FRAMEWORK FOR SELECTION AND USE OF APPROPRIATE RURAL SANITATION TECHNOLOGIES IN LOW-INCOME SETTINGS

BY

ARTWELL KANDA (19240865)

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PROMOTOR: Dr. Esper Jacobeth Ncube

CO-PROMOTOR: Prof. Kuku Voyi

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ABSTRACT

Access to safely managed sanitation remains low in rural communities of low- and middle-income countries. Inappropriate technology options, lack of community participation and not fully considering social factors in the local context result in failure of sanitation interventions. Demand-driven approaches considering alternatives in the local context are perceived to improve access to sanitation services. A comprehensive procedure is needed to aid the selection of appropriate options. The impact of sanitation interventions on health outcomes were investigated by a systematic review of randomised controlled trials (RCTs) from 2000 to 2019 based on the PRISMA checklist. 15 of the 746 records from six electronic databases were included. Results indicated that RCTs that showed significant positive impact were: 1/10 for prevalence of disease, 2/8 for child growth and 3/9 for infestation of parasites. Findings were suggestive and inconclusive prompting the need for further trials. The strengths and limitations of available frameworks (2000 - 2019) to select appropriate technologies (ASTs) for rural communities in low- and middle-income settings (LMISs) were critically reviewed. Findings from 12 of the 953 included records that were assessed on 22 criteria indicated that frameworks did not fully address criteria on sanitation demand and behaviour, framework limitations, and flexibility, among others. These shortcomings are used to inform future framework development. A mixed method research design was used to understand how households in a rural district of Zimbabwe adapted their sanitation needs to the Blair ventilated improved pit (BVIP) latrine. A questionnaire survey (790 households) and six focus group discussions (FGDs) were used in a rural district of Zimbabwe to understand how households which could not afford a standard household Blair ventilated improved pit (BVIP) latrine design met their sanitation needs. Households constructed incomplete or poor quality BVIP latrines, considered alternatives, shared latrines or practised open defaecation. Alternative options are needed with government support. Drivers and barriers to sustained use of the BVIP latrine, and how rural households adapt it to climate change were studied among 238 households with BVIP latrines in a rural district of Zimbabwe. Drivers for sustained latrine use were technological, social and public health factors. Barriers included latrine design (e.g., distance from the home or poorly/incomplete construction) and social (e.g., presence of extended family, bad smell and security) factors. Adaptation of the BVIP latrine to effects of climate change were odour and erosion control, adding wood ash, alternative options, and constructing raised and conventional designs. Alternative options are needed for equity and universal access. An integrated multi-criteria decision analysis (MCDA) framework was developed based on the nine steps of the simple multi-attribute rating technique (SMART). Data from literature reviews and household surveys were used. Stakeholders participated in evaluating and weighting criteria, scoring alternatives and validating the procedure. A ranking of alternatives based on total utility values indicated that the urine diverting dry latrine had the highest value (72.54) followed by the BVIP latrine (67.10). The framework was verified to follow a laid down methodology, considered robust based on criteria changes and reasonable based on expert opinion.

Key words: appropriate technology, framework, multi-criteria decision analysis, rural communities, sanitation planning.

DECLARATION

UNIVERSITY OF PRETORIA

DECLARATION OF ORIGINALITY

Full names of student: **Artwell Kanda**

Student number: **19240865**

Declaration

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ETHICS STATEMENT

The author, *Artwell Kanda*, obtained approval from the Faculty of Health Sciences Ethics Committee for this research (Ref. 662/2019). The author declares to have observed ethical standards required by the University of Pretoria's Code of Ethics for Researchers and the Policy Guidelines for Responsible Research. Permission to conduct the study was received in writing from the Ministry of Health and Childcare, Medical director, Mashonaland Central.

