The elimination of open defecation and its adverse health effects: a moral imperative for governments and...

Article *in* Journal of Water, Sanitation and Hygiene for Development · February 2017

DOI: 10.2166/washdev.2017.027

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Review Paper

The elimination of open defecation and its adverse health effects: a moral imperative for governments and development professionals

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ABSTRACT

In 2015 there were 965 million people in the world forced to practise open defecation (OD). The adverse health effects of OD are many: acute effects include infectious intestinal diseases, including diarrheal diseases which are exacerbated by poor water supplies, sanitation and hygiene; adverse pregnancy outcomes; and life-threatening violence against women and girls. Chronic effects include soil-transmitted helminthiases, increased anaemia, giardiasis, environmental enteropathy and small-intestine bacterial overgrowth, and stunting and long-term impaired cognition. If OD elimination by 2030 is to be accelerated, then a clear understanding is needed of what prevents and what drives the transition from OD to using a latrine. Sanitation marketing, behaviour change communication, and 'enhanced' community-led total sanitation ('CLTS + '), supplemented by 'nudging', are the three most likely joint strategies to enable communities, both rural and periurban, to become completely OD-free and remain so. It will be a major Sanitation Challenge to achieve the elimination of OD by 2030, but helping the poorest currently plagued by OD and its serious adverse health effects should be our principal task as we seek to achieve the sanitation target of the Sustainable Development Goals – indeed it is a moral imperative for all governments and development professionals.

Key words | child health, diarrhea, environmental enteropathy, impaired cognition, open defecation, stunting

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INTRODUCTION

In 2015 965 million people had no sanitation facility and were therefore forced to defecate in the open (WHO/UNICEF 2015) (Figure 1). The average proportion of 'open defecators' in developing countries is 16%, and in the least-developed countries 20%. Table 1 lists those countries with more than 15% open defecators and highlights those with more than 50%. Most of these open defecators are poor and live in rural areas – for example, in India, which had a total of 564 million open defecators in 2015, 61% of the rural population were open defecators *vs* only 10% of the urban population (WHO/UNICEF 2015), and 95% of the poorest quintile in rural areas were open defecators *vs* only 2% of the richest quintile (Figure 2). However, in low-income urban areas the number of open defecators can also be very high: for example, in India Gupta *et al.* (2009) found that 35–47% of poor households in Delhi, Indore, Meerut and Nagpur did not have any toilet facility.

Part of the sanitation target of the Sustainable Development Goals is to eliminate open defecation (OD) by 2030 (United Nations General Assembly 2015). If the same proportion of 'open defecators' to the total without improved sanitation in 2015 (965 million to 2.4 billion, i.e. 42%) is assumed for 2030, then 42% of the 2016–2030 population increase of 1.1 billion (UNDESA 2015), plus the current number of open defecators,

doi: 10.2166/washdev.2017.027

Figure 1 | OD by a young boy in periurban India (photograph courtesy of Professor Barbara Evans, University of Leeds).

are required to move from OD to fixed-point defecation, preferably (in the new terminology of JMP 2015b) to 'basic' sanitation or ideally 'safely-managed' sanitation, i.e. a total of nearly 1.4 billion people, or some 260,000 per day during 2016–2030.

In 1990, 31% of the then developing-country population of 4.1 billion were open defecators, and in 2015 16% of the then developing-country population of 6 billion were open defecators, i.e. 1.29 billion and 965 million, respectively (WHO/UNICEF 2015). Thus, during the whole of the 25-year period 1991–2015 there was a reduction in OD of 325 million people, equivalent to only 36,000 per day; this was due in part to the large population increase during this period.

In 2010, 19% of the then developing-country population of 5.6 billion were open defecators (WHO/UNICEF 2012), i.e. 1.069 billion people. Subtracting from this the 965 million open defecators in 2015 gives the number of people removed from OD during the 5-year period 2011–2015, i.e. 104 million, equivalent to 57,000 people per day. This is better than that achieved during 1991–2015, but it is still far short, by a factor of 4, of the requirement for 2030.

However, some countries have done very well in reducing OD: for example, in rural Vietnam 43% of the population practised OD in 1990, but by 2015 this had been reduced to 1%; in Bangladesh the corresponding figures were 40 and 2%; and in Mexico they were 51 and 4% (WHO/UNICEF 2015). Given that there are 'no solutions without political solutions', the exceptionally good progress in these and some other countries may have been due, at least in part, to their politicians and senior civil servants 'thinking clean', i.e. deciding that OD was not 'clean' and that therefore something had to be done to reduce or eliminate it, and then transposing this decision into action.

At the current rate of global progress, the target of no OD by 2030 is unlikely to be realised. Thus to achieve the SDG target of 'No OD by 2030' requires a huge global step-change in addressing and reducing to zero the prevalence of OD in developing countries. To do this, Ministry of Health officials and development professionals need to be fully aware of the major adverse health consequences of OD, and how best to eliminate OD – in particular, what mix of sanitation 'hardware', social-science 'software', and financial support is appropriate.

Table 1 | Countries with more than 15% and more than 50% of their populations practising OD in 2015 (WHO/UNICEF 2015)

Region	Countries with >15% OD[a] and percentages of populations practising OD[b,c]
Africa	Angola (30%), **Benin (53%), Burkina Faso (55%),** Cabo Verde (24%), Central African Republic (22%), **Chad (64%)**, Côte d'Ivoire (26%), Djibouti (20%), **Eritrea (77%)**, Ethiopia (29%), Ghana (15%), Guinea (22%), Guinea-Bissau (17%), Lesotho (33%), Liberia (48%), Madagascar (40%), Mauritania (35%), Mozambique (39%), Namibia (48%), **Niger (73%)**, Nigeria (25%), **São Tome e Principe (54%)**, Sierra Leone (24%), **South Sudan (74%), Togo (52%)**, Zimbabwe (28%)
Asia Pacific	Cambodia (47%), India (44%), Indonesia (20%), Kiribati (36%), Laos (33%), Nepal (32%), **Solomon Islands (54%)**, Timor-Leste (26%)
Latin America & Caribbean	Bolivia (17%), Haiti (19%)

[a]The average 2015 OD rate for developing countries was 16%, and for the least developed countries 20%.
[b]Some countries with high OD rates in 1990 reported in WHO/UNICEF (2015) have no reported OD rates for 2015 (and are thus excluded from this table).
[c]Countries with >50% open defecators are shown in **bold**.

