The public health benefits of urban sanitation in low and middle income countries

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Abstract

A review of the so-called “non-health” benefits of urban sanitation shows them to be important indicators of human wellbeing, and more important to the householder than those which benefit health in the narrower sense of preventing disease. The health benefits are surprisingly difficult to measure, but recent advances suggest that they are greater than previously thought.

Keywords: Sanitation health excreta

1 Defining interventions and benefits

Before we consider the relationship between sanitation and public health, we need to define what we mean by health and also by sanitation. “Sanitation” in many contexts is taken to include not only excreta disposal but also a broad range of environmental health measures including water supply, drainage, solid waste management, and even mosquito vector control. In this paper, the word ‘sanitation’ is used in its narrow sense of excreta disposal.

However, I believe there is insufficient recognition of the fact that environmental health interventions have multiple outcomes, and so I shall include what are sometimes called the “non-health” benefits of sanitation, although it could be argued that some of them are indeed beneficial to health. All of them represent contributions which sanitation can make towards human well-being, beyond the simple reduction of cases of infectious disease.

These other dimensions to the benefit of sanitation include comfort, convenience, privacy, security, social status and aesthetic benefits. To some extent they can be summed up by the word dignity. The owners and users of domestic sanitation are usually more acutely conscious of these benefits than they are of any improvement to their health which sanitation might bring. Many of the diseases related to poor sanitation have chronic, insidious and diffuse effects, such as the anaemia caused by ~~b~~hookworm; others, such as diarrhoea, occur only periodically and few people can remember whether they had more episodes or fewer in the last year compared with previous years. The end result is that most people do not notice if their health improves as a result of improvements in sanitation. They also often lack the knowledge of disease causation and transmission to see a link. By contrast, they will certainly notice if, after years of defecation in the open after dark, they are able to practi~~c~~se it in a secure private cubicle with a roof.

2 Gender

There is a strong gender dimension to these “non-health” benefits. In many settings, women are under strong social pressure not be seen relieving themselves, or even going to the place where they will relieve themselves or returning from it. This can mean that they are effectively imprisoned by daylight, obliged to wait until dark before venturing out. That wait can itself lead to secondary health hazards such as urinary tract infections. It is not only shame and a sense of propriety that drive women's behaviour here, but frequently they are exposed to harassment and a very real risk of assault, rape and even murder. In recent years there have been a number of accounts in the international news media of the murder of young women in India who were on their way to a defecation area.

2.1 Gender-based violence

The risk of gender-based violence associated with defecation is not limited to backward rural areas. It has been found almost everywhere people have looked; around community toilets in urban areas in Nairobi, Kenya (Anon, 2010), in Kampala, Uganda and in a number of cities in India (Sommer et al., 2014). For example, Biran et al. (2011) found in Bangalore that usage of community toilet blocks by males was double that by females, although the population served was evenly divided by gender. Female usage was found to fall off very sharply with distance from the home, and female residents confirmed that the reason for their low usage was the risk of harassment and assault. The pattern was the same, whatever the arrangements made for the management of the toilet block.

It is not yet clear whether the presence of the sanitation facilities increases the amount of gender violence, or whether they simply precipitate a tendency which is latent in the culture. A general toolkit to help local organizations to address the problem has been produced by 28 humanitarian and development organizations led by WaterAid (House et al., 2014), but it is based more on reasoned extrapolation than documented managerial experience.

What is needed now is to test the claims of a few veteran Indian NGOs to have almost vanquished the problem by mobilising the local community to provide security. If they are substantiated, they should be documented and the NGOs asked to provide training to staff of some of the other NGOs promoting shared, communal or collective sanitation.

Sanitation is important to women, not only at home but also at school. When school toilets are absent, insufficient in number, poorly maintained, or lacking in privacy, girl pupils will be reluctant to use them. On the other hand, toilets become all the more necessary as puberty brings the need for a private space for menstrual hygiene management. Whatever the reason why a girl needs a toilet at school, if it is not available to her she is likely to go home. She is unlikely to return to school that day, and the next day she will have the added difficulty of catching up and possibly the embarrassment of explaining her absence. It is little wonder that for these reasons girls are more likely to be absent from school than boys, and ultimately more likely to drop out of school completely. There is a body of anecdotal evidence that schools sanitation can significantly increase female enrolment and attendance (Bartram and Cairncross, 2010). Few curriculum improvements could obtain that result.

