Impact of a sanitation intervention on quality of life and mental well-being in low-income urban neighbourhoods of Maputo, Mozambique: an observational study

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ABSTRACT

Objectives Toilet users often report valuing outcomes such as privacy and safety more highly than reduced disease, but effects of urban sanitation interventions on such outcomes have not been assessed quantitatively. In this study, we evaluate the impact of a shared sanitation intervention on quality of life (QoL) and mental well-being.

Design We surveyed individuals living in intervention and control clusters of a recent non-randomised controlled trial, and used generalised linear mixed regression models to make an observational comparison of outcomes between arms.

Setting Low-income unsewered areas of Maputo City, Mozambique.

Participants We interviewed 424 participants, 222 from the prior trial’s intervention group and 202 from the control group.

Interventions The control group used low-quality pit latrines. The intervention group received high-quality shared toilets, with users contributing 10%–15% of capital cost.

Outcomes Our primary outcome was the Sanitation-related QoL (SanQoL) index, which applies respondent-derived weights to combine perceptions of sanitation-related disgust, privacy, safety, health and shame. Secondary outcomes were the WHO-5 mental well-being index and a sanitation Visual Analogue Scale.

Results The intervention group experienced a 1.6 SD gain in SanQoL compared with the control group. This adjusted SanQoL gain was 0.34 (95% CI 0.29 to 0.38) on a 0–1 scale with control mean 0.49. Effect sizes were largest for safety and privacy attributes. Intervention respondents also experienced a 0.2 SD gain in mental well-being. The adjusted gain was 6.2 (95% CI 0.3 to 12.2) on a 0–100 scale with control mean 54.4.

Conclusions QoL outcomes are highly valued by toilet users and can be improved by sanitation interventions. Such outcomes should be measured in future sanitation trials, to help identify interventions which most improve people’s lives. Since SanQoL weights are derived from respondent valuation, our primary result can be used in economic evaluation.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- We achieved balance on observable characteristics by enrolling individuals living in intervention and control clusters of a recent non-randomised controlled trial.
- Because intervention compound residents previously shared a low-quality toilet in the same location, the mechanism driving our results is likely to be the characteristics of intervention toilets.
- No previous study has evaluated the impact of an urban sanitation intervention on outcomes such as user-reported privacy, safety or mental well-being.
- Limitations include the absence of preintervention outcome data, risk of bias from the eligibility criterion of still using the type of toilet consistent with intervention/control status.

INTRODUCTION

Nearly two billion people globally lack access to ‘basic’ sanitation.1 This deficit leads to 400,000 deaths from diarrhoeal disease annually, as well to helminth infections and other diseases.2 However, inadequate sanitation has negative consequences beyond infectious disease, including for perceived outcomes such as privacy, safety and dignity.3–5 These outcomes are considered aspects of quality of life (QoL) under the capability approach,6 since they capture what people can be and do. Furthermore, these outcomes map onto regularly defined features of QoL, in general, such as health, personal security and environmental conditions.7–8 Sanitation-related QoL (SanQoL) is then defined as the subset of overall QoL, which is directly affected by sanitation practices or services.9

Many factors are hypothesised to moderate effects of sanitation interventions on QoL outcomes.5–9 Some of these factors relate to individual characteristics. For example,
women and girls might be at greater risk of infringements to their sanitation-related safety and privacy than men and boys. People with reduced mobility such as older or disabled people may be more likely to fear falling into a pit latrine. Other factors relate to the environment. For example, someone using a nearby toilet in an urban neighbourhood perceived as unsafe may feel less secure using it at night than someone in a rural area.

In studies of what toilet users most value about sanitation, QoL outcomes such as privacy or status are usually high up their list, and often above disease prevention. Therefore, expected QoL payoffs from household sanitation investments are important determinants of whether the public good of an excreta-free environment is achieved. Since different sanitation interventions plausibly improve QoL to different extents, measurement of such outcomes in sanitation impact evaluations may help identify the most effective interventions.

However, infectious disease outcomes have often been the focus of sanitation impact evaluations. A systematic review of qualitative studies of sanitation’s relationship with mental and social well-being identified innovation in quantitative measurement of such outcomes as a research priority. One quantitative study has explored the association in the general population between urban sanitation access and mental well-being outcomes, and another has been undertaken in a rural area. No studies have quantified the broader QoL effect of a specific urban sanitation intervention, with one such study ongoing, and another undertaken in a rural area. In this study, we evaluate the effect of a shared urban sanitation intervention on SanQoL and mental well-being in urban Mozambique, as compared with existing use of shared pit latrines.

METHODS

Setting

In Mozambique, only 37% of the population has access to basic sanitation as defined by WHO/UNICEF. Maputo city, Mozambique’s capital, has a population of 1.1 million, with the majority living in basic settlements with unpaved roads. Pit latrines are used by 41% of people, and less than half of faecal waste is safely managed. Our study site comprises low-income neighbourhoods in a 10 km² area of the Nhlamankulu district (further detail and maps in online supplemental appendix A). In this area, the poorest people live in informally walled ‘compounds’ with many households sharing the same toilet. Though 99% have access to on-premises piped water, low-quality pit latrines are common. Such latrines often have unlined pits and squatting slabs made of wood or tyres, and no water seal (u-bend) providing a barrier to smells and flies. Privacy is a challenge since latrine walls are usually made with scrap corrugated iron or plastic sheeting, often with gaps and holes. Doors are makeshift and roofs uncommon.

Study design

We report an observational study sampling households from the intervention and control clusters of a prior non-randomised trial with a controlled before-and-after design (ClinicalTrials.gov, NCT02362932). Intervention compounds in the Maputo Sanitation trial (MapSan) were identified in 2015–2016 using the following criteria: (1) inhabitants sharing poor-quality sanitation; (2) at least 12 inhabitants; (3) inhabitants willing to contribute financially to construction; (4) legal on-plot piped water; (5) located in predefined neighbourhoods; (6) sufficient space for construction; (7) accessible for transportation of construction materials and (8) water table low enough for septic tank installation.

The MapSan trial enrolled the compound if there was at least one resident child younger than 48 months. As each intervention compound was enrolled, investigators concurrently enrolled a control compound according to criteria 1–4 above and by number of inhabitants (cluster size). Control compounds were located in the same or adjacent neighbourhoods. MapSan concluded that the intervention had no effect on any measure of child health, with a 24-month diarrhoea prevalence ratio of 0.84 (95% CI 0.47 to 1.51).

Participants

Eligible participants for our study were people aged 18 or over and: (1) living in MapSan intervention or control compounds for 4 or more years, since before the intervention; (2) still using the type of toilet consistent with intervention/control status (eg, pit latrine if control). The first criterion ensured that, prior to the intervention, all our participants had been using a pit latrine without a water seal in that same compound they still lived on. This aimed to reduce risk of selection bias, because there had been migration out of and into MapSan-enrolled compounds since 2015. The second criterion was motivated by the knowledge that an unknown number of control compounds had: (A) received non-government organisation (NGO) sanitation interventions under a post-MapSan programme or (B) autonomously upgraded their toilets. This criterion aimed to ensure a sufficient sample of people using low-quality toilets for the purposes of validity assessments reported elsewhere.

We aimed to recruit two people per compound (one man, one woman) from different households. We used trial records to preassess eligibility for the 593 MapSan compounds (clusters), leading to the exclusion of 35 (figure 1). The two lists of remaining MapSan intervention and control compounds were then randomly reordered, and visited in that new order. Procedures for sampling individuals within a compound are in online supplemental appendix B. They are summarised as inspection of the toilet used to assess eligibility, followed by listing of eligible individuals and then random sampling. A team of four fieldworkers interviewed participants in Portuguese.
unless the participant preferred to talk in Changana, a local language in which all interviewers were fluent.

**Interventions**

The intervention we evaluated was implemented by Water 
& Sanitation for the Urban Poor, an NGO. Compounds were provided with a subsidised pour-flush toilet with a water seal and concrete superstructure, discharging to a septic tank with soakaway (photos and further intervention details in online supplemental appendix A). Two toilet types were provided, depending on user numbers. A shared toilet (ST) with one stance (cubicle) was designed for around 15 people, while a community sanitation block (CSB) with two stances was designed for at least 21 people. Both STs and CSBs had metal doors lockable from the inside. Compound inhabitants had to pay a 10%–15% capital contribution—approximately US$120 for CSB (2015 prices) and US$80 for ST.

**Outcomes**

The primary outcome is an index of SanQoL, deriving from a capability-based questionnaire informed by qualitative research. SanQoL measures aspects of self-perceived QoL which are directly affected by sanitation practices or services. Validity and reliability of SanQoL were previously assessed in the Maputo setting through cognitive interviews and psychometric analysis. The five SanQoL attributes are disgust, health, privacy, safety and shame, measured on a four-level frequency scale (table 1).

Responses are combined as an index by weighting attributes according to their relative importance, assessed via a ranking exercise undertaken with all study participants (online supplemental appendix B). The ensuing weights, which sum to 1 (table 1), were used to calculate SanQoL index values on a 0–1 scale. Higher scores are better, with 0 representing ‘no sanitation-related capability’ and 1 ‘full sanitation-related capability’. Histograms of outcome variables by group are in online supplemental appendix C.

The second outcome is a sanitation Visual Analogue Scale (VAS). We asked people to indicate on a paper-based 0–10 scale how they felt about their ‘level of sanitation today’, where 0 is ‘worst imaginable sanitation’ and 10 is ‘best imaginable sanitation’ (online supplemental appendix B). The rationale for including the sanitation VAS was to explore whether an effect size comparable to that for SanQoL would be seen when people rated their level of sanitation directly rather than via questionnaire items.

The third outcome is the WHO-5 mental well-being index, a multiattribute instrument for assessing subjective mental well-being. It comprises five items related to feeling cheerful, calm, active, well rested and finding...
enjoyment in daily life, scored on a frequency scale (online supplemental appendix B). Scores are summed with equal weighting and rescaled to 0–100, with higher scores better. The rationale for including WHO-5 was that mental well-being is thought to be influenced by sanitation but, unlike SanQoL, is not specific to sanitation.4

**Hypotheses**

We analysed participants according to trial arm, to test the overarching hypothesis that the intervention was associated with an improvement in QoL. Specific hypotheses were, first, that the intervention would be associated with higher SanQoL index values and sanitation VAS scores, because better-quality toilets have the potential to improve people’s sanitation-related capabilities.9 14 Second, we hypothesised that the intervention would be associated with higher mental well-being (WHO-5) scores, based on qualitative evidence4 and earlier cross-sectional studies.21 22

We carried out exploratory moderation analyses for which the study was not powered. We assessed the hypotheses that for all three outcomes any effect would be larger for women than men,30 31 and larger for elderly people (aged 60+)32 than non-elderly.12

**Statistical analyses**

The sample size calculation for the number of participants to be surveyed was estimated according to a formula for the comparison of two means with 80% power and significance at 0.05. The required sample size to detect a 0.05 mean difference in SanQoL with an SD of 0.15 and intracluster correlation coefficient of 0.4 was estimated as 398. We computed a wealth index using principal components analysis,33 using the asset list from the most recent Mozambican Demographic and Health Survey. P values less than 0.05 were considered statistically significant evidence of association. We ran analyses in Stata V.17.34

To test hypotheses, we used generalised linear mixed models (GLMM), with gaussian distribution and identity link. Analyses were not prespecified. The model for SanQoL index values was as follows, with other hypotheses tested using the same model structure but a different dependent variable.

\[
S_{ij} = \alpha_0 + \alpha_1 T + \beta X_{ij} + u_i + \varepsilon_{ij}
\]

where:

- \(S_{ij}\) represents the SanQoL index value for individual \(j\) in compound \(i\).
- \(T\) is 1 for intervention and 0 for control.
- \(X_{ij}\) is a vector of covariates.
- \(\alpha_0\) is a constant with no interpretation in this case.
- \(\alpha_1\) is a coefficient and \(\beta\) a vector of coefficients.
- \(u_i\) is a random effect at the compound level.
- \(\varepsilon_{ij}\) is the error term.

SEs were clustered at the compound level, since the intervention was delivered at this level, requiring the assumption that errors are not correlated across compounds. Spatial distribution of compounds was within one small area of Maputo (map in online supplemental appendix A). We included two types of covariates in \(X_{ij}\). First, we adjusted for characteristics which were unbalanced at the 5% level between groups (table 2), that is, the wealth index only. Second, we included binary variables for gender and being elderly (aged 60+), because they are considered predictive of the participant’s response to the intervention (as hypothesised in moderation analyses outlined above).35 36 Only two participants had missing data for outcomes or covariates (one for WHO-5, one for the wealth index).

To test the hypothesis that intervention effects would be larger for women than men, we included a factorial interaction with \(T\) for the gender variable. To test the hypothesis that intervention effects would be larger for older people, we included a factorial interaction with \(T\) for the aged 60+ binary variable. As an additional exploratory analysis, we assessed effects on each of the five SanQoL attributes individually, by regressing on their raw scores (ranging 0–3). The rationale was to explore whether larger effect sizes were seen on some dimensions than others.

We assessed the sensitivity of results as follows. First, we included in \(X\) only covariates significantly different between groups at the 10% level (table 2) and excluded the gender and aged 60+ binary variables. Second, we included additional covariates hypothesised as predicting SanQoL and VAS (as well as gender and being aged 60+): whether the dwelling was rented, the number of people sharing a toilet stance, and whether the toilet was shared with other households. Third, we included

| Attribute | Psychometric item | Responses | Weight in index valuation |
|-----------|-------------------|-----------|--------------------------|
| Disgust   | Can you use the toilet without feeling disgusted? | Always | 0.22 |
|           |                   | Sometimes| 0.29 |
|           |                   | Rarely   | 0.20 |
|           |                   | Never    | 0.13 |
| Privacy  | Can you use the toilet in private, without being seen? | Always | 0.16 |
| Shame     | Can you use the toilet without feeling ashamed for any reason? | Always | 0.16 |
| Safety    | Are you able to feel safe while using the toilet? | Always | 0.16 |

In estimating index values, attribute-level scores are applied as ‘always’=3, ‘never’=0, etc. (formulae in online supplemental appendix B). SanQoL, Sanitation-related Quality of Life.
additional covariates hypothesised as predicting mental well-being: having a partner, being in moderate pain, or having moderate problems walking. Fourth, we explored whether using a GEE or ordinary least squares (OLS) specification instead of GLMM affected the results. We include the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist, as well as a reflexivity statement (online supplemental appendix D).

### Ethical approval

The study received prior approval from the Comité Nacional de Bioética para a Saúde (IRB00002657) at the Ministry of Health in Mozambique, and the Research Ethics Committee of the London School of Hygiene and Tropical Medicine (Ref: 14609). Informed, written consent was obtained from all participants. Data have been published in accordance with consent.