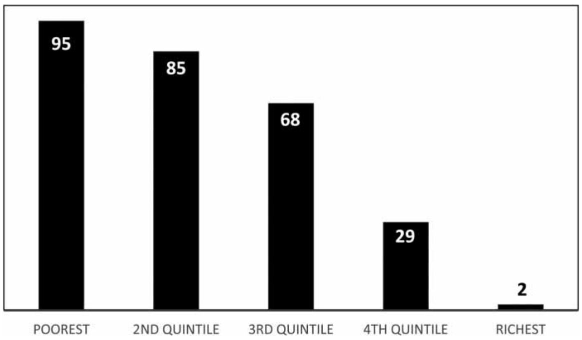

Figure 2 | Percentage of rural population in India practising OD, by wealth quintile (JMP 2015a).

ADVERSE HEALTH EFFECTS OF OD

The adverse health effects of OD can be divided into acute effects and chronic effects. Both cause a high burden of disease and a large number of premature deaths, especially in children under five years of age. These adverse health effects of OD occur because OD results in massive faecal contamination of the local environment; consequently, open defecators are repeatedly exposed to faecal bacteria and faecal pathogens, and this is particularly serious for young children whose immune systems and brains are not yet fully developed.

Acute health effects of OD

The principal acute adverse health effect of OD is infectious excreta-related intestinal disease, of which diarrheal diseases (DD) are the most common. DD were the third cause of death in children under five years of age (U5) in 2015 in low-income and lower-middle-income countries (LICs and LMICs), resulting in 499,000 deaths (8.6% of all U5-deaths), and a disability-adjusted life year (DALY) loss of 45.1 million years (8.5% of total U5-DALY losses) (IHME 2016). One of the commonly ascribed reasons for high incidences of DD is a poor water supply, poor sanitation, and poor hygiene, especially poor hand-hygiene (WHO 2014). The burden of U5-disease in LICs and LMICs in 2015 due to no handwashing-with-soap was a DALY loss of 26.4 million years (5.7% of total U5-DALY losses); the corresponding figure for unsafe sanitation was a DALY loss of 26.6 million years (5.7% of total U5-DALY losses) (IHME 2016). The World is not good at handwashing: Freeman *et al.* (2014) estimated that globally 81% of people do not practise safe handwashing.

A further acute health effect of OD is adverse pregnancy outcomes, such as increases in low birth weights, preterm births, stillbirths, and spontaneous abortions (Padhi *et al.* 2015).

Finally, there is violence against women and girls, which is often life-threatening. Violence against women and girls of all ages in LICs and LMICs caused a DALY loss of 7.8 million years in 2015 (IHME 2016). Physical violence, which may include murder, rape, stabbing and other bodily harm, is a not uncommon experience for women and girls as they journey to a place of OD, especially at night (Gómez *et al.* 2008). Bhalla (2014) reported the occurrence of two 'open-defecation murders' in rural India:

> 'The two [girl] cousins, who were from a low-caste Dalit community and aged 14 and 15, went missing from their village home in Uttar Pradesh's Budaun district when they went out to go to the toilet [in a neighbouring field]. The following morning, villagers found the bodies of the two teenagers hanging from a mango tree in a nearby orchard.'

It transpired that the two girls had been attacked and gang-raped by five local men before they were hanged. Unfortunately, such incidents are not at all uncommon: Gosling *et al.* (2015) reported that many women in Bhopal and Delhi, India, and Kampala, Uganda experienced violence and harassment on a daily basis.

Such violence may often induce longer-term psychological damage. To help counter such violence House *et al.* (2014) have prepared a practitioner's toolkit on 'Violence, Gender and WASH'.

Chronic health effects of OD

There are five principal widespread chronic health effects most probably due to OD: soil-transmitted helminthiases (STHs), increased anaemia, giardiasis, environmental enteropathy and small-intestine bacterial overgrowth (SIBO), and stunting (low height-for-age) with accompanying impaired cognition.

Soil-transmitted helminthiases

The most common STHs are ascariasis (caused by the human roundworm, *Ascaris lumbricoides*), trichuriasis (caused by the human whipworm, *Trichuris trichiura*), and human hookworm disease (caused by *Ancylostoma duodenale* and *Necator americanus*). Globally, an estimated 439 million people were infected with hookworm in 2010, 819 million with *A. lumbricoides* and 465 million with *T. trichiura* (Pullan *et al.* 2014). The burdens of disease associated with these STHs are high: in 2015 ascariasis in LICs and LMICs caused an all-age both-sex DALY loss of 878,000 years, trichuriasis 340,000 years, and human hookworm disease 2.2 million years (IHME 2016).

Ascariasis, trichuriasis and hookworm disease cause impaired cognition, notably in school-aged children (Nokes *et al.* 1992; Partovi *et al.* 2007; Spears & Haddad 2015). The areas most affected are verbal fluency, short-term memory, and speed of information processing, which are precisely the areas most needed for people to be able to contribute effectively to socio-economic development. Infection with two or more of these helminths impairs cognition to a greater extent than infection with only one (Jardim-Botelho *et al.* 2008).

Trichuriasis is associated with 'anaemia (see "Increased anaemia" below), growth retardation (i.e. stunting – see "Environmental enteropathy and SIBO" below) and intestinal leakiness' (Cooper *et al.* 1992). In a study of 9,860 refugees in Texas, latent tuberculosis infection was found to be positively associated in those refugees with hookworm infection (Board & Suzuki 2015).

The World Health Organization has a global target to eliminate morbidity due to STHs in preschool and school-age children by 2020 (WHO 2016). This is to be achieved by regularly treating (deworming at school) at least 75% of the children in endemic areas – an estimated 873 million children.

Increased anaemia

In adults, anaemia reduces productivity and is associated with higher maternal mortality; in children, it impairs physical and cognitive development directly, and it also affects human capital accumulation via impacts on behaviours such as school attendance (Coffey & Geruso 2015). Iron-deficiency anaemia caused an all-age both-sex DALY loss in LICs and LMICs of 36.1 million years in 2015 (IHME 2016). In a study on anaemia in Nepal, Coffey & Geruso (2015) found that 'poor local sanitation and, specifically, OD cause lower hemoglobin and higher rates of anemia in children'.