PUBLICATIONS

In line with objectives of the thesis, the following articles were published in non-predatory journals, listed in ISI or Scopus (First page of publication is given in appendices):

1. Kanda A, Ncube EJ, Voyi K. Effect of sanitation interventions on health outcomes: a systematic review of cluster-randomised controlled trials in rural communities of low- and middle-income countries. *Int J Environ Res Public Health*. 2021; 18(16):8313.
2. Kanda A, Ncube EJ, Voyi K. Frameworks for selecting appropriate rural sanitation technology options in low- and middle-income countries: a critical review *Int J Environ Health Res*. 2021; Doi: 10.1080/09603123.2021.1963685
3. Kanda A, Ncube EJ, Voyi K. Adapting sanitation needs to a latrine design (and its upgradable models): a mixed method study under lower middle-income rural settings. *Sustainability*. 2021; 13(23):13444. Doi: 10.3390/su132313444.
4. Kanda A, Ncube EJ, Voyi K. Drivers and barriers to sustained use of Blair ventilated improved pit latrine after nearly four decades in rural Zimbabwe. *Plos One*. 2022; 17(4): e0265077. Doi: 10.1371/journal.pone.0265077
5. Kanda A, Ncube EJ, Voyi K. Selection of appropriate on-site household sanitation options for rural communities of Zimbabwe - case of Mbire district, Zimbabwe. *Int J Environ Health Res.* 2023;
   Doi: 10.1080/09603123.2023.2166021

CONFERENCE PRESENTATIONS

Accepted poster presentation for PHASA Conference, 11 - 14 September 2022, Durban, South Africa:

1. Kanda A, Ncube EJ, Voyi K. Impact of sanitation on health outcomes in rural communities of low- and middle-income settings: A systematic review of cluster-randomised controlled trials.
2. Kanda A, Ncube EJ, Voyi K. Drivers and barriers to sustained use of a local sanitation technology innovation after four decades in a rural district of Zimbabwe.

DEDICATION

To Eve, Alex, Ashley, Alvin and Aysha.

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LIST OF ACRONYMS

AST	appropriate sanitation technology
BVIP	Blair ventilated improved pit
CAMPFIRE	Communal areas management programme for indigenous resources
CI	Confidence interval
CLTS	Community-led total sanitation
DRA	demand-responsive approach
EHT	environmental health technician
FGD	Focus Group Discussion
HAZ	Height-for-age Z-score
IRWSSP	Integrated Rural Water Supply and Sanitation Programme
LCA	Life cycle assessment
LMICs	Low- and Middle-income Countries
LMISs	low- and middle-income settings
MAUT	Multi-attribute utility theory
MCDA	Multiple criteria decision analysis
NAC	National action committee
OR	Odds ratio
PHHE	Participatory Health and Hygiene Education

PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
QMRA	Quantitative microbial risk assessment
RCT	randomised controlled trial
SDG	Sustainable Development Goal
SMART	Simple multi-attribute rating technique
STH	Soil-transmitted helminths
SWOT	strengths, weaknesses, opportunities and threats
uBVIP	upgradable Blair ventilated improved pit
UDDT	Urine diverting dry toilet
UNICEF	United Nations Children's Fund
VIP	ventilated improved pit
WASH	Water, sanitation and hygiene
WAZ	Weight-for-age Z-score
WHO	World Health Organisation
ZIMCATS	Zimbabwe community approaches to total sanitation
ZimVAC	Zimbabwe vulnerability assessment committee

CONCEPTUAL DEFINITIONS

Appropriate (sanitation) technology: affordable option to be used and maintained to meet one's sanitation needs.

Criteria: key concerns or considerations influencing a particular decision

Decision-making: process of making choices by assessing alternatives to achieve decision objectives

Improved sanitation: facility that hygienically separate excreta from human contact

On-site sanitation option: Collects, store or treats excreta within a household

Rural (health developmental contextual meaning): geographical area located outside towns and cities with low population density

Safely managed (sanitation service): Household unshared improved service, treatment or disposal of excreta

Sanitation: facility which prevents human contact with excreta

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CHAPTER 1: GENERAL INTRODUCTION

1.1 Overview

Sustainable Development Goal (SDG) target 6.2: “By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations” is meant to address the sanitation needs of the previously unserved and new populations. Rural sanitation generally lags behind its urban counterpart in terms of attention and resource mobilisation. Rural areas need prioritisation since this is where most people live, access is limited, and most households are poor. The new SDGs puts pressure on national governments to address rural sanitation through crafting of new policy, policy reform and/or new strategies. There are many proven sanitation technologies on the sanitation market, however, appropriate ones should be selected to suit local conditions.

