the physical and social deprivation suffered by women from lack of sanitary facilities. Third, adult immune systems are weakened by child undernutrition and adults who were undernourished as children run the risk of having higher prevalence of diabetes, obesity and other non-infectious conditions (Adair *et al.* 2013). Fourth, lack of sanitation has costs in stress and inconvenience, and discriminates against women and their employment. Fifth, impaired cognitive development is associated with stunting (Dillingham & Guerrant 2004; Spears & Lamba 2013). Finally, attendance and retention, especially of adolescent girls starting menstruation (Pearson & McPhedran 2008) and performance at school are affected. According to Dillingham & Guerrant (2004), the best surrogate predictor of cognitive development and school performance is height-for-age Z score at two years old, the anthropometric measure that also best correlates with burdens of diarrhoea at 0–2 years old. Taken together, these factors which were not accounted for in the WSP (2011) calculation of GDP loss may well offset any inflation from a high diarrhoea figure used, and even mean that the 6.4% estimate GDP loss due to inadequate sanitation in India is an underestimate.

CAUSES OF UNDERNUTRITION AND STUNTING: THE FTIS AND THE 5 AS

The accumulation of evidence adduced above builds and supports the core argument and central message of this review, that poor sanitation, lack of hygiene, and open defecation, by spreading FTIs, are major causes of undernutrition in India, and that this link has been largely overlooked, neglected and a blind spot. Much previous analysis has been framed by professional specializations

and humanitarian concerns: epidemiologists have tended to narrow attention to single infections or conditions, and agriculturalists to food production, while nutritionists, economists, public administrators, political scientists and committed activists have concentrated on the immediate and common sense humanitarian imperative of enabling children and others to have more and better food. For a fuller understanding, we adopt a new starting point, beginning with pathways in and out of the human body. We do this by separating out 5 As of undernutrition, all of which are relevant. The first two concern getting enough good food into the body. The last three concern the infections which then come out, bearing with it the transmission of the less obvious FTIs.

The first two As: food in

The first two As concern getting food into the body.

1. Availability. This agricultural production and food stocks approach is common sense. There has to be enough food in the country and distributed throughout it. India has succeeded in avoiding major famines since 1943 (Devereux 2007), ensuring overall food availability. The focus of this typically FAO approach has been extended conceptually and practically to embrace food systems for better nutrition (FAO 2013). Food systems include availability of adequate quantity and quality (balanced diet, micronutrients, lack of contamination and pollution, etc.) of food at all times of the year.
2. Access. This great contribution of Amartya Sen (1981) is now well understood. People can die of famine when there is food available if they do not have 'entitlements', and cannot obtain it. Though full-blown famines in India have been eliminated, for the most vulnerable and disadvantaged groups, access to adequate food remains an acute problem often with a seasonal dimension. Access is thus a major concern of policy and practice. The standard diagnosis of undernutrition is that children are not getting enough food and not enough good food, and that they suffer from micronutrient deficiencies. National programmes seek to improve and increase food and its delivery, especially to the most vulnerable and deprived. This

is then the overwhelming focus of research, advocacy and action. A collection of papers in 2009 (Haddad & Zeitlyn 2009) called for improved governance, new initiatives, promoting the status of women, more resources, better monitoring of the Integrated Child Development Services (ICDS) and more and better data on nutritional status in the Indian context. Ration cards, the Public Distribution System, midday meal schemes in schools and pre-school feeding in Anganwadi centres, the ICDS, food subsidies, overcoming corruption connected with these, and other related issues of governance and food justice, are and will properly remain the subject of much analysis, recommendations and action (see for instance Saxena 2012; Haddad *et al.* 2012; Mander 2013). Nothing that follows should detract from the value of such approaches, nor from their achievements.

That said, there is widespread evidence of the limitations of feeding programmes in reducing undernutrition and stunting (see for instance Dewey & Adu-Afarwuah 2008). We suggest that the humane and common sense imperative of getting enough good food into the mouths of children tends to obscure the nutritional significance of what happens to the food after it has been eaten. This brings us to:

The last 3 As: infections out

While the first two As concern getting food into the body, the next 3 As concern the infections that then come out, the FTIs and their effects:

3. Absorption. Much food that is ingested is not absorbed. This can be understood to happen in three ways which also interact with each other:
 - i. *Damage to the wall of the gut.* In particular, bacterial infections and parasites damage the villi (the folds which multiply the absorptive area) of the small intestine and reduce surface area and absorptive capacity (Humphrey 2009).
 - ii. *Diarrhoeas*, including but not only cholera, shigellosis, rotavirus, cryptosporidiosis, and campylobacter, dehydrate and evacuate nutrients, which then cannot be absorbed (Black *et al.* 2008).