### Table 2 Characteristics of sample

| Characteristic                                      | Control (n=202) | Intervention (n=222) | P value for difference (t-test) |
|----------------------------------------------------|----------------|----------------------|--------------------------------|
| **Demographic characteristics**                    |                |                      |                                |
| Respondent is male                                 | 101 (50%)      | 103 (46%)            | 0.459                          |
| Respondent age                                     | 38.4 (14.9)    | 41.2 (15.6)          | 0.059*                         |
| Respondent aged 60+                                | 23 (11%)       | 32 (14%)             | 0.355                          |
| Respondent has a partner                           | 107 (53%)      | 107 (48%)            | 0.327                          |
| Household size                                     | 5.0 (2.8)      | 5.2 (3.2)            | 0.405                          |
| No of children under 14                            | 1.4 (1.5)      | 1.2 (1.6)            | 0.122                          |
| **Wealth index**                                   |                |                      |                                |
| Wealth index score                                 | -0.13 (1.00)   | 0.12 (0.99)          | 0.010**                        |
| *Dwelling has cement or tiled floor*               | 184 (91%)      | 210 (95%)            | 0.160                          |
| *Dwelling has concrete exterior walls*             | 140 (69%)      | 143 (64%)            | 0.287                          |
| *Access to electricity connection*                 | 167 (83%)      | 192 (86%)            | 0.277                          |
| *Access to piped water connection*                 | 199 (99%)      | 217 (98%)            | 0.563                          |
| Household cooks indoors                            | 114 (56%)      | 114 (51%)            | 0.295                          |
| Household owns television                          | 153 (76%)      | 184 (83%)            | 0.069*                         |
| Household owns fridge                              | 98 (49%)       | 128 (58%)            | 0.060*                         |
| Household owns mobile phone                        | 166 (82%)      | 191 (86%)            | 0.278                          |
| Household owns bicycle                             | 7 (3%)         | 6 (3%)               | 0.656                          |
| Household owns radio                               | 63 (31%)       | 96 (43%)             | 0.010**                        |
| Household owns watch                               | 89 (44%)       | 130 (59%)            | 0.002***                       |
| **Other respondent characteristics**               |                |                      |                                |
| Respondent completed primary school or above       | 128 (63%)      | 140 (63%)            | 0.949                          |
| Respondent completed secondary school or above     | 18 (9%)        | 33 (15%)             | 0.060*                         |
| Respondent has moderate problems walking, or worse | 12 (6%)        | 13 (6%)              | 0.971                          |
| Respondent has moderate pain or discomfort, or worse| 21 (10%)      | 17 (8%)              | 0.325                          |
| Respondent rents dwelling                          | 60 (30%)       | 54 (24%)             | 0.213                          |
| Respondent’s dwelling has zinc or concrete roof    | 202 (100%)     | 222 (100%)           | n/a                            |
| **Compound-level water & sanitation characteristics**|            |                      |                                |
| Water available at least 8 hours/day               | 99 (49%)       | 110 (50%)            | 0.912                          |
| Uses on-plot toilet                                | 197 (98%)      | 219 (99%)            | 0.397                          |
| Shares toilet with other household(s)              | 181 (90%)      | 196 (88%)            | 0.667                          |
| No of households sharing stance                    | 3.3 (1.7)      | 3.2 (1.6)            | 0.511                          |
| No of people sharing stance                        | 11.8 (5.2)     | 12.6 (6.6)           | 0.170                          |

Data are n (%) for categorical variables and mean (SD) for numerical variables. *, **, *** indicate significance at the 10%, 5% and 1% level. Variables included in the wealth index are italicised. One participant had missing data for the wealth index. In the replication dataset, we categorised age, household size and children under 14 to maintain full anonymity, since several values were shared by five people or fewer. This table reports the mean of continuous values.
**Patient and public involvement**

Members of the public were not involved in the design or conduct of this specific study. However, members of the public were involved in development of the SanQoL outcome measure as: (1) participants in the qualitative research informing attribute identification and (2) participants in the piloting and cognitive interviews informing item development.28

**RESULTS**

We sampled individuals from 424 different households across 272 compounds (clusters), of which 130 were control and 142 intervention, during April–May 2019 (figure 1). In some compounds, only one man or woman was eligible (mean respondents per cluster: 1.6). The response rate among eligible participants was 99%. There was no evidence of difference in background characteristics between intervention/control at the 5% level, except for the wealth index score (table 2). There were two further differences at the 10% level (age and secondary education). People living in intervention compounds were slightly wealthier than controls, but assets that were different were the less expensive ones (eg, watch, radio).

**Primary outcome**

The intervention was associated with an adjusted gain in SanQoL of 0.34 (95% CI 0.29 to 0.38), noting that SanQoL is measured on a 0–1 scale and the control mean was 0.49 (table 3). Full regression results are in online supplemental appendix E. The effect size was very large at 1.6 SD. None of the three covariates (wealth, gender and aged 60+) were significant at the 5% level. The additional exploratory analyses regressing on each of the five SanQoL attributes individually are reported in online supplemental appendix E.

**Secondary outcomes**

Measured on the sanitation VAS, which is scored 0–10, the intervention was associated with a 2.9 point gain (95% CI 2.4 to 3.4) (table 3). The effect size was very large at 1.3 SD, similar to that for SanQoL. Considering WHO-5 mental well-being, measured on a 0–100 scale, the intervention was associated with a 6.2 point gain (95% CI 0.3 to 12.2) (table 3). The effect size was small at 0.2 SD. There was evidence for people aged 60+ having lower mental well-being outcomes across the sample (online supplemental appendix E). For neither secondary outcome were any other covariates significant at the 5% level.

**Moderating effects**

Recalling that our study was not powered for subgroup analyses, including an interaction term for the intervention with gender provided no evidence for any outcome that women benefited more from better toilets than men (table 4). There was also no evidence that people aged 60+ benefitted more than under-60s, for any outcome.

**Sensitivity analyses**

When only covariates significantly different between groups at the 10% level were included (table 2), there was no meaningful difference to results for any of the three outcomes (online supplemental appendix F). Second, when further covariates hypothesised as predicting SanQoL and VAS were included, there was no evidence of omitted variable bias in terms of the sizes and p values of coefficients on the intervention variable. However, the coefficient on the binary covariate for sharing the toilet was negative and significant at the 1% level in both SanQoL and VAS regressions. This finding, indicating that those across the sample sharing toilets with other households had worse SanQoL, is explored as a factorial interaction in online supplemental appendix G. Third, when all covariates hypothesised as predicting mental well-being were included in the WHO-5 regression, there was no evidence of omitted variable bias. Fourth, using a GEE or OLS specification did not affect headline results for SanQoL or VAS. The effect on WHO-5 was significant only at the 10% level in the OLS regression, but OLS is unlikely to be appropriate for the hierarchical structure of our data. Furthermore, residuals were bimodally

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**Table 3** Effects on primary and secondary outcomes

| Outcome                  | Means                         | Unadjusted models | Adjusted models |
|--------------------------|-------------------------------|-------------------|-----------------|
|                          | Control (n=202) | Interv’n (n=222) | SanQoL (0–1 scale) | Unadjusted difference (95% CI) | P value | Adjusted difference (95% CI) | P value | Adjusted effect size (Cohen’s d) |
|                          | Mean (SE)       | Mean (SE)        | 0.49 (0.02)       | 0.34*** (0.29 to 0.38) | <0.001 | 0.34*** (0.29 to 0.39) | <0.001 | 1.6 |
|                          |                 |                 | Sanitation VAS (0–10 scale) | 4.1 (0.2) | 7.0 (0.1) | 2.9*** (2.4 to 3.4) | <0.001 | 2.9*** (2.4 to 3.4) | <0.001 | 1.3 |
|                          |                 |                 | WHO-5 (0–100 scale) | 54.4 (1.9) | 58.7 (1.9) | 5.6* (-0.4 to 11.6) | 0.065 | 6.2** (0.3 to 12.2) | 0.041 | 0.2 |

Adjusted models include gender, aged 60+ and wealth score as covariates. SEs are clustered at the compound level. *, **, *** indicate significance at the 10%, 5% and 1% level. Detailed regression output is in online supplemental appendix E.

SanQoL, Sanitation-related Quality of Life; VAS, Visual Analogue Scale.
distributed in the WHO-5 OLS regression, suggesting GLMM/GEE specifications are preferred. We conclude from our sensitivity analyses that our main models were appropriate for testing our hypotheses. Comparing effects between the two intervention toilet designs, there was weak evidence (p=0.079) for users of STs having higher SanQoL than users of CSBs (online supplemental file 1 - Appendix E).

**DISCUSSION**

In this observational study building on the design of the earlier MapSan trial, we find that users of high-quality shared toilets experienced a 1.6 SD gain in SanQoL compared with pit latrines, and a 0.2 SD gain in broader mental well-being. A non-randomised controlled trial of this intervention found no effect on under-5 health outcomes.41 Therefore, our findings demonstrate that better toilets can improve people’s lives beyond infectious disease, at a time when several randomised trials have questioned the health effects of sanitation improvements.42

Since all people in intervention compounds were previously sharing a low-quality toilet with the same people in the same location, the mechanism driving our results is likely to be the specific characteristics of intervention toilets. Solid walls and doors likely improved perceptions of privacy, safety and shame compared with PLs with makeshift walls and doors (photos in online supplemental appendix A). The pour-flush interface was likely to have reduced smells and visible faeces compared with PLs without water seals, improving perceptions of disgust, shame and health risk. Users value such toilet characteristics—a choice experiment in urban Zambia found willingness to pay (WTP) additional rent for solid toilet doors was 8% of median monthly rent, and WTP for flush toilets as opposed to pit latrines was 5% of rent.43

While it is intuitive that people using better-quality toilets experience more privacy or less disgust, our contribution is in quantifying this to inform decisions based on comparative effectiveness, which has not previously been done.41 The fact that SanQoL is specific to sanitation limits its broader relevance. However, such ‘condition-specific’ outcomes focused on experienced symptoms (eg, of arthritis or asthma) within only a few QoL domains are regularly used to evaluate interventions targeting those specific problems.42 The small effect on mental well-being was expected, as it is a more distal outcome than SanQoL. A previous cross-sectional study identified associations of urban sanitation access with WHO-5,21 and our contribution is in evaluating a specific urban sanitation intervention.

Despite willingness to contribute financially to 10%–15% of capital costs being an enrolment criterion for both intervention and control in MapSan, it is possible that wealthier people were more likely to uptake the intervention due to being able to afford this contribution. Since our survey was 4 years after the intervention, wealth differences could be as a result of the intervention. However, any wealth effect might be in the other direction since intervention households reported spending substantially more than controls on both cleaning and maintenance.43

Our hypotheses about women benefitting more than men and elderly people more than non-elderly were not supported. While our study was not powered for these analyses, p values on interaction terms were very large in all cases (table 4), suggesting that increased power may not have altered results. In the main analyses without interactions (table 3), neither gender nor aged 60+ covariates were significant at the 5% level, except in the case of aged 60+ for the mental well-being outcome (online supplemental appendix E). These hypotheses were informed by the qualitative literature,40–13 and we are not aware of any quantitative evidence for sanitation interventions disproportionately benefitting women or older people for any QoL outcome. Evidence for gendered monetary valuation of toilet attributes in the WTP literature is also mixed. Studies of WTP for latrine slabs (in Tanzania),44 and for other toilet attributes (in Zambia)39 44 find no evidence of gendered differences in valuations. A WTP study in Kenya found higher uptake of discount vouchers among men.44

Limitations of our study include that we relied on the controlled before-and-after design of a previous trial in which the intervention was not randomly allocated, risking

Table 4  Moderating effects on outcomes by gender and aged 60+

| Outcome | Gender interaction model | Age interaction model |
|---------|-------------------------|-----------------------|
|         | Female | P value | Female * intervention | P value | Aged 60+ | P value | Aged 60+ * intervention | P value |
| SanQoL  (0–1 scale) | −0.02  | 0.49    | 0.03 | 0.49    | −0.03  | 0.57    | 0.03   | 0.62    |
| Sanitation VAS (0–10 scale) | −0.45  | 0.06*   | 0.29 | 0.37    | −0.14  | 0.75    | −0.02  | 0.98    |
| WHO-5  (0–100 scale) | −2.91  | 0.25    | −0.77 | 0.84    | −10.6  | 0.01**  | −4.09  | 0.47    |

Interaction models includes gender, aged 60+, and wealth score as covariates, in addition to the interaction term indicated in columns. SEs are clustered at the compound level. *, **, *** indicate significance at the 10%, 5% and 1% level. Detailed regression outputs are in online supplemental appendix E. Coeff.=coefficient.
selection bias. Our eligibility criterion of having lived on the compound since before the intervention aimed to reduce risk of bias from in-migration to intervention compounds as a result of the high-quality sanitation facilities. This criterion may have introduced bias if differential rates of out-migration took place, though the MapSan trial found no evidence of this between 2015 and 2018. 

Our eligibility criterion of still using the type of toilet consistent with intervention/control status aimed to ensure the integrity of validity assessments reported elsewhere. However, it also meant that this study does not provide an unbiased estimate of the effect of the intervention. Our design necessitates adjusting for covariates which may be imprecisely measured, and the absence of pre-intervention SanQoL data precluded adjustment for baseline values. While our comparison groups were well-balanced overall, and we adjusted for unbalanced covariates, we cannot account for unobserved confounding. The magnitude of the effect size (1.6 SD) for our primary outcome means it is unlikely to be explained by bias alone. The finding for the mental well-being outcome is more precarious, however, due to its smaller effect size (0.2 SD) and higher p value (0.04).

As with any subjective self-reported outcome, there is risk of reporting bias which is difficult to account for, though we assume that any measurement error was not correlated with toilet type. In introducing themselves, fieldworkers emphasised that they were not linked to the implementing NGO or government, but intervention respondents may have wanted to appear grateful and control respondents may have wanted to appear badly off. Reporting bias could pose more of a risk to appear grateful and control respondents may have wanted government, but intervention respondents may have wanted sised that they were not linked to the implementing NGO or

The funders had no role in the identification, design, conduct, or reporting of the analysis.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The study received prior approval from the Comité Nacional de Bioética para a Saúde (IRB00002657) at the Ministry of Health in Mozambique, and the Research Ethics Committee of the London School of Hygiene and Tropical Medicine (Ref: 14609). Informed, written consent was obtained from all participants. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. Deidentified individual participant data, data dictionary and replication code are available open access on the LSHTM data repository (ref. 39).