2.2 Significance of “non-health” benefits

Few would dispute that the prevention of violence and the education of women contribute towards public health, in which case “non-health benefits” is a misnomer. However, these factors are often neglected by sanitation planners by comparison with the importance given to conventional definitions of health benefit. Even if conventional benefits such as the reduction of episodes of diarrhoea, and of the prevalence of intestinal worms are uppermost in the minds of decision-makers, it is essential to remember that they will not count for much in the minds of local people, in persuading them to adopt sanitation (Cairncross, 1992; Jenkins, 1999).

In order to reach the sustainable development goals for the coming decades, sanitation programs will have to leverage the investment of individual households, at least in the low income countries. In order to develop that process, we need to learn much more about what makes sanitation attractive to ordinary people. Studying the so-called “non-health” benefits is a step in that direction.

3 Health benefits

The following example should help to illustrate the way sanitation-related pathogenic organisms are collected in a sewerage system. Imagine a typical tropical town in a low income country. Unusually, all the households are connected to the town sewerage system. Table 1 shows in the left-hand column a list of typical pathogens found in faeces, and the next column shows a typical prevalence for each pathogen. That is, the proportion of the population which is infected with it. The next column shows the results of clinical studies of infected people, in which the number of organisms of the pathogen per gram of faeces is multiplied by the typical daily faecal weight of about 200 g to give the total number excreted daily.

Table 1 Possible concentration of pathogens in wastewater from a tropical town.

alt-text: Table 1

Source: *Feachem et al. (1983).*

Pathogen	Prevalence of infection (%)	Total daily per infected person	Concentration per litre of sewage[a]
Enteroviruses	5	10^8	5000
Salmonella	7	10^8	7000
Shigella	7	10^8	7000
Vibrio cholerae	1	10^8	1000
Entamoeba histolytica	30	10^7	3000
Ascaris	60	10^6	600
Hookworms	40	10^5	40
S. mansoni	25	4×10^3	1
Taenia saginata	1	10^6	10
Trichuris	60	2×10^5	120

[a] Assumes 90% die-off in sewer system, septic tanks etc.

3.1 “Sanitary hydrology”

Now we estimate the quantity of waste water produced per person as roughly equal to their water consumption. If everybody is connected to the sewer system, they must be also connected to the water supply; otherwise the sewer system would not function. From that we deduce a water consumption (or at least a wastewater production) of about 100 L per person per day. We divide the total number of pathogens by the total volume of wastewater to obtain the concentration of the pathogens in the wastewater. For example, with a cholera prevalence of about 1%, and the daily production of 10^8 vibrios per infected person, we would expect a concentration of 10^6 in sewage produced by an infected person, and hence of 10^4 in sewage from the population as a whole. There is a final adjustment to make; it is estimated that roughly 90% of the excreted pathogens do not pass through the sewer system (Feachem et al., 1983). The bacteria and viruses tend to die along the way, and the worm eggs tend to be removed by sedimentation, particularly if there are septic tanks between the households and the sewer network. With this adjustment, we estimate a concentration of 10^3 vibrios per litre, which corresponds to the value in the table. To summarise:

Cholera vibrios~~*Cholera vibrios*~~

Number per infected person 10^8 per patient.

D~~d~~ivided by water consumption 10^6 per contaminated litre.

A~~a~~djusted for prevalence 10^4 per litre overall in house.

A~~a~~djusted for die-off in sewers 10^3 per litre overall in sewer.

The results were reported in the last column of Table 1. Looking down the list, there are several points to be made. First, though the calculation and underlying assumptions were rough and ready, the results are borne out by studies of the microbiology of wastewater (e.g. Mara and Silva, 1986). Second, they show that wastewater is highly infectious material. These are not figures for a cholera hospital or the effluent from an infected household. These are averages for the community as a whole, and they show how the sewer system draws together all the pathogens which may be present in the community. Third, the figures for viruses and bacteria are higher than those for intestinal worm parasites; this is partially countered by the larger infectious dose for the viruses and bacteria. Fourth, these figures are for wastewater which has typically been settled, at least in a septic tank, and so is likely to be almost transparent. Clarity or turbidity of the wastewater is no guide to its infectiousness.