Giardiasis

The long-term post-infection consequences of giardiasis include low height-for-age, low weight-for age, small mid-upper-arm-circumference-for-age, low serum-levels of zinc and iron, chronic and persistent diarrhea with consequent malabsorption, irritable bowel syndrome deficiencies, and impaired cognition (Halliez & Buret 2013).

Environmental enteropathy and SIBO

There has been considerable research on the association between stunting (see 'Stunting' below) and environmental enteropathy (also called tropical enteropathy and environmental enteric dysfunction). Environmental enteropathy is a condition which results in the malabsorption of nutrients in the small intestine and this leads to stunting; some or many of the nutrients in a child's foods are not absorbed and so are unavailable for the child's growth. The term 'environmental enteropathy' was used by Fagundes-Neto *et al.* (1984) to describe a common syndrome in which there are non-specific histopathological and functional changes of the small intestine in children of poor families living in conditions lacking basic sanitary facilities and chronically exposed to faecal contamination. They studied 112 children and found that carbohydrate load tests revealed 49% lactose malabsorption, 30% sucrose malabsorption and 5% glucose malabsorption, and that small bowel biopsy showed partial villous atrophy in 94% of the samples studied.

More recent research has confirmed these findings. Humphrey (2009) reported that a key cause of child undernutrition was environmental enteropathy, and that this enteropathy is caused by faecal bacteria ingested in large quantities by young children living in conditions of poor sanitation and hygiene. She postulated that provision of toilets and promotion of handwashing after faecal contact could reduce or prevent environmental enteropathy and its adverse effects on growth; and she noted that prevention of this enteropathy, which afflicts almost all children in the developing world, will be crucial to normalise child growth, and that this will not be possible without the provision of toilets. Mbuya & Humphrey (2016) endorsed this by stating that the unhygienic environments in which infants and young children live and grow must contribute to, if not be the overriding cause of, this environmental enteric dysfunction. They suggested that a household-level package of 'baby-WASH' interventions (sanitation and water improvement, handwashing with soap, ensuring a clean play and infant-feeding environment, and food hygiene) that interrupted specific pathways through which feco-oral transmission occurs in the first two years of a child's life may be central to global stunting-reduction efforts.

Donowitz & Petri (2015) found that:

> 'Small-intestine bacterial overgrowth (SIBO) occurs when colonic quantities of commensal bacteria are present in the small bowel. SIBO is associated with conditions of disrupted gastrointestinal (GI) motility leading to stasis of luminal contents. Recent data show that SIBO is also found in children living in unsanitary conditions who do not have access to clean water. SIBO leads to impaired micronutrient absorption and increased GI permeability, both of which may contribute to growth stunting in children.'

Stunting

Target #2.2 of the Sustainable Development Goals includes 'achieving, by 2025, the internationally agreed targets on stunting and wasting in children under five years of age' (United Nations General Assembly 2015). The 'internationally agreed target' for stunting is to reduce by 2025 the number of stunted children under the age of 5 in 2010 by 40% (de Onis *et al.* 2013). Stunting is defined as a height that is two or more standard deviations below the median height for the child's age and sex. (The World Health Organization publishes charts and tables for boys' and girls' median heights-for-age and values of the appropriate standard deviations (WHO 2015). A '*z* score' is used: for example, a *z* score of −2 means that a child's height is two standard deviations below the median height for that child's age and sex, and the child is therefore considered stunted; for severe stunting the *z* score is −3 or lower.) In developing countries as a whole stunting is decreasing – from 251 million children under five in 1990 to 156 million children in 2014, except in Africa where it is increasing – from 47 million children in 1990 to 58 million in 2014 (UNICEF 2015). Stunting affects poor children much more than children from rich families: for example, in least developed countries, 49% of the poorest children are stunted *vs* 26% of the richest children; boys are more stunted than girls (43 *vs* 38%), and children living in rural areas are more stunted than those in urban areas (43 *vs* 32%) (UNICEF 2015). In 2015 stunting caused a U5-DALY loss in LICs and LMICs of 21.4 million years (IHME 2016).

Stunting is exacerbated by (a) the density of OD – the number of people practising OD per km^2 (Spears 2013); (b) environmental enteropathy and SIBO (see 'Environmental enteropathy and SIBO' above); and (c) DD and STHs (see 'Soil-transmitted helminthiases' above) (Spears & Haddad 2015). In a 10-year study of 119 slum children in northeast Brazil, Moore *et al.* (2001) found that children who had had a high burden (~9 episodes) of DD in their first two years of life were on average 3.6 cm shorter at age seven than other children, and those children who had also had an early childhood helminthiasis were on average a further 4.6 cm shorter at the same age. In a study of children living in a periurban shanty town in Lima, Peru, Berkman *et al.* (2002) found that:

> 'During the first two years of life, 46 (32%) of 143 children were stunted. Children with severe stunting in the second year of life scored 10 points lower on the WISC-R ['Wechsler Intelligence Scales for Children – Revised' (Wechsler 1974)] test at age nine than children without severe stunting [in their second year of life]. Children with more than one episode of *Giardia lamblia* per year scored 4.1 points lower than children with one episode or fewer per year. Neither diarrhea prevalence nor *Cryptosporidium parvum* infection was associated with WISC-R scores'.

Eppig *et al.* (2010), in their study on the prevalence of infectious-disease agents and cognitive ability, postulated that the bodies of young children face a competition for energy (derived from their nutrient intake) between the development and use of their brain and the development and use of their immune system. Children repeatedly exposed to infectious-disease agents are seriously disadvantaged:

> '[They] must activate [their] immune system to fight off the infection, at energetic expense. Of these, diarrheal diseases may impose the most serious cost on their hosts' energy budget. First, diarrheal diseases are the most common category of disease on every continent, […] Second, diarrhea can prevent the body from accessing any nutrients at all. If exposed to diarrheal diseases during their first five years, individuals may experience lifelong detrimental effects to their brain development, and thus intelligence'.

To this 'brain' scenario can be added stunting: the more nutrients children do not get through exposure to infectious-disease agents or, in the reasoning of environmental enteropathy given above, through continuous exposure to faecal bacteria, the more they will be stunted.