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CONCLUSION

QoL outcomes are valued by toilet users and can be improved by sanitation interventions. If applied in future impact evaluations alongside health outcomes, SanQoL, WHO-5 and similar measures could help sanitation decision-makers understand which types of sanitation interventions most improve people’s QoL as well as prevent disease. Some interventions may improve one but not the other. QoL indices with weighting derived from respondent valuation tasks, such as SanQoL, can also be used in economic evaluation to identify interventions which are most efficient use of resources, not only those which are most effective.

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Online Appendices

Ross et al. “Impact of a sanitation intervention on quality of life and mental wellbeing in low-income urban neighbourhoods of Maputo, Mozambique”

A. Additional information on setting and intervention
B. Additional methods
C. Distributions of outcome variables
D. Reporting checklists
E. Additional results
F. Sensitivity analyses
G. The role of sharing toilets
A. Additional information on setting and intervention

*Photographs with typical examples of main toilet types*

Below are photographs of typical toilets of each type. CSB and ST designs are fairly homogenous, with some variation in the type of squat plate or seat pan used. The level of sanitation service they provide is the same, though CSBs also have a rooftop water tank and two laundry stations. Pit latrines are far more diverse. Some may nominally meet the WHO/UNICEF Joint Monitoring Programme’s definition of an improved technology (e.g. photo 2 has a concrete slab). Such latrines may therefore be categorised as “limited” sanitation (since they are shared) rather than “unimproved”.

*Figure A-1: Pit latrines (control)*

| 1. Pit latrine with tyre and wood for squatting | 2. Pit latrine with concrete slab |
|-----------------------------------------------|----------------------------------|
| ![Photo 1](image1.jpg) | ![Photo 2](image2.jpg) |

| 3. Fabric door providing limited privacy | 4. No door and adjacent greywater pit |
|----------------------------------------|-------------------------------------|
| ![Photo 3](image3.jpg) | ![Photo 4](image4.jpg) |
**Figure A-2: Shared toilets and community sanitation blocks (intervention)**

| Exterior                  |  |  |
|---------------------------|---|---|
| 1. Shared toilet (ST)     | 2. Community sanitation block (CSB) |
| ![Shared toilet](image1)  | ![Community sanitation block](image2) |

| Interior (varied between CSB / ST depending on design) |  |  |
|-------------------------------------------------------|---|---|
| 3. Squat pan                                          | 4. Seat pan |
| ![Squat pan](image3)                                  | ![Seat pan](image4) |
Map of respondent households within Maputo

Figure A-3 Panel A shows the greater Maputo region which, including the adjoining city of Matola, has a population of 2.9 million. Panel B shows the geolocations of households included in our survey (n=424). They are situated within a small area of about 10km² within the Nhlamankulu district. Since compounds were randomly sampled from the list of MapSan-enrolled compounds, this broadly represents the implementation area of the intervention overall.

Figure A-3: Maps of Maputo

A. Greater Maputo region

Source: Batran et al. (2018)

B. Respondent households within Maputo City

Source: Google Earth
Additional information on intervention delivery

The roles of key stakeholders involved in intervention delivery are summarised below. Further information is provided elsewhere.\(^{3,4}\)

### Table A-1: Stakeholders involved in intervention delivery

| Stakeholder                             | Overall role                                      | Key activities                                      |
|-----------------------------------------|--------------------------------------------------|----------------------------------------------------|
| WSUP (NGO)                              | Provider and project lead                        | • Project design and management                     |
|                                         |                                                  | • Manage design consultants                         |
|                                         |                                                  | • Manage construction contractors                  |
|                                         |                                                  | • Supervise construction                            |
| Community-based organisations           | Sub-contractor facilitating community engagement | • Facilitate site selection                         |
|                                         |                                                  | • Collect household capital contribution            |
| Construction firms                     | Sub-contractors constructing the toilet infrastructure | • Dismantle old toilet                            |
|                                         |                                                  | • Construct new toilet                             |
| Households                              | User of infrastructure                           | • Contribute 10-15% of capital costs                |
|                                         |                                                  | • Clear site of material                           |
|                                         |                                                  | • Participate in meetings and data collection       |
| Municipality (Conselho Municipal de Maputo, CMM) | Oversight and approvals by department for water and sanitation | • Approve designs and procurement                   |
|                                         |                                                  | • Provide permits for CSBs                          |
|                                         |                                                  | • Monitor infrastructure                           |
| World Bank                              | Oversight of overall programme                   | • Fund overall project                             |
|                                         |                                                  | • Oversight of delivery                            |

### Table A-2: Intervention description using TIDieR checklist (Hoffman et al. 2014)\(^5\)

| Item | Notes                                                                                                                                 |
|------|----------------------------------------------------------------------------------------------------------------------------------------|
| 1    | Provide the name or a phrase that describes the intervention. Subsidised pour-flush toilets shared by multiple households. |
| 2    | Describe any rationale, theory, or goal of the elements essential to the intervention. In this setting there is limited space and willingness or ability to pay for private toilets, and households already use low-quality shared pit latrines. |
| 3    | Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL). The intervention provided two types of toilet facility (photos above), alongside education on their use and maintenance. There were also two hygiene promotion visits after completion of construction, carried out by paid staff who received 2 days of training. These focused on contamination routes, good personal hygiene practice, and handwashing with soap. More information is provided elsewhere.\(^3,4,6\) |
| 4    | Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities. Key procedures included: 1. Community engagement and site identification – undertaken by eight contracted community-based organisations (CBOs), e.g. assessment of |
| Demand for better toilets and localised environmental issues affecting site selection (e.g. water table) |
|--------------------------------------------------|
| 2. Site selection and preparation – site selection undertaken by WSUP in discussion with CBOs, and site preparation (e.g. emptying of old latrine pits) undertaken by contracted firms. |
| 3. Toilet construction – undertaken by contracted construction firms |
| 4. Education on use, maintenance and hygiene – undertaken by contracted ‘sanitation activists’ |

| For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given. |
|--------------------------------------------------|
| Main stakeholders in delivery included: |
| 1. **Water and Sanitation for the Urban Poor** (international NGO) – overall lead on intervention delivery. Team included engineers and community engagement specialists. |
| 2. **Various community-based organisations** – sub-contractor facilitating community engagement. 48 people trained. Teams included facilitators from the local area of the intervention. |
| 3. **Various construction firms** – Sub-contractors building the toilet infrastructure. They were predominantly small local firms. |
| 4. **Sanitation activists** – Sub-contractors educating toilet users and promoting hygiene. 55 people trained. |
| 5. **Municipality and World Bank** – oversight and approvals. Team included engineers. |

| Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group. |
|--------------------------------------------------|
| All engagement was face-to-face. As this was shared sanitation, any site visits were made to compound members jointly, rather than individually. |

| Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features. |
|--------------------------------------------------|
| Setting described fully in manuscript main body. |

| Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose. |
|--------------------------------------------------|
| All aspects of the intervention delivered only once, except for two hygiene promotion visits. |

| If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how. |
|--------------------------------------------------|
| n/a |

| If the intervention was modified during the course of the study, describe the changes (what, why, when, and how). |
|--------------------------------------------------|
| n/a |

| Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them. |
|--------------------------------------------------|
| n/a |

| Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned. |
|--------------------------------------------------|
| Fidelity was assessed by Bick et al.⁴ |
B. Additional methods

Sampling of individuals

Upon arrival at the next compound on the list, and with the approval of a resident, fieldworkers inspected the toilet to assess eligibility. Next, by talking to residents, they listed all eligible people based on the inclusion criteria. For the male respondent, sampling was random from the list of eligible men within the compound, by approaching households starting from the house opposite the compound entrance, and working leftwards until an eligible man was identified. The same process was then followed for eligible women, with the condition that the female respondent not be from the same household as the male respondent. If only one eligible respondent could be identified on a compound, we moved onto the next compounds. We continued visiting compounds until the target sample size was reached. Interviews were in Portuguese, unless the respondent preferred to talk in Changana, a local language in which all interviewers were fluent. We collected data on smartphones using the mWater surveyor application.

Ranking exercise

The ranking exercise comprised a velcro-covered A4 plastic board with a 30cm vertical line and 10 intervals from 1-10 marked, as well as velcro-backed laminated cards (Figure B-1). The exercise was based on methods reported in Drummond et al. Each of the cards was labelled with attributes emerging from prior qualitative work, which were already familiar to respondents from the earlier parts of the questionnaire. Participants were asked to place the cards on the scale according to their relative importance. They were first asked to choose the card representing the attribute they thought most important for a good toilet and a good life. They were asked not to focus on their current toilet but consider their ideal toilet. They were then asked to do the same for the least important attribute of the remaining cards. These were placed at the top (10) and bottom (1) of the board. The enumerator explained that being at position 1 does not mean that attribute is not important, but just that it is less important than the others. The respondent was then asked to stick the remaining cards to the board, at the places on the line that they consider reflected relative importance. Moving attributes was allowed. Placing more than one attribute at the same position was also allowed (only 5 out of 424 participants did so), which is accounted for in Equation A such that weights still sum to 1.
Using data on mean ranks, we estimated weights (Equation A) for each SanQoL dimension using the rank sum method, as previously used in index valuation. Mean ranks are reported elsewhere, as are differences in attribute ranks by gender, aged 60+, and treatment.

**Equation A – attribute weights for a population**

\[ w_i = \frac{N - R_i + 1}{\sum_{i=1}^{N} (N - R_i + 1)} \]

**Equation B – SanQoL index value for an individual**

\[ S_j = \frac{\sum_{i=1}^{N} x_{ij} w_i}{3} \]

where:
- \( w_i \) is the weight of the ith attribute
- \( N \) is the number of attributes
- \( R_i \) is the mean rank of the ith attribute in the population
- \( x_{ij} \) are item scores ranging from 0-3 for the jth individual, where “always”=3 and “never”=0.
- \( S_j \) is the SanQoL index value for the jth individual
Visual analogue scale (VAS)
The sanitation VAS was adapted from the VAS in the EQ-5D measure of health-related quality of life, with emoji visualisation informed by the visual pain scale. The enumerator reads out the guidance (Figure B-2) then the respondent indicates their selected level on the scale with a pencil. The VAS gives us information about people’s overall assessment of their level of sanitation, while SanQoL restricts the evaluative space to five attributes with population-based weights. The VAS therefore measures something conceptually different, but complementary, to SanQoL.

**Figure B-2: sanitation VAS**

0 = Worst sanitation you can imagine

10 = Best sanitation you can imagine

Mark an X on the scale to indicate how you feel about your level of sanitation today.

Consider all sanitation practices, including defecation, urination, bathing, menstrual hygiene and any related practices.

WHO-5 attributes
WHO-5 attributes are listed in the table below. The raw score ranges from 0 to 25, and is multiplied by 4 to reach a score where 100 represents best possible mental wellbeing and 0 worst possible.

**Table B-1: WHO-5 attributes**

| # | Attribute | Item | Responses |
|---|-----------|------|-----------|
| 1 | Cheerful | In the last 2 weeks have you felt cheerful and in good spirits? | 0 - At no time |
|   |           |      | 1 - Some of the time |
|   |           |      | 2 - Less than half of the time |
|   |           |      | 3 - More than half of the time |
|   |           |      | 4 - Most of the time |
|   |           |      | 5 - All of the time |
| 2 | Calm      | In the last 2 weeks have you felt calm and relaxed? | |
| 3 | Active    | In the last 2 weeks have you felt active and vigorous? | |
| 4 | Fresh     | In the last 2 weeks have you woken up feeling fresh and rested? | |
| 5 | Interest  | In the last 2 weeks have you had a daily life filled with things that interest you | |

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C. Distributions of outcome variables

*Figure C-1: Histograms of primary and secondary outcomes by toilet type*

Panel 1 - SanQoL index values

Panel 2 – Sanitation VAS

Panel 3 – WHO-5 index

*Figure C-2: Distributions of SanQoL attributes by intervention and control*

Note: Scores range from 0-3 representing a scale from never to always (Table 1).
### Table C-1: Polychoric inter-item correlations for SanQoL attributes

|                | Disgust | Health | Shame | Safety | Privacy |
|----------------|---------|--------|-------|--------|---------|
| Disgust        | 1.00    |        |       |        |         |
| Health         | 0.56    | 1.00   |       |        |         |
| Shame          | 0.52    | 0.53   | 1.00  |        |         |
| Safety         | 0.41    | 0.47   | 0.49  | 1.00   |         |
| Privacy        | 0.40    | 0.43   | 0.54  | 0.70   | 1.00    |

### Table C-2: SanQoL questions in Portuguese

| #   | Dimension | Question                                                                 | Responses                      |
|-----|-----------|--------------------------------------------------------------------------|--------------------------------|
| 1   | Disgust   | Can you use the toilet without feeling disgusted?                         | Pode usar a casa de banho sem se sentir nojo? |
|     | Nojo      |                                                                          |                                |
| 2   | Health    | Can you use the toilet without worrying that it spreads diseases?         | Pode usar a casa de banho sem se preocupar que espalhe doenças? |
|     | Saúde     |                                                                          |                                |
| 3   | Privacy   | Can you use the toilet in private, without being seen?                   | Pode usar a casa de banho com privacidade, sem ser visto/a? |
|     | Privacidade|                                                                         |                                |
| 4   | Shame     | Can you use the toilet without feeling ashamed for any reason?           | Pode usar a casa de banho sem sentir vergonha por qualquer motivo? |
|     | Vergonha  |                                                                          |                                |
| 5   | Safety    | Are you able to feel safe while using the toilet?                         | É capaz de se sentir seguro/a ao usar esta casa de banho? |
|     | Segurança  |                                                                          |                                |
D. Reporting Checklists

STROBE checklist

We report below which sub-sections provide information required in the STROBE checklist, using the form available at [https://www.strobe-statement.org/checklists/](https://www.strobe-statement.org/checklists/)

| Item No | Recommendation |
|---------|----------------|
| Title and abstract | 1 | (a) Indicate the study’s design with a commonly used term in the title or the abstract  
Authors: the title and abstract note that it is an observational comparison study of clusters previously enrolled in a non-randomised controlled trial. See p.1-2  
(b) Provide in the abstract an informative and balanced summary of what was done and what was found  
Authors: the abstract provides succinct background, methods that articulate the study design and outcomes, results, and their interpretation. See p.2 |
| Introduction | 2 | Explain the scientific background and rationale for the investigation being reported  
Authors: background and rationale are reported in the introduction. See p.4 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses  
Authors: the aim is stated in the last sentence of the introduction (p.4). Hypotheses are summarised in a methods sub-section of methods (p.7), but were not formally prespecified. |
| Methods | 4 | Present key elements of study design early in the paper  
Authors: there is a “study design” sub-section at the beginning of methods (p.5) |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection  
Authors: there is a specific “setting” sub-section in methods (p.4), including locations, and a map provided in Online Appendix A. The remaining aspects are reported in other parts of the methods section. |
| Participants | 6 | (a) Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up  
Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls  
Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants |
**Authors:** the eligibility criteria are listed in the “participants” sub-section of methods (p.5), as are methods for sampling of participants, with additional detail provided in Online Appendix B.