3.2 The Bradley classification of excreta-related diseases

From that initial crude model, we can move on to a classification of sanitation-related diseases (Feachem et al., 1983) which discriminates those on which sanitation has a greater and lesser impact. In order to do this, we need to introduce a number of conceptual refinements. The first is to distinguish among faecal oral infections (often called the diarrhoeal diseases) between those with relatively high infectious doses (mainly bacterial) and those with relatively low ones (mainly viral or protozoal). The lower infectious dose pathogens are more likely to be transmitted in relatively hygienic environments anyway, and therefore are less affected by the presence or absence of excreta disposal facilities.

3.3 Animals

There is another factor which can reduce the effect of sanitation on the bacterial faecal-oral diseases. Many of the bacterial diarrhoeal diseases have animal reservoirs in addition to the human host; examples include Campylobacter, the Salmonella family, and *E. coli*~~*E. coli*~~ 0157. These pathogens are transmitted by humans and animals in parallel, with all combinations permitted; human-animal, human-human, animal-animal and animal-human (Fig. 1, transmission in parallel).

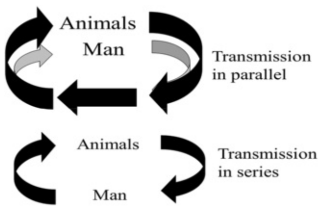

Fig. 1 Role of animals in disease transmission (a) in parallel (b) in series.

alt-text: Fig. 1

Hygienic disposal of human excreta will have little impact on such pathogens if animal excreta still pollute the environment. On the other hand, the tape worms are transmitted by humans and animals in series (Fig. 1, transmission in series), so that animals must be in contact with human excreta and people must eat affected meat from the animals for the disease to continue.

Cutting the cycle at any point can eliminate the disease. On the other hand, the water-based worms such as schistosomiasis (bilharzia) multiply many times in their aquatic snail host, so that a single person defecating near water may infect enough snails to give schistosomiasis to the whole village. Sanitation could help to control the disease, but only if used conscientiously and by the entire population; the species of schistosomiasis found in East Asia is also found in various animals, so that here too, the disposal of human excreta has little impact on the disease while animals' excreta are still deposited at random.

One might well ask what this has to do with health in urban areas. The answer is that in low income countries, animals are common in urban areas, from the sacred cows of India to the chickens found in almost any shanty town worldwide.

4 How much disease can sanitation prevent?

By consideration of such biological factors and the importance of other transmission routes, Feachem et al. (1983) derived the classification of excreta-related diseases in Table 2. In each cell on the left side of the Table, there is a category of excreta-related pathogen. The constraint on rapid transmission of each arises from different biological factors.

Table 2 The Bradley classification of excreta-related infections.

alt-text: Table 2

Source: Feachem et al. (1983).

Disease group	Impact of sanitation
Non-bacterial faeco-oral	Negligible
Bacterial faeco-oral:	Slight to moderate
Soil-transmitted worms	Great
Beef & pork tapeworms	Great
Water-based worms	Moderate
Insect vector (flies, cockroaches)	Slight to moderate

Even if we discount the role of animals in faecal contamination of urban residential areas, there is a bewildering variety of transmission routes for faecal-oral infections, as illustrated by the aptly-named F diagram (Fig. 2). Nevertheless, the logic of the diagram suggests that sanitation might have greater impact than water supply and hygiene interventions, because it acts upstream of those others, protecting the environment from contamination by excreta rather than protecting potential future hosts from infection by an already contaminated environment. On the other hand, if other routes can be shown to be involved in a certain proportion of the transmission of the same diseases, it follows that this proportion at least is not associated with sanitation. For example, two community intervention studies, one in Asia and one in Africa, showed that 23% and 26% of diarrhoea respectively was transmitted by flies (Chavasse et al., 1999; Emerson et al., 1999). Similarly, a systematic review (Curtis and Cairncross, 2003) found that handwashing with soap was associated with an incidence of diarrhoea in young children which was 47% lower than otherwise.

