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Behaviour change intervention to improve shared toilet maintenance and cleanliness in urban slums of Dhaka: a cluster-randomised controlled trial†

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Abstract

OBJECTIVES Shared toilets in urban slums are often unclean and poorly maintained, discouraging consistent use and thereby limiting impacts on health and quality of life. We developed behaviour change interventions to support shared toilet maintenance and improve user satisfaction. We report the intervention effectiveness on improving shared toilet cleanliness.

METHODS We conducted a cluster-randomised controlled trial among users of 1226 shared toilets in 23 Dhaka slums. We assessed baseline toilet cleanliness in January 2015. The six-month intervention included provision of hardware (bin for solid waste, 4 l flushing bucket, 70 l water reservoir), and behaviour change communication (compound meetings, interpersonal household sessions, signs depicting rules for toilet use). We estimated the adjusted difference in difference (DID) to assess outcomes and accounted for clustering effects using generalised estimating equations.

RESULTS Compared to controls, intervention toilets were more likely to have water available inside toilet cubicles (DID: +4.7%, 95% CI: 0.2, 9.2), access to brush/broom for cleaning (DID: +8.4%, 95% CI: 2, 15) and waste bins (DID: +63%, 95% CI: 59, 66), while less likely to have visible faeces inside the pan (DID: −13%, 95% CI: −19, −5), the smell of faeces (DID: −7.6%, 95% CI: −14, −1.3) and household waste inside the cubicle (DID: −4%, 95% CI: −7, −1).

CONCLUSIONS In one of few efforts to promote shared toilet cleanliness, intervention compounds were significantly more likely to have cleaner toilets after six months. Future research might explore how residents can self-finance toilet maintenance, or employ mass media to reduce per-capita costs of behaviour change.

keywords behaviour change, shared toilet, cleanliness, sanitation, urban slum, Bangladesh

Introduction

Access to improved sanitation is increasing in urban slums [1, 2], and this progress improves quality of life [3]. However, interventions to increase this access do not always demonstrate measurable impacts on health [4]. Inconsistent use of toilets may partly explain these limited health impacts [4]. If toilets are poorly constructed or damaged, undesirable or used only intermittently, they will not effectively perform their function of sequestering faecal contaminants from the environment. Effective toilet maintenance is a pre-requisite for realising the health benefits of sanitation [5].

Shared toilets in urban slums are often unclean and poorly maintained [6], which results in underused or abandoned facilities [7–9]. Moreover, extremely dirty or dysfunctional toilets heighten exposure to faecal pathogens [8]. WHO classifies shared toilets as unimproved sanitation, specifically because of the difficulties entailed in maintaining cleanliness and functionality among a multitude of users [10]. Shared toilet cleanliness is highly valued by users [7–9]. The main reasons for

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dissatisfaction with shared toilets include dirty and smelly conditions [9] as well as privacy concerns. Despite the limitations of shared sanitation, consensus is growing that shared toilets are the only viable sanitation option for urban slums [8, 11, 12]. Private toilet ownership is not widely achievable there because of scarce space, where demand for cheap housing takes precedent over construction of additional facilities; besides, weak social cohesion and frequent resident turnover discourage investment in toilet maintenance or improvements [13, 14]. Where shared facilities exist, ineffective access to municipal services may render them unusable [13–15].

Conventional behaviour change interventions for shared toilets are often ineffective because they do not address contextual factors, such as constraints to maintaining cleanliness [16]. The design of behaviour change interventions through formative research can address community concerns and contextual factors, and potentially is more effective in changing behaviours [17].

We have previously reported results of iterative formative research and pilot testing to understand the community context and local constraints to toilet maintenance [18 and Yeasmin F, Luby S, Saxton R *et al.*, unpublished article]. Based on the findings, we developed a multicomponent behaviour change intervention. The intervention included provision of low-cost hardware and promoted practical actions to maintain the cleanliness of shared toilets [18 and Yeasmin F, Luby S, Saxton R *et al.*, unpublished article]. We report here our evaluation of the effectiveness of the intervention on improving the quality and cleanliness of shared toilets available to urban slum residents of Dhaka.

Methods

Study design

We conducted a cluster-randomised controlled trial among users of shared toilets in 23 urban slums from three areas of Dhaka, Bangladesh, to evaluate the effectiveness of the intervention to improve and maintain toilet cleanliness. We focused on shared toilets within household compounds and not public toilets, so that there was an identifiable group of users with some pre-established norms for using and maintaining the shared facility. We divided 23 slums into 38 distinct clusters that included a buffer zone, that is, road, canal, market, drain; a cluster was the smallest geographical area and the unit of randomisation. After the baseline survey, an epidemiologist not associated with the study pair-matched clusters based on the number of toilet cubicles per cluster because we wanted to assign comparable numbers of toilets to intervention and control: ≤25 cubicles, 26–36 cubicles, 37–50 cubicles, 51–61 cubicles, 62–70 cubicles and >70 cubicles per cluster. Afterwards, the epidemiologist assigned one member of each pair into intervention and the remaining to control.

Data collection

Field assistants selected the second-nearest household user of the selected shared toilet to complete the survey. If there were multiple households at the same distance from the toilet, they selected the household to the right of that toilet. The field team conducted visual and olfactory inspections of all toilet cubicles to assess structure and provision of water, distance to water source, presence of visible faeces, urine, other liquid, dirt or solid waste inside the toilet pan and cubicle and on the path leading to the toilet and smell of urine and faeces inside the toilet cubicle. They conducted baseline survey interviews with one adult user from each selected toilet from 15 November 2014 through 25 January 2015. We conducted the endline survey from 8 August to 30 September 2015, after six months of intervention.