The long-term consequences of childhood stunting include adverse effects on cognitive development, school achievement, economic productivity in adulthood, and maternal reproductive outcomes (Dewey & Begum 2011). Adverse 'maternal reproductive outcomes' include not only adverse neonatal and infant outcomes, but also chronic diseases in adulthood for the surviving children in their later life – for example, increased cardiovascular disease, high blood pressure, respiratory diseases, and Paget's disease (Barker 1994).

Hoddinott *et al.* (2013) make the economic case for reducing stunting. Using 'credible estimates of benefit-cost ratios (BCRs) for a plausible set of nutritional interventions to reduce stunting', they found that in 17 high-burden countries these BCRs ranged from 3.6 (Democratic Republic of the Congo) to 48 (Indonesia), with a median value of 18 (Bangladesh). Thus reducing stunting is a very good economic proposition, and so investment in sanitation to reduce stunting is also a very good economic proposition (Augsburg *et al.* 2015). The importance of this has been confirmed by Danaei *et al.* (2016), who studied the risk factors for childhood stunting at age two in 137 developing countries. They found that 36% of two-year olds were stunted, and that unimproved sanitation was the second highest risk factor for stunting, with 7.2 million attributable cases (out of a total of 44.1 million cases – i.e. 16%); the highest risk factor was foetal growth restriction (10.8 million attributable cases), and the third highest was DD (5.8 million attributable cases).

In summary: (a) OD → violence against women and girls as they walk to OD sites, including murder, rape, stabbing, other serious bodily harm, and any resulting longer-term psychological/psychosocial damage; and (b) high OD density → extreme faecal contamination of the local environment → frequent ingestion of large numbers of faecal bacteria and faecal pathogens, and frequent percutaneous entry of hookworm larvae, by young children → high incidence of infectious intestinal disease and helminthiases, and mass development of SIBO and environmental enteropathy → high levels of nutrient malabsorption and childhood stunting, and all the cognitive and physical consequences thereof.

SOCIAL PREFERENCE FOR OD

Despite these associated adverse health outcomes, OD is often a *preferred* practice, notably in rural India, where 61% of the population are open defecators (WHO/UNICEF 2015), Coffey *et al.* (2014) found robust evidence that supported a preference for OD, with many respondents in their survey in rural India claiming that OD was more pleasurable and desirable than latrine use. Devine & Kullmann (2011) found that in rural East Java, Indonesia, many men considered OD 'normal', and that it had distinct benefits such as social interaction and physical comfort (especially in the case of defecation in a river). Tiwaril (2016) reported that in rural Uttar Pradesh, India, because they were used to the 'comfortable fields', 90 families quietly demolished the toilets inside their house that were built under the Swachh Bharat Abhiyaan (see below), as they preferred to resume OD.

Figure 2 shows that even some of the two richest wealth quintiles in India practise OD, presumably because they prefer this to using a toilet (which they could easily afford).

Of course, in other countries where OD is common (Table 1), a social preference for OD may not exist. People in these countries may be practising OD because they cannot afford a latrine (Augsburg *et al.* 2015), or because, if they live in urban slums, there is no space available to construct latrines.

SWACHH BHARAT ABHIYAAN – 'CLEAN INDIA MISSION'

In his 2014 Independence Day speech, the Prime Minister of India, Shri Narendra Modi, spoke about OD and the need for toilets (Modi 2014a):

> 'Has it ever pained us that our mothers and sisters have to defecate in open? Whether dignity of women is not our collective responsibility? The poor womenfolk of the village wait for the night; until darkness descends, they can't go out to defecate. What bodily torture they must be feeling, how many diseases that act might engender. Can't we just make arrangements for toilets for the dignity of our mothers and sisters?'

On 2 October 2014 Prime Minister Modi launched 'Swachh Bharat Abhiyaan' (SBA, 'Clean India Mission'), one objective of which is to end OD by 2 October 2019, the 150th anniversary of Mahatma Gandhi's birth (Modi 2014b). This is clearly a very ambitious five-year target, given that India has 565 million open defecators; this is the largest country-number in the world (by over an order of magnitude) and represents 54% of all open defecators (WHO/UNICEF 2015).

SBA followed on from the Total Sanitation Campaign (TSC) instituted in 1999. A review of TSC by WaterAid India (2008) found much variability in results from state to state, especially in states where the approach was centralized, rather than being decentralized to the community level. Menon (2015) criticized SBA for this reason, stating that subsidy-driven Swachh Bharat was a failed, old idea, and that a community-driven approach was needed to stop OD. This is in agreement with WaterAid India's (2008) finding that community-led total sanitation (CLTS) could be one of the approaches explored for faster and more sustainable results on the ground.

THE CLTS APPROACH TO ENDING OD

IDS (2016) describes CLTS as:

> 'An innovative methodology for mobilising communities to completely eliminate open defecation (OD). Communities are facilitated to conduct their own appraisal and analysis of open defecation and take their own action to become open-defecation free (ODF).'

In Bangladesh, the success in reducing rural OD from 40% in 1990 to 2% in 2015 (WHO/UNICEF 2015), and to <1% in 2016 (Ministry of Local Government Rural Development and Co-operatives 2016), has long been ascribed to properly-designed and well-executed CLTS (Sanan & Moulik 2007).

Further information on CLTS and the elimination of OD is given by Kar & Chambers (2008) and Bongartz *et al.* (2016). Importantly, CLTS does not prescribe the adoption of any one particular sanitation technology; thus all appropriate sanitation options should be considered with the beneficiary communities, recognising that the available technical options are likely to be different in urban and rural areas. WSP/MDWS (2014) details some of the best practices in rural sanitation in India.

ACCELERATING THE ELIMINATION OF OD

If progress towards OD elimination is to be accelerated, then a clear understanding of what prevents and what drives the transition from OD to using a latrine is necessary. Augsburg *et al.* (2015) found that cost was the principal consideration that militated against latrine adoption in both India and Nigeria; this indicates that subsidies and access to credit (e.g. subsidized microfinance loans) are clearly important (see, for example, Evans *et al.* 2009; Newman *et al.* 2014).