- iii. *Intestinal parasites* steal nutrients from the child, or more generally the human host, as well as damaging the wall to which they adhere. Parasites implicated include giardia, amoebiasis, ascariis, hookworm (which feeds on blood and causes anaemia) trichuris and tapeworms. For instance, a review published by Simavi (2012) estimates that 44 million women in India are infected by helminths at any one time, causing increased anaemia rates, low infant birth weight, and increased intrauterine growth retardation.
4. Antibodies. As with EE, infections in the intestine which penetrate into the rest of the body are fought with antibodies. Producing these antibodies diverts nutritional energy and proteins from growth to defence (Humphrey 2009).
5. Allopathogens (Greek *allos* = other). Besides those pathogens that more directly affect absorption, there are others. These include Hepatitis A, B and E, typhoid fever (bacteria, salmonella), liverfluke, poliomyelitis and other enteroviruses, neurocysticercosis (causing some one-third of cases of epilepsy worldwide), schistosomiasis (though not in India), trachoma, and other zoonoses transmitted through intermediate hosts. These have varied multiple effects on absorption, antibodies, and physical disabilities. We have identified allopathogens as a category designed to draw attention to the multiplicity of FTIs, including those that are relatively neglected and are easy to overlook.

PRACTICAL IMPLICATIONS

These categories and this analysis have many implications. The research of Dean Spears (Spears 2012a, 2012b; Spears *et al.* 2013) and other sources and evidence above show that the persistence of undernutrition and stunting in India is no longer a puzzle. The evidence suggests that fully open defecation free conditions and hygienic practices should reduce it by half or more. With this no longer a blind spot, the framework and thinking of the 5As has many practical implications. These point to new emphases and foci for medical and nutritional research and for

professional training and orientation. The substantial, if not radical, implications for government and civil society policy and practice are beyond the remit of this review.

Medical and nutritional research

Offsetting the diarrhoea bias in research to achieve a balance with other FTIs requires a deliberate reorientation of priorities including research funding to support the neglected investigation of non-diarrhoeal FTIs and FTI interrelationships. With the narrowing of focus that is necessary with specialization, some of this will need more work on, for instance, individual soil-transmitted helminths such as hookworm, ascariis and trichuris, and on the fifth A – allopathogens. Other candidate priorities concern more directly the links between open defecation, FTIs and nutrition. What these should be will depend on trade-offs between cost, professional time, time scale before results are available, relative ease of research and potential benefits. We do not presume to be able to assess these or to make definitive judgements, nor to produce an authoritative list. However, the evidence adduced above, together with the 5 As framework, point to the following research questions for consideration:

- How can the prevalence of EE in populations be more cheaply, easily and quickly assessed? Should Research and Development to identify such methods be a priority in research funding?
- How prevalent are non-diarrhoeal FTIs among children and others? Here the prevalence and persistence of EE in India is a major and vital unknown. Among Indian children, is EE found in 20, 50, 80%, or more? And what are the percentages among those who are undernourished?
- How relatively significant is the impact of EE on undernutrition, stunting and cognitive development?
- How do open defecation, population density, FTIs and undernutrition/stunting map together? Can geographical hot spots be identified for intervention?
- The fourth A – antibodies. How much nutritional energy is used, and how much protein consumed, to make antibodies and fight infections from FTIs? How relatively significant is this?
- What are the cumulative and interactive effects of multiple FTIs in the same undernourished child or children?

- What are the positive impacts on reduced stunting of open defecation free conditions, good sanitation and hygienic behaviour?
- How many calories and how many millions of tonnes of foodgrains are wasted annually in India through FTIs?

This list has been generated by the analysis in this paper. For other recently identified research priorities, based on a critical review of *Adair et al. (2013)*, see *Bhutta (2013)*.

Professional orientation, training and incentives

A starting point here is a critically reflective examination of current professional orientations, at both personal and institutional levels. Nutritional, WASH, medical, administrative and other professional teaching and training can be challenged to move out of traditional comfort zones by:

- Reviewing and radical restructuring of curricula and syllabuses.
- Rewriting textbooks and broadening these to eschew narrow disciplinary or departmental tunnel vision.
- Confronting specialization and incentive systems of journals and peer-reviewed publications where these stand in the way and discourage cross-disciplinary or unconventional research on neglected linkages.
- Offsetting the incentives of conventionally rigorous research, which encourages concentration on what is readily measurable and easily controlled, and recognizing and rewarding those who push the frontiers of knowledge by gaining insights in other ways.
- Setting up prestigious awards for work in this area.

