# Effect of a behaviour change intervention on the quality of peri-urban sanitation in Lusaka, Zambia: a randomised controlled trial

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## Summary

**Background** Poor sanitation in peri-urban areas is a growing public health problem. We tested a scalable, demand-side behaviour change intervention to motivate landlords to improve the quality of shared toilets within their plots.

**Methods** We did a residential plot-randomised controlled trial in a peri-urban community in Lusaka, Zambia. We enrolled adult resident landlords on plots where at least one tenant lived. We allocated landlords 1:1 to intervention and control arms on the basis of a random number sequence. The intervention was developed using the Behaviour Centred Design approach and consisted of a series of group meetings designed to motivate sanitation quality improvement as a way to build wealth and reduce on-plot conflict; no subsidies or materials were provided. The control group received no intervention. The four primary outcomes were having a rotational cleaning system in place (to improve hygiene); having a solid door on the toilet used by tenants with an inside lock (for privacy); having an outside lock (for security); and having a sealed toilet (to reduce smell and contamination). We measured outcomes 1 month before the start of the intervention and 4 months after the end of the intervention. Data collectors measuring outcomes were blinded to group assignment. We analysed outcomes by intention to treat, including all landlords with study-end results. Because the outcomes were assumed to not be independent, we used a family-wise error rate of 0·05 to calculate an adjusted significance level of 0·0253. This study was registered with ClinicalTrials.gov, number NCT03174015.

**Findings** Between June 9 and July 6, 2017, 1085 landlords were enrolled and randomly assigned to the intervention (n=543) or the control group (n=542). The intervention was delivered from Aug 1, 2017, and evaluated from Feb 15 to March 5, 2018. Analysis was based on the 474 intervention and 454 control landlords surveyed at study end. The intervention was associated with improvements in the prevalence of cleaning rotas (relative risk 1·16, 95% CI 1·05–1·30; p=0·0011), inside locks (1·34, 1·10–1·64; p=0·00081), outside locks (1·27, 1·06–1·52; p=0·0028), and toilets with simple covers or water seals (1·25, 1·04–1·50; p=0·0063).

**Interpretation** It is possible to improve the structural quality and cleanliness of shared sanitation by targeting landlords with a scalable, theory-driven behaviour change intervention without subsidy or provision of the relevant infrastructure.

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## Introduction

Unplanned peri-urban settlements are growing rapidly, with populations expected to more than double to 2 billion people globally by 2035.[1] Residents of these peri-urban areas experience multiple deprivations associated with poor infrastructure, social problems, weak local governments,[1] and economic failures resulting in poverty traps.[2] As a consequence, the health status of residents is typically poorer than for populations of both rural and planned urban areas.[3] Sanitation presents a particular challenge, both from the perspective of public health and for the quality of life in peri-urban areas. Although most people have some form of toilet, the quality of sanitation provision remains poor: sewer connections are rare and on-site solutions are often poorly constructed; unhygienic, shared sanitation presents maintenance challenges; and emptying remains expensive and is frequently done manually.[4,5]

Although there is some evidence of better sanitation leading to improved health outcomes, little work has been done to establish granular evidence for specific components besides having an improved slab, sewer connection, or a household (rather than shared) toilet.[6] However, it is important to view the impacts of sanitation from a broader conception of health, such as the Healthy Sanitation Framework, which captures hygiene, accessibility, desirability, sustainability, and use as key components of healthy sanitation in any setting.[7] From this perspective, there is also strong evidence of sanitation quality affecting psychosocial stress and

## Research in context

### Evidence before this study

The Sustainable Development Goals aim for safely managed sanitation for all by 2030 but existing plans call primarily for large-scale infrastructure construction without much consideration of the role of consumer demand. However, large-scale migration to urban areas means that such approaches will be inadequate to address the rapidly growing sanitation needs, particularly those in peri-urban areas. To identify relevant literature, we searched MEDLINE, Embase, Scopus, Web of Science, and PubMed Central with the terms ((“sanitation” OR “toilet” OR “latrine”) AND (“demand” OR “motivation” OR “driver” OR “determinant”) AND (“slum” OR “urban” OR “peri-urban”)) for articles published in English before April 1, 2016, as well as consulting experts for relevant grey literature or evidence from other settings. There is some evidence that communities might be able to work together to install low-capacity sewerage or manage communal toilet blocks and that shared toilet cleaning behaviours can be improved through provision of materials or encouraging discussions between landlords and tenants. However, there is little evidence about how to motivate the improvement of the structural quality of existing shared toilets in peri-urban areas or how to sustainably ensure cleanliness.

### Added value of this study

This study showed that a theory-based, creative intervention targeting landlords was able to achieve gains in cleanliness and structural quality through behaviour change messaging alone. Breaking the information asymmetry around tenant willingness to pay for sanitation led to landlords beginning to make improvements to the toilets used by their tenants across several important categories of healthy sanitation. Introducing an improved system for toilet cleaning led to higher rates of cleaning and cleanliness within 6 months of the relevant messages being delivered.