Intervention delivery

Dustha Shasthya Kendra (DSK), a non-government organisation delivered the intervention (hardware provision and behaviour change communication) through 50 community promoters commencing the week after completing the baseline survey. The implementation team was led by an icddr,b programme manager, who had a Master of Public Health, and a WASH joint director at DSK, who had a Master of Business Administration. The team maintained multiple layers of supervision to ensure optimal delivery of the intervention. The community promoters were experienced in delivering WASH interventions and conducting courtyard sessions in urban slum areas. The minimum educational qualification for the promoter team was high school graduation. Community promoters provided messages on toilet use and cleanliness, especially how to flush after toilet use, how and where to dispose trash to prevent toilet blockages, and the importance of using a potty to collect and dispose of faeces for children under three years old who are unable to use the toilet. They disseminated behaviour change communication through signs posted in and around the toilet cubicle, and at weekly compound meetings using flip charts during the first month and biweekly household visits for the remaining five months. Community promoters informed the compound landlord or caretaker before message dissemination sessions to seek approval to conduct the session and ensure their participation. Along

with behaviour change communication they distributed hardware to support the intervention among all intervention compounds, including a plastic waste bin, and a 4 l flushing bucket for each cubicle, and for compounds that faced intermittent water availability, a 70 l plastic water storage reservoir. Community promoters also solved problems related to damaged hardware and helped troubleshoot cooperative maintenance among residents when issues arose during their visits, or after receiving phone calls from intervention compounds.

Outcome variables

Our primary pre-specified outcome used to assess cleanliness was 'visible faeces inside the pan'. Pre-specified secondary outcome variables included: (i) visible faeces outside the pan, (ii) visible faeces on path leading up to the toilet, (iii) visible faeces inside hole of the pan, (iv) spit, mucous on walls/doors of toilet cubicles, (v) cigarette butts inside toilet cubicles, (vi) water logging inside toilet cubicles, (vii) visible household waste/waste wrapped in polythene inside toilet cubicles and (viii) visible rags/sanitary pads inside toilet cubicles.

Materials used for menstrual management disposed in the toilet had contributed to toilet blockages [Yeasmin F, Luby S, Saxton R *et al.*, unpublished article]. Our intervention encouraged menstruating residents to conceal these items by wrapping them in polythene before disposal in the waste bin, both to maintain their privacy and because bin emptiers were reluctant to handle waste bins if they contained these sensitive items [Yeasmin F, Luby S, Saxton R *et al.*, unpublished article]. We measured 'waste wrapped in polythene' and 'visible rags/sanitary pads' to account for both scenarios.

Sample size

We estimated that 50% of shared toilets in urban slum were not clean [12, 19]. We presumed the intervention could improve cleanliness by 11% [20]. We used the STATA sampsi command for two samples, where the following formula was used:

$$n = \frac{2(p)(1-p)(Z_\beta + Z_{\alpha/2})}{(p_1 - p_2)^2}$$

where Z_β was 0.84, $Z_{\alpha/2}$ was 1.96, p_1 was 50 and p_2 was 39.

Assuming a design effect of 1.8, we aimed to enrol 614 shared toilets for each study group, which would provide 80% power at 95% confidence after accounting for an assumed 1% dropout rate. The sampling unit was a shared toilet within a compound, defined as 'a toilet used by two or more households that drained into a common septic tank/sewerage/open space' and thus we selected 1228 shared toilets.

Data analysis

To assess the balance of demographic characteristics and water, sanitation and hygiene infrastructure available between the intervention and control arms, we calculated proportions for categorical variables, means for symmetric continuous variables and medians for skewed continuous variables.

We estimated the adjusted difference in difference (DID) to determine whether there were changes in the quality and cleanliness of shared toilets between baseline and endline, and whether any change observed in the intervention compounds was greater than that observed in control compounds. We accounted for the effect of clustering in estimating 95% confidence limits and *P*-values using generalised estimating equations (GEE).

Ethical approval

Field assistants obtained informed consent from participants. We obtained approval from icddr,b's Ethical Review Committee and Stanford University's Institutional Review Board. This study was registered under ClinicalTrials.gov (SPO-113016).

Results

Two household users declined to participate, thus we excluded observations of those two toilets. We collected baseline observation and survey data for 1226 toilets and their users. At endline, 10 toilets sampled at baseline had been demolished in the interim, and a further two toilets had been abandoned by their users. Thus, we collected and analysed complete observation data from 1214 shared toilets and survey data from their users (Figure 1).

Intervention and control households were similar in terms of age, sex, education level and household size (Table 1). Baseline toilet characteristics were also broadly similar for intervention and control households in terms of types of toilet drainage, percentage with water seal present, type of water source, availability of water during spot check and number of users per toilet cubicle (Table 2).

Toilet characteristics changed somewhat for both intervention and control compounds between baseline and endline: specifically, changes in types of toilet drainage,