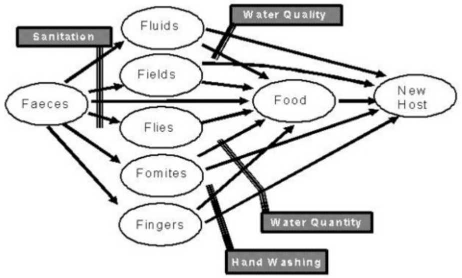

Fig. 2 The F diagram.

Note: The F-diagram shows the main transmission routes (ovals) for faecal-oral infections, and the role of water, sanitation and hygiene interventions (rectangles) in blocking those routes.

Source: adapted from Wagner and Lanoix (1958).

alt-text: Fig. 2

Taken together, those results would suggest that more than 70% of diarrhoeal disease is transmitted by one or another of those two routes, leaving less than 30% to be transmitted by other means. While transmission by the waterborne route is often overestimated (Schmidt and Cairncross, 2009), there is some reason to believe that transmission attributable to a lack of adequate sanitation is more significant than these data seem to imply.

First, it is not certain that the impacts of water supply, sanitation, fly control etc. add together. As mentioned above, sanitation acts upstream of most other environmental interventions. For example, if latrines prevent flies from having contact with excreta, they will reduce transmission by the fly-borne route as well as by reducing human contact with excreta.

Second, the *a priori* classification by Feachem et al. (1983) has sometimes been proved inaccurate when compared to real data. For example, Table 3 shows the four most important risk factors for Giardia infection in children aged 2–45 months in Salvador da Bahia, Brazil. According to the classification in Table 2, Giardia with its low infectious dose would be expected to show only “slight to moderate” reductions arising from sanitation improvements, but in practice two of the most significant risk factors (the bottom two rows in Table 3) relate to problems with sanitation. This suggests a closer link than “slight to moderate” between giardiasis and a lack of sanitation.

Table 3 Four most significant risk factors for Giardia infection in young children; Salvador da Bahia, Brazil.

alt-text: Table 3

Source: *Prado et al. (2003) Epidemiol. Infect. 131(2): 899-906*

Risk factor	Odds Ratio (95% CI)
Nº of children in family < 5 years	2.08 (1.32–3.27)
Solid waste not collected	1.97 (1.22–3.16)
Presence of visible sewage near house	1.85 (1.16–2.96)
Absence of a toilet	2.51 (1.33–4.71)

Third, most people's expectations of health impacts of environmental measures are based on the influential reviews by (Esrey et al. (1991), See Fig. 3), although many weaknesses were noted in the studies reviewed. In particular, most of the studies on sanitation were in fact studies of water supply ***and*** sanitation; they were used to estimate the benefits from water supply and also from sanitation. Sometimes the benefits for water supply and sanitation are eerily similar; this is not surprising, because often they are from the same study. Similarly, the impacts from water supply and sanitation combined appear not to be any larger than the greater of the two individually; here also it is likely that we have one set of studies compared with itself.

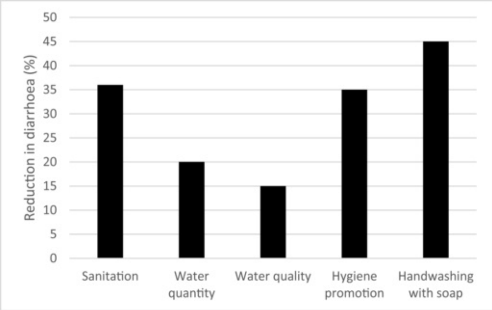

Fig. 3 Effects of improved water supply, sanitation and hygiene on diarrhoea in young children according to reviews around the turn of the century.