### Implications of all the available evidence

Large-scale planned investments in urban and peri-urban sanitation—currently estimated at US$1 trillion from 2015 to 2030 to reach the Sustainable Development Goal for sanitation—should consider the role of consumer demand in achieving safely managed sanitation and improving public health in a cost-effective and sustainable way. Similar programmes should be evaluated in other settings and incorporated into comprehensive sanitation master plans being developed in cities in many lower-income and middle-income countries, and longer-term studies looking at larger investments by consumers are now warranted.

wellbeing through routes such as the lack of privacy, poor personal safety, and conflict between those sharing a toilet over cleaning and maintenance.[5]

Although the Sustainable Development Goals’ call for universal access to safely managed sanitation[8] has increased the political will to tackle the problem of poor sanitation in unplanned urban areas, how this universal access should be achieved remains unclear. Municipalities, health authorities, and the private sector all need to play a role, whether in planning, regulation, or the provision of financial subsidies and emptying services.[9] Even the targets are unclear because shared sanitation, which is the only feasible option in many peri-urban areas, is currently categorised as a limited rather than safely managed form of sanitation,[8] thus falling short of the Sustainable Development Goals’ target. In the meantime, households also have a role in improving their own sanitation. In this project, we investigated to what extent sanitation could be improved by the residents of an informal settlement in Zambia themselves, through behaviour change promotion alone, in the absence of institutional change or financial subsidy.

Few trials have assessed interventions to improve sanitation in resource-poor settings, whether in urban or rural areas. Although the community-led total sanitation approach has been widely used in rural areas to improve demand for sanitation, evidence for its effectiveness remains inconclusive[10] and its applicability to urban contexts unproven.[11] A few studies have shown that the cleanliness of shared sanitation can be improved through plot-level discussions[12] or by providing cleaning materials and behaviour-change messages,[13] but none have examined how to improve the structural quality of toilets.

Of more than 2 million residents of Lusaka, Zambia, 70% live in peri-urban areas,[14] which are unplanned, informal settlements sometimes referred to as slums.[3] Official figures suggest that the prevalence of open defecation is low (1% of the population)[14] but the quality of toilet superstructures, interfaces, and containment systems varies substantially.[7] Although a few toilets are used by only a single household, most are shared by multiple households on the same plot of land, which can lead to higher risks of disease transmission, especially if they are poorly maintained.[15] While the Lusaka Water and Sewerage Company, the privatised utility responsible for sanitation in Lusaka Province, is planning investment in sewerage lines and treatment plants, it also aims to provide higher-quality shared toilets but lacks an evidence base or plan for boosting demand to increase cost-sharing or improve sustainability.[16]

Our study took place in Bauleni, an informal settlement in southeast Lusaka with approximately 4000 plots. Our formative research showed that most toilets were shared by multiple households, with a resident landlord responsible for toilet provision for the multiple households living on each plot. The poor quality of toilet provision appeared to relate to the fact that landlords undervalued their tenants’ willingness to pay for quality improvements. Such willingness to pay has been identified in several similar settings, although often

using stated preference methods that might inflate estimates. For example, estimated increases in rent ranging from 1·6%[17] to 60%[18] have been reported for the construction of a toilet where none was previously present, whereas moving from a simple pit latrine to a flush toilet resulted in rental price increases of 16%.[19] In Lusaka, poorly cleaned toilets seemed to result from coordination failures caused by cleaning systems that were difficult to remember and provided little accountability.[20] Landlords were unaware of how improving sanitation could reduce the burden of managing a plot both financially and socially, viewing sanitation as a basic service to provide rather than as an investment to build wealth and reduce conflict. This result suggested that an intervention targeted at landlords, based on the motives of profit and conflict reduction, could be more effective than using health-based messages, as described on the study website and in detail in a forthcoming paper on the process of intervention development. We identified four key behaviours as being feasible, desired, and important for public health: having a well-functioning cleaning system (for cleanliness and sustainability), a lock on the inside of the door (for privacy), a lock on the outside of the door (to restrict access by outsiders), and a sealed toilet (for reduced smell and improved hygiene).

Working with a creative agency, we used the Behaviour Centred Design (BCD) approach to design an intervention targeted at landlords called the Bauleni Secret.[21] Landlords were invited to meetings where they were exposed to films, emotional demonstrations (so called emo-demos), interactive games, and learned practical skills based on a reinforcement learning model.[22] Here, we report the results of a randomised controlled trial of this intervention on the four key behaviours.

## Methods

### Study design and participants

We did a randomised, controlled trial in Lusaka, Zambia. We mapped the entire Bauleni area and demarcated it into zones on the basis of health facility-derived boundaries. To minimise the risk of information contamination between intervention groups, data collectors selected every fourth plot by walking down each street from the centre of these zones. Only landlords were enrolled in the intervention but both landlords and tenants were surveyed for the evaluation. Eligibility criteria for plots were having a landlord living on the plot (which accounted for about 80% of plots in Bauleni[23]) who was at least 18 years old and having at least one tenant household living on the plot with an adult tenant who was at least 18 years old. Landlords already meeting the four primary outcomes were still eligible for participation. We randomly selected an adult tenant head of household on the plot to gather data on mediating variables and any indirect programme effects on tenants. To do this, landlords were asked to number the tenant households on their plot, after which we used ODK Collect (version 1.4.10), our data collection tool, to randomly select a household. We surveyed the same landlords at baseline and follow-up; however, a tenant was randomly selected at each point.

Prior to enrolment, data collectors read an information sheet to all potential participating landlords or tenants in English or one of two local languages (Bemba and Nyanja), answered any questions raised, and obtained written consent or a witnessed thumbprint. No compensation was provided for participation. Ethical approval for this study was provided by the London School of Hygiene & Tropical Medicine (reference 12157) and University of Zambia Biomedical Research Ethics Committee in Lusaka, Zambia (reference 002-02-17).