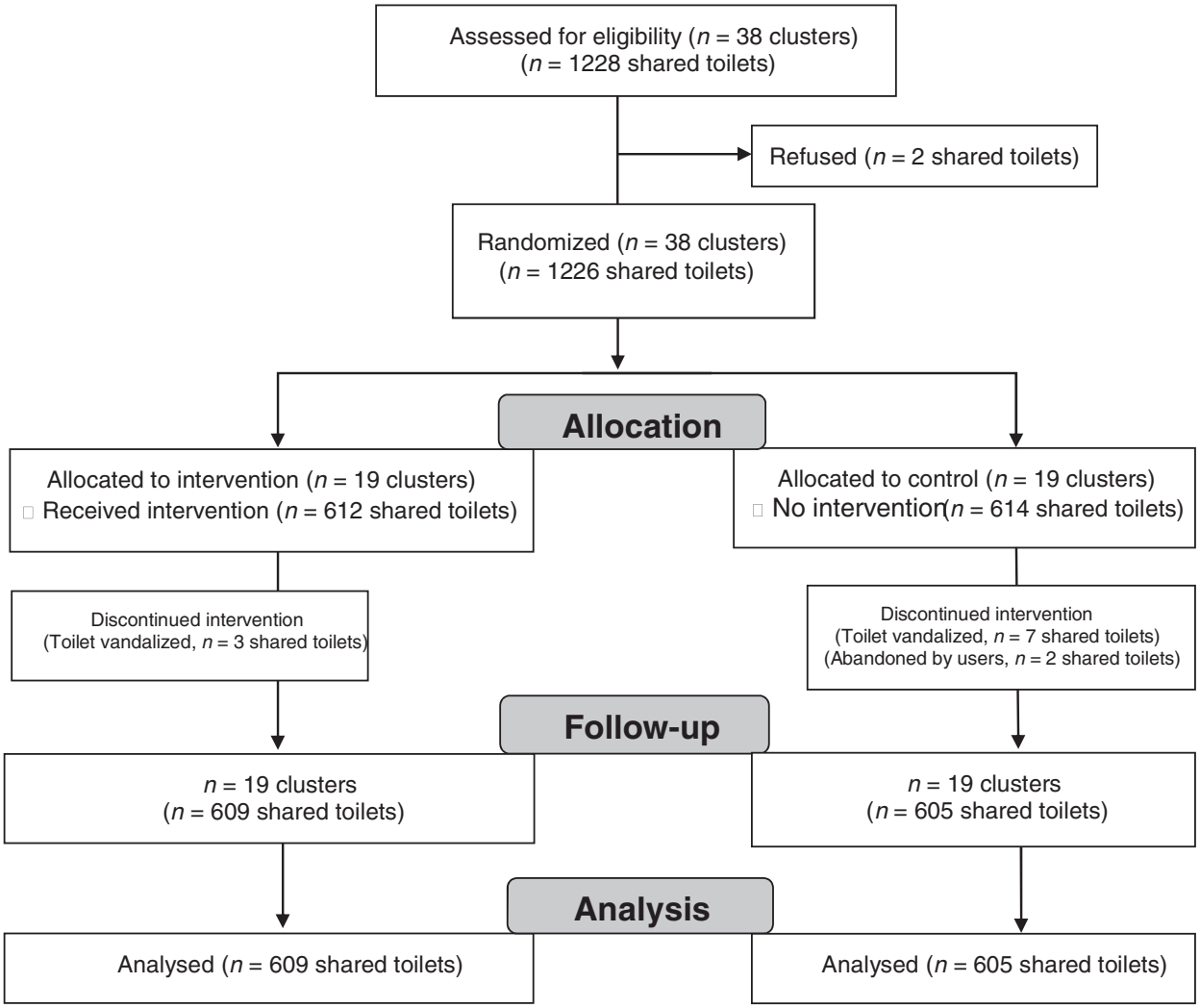

Figure 1 CONSORT flow diagram.

presence of water seal and type of water source (Table 2). Landlords or compound managers were primarily responsible for construction or maintenance of the toilets for both groups (Table 3). Respondents from the control group acknowledged being visited by a community promoter (other than our own): 29% during baseline and 34% during endline (Table 3).

Uptake of the intervention

Toilets in intervention compounds were more likely to have water reservoirs beside the toilets (DID: +52%, 95% confidence interval [CI]: 43, 58) and water available via a tap/spigot inside toilet cubicles (DID: +4.7%, 95% CI: 0.2, 9.2) than those in the control group (Table 2). Toilets from the intervention group were more likely to have cleaning materials such as brush/broom for toilet cleaning inside the toilet cubicles (DID: +8.4%, 95% CI: 2, 15) and water for toilet cleaning adjacent to the toilet facilities (DID: +12%, 95% CI: 4.9, 19) than control toilets (Table 2). The waste bins provided by the project to collect solid waste were still in place inside 64% of the toilet cubicles during the endline survey (DID: +63%, 95% CI: 59, 66) (Table 2).

Effectiveness of the intervention on pre-specific outcomes

The intervention group was less likely to have a toilet with visible faeces inside the pan than the control group (DID: −13%, 95% CI: −19, −5) (Table 4), the primary

Table 1 Demographic characteristics of respondent households, urban slum residents in Dhaka

Indicators	Baseline		Endline	
	Intervention ($N = 612$) *n* (%)	Control ($N = 614$) *n* (%)	Intervention ($N = 609$) *n* (%)	Control ($N = 605$) *n* (%)
Female respondent	452 (74)	461 (75)	501 (82)	472 (78)
Age (in years) of respondent (mean, SD)	33 (11)	34 (13)	33 (12)	34 (12)
Respondents' years of education (mean, SD)	3.5 (3.6)	3.2 (3.2)	3.7 (3.6)	3 (3.3)
No formal education	256 (42)	243 (40)	225 (37)	261 (43)
Household size (mean, SD)	4.4 (1.8)	4.5 (1.8)	4.4 (1.8)	4.5 (1.7)
Main occupation of respondent				
Housewife	354 (58)	375 (61)	390 (64)	358 (59)
Small business	64 (10)	60 (9.8)	60 (9.9)	56 (9.3)
Salaried job	58 (9)	50 (8)	54 (8.9)	54 (8.9)
Day labourer	29 (4.7)	46 (7.5)	31 (5.1)	27 (4.5)
Driver	50 (8.2)	26 (4.2)	15 (2.5)	38 (6.3)
Garment worker	19 (3.1)	14 (2.3)	7 (1.2)	16 (2.6)
Domestic maid/servant	15 (2.5)	18 (2.9)	30 (4.9)	34 (5.7)
Unemployed/disabled	19 (3.1)	21 (3.4)	17 (2.8)	13 (2.2)
Monthly reported household income in USD (mean, SD)	155 (87)	156 (84)	184 (109)	178 (110)
Number of children <5 years old in households (mean, SD)	0.43 (0.49)	0.42 (0.49)	0.41 (0.49)	0.40 (0.49)
Number of differently able persons in households (mean, SD)	0.02 (0.13)	0.01 (0.11)	0.01 (0.12)	0.02 (0.14)
Number of pregnant women in households (mean, SD)	0.05 (0.22)	0.04 (0.19)	0.05 (0.22)	0.33 (0.18)

pre-specified outcome. Two pre-specified secondary outcomes were significantly improved in the intervention group: the likelihood of visible faeces inside hole of the pan (DID: −8.5%, 95% CI: −15, −2.3) and visible household waste wrapped in polythene (DID: −4%, 95% CI: −7, −1). The other six pre-specified secondary outcomes were not significantly different in interventions *vs.* control compounds including visible faeces outside the pan, visible faeces on path leading up to the toilet, spit or mucous on walls/doors of toilet cubicle, cigarette butts present inside the toilet cubicle, water logging inside the toilet cubicle and visible rags/sanitary pads inside (Table 4). Notably, presence of visible faeces inside the pan, inside the hole of the pan and presence of household waste/waste wrapped by polythene also decreased in the control group from baseline to endline though the difference in difference analysis shows that the changes in the intervention group were larger.