Sources: Sanitation and water supply: Esrey et al. (1991); Hygiene promotion: Huttly et al. (1997); Handwashing with soap Curtis and Cairncross (2003).

alt-text: Fig. 3

5 Confounding

Until the beginning of this century, when the Bill and Melinda Gates foundation first began to fund randomised intervention studies of sanitation, practically all studies of the subject were in fact quasi-experimental comparisons – what epidemiologists call observational, as opposed to intervention studies. For such studies to be valid, the exposure groups – those with and without sanitation respectively – must be comparable in other respects. In practice, households which own a latrine are likely to be different in many ways from those which do not. They are likely to be richer, better educated, more open to change and more conscious of hygiene. All of these factors are likely to be associated with better health. Since they are usually a self-selected exposure group (Coronary Drug Project Research Group, 1980), a study of the health impact is likely to be confounded in ways it is impossible to control.

This can be illustrated with two sets of data, one from Bangladesh (Table 4) and the other from Brazil.

Table 4 ‘Determinants’ of good hand washing among 90 rural Bangladeshi women.

alt-text: Table 4

Source: Hoque et al. (1995).

	Observed hand washing behaviour after defecation		
	Good	Poor	Rel. rate (95% CI)
Own sanitary latrine used			
yes	22	11	1.73 (1.15–2.59)
no	22	35	
Owns agricultural land			
yes	36	24	2.25 (1.20–4.22)
no	8	22	
Believes that washing hands prevents diseases			
yes	26	27	1.01 (0.66–1.55)
no	21	18	

In the Bangladesh study (Hoque et al., 1995), 90 rural women were observed washing their hands after defecation. They were scored on how thorough their practice was; for instance, whether they used soap and whether they rubbed their hands together. They did not know this was an objective of the experiment. Few would be surprised to see that women in households which owned a latrine were more likely to wash their hands thoroughly. Nor is it surprising that women from wealthier land-owning households were also more likely to wash their hands thoroughly. What is surprising is that a woman's belief that handwashing protects her family's health seems to have no effect whatever on her handwashing practice!

The Brazilian study (Strina et al., 2003), in an urban setting but with similar design, had similar results. If a child's comforter fell on the floor, latrine-owning mothers were more likely to wash the comforter before returning it to the child; mothers lacking a latrine were more likely to return the comforter straight to the child's mouth. The point is that latrine ownership did not cause a preoccupation with hygiene; rather, their preoccupation with hygiene impelled some families to install a latrine.

Let the reader who is still unconvinced of the importance of confounding consider the likely result of a study of ownership of televisions or air fresheners and diarrhoea. They would almost certainly appear to show that families with televisions and air fresheners suffer from less diarrhoea, although there is no evidence that a TV or an air freshener can protect anyone from food poisoning!

5.1 The travail of trials

Most observers of the field had long reached the conclusion that more rigorous studies (such as randomised controlled trials) of the health benefit of sanitation were unlikely to appear for many years, if ever. It was too expensive to provide hundreds of people with latrines at random, and monitor their diarrhoea for a year at least. Such studies were likely to cost millions of dollars, and to be ruled unethical if not. They also required a heroic effort on the implementation of the intervention with a view to being able to say, if little or no benefit was found, that the fault was in the intervention and not in the experimental design.

The involvement of the Bill and Melinda Gates Foundation changed all that; with other funding agencies such as the World Bank running at their heels, they reversed a long-held antipathy to the sanitation sector and planned to invest substantial amounts in sanitation programmes, ~~but~~ and also into testing the belief that sanitation could reach a high cost-benefit ratio. Then the results of the first two trials arrived almost simultaneously (Clasen et al., 2014; Patil et al., 2014). Both were in rural India, and both failed to detect any substantial health effect, but this result is not surprising when one realises that the intervention in one trial reduced the rate of adult open defecation by no more than 10%, and that in the other, while women and children used the new toilets, the example was not followed by most men. Focussing all their attention on the conduct and rigour of their trial, the researchers had neglected the substantial challenge of designing and implementing an effective intervention in this field. Lest anyone should conclude that rural Indian society is too conservative for successful behaviour change, an excellent example of just such a success was published in the same year (Biran et al., 2014). Working in rural India with limited resources, they increased the proportion of local people who regularly washed their hands with soap after defecation and before handling food from 2% to 37% or more.