### Randomisation and masking

A statistician supporting the team (SB), who had no access to study data, randomly allocated plots using a random number generator in a 1:1 ratio to the intervention or to a control group receiving no intervention. Data collectors did not have a role in programme delivery and were masked as to the allocation of survey respondents at baseline and until the final set of questions covering intervention exposure during data collection at study end. Participants were masked as to their allocation status at baseline and were told only that they were taking part in a study to understand the sanitation situation in the area. Intervention participants were contacted within 4 weeks of the baseline survey and invited to participate in the intervention and thus could not be masked to the intervention during data collection at study end.

For the **study website** see http://bentidwell.com/sandem

### Procedures

The BCD framework[21] was used to design the intervention. BCD is based on a reinforcement learning paradigm and includes a generic theory of change for behaviour in which individuals get exposed to planned changes in the environment that cause mental processing that can lead to revaluation of the target behaviour. Further elements of the intervention can make it easier for the behaviour to be performed, also reducing its cost and therefore increasing its likelihood of happening widely. Reinforcement learning occurs when the reward or punishment from performance is greater than expected, causing a feedback loop between the performance and revaluation stages. BCD also includes a design process that assesses existing knowledge, fills gaps in knowledge through formative research, and then creates, delivers, and evaluates the intervention. It has been successfully used to change a range of hygiene and nutrition behaviours.[24–26] We worked with a local creative agency, DDB Iris (Lusaka, Zambia), to develop a campaign based on a creative brief derived from the formative research. The creative agency generated concepts, campaign manuals, and branding. These were iteratively refined with input from the study team based

on theoretical considerations, research design, and logistical constraints, as well as pilot tests of materials and the entire intervention.

The intervention was marketed to landlords as a secret society-style intervention in which landlords were invited to participate in a selective programme that would share secrets about how to build their wealth and bring peace to their plots. Secrecy was emphasised to limit meeting attendance to landlords enrolled in the treatment and to reduce information sharing outside of the meetings to minimise contamination. Participants attended a series of meetings, each of which promoted one of four outcomes: sealed toilets, locks on the inside of toilet doors, locks on the outside of toilet doors, and a *pamodzi* cleaning rota. A *pamodzi* (meaning "togetherness" in Nyanja) rota was a specific kind of cleaning rota system, designed and branded for the intervention. We encouraged turns for cleaning lasting a week (instead of the more common daily turns), which we observed infrequently in our formative research but hypothesised would encourage all individuals to participate by making their failure to participate more noticeable.[23] We also introduced using a visible marker or emblem to identify the responsible household in response to challenges identifying who was responsible for cleaning reported in our formative research.[23]

Based on the initial mapping process, four meeting venues located in different parts of Bauleni were secured and each group of landlords was assigned to meet at the closest venue. Meetings followed the reinforcement learning-based structure and were led by four pairs of facilitators consisting of a trained actor and a neighbourhood health committee member. This pairing allowed exciting and entertaining non-health messages to be presented via a trusted community leader. At each meeting, participants were shown videos of tenants' perspectives on the outcome of focus to provoke discussion; demonstrations and games were used to re-evaluate the benefits of solving the sanitation issues being discussed; and sessions were run to help participants with the practicalities of implementing these solutions, providing knowledge and practice of making the sanitation improvements. The practical sessions also featured commitments to a so-called improvement buddy, where landlords were encouraged to find a partner and plan a time to go together to purchase materials and help each other to install improvements. Follow-up monitoring visits by programme staff before the next meeting helped participants to troubleshoot any barriers they faced and provided material for discussion in upcoming meetings. Landlords were instructed to get tenant signatures on a card handed out at the end of each meeting, verifying that the relevant improvement had been made; these were collected and discussed at the following meeting. To stimulate attendance, a prize draw for one of three smartphones was offered to landlords who attended all four meetings and had four improvement cards signed by their tenants. Meeting components tailored to each primary outcome are described in the protocol on the study website.

The standard group meetings took place every 2 weeks. We scheduled additional meetings (called catch-all meetings) for landlords who were unable to attend at their scheduled time or location and delivered the intervention to individual landlords at their homes if they were unable to attend any gathering; all of these meetings were completed within 2 months of the completion of the standard group meetings. Data for primary and secondary outcomes were measured at enrolment, which was about 1 month before the first meeting, and at study end, which was 4 months after the last standard group meeting (excluding the catch-all meetings). We observed the presence of internal and external locks, sealed toilets and use of the suggested rota emblem, while the presence of a functioning cleaning rota was reported by the landlord. If more than one toilet was present on the plot, the landlord was asked to identify and answer questions about the toilet most frequently used by tenants.

We collected the following additional data at baseline and study end: we asked landlords about demographics, plot characteristics, characteristics of the toilet, attitudes towards sanitation, and tenant rental fees and turnover. We also asked landlords about exposure to the intervention at study end. We collected data from tenants on demographics, housing characteristics, toilet improvement preferences and willingness to pay, satisfaction with living on the plot, and rental fee history. We also asked them about some subjective aspects of sanitation and about the cleaning procedures in place that we had also asked landlords about to compare their responses.

Data collectors all had prior experience with working on research studies and received a week of classroom and field-based training, with particular attention being paid to analysing and improving the reliability of toilet observations. Questionnaires were developed in English, translated into Bemba and Nyanja, and then back-translated to ensure accuracy and pilot tested during data-collector training under close supervision of the study team.

All data collectors received human subject protection training and certification. Names, government-issued plot numbers, and GPS coordinates were collected for the purpose of surveying the same respondents at baseline and at study end, but were removed from final datasets to protect anonymity.