Associations between intervention exposure and other outcomes

The smell of faeces was also less prevalent in intervention cubicles than control cubicles (DID: −7.6%, 95% CI: −14, −1.3).

Discussion

Ours is one of very few efforts to problematise shared toilet cleanliness [19, 21], and is unique in considering toilet cleanliness as a primary outcome rather than a covariate. In our study, compounds that received the intervention were significantly more likely to have cleaner toilets after the intervention was in place for six months, indicating effective intervention deployment. The intervention likely reduced cleaning burden, because cleaning materials were more common in the cubicle reducing the need to fetch these from the home. Moreover, water for flushing was stored proximally rather than carried from home. These changes were possible and directly attributable to intervention messages and hardware support provided by the study.

The intervention had significant impacts on shared toilet users' satisfaction with their available toilet facilities. Our intervention showed an improvement in the primary outcome indicator (visible faeces in the pan), which was important for users who were discouraged from using unclean, smelly toilets, potentially defecating in the open. Furthermore, faeces left in the pan could be accessed by insects and subsequently spread throughout the environment, negating the potential health impact of toilet use.

Table 2 Toilet characteristics, water source and toilet access of the shared toilet users in urban slums in Dhaka (Spot check)

Indicators	Intervention			Control			
	Baseline (*N* = 612) *n* (%)	Endline (*N* = 609) *n* (%)	Difference* (%) CI	Baseline (*N* = 614) *n* (%)	Endline (*N* = 605) *n* (%)	Difference* (%) CI	DID* (%) CI
Type of toilet							
Flush or pour flush toilet connected to somewhere else such as canal, ditch, river	339 (55)	354 (58)	2.6 (−2.4, 7.5)	357 (58)	382 (63)	5 (−0.1, 10)	−2.5 (−9.6, 4.6)
Piped sewer system	121 (20)	76 (12)	**−7.4 (−11, −4.1)**	94 (15)	41 (6.8)	**−8.8 (−12, −5.8)**	1.4 (−3.1, 5.8)
Toilet with septic tank	91 (15)	117 (19)	**4.4 (0.5, 8.3)**	77 (13)	114 (19)	**6.4 (2.5, 10)**	−2 (−7.5, 3.5)
Off-set pit	21 (3.4)	30 (4.9)	1.6 (−0.6, 3.8)	30 (4.9)	27 (4.5)	−0.5 (−2.7, 1.8)	2 (−1.1, 5.2)
Pit toilet with slab (Non-flush toilet)	21 (3.4)	3 (0.5)	**−2.9 (−4.4, −1.4)**	25 (4.1)	1 (0.2)	**−3.9 (−5.5, −2.4)**	1 (−1.2, 3.2)
Pit directly underneath	7 (1.1)	16 (2.6)	1.5 (0, 3)	14 (2.3)	15 (2.5)	0.2 (−1.5, 1.9)	1.3 (−0.9, 3.5)
Pit toilet without slab (Non-flush toilet)	1 (0.2)	0	−0.2 (−0.5, 0.20)	3 (0.5)	1 (0.2)	−0.3 (−0.9, 0.3)	0.2 −0.6, 0.9)
Hanging toilet (drains directly into pond)	11 (1.8)	13 (2.1)	0.3 (−1.1, 1.9)	14 (2.3)	24 (3.8)	1.7 (−0.1, 3.6)	−1.4 (−3.8, 1)
Toilet with functional water seal	115 (19)	249 (41)	**22 (18, 26)**	108 (18)	255 (42)	**25 (20, 29)**	−2.7 (−9, 3.6)
Faeces coming out from the septic tank, pit or from connected line	27 (4.4)	26 (4.3)	−0.1 (−2.4, 2.1)	25 (4.1)	12 (1.9)	**−2.1 (−3.9, −0.2)**	1.9 (−1, 4.9)
Water source							
Common tap/hand pump inside compound	456 (76)	294 (48)	**−27 (−32, 22)**	518 (86)	334 (55)	**−31 (−35, 26)**	3.5 (−3.1, 10)
Municipal supply for toilet use	0	62 (10)	**10 (7.8, 12)**	0	31 (5)	**5.1 (3.4, 6.9)**	**5 (2.1, 7.8)**
Shallow/deep tube well	31 (5.1)	37 (6.1)	1 (−1.5, 3.5)	17 (2.8)	48 (7.9)	**5.1 (2.7, 7.5)**	**−4.1 (−7.5, −0.6)**
Municipal water stored in reservoir	102 (17)	215 (35)	**18 (14, 22)**	58 (10)	189 (31)	**22 (17, 26)**	−3.6 (−9.3, 2.2)
Supplied by water bearer	11 (1.8)	1 (0.16)	−1.7 (−2.7, −0.6)	9 (1.5)	1 (0.17)	−1.3 (−2.4, −0.3)	−0.3 (−1.8, 1.2)
Types of reservoir							
Reservoir/tank beside toilet	294 (48)	155 (26)	**−22 (−27, −17)**	216 (35)	103 (17)	**−18 (−22, −14)**	−4.5 (−11, 2.1)
Concrete reservoir underground with hand pump	53 (8.7)	5 (0.8)	**−7.8 (−10, −5.6)**	59 (9.6)	10 (1.7)	**−7.9 (−10, −5.6)**	0.1 (−3.2, 3.3)
Bucket kept beside toilet	8 (1.3)	377 (62)	**60 (53, 66)**	125 (20)	182 (30)	**9 (5, 16)**	**52 (43, 58)**
Tank on the roof	6 (0.9)	5 (0.8)	−0.2 (−1.2, 0.9)	2 (0.3)	2 (0.3)	0 (−0.6, 0.6)	−0.2 (−1.4, 1.1)
No arrangement	244 (40)	259 (43)	2.6 (−2.6, 7.8)	313 (51)	103 (17)	**−34 (−39, −29)**	**−37 (30, 44)**
Water source inside toilet cubicle	*N* = 907	*N* = 912		*N* = 876	*N* = 883		
Only *bodna*	525 (58)	603 (66)	**8.2 (3.9, 12)**	555 (63)	586 (66)	3.2 (−1.2, 7.6)	4.9 (−1.1, 11)
Bucket	45 (4.9)	121 (13)	**8.3 (5.8, 11)**	28 (3.2)	47 (5.3)	**2.3 (0.5, 4.2)**	**6 (2.9, 9.2)**
Water tap	40(4.4)	37 (4.1)	−0.4 (−2.2, 1.4)	36 (4.1)	41 (4.6)	0.6 (−1.2, 2.5)	−1 (−3.6, 1.6)
Nothing kept for storing water	297 (33)	151 (17)	**−16 (−20, −13)**	257 (29)	209 (24)	**−6.3 (−10, −2.4)**	**−9.9 (−15, −4.6)**
Water available inside toilet cubicle†	122/907 (13)	199/912 (22)	**8.4 (4.9, 12)**	91/876 (10)	120/883 (14)	**3.7 (0.8, 6.6)**	**4.7 (0.2, 9.2)**
Access to cleaning materials for the toilet							
Carry from home	322 (74)	139 (23)	**−51 (−56, −46)**	322 (72)	173 (29)	**−44 (−49, −39)**	−6.8 (−14, 0.5)
Adjacent to toilet facility	57 (13)	287 (47)	**33 (28, 39)**	56 (12)	278 (46)	**34 (28, 38)**	−0.1 (−7, 7)
Inside the toilet chamber	37 (9)	168 (28)	**19 (15, 24)**	51 (11)	129 (21)	**11 (6.6, 15)**	**8.4 (2, 15)**
Unavailable	20 (5)	15 (2.5)	−2.1 (−4.3, 0.01)	21 (5)	25 (4.1)	−0.6 (−3, 1.8)	−1.5 (−4.8, 1.8)