A compromise solution to the dilemma of measuring health impact of sanitation is to conduct a quasi-experimental study where the decision to install sanitation was taken, not at the level of individual households, but at the level of communities. This has some logic because of the externalities involved; ***my*** latrine protects ***my*** neighbours from ***my*** excreta; it does not protect ***me*** from ***theirs***. It may protect me from my own excreta, but that is of little public health impact because pathogens are likely to be passed among family members anyway. This was the approach taken by Moraes et al. (2003), who compared three groups of three favelas in Brazil.

5.2 ~~2.~~ Moraes; comparing favelas in Brazil

With the transition from military rule to municipal democracy in the 1980s, the city administration of Salvador da Bahia, Brazil had designed a low-cost drainage intervention to prevent the frequent flooding of low-lying communities with faecally contaminated surface water. The covered drainage channels also served as walkways allowing access to the community by emergency services and others, and the flood prevention marked a significant improvement in the residential environment. The three communities with drains alone were among those most closely connected to the politicians and which were among the first to lobby for this improvement. Those which moved a little more slowly had time to notice that many residents were connecting their toilets to the drains, turning them into open sewers. They were the luckiest, as the engineers agreed to their request for drains ***and*** sewers. Finally, the least savvy and well-connected were at the back of the queue when the money for the project ran out and the politicians had to stand down for the next election. Of course, the engineers had other criteria, such as the possibility of access to the neighbourhood by construction machinery. Altogether, Moraes & al. argued that the result of the process was a sort of “politico-administrative randomisation.” Ranking the three groups of favelas in order of their political influence, we have:

1. Drains
2. Sewers and drains
3. No intervention; control

When Moraes et al. (2003) examined the effect of sanitation on diarrhoea incidence within individual households, after controlling for confounding by a number of other risk factors, they found that the lack of a household toilet was associated with a risk of diarrhoea in young children which was double that in their peers who had toilets. This analysis is likely to suffer from some confounding, not all of which can be controlled, as mentioned above. It is therefore of some interest that when the data were analysed by comparing neighbourhood intervention groups (2 versus 3 above) so that confounding was less likely, the ratio of diarrhoea risk between the two extreme groups (Drains and sewers versus no intervention) was not two to one, but three to one.

Thus, the risk of diarrhoea showed a stronger association with an ecological variable (the infrastructure in one's neighbourhood) than with a household variable (ownership of a toilet). This is to be expected in view of the externalities mentioned in Section 5.1.

Moreover, this relatively large ratio would suggest that sanitation has much greater impact on people's health than had previously been supposed.

5.3 The big project; before and after

That this was the case in Salvador, where coverage with on-plot water connections was already well above 90%, is significant because it strongly contradicts many people's interpretation of the influential review by Esrey et al. (1991). Esrey had suggested that either water or sanitation can produce health benefits but together they would not produce more (Section 3.3 above). In Salvador, with almost complete water supply coverage, the addition of sanitation seems to offer benefits much larger than the Esrey review suggested.

However, Moraes' study remains an observational study, and therefore particularly susceptible to confounding. An intervention study provides more robust evidence of an association (e.g. between sanitation and health) and so is always preferable. An opportunity to carry one out arose a few years later in the same city when a right-wing government leveraged US$440 million for a citywide sanitation programme. In the process of this seven year long sewerage construction programme, the proportion of the city's 2.4 million population with access to sewers increased from 26% to 80%.

Researchers at the Federal University of Bahia rose to the challenge. They conducted two large cohort follow-up studies of young children, one before and one after the construction project. Each included nearly 1000 children under five, who lived in 24 sentinel areas chosen to represent conditions around the city, and who were followed for nearly a year. The results are shown in Table 5. To summarise:

- Diarrhoea rates had fallen by 21% overall, and by twice that in the areas of the city with the highest initial risk of diarrhoea;
- Adjustment for confounders hardly alters this, thus confirming the finding;
- Adjustment for the proportion of households with project sewers in the neighbourhood made the effect disappear; adjusted PR ~1.0.

Table 5 Diarrhoea Prevalence Ratios (PR) after/before the intervention.

alt-text: Table 5

Source: Barreto et al. (2007).