**(b) Cohort study**—For matched studies, give matching criteria and number of exposed and unexposed

CASE-control study—For matched studies, give matching criteria and the number of controls per case

**Authors:** our study design did not use matching directly, but relied on the methods for identification of intervention/control compounds applied by the MapSan trial which are reported in the “study design” sub-section of methods (p.5).

| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable |
| --- | --- | --- |
| **Authors:** Outcomes are defined in an “outcomes” sub-section of methods (p.6), with additional information provided in Online Appendix B. Other variables are defined in the “statistical analysis” section (p.7), with more detail in the data dictionary on LSHTM Data Compass repository (link in manuscript). |

| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group |
| --- | --- | --- |
| **Authors:** All data are primary and measured by household survey (see #7 above). Further detail on the administration of the survey are in the “participants” sub-section of methods (p.5), with further detail in Online Appendix B. |

| Bias | 9 | Describe any efforts to address potential sources of bias |
| --- | --- | --- |
| **Authors:** Efforts to address bias are described in the “participants” sub-section of methods (p.5), and also in the “study design” sub-section (p.5). Sensitivity analyses to explore risk of bias in the analytical approach are described on p.8. |

| Study size | 10 | Explain how the study size was arrived at |
| --- | --- | --- |
| **Authors:** The sample size calculation is described in the “statistical analyses” section (p.7). |

| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why |
| --- | --- | --- |
| **Authors:** Regression models are described in the “statistical analyses” section (p.7). |

| Statistical methods | 12 | (a) Describe all statistical methods, including those used to control for confounding |
| --- | --- | --- |
| **Authors:** Covariates adjusted for are described in the “statistical analyses” section (p.7). |
| (b) Describe any methods used to examine subgroups and interactions |
| **Authors:** Approaches to interactions with gender and being elderly are described in the “statistical analyses” section (p.7). |
| (c) Explain how missing data were addressed |
| **Authors:** We state in the “statistical analyses” section (p.7) that only 2 participants had missing data for outcomes or covariates (one for WHO-
With 424 respondents each represents 0.2% of the sample and is not an important source of bias.

(d) Cohort study—If applicable, explain how loss to follow-up was addressed

Case-control study—if applicable, explain how matching of cases and controls was addressed

Cross-sectional study—if applicable, describe analytical methods taking account of sampling strategy

Authors: we explain the approach to adjusting for clustering in the “statistical analyses” section (p.7).

(e) Describe any sensitivity analyses

Authors: sensitivity analyses are described on p.7.

### Results

**Participants**

13*  
(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed

Authors: numbers of compounds are described in the participant flow diagram (Figure 1)

(b) Give reasons for non-participation at each stage

Authors: reasons are explained in Figure 1

(c) Consider use of a flow diagram

Authors: See Figure 1

**Descriptive data**

14*  
(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders

Authors: Participant characteristics are summarised in Table 2, separately for intervention and control groups.

(b) Indicate number of participants with missing data for each variable of interest

Authors: the note to Table 2 states that one participant had missing data for the wealth index.

(c) Cohort study—Summarise follow-up time (eg, average and total amount)

Authors: n/a

**Outcome data**

15*  
Cohort study—Report numbers of outcome events or summary measures over time

Authors: n/a

Case-control study—Report numbers in each exposure category, or summary measures of exposure

Authors: n/a

Cross-sectional study—Report numbers of outcome events or summary measures

Authors: Distributions of outcomes are presented in histograms in Online Appendix C, separately for intervention and control groups, as are distributions of individual SanQoL attributes

**Main results**

16  
(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included

Authors: we explain the approach to adjusting for clustering in the “statistical analyses” section (p.7).
Authors: unadjusted and adjusted estimates with 95% CIs are provided in Tables 3 and 4. The rationale for adjustment is provided in the “statistical analyses” section of methods (p.7).

(b) Report category boundaries when continuous variables were categorized

Authors: the note to Table 2 states that in the replication dataset available online, we categorised age, household size and children under 14 to maintain full anonymity, since several values were shared by 5 people or fewer.

(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

Authors: n/a

Other analyses

17 Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

Authors: interactions are reported in the results section (p.9), with full results tabulated in Online Appendix E. Sensitivity analysis findings are described in the results section (p.9), with full tables in Online Appendix F.

Discussion

Key results

18 Summarise key results with reference to study objectives

Authors: Key results are summarised in the first paragraph of the discussion (p.13).

Limitations

19 Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias

Authors: Limitations are discussed in two paragraphs towards the end of the discussion (p.13), including sources and direction of potential bias.

Interpretation

20 Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence

Authors: Interpretation is undertaken in the first paragraph of our discussion (p.13), with potential mechanisms discussed in the second paragraph.

Generalisability

21 Discuss the generalisability (external validity) of the study results

Authors: generalisability is considered in the final paragraph of the discussion (p.13)

Other information

Funding

22 Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

Authors: This work was supported by the Economic and Social Research Council through a PhD studentship. The fieldwork was funded by the Bill & Melinda Gates Foundation. The funders had no role in the identification, design, conduct, or reporting of the analysis. The original funders of the MapSan trial on which our study is based were the United States Agency for International Development and the Bill & Melinda Gates Foundation.

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
## Reflexivity Statement and checklist

### Reflexivity statement (Table 1 from Morton et al. 2021)\textsuperscript{14}

| Area | Question | Response |
|------|----------|----------|
| Study conceptualisation | 1. How does this study address local research and policy priorities? | The National Strategy for Urban Water and Sanitation in Mozambique has the objective of universal access to sanitation services by 2025, but in 2020 only 61% of the urban population had access to “basic” sanitation. Sanitation decision-makers at the Maputo City Council are interested means by which they can improve on-site sanitation in informal settlements where sewerage expansion is unrealistic in the medium-term. Understanding which interventions most improve people’s quality of life will help identify interventions most likely to achieve sustained uptake at scale, and all research collaborators buy into the importance of this. |
| | 2. How were local researchers involved in study design? | ZA led the fieldwork in 2018 for the qualitative study which informed the development of the SanQoL measure, and undertook discussions of methods for the present study with IR at that time. ZA and IR had also collaborated on a separate household survey in 2018 in the same setting, which informed the approach to sampling and data collection in the present study. ZA and IR refined the methods for the present study, especially the SanQoL questions and other outcomes, through discussion, fieldworker training, cognitive interviews and piloting. RN contributed to study design by inputting into the protocol and data collection instruments. |
| Research management | 3. How has funding been used to support the local research team(s)? | This study was funded under the Maputo Sanitation trial (MapSan) programme of research (clinicaltrials.gov, NCT02362932). The associated funding covered salary costs of ZA and RN for several years, as well as other staff at the Instituto Nacional de Saúde (INS) and WE Consult. The team has supported an INS researcher to successfully apply for a funded PhD programme, and has supported three grant proposals led by early career researchers at INS. |
| Data acquisition and analysis | 4. How are research staff who conducted data collection acknowledged? | The four members of the fieldwork team are named in the acknowledgements. |
| | 5. How have members of the research partnership been provided with access to study data? | The data are available open access online. |
| | 6. How were data used to develop analytical skills within the partnership? | As required for a PhD thesis, the analysis was conducted independently by IR with only limited support from the supervisors GG and OC. |
| Data interpretation | 7. How have research partners collaborated in interpreting study data? | ZA and IR discussed emerging trends in data as it came in. ZA and IR also discussed interpretation of observations for some variables which informed data cleaning and analysis. ZA and RN inputted into iterations of the manuscript. |
| Drafting and revising for | 8. How were research partners supported to develop writing skills? | As part of the PhD thesis, the first draft of the manuscript was completed independently by IR. |
intellectual content

9. How will research products be shared to address local needs?

This study will be published open access. IR undertook a scoping of the health economics policy community in Mozambique while based there during data collection, and will share results of the study with identified stakeholders. There is a dissemination plan for the broader body of research, which will include engagement of urban sanitation stakeholders in Maputo upon IR’s next travel to Mozambique.

Authorship

10. How is the leadership, contribution and ownership of this work by LMIC researchers recognised within the authorship?

ZA and RN contributed to study design and data interpretation as outlined in the answers to questions #2 and #7 above. The study was part of IR’s PhD thesis and predominantly his work, so he has the first author position. Of the more senior members of the study team (RN, OC, JB, CO, GG), all co-authors agree that OC played the most substantial role in guiding the study’s methods and interpretation and in supervising this part of IR’s PhD thesis, which is why he has the last author position.

11. How have early career researchers across the partnership been included within the authorship team?

There are two early career researchers within the authorship team, ZA (based in Mozambique) and IR (based in the UK).

12. How has gender balance been addressed within the authorship?

Four authors are male (IR, JB, CO, and OC) and three female (GG, ZA, and RN).

Training

13. How has the project contributed to training of LMIC researchers?

This specific study did not include a training component. However, under the broader MapSan programme of research, Mozambican researchers from INS received training on different research methods related to epidemiology and laboratory skills.

Infrastructure

14. How has the project contributed to improvements in local infrastructure?

This specific study has not directly contributed to improvements in local infrastructure.

Governance

15. What safeguarding procedures were used to protect local study participants and researchers?

The participant information sheet was approved by ethical review committees in Mozambique and the UK. It details procedures for confidentiality, withdrawal, and complaints. Fieldwork team members worked in pairs, keeping in contact with ZA by phone on their location. Their training included guidance on what to do in the event of an emergency.

Checklist (Table 2 from Morton et al. 2021)

| Area          | Question                                                                 | Response                                                                 |
|---------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Engagement    | Has the research team engaged constructively with the reflexivity statement? | Yes, all questions have been completed in the table above.               |
| Co-development| Have the research partners co-developed the research study?               | Yes, as illustrated in responses to questions 2, 3, 7 and 10 in the table above. |
|               | Does the study address priority research questions for the LMIC partner(s)? | Yes, see answer to question 1 above.                                      |
| Authorship    | Is there a LMIC partner who is the first or last author?                  | No.                                                                      |
|               | If not, what is the explanation?                                          | Reasons are set out in response to question 10 above (PhD thesis, supervision, and level of support to the specific study) |
| Dissemination                                                                 |                                                                                                                                 |
|------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| How have LMIC early career researchers been incorporated as authors?         | Yes, see answer to question 11 above.                                                                                         |
| How are data shared with LMIC partners to address research needs?            | Data are available open access online.                                                                                       |
| Is there open access funding to improve publication dissemination?           | Yes, one of the funders (BMGF) ensures open access for any studies carried out with this funding.                             |
## E. Additional results

Full regression output for main models

### Table E-1: Regression output underlying Tables 3 and 4

|                        | SanQoL index value | Sanitation-VAS | WHO-5 index |
|------------------------|--------------------|----------------|-------------|
|                        | (1) main           | (2) gender     | (3) age     | (4) main | (5) gender | (6) age | (7) main | (8) gender | (9) age |
|                        | regression        | interaction    | interaction | regression | interaction | interaction | regression | interaction | interaction |
| Intervention toilet    | 0.34*** (0.02)     | 0.33*** (0.03) | 0.34*** (0.02) | 2.91*** (0.24) | 2.76*** (0.30) | 2.91*** (0.26) | 6.25** (3.05) | 6.65* (3.80) | 6.78** (3.22) |
| Aged 60+               | -0.01 (0.03)       | -0.01 (0.03)   | -0.03 (0.05)  | -0.15 (0.27)   | -0.12 (0.28)   | -0.14 (0.45)   | -12.95*** (2.91) | -13.03*** (2.95) | -10.64** (4.20) |
| Female                 | -0.01 (0.02)       | -0.02 (0.03)   | -0.01 (0.02)  | -0.30* (0.16)  | -0.45* (0.24)  | -0.30* (0.16)  | -3.31* (1.94)   | -2.91 (2.56)   | -3.47* (1.98) |
| Wealth index score     | -0.01 (0.01)       | -0.01 (0.01)   | -0.01 (0.01)  | -0.07 (0.10)   | -0.07 (0.10)   | -0.07 (0.10)   | 0.98 (1.12)     | 0.98 (1.12)    | 1.00 (1.11)   |
| Intervention toilet * female | 0.03 (0.04) | 0.29 (0.33)   |              |              |              | -0.77 (3.88)   |
| Intervention toilet * aged 60+ | 0.03 (0.06) |              |              | -0.02 (0.57)  |              |              | -4.09 (5.69)   |
| Constant               | 0.50*** (0.02)     | 0.51*** (0.03) | 0.50*** (0.02) | 4.28*** (0.20) | 4.36*** (0.22) | 4.28*** (0.20) | 57.01*** (2.40) | 56.82*** (2.53) | 56.83*** (2.40) |
| Observations           | 423                | 423            | 423          | 423          | 423          | 423          | 422          | 422          | 422          |

Note: Cells report regression coefficients, with standard errors (clustered at compound level) in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent level. SanQoL is on a 0-1 scale, VAS is on a 0-10 scale, and WHO-5 is on a 0-100 scale.
Residuals are approximately normally distributed for all three main results (Figure E-1), and plots of residuals against fitted values for the fixed portions raise no concerns about heteroscedasticity. For the SanQoL plot (panel 4) the plot for the intervention group appears truncated, due to the modal SanQoL index value being 1, which effectively censors the residuals.

Figure E-1: Histograms of residuals and residuals-vs-fitted plots for main results in Table 3 (column references are to Table D-1)
Role of toilet type

Below is the regression output for the main results regressions on SanQoL index values, but including toilet type as a covariate to estimate whether there was a difference between shared toilets (ST) and community sanitation blocks (CSB). It shows that there is weak evidence (p=0.079) for a larger effect of the intervention on ST users than CSB users, which is important for subsequent cost-effectiveness analysis.

Table E-2: Regression output including toilet type as covariate

|                     | Coefficient | Standard Error |
|---------------------|-------------|----------------|
| Intervention toilet | 0.28***     | (0.04)         |
| Aged 60+            | -0.02       | (0.03)         |
| Female              | -0.01       | (0.02)         |
| Wealth index score  | -0.01       | (0.01)         |
| Toilet type = ST    | 0.068*      | (0.04)         |
| Constant            | 0.50***     | (0.02)         |

Note: Cells report regression coefficients, with standard errors (clustered at compound level) in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent level.
Regression on individual SanQoL attribute scores

In regressions on individual attribute scores, the intervention was associated with gains across all five SanQoL attributes. Effect sizes were largest for safety (1.5 SD) and privacy (1.4 SD). Coefficients on interaction terms for gender and aged over 60 were not significant, as with SanQoL index values.