Table 2 (*Continued*)

Indicators	Intervention			Control			
	Baseline (N = 612) n (%)	Endline (N = 609) n (%)	Difference* (%) CI	Baseline (N = 614) n (%)	Endline (N = 605) n (%)	Difference* (%) CI	DID* (%) CI
Access to water for cleaning the toilet using cleaning materials							
Adjacent to toilet facility	377 (62)	459 (75)	**14 (8.7, 19)**	408 (66)	412 (68)	1.6 (−3.5, 6.8)	**12 (4.9, 19)**
Carry from home	44 (7.2)	9 (1.5)	**−5.7 (−7.9, −3.6)**	25 (4.07)	23 (3.8)	−0.2 (−2.4, 1.9)	**−5.5 (−8.6, −2.4)**
Inside the toilet chamber	29 (4.7)	44 (7.2)	2.5 (−0.1, 5)	31 (5.05)	40 (6.6)	1.8 (−0.7, 4.3)	0.7 (−2.8, 4.1)
Dug well	10 (1.6)	19 (3.1)	1.5 (−0.1, 3.1)	7 (1.1)	21 (3.5)	**2.3 (0.6, 3.9)**	−0.8 (−3.2, 1.5)
Must carry from distant community tap	5 (0.8)	12 (1.9)	1.1 (−0.1, 2.4)	5 (0.8)	12 (1.9)	1.2 (−0.1, 2.5)	−0.01 (−1.9, 1.8)
Number of functional‡ toilet cubicles (median, IQR)	1 (1, 2)	1 (1, 2)	-	1 (1, 2)	1 (1, 2)	-	-
Number of user household per toilet (mean, SD)	9.8 (9.6)	9.9 (11)	0.1 (−0.9, 1.2)	9.2 (7.8)	9.3 (9.7)	0.06 (−0.9, 1)	0.06 (−1, 11)
Number of users per toilet (mean, SD)	40 (43)	39 (50)	−1.3 (−6, 3.5)	35 (34)	35 (34)	−0.15 (−3.7, 3.4)	−1.2 (−7, 4.9)
Number of users per toilet cubicle (mean, SD)	26 (20)	22 (17)	−3.4 (−5.5, −1.4)	24 (16)	23 (14)	−1.2 (−2.8, 0.5)	−2.3 (−4.9, 0.3)
Toilet can be accessed 24 h a day	612 (100)	608 (99.8)	−0.2 (−0.5, 0.2)	613 (99.8)	605 (100)	0.2 (−0.2, 0.5)	−0.3 (−0.8, 0.1)
Toilet has a peak time when users experience a long queue	256 (42)	308 (51)	**8.7 (3.4, 14)**	316 (51)	338 (56)	4.3 (−1.2, 9.8)	4.4 (−3.2, 12)
Peak times of the toilet having long queues							
5.01 AM to 8.00 AM	256 (42)	305 (50)	**8.2 (2.9, 14)**	315 (51)	336 (56)	4.1 (-1.3, 9.6)	4.1 (-3.5, 12)

*Cluster-adjusted difference shown and text highlighted for $P < 0.05$.
†Water available inside the toilet from the following source: municipal supply, bucket or water tap inside toilet.
‡Usable on the day of the survey.