Augsburg & Rodríguez-Lesmes (2015), working in low-income urban areas and slums and rural areas in India, found that there was a strong correlation of toilet ownership with perceived health, with households that owned a toilet believing themselves and their family to be healthier than their peers who did not – thus suggesting that, contrary to often held views, health considerations play at least some role in the decision to acquire sanitation.

Village-wide and slum-wide elimination of OD depends for its success on: (1) the selection and community-wide installation, both with the participation of the beneficiary community, of a locally-suitable sanitation technology, which the local community understands and agrees to use sustainably; and (2) the selection, installation (again with community participation) and correct use of a locally appropriate handwashing-with-soap facility.

It is very important that the whole community becomes 'open defecation free' (ODF). Andrés *et al.* (2014), in a study involving 209,762 children under the age of four in rural India, which investigated the potential benefits, in terms of a reduction in diarrhea, to children living in households with 'improved' sanitation facilities, found that there was no improvement at all until 30% coverage was achieved (i.e. 30% of all households in the village community having their own improved sanitation facility), and that half of the potential benefits were only reached when coverage was approximately 75%. Vyas *et al.* (2013) found a similar relationship between stunting and ODF status in rural Cambodia: children living in completely ODF villages had z-scores above -1.5 during the whole of their first five years of life, whereas those living in villages where everyone practised OD had z-scores below -2 from age 20 months onwards; those children living in villages where some people practised OD had z-scores close to -2 from age two onwards. Such externalities (external, that is, to each individual household) reflect the relative importance of faeco-oral disease transmission in the 'public' and 'private' domains, as discussed by Cairncross *et al.* (1996). In order to interrupt transmission, interventions are needed in both the private domain (individual household-level improved sanitation) and in the public domain (all of one's co-villagers having their own improved sanitation facility). CLTS seeks to establish a social norm for eliminating OD in the whole community such that it, as a unit, realises all the disadvantages of OD (especially those for women and girls), so that every household in the community has and uses a safely-managed latrine.

Sanitation marketing and behaviour change communication

WSP (2016) defines sanitation marketing (SM) as:

> 'An emerging field that applies social and commercial marketing approaches to scale up the supply and demand for improved sanitation facilities. While formative research is the foundation of any sanitation marketing program, essential to understanding what products the target population desires and what price they're willing to pay for them, components such as the marketing mix, communications campaign, and implementation are also critical to the design and implementation of effective program.'

Devine & Kullmann (2011) recommend CLTS and behaviour change communication (BCC) as useful adjuncts to SM because, while CLTS focuses on changing community practices, BCC focuses on changing individual or household behaviours. Thus BCC can be used to sustain and supplement CLTS in motivating individuals to become open-defecation-free and sustain this behaviour over time. Perez (2012) reported on research carried out in Bangladesh which examined the long-term sustainability of sanitation behaviours and facilities in areas that were declared ODF; one of the main findings was that the BCC campaign directed at households to stop practising OD was very pervasive: campaign messages were communicated through various channels and settings, including messaging by members and officers of the local Union Parishad (the smallest rural administrative unit) at meetings, rallies, over loudspeaker announcements, and through household visits by Union Parishad members or NGO workers.

ODF+ and CLTS+

There is currently a move, at least in thinking, from ODF to 'ODF+' – that is, to develop sound models to ensure that, once ODF status has been achieved, it is sustained for all time, and how CLTS might be modified (and perhaps described as 'CLTS+') to encourage this to happen, including such topics as locally correct latrine selection, latrine financing and possible subsidies, sufficient water supplies for personal and domestic hygiene (handwashing with soap, and cleansing used cooking and eating utensils), and household- and community-level operation and maintenance (Bongartz *et al.* 2016). 'Nudging theory' has been recommended as a means to change OD practice to ODF+ (Neal *et al.* 2016) – 'nudges' are small changes to the mental environment that can channel decision-making and behaviour in new ways. Nudging is based on scientific findings from psychology, cognitive science and behavioural economics, on which Neal *et al.* (2016) proposed a framework of eight principles to support the initiation and maintenance of OD behaviour change: (1) ensure critical sanitation products and infrastructure are immediately and consistently physically available for the users; (2) create or capitalize on context change to drive new behaviour of toilet use; (3) piggyback on other existing behaviours and cues (e.g. washing clothes, water gathering); (4) strategically increase friction for the undesired behaviour (OD) and lessen it for the desired one (sustained toilet use); (5) support context-stable repetition for latrine use; (6) embed ritualized elements in the change process (e.g. integrate OD messaging into already ritualized cultural practices); (7) leverage point-of-action reminders and cues (e.g. use of coloured agents to clean latrine slabs); and (8) highlight descriptive and localized norms that reduce cognitive demands (e.g. develop systems to address the whole community or a women's group, rather than individual households).

CLTS+, supplemented with 'nudging', would enable rural households to move directly from OD to 'safely-managed' on-site sanitation and hygiene – which is the SDG target (JMP 2015b). The technologies for safely-managed on-site sanitation are well established – for example, arborloos (which are especially suitable in low-density rural areas; fruit or medicinal trees are planted in the shallow pits when full to provide food and income) (Morgan 2004), single-pit VIP latrines, urine-diverting eThekwini latrines (which, because they are wholly above-ground, are suitable in areas subject to flooding or with high groundwater tables and where pit emptying is difficult or not well practised) (WIN-SA 2006), and single-pit or alternating twin-pit pour-flush latrines.

In low-income urban areas it is more difficult to move to safely-managed sanitation as faecal-sludge management is more complex and more expensive than in rural areas. However, safely-managed sanitation can be readily achieved with off-site systems such as condominial sewerage (Melo 2005, 2008); household financial costs for this sanitation system are low – for example, in the state of Rio Grande do Norte in Brazil (where the system was developed in the early 1980s) the monthly charge is only BRL 2.18 (GBP 0.50, USD 0.63) per household per month (CAERN 2016). In urban slums, which are home to some 881 million people (30% of the urban population in developing countries, up to 56% in Sub-Saharan Africa) (UN-Habitat 2015), household-level sanitation is infeasible due to space constraints. Safely-managed shared sanitation is, however, a feasible and tested sanitation option to replace OD in low-income high-density urban areas (Burra *et al.* 2003; Mara 2016).