	Total population	Areas with high baseline risk[a]
Prevalence ratios (PR) after/before project	PR (95% CI)	PR (95% CI)
Unadjusted	0.79 (0.75–0.82)	0.58 (0.55–0.61)
Adjusted for baseline sewerage and confounders	0.78 (0.74–0.81)	0.57 (0.54–0.61)
Adjusted as above, and for neighbourhood coverage with project sewers	1.02 (0.90–1.16)	1.02 (0.90–1.16)

Note that: Percentage reduction in diarrhoea = (1–PR) x 100.

[a] 12/24 study neighbourhoods > 8 diarrhoea days/child. (In footnote to Table 5, delete period after "child".)-year.

Of course this did not mean that the impact was not real; only that the variation in the impact between different parts of the city could be explained by the variation in coverage with sewers.

The outcomes measured by the researchers were not limited to diarrhoeal disease. They also included intestinal parasites; Ascaris, Trichuris and Giardia. After controlling for confounders, these showed reductions in prevalence of 50%, 66% and 60% respectively (Barreto et al., 2010). Controlling for spatial variation in project inputs diminished the effect, demonstrating that the effect was greater where the project had been more thoroughly implemented.

6 Defeating poverty as well as disease

The data from the cohort studies were subjected to a hierarchical effect decomposition strategy, allowing investigation of the extent to which distal variables were mediated by more proximal ones with regard to their effect on disease risk (Genser et al., 2008). By adjusting the outcome variable for each intermediate variable, and putting the adjusted and unadjusted Prevalence Ratio into the following formula, one could derive a figure for the proportion of the overall association which was mediated by each intermediate variable:

Mediating Proportion = $(PR_{adj}-PR_{unadj})/(1-PR_{unadj})$

where PR_{adj} and PR_{unadj} referred to adjusted and unadjusted prevalence ratios respectively.

The data from before the intervention showed a close association between poverty and disease; socio–economic status accounted for 23% of the variance in the risk of diarrhoea, with the lion's share mediated by the complex of variables termed, "Neighbourhood infrastructure, sanitation and living conditions." The pattern of mediation is shown in Fig. 4(a) where the thickness of each vertical bar is proportionate to the proportion mediated of the association between diarrhoea risk and socioeconomic status (In Fig 4, the A and B to label the two figures should be in lower case.).

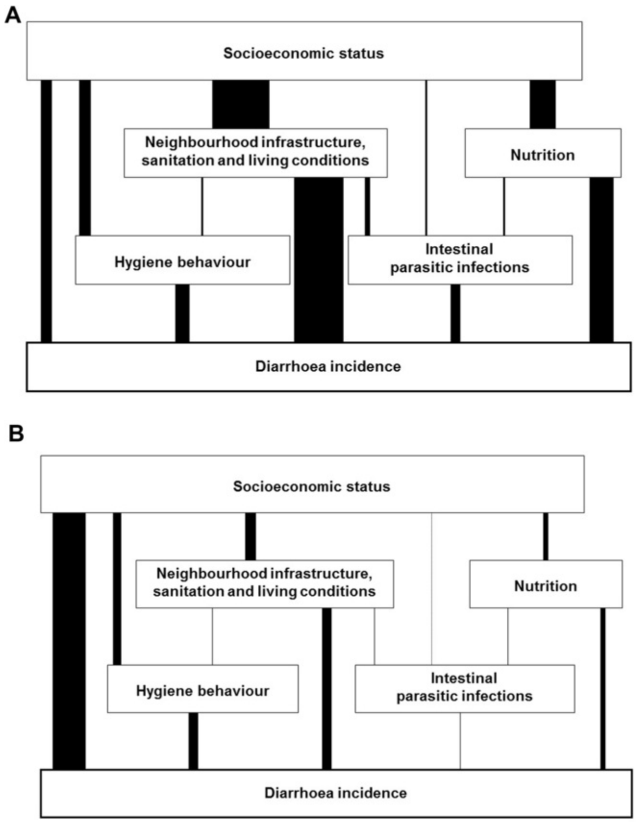

Fig. 4 (a) Intermediate variables in Salvador da Bahia before implementation of the sanitation project. (b) The same analysis performed on the data collected after completion of the intervention.