The aim should be to create a new generation of medical, nutritional, WASH, administrative and other professionals with a broader awareness of the significance of FTIs in undernutrition and commitment to eliminating them through sanitation and hygienic behaviour.

IN CONCLUSION

The scale of the current tragedy is such that open defecation, lack of rural sanitation and hygiene, and undernutrition in India are one of humankind's greatest and gravest problems. It is precisely for that reason that the potential for enhanced

human wellbeing by eliminating FTIs through sanitation and hygienic behaviour is so phenomenal. A vision can be shared of health, dignity and safety for women, higher GDP, undernutrition sharply reduced, children more active and achieving more of their potential, food access programmes with much more of the food actually nourishing children and adults instead of being lost through FTIs, and on a wide scale undernutrition and poverty reduced, cognition improved, and stunting across the whole population in decline. The danger is that in 2022, the target date for an open defecation-free India (2022 was the target date before the 2014 election. The new Government may revise this), rural open defecation and the undernutrition of children will not differ much from 2014. Senior politicians of all parties, all government departments, government officials, civil society, religious and other local leaders, activists, the media – all have key roles working together. Without a radical and effective programme enacted on the ground and widespread change in social norms and behaviour, the tragic prospect is that in 2022 India will stand out even more alone in the world, left even further behind by Africa and its neighbours, with FTIs continuing to stunt and harm Indian children for decades to come.

DISCLAIMER

The views expressed herein are those of the authors and do not necessarily reflect those of UNICEF, the United Nations or the Institute of Development Studies, Sussex.

ACKNOWLEDGEMENTS

For comments, sources and advice generously given we are grateful to David Addis, Suzanne Coates, Juan Costain, Aidan Cronin, Oliver Cumming, Tania Goldner, Andrés Hueso, Guy Hutton, Rolf Luyendijk, Louise Maule, Aparna Munshi, Frank Odhiambo, Dimple Save, Dean Spears, Yael Velleman, Naomi Vernon and five anonymous reviewers.

REFERENCES

- 3IE International Initiative for Impact Evaluation 2009 Synthetic Review 001. In: *Water, Sanitation and Hygiene Interventions to Combat Childhood Diarrhoea in Developing Countries* (H.