The intervention also decreased the presence of visible faeces in the hole of the pan, indicating that there were fewer toilet blockages, and that 4l buckets carried adequate water to propel the faeces down into the pit. Measuring this indicator separately was important in this context because presence of faeces in the pan hole could indicate that the sludge pit is completely full. Our intervention decreased the visible waste wrapped in polythene inside the toilet cubicle. We encouraged residents to dispose of sensitive items privately in the waste bin and to avoid putting them into the toilet pit. The larger implication of this improvement is likely fewer blockages and reduction in bulky items in the sludge pit facilitates safer removal of faecal sludge.

Our trial results demonstrated that a behaviour change intervention built upon in-depth, qualitative understanding of the perspective and constraints of local residents could improve toilet cleanliness. These improvements were possible even in settings with severe constraints, notably, during water shortages and in the absence of a faecal sludge management system. Our strategies made a difference, but the magnitude of the effects observed was relatively small, likely in part due to the absence of functional systems for solid waste removal and safe faecal sludge disposal [18 and Yeasmin F, Luby S, Saxton R *et al.*, unpublished article]. The observed changes may have been more pronounced if accompanied by government-level changes in service provision.

Government authorities have little incentive to grant formal legal status to these settlements, because political elites profit by taking financial kickbacks from local power-brokers (*mastaans*) [22] who arrange expensive substandard services in the absence of formal systems [11]. Politicians have an incentive to avoid formalising settlements so that residents remain dependent on high-cost services provided by local party associates who, in turn, provide politicians a cut of the revenue stream extracted from residents [11, 13]. Our intervention functioned within the constraints of this 'informality' [22] by relying on residents to ensure compound-level provision of water for flushing and waste disposal systems. This strategy, while immediately implementable, resulted in more modest improvements than might be achievable under ideal levels of access to municipal services including piped water, sewerage and waste removal.

We know of only one other study that measured changes in toilet cleaning behaviours [23]. Tumwebaze and colleagues conducted a pre-*vs.* post-intervention study after three months of intervention to test the effectiveness of group discussions to improve cleaning behaviours in Kampala, Uganda during 2015. They showed that group discussions and public commitments were followed by improved toilet cleanliness. Their strategy was similar to our compound meetings and signs/landlords indicating what actions are expected (rules for latrine use). Their approach did not include provision of hardware to facilitate cleaning action. The enduring presence of hardware serves as both a reminder of the rules for toilet use, and aid for flushing.

Many studies evaluating interventions to improve water and sanitation use a before and after study design with no control group [23–25]. Our study results demonstrated that this common approach risks overestimating the impact of interventions in a dynamic urban community. Without a simultaneous control group, we would have concluded that the intervention improved toilet cleanliness by 22% rather than the 13% improvement seen when we adjusted for the experience in the control group. Physical characteristics of toilets from control compounds changed from baseline to endline, possibly initiated by landlords/compound managers who were responsible for construction or maintenance of the toilet, or because these communities received a sanitation intervention from one of the many NGOs engaged in sanitation work in these communities, unrelated to our research.

We restricted this intervention to shared toilets where access was restricted within a compound and not open public toilets, thus the results are unlikely to be directly applicable to open access public toilets.

As the intervention included clearly visible hardware components and communication materials, data collectors were not blinded to the intervention group. Thus, there was some risk that respondents may have been unconsciously biased in their evaluations. We minimised this risk using standardised objective measures for pre-specified outcome variables and training the team thoroughly. We also conducted inter-rater reliability testing during training to confirm that each evaluator was observing and recording the same details in the same way. We sent pairs of observers to separately observe and code the same toilet in the same instance, then compared the rates of agreement. When paired observers assessed and rated toilet cleanliness with 80% agreement, they passed their training. However, the indicator 'smell of faeces inside cubicles' was not pre-specified and might have lower reliability as the sense of smell might vary from person to person.

If users cease open defecation and consistently use clean toilets, we still might not achieve optimal health impacts as toilets may continue to drain or empty somewhere other than into a sealed pit or sanitary sewer [26]. We observed a number of toilet drainage systems without flow that contaminated the community environment, but

Table 3 Shared toilet construction, management and sanitation intervention among urban slum residents in Dhaka (Reported)