Table E-3: Summary of effects on individual SanQoL attribute scores (ranging 0-3) and interactions with gender and old age

| Means | Disgust | Health | Shame | Safety | Privacy |
|-------|---------|--------|-------|--------|---------|
|       | Control (n=202) Mean (SE) | 1.59 (0.082) | 1.40 (0.085) | 1.56 (0.081) | 1.29 (0.080) | 1.58 (0.081) |
|       | Intervention (n=222) Mean (SE) | 2.32 (0.067) | 2.36 (0.060) | 2.40 (0.068) | 2.64 (0.044) | 2.84 (0.037) |
|       | Main model (unadjusted) Unadjusted difference (95% CI) | 0.72 (0.50 - 0.94) | 0.96 (0.74 - 1.18) | 0.82 (0.6 - 1.04) | 1.35 (1.16 - 1.54) | 1.26 (1.07 - 1.45) |
|       | p-value | <0.001*** | <0.001*** | <0.001*** | <0.001*** |
|       | Main model (adjusted) Adjusted difference (95% CI) | 0.75 (0.53 - 0.97) | 0.96 (0.74 - 1.18) | 0.80 (0.58 - 1.02) | 1.36 (1.16 - 1.56) | 1.25 (1.06 - 1.44) |
|       | p-value | <0.001*** | <0.001*** | <0.001*** | <0.001*** |
|       | Adjusted effect size | 0.7 | 0.9 | 0.7 | 1.5 | 1.4 |
|       | Gender interaction model (adjusted) p-value on coefficient for Female*Intervention | 0.56 | 0.98 | 0.19 | 0.29 | 0.83 |
|       | Over-60 interaction model (adjusted) p-value on coefficient for Over-60*Intervention | 0.43 | 0.28 | 0.87 | 0.15 | 0.54 |

Models include gender, aged over-60, and wealth score as covariates. Standard errors are clustered at the compound level. *, **, *** indicate significance at the 10, 5 and 1 percent level. Detailed regression output is in Online Appendix E.
Below is the regression output underlying the above table.

Table E-4: Regression output for individual SanQoL attribute scores without gender/age interactions

| SanQoL attributes | Disgust   | Health   | Shame    | Safety   | Privacy  |
|-------------------|-----------|----------|----------|----------|----------|
| Intervention toilet | 0.75***   | 0.96***  | 0.80***  | 1.36***  | 1.25***  |
|                    | (0.11)    | (0.11)   | (0.11)   | (0.10)   | (0.10)   |
| Aged 60+           | -0.07     | -0.07    | 0.03     | 0.06     | -0.10    |
|                    | (0.17)    | (0.13)   | (0.15)   | (0.13)   | (0.12)   |
| Female             | -0.04     | 0.08     | 0.07     | -0.30*** | 0.02     |
|                    | (0.09)    | (0.09)   | (0.10)   | (0.08)   | (0.08)   |
| Wealth index score | -0.10**   | -0.03    | 0.07     | -0.00    | 0.03     |
|                    | (0.05)    | (0.05)   | (0.05)   | (0.04)   | (0.04)   |
| Constant           | 1.62***   | 1.38***  | 1.55***  | 1.43***  | 1.59***  |
|                    | (0.10)    | (0.10)   | (0.10)   | (0.10)   | (0.10)   |
| Observations       | 423       | 423      | 423      | 423      | 423      |

Note: Cells report regression coefficients, with standard errors (clustered at compound level) in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent level. Attribute scores are on a 0-3 scale.
Table E-5: Regression output for individual SanQoL attribute scores including gender/age interactions

|                     | SanQoL attributes: gender interactions | SanQoL attributes: age interactions |
|---------------------|----------------------------------------|-------------------------------------|
|                     | Disgust | Health | Shame | Safety | Privacy | Disgust | Health | Shame | Safety | Privacy |
| Intervention toilet | 0.69*** | 0.96*** | 0.66*** | 1.27*** | 1.27*** | 0.71*** | 0.92*** | 0.78*** | 1.42*** | 1.24*** |
|                     | (0.15)  | (0.15)  | (0.16)  | (0.13)  | (0.13)  | (0.12)  | (0.12)  | (0.12)  | (0.11)  | (0.10)  |
| Aged 60+            | -0.06   | -0.07   | 0.05    | 0.07    | -0.10   | -0.22   | -0.26   | -0.05   | 0.34    | -0.14   |
|                     | (0.17)  | (0.14)  | (0.16)  | (0.13)  | (0.13)  | (0.28)  | (0.24)  | (0.28)  | (0.24)  | (0.22)  |
| Female              | -0.10   | 0.08    | -0.06   | -0.39*** | 0.04    | -0.03   | 0.09    | 0.08    | -0.31*** | 0.02    |
|                     | (0.15)  | (0.16)  | (0.16)  | (0.14)  | (0.14)  | (0.10)  | (0.10)  | (0.10)  | (0.08)  | (0.08)  |
| Wealth index score  | -0.10** | -0.03   | 0.07    | -0.00   | 0.03    | -0.10** | -0.04   | 0.07    | -0.00   | 0.03    |
|                     | (0.05)  | (0.05)  | (0.05)  | (0.04)  | (0.04)  | (0.05)  | (0.05)  | (0.05)  | (0.04)  | (0.04)  |
| Intervention toilet # female | 0.11    | 0.00    | 0.26    | 0.18    | -0.03   | 0.26    | 0.33    | 0.13    | -0.49*   | 0.07    |
|                     | (0.20)  | (0.19)  | (0.20)  | (0.17)  | (0.16)  | (0.34)  | (0.29)  | (0.34)  | (0.27)  | (0.27)  |
| Intervention toilet # over-60 | 1.65*** | 1.38*** | 1.62*** | 1.48*** | 1.58*** | 1.64*** | 1.39*** | 1.56*** | 1.41*** | 1.59*** |
|                     | (0.12)  | (0.12)  | (0.12)  | (0.11)  | (0.11)  | (0.10)  | (0.10)  | (0.10)  | (0.10)  | (0.10)  |
| Constant            |         |         |         |         |         |         |         |         |         |         |
| Observations        | 423     | 423     | 423     | 423     | 423     | 423     | 423     | 423     | 423     | 423     |

Note: Cells report regression coefficients, with standard errors (clustered at compound level) in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent level. Attribute scores are on a 0-3 scale.
F. Sensitivity analyses

Table F-1: Sensitivity analyses for SanQoL and VAS

|                       | Outcome: SanQoL index value (0-1 scale) | Outcome: Sanitation VAS (0-10 scale) |
|-----------------------|----------------------------------------|--------------------------------------|
|                       | (1) Headline GLMM (main model)         | (6) Headline GLMM (main model)       |
|                       | (2) Main model GEE                     | (7) Main model GEE                    |
|                       | (3) Main model OLS                     | (8) Main model OLS                    |
|                       | (4) GLMM with only 10% level covariates| (9) GLMM with only 10% level covariates|
|                       | (5) GLMM with predictor covariates     | (10) GLMM w/ t predictor covariates   |
| Pour-flush toilet     | 0.34*** (0.02)                         | 2.91*** (0.24)                        |
| (Intervention)        |                                        |                                      |
| Aged 60+              | -0.01 (0.03)                           | -0.15 (0.27)                          |
|                       |                                        |                                      |
| Female                | -0.01 (0.02)                           | -0.30* (0.16)                         |
|                       |                                        |                                      |
| Wealth index score    | -0.01 (0.01)                           | -0.07 (0.10)                          |
|                       |                                        |                                      |
| Participant age       | -0.01 (0.00)                           | -0.01 (0.03)                          |
| (categorised)         |                                        |                                      |
| Completed secondary   | 0.05 (0.03)                            | 0.61** (0.25)                         |
| school or above       |                                        |                                      |
| Number of people      | 0.00 (0.00)                            | 0.03* (0.02)                          |
| sharing toilet stance |                                        |                                      |
| Shares toilet with    | -0.14*** (0.03)                        | -1.14*** (0.34)                       |
| other households      |                                        |                                      |
| Renter                | 0.03 (0.02)                            | 0.06 (0.20)                           |
|                       |                                        |                                      |
| Constant              | 0.50*** (0.02)                         | 4.28*** (0.20)                        |
|                       |                                        |                                      |
| Observations          | 423                                    | 423                                  |

Note: standard errors are shown in parentheses, which are clustered at the compound level; *, **, *** indicate significance at the 10, 5 and 1 percent level. In the main paper, Table 2 presents the mean of respondent age as a continuous variable. We categorised age in the publicly available replication dataset to maintain full
anonymity, since several ages were shared by 5 people or fewer. We apply the categorised variable in these robustness checks for full replicability, but applying the continuous variable makes no difference to results.

Table F-2: Sensitivity analyses for WHO-5

| Outcome: WHO-5 index (0-100 scale) | (1) Headline GLMM (main model) | (2) Main model GEE | (3) Main model OLS | (4) MEGLM with only 10% level covariates | (5) MEGLM with predictor covariates |
|------------------------------------|-------------------------------|--------------------|--------------------|--------------------------------------|-----------------------------------|
| Pour-flush toilet (Intervention)   | 6.25** (3.05)                 | 6.27** (3.04)      | 4.83 (3.15)        | 6.56** (3.02)                        | 6.21** (2.88)                      |
| Aged 60+                           | -12.95*** (2.91)              | -12.87*** (3.30)   | -15.98*** (3.41)   | -6.19** (3.13)                       |                                   |
| Female                             | -3.31* (1.94)                 | -3.34* (1.88)      | -2.19 (2.06)       | -1.29 (2.01)                         |                                   |
| Wealth index score                 | 0.98 (1.12)                   | 0.99 (1.19)        | 0.78 (1.36)        | 0.77 (1.14)                          |                                   |
| Participant age (categorised)      |                               |                    | -1.67*** (0.37)    |                                     |                                   |
| Completed secondary school or above|                               |                    | 1.44 (3.60)        |                                     |                                   |
| Has partner                        |                               |                    |                   | -1.95 (2.09)                         |                                   |
| Pain scale                         |                               |                    | 7.23*** (2.24)     |                                     |                                   |
| Problems walking scale             |                               |                    | 5.79** (2.71)      |                                     |                                   |
| Constant                           | 57.01*** (2.40)               | 57.00*** (2.39)    | 57.39*** (2.47)    | 60.68*** (2.76)                      | -4.87 (11.32)                     |
| Observations                       | 422                           | 422                | 422                | 422                                  | 423                               |

Note: standard errors are shown in parentheses, which are clustered at the compound level; *, **, *** indicate significance at the 10, 5 and 1 percent level.
G. The role of sharing toilets

During study design it was anticipated that most people in our sample would be sharing toilets with other households, since this was a condition of MapSan enrolment four years previously. In the event, 90% of control and 88% of intervention households used shared toilets (Table 2 in manuscript). The households using private toilets were all single-household compounds, likely due to empty dwellings (driven by rental markets or migration) or changes in compound living arrangements since the intervention.

In this appendix, we discuss means by sharing status and explore sharing in another set of regressions. In the set of robustness checks including all covariates hypothesised ex ante as predicting SanQoL, the binary covariate for sharing the toilet with other households was significant at the 1% level with a negative coefficient. This is likely explained by differences within the control group, where people using private PLs had higher SanQoL than people using shared PLs (Figure G-1a). In the intervention group, sharing made little difference.

Figure G-1: Differences between groups using private and shared toilets

(a) SanQoL – mean index value by sharing and treatment group

(b) VAS – mean score by sharing and treatment group

(c) WHO-5 – mean score by sharing and treatment group

Note. error bars are 95% CIs
Table 2 in the manuscript demonstrated that the mean number of people per stance (cubicle) did not differ at the 5% level between intervention and control groups. This was also the case for analyses within private and shared, with 7.2 and 7.3 people on average using private toilets in control and intervention groups respectively, compared to 12.3 and 13.3 for shared toilets.

Considering VAS scores, a slightly different pattern was observed. Mean scores amongst people sharing intervention toilets were slightly lower than those not sharing, while there was no difference at the 5% level amongst controls (Figure G-1b). For both outcomes however, the intervention was associated with a substantial difference regardless of sharing status. For mental wellbeing, the picture is different again (Figure G-1c). There is a difference in WHO-5 amongst people using private toilets, but not amongst people sharing.

We ran a regression specified as per the headline results, but including a factorial interaction term between the intervention and the binary sharing variable (Table G-1). The results are easier to interpret in the light of Figure G-1.

**Table G-1: Interactions with sharing toilets**

|                      | SanQoL index value | VAS score | WHO-5 index score |
|----------------------|--------------------|-----------|-------------------|
| Intervention         | 0.15*** (0.05)     | 3.94*** (0.59) | 27.91*** (7.59)   |
| Aged 60+             | -0.02 (0.03)       | -0.16 (0.27)  | -12.73*** (2.89)  |
| Female               | -0.01 (0.02)       | -0.33** (0.16) | -3.61* (1.93)     |
| Wealth index score   | -0.01 (0.01)       | -0.10 (0.10)  | 0.66 (1.12)       |
| Shares toilet with other households | -0.24*** (0.04) | -0.27 (0.52)  | 7.88 (6.65)       |
| Intervention # shares toilet | 0.22*** (0.05) | -1.20* (0.64) | -25.29*** (8.34)  |
| Constant             | 0.71*** (0.03)     | 4.54*** (0.50) | 50.30*** (6.38)   |
| Observations         | 423                | 423        | 422               |

We make three interpretations from these results. First, amongst people sharing toilets with other households, there was strong evidence \((p<0.001)\) that the intervention was associated with a difference in SanQoL of 0.37 \((95\% \text{ CI: } 0.32 - 0.41)\). This is greater than the difference of 0.34 in the sample as a whole, and substantially larger than the difference of 0.15 \((95\% \text{ CI: } 0.11 - 0.19)\).
CI: 0.06 – 0.24) amongst those using private toilets. However, this is likely driven by the fact that SanQoL was already higher in the control group amongst those using private toilets (Figure G-1a) so scores didn’t “have as far to travel” on a 0-1 scale.

Second, the opposite trend was seen in VAS scores. Amongst users of shared toilets the intervention was associated with a difference of 2.7 (95% CI: 2.2 – 3.2), while in private toilets it was associated with a difference of 3.9 (95% CI: 2.8 – 5.1). Scores in the intervention group simply increased more for private than shared (Figure G-1b). Third, for WHO-5 scores, there was no evidence of a difference amongst users of shared toilets (95% CI: -3.8 – 9.1), compared to a substantial difference of 27.9 amongst users of private toilets (95% CI: 13.0 – 42.8). This slightly odd result is again likely driven by the fact that WHO-5 scores were lower for households in the control group using private latrines (Figure G-1c).