In addition, there is a need in CLTS+ for local businesses and tradesmen to be trained in latrine selection, construction, and financing, and also, where appropriate, the provision of locally-produced and locally-suitable pour-flush squat-pans or pedestal-seat units (Sy *et al.* 2014), hardware for urine-diverting eThekwini latrines, pipework and accessories for condominial sewerage, and also facilities for handwashing with soap (Jenkins *et al.* 2013).

CONCLUDING REMARKS

1. This paper has sought to review and collate key evidence on OD, especially the numbers of people practising OD, the health effects of OD, and how best OD might be eliminated.
2. The adverse health consequences of OD are so extreme that, if ODF+ status in not reached in rural villages, small towns and low-income periurban areas, including slums, there will be more 'lost generations' of physically-impaired and cognitively-challenged children and adults. All Ministry of Health officials and development professionals need to be aware of the physical and mental outcomes of OD in young children, some of which are irreversible.
3. The elimination of OD is primarily a complex sociocultural and sociopolitical task. It is not a major technical or financial challenge as CLTS, with its option to consider all types of sanitation and handwashing facilities, does not require the development of new technologies specifically for OD elimination as several existing technologies are already fit-for-purpose; nor does it always necessitate the provision of subsidies. The further development and rigorous field-testing of 'CLTS+' is needed to ensure that there is no reversion to OD in communities which have become OD-free.
4. SM and BCC are very valuable techniques and should be applied as the first steps in CLTS/CLTS+ – i.e. these

three techniques should be used in sequence for best results.

5. It will be a major sanitation challenge to achieve the elimination of OD by 2030, but it is a challenge that governments and development professionals should stand up to and embrace. Helping the poorest plagued by OD should be our principal task as we all seek to achieve the sanitation target of the Sustainable Development Goals – indeed it is our moral imperative.

REFERENCES

Andrés, L. A., Briceño, B., Chase, C. & Echenique, J. A. 2014 *Sanitation and Externalities: Evidence from Early Childhood Health in Rural India* (Policy Research Working Paper No. 6737). World Bank, Washington, DC.

Augsburg, B. & Rodríguez-Lesmes, P. 2015 *Sanitation Dynamics: Toilet Acquisition and Its Economic and Social Implications* (IFS Working Paper W15/15). Institute for Fiscal Studies, London.

Augsburg, B., Caeyers, B. & Oteiza, F. 2015 *The Costs and Benefits of Investing in A Toilet: Views From Indian and Nigerian Households and Their Policy Implications.* Institute for Fiscal Studies, London.

Barker, D. J. P. 1994 *Mothers, Babies and Disease in Later Life.* BMJ Publishing Group, London.

Berkman, D. S., Lescano, A. G., Gilman, R. H., Lopez, S. L. & Black, M. M. 2002 Effects of stunting, diarrhoeal disease, and parasitic infection during infancy on cognition in late childhood: a follow-up study. *Lancet* **359**, 564–571.

Bhalla, N. 2014 *Teen Girls Gang-Raped and Hanged From A Tree – Police.* Thomson Reuters Foundation, New Delhi. Available from: http://in.reuters.com/article/uk-india-killings-idINKBN0E91AI20140529 (accessed 6 February 2016).

Board, A. R. & Suzuki, S. 2015 The interrelation between intestinal parasites and latent TB infections among newly resettled refugees in Texas. *Int. Health* **8** (1), 67–72.

Bongartz, P., Vernon, N. & Fox, J. 2016 *Sustainable Sanitation for All: Experiences, Challenges, and Innovations.* Practical Action Publishing, Rugby.

Burra, S., Patel, S. & Kerr, T. 2003 Community-designed, built and managed toilet blocks in Indian cities. *Environ. Urban.* **15** (2), 11–32.

CAERN 2016 Tabela Tarifária Única *2015.* Compahnia de Águas e Esgotos do Rio Grande do Norte, Natal. Available from: www.caern.rn.gov.br (accessed 18 November 2016).

Cairncross, S., Blumenthal, U., Kolsky, P., Moraes, L. & Tayeh, A. 1996 The public and domestic domains in the transmission of disease. *Trop. Med. Int. Health* **1** (1), 27–34.

Coffey, D. & Geruso, M. 2015 *Sanitation, Disease, and Anemia: Evidence From Nepal.* College of Liberal Arts, University of Texas at Austin, Austin, TX. Available from: https://laits.utexas.edu/~mlg2296/images/SanitationAnemia.pdf (accessed 18 January 2016).

Coffey, D., Gupta, A., Hathi, P., Khurana, N., Spears, D., Srivastav, N. & Vyas, S. 2014 *Revealed Preference for Open Defecation: Evidence from a New Survey in Rural North India* (SQUAT Working Paper No. 1). RICE Institute, Amston, CT.

Cooper, E. S., Whyte-Alleng, C. A. M., Finzi-Smith, J. S. & MacDonald, T. T. 1992 Intestinal nematode infections in children: the pathophysiological price paid. *Parasitology* **104**, S91–S103.

Danaei, G., Andrews, K. G., Sudfeld, C. R., Fink, G., McCoy, D. C., Peet, E., Sania, A., Smith Fawzi, M. C., Ezzati, M. & Fawzi, W. W. 2016 Risk factors for childhood stunting in 137 developing countries: a comparative risk assessment analysis at global, regional, and country levels. *PLoS Med.* **13** (11), e1002164.

de Onis, M., Dewey, K. G., Borghi, E., Onyango, A. W., Blössner, M., Daelmans, B., Piwoz, E. & Bianca, F. 2013 The World Health Organization's global target for reducing childhood stunting by 2025: rationale and proposed actions. *Matern. Child Nutr.* **9** (Suppl. 2), 6–26.

Devine, J. & Kullmann, C. 2011 *Introductory Guide to Sanitation Marketing.* Water and Sanitation Program, World Bank, Washington, DC.

Dewey, K. G. & Begum, K. 2011 Long-term consequences of stunting in early life. *Matern. Child Nutr.* **7**(Suppl. 3), 5–18.

Donowitz, J. R. & Petri Jr, W. A. 2015 Pediatric small intestine bacterial overgrowth in low-income countries. *Trends Mol. Med.* **21** (1), 6–15.

Eppig, C., Fincher, C. L. & Thornhill, R. 2010 Parasite prevalence and the worldwide distribution of cognitive ability. *Proc. R. Soc. B Biol. Sci.* **277**, 3801–3808.