- Waddington, B. Snilstveit, H. White & L. Fewtrell, eds). http://www.dfid.gov.uk/R4D/PDF/Articles/SR_Sanitation.pdf. (accessed March 2013).
- Adair, L. S., Caroline, H., Fall, D., Osmond, C., Stein, A. D., Martorell, R., Ramirez-Zea, M., Singh Sachdev, H., Dahly, D. L., Bas, I., Norris, S. A., Mickelsfield, L., Hallal, P. & Victoria, C. G. 2013 Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: findings from five birth cohort studies. *Lancet* **382** (9891), 525–534.
- Balarajan, Y., Subramanian, S. V. & Fawzi, W. W. 2013 Maternal iron and folic acid supplementation is associated with lower risk of low birth weight in India. *J. Nutr.* **143** (8), 1309–1315.
- Bartram, J. & Cairncross, S. 2010 Hygiene, sanitation, and water: forgotten foundations of Health. *PLoS Med.* **7** (7) e1000367. doi:10.1371/journal.pmed.1000367.
- Bhutta, Z. A. 2013 Early nutrition and adult outcomes: pieces of the puzzle. *Lancet* **382** (9891), 486–487.
- Bhutta, Z. A., Ahmed, T., Black, R. E., Cousens, S., Dewey, K., Giugliani, E., Haider, B. A., Kirkwood, B., Morris, S. S., Sachdev, H. P. S., Shekar, M. for the Maternal and Child Undernutrition Study Group 2008 What works? Interventions for maternal and child undernutrition and survival. *Lancet* **371** (9610), 417–440.
- Black, R. E., Allen, L. H., Bhutta, Z. A., Caulfield, L. E., de Onis, M., Ezzati, M., Mathers, C., Rivera, J. for the Maternal and Child Undernutrition Study Group 2008 Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet* **371** (9608), 243–260.
- Cairncross, S. 1998 The impact of sanitation and hygiene on health and nutrition. Workshop presentation, 10 June 1998, in *The WATERfront*, Issue 12, UNICEF, New York.
- Chambers, R. & von Medeazza, G. 2013 Sanitation and stunting in India: undernutrition's blind spot. *Econ. Polit. Wkly.* **XLVIII** (25), 15–18.
- CHERG, Cairncross, S., Hunt, C., Boisson, S., Bostoen, K., Curtis, V., Fung, I. C. H., Schmidt, W.-P. 2010 Water, sanitation and hygiene for the prevention of diarrhoea. *Int. J. Epidemiol.* **39**, 193–i205.
- Curtis, V. & Cairncross, S. 2003 Effect of washing hands with soap on diarrhoea risk in the community: A systematic review. *Lancet Infect. Dis.* **3**, 275–281.
- Dangour, A. D., Watson, L., Cumming, O., Boisson, S., Velleman, Y., Cavill, S., Allen, E. & Uauy, R. 2013 Interventions to improve water quality and supply, sanitation and hygiene practices, and their effects on the nutritional status of children (Protocol). *Cochrane Database Syst. Rev.* **10**, Art. No.: CD009382.
- Das, J., Hammer, J. & Sanchez-Paramo, C. 2012 The impact of recall periods on reported morbidity and health seeking behaviour. *J. Dev. Econ.* **98** (1), 76–88.
- Deaton, A. & Dreze, J. 2009 Food and nutrition in India: facts and interpretations. *Econ. Polit. Wkly.* **54** (7), 42–64.
- Devereux, S. 2007 *The New Famines: Why Famines Persist in an Era of Globalization*. Routledge, London.
- Dewey, K. G. & Adu-Afarwaah, S. 2008 Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries. *Matern. Child. Nutr.* **4** (1), 24–85.
- Dillingham, R. & Guerrant, L. R. 2004 Childhood stunting: measuring and stemming the staggering costs of inadequate water and sanitation. *Lancet* **363** (9403), 94–95.
- Ejemot, R. I., Ehiri, J. E., Meremikwu, M. M. & Critchley, J. A. 2008 Hand washing for preventing diarrhoea. *Cochrane Database Syst. Rev.* **1**, Art. No.: CD004265.
- EPW 2012 Toilets can be temples. *Econ. Polit. Wkly.* **XLVII** (42), 7–7.
- Esrey, S. A. 1996 Water, waste, and well-being: a multicountry study. *Am. J. Epidemiol.* **143** (6), 608–623.
- Fagundes-Neto, U., Lima, F. L., Patricio, F. L. & Toledo, M. R. 1994 Tropical enteropathy in early childhood: a syndrome caused by contaminated environment. *J. Trop. Pediatr.* **30** (4), 204–209.
- FAO 2013 *The State of Food and Agriculture: Food Systems for Better Nutrition*, FAO, Rome.
- Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L. & Colford Jr., J. M. 2005 Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *Lancet Infect. Dis.* **5** (1), 42–52.
- Fewtrell, L., Prüss-Üstün, A., Bos, R., Gore, F. & Bartram, J. 2007 *Water, sanitation and hygiene: quantifying the health impact at national and local levels in countries with incomplete water supply and sanitation coverage*. World Health Organization, Geneva (WHO Environmental Burden of Disease Series No. 15).
- Fink, G., Gunther, I. & Hill, K. 2011 The effect of water and sanitation on child health: evidence from the demographic and health surveys 1986–2007. *Int. J. Epidemiol.* **40** (5), 1–9.
- Ghosh, A., Gupta, A. & Spears, D. 2014 Are children in West Bengal shorter than children in Bangladesh? *Econ. Polit. Wkly.* **XLIX** (8), 21–24.
- Haddad, L. & Zeitlyn, S. (eds). 2009 Lifting the curse: overcoming persistent undernutrition in India. *IDS Bulletin* **40** (4), Institute of Development Studies, Brighton.
- Haddad, L., Chandrasekhar, C. P. & Swain, B. (eds). 2012 Standing on the threshold: food justice in India. *IDS Bulletin* **43** (s1), Institute of Development Studies, Brighton.
- Hall, A., Hewitt, G., Tuffrey, V. & de Silva, N. 2008 A review and meta-analysis of the impact of intestinal worms on child growth and nutrition. *Matern. Child. Nutr.* **4** (s1), 118–236.
- Hammer, J. & Spears, D. 2013 Village sanitation and children's human capital: evidence from a randomized experiment by the Maharashtra Government. Policy Research Working Paper 6580, Water and Sanitation Program, World Bank, August.
- Haslam, N. 2012 *Psychology in the Bathroom*. Palgrave Macmillan, Basingstoke, pp. 6–8.
- Hueso, A. & Bell, B. 2013 An untold story of policy failure: the Total Sanitation Campaign in India. *Water Pol.* **15**, 1001–1017.
- Humphrey, J. 2009 Child undernutrition, tropical enteropathy, toilets and handwashing. *Lancet* **374** (9694), 1032–1035.