### Outcomes

We chose four primary outcomes: (1) having a rotational cleaning system in place (reported by the landlord); (2) having a solid door on the toilet used by tenants with an inside lock or (3) an outside lock (both directly observed); and (4) having a sealed toilet (either a simple cover or pour-flush toilet) for reducing smell and preventing contact with faecal material (directly observed). These outcomes were

chosen because each covered one of the four different aspects of sanitation quality (hygiene, desirability, accessibility, and sustainability) as defined by our public health improvement framework for sanitation,[7] required different types of behaviour (one time *vs* ongoing) and commitment (inexpensive and quick *vs* expensive and time consuming), were done by different responsible individuals (tenants or landlords), and were feasible to change within the intervention time period. No health outcomes were measured. We established the validity and reliability of these measures in an area of Bauleni not included in the intervention.[7]

We defined our secondary outcomes as landlords having amassed materials and carried out partial construction of improvements (both observed); landlords having saved money towards an improvement (reported by the landlord); and landlords and tenants having taken up aspects of a *pamodzi* rota (week-long turns reported by the landlord; visible marker of responsibility observed). Further secondary outcomes that will be assessed in a forthcoming process evaluation are landlords having made improvements across all aspects of sanitation, beyond the study outcomes, as measured by a composite index;[7] and improvement of landlord attitudes towards sanitation and increased willingness to pay for sanitation by landlords, both measured through open-ended self report.

Serious adverse events were monitored by all data collection staff and intervention delivery staff, who were instructed to report any suspected events immediately to the Study Coordination Centre.

### Statistical analysis

We calculated the sample size using a power of 80% and a family-wise error rate (FWER) of 0·05 to calculate the significance level. FWER was used because the multiple primary outcomes were not assumed to be independent. The adjusted significance level α was calculated using the following formula,[27] where $h$ is the number of outcomes:

$$\alpha = 1 - (1 - \mathrm{FWER})^{(1/\sqrt{h})}$$

The FWER-adjusted α was 0·0227 based on an initial plan of including five outcomes, although one outcome—presence of a handwashing stand—was removed during the formative research process as no suitable, locally available solution was identified. Sample sizes were calculated for each of the five planned primary outcomes using a change of 5 percentage points for the sealed toilet outcome and of 10 percentage points for the others as the minimum targets of practical significance. The largest required sample size was selected and revised target levels based on this sample size were calculated for the four final primary outcomes (α = 0·0253 with 80% power; table 1).

Data was collected using ODK Collect (version 1.4.10) and analysed using R (version 3.4.1). Data completeness and integrity was ensured by requiring responses to all questions (with "doesn't know" and "won't say" options), avoiding freely entered text responses when possible, and validating and range limiting numerical entries. We analysed the primary outcomes on an intention-to-treat basis, excluding landlords lost to follow-up. We used log-binomial regression to estimate the effects of the intervention on the primary outcomes at study end. We adjusted p values for multiple-outcomes testing using FWER. Similarly, we calculated absolute risk increase using a generalised linear model with a binomial distribution and identity link function, again with p values adjusted for FWER. We followed a similar analytic approach for most secondary outcomes, including an adjusted analysis incorporating plot income, education, initial sanitation quality, and number of tenant households on the plot as covariates using FWER and exploratory analyses of the uptake of outcome components (such as adopting the improved cleaning rota) and taking steps towards making improvements (using α = 0·05).

We prespecified a loss to follow-up threshold of 10%, after which we would do a multiple imputation analysis established in the study protocol. We used the full dataset with baseline and study-end data combined to do a full conditional specification, where missing values are computed for one variable at a time sequentially, allowing baseline values (which were missing less frequently) to be used to impute study-end data. Analysis was done using the *mice* package (version 3.1.0) in R.[28]

This trial is registered at ClinicalTrials.gov, number NCT03174015.

| | Existing level | Initial target level | Sample size required (per arm) | Final target level |
|---|---|---|---|---|
| Sealed toilet | 5% | 10% | 539 | 9·9% |
| Inside lock | 52% | 62% | 476 | 61·3% |
| Outside lock | 46% | 56% | 486 | 55·4% |
| Cleaning rota | 54% | 64% | 470 | 63·2% |

*Table 1:* **Sample size calculations by primary outcome**

### Role of the funding source

The funder of the study had no role in the data collection, analysis, or interpretation; trial design; or participant recruitment. JBT, JC, and RA had full access to the study data and JBT takes final responsibility for the decision to submit for publication.

## Results

Between June 9 and July 6, 2017, 1137 resident plot owners were surveyed, of whom less than 5% were excluded because they had no tenants (figure). 1085 landlords were enrolled in the study and randomly assigned to the intervention (n=543) or the control group (n=542). Intervention delivery began on Aug 1, 2017, with the last meeting taking place on Sept 23, 2017, and 928 participants were surveyed at study end from Feb 15 to March 5, 2018