Note that comparisons between users of private toilets are based on a sample of only 20-25 people per treatment group.

Overall, the “private toilet” sub-group represents only 11% of the sample, and the intervention aimed to deliver high-quality shared sanitation rather than private sanitation. This invites the conclusion that the main results should be the focus. However, it is important that only four years after the intervention, the benefits of toilets which were meant to be shared were in fact being enjoyed by only one household (with mean size 7.3) in 12% of intervention compounds. To explore the quality of life effects of shared sanitation by comparison to private toilets, future studies would need to be adequately powered for this analysis.
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Online Appendices

Ross et al. “Impact of a sanitation intervention on quality of life and mental wellbeing in low-income urban neighbourhoods of Maputo, Mozambique”

A. Additional information on setting and intervention
B. Additional methods
C. Distributions of outcome variables
D. Reporting checklists
E. Additional results
F. Sensitivity analyses
G. The role of sharing toilets
A. Additional information on setting and intervention

*Photographs with typical examples of main toilet types*

Below are photographs of typical toilets of each type. CSB and ST designs are fairly homogenous, with some variation in the type of squat plate or seat pan used. The level of sanitation service they provide is the same, though CSBs also have a rooftop water tank and two laundry stations. Pit latrines are far more diverse. Some may nominally meet the WHO/UNICEF Joint Monitoring Programme’s definition of an improved technology (e.g. photo 2 has a concrete slab). Such latrines may therefore be categorised as “limited” sanitation (since they are shared) rather than “unimproved”.

*Figure A-1: Pit latrines (control)*

| 1. Pit latrine with tyre and wood for squatting | 2. Pit latrine with concrete slab |
|------------------------------------------------|----------------------------------|
| ![Pit latrine with tyre and wood for squatting](image1) | ![Pit latrine with concrete slab](image2) |
| 3. Fabric door providing limited privacy | 4. No door and adjacent greywater pit |
| ![Fabric door providing limited privacy](image3) | ![No door and adjacent greywater pit](image4) |
Figure A-2: Shared toilets and community sanitation blocks (intervention)

| Exterior                  |   |
|---------------------------|---|
| 1. Shared toilet (ST)     | 2. Community sanitation block (CSB) |
| ![Shared toilet](image1)  | ![Community sanitation block](image2) |

| Interior (varied between CSB / ST depending on design) |   |
|--------------------------------------------------------|---|
| 3. Squat pan                                           | 4. Seat pan |
| ![Squat pan](image3)                                   | ![Seat pan](image4) |
Map of respondent households within Maputo

Figure A-3 Panel A shows the greater Maputo region which, including the adjoining city of Matola, has a population of 2.9 million. Panel B shows the geolocations of households included in our survey (n=424). They are situated within a small area of about 10km² within the Nhlanhankulu district. Since compounds were randomly sampled from the list of MapSan-enrolled compounds, this broadly represents the implementation area of the intervention overall.

Figure A-3: Maps of Maputo

A. Greater Maputo region

B. Respondent households within Maputo City

Source: Batran et al. (2018)

Source: Google Earth
Additional information on intervention delivery

The roles of key stakeholders involved in intervention delivery are summarised below. Further information is provided elsewhere.\(^3,4\)

Table A-1: Stakeholders involved in intervention delivery

| Stakeholder               | Overall role                                      | Key activities                                      |
|---------------------------|---------------------------------------------------|----------------------------------------------------|
| WSUP (NGO)                | Provider and project lead                         | • Project design and management                    |
|                           |                                                   | • Manage design consultants                        |
|                           |                                                   | • Manage construction contractors                  |
|                           |                                                   | • Supervise construction                           |
| Community-based organisations | Sub-contractor facilitating community engagement | • Facilitate site selection                        |
|                           |                                                   | • Collect household capital contribution           |
| Construction firms        | Sub-contractors constructing the toilet infrastructure | • Dismantle old toilet                             |
|                           |                                                   | • Construct new toilet                             |
| Households                | User of infrastructure                            | • Contribute 10-15% of capital costs               |
|                           |                                                   | • Clear site of material                           |
|                           |                                                   | • Participate in meetings and data collection       |
| Municipality (Conselho Municipal de Maputo, CMM) | Oversight and approvals by department for water and sanitation | • Approve designs and procurement                  |
|                           |                                                   | • Provide permits for CSBs                         |
|                           |                                                   | • Monitor infrastructure                          |
| World Bank                | Oversight of overall programme                    | • Fund overall project                             |
|                           |                                                   | • Oversight of delivery                            |

Table A-2: Intervention description using TIDieR checklist (Hoffman et al. 2014)\(^5\)

| Item | Notes |
|------|-------|
| 1    | Provide the name or a phrase that describes the intervention. | Subsidised pour-flush toilets shared by multiple households |
| 2    | Describe any rationale, theory, or goal of the elements essential to the intervention. | In this setting there is limited space and willingness or ability to pay for private toilets, and households already use low-quality shared pit latrines. |
| 3    | Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL). | The intervention provided two types of toilet facility (photos above), alongside education on their use and maintenance. There were also two hygiene promotion visits after completion of construction, carried out by paid staff who received 2 days of training. These focused on contamination routes, good personal hygiene practice, and handwashing with soap. More information is provided elsewhere.\(^3,4,6\) |
| 4    | Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities. | Key procedures included: 1. Community engagement and site identification – undertaken by eight contracted community-based organisations (CBOs), e.g. assessment of |
|   |   |   |
|---|---|---|
| **5** | For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given. | Demand for better toilets and localised environmental issues affecting site selection (e.g. water table)  
2. Site selection and preparation – site selection undertaken by WSUP in discussion with CBOs, and site preparation (e.g. emptying of old latrine pits) undertaken by contracted firms.  
3. Toilet construction – undertaken by contracted construction firms  
4. Education on use, maintenance and hygiene – undertaken by contracted ‘sanitation activists’ |
| **6** | Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group. | Main stakeholders in delivery included:  
1. **Water and Sanitation for the Urban Poor** (international NGO) – overall lead on intervention delivery. Team included engineers and community engagement specialists.  
2. **Various community-based organisations** – sub-contractor facilitating community engagement.  
48 people trained. Teams included facilitators from the local area of the intervention.  
3. **Various construction firms** – Sub-contractors building the toilet infrastructure. They were predominantly small local firms.  
4. **Sanitation activists** – Sub-contractors educating toilet users and promoting hygiene. 55 people trained.  
5. **Municipality and World Bank** – oversight and approvals. Team included engineers. |
| **7** | Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features. | All engagement was face-to-face. As this was shared sanitation, any site visits were made to compound members jointly, rather than individually. |
| **8** | Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose. | Setting described fully in manuscript main body. |
| **9** | If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how. | All aspects of the intervention delivered only once, except for two hygiene promotion visits. |
| **10** | If the intervention was modified during the course of the study, describe the changes (what, why, when, and how). | n/a |
| **11** | Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them. | n/a |
| **12** | Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned. | Fidelity was assessed by Bick et al.4 |
B. Additional methods

Sampling of individuals

Upon arrival at the next compound on the list, and with the approval of a resident, fieldworkers inspected the toilet to assess eligibility. Next, by talking to residents, they listed all eligible people based on the inclusion criteria. For the male respondent, sampling was random from the list of eligible men within the compound, by approaching households starting from the house opposite the compound entrance, and working leftwards until an eligible man was identified. The same process was then followed for eligible women, with the condition that the female respondent not be from the same household as the male respondent. If only one eligible respondent could be identified on a compound, we moved onto the next compounds. We continued visiting compounds until the target sample size was reached. Interviews were in Portuguese, unless the respondent preferred to talk in Changana, a local language in which all interviewers were fluent. We collected data on smartphones using the mWater surveyor application.

Ranking exercise

The ranking exercise comprised a velcro-covered A4 plastic board with a 30cm vertical line and 10 intervals from 1-10 marked, as well as velcro-backed laminated cards (Figure B-1). The exercise was based on methods reported in Drummond et al. Each of the cards was labelled with attributes emerging from prior qualitative work, which were already familiar to respondents from the earlier parts of the questionnaire. Participants were asked to place the cards on the scale according to their relative importance. They were first asked to choose the card representing the attribute they thought most important for a good toilet and a good life. They were asked not to focus on their current toilet but consider their ideal toilet. They were then asked to do the same for the least important attribute of the remaining cards. These were placed at the top (10) and bottom (1) of the board. The enumerator explained that being at position 1 does not mean that attribute is not important, but just that it is less important than the others. The respondent was then asked to stick the remaining cards to the board, at the places on the line that they consider reflected relative importance. Moving attributes was allowed. Placing more than one attribute at the same position was also allowed (only 5 out of 424 participants did so), which is accounted for in Equation A such that weights still sum to 1.
Using data on mean ranks, we estimated weights (Equation A) for each SanQoL dimension using the rank sum method,\(^8\) as previously used in index valuation.\(^9,10\) Mean ranks are reported elsewhere,\(^11\) as are differences in attribute ranks by gender, aged 60+, and treatment.

**Equation A – attribute weights for a population**

\[ w_i = \frac{N - R_i + 1}{\sum_{i=1}^{N}(N - R_i + 1)} \]

**Equation B – SanQoL index value for an individual**

\[ S_j = \frac{\sum_{i=1}^{N}(x_{ij} * w_i)}{3} \]

where:
- \( w_i \) is the weight of the \( i \)th attribute
- \( N \) is the number of attributes
- \( R_i \) is the mean rank of the \( i \)th attribute in the population
- \( x_{ij} \) are item scores ranging from 0-3 for the \( j \)th individual, where “always”=3 and “never”=0.
- \( S_j \) is the SanQoL index value for the \( j \)th individual
**Visual analogue scale (VAS)**

The sanitation VAS was adapted from the VAS in the EQ-5D measure of health-related quality of life, with emoji visualisation informed by the visual pain scale. The enumerator reads out the guidance (Figure B-2) then the respondent indicates their selected level on the scale with a pencil. The VAS gives us information about people’s overall assessment of their level of sanitation, while SanQoL restricts the evaluative space to five attributes with population-based weights. The VAS therefore measures something conceptually different, but complementary, to SanQoL.

*Figure B-2: sanitation VAS*

![Visual Analogue Scale Image]

Mark an X on the scale to indicate how you feel about your level of sanitation today.

**WHO-5 attributes**

WHO-5 attributes are listed in the table below. The raw score ranges from 0 to 25, and is multiplied by 4 to reach a score where 100 represents best possible mental wellbeing and 0 worst possible.

*Table B-1: WHO-5 attributes*

| # | Attribute | Item                                                                 | Responses                               |
|---|-----------|---------------------------------------------------------------------|-----------------------------------------|
| 1 | Cheerful  | In the last 2 weeks have you felt cheerful and in good spirits?     | 0 - At no time                          |
|   |           |                                                                     | 1 - Some of the time                    |
|   |           |                                                                     | 2 - Less than half of the time          |
|   |           |                                                                     | 3 - More than half of the time          |
|   |           |                                                                     | 4 - Most of the time                    |
|   |           |                                                                     | 5 - All of the time                     |
| 2 | Calm      | In the last 2 weeks have you felt calm and relaxed?                 | 0 - At no time                          |
| 3 | Active    | In the last 2 weeks have you felt active and vigorous?              | 1 - Some of the time                    |
| 4 | Fresh     | In the last 2 weeks have you woken up feeling fresh and rested?    | 2 - Less than half of the time          |
| 5 | Interest  | In the last 2 weeks have you had a daily life filled with things that interest you | 3 - More than half of the time          |
|   |           |                                                                     | 4 - Most of the time                    |
|   |           |                                                                     | 5 - All of the time                     |
C. Distributions of outcome variables

Figure C-1: Histograms of primary and secondary outcomes by toilet type

Panel 1 - SanQoL index values
Panel 2 – Sanitation VAS
Panel 3 – WHO-5 index

Figure C-2: Distributions of SanQoL attributes by intervention and control

Note: Scores range from 0-3 representing a scale from never to always (Table 1).
### Table C-1: Polychoric inter-item correlations for SanQoL attributes

|          | Disgust | Health | Shame | Safety | Privacy |
|----------|---------|--------|-------|--------|---------|
| Disgust  | 1.00    |        |       |        |         |
| Health   | 0.56    | 1.00   |       |        |         |
| Shame    | 0.52    | 0.53   | 1.00  |        |         |
| Safety   | 0.41    | 0.47   | 0.49  | 1.00   |         |
| Privacy  | 0.40    | 0.43   | 0.54  | 0.70   | 1.00    |

### Table C-2: SanQoL questions in Portuguese

| #  | Dimension | Question                                                                 | Responses          |
|----|-----------|--------------------------------------------------------------------------|--------------------|
| 1  | Disgust   | Can you use the toilet without feeling disgusted?                         |                    |
|    | Nojo      | Pode usar a casa de banho sem se sentir nojo?                             |                    |
| 2  | Health    | Can you use the toilet without worrying that it spreads diseases?         | 3 – Always (sempre) |
|    | Saúde     | Pode usar a casa de banho sem se preocupar que espalhe doenças?           | 2 – Sometimes (as vezes) |
|    |           |                                                                          | 1 – Rarely (raramente) |
|    |           |                                                                          | 0 – Never (nunca)   |
| 3  | Privacy   | Can you use the toilet in private, without being seen?                   |                    |
|    | Privacidade | Pode usar a casa de banho com privacidade, sem ser visto/a?              |                    |
| 4  | Shame     | Can you use the toilet without feeling ashamed for any reason?           |                    |
|    | Vergonha  | Pode usar a casa de banho sem sentir vergonha por qualquer motivo?       |                    |
| 5  | Safety    | Are you able to feel safe while using the toilet?                        |                    |
|    | Segurança  | É capaz de se sentir seguro/a ao usar esta casa de banho?                |                    |
D. Reporting Checklists

STROBE checklist

We report below which sub-sections provide information required in the STROBE checklist, using the form available at [https://www.strobe-statement.org/checklists/](https://www.strobe-statement.org/checklists/)

| Item No | Recommendation |
|---------|----------------|
| Title and abstract | 1 | (a) Indicate the study’s design with a commonly used term in the title or the abstract

Authors: the title and abstract note that it is an observational comparison study of clusters previously enrolled in a non-randomised controlled trial. See p.1-2

(b) Provide in the abstract an informative and balanced summary of what was done and what was found

Authors: the abstract provides succinct background, methods that articulate the study design and outcomes, results, and their interpretation. See p.2

| Introduction | 2 | Explain the scientific background and rationale for the investigation being reported

Authors: background and rationale are reported in the introduction. See p.4

| Objectives | 3 | State specific objectives, including any prespecified hypotheses

Authors: the aim is stated in the last sentence of the introduction (p.4). Hypotheses are summarised in a methods sub-section of methods (p.7), but were not formally prespecified.

| Methods | 4 | Present key elements of study design early in the paper

Authors: there is a “study design” sub-section at the beginning of methods (p.5)

| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection

Authors: there is a specific “setting” sub-section in methods (p.4), including locations, and a map provided in Online Appendix A. The remaining aspects are reported in other parts of the methods section.

| Participants | 6 | (a) Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up

Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls

Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants

Supplemental material

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Authors: the eligibility criteria are listed in the “participants” sub-section of methods (p.5), as are methods for sampling of participants, with additional detail provided in Online Appendix B.