- Kosek, M. & 24 others of the MAL-ED network 2013 [Fecal markers of intestinal inflammation and permeability associated with the subsequent acquisition of linear growth deficits in infants](#). *Am. J. Trop. Med. Hyg.* **88** (2), 390–396.
- Krishna, A. 2010 *One Illness Away: Why People Become Poor and How They Escape Poverty*. Oxford University Press, Oxford.
- Lin, A., Arnold, B. F., Afreen, S., Goto, R., Huda, T. M., Haque, R., Raqib, R., Unicomb, L., Ahmed, T., Colford Jr., J. M. & Luby, S. P. 2013 [Household environmental conditions are associated with enteropathy and impaired growth in rural Bangladesh](#). *Am. J. Trop. Med. Hyg.* **89** (1), 130–137.
- Lindenbaum, J. 1973 Tropical enteropathy. *Gastroenterology* **64**, 637–652, cited in Fagundes-Neto *et al.* 1994.
- Liu, L., Johnson, H. L., Cousens, S., Perin, J., Scott, S., Lawn, J. E., Rudan, I., Campbell, H., Cibulskis, R., Li, M., Mathers, C., Black, R. E. (for the Child Health Epidemiology Reference Group of WHO and UNICEF) 2012 [Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000](#). *Lancet* **379** (9832), 2151–2161.
- Loevinsohn, M., Mehta, L., Cuming, K., Nicol, A., Cumming, O. & Ensink, J. 2014 'The cost of a knowledge silo: a systematic re-review of water, sanitation and hygiene interventions'. *Health Pol. Plann.* 1–15.
- Lunn, P. G., Northrop-Clewes, C. A. & Downes, R. M. 1991 [Intestinal permeability, mucosal injury, and growth faltering in Gambian infants](#). *Lancet* **338**, 907–910.
- Mander, H. 2013 *Ash in the Belly: India's Unfinished Battle against Hunger*. Penguin Books India, New Delhi.
- Menzies, I. S., Zuckerman, M. J., Nukajam, W. S., Somasundaram, S. G., Murphy, B., Jenkins, A. P., Crane, R. S. & Gregory, G. G. 1999 [Geography of intestinal permeability and absorption](#). *Gut* **44**, 483–489.
- Naandi Foundation 2012 *The HUNGaMA*. Survey Report 2011. Naandi Foundation Hyderabad. www.hungamaforchange.org.
- Narayanan, R., van Norden, H., Patkar, A. & Gosling, L. 2011 *Equity and Inclusion in Sanitation and Hygiene in South Asia*. A Regional Synthesis Paper. UNICEF; WSSCC; WaterAid.
- NFHS-1 1995 National Family Health Survey -1, International Institute for Population Sciences (1992–1993). IIPS, Mumbai.
- NFHS-2 2000 National Family Health Survey -2, International Institute for Population Sciences (1998–1999). IIPS, Mumbai.
- NFHS-3 2007 National Family Health Survey -3, International Institute for Population Sciences (2005–2006). IIPS, Mumbai.
- Norhayati, M., Othuman, P., Azizi, O. & Fatmah, M. S. 1997 Efficacy of single dose albendazole on the prevalence and intensity of infection of soil-transmitted helminths in Orang Asli children in Malaysia. *Southeast. Asian J. Trop. Med. Pub. Health* **28**, 563–569.
- Paul, V. K., Sachdev, H. S., Mavalankar, D., Ramachandran, P., Sankar, M. J., Bhandari, N., Sreenivas, V., Sundaraman, T., Govil, D., Osrin, D. & Kirkwood, B. 2011 Reproductive health, and child health and nutrition in India: meeting the challenge. *Lancet* **377** 9762, 332–349.
- Pearson, J. & McPhedran, K. 2008 [A literature review of the non-health impacts of sanitation](#). *Waterlines* **27** (1), 48–61.
- Prendergast, A., Rukobo, S., Chasekwa, B., Mutasa, K., Ntozini, R., Nduduzi, N., Mbuya, N., Jones, A., Moulton, L., Stolzhus, R. & Humphrey, J. 2014 [Stunting is characterized by chronic inflammation in Zimbabwean infants](#). *PLOS One*, **9** (2), e86928.
- Prüss-Üstün, A. & Corvalán, C. 2006 *Preventing Disease through Healthy Environments: Towards an Estimate of the Environmental Burden of Disease*. World Health Organization, Geneva, 44.