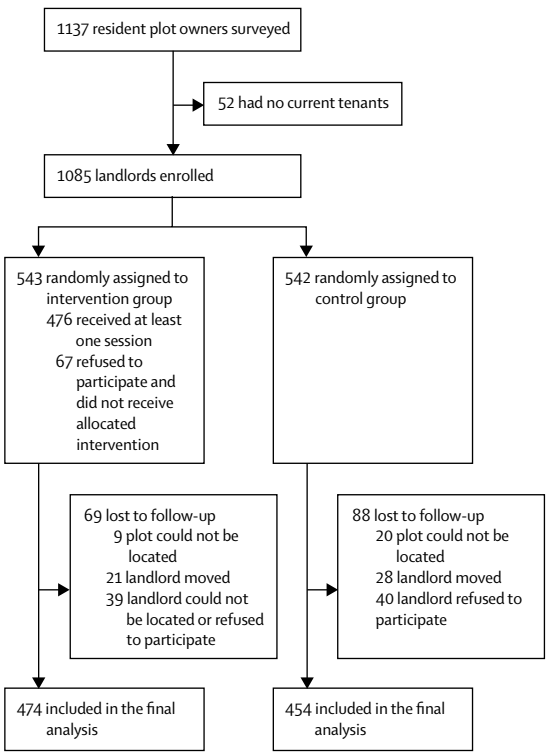


***Figure:*** **Trial profile**

(474 in the intervention group and 454 in the control group). Loss to follow-up in this highly mobile and informal environment was due to landlords moving (n=49), inaccurate plot addresses (n=29), or landlords being unreachable or unwilling to respond to the study-end survey despite repeated attempts to interview them (n=79; figure). 67 landlords allocated to the intervention failed to attend any meeting or to receive any programme message directly from the programme staff, with some reporting a lack of interest in sanitation or, conversely, already having high-quality sanitation. Additionally, of the 454 landlords in the control group surveyed at study end, 105 (23%) had heard of the programme, 50 (11%) said that someone had talked to them about programme messages, and 19 (4%) said that they had made sanitation improvements due to programme exposure. We therefore avoid reporting per-protocol results due to these conflicting biases that might have affected them.

Landlord, tenants, and plots were broadly similar (table 2). Most landlord respondents were women and many landlords had completed at least some secondary education (table 2). Landlords generated a mean of 1390 Kw (SD 1090; approximately US$140) in rental income from the plot each month. More than one third of all plots had electricity and slightly more had water. Almost all landlords had toilets on the plot, most of which had a solid door on which the landlords could easily mount the locks promoted in the programme. About a quarter of plots in the sample had more than one toilet, usually because the landlord had a separate toilet from the tenants.

| | Intervention (n=543) | Control (n=542) |
|---|---|---|
| **Landlords** | | |
| Age, years | 45·8 (15·2) | 46·6 (15·3) |
| Gender | | |
| Female | 371 (68%) | 384 (71%) |
| Male | 172 (32%) | 158 (29%) |
| Education | | |
| Primary or less | 148 (27%) | 169 (31%) |
| Started or completed secondary | 369 (68%) | 345 (64%) |
| Beyond secondary | 24 (4%) | 23 (4%) |
| **Tenants** | | |
| Age, years | 30·9 (9·0) | 30·9 (9·3) |
| Gender | | |
| Female | 415 (76%) | 410 (76%) |
| Male | 128 (24%) | 132 (24%) |
| Education | | |
| Primary or less | 107 (20%) | 90 (17%) |
| Started or completed secondary | 410 (76%) | 414 (76%) |
| Beyond secondary | 25 (5%) | 38 (7%) |
| Monthly rent, Kw | 456 (189) | 464 (188) |
| Monthly income, Kw | 1303 (941) | 1339 (984) |
| **Plot characteristics** | | |
| Doors per plot | 3·07 (2·23) | 3·03 (1·98) |
| Rooms per door | 1·85 (0·75) | 1·94 (0·71) |
| Electricity | 211 (39%) | 185 (34%) |
| Water on plot | 220 (41%) | 209 (39%) |
| **Toilet characteristics** | | |
| Has a toilet on plot | 531 (98%) | 525 (97%) |
| More than one toilet on plot | 134 (25%) | 135 (25%) |
| Solid walls | 421 (78%) | 428 (79%) |
| Solid roof | 237 (44%) | 261 (48%) |
| Floor easy to clean | 377 (69%) | 391 (72%) |
| Sealed toilet | 109 (20%) | 110 (20%) |
| Flushing toilet | 78 (14%) | 74 (14%) |
| Simple toilet cover | 31 (6%) | 36 (7%) |
| Vent pipe | 89 (16%) | 86 (16%) |
| Solid door | 362 (67%) | 387 (71%) |
| Inside lock | 164 (30%) | 189 (35%) |
| Outside lock | 200 (37%) | 214 (39%) |
| Cleaning rota | 312 (57%) | 295 (54%) |

Data are n (%) or mean (SD).

***Table 2:*** **Baseline characteristics by study arm**

6 months after the delivery of the intervention began, landlords reported the presence of a cleaning rota on 72·3% of intervention plots and 62·1% of control plots (relative risk [RR] 1·16, 95% CI 1·05–1·30; table 3). Inside

| | Intervention | Control | Absolute risk increase (95% FWER CI) | Relative risk (95% FWER CI); p value | |
|---|---|---|---|---|---|
| | | | | Unadjusted | Adjusted |
| Cleaning rota | 339/469 (72%) | 275/443 (62%) | 10·2% (3·3–17·1) | 1·16 (1·05–1·30); p=0·0011 | 1·12 (1·02–1·23); p=0·0063 |
| Inside lock | 196/450 (44%) | 141/434 (32%) | 11·1% (3·8–18·3) | 1·34 (1·10–1·64); p=0·00081 | 1·26 (1·07–1·49); p=0·0021 |
| Outside lock | 212/451 (47%) | 161/435 (37%) | 10·0% (2·6–17·3) | 1·27 (1·06–1·52); p=0·0028 | 1·24 (1·04–1·46); p=0·0052 |
| Sealed toilet | 207/452 (46%) | 160/436 (37%) | 9·1% (1·7–16·4) | 1·25 (1·04–1·50); p=0·0063 | 1·17 (0·99–1·38); p=0·032 |

95% CIs and p values are calculated on FWER-adjusted α = 0·0253. FWER=family-wise error rate.