Indicators	Intervention			Control			
	Baseline (N = 612) n (%)	Endline (N = 609) n (%)	Difference* (%) CI	Baseline (N = 614) n (%)	Endline (N = 605) n (%)	Difference* (%) CI	DID* (%) CI
Person/organisation responsible for construction of the toilet							
Landlord or compound manager	404 (66)	499 (82)	**16 (11, 20)**	393 (64)	496 (82)	**18 (13, 23)**	−2.3 (−8.8, 4)
NGO or other outside group	118 (19)	93 (15)	−3.8 (−7.8, 0.1)	101 (16)	89 (15)	−1.6 (−5.5, 2.3)	−2.2 (−7.8, 3.3)
Respondent's household contributed	100 (16)	23 (3.8)	**−13 (−16, −9)**	149 (24)	27 (4.5)	**−20 (−24, −16)**	**7 (2, 12)**
Neighbours or other compound residents	11 (1.8)	11 (1.8)	0	19 (3.1)	6 (0.9)	**−2 (−4, −0.5)**	2 (−0.01, 4)
Community based organisation or other community group	4 (0.7)	34 (5.6)	**4.9 (3, 6.7)**	0	7 (1.2)	1 (0.3, 1.9)	**3.8 (1.8, 5.8)**
Person/organisation responsible for managing upgrades/improvements to the toilet structure							
Landlord or compound manager manages cost	552 (90)	590 (97)	**6.7 (4, 9)**	566 (92)	588 (97)	**4.9 (2.5, 7.5)**	1.7 (−1.9, 5.4)
Residents manage cost	46 (8)	19 (3.1)	**−4.4 (−6.8, −1.9)**	45 (7)	16 (2.6)	**−4.7 (−7, −2.3)**	0.3 (−3, 4)
Maintenance committee collects funds	16 (2.6)	17 (2.8)	0.2 (−1.5, 1.9)	11 (1.8)	1 (0.2)	**−1.5 (−2.6, −0.5)**	1.7 (−0.3, 3.7)
Received messages regarding sanitary toilet use and faeces disposal	422 (69)	520 (85)	**15 (12, 19)**	462 (75)	374 (62)	**−14 (−18, −10)**	**29 (23, 35)**
Sources of messages regarding sanitary toilet use and faeces disposal (multiple response)							
NGO worker	228 (37)	496 (81)	**44 (40, 49)**	254 (41)	276 (46)	4 (−1, 9)	**40 (33, 47)**
Relative/friends/neighbours/parents	192 (31)	42 (6.9)	**−24 (−30, −21)**	215 (35)	85 (14)	**−21 (−25, −17)**	−3 (9, 2)
TV/radio	155 (25)	242 (40)	**14 (10, 19)**	133 (22)	171 (28)	**6 (2, 11)**	**8 (1, 15)**
Poster	9 (1.5)	80 (13)	**12 (9, 14)**	13 (2.1)	14 (2.3)	0.18 (−1, 2)	**11 (8, 15)**
*D*rama	3 (0.5)	35 (5.8)	**5 (3, 7)**	4 (0.7)	14 (2.3)	**2 (.31, 3)**	**4 (1, 6)**
Govt. health assistant	11 (1.8)	16 (2.6)	0.82 (−0.80, 2)	13 (2.1)	8 (1.3)	−0.80 (−2, 0.63)	2 (−0.53, 4)
Health promoter visited households for teaching about messages of sanitary toilet use and faeces disposal	151 (25)	489 (80)	**60 (60, 65)**	181 (29)	206 (34)	**6.0 (1.0, 12)**	**54 (50, 61)**
Health promoter visited households from; (responses collected at endline only)							
BRAC	-	3 (0.5)	-	-	6 (1.0)	-	-
DSK	-	378 (62)	-	-	99 (16)	-	-
WSUP	-	137 (23)	-	-	5 (0.8)	-	-
icddr,b	-	162 (27)	-	-	53 (8.8)	-	-

*Cluster-adjusted difference shown and text highlighted for $P < 0.05$.

Table 4 Shared toilet cubicle cleanliness in urban slums in Dhaka (Spot-check)

Indicators	Intervention			Control			
	Baseline (N = 907) n (%)	Endline (N = 912) n (%)	Difference* (%) CI	Baseline (N = 876) n (%)	Endline (N = 883) n (%)	Difference* (%) CI	DID* (%) CI
Primary outcome†							
Visible faeces							
Inside pan	282 (32)	83 (9.1)	**−22 (−25, −18)**	203 (23)	124 (14)	**−9 (−11, −7)**	**−13 (−18, −8)**
Secondary outcomes							
Visible faeces†							
Outside pan	68 (7.5)	21 (2.3)	**−5.2 (−7.2, −3.3)**	64 (7.3)	31 (3.5)	**−3.9 (−5.9, −1.8)**	−1.4 (−4.3, 1.9)
On path leading up to the toilet	57 (6.3)	55 (6.1)	−0.2 (−2.3, 1.9)	72 (8.2)	56 (6.3)	−1.7 (−3.9, 0.5)	1.5 (−1.6, 4.6)
Inside hole of the pan	433 (48)	297 (33)	**−15 (−20, −11)**	399 (46)	351 (40)	**−6.7 (−11, −2.3)**	**−8.5 (−15, −2.3)**
Visible inside the toilet cubicle†							
Spit, cough on walls/doors	199 (22)	153 (17)	**−5.2 (−8.7, −1.8)**	257 (29)	187 (21)	**−7.9 (−12, −4.1)**	2.8 (−2.5, 7.9)
Cigarette butts	95 (10)	50 (5.8)	**−5 (−7.1, −2.6)**	112 (13)	73 (8.7)	**−4.5 (−7.4, −1.7)**	−0.5 (−4.1, 3.2)
Water logging	90 (10)	35 (3.8)	**−6 (−8, −4)**	77 (8.8)	41 (4.7)	**−4 (−6, −2)**	−2 (−5, 1)
Household waste/waste wrapped in polythene	91 (10)	36 (3.9)	**−6 (−8, −4)**	43 (4.9)	26 (2.9)	**−2 (−4, −0.2)**	**−4 (−7, −1)**
Rags/sanitary pads	43 (4.7)	12 (1.4)	**−3.4 (−4.9, −1.9)**	47 (5.6)	23 (2.6)	**−2.8 (−4.5, −1)**	−0.6 (−2.9, 1.7)
Smell of							
Faeces	521 (57)	319 (35)	**−23 (−27, −18)**	504 (58)	382 (44)	**−15 (−20, −11)**	**−7.6 (−14, −1.3)**
Urine	463 (51)	264 (29)	**−22 (−26, −18)**	516 (59)	333 (38)	**−22 (−26, 18)**	−0.01 (−0.6, 0.5)
Cigarettes	83 (9.2)	54 (5.9)	**−3 (−5.6, −0.9)**	111 (13)	65 (7.4)	**−5.5 (−8.2, −2.7)**	2.2 (−1.3, 5.8)
Functional‡ toilet cubicle	N = 919 906 (99)	N = 892 877 (98)	−1.2 (−0.6, 2.5)	N = 935 916 (98)	N = 909 877 (96)	−1.9 (−2.3, 4.6)	0.5 (−3.5, 1.8)
Visible cracks on the pan	125 (14)	86 (9.4)	−4.4 (−7.3, −1.4)	84 (9.6)	80 (9.6)	−0.5 (−3.2, 2.2)	−3.8 (−7.8, 0.1)
Waste bin inside the toilet cubicle	6 (0.7)	590 (65)	**64 (61, 67)**	3 (0.3)	13 (1.5)	**1.1 (0.2, 2)**	**63 (59, 66)**

*Cluster adjusted difference shown and text highlighted for $P < 0.05$.
†Pre-specified outcome variables.
‡Usable on the day of the survey.

upgrading dysfunctional infrastructure was beyond the scope of our intervention.