Evans, B., van der Voorden, C. & Peal, A. 2009 *Public Funding for Sanitation: The Many Faces of Sanitation Subsidies.* Water Supply & Sanitation Collaborative Council, Geneva.

Fagundes-Neto, U., Viaro, T., Wehba, J., da Silva Patrício, F. R. & Machado, N. L. 1984 Tropical enteropathy (Environmental enteropathy) in early childhood: a syndrome caused by contaminated environment. *J. Trop. Pediatr.* **30** (4), 204–209.

Freeman, M. C., Stocks, M. E., Cumming, O., Jeandron, A., Higgins, J. P. T., Wolf, J., Prüss-Üstün, A., Bonjour, S., Hunter, P. R., Fewtrell, L. & Curtis, V. 2014 Hygiene and health: systematic review of handwashing practices worldwide and update of health effects. *Trop. Med. Int. Health* **19**, 906–916.

Gómez, M., Gomez, S., Kabajuni, A., Kaur, P., King, W. & Ricciardi, V. 2008 *Women, Slums and Urbanisation: Examining the Causes and Consequences.* Centre on Housing Rights and Evictions, Geneva.

Gosling, L., Irvine, C., Schechtman, L. & Velleman, Y. 2015 *Nowhere to Go: How a Lack of Safe Toilets Threatens to Increase Violence Against Women in Slums.* WaterAid Sverige, Stockholm.

Gupta, K., Arnold, F. & Lhungdim, H. 2009 *Health and Living Conditions in Eight Indian Cities* (Report for National Family Health Survey – 3, India, 2005–06). International Institute for Population Sciences, Mumbai.

Halliez, M. C. M. & Buret, A. G. 2013 Extra-intestinal and long-term consequences of *Giardia duodenalis* infections. *World J. Gastroenterol.* **19** (47), 8974–8985.

Hoddinott, J., Alderman, H., Behrman, J. R., Haddad, L. & Horton, S. 2013 The economic rationale for investing in stunting reduction. *Matern. Child Nutr.* **9**(Suppl. 2), 69–82.

House, S., Ferron, S., Sommer, M. & Cavill, S. 2014 *Violence, Gender and WASH: A Practitioner's Toolkit.* WaterAid, London. Available from: http://violence-wash.lboro.ac.uk (accessed 21 January 2016).

Humphrey, J. H. 2009 Child undernutrition, tropical enteropathy, toilets, and handwashing. *Lancet* **374**, 1032–1035.

IDS 2016 *Maximising the Potential of Community-led Total Sanitation*. Institute of Development Studies, University of Sussex, Falmer, Brighton. http://www.ids.ac.uk/project/sharing-lessons-improving-practice-maximising-the-potential-of-community-led-total-sanitation (accessed 24 February 2016).

IHME 2016 *GBD [Global Burden of Disease]* Compare 1990–*2015*. Institute for Health Metrics and Evaluation, University of Washington, Seattle, WA. Available from: http://vizhub.healthdata.org/gbd-compare (accessed 16 November 2016).

Jardim-Botelho, A., Raff, S., Rodrigues, Rde Á., Hoffman, H. J., Diemert, D. J., Corrêa-Oliveira, R., Bethony, J. M. & Gazzinelli, M. F. 2008 Hookworm, *Ascaris lumbricoides* infection and polyparasitism associated with poor cognitive performance in Brazilian schoolchildren. *Trop. Med. Int. Health* **13** (8), 994–1004.

Jenkins, M. W., Anand, A. R., Revell, G. & Sobsey, M. D. 2013 Opportunities to improve domestic hygiene practices through new enabling products: a study of handwashing practices and equipment in rural Cambodia. *Int. Health* **5** (4), 295–301.

JMP 2015a *India: JMP Wealth Quintiles*. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, World Health Organization, Geneva. http://www.wssinfo.org/documents/?tx_displaycontroller[type]=wealth_quintiles (accessed 18 January 2016).

JMP 2015b WASH Post-2015: Proposed Indicators for Drinking Water, Sanitation and Hygiene *(revised edition)*. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, World Health Organization, Geneva.

Kar, K. & Chambers, R. 2008 *Handbook on Community-led Total Sanitation.* CLTS Knowledge Hub, Institute for Development Studies, University of Sussex, Falmer, Brighton.

Mara, D. 2016 Shared sanitation: to include or to exclude? *Trans. R. Soc. Trop. Med. Hyg.* **110** (5), 265–267.

Mbuya, M. N. & Humphrey, J. H. 2016 Preventing environmental enteric dysfunction through improved water, sanitation and hygiene: an opportunity for stunting reduction in developing countries. *Matern. Child Nutr.* **12**(Suppl. 1), 106–120.

Melo, J. C. 2005 *The Experience of Condominial Water and Sewerage Systems in Brazil: Case Studies from Brasília, Salvador, and Parauapebas.* Water and Sanitation Program, World Bank, Washington, DC.

Melo, J. C. 2008 *Sistema Condominial: Uma Resposta ao Desafio da Universalização do Saneamento.* Ministério das Cidades, Brasília.

Menon, S. 2015 *Swachh Bharat Campaign: More Money Down the Drain.* Governance Now (Noida, UP), 10 December. Available from: www.governancenow.com/news/regular-story/more-money-drain (accessed 18 January 2016).

Ministry of Local Government, Rural Development and Co-operatives 2016 *Bangladesh Country Paper*. Report presented at the Sixth South Asian Conference on Sanitation (SACOSAN-VI), 11–13 January, Dhaka. Available from: www.sacosanvi.gov.bd/data/frontImages/Bangladesh_Country_Paper.pdf (accessed 15 November 2016).

Modi, N. 2014a *Prime Minister Narendra Modi's Speech on 68th Independence Day at Red Fort, 16 August*. Available from: www.narendramodi.in/text-of-pms-speech-at-red-fort-2 (accessed 18 January 2016).

Modi, N. 2014b *Text of Prime Minister, Shri Narendra Modi, at the launch of Swachhata Mission, 2 October*. Available from: www.narendramodi.in/text-of-prime-minister-shri-narendra-modi-at-the-launch-of-swachhata-mission-2872 (accessed 18 January 2016).