***Table 3:*** **Effects of the intervention on primary outcomes at 6 months after start of intervention**

locks were observed on 43·6% of intervention plots versus 32·5% in the control group (1·34, 1·10–1·64), whereas outside locks were observed on 47·0% of the intervention plots compared with 37·0% in the control group (1·27, 1·06–1·52). Sealed toilets were present on 45·8% of intervention plots compared with 36·7% in the control group (1·25, 1·04–1·50). Details of the parameter estimates for unadjusted and adjusted models are presented in the appendix. Due to the high loss to follow-up (14·5%), we used multiple imputation of the missing data to supplement the complete records analysis to assess any bias due to differential loss to follow-up (appendix), but these results led to no changes in interpretation.

We also explored how the intervention results varied by landlord and plot characteristics using logistic regression to understand inequities in impacts on participants and how this intervention might work in other settings (appendix). RR estimates were adjusted for monthly rent, landlord education level, presence of a separate toilet for the landlord, presence of water on the plot, and the number of households living on the plot (table 3). Plot income—a measure of a landlord's total rent revenue from the plot—was positively associated with each of the outcomes except for sealed toilet. The presence of a water connection on the plot was also positively associated with each outcome, other than presence of a cleaning rota, but this positive association was largely due to its correlation with plot income. The number of doors was also negatively associated with each of the three structural outcomes, as might be expected, because the more rooms for a given plot income (and thus the lower the rental cost per room), the lower the quality the housing was in general. Some change between baseline and study end was observed for cleaning rotas and sealed toilets in the control group, although there was no change in the interpretation of the statistical significance of the primary outcomes as a result.

The intervention encouraged not just having a cleaning rota of any kind but starting the potentially more effective *pamodzi* rota system. At the follow-up monitoring visits between meetings, 336 (71%) of 475 landlords in the intervention group reported having started a *pamodzi* rota, with 283 (84%) of those who started one reporting it still operating at study end. Weekly rota turns, a component of the *pamodzi* rotas that was more commonly followed by intervention landlords at study end (187 [41%] of 458 landlords in the intervention group *vs* 144 [33%] of 443 landlords in the control group; RR 1·26, 95% CI 1·04–1·47), made it more likely for the floor (364 [83%] of 438 landlords *vs* 76 [77%] of 99 landlords; 1·08, 1·02–1·15) and pan (357 [82%] of 438 landlords *vs* 74 [75%] of 99 landlords; 1·08, 1·01–1·15) to be clean than did having a daily rota.

See Online for appendix

Because the time between the delivery of the lesson on creating a sealed toilet and the study-end data collection was only 4 months, we assessed whether landlords reported saving funds for or were observed to have collected materials for or begun construction on toilet improvements (table 4). Although differences for these three categories individually were not statistically significant, landlords in the intervention group were more likely to have taken a step towards making an improvement (RR 1·31, 95% CI 1·07–1·56).

No potential serious adverse events were reported during the trial.

## Discussion

We found that plots in the intervention group had significantly better quality toilets compared with those in the control group across all four dimensions of quality improvement, with an approximate 10 percentage-point increase in the intervention group in the proportion of toilets with inside and outside locks, cleaning rotas, and sealed toilets. The primary outcomes were selected to cover the major aspects of sanitation from a public health perspective and to represent a range of kinds of behaviour. The intervention appeared to have been effective in driving improvements in each of these outcomes. In addition, we found that landlords in the intervention group were more slightly likely to have saved money, purchased materials, or begun construction of toilet improvements. Although these improvements were generally not expensive to implement, they provide substantially increased utility to these simple sanitation facilities—which is itself an important lesson for both householders in such contexts and public health professionals.

| | Intervention (n=474) | Control (n=454) | Percentage point difference (95% CI); p value |
|---|---|---|---|
| Has taken no steps towards an improvement | 293 (62%) | 322 (71%) | −9·1% (−15·1 to −3·0); p=0·0042 |
| Has saved money towards an improvement but has not started construction | 31 (7%) | 21 (5%) | 1·9% (−1·1 to 4·9); p=0·26 |
| Has purchased building materials but has not begun construction | 59 (12%) | 40 (9%) | 3·6% (−0·4 to 7·6); p=0·092 |
| Has begun construction but has not finished | 91 (19%) | 71 (16%) | 3·6% (−1·2 to 8·5); p=0·18 |

*Table 4:* **Steps taken towards sanitation improvement**

We suspect that there were several reasons for the intervention's apparent success. These include the use of a systematic and theory-based process to understand the problem, the isolation of key behaviours to be changed, and the creative design and careful evaluation of the intervention. Delivering surprising messages to landlords, incorporating social learning and influence through landlord group meetings, and accountability mechanisms to facilitate behaviour were also probably key in ensuring that desired improvements were carried out. A full process evaluation will be published elsewhere to further establish successful intervention mechanisms.

Improvements requiring collective and coordinated action, such as changing the duration and mechanics of cleaning rotas, were also effective. At least one other intervention focusing exclusively on shared cleaning has been effective,[12] but the long-term impact of either intervention on cleaning behaviours is unknown. We hypothesise that altering the cleaning system to reduce potential free-rider problems (ie, a tenant not sharing the responsibility for cleaning the services they use) using a visible symbol to indicate the presence of a social norm and facilitate accountability for cleaning could be effective in the long term. However, future work is needed on the question of sustainability, as well as on the potential health impact of a range of toilet improvements.