Source: Bartram and Cairncross (2010); data from Genser et al. (2008).

alt-text: Fig. 4

It is not difficult to interpret the story. If you were poor in Salvador da Bahia, you could only afford to live in an area where infrastructure was lacking and deficient, sanitation was absent and living conditions were a health hazard; it is not surprising that your children suffered from frequent bouts of diarrhoea.

Socioeconomic status predicted 23% of the variance in diarrhoea risk, mostly through the neighbourhood infrastructure and living conditions. The thickness of each vertical bar is proportional to the proportion of the overall association which is mediated by that route.

Now, if we turn to the same analysis performed after the completion of the project, the difference is quite striking.

Fig. 4(b) shows the rather different pattern found after the sanitation project had been implemented. Now, socioeconomic status predicted only 11% of the variance in diarrhoea risk, halving the strength of the association, and the mediating role of neighbourhood infrastructure, sanitation and living conditions has almost vanished. Factors other than poverty now determine who has access to sanitation infrastructure, and who gets most diarrhoea; for instance, some relatively well-off households may live on the wrong side of a hill, precluding the installation of a connection to the main sewer network. Hygiene behaviour still plays a role, as does nutrition, but both are considerably reduced. Provision of services to the mass of the population makes it harder to think of them as “the great unwashed”. Sanitation offers “non-health” benefits which prove, on examination, to be significant indicators of wellbeing, as we saw earlier in this paper. As can be seen from this concluding example, a close examination of the health benefits shows effects going well beyond a narrow biological concept of health, helping to undermine the stigma which attaches to the poor by the linking of poverty and disease.

7 Concluding remarks

Analysis of the diverse benefits arising from urban sanitation projects can be complex, but that is not an excuse to ignore them. In low and middle income countries, sanitation can transform people's lives – indeed it can save people's lives and make them worth living. Economists have usually focussed their attention on the costs of sanitation, rather than its benefits. This needs to change, particularly in view of the demonstrable externalities of the sector, and the increasing reliance by governments and municipalities upon leveraged investment by the households themselves, rather than on more conventional sources of municipal finance.

We also still have much to learn about how to promote sanitation in urban environments, on a countrywide scale. A case study of the difficulties is provided by Jiménez et al. (2014). Various approaches have been proposed and endorsed, such as Community-Led Total Sanitation (www.clts.org) and Community Health Clubs (www.africaahead.org), but it is more useful to see them as options, each suitable for different conditions, than as rivals. Most of them share a dependence on thorough training of field staff, a tendency to become less effective when scaled up, and to emphasise adoption of sanitation over the need for maintenance, repair and replacement to ensure sustainable use.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jup.2018.03.001.

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Appendix A. Supplementary data

The following is the supplementary data related to this article:

Multimedia Component 1

Data profile

alt-text: Data profile

Highlights

- Ecological variables (relating to the whole area) show more impact than household variables. (The first bullet should be split in two, after "variables") The impacts are much greater than those ~~(e.g. diarrhoea reduction by about 36%)~~ suggested in the systematic reviews by Esrey et al. (1991).
- Excreta-related diseases can affect children's physical and cognitive development.
- We know very little about how these infections and outcomes interact.

Queries and Answers

Query: Highlights should only consist of "125" characters per bullet point, including spaces. The highlights provided are too long; please edit them to meet the requirement.
Answer: Ecological variables (relating to the whole area) show more impact than household variables.
The impacts are much greater than those suggested in the systematic reviews by Esrey et al. (1991).
Excreta-related diseases can affect children’s physical and cognitive development.
We know very little about how these infections and outcomes interact.
Attachments: Highlights.docx

Query: Please check the paragraphs below "Cholere vibrios" and correct if necessary.
Answer: Done

Query: Please check the layout of Table 4 and correct if necessary.
Answer: Done

Query: Please check the figure caption 4 and correct if necessary.
Answer: Labels a and b for the two parts of the Figure should be in lower case, and preferably in brackets.

Query: Please confirm that given names and surnames have been identified correctly and are presented in the desired order and please carefully verify the spelling of all authors’ names.
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