- Prüss-Üstün, A., Kay, D., Fewtrell, L. & Bartram, J. 2004 Unsafe water, sanitation and hygiene. In: *Comparative Quantification of Health Risks* (M. Ezzati, A. D. Lopez, A. Rodgers & C. J. L. Murray, eds). World Health Organisation, Geneva, pp. 1321–1352.
- Prüss-Üstün, A., Bartram, J., Clasen, T., Colford, J. M., Cumming, O., Curtis, V., Bonjour, S., Dangour, A. D., De France, J., Fewtrell, L., Freeman, M. C., Gordon, B., Hunter, P. R., Johnston, R. B., Mathers, C., Mäusezahl, D., Medlicott, K., Neira, M., Stocks, M., Wolf, J. & Cairncross, S. 2014 [Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries](#). *Trop. Med. Int. Health*, **19** (8), 894–905.
- Ramalingaswami, V., Jonsson, U. & Rohde, J. 1996 Commentary: The Asian Enigma. *The Progress of Nations 1996 – Nutrition*. UNICEF, New York.
- Saxena, N. C. 2012 *Hunger, Under-Nutrition and Food Security in India*. Working Paper 44, Chronic Poverty Research Centre, Indian Institute of Public Administration.
- Schlaudecker, E. P., Steinhoff, M. C. & Moore, S. R. 2011 [Interactions of diarrhoea, pneumonia, and malnutrition in childhood: recent evidence from developing countries](#). *Curr. Opin. Infect. Dis.* **24** (5), 496–502.
- Schultz, T. & Strauss, J. (eds). 2008 *Handbook of Development Economics*, Vol. 4, Elsevier, Amsterdam, 3565.
- Sen, A. 1981 *Poverty and Famines: An Essay on Entitlement and Famines*. Clarendon Press, Oxford.
- Simavi (2012) *Getting It Right: Improving Maternal Health through Water, Sanitation & Hygiene*. September 2012. www.simavi.nl/assets/Uploads/Simavi-Publicatie_Getting-It-Right.pdf
- Spears, D. 2012a [How Much International Variation in Child Height Can Sanitation Explain? Rice Institute Working Paper](#), 10 December.
- Spears, D. 2012b [Effects of Rural Sanitation on Infant Mortality and Childhood Stunting: Evidence from India's Total Sanitation Campaign](#). Rice Institute Working Paper, 3 July.
- Spears, D. 2014 [Increasing average exposure to open defecation in India 2001–2011](#).
- Spears, D., Ghosh, D. & Cumming 2013 [Open defecation and childhood stunting in India: an ecological analysis of new data from 112 districts](#). *PLoS ONE* **8** (9).
- Spears, D. & Lamba, S. 2013 [Effects of Early-Life Exposure to Sanitation on Childhood Cognitive Skills: Evidence from](#)

- India's Total Sanitation Campaign, Typescript 20. September 2013.
- UNICEF 2012 *The State of the World's Children 2012 'Children in an Urban World'*. UNICEF, New York.
- UNICEF 2013 League Table Stunting in Children under age 5. www.unicef.org/pon00/leaguetos1.htm. (accessed 7 January 2013).
- WHO 2005 Deworming for Health and Development. Report of the third global meeting of the partners for parasite control. World Health Organization, Geneva.
- WHO & UNICEF 2012 *Progress on Drinking Water and Sanitation: 2012 Update*. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, Geneva/New York.
- WHO & UNICEF 2014 *Progress on Drinking Water and Sanitation: 2014 Update*. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, Geneva/New York.
- WSP 2011 *Economic Impacts of Inadequate Sanitation in India*. Water and Sanitation Program, World Bank.
- WSP 2012a *Africa: Economics of Sanitation Initiative*. www.wsp.org/content/africa-economic-impacts-sanitation. (accessed 29 June 2012).
- WSP 2012b *East Asia: Economics of Sanitation Initiative*. www.wsp.org/content/east-asia-economic-impacts-sanitation. (accessed 29 June 2012).

First received 26 February 2014; accepted in revised form 2 July 2014. Available online 26 July 2014