We would have liked to observe the impact of the intervention on improving sealed toilets over a longer time period. Larger improvements required mobilisation of financial resources, and with 9% more landlords taking steps towards an improvement in the intervention arm, some additional impact might have been achieved over time. However, it became clear that working in this peri-urban context brought trade-offs between duration and loss to follow-up and additional complications such as landlords choosing to purchase or move to new plots with better toilets, rather than improving their own toilet. Numbers of landlords refusing to participate by study end might not have changed with a longer time to follow-up but the high turnover rate would have led to continued attrition. For future work, we suggest focusing specifically on larger infrastructural improvements with either repeated study-end measures using a lighter-touch instrument or looking at immediate impact on the willingness to pay for or purchase of specific products at the time when the intervention is delivered.

Several potential sources of bias arose during the execution of this study. About 15% of the sample across arms were lost to follow-up, so a multiple imputation analysis was done to explore how this might have affected our results. Although multiple imputation analysis resulted in no changes in the interpretation of the study results based on complete cases, this level of loss to follow up remains a major challenge in this setting. Measurement errors are also a major challenge in this setting.[7] However, observational, validated measures were used for primary outcomes where possible, which were collected while data collectors were still masked to treatment status. It therefore seems likely that the improvements in toilet quality seen in the intervention group were due to the Bauleni Secret intervention.

The possibility of contamination was also a serious consideration, as we individually randomised plots within the same neighborhood. We attempted to avoid this in the design by geographically spacing out those who were enrolled, selecting 543 of the approximately 4000 plots in the study area, and by emphasising the secret society aspect of the intervention to reduce information sharing. We measured self-reported exposure to the intervention in our study end data collection and found very low levels of exposure in the control group. Any contamination would only have reduced the measured impact of the intervention.

Several contextual elements might have affected our results. Owners of plots in the study area had secure land tenure backed by official government documents and records. Plots were originally only intended for occupancy by one household, and so there was some uncertainty about the legality of the status quo; however, this did not seem to be a barrier to investing in improvements to the plot. A large percentage of landlords living on these plots shared the same toilet as tenants, which is likely to have made the intervention more effective. Furthermore, a cholera outbreak occurred in Lusaka near the end of the study, which might have temporarily resulted in higher levels of motivation to improve toilets. However, the median number of households on a plot (three) in our sample might be much lower than other settings.[5,12] This means the return on investment for toilet improvements associated with increasing rent might be higher than in our study. The general motivation of landlords to increase profits and reduce the hassle of management seems likely to be applicable in other settings.[29]

To our knowledge, this study is the first to show that a purely behavioural intervention, independent of institutional reform or financial incentives, can improve the quality of shared toilets in peri-urban areas. It remains to be seen if such approaches can be scaled up so as to contribute to solving the growing problem of sanitation in unplanned urban settlements. As the number of people using shared toilets has increased from 204 million to 465 million over the period 1990 to 2015 in Africa alone,[30] an understanding of what constitutes safely managed shared sanitation and how to achieve it are crucially important. Governments should consider including behaviour change communication to improve demand for better quality toilets in urban sanitation programming, while at the same time addressing other crucial issues, such as the availability of effective technologies, emptying services, and land tenure.

As this trial was designed to be a proof-of-concept for the possibility of improving sanitation quality through demand generation alone, we did not attempt to measure changes in health outcomes, but we encourage the pursuit of larger-scale trials using broad measures of health impact in the future. However, the results of this trial show that better cleaning and structural improvements of peri-urban shared sanitation are possible through a behaviour change intervention. Both the profit motives of landlords and willingness to pay of tenants might overcome traditional behavioural hurdles to investing in preventive behaviours, as landlords can draw on a profit motive to justify upfront costs and tenants can avoid upfront costs altogether. Improved coordination mechanisms might be effective in these ad-hoc social groupings where tenants rarely have pre-existing relationships.[23] Due to the trend of rapid global urbanisation, approaches such as these will increasingly be required to motivate environmental health interventions beyond those that work in rural or better constructed urban settings. Broad efforts to secure land tenure and improve infrastructure are doubtless needed as well and large-scale investments are certainly warranted. The private sector also has a part to play in providing appropriate products, which will hopefully be encouraged by increasing acknowledgment of willingness to pay for sanitation. The results of this trial suggest that in conjunction with such efforts, a theory-based, creatively designed demand-side-only intervention could play an important part in improving the quality of peri-urban sanitation.

#### Contributors

All authors participated in study design. JC and JBT designed the data collection tools with input from RC and RA. JC managed the data collection process. JBT and SB conducted the data analysis and interpretation. JBT drafted the initial manuscript, and all authors contributed equally to revising the manuscript.

#### Declaration of interests

We declare no competing interests.

#### Data sharing

De-identified, individual-level data, field descriptions, the full study protocol, and data collection tools, will be made available upon request to the corresponding author.