(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed
Case-control study—For matched studies, give matching criteria and the number of controls per case

Authors: our study design did not use matching directly, but relied on the methods for identification of intervention/control compounds applied by the MapSan trial which are reported in the “study design” sub-section of methods (p.5).

Variables
7 Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable

Authors: Outcomes are defined in an “outcomes” sub-section of methods (p.6), with additional information provided in Online Appendix B. Other variables are defined in the “statistical analysis” section (p.7), with more detail in the data dictionary on LSHTM Data Compass repository (link in manuscript).

Data sources/measurement
8* For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group

Authors: all data are primary and measured by household survey (see #7 above). Further detail on the administration of the survey are in the “participants” sub-section of methods (p.5), with further detail in Online Appendix B.

Bias
9 Describe any efforts to address potential sources of bias

Authors: Efforts to address bias are described in the “participants” sub-section of methods (p.5), and also in the “study design” sub-section (p.5). Sensitivity analyses to explore risk of bias in the analytical approach are described on p.8.

Study size
10 Explain how the study size was arrived at

Authors: the sample size calculation is described in the “statistical analyses” section (p.7).

Quantitative variables
11 Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why

Authors: regression models are described in the “statistical analyses” section (p.7).

Statistical methods
12 (a) Describe all statistical methods, including those used to control for confounding

Authors: covariates adjusted for are described in the “statistical analyses” section (p.7).

(b) Describe any methods used to examine subgroups and interactions

Authors: approaches to interactions with gender and being elderly are described in the “statistical analyses” section (p.7).

(c) Explain how missing data were addressed

Authors: We state in the “statistical analyses” section (p.7) that only 2 participants had missing data for outcomes or covariates (one for WHO-
5, one for the wealth index). With 424 respondents each represents 0.2% of the sample and is not an important source of bias.

(d) Cohort study—If applicable, explain how loss to follow-up was addressed
Case-control study—if applicable, explain how matching of cases and controls was addressed
Cross-sectional study—if applicable, describe analytical methods taking account of sampling strategy

Authors: we explain the approach to adjusting for clustering in the “statistical analyses” section (p.7).

(e) Describe any sensitivity analyses

Authors: sensitivity analyses are described on p.7.

Results

Participants 13*  (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed

Authors: numbers of compounds are described in the participant flow diagram (Figure 1)

(b) Give reasons for non-participation at each stage

Authors: reasons are explained in Figure 1

(c) Consider use of a flow diagram

Authors: See Figure 1

Descriptive data 14*  (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders

Authors: Participant characteristics are summarised in Table 2, separately for intervention and control groups.

(b) Indicate number of participants with missing data for each variable of interest

Authors: the note to Table 2 states that one participant had missing data for the wealth index.

(c) Cohort study—Summarise follow-up time (eg, average and total amount)

Authors: n/a

Outcome data 15*  Cohort study—Report numbers of outcome events or summary measures over time

Authors: n/a

Case-control study—Report numbers in each exposure category, or summary measures of exposure

Authors: n/a

Cross-sectional study—Report numbers of outcome events or summary measures

Authors: Distributions of outcomes are presented in histograms in Online Appendix C, separately for intervention and control groups, as are distributions of individual SanQoL attributes

Main results 16  (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
Authors: unadjusted and adjusted estimates with 95% CIs are provided in Tables 3 and 4. The rationale for adjustment is provided in the “statistical analyses” section of methods (p.7).

(b) Report category boundaries when continuous variables were categorized

Authors: the note to Table 2 states that in the replication dataset available online, we categorised age, household size and children under 14 to maintain full anonymity, since several values were shared by 5 people or fewer.

(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

Authors: n/a

Other analyses 17 Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

Authors: interactions are reported in the results section (p.9), with full results tabulated in Online Appendix E. Sensitivity analysis findings are described in the results section (p.9), with full tables in Online Appendix F.

Discussion

Key results 18 Summarise key results with reference to study objectives

Authors: Key results are summarised in the first paragraph of the discussion (p.13).

Limitations 19 Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias

Authors: Limitations are discussed in two paragraphs towards the end of the discussion (p.13), including sources and direction of potential bias.

Interpretation 20 Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence

Authors: Interpretation is undertaken in the first paragraph of our discussion (p.13), with potential mechanisms discussed in the second paragraph.

Generalisability 21 Discuss the generalisability (external validity) of the study results

Authors: generalisability is considered in the final paragraph of the discussion (p.13)

Other information

Funding 22 Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

Authors: This work was supported by the Economic and Social Research Council through a PhD studentship. The fieldwork was funded by the Bill & Melinda Gates Foundation. The funders had no role in the identification, design, conduct, or reporting of the analysis. The original funders of the MapSan trial on which our study is based were the United States Agency for International Development and the Bill & Melinda Gates Foundation.

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
### Reflexivity Statement and checklist

**Reflexivity statement (Table 1 from Morton et al. 2021)**

| Area                     | Question                                                                 | Response                                                                                                                                                                                                 |
|--------------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Study conceptualisation** | 1. How does this study address local research and policy priorities?     | The National Strategy for Urban Water and Sanitation in Mozambique has the objective of universal access to sanitation services by 2025, but in 2020 only 61% of the urban population had access to “basic” sanitation. Sanitation decision-makers at the Maputo City Council are interested in improving on-site sanitation in informal settlements where sewerage expansion is unrealistic in the medium-term. Understanding which interventions most improve people’s quality of life will help identify interventions most likely to achieve sustained uptake at scale, and all research collaborators buy into the importance of this. |
|                          | 2. How were local researchers involved in study design?                  | ZA led the fieldwork in 2018 for the qualitative study which informed the development of the SanQoL measure, and undertook discussions of methods for the present study with IR at that time. ZA and IR had also collaborated on a separate household survey in 2018 in the same setting, which informed the approach to sampling and data collection in the present study. ZA and IR refined the methods for the present study, especially the SanQoL questions and other outcomes, through discussion, fieldworker training, cognitive interviews and piloting. RN contributed to study design by inputting into the protocol and data collection instruments. |
| **Research management**   | 3. How has funding been used to support the local research team(s)?      | This study was funded under the Maputo Sanitation trial (MapSan) programme of research (clinicaltrials.gov, NCT02362932). The associated funding covered salary costs of ZA and RN for several years, as well as other staff at the Instituto Nacional de Saúde (INS) and WE Consult. The team has supported an INS researcher to successfully apply for a funded PhD programme, and has supported three grant proposals led by early career researchers at INS. |
| **Data acquisition and analysis** | 4. How are research staff who conducted data collection acknowledged?   | The four members of the fieldwork team are named in the acknowledgements.                                                                                                                                    |
|                          | 5. How have members of the research partnership been provided with access to study data? | The data are available open access online.                                                                                                                                                               |
|                          | 6. How were data used to develop analytical skills within the partnership? | As required for a PhD thesis, the analysis was conducted independently by IR with only limited support from the supervisors GG and OC.                                                                    |
| **Data interpretation**   | 7. How have research partners collaborated in interpreting study data?   | ZA and IR discussed emerging trends in data as it came in. ZA and IR also discussed interpretation of observations for some variables which informed data cleaning and analysis. ZA and RN inputted into iterations of the manuscript. |
| **Drafting and revising for** | 8. How were research partners supported to develop writing skills?      | As part of the PhD thesis, the first draft of the manuscript was completed independently by IR.                                                                                                           |
9. How will research products be shared to address local needs?

This study will be published open access. IR undertook a scoping of the health economics policy community in Mozambique while based there during data collection, and will share results of the study with identified stakeholders. There is a dissemination plan for the broader body of research, which will include engagement of urban sanitation stakeholders in Maputo upon IR’s next travel to Mozambique.

10. How is the leadership, contribution and ownership of this work by LMIC researchers recognised within the authorship?

ZA and RN contributed to study design and data interpretation as outlined in the answers to questions #2 and #7 above. The study was part of IR’s PhD thesis and predominantly his work, so he has the first author position. Of the more senior members of the study team (RN, OC, JB, CO, GG), all co-authors agree that OC played the most substantial role in guiding the study’s methods and interpretation and in supervising this part of IR’s PhD thesis, which is why he has the last author position.

11. How have early career researchers across the partnership been included within the authorship?

There are two early career researchers within the authorship team, ZA (based in Mozambique) and IR (based in the UK).

12. How has gender balance been addressed within the authorship?

Four authors are male (IR, JB, CO, and OC) and three female (GG, ZA, and RN).

13. How has the project contributed to training of LMIC researchers?

This specific study did not include a training component. However, under the broader MapSan programme of research, Mozambican researchers from INS received training on different research methods related to epidemiology and laboratory skills.

14. How has the project contributed to improvements in local infrastructure?

This specific study has not directly contributed to improvements in local infrastructure.

15. What safeguarding procedures were used to protect local study participants and researchers?

The participant information sheet was approved by ethical review committees in Mozambique and the UK. It details procedures for confidentiality, withdrawal, and complaints. Fieldwork team members worked in pairs, keeping in contact with ZA by phone on their location. Their training included guidance on what to do in the event of an emergency.

Checklist (Table 2 from Morton et al. 2021)

| Area          | Question                                                                 | Response                                                                 |
|--------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Engagement   | Has the research team engaged constructively with the reflexivity statement? | Yes, all questions have been completed in the table above.               |
| Co-development | Have the research partners co-developed the research study?             | Yes, as illustrated in responses to questions 2, 3, 7 and 10 in the table above. |
|              | Does the study address priority research questions for the LMIC partner(s)? | Yes, see answer to question 1 above.                                       |
| Authorship   | Is there a LMIC partner who is the first or last author?                 | No.                                                                       |
|              | If not, what is the explanation?                                         | Reasons are set out in response to question 10 above (PhD thesis, supervision, and level of support to the specific study) |
| Dissemination | How have LMIC early career researchers been incorporated as authors? | Yes, see answer to question 11 above. |
|--------------|-----------------------------------------------------------------|-------------------------------------|
|              | How are data shared with LMIC partners to address research needs? | Data are available open access online. |
|              | Is there open access funding to improve publication dissemination? | Yes, one of the funders (BMGF) ensures open access for any studies carried out with this funding. |
E. Additional results

Full regression output for main models

Table E-1: Regression output underlying Tables 3 and 4

|                        | SanQoL index value | Sanitation-VAS | WHO-5 index |
|------------------------|--------------------|----------------|-------------|
|                        | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| **Intervention toilet**| 0.34*** | 0.33*** | 0.34*** | 2.91*** | 2.76*** | 2.91*** | 6.25** | 6.65* | 6.78*** |
|                        | (0.02) | (0.03) | (0.02) | (0.04) | (0.03) | (0.02) | (0.05) | (0.05) | (0.05) |
| **Aged 60+**           | -0.01 | -0.01 | -0.03 | -0.15 | -0.12 | -0.14 | -12.95*** | -13.03*** | -10.64*** |
|                        | (0.03) | (0.03) | (0.05) | (0.07) | (0.07) | (0.05) | (0.09) | (0.09) | (0.09) |
| **Female**             | -0.01 | -0.02 | -0.01 | -0.30* | -0.45* | -0.30* | -3.31* | -2.91 | -3.47* |
|                        | (0.02) | (0.03) | (0.02) | (0.05) | (0.05) | (0.04) | (0.07) | (0.07) | (0.07) |
| **Wealth index score** | -0.01 | -0.01 | -0.01 | -0.07 | -0.07 | -0.07 | 0.98 | 0.98 | 1.00 |
|                        | (0.01) | (0.01) | (0.01) | (0.02) | (0.02) | (0.01) | (0.03) | (0.03) | (0.03) |
| **Intervention toilet * female** | 0.03 | 0.29 | -0.07 | (0.04) | (0.33) | (3.88) |
| **Intervention toilet * aged 60+** | 0.03 | 0.02 | -4.09 | (0.06) | (0.57) | (5.69) |
| **Constant**           | 0.50*** | 0.51*** | 0.50*** | 4.28*** | 4.36*** | 4.28*** | 57.01*** | 56.82*** | 56.83*** |
|                        | (0.02) | (0.03) | (0.02) | (0.02) | (0.02) | (0.02) | (2.40) | (2.53) | (2.40) |
| **Observations**       | 423 | 423 | 423 | 423 | 423 | 423 | 422 | 422 | 422 |

Note: Cells report regression coefficients, with standard errors (clustered at compound level) in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent level. SanQoL is on a 0-1 scale, VAS is on a 0-10 scale, and WHO-5 is on a 0-100 scale.
Residuals are approximately normally distributed for all three main results (Figure E-1), and plots of residuals against fitted values for the fixed portions raise no concerns about heteroscedasticity. For the SanQoL plot (panel 4) the plot for the intervention group appears truncated, due to the modal SanQoL index value being 1, which effectively censors the residuals.

Figure E-1: Histograms of residuals and residuals-vs-fitted plots for main results in Table 3 (column references are to Table D-1)
Role of toilet type

Below is the regression output for the main results regressions on SanQoL index values, but including toilet type as a covariate to estimate whether there was a difference between shared toilets (ST) and community sanitation blocks (CSB). It shows that there is weak evidence (p=0.079) for a larger effect of the intervention on ST users than CSB users, which is important for subsequent cost-effectiveness analysis.

Table E-2: Regression output including toilet type as covariate

|                         |         |         |
|-------------------------|---------|---------|
| Intervention toilet     | 0.28*** | (0.04)  |
| Aged 60+                | -0.02   | (0.03)  |
| Female                  | -0.01   | (0.02)  |
| Wealth index score      | -0.01   | (0.01)  |
| Toilet type = ST        | 0.068*  | (0.04)  |
| Constant                | 0.50*** | (0.02)  |
| Observations            | 423     |         |

Note: Cells report regression coefficients, with standard errors (clustered at compound level) in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent level.
Regression on individual SanQoL attribute scores

In regressions on individual attribute scores, the intervention was associated with gains across all five SanQoL attributes. Effect sizes were largest for safety (1.5 SD) and privacy (1.4 SD). Coefficients on interaction terms for gender and aged over 60 were not significant, as with SanQoL index values.