Implications for future research

In conclusion, to improve the quality and cleanliness of shared toilet facilities, behaviour change based on community context and local constraints, targeting the central role that landlords and community managers play can be particularly effective in similar low-income urban settings.

Future research should explore how to break the political economy dynamic that incentivises policy makers to provide poor services. Research that works to make marginal improvements within these contexts might explore how residents can self-finance toilet maintenance to sustain these efforts without programme funds, and how compound managers or landlords, who already engage in toilet construction, might implement maintenance strategies similar to ours using low-cost, locally available items, without project funding. Use of mass media campaigns could be tested to reduce the per-capita costs associated with behaviour change communication, by widely expanding the potential reach of those campaigns. Further evaluations should also assess the sustainability of these efforts to improve toilet cleanliness.

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References

1. United Nations. The millennium development goals report 2012. New York: United Nations, 2012.
2. WHO UNICEF. Progress on drinking water and sanitation: 2012 update. New York and Geneva: World Health Organization and United Nations Children's Fund, 2012.
3. Sahoo KC, Hulland KR, Caruso BA *et al.* Sanitation-related psychosocial stress: a grounded theory study of women across the life-course in Odisha, India. *Soc Sci Med* 2015: **139**: 80–89.
4. Clasen T, Boisson S, Routray P *et al.* Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: a cluster-randomised trial. *Lancet Glob Health* 2014: **2**: e645–e653.
5. Luby S. Is targeting access to sanitation enough? *Lancet Glob Health* 2013: **2**: e619–e620.
6. Rahman MM, Atkins PJ, McFarlane C. Factors affecting slum sanitation projects in Dhaka City: learning from the dynamics of social-technological-governance systems. *J Water Sanit Hyg Dev* 2014: **4**: 346–358.
7. Biran A, Jenkins MW, Dabrase P, Bhagwat I. Patterns and determinants of communal latrine usage in urban poverty pockets in Bhopal, India. *Trop Med Int Health* 2011: **16**: 854–862.
8. Günther I, Niwagaba BC, Lüthi C, Horst A, Mosler H-J, Tumwebaze KI. When is shared sanitation improved sanitation? The correlation between number of users and toilet hygiene. Zurich, Switzerland: ETH Zurich, 2012 MPRA Paper No. 45830.
9. Tumwebaze IK, Orach CG, Niwagaba C, Luthi C, Mosler H-J. Sanitation facilities in Kampala slums, Uganda: users' satisfaction and determinant factors. *Int J EnvironHealth Res* 2013: **23**: 191–204.
10. WHO UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation. WHO UNICEF; [cited 2016]. Available from: http://www.wssinfo.org/definitions-methods/watsan-ladder/.
11. Hossain S. Informal dynamics of a public utility: rationality of the scene behind a screen. *Habitat Int* 2011: **35**: 275–285.
12. Schouten MAC, Mathenge RW. Communal sanitation alternatives for slums: a case study of Kibera, Kenya. *Phys Chem Earth Parts A/B/C* 2010: **35**: 815–822.
13. Anjaria JS. Street hawkers and public space in Mumbai. *Econ Polit Wkly* 2007: **41**: 2140–2146.
14. World Bank. Dhaka: Improving living conditions for the urban poor. Washington, DC: World Bank, 2007.
15. Noar SM. A 10-year retrospective of research in health mass media campaigns: where do we go from here? *J Health Commun* 2006: **11**: 21–42.
16. Mazeau AP. No toilet at home: implementation, usage and acceptability of shared toilets in urban Ghana [PhD]. Leicestershire, UK: Loughborough University; 2013.
17. Fishbein M, Cappella JN. The role of theory in developing effective health communications. *J Commun* 2006: **56**: S1–S17.
18. Ronald ES, Yeasmin F, Alam M *et al.* If I do not have enough water, then how could I bring additional water for toilet cleaning?! Addressing water scarcity to promote hygienic use of communal toilets in Dhaka, Bangladesh. *Tropical Med Int Health* 2017: doi:10.1111/tmi.12914.
19. Tumwebaze IK, Niwagaba CB, Günther I, Mosler H-J. Determinants of households' cleaning intention for shared toilets: case of 50 slums in Kampala, Uganda. *Habitat Int* 2014: **41**: 108–113.
20. Swami HM, Thakur JS, Gupta M, Bhatia SP. Improving environmental conditions of a slum in Chandigarh by an awareness campaign. *J Environ Sci Eng* 2004: **46**: 252–256.

21. Tumwebaze IK, Mosler H-J. Why clean the toilet if others don't? Using a social dilemma approach to understand users of shared toilets' collective cleaning behaviour in urban slums: a review. *J Water Sanit Hyg Dev* 2014: **4**: 359–370.
22. Hossain S. The informal practice of appropriation and social control–experience from a Bosti in Dhaka. *Environ Urban* 2013: **25**: 209–224.
23. Tumwebaze IK, Mosler H-J. Effectiveness of group discussions and commitment in improving cleaning behaviour of shared sanitation users in Kampala, Uganda slums. *Soc Sci Med* 2015: **147**: 72–79.
24. Elsanousi S, Abdelrahman S, Elshiekh I *et al.* A study of the use and impacts of LifeStraw™ in a settlement camp in southern Gezira, Sudan. *J Water Health* 2009: **7**: 478–483.
25. Moll DM, McElroy RH, Sabogal R, Corrales LF, Gelting RJ. Health impact of water and sanitation infrastructure reconstruction programmes in eight Central American communities affected by Hurricane Mitch. *J Water Health* 2007: **5**: 51–65.
26. Peal A, Evans B, Blackett I, Hawkins P, Heymans C. Fecal sludge management: a comparative analysis of 12 cities. *J Water Sanit Hyg Dev* 2014: **4**: 563–575.

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