Moore, S. R., Lima, A. A. M., Conaway, M. R., Schorling, J. B., Soares, A. M. & Guerrant, R. L. 2001 Early childhood diarrhoea and helminthiases associate with long-term linear growth faltering. *Int. J. Epidemiol.* **30** (6), 1457–1464.

Morgan, P. 2004 *The Arborloo Book: How to Make A Simple Pit Toilet and Grow Trees or Make Humus for the Garden.* Stockholm Environment Institute, Stockholm.

Neal, D., Vujcic, J., Burns, R., Wood, W. & Devine, J. 2016 *Nudging and Habit Change for Open Defecation: New Tactics From Behavioral Science.* Water and Sanitation Program, World Bank, Washington, DC.

Newman, A., Smets, S. & Kov, P. 2014 *Making Toilets More Affordable for The Poor Through Microfinance.* Water and Sanitation Program, World Bank, Washington, DC.

Nokes, C., Grantham-McGregor, S. M., Sawyer, A. W., Cooper, E. S., Robinson, B. A. & Bundy, D. A. P. 1992 Moderate to heavy infections of *Trichuris trichiura* affect cognitive function in Jamaican school children. *Parasitology* **104** (3), 539–547.

Padhi, B. K., Baker, K. K., Dutta, A., Cumming, O., Freeman, M. C., Satpathy, R., Das, B. S. & Panigrahi, P. 2015 Risk of adverse pregnancy outcomes among women practicing poor sanitation in rural India: a population-based prospective cohort study. *PLoS Med.* **12** (7), e1001851.

Partovi, F., Khalili, G., Kariminia, A. & Mahmoudzadeh-Niknam, H. 2007 Effect of *Giardia lamblia* infection on the cognitive function of school children. *Iran. J. Public Health* **36** (1), 73–78.

Perez, E. 2012 *What Does It Take to Scale Up Rural Sanitation?* Water and Sanitation Program, World Bank, Washington, DC.
Pullan, R. L., Smith, J. L., Jasrasariaand, R. & Brooker, S. J. 2014 Global numbers of infection and disease burden of soil transmitted helminth infections in 2010. *Parasit. Vectors* **7**, 37.
Sanan, D. & Moulik, S. G. 2007 *Community-Led Total Sanitation in Rural Areas: An Approach That Works.* Water and Sanitation Program – South Asia, World Bank, New Delhi.
Spears, D. 2013 *How Much International Variation in Child Height Can Sanitation Explain?* (Policy Research Working Paper No. 6351). World Bank, Washington, DC.
Spears, D. & Haddad, L. J. 2015 *The Power of WASH: Why Sanitation Matters for Nutrition*. In: 2014–*2015 Global Food Policy Report*, pp. 19–23. International Food Policy Research Institute, Washington, DC.
Sy, J., Warner, R. & Jamieson, J. 2014 *Tapping the Markets: Opportunities for Domestic Investments in Water and Sanitation for the Poor.* World Bank, Washington, DC.
Tiwaril, M. 2016 UP villagers prefer open fields, raze Swachh loos. The Times of India, New Dehli, 14 January. http://timesofindia.indiatimes.com/city/bareilly/UP-villagers-prefer-open-fields-raze-Swachh-loos/articleshow/50582495.cms (accessed 6 February 2017).
UNDESA 2015 *World Population Prospects: The 2015 Revision – Data Booklet.* United Nations Department of Economic and Social Affairs, Population Division, New York, NY.
UN-Habitat 2015 *Slum Almanac 2015–2016: Tracking Improvement in the Lives of Slum Dwellers*. United Nations Human Settlements Programme, Nairobi.
UNICEF 2015 *Child Nutrition Interactive Dashboard – 2015 Edition*. UNICEF, New York, NY. Available from: http://data.unicef.org/resources/child-nutrition-interactive-dashboard-2015-edition.html (accessed 18 January 2016).
United Nations General Assembly 2015 *Transforming Our World: The 2030 Agenda for Sustainable Development* (Document A/RES/70/1, 21 October). United Nations, New York, NY.
Vyas, S., Spears, D., Kov, P. & Smets, S. 2013 *Investing in the Next Generation: Growing Tall and Smart with Toilets – Stopping Open Defecation Improves Children's Height in Cambodia.* Water and Sanitation Program, World Bank, Washington, DC.
WaterAid India 2008 *Feeling the Pulse: A Study of the Total Sanitation Campaign in Five States*. WaterAid India, New Delhi.
Wechsler, D. 1974 *Wechsler Intelligence Scales for Children – Revised.* Psychological Corporation, Harcourt Brace Jovanovich Inc., San Antonio, TX.
WHO 2014 *Preventing Diarrhoea through Better Water, Sanitation and Hygiene: Exposures and Impacts in Low- and Middle-Income Countries*. World Health Organization, Geneva.
WHO 2015 *Child Growth Standards: Length/height for Age*. World Health Organization, Geneva. Available from: www.who.int/childgrowth/standards/height_for_age/en/ (accessed 17 January 2016).
WHO 2016 *Soil-Transmitted Helminth Infections* (Fact sheet). World Health Organization, Geneva. Available from: www.who.int/mediacentre/factsheets/fs366/en/# (accessed 9 March 2016).
WHO/UNICEF 2012 *Progress on Drinking Water and Sanitation: 2012 Update*. Joint Monitoring Programme for Water Supply and Sanitation, World Health Organization, Geneva.
WHO/UNICEF 2015 *Progress on Sanitation and Drinking-water – 2015 Update and MDG Assessment*. Joint Monitoring Programme for Water Supply and Sanitation, World Health Organization, Geneva.
WIN-SA 2006 *eThekwini's Water and Sanitation Programme* (Lessons Series No. 2). Water Information Network – South Africa, Pretoria.
WSP 2016 *Sanitation Marketing Toolkit*. Water and Sanitation Program, World Bank, Washington, DC. Available from: https://wsp.org/toolkit/toolkit-home (accessed 17 November 2016).
WSP/MDWS 2014 *Pathway to Success: Compendium of Best Practices in Rural Sanitation*. Water and Sanitation Program, World Bank and Ministry of Drinking Water and Sanitation, New Delhi.

First received 2 February 2016; accepted in revised form 17 December 2016. Available online 4 February 2017