Table E-3: Summary of effects on individual SanQoL attribute scores (ranging 0-3) and interactions with gender and old age

|                      | Disgust | Health | Shame | Safety | Privacy |
|----------------------|---------|--------|-------|--------|---------|
|                      | Mean (SE) | Mean (SE) | Mean (SE) | Mean (SE) | Mean (SE) |
| Control (n=202)     | 1.59 (0.082) | 1.40 (0.085) | 1.56 (0.081) | 1.29 (0.080) | 1.58 (0.081) |
| Intervention (n=222)| 2.32 (0.067) | 2.36 (0.060) | 2.40 (0.068) | 2.64 (0.044) | 2.84 (0.037) |
|                      |          |        |       |        |         |
| Main model (unadjusted) | 0.72 (0.50 - 0.94) | 0.96 (0.74 - 1.18) | 0.82 (0.6 - 1.04) | 1.35 (1.16 - 1.54) | 1.26 (1.07 - 1.45) |
| p-value              | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** |
| Main model (adjusted) | 0.75 (0.53 - 0.97) | 0.96 (0.74 - 1.18) | 0.80 (0.58 - 1.02) | 1.36 (1.16 - 1.56) | 1.25 (1.06 - 1.44) |
| p-value              | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** |
| Adjusted effect size | 0.7 | 0.9 | 0.7 | 1.5 | 1.4 |

| Gender interaction model (adjusted) | p-value on coefficient for Female*Intervention | 0.56 | 0.98 | 0.19 | 0.29 | 0.83 |
| Over-60 interaction model (adjusted) | p-value on coefficient for Over-60*Intervention | 0.43 | 0.28 | 0.87 | 0.15 | 0.54 |

Models include gender, aged over-60, and wealth score as covariates. Standard errors are clustered at the compound level. *, **, *** indicate significance at the 10, 5 and 1 percent level. Detailed regression output is in Online Appendix E.
Below is the regression output underlying the above table.

Table E-4: Regression output for individual SanQoL attribute scores without gender/age interactions

| SanQoL attributes | Disgust   | Health   | Shame    | Safety   | Privacy   |
|-------------------|-----------|----------|----------|----------|-----------|
| Intervention toilet | 0.75***   | 0.96***  | 0.80***  | 1.36***  | 1.25***   |
|                    | (0.11)    | (0.11)   | (0.11)   | (0.10)   | (0.10)    |
| Aged 60+           | -0.07     | -0.07    | 0.03     | 0.06     | -0.10     |
|                    | (0.17)    | (0.13)   | (0.15)   | (0.13)   | (0.12)    |
| Female             | -0.04     | 0.08     | 0.07     | -0.30*** | 0.02      |
|                    | (0.09)    | (0.09)   | (0.10)   | (0.08)   | (0.08)    |
| Wealth index score | -0.10**   | -0.03    | 0.07     | -0.00    | 0.03      |
|                    | (0.05)    | (0.05)   | (0.05)   | (0.04)   | (0.04)    |
| Constant           | 1.62***   | 1.38***  | 1.55***  | 1.43***  | 1.59***   |
|                    | (0.10)    | (0.10)   | (0.10)   | (0.10)   | (0.10)    |
| Observations       | 423       | 423      | 423      | 423      | 423       |

Note: Cells report regression coefficients, with standard errors (clustered at compound level) in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent level. Attribute scores are on a 0-3 scale.
Table E-5: Regression output for individual SanQoL attribute scores including gender/age interactions

|                  | SanQoL attributes: gender interactions | SanQoL attributes: age interactions |
|------------------|----------------------------------------|------------------------------------|
|                  | Disgust  | Health  | Shame   | Safety  | Privacy | Disgust  | Health  | Shame   | Safety  | Privacy |
| Intervention toilet | 0.69***  | 0.96***  | 0.66***  | 1.27***  | 1.27***  | 0.71***  | 0.92***  | 0.78***  | 1.42***  | 1.24***  |
|                  | (0.15)   | (0.15)   | (0.16)   | (0.13)   | (0.13)   | (0.12)   | (0.12)   | (0.12)   | (0.11)   | (0.10)   |
| Aged 60+         | -0.06    | -0.07    | 0.05     | 0.07     | -0.10    | -0.22    | -0.26    | -0.05    | 0.34     | -0.14    |
|                  | (0.17)   | (0.14)   | (0.16)   | (0.13)   | (0.13)   | (0.28)   | (0.24)   | (0.28)   | (0.24)   | (0.22)   |
| Female           | -0.10    | 0.08     | -0.06    | -0.39***  | 0.04     | -0.03    | 0.09     | 0.08     | -0.31***  | 0.02     |
|                  | (0.15)   | (0.16)   | (0.16)   | (0.14)   | (0.14)   | (0.10)   | (0.10)   | (0.10)   | (0.08)   | (0.08)   |
| Wealth index score | -0.10**  | -0.03    | 0.07     | -0.00    | 0.03     | -0.10**  | -0.04    | 0.07     | -0.00    | 0.03     |
|                  | (0.05)   | (0.05)   | (0.05)   | (0.04)   | (0.04)   | (0.05)   | (0.05)   | (0.05)   | (0.04)   | (0.04)   |
| Intervention toilet # female | 0.11    | 0.00     | 0.26     | 0.18     | -0.03    | 0.26     | 0.33     | 0.13     | -0.49*    | 0.07     |
|                  | (0.20)   | (0.19)   | (0.20)   | (0.17)   | (0.16)   | (0.34)   | (0.29)   | (0.34)   | (0.27)   | (0.27)   |
| Intervention toilet # over-60 | 1.65***  | 1.38***  | 1.62***  | 1.48***  | 1.58***  | 1.64***  | 1.39***  | 1.56***  | 1.41***  | 1.59***  |
|                  | (0.12)   | (0.12)   | (0.12)   | (0.11)   | (0.11)   | (0.10)   | (0.10)   | (0.10)   | (0.10)   | (0.10)   |
| Constant         |          |          |          |          |          |          |          |          |          |
|                  |          |          |          |          |          |          |          |          |          |
| Observations     | 423      | 423      | 423      | 423      | 423      | 423      | 423      | 423      | 423      |

Note: Cells report regression coefficients, with standard errors (clustered at compound level) in parentheses. *, **, *** indicate significance at the 10, 5 and 1 percent level. Attribute scores are on a 0-3 scale.
## F. Sensitivity analyses

Table F-1: Sensitivity analyses for SanQoL and VAS

| Outcome: SanQoL index value (0-1 scale) | Outcome: Sanitation VAS (0-10 scale) |
|----------------------------------------|--------------------------------------|
| (1) Headline GLMM (main model)         | (6) Headline GLMM (main model)       |
| (2) Main model GEE                     | (7) Main model GEE                   |
| (3) Main model OLS                     | (8) Main model OLS                   |
| (4) GLMM with only 10% level covariates| (9) GLMM with only 10% level covariates|
| (5) GLMM with predictor covariates     | (10) GLMM w/ t predictor covariates  |
|----------------------------------------|--------------------------------------|
| Pour-flush toilet (Intervention)       | 2.87***                              |
|                                        | (0.25)                               |
| Aged 60+                               | 2.87***                              |
|                                        | (0.24)                               |
| Female                                 | 2.86***                              |
|                                        | (0.24)                               |
| Wealth index score                     | 2.87***                              |
|                                        | (0.24)                               |
| Participant age (categorised)          | 2.91***                              |
|                                        | (0.24)                               |
| Completed secondary school or above    | 2.91***                              |
|                                        | (0.24)                               |
| Number of people sharing toilet stance | 2.87***                              |
|                                        | (0.24)                               |
| Shares toilet with other households    | 2.86***                              |
|                                        | (0.24)                               |
| Renter                                 | 2.87***                              |
|                                        | (0.24)                               |
| Constant                               | 4.28***                              |
|                                        | (0.20)                               |
| Observations                           | 423                                  |

Note: standard errors are shown in parentheses, which are clustered at the compound level; *, **, *** indicate significance at the 10, 5 and 1 percent level. In the main paper, Table 2 presents the mean of respondent age as a continuous variable. We categorised age in the publicly available replication dataset to maintain full
anonymity, since several ages were shared by 5 people or fewer. We apply the categorised variable in these robustness checks for full replicability, but applying the continuous variable makes no difference to results.

Table F-2: Sensitivity analyses for WHO-5

| Outcome: WHO-5 index (0-100 scale) | (1) Headline GLMM (main model) | (2) Main model GEE | (3) Main model OLS | (4) MEGLM with only 10% level covariates | (5) MEGLM with predictor covariates |
|------------------------------------|--------------------------------|-------------------|-------------------|-----------------------------------------|-----------------------------------|
| Pour-flush toilet (Intervention)   | 6.25**                          | 6.27**            | 4.83              | 6.56**                                  | 6.21**                            |
|                                    | (3.05)                          | (3.04)            | (3.15)            | (3.02)                                  | (2.88)                            |
| Aged 60+                           | -12.95***                       | -12.87***         | -15.98***         | -6.19**                                 |                                   |
|                                    | (2.91)                          | (3.30)            | (3.41)            | (2.13)                                  |                                   |
| Female                             | -3.31*                          | -3.34*            | -2.19             | -1.29                                   |                                   |
|                                    | (1.94)                          | (1.88)            | (2.06)            | (2.01)                                  |                                   |
| Wealth index score                 | 0.98                            | 0.99              | 0.78              | 0.77                                    |                                   |
|                                    | (1.12)                          | (1.19)            | (1.36)            | (1.14)                                  |                                   |
| Participant age (categorised)      | -1.67***                        |                   |                   | -1.67***                                |                                   |
|                                    | (0.37)                          |                   |                   | (0.37)                                  |                                   |
| Completed secondary school or above| 1.44                            |                   |                   | 1.44                                    |                                   |
|                                    | (3.60)                          |                   |                   | (3.60)                                  |                                   |
| Has partner                        |                                 |                   |                   | -1.95                                   |                                   |
|                                    |                                 |                   |                   | (2.09)                                  |                                   |
| Pain scale                         |                                 |                   |                   | 7.23***                                 |                                   |
|                                    |                                 |                   |                   | (2.24)                                  |                                   |
| Problems walking scale             |                                 |                   |                   | 5.79**                                  |                                   |
|                                    |                                 |                   |                   | (2.71)                                  |                                   |
| Constant                           | 57.01***                        | 57.00***          | 57.39***          | 60.68***                                | -4.87                             |
|                                    | (2.40)                          | (2.39)            | (2.47)            | (2.76)                                  | (11.32)                           |
| Observations                       | 422                             | 422               | 422               | 422                                     | 423                               |

Note: standard errors are shown in parentheses, which are clustered at the compound level; *, **, *** indicate significance at the 10, 5 and 1 percent level.
G. The role of sharing toilets

During study design it was anticipated that most people in our sample would be sharing toilets with other households, since this was a condition of MapSan enrolment four years previously. In the event, 90% of control and 88% of intervention households used shared toilets (Table 2 in manuscript). The households using private toilets were all single-household compounds, likely due to empty dwellings (driven by rental markets or migration) or changes in compound living arrangements since the intervention.

In this appendix, we discuss means by sharing status and explore sharing in another set of regressions. In the set of robustness checks including all covariates hypothesised ex ante as predicting SanQoL, the binary covariate for sharing the toilet with other households was significant at the 1% level with a negative coefficient. This is likely explained by differences within the control group, where people using private PLs had higher SanQoL than people using shared PLs (Figure G-1a). In the intervention group, sharing made little difference.

Figure G-1: Differences between groups using private and shared toilets

(a) SanQoL – mean index value by sharing and treatment group

(b) VAS – mean score by sharing and treatment group

(c) WHO-5 – mean score by sharing and treatment group

Note. error bars are 95% CIs
Table 2 in the manuscript demonstrated that the mean number of people per stance (cubicle) did not differ at the 5% level between intervention and control groups. This was also the case for analyses within private and shared, with 7.2 and 7.3 people on average using private toilets in control and intervention groups respectively, compared to 12.3 and 13.3 for shared toilets.

Considering VAS scores, a slightly different pattern was observed. Mean scores amongst people sharing intervention toilets were slightly lower than those not sharing, while there was no difference at the 5% level amongst controls (Figure G-1b). For both outcomes however, the intervention was associated with a substantial difference regardless of sharing status. For mental wellbeing, the picture is different again (Figure G-1c). There is a difference in WHO-5 amongst people using private toilets, but not amongst people sharing.

We ran a regression specified as per the headline results, but including a factorial interaction term between the intervention and the binary sharing variable (Table G-1). The results are easier to interpret in the light of Figure G-1.

We make three interpretations from these results. First, amongst people sharing toilets with other households, there was strong evidence ($p<0.001$) that the intervention was associated with a difference in SanQoL of 0.37 (95% CI: 0.32 – 0.41). This is greater than the difference of 0.34 in the sample as a whole, and substantially larger than the difference of 0.15 (95%
CI: 0.06 – 0.24) amongst those using private toilets. However, this is likely driven by the fact that SanQoL was already higher in the control group amongst those using private toilets (Figure G-1a) so scores didn’t “have as far to travel” on a 0-1 scale.

Second, the opposite trend was seen in VAS scores. Amongst users of shared toilets the intervention was associated with a difference of 2.7 (95% CI: 2.2 – 3.2), while in private toilets it was associated with a difference of 3.9 (95% CI: 2.8 – 5.1). Scores in the intervention group simply increased more for private than shared (Figure G-1b). Third, for WHO-5 scores, there was no evidence of a difference amongst users of shared toilets (95% CI: -3.8 – 9.1), compared to a substantial difference of 27.9 amongst users of private toilets (95% CI: 13.0 – 42.8). This slightly odd result is again likely driven by the fact that WHO-5 scores were lower for households in the control group using private latrines (Figure G-1c).

Note that comparisons between users of private toilets are based on a sample of only 20-25 people per treatment group.

Overall, the “private toilet” sub-group represents only 11% of the sample, and the intervention aimed to deliver high-quality shared sanitation rather than private sanitation. This invites the conclusion that the main results should be the focus. However, it is important that only four years after the intervention, the benefits of toilets which were meant to be shared were in fact being enjoyed by only one household (with mean size 7.3) in 12% of intervention compounds. To explore the quality of life effects of shared sanitation by comparison to private toilets, future studies would need to be adequately powered for this analysis.
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