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For more on the **SHARE Research Consortium** see http://www.shareresearch.org

#### References

1 UN-HABITAT. The challenge of slums: global report on human settlements. London: Earthscan Publications, 2003.
2 Marx B, Stoker T, Suri T. The economics of slums in the developing world. *J Econ Perspect* 2013; **27:** 187–210.
3 Ezeh A, Oyebode O, Satterthwaite D, et al. The history, geography, and sociology of slums and the health problems of people who live in slums. *Lancet* 2017; **389:** 547–58.
4 Nakagiri A, Niwagaba CB, Nyenje PM, Kulabako RN, Tumuhairwe JB, Kansiime F. Are pit latrines in urban areas of Sub-Saharan Africa performing? A review of usage, filling, insects and odour nuisances. *BMC Public Health* 2016; **16:** 120.
5 Shiras T, Cumming O, Brown J, Muneme B, Nala R, Dreibelbis R. Shared latrines in Maputo, Mozambique: exploring emotional well-being and psychosocial stress. *BMC Int Health Hum Rights* 2018; **18:** 30.
6 Freeman MC, Garn JV, Sclar GD, et al. The impact of sanitation on infectious disease and nutritional status: a systematic review and meta-analysis. *Int J Hyg Environ Health* 2017; **220:** 928–49.
7 Tidwell JB, Chipungu J, Chilengi R, Aunger R. Assessing peri-urban sanitation quality using a theoretically derived composite measure in Lusaka, Zambia. *J Water Sanit Hyg Dev* 2018; **8:** 668–78.
8 Evans B, Hueso A, Johnston R, et al. Limited services? The role of shared sanitation in the 2030 Agenda for Sustainable Development. *J Water Sanit Hyg Dev* 2017; **7:** 349–51.
9 McGranahan G. Realizing the right to sanitation in deprived urban communities: meeting the challenges of collective action, coproduction, affordability, and housing tenure. *World Dev* 2015; **68**: 242–53.
10 Venkataramanan V, Crocker J, Karon A, Bartram J. Community-led total sanitation: a mixed-methods systematic review of evidence and its quality. *Environ Health Perspect* 2018; **126:** 388–96.
11 Myers J. Urban community-led total sanitation: a potential way forward for co-producing sanitation services. *Waterlines* 2016; **35:** 388–96.
12 Tumwebaze IK, Mosler HJ. 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.
13 Alam MU, Winch PJ, Saxton RE, et al. Behaviour change intervention to improve shared toilet maintenance and cleanliness in urban slums of Dhaka: a cluster-randomised controlled trial. *Trop Med Int Health* 2017; **22:** 1000–11.
14 Ministry of Local Government and Housing. National urban sanitation strategy (Lusaka, Zambia). Lusaka: Government of the Republic of Zambia, 2014.
15 Heijnen M, Cumming O, Peletz R, et al. Shared sanitation versus individual household latrines: a systematic review of health outcomes. *PLoS One* 2014; **9:** e93300.
16 World Bank. Project appraisal document 1204: proposed credit to the Republic of Zambia for a Lusaka sanitation project. Washington, DC: World Bank, 2015.
17 Gulyani S, Bassett EM, Talukdar D. Living conditions, rents, and their determinants in the slums of Nairobi and Dakar. *Land Econ* 2012; **88:** 251–74.
18 Van Houtven G, Pattanayak SK, van den Berg C, Yang J-C. The use of willingness to pay experiments: estimating demand for piped water connections in Sri Lanka. Washington, DC: World Bank, 2006.
19 Knight JR, Herrin WE, Balihuta AM. Housing prices and maturing real estate markets: evidence from Uganda. *J Real Estate Finance Econ* 2004; **28:** 5–18.
20 Chipungu J, Tidwell JB, Chilengi R, Curtis V, Aunger R. The social dynamics around shared sanitation in an informal settlement of Lusaka, Zambia. *J Water Sanit Hyg Dev* 2018; published online Dec 12. DOI:10.2166/washdev.2018.102.

21 Aunger R, Curtis V. Behaviour Centred Design: towards an applied science of behaviour change. *Health Psychol Rev* 2016: 1–22.

22 Niv Y. Reinforcement learning in the brain. *J Math Psychol* 2009; **53:** 139–54.

23 Tidwell JB, Chipungu J, Chilengi R, Curtis V, Aunger R. Theory-driven formative research on on-site, shared sanitation quality improvement among landlords and tenants in peri-urban Lusaka, Zambia. *Int J Environ Health Res* 2018; published online Nov 7. DOI:10.1080/09603123.2018.1543798.

24 Biran A, Schmidt WP, Varadharajan KS, et al. Effect of a behaviour-change intervention on handwashing with soap in India (SuperAmma): a cluster-randomised trial. *Lancet Glob Health* 2014; **2:** 145–54.

25 Greenland K, Chipungu J, Curtis V, et al. Multiple behaviour change intervention for diarrhoea control in Lusaka, Zambia: a cluster randomised trial. *Lancet Glob Health* 2016; **4:** e966–77.

26 Gautam OP, Schmidt W-P, Cairncross S, Cavill S, Curtis V. Trial of a novel intervention to improve multiple food hygiene behaviors in Nepal. *Am J Trop Med Hyg* 2017; **96:** 1415–26.

27 Braun H. Multiple comparisons: 1948–1983. New York, NY: Chapman & Hall, 1994.

28 Buuren Sv, Groothuis-Oudshoorn K. mice: multivariate imputation by chained equations in R. *J Stat Softw* 2010; **45:** 1–68.

29 Isunju JB, Schwartz K, Schouten MA, et al. Socio-economic aspects of improved sanitation in slums: A review. *Public Health* 2011; **125:** 368–76.

30 UNICEF, WHO. Progress on sanitation and drinking water—2015 update and MDG assessment. Geneva: World Health Organization, 2015.