The current work proposes a simple, transparent and comprehensive framework to select and use appropriate sanitation technologies (ASTs) for low -and middle-income settings (LMISs) presented as thesis by publications. The ultimate aim is to promote latrine use (behaviour change) by considering alternative options in diverse environments to reduce exposure to faecal pathogens. A background to the study establishes the current status quo in terms of access to rural sanitation, the need to prioritise rural sanitation and policy reform (Chapter 1). The impact of sanitation interventions on health outcomes (prevalence of disease, child growth and infestation of internal parasites/pathogens) using randomised controlled trials (RCTs) were reviewed (Chapter 2). It appears there is limited and suggestive evidence, prompting the need for more rigorous studies aiming at high access to sanitation. Existing

frameworks to select ASTs for rural communities of LMICs were reviewed (Chapter 3). Few existing frameworks (2000 - 2019) appeared to vary in design and application due to the lack of a standard format, a gap between science and practice. They did not fully address assessment criteria on sanitation demand and behaviour, framework limitations, flexibility and full consideration of socio-cultural factors. These shortcomings are used to inform future framework development.

Community surveys allowed the establishment of baseline data on relevant rural sanitation issues (Chapters 4 and 5). These include how households adapt their sanitation needs to a single latrine option which is considered as a national choice, and how they adapted the BVIP latrine to effects of climate change. An investigation into drivers and barriers to sustained use of a single sanitation option, the Blair ventilated improved pit (BVIP) latrine was done. Although households appeared to prefer the BVIP latrine for reasons at individual, household and community levels, there were some latrine design, financial and environmental barriers to its adoption and sustained use. Households adapted the BVIP latrine to the effects of climate change though.

Chapters 6 describes the development and evaluation of a multi-criteria decision analysis (MCDA) framework based on the nine steps of the simple multi-attribute rating technique (SMART). The framework was verifiable using a checklist from literature, considered reasonable based on expert opinion and appeared to be robust through a sensitivity analysis. A strength, weakness, opportunity and threat (SWOT) analysis was done. A policy brief was developed based on the study (Appendix 7). The conclusions drawn and recommendations suggested are presented in Chapter 7.

The proposed framework may be used by sanitation planners, intervention implementers and beneficiaries. It decision makers with information on existing sanitation practices and potential opportunities to consider alternatives. A mixed methods research design was used for the study. The work was approved by the Faculty of health Sciences Ethics Committee (662/2019). Permission to conduct the study was granted from the health ministry and local community leaders.

1.2 Background to the study

By 2015 with about 32% of the global population (2.4 billion) still lacked access to improved sanitation (1). About 82.7% of those unserved globally were from southern Asia (39.71%), sub Saharan Africa (28.96%) and eastern Asia (14.04%) (1). These regions had the lowest access to improved sanitation, low quality, not affordable health care (2), borne the burden of diarrhoeal diseases and corresponding high mortality (3). Diarrhoea remained one of the leading causes of the deaths of children under five in low- and middle-income countries (LMICs) after malaria and pneumonia (4) despite it being preventable through water, sanitation and hygiene (WASH) interventions (5). Studies are still needed to understand the impact of sanitation interventions on health outcomes such as the prevalence of diarrhoea and child growth.

Observational studies appear to claim positive effect of having access to sanitation services (6,7) on health outcomes. However, randomised controlled trials (RCTs) remain inconclusive (8-10). Success and failure stories of sanitation interventions in rural areas of LMICs are described (11-13). Rural communities lag behind urban areas in accessing sanitation services (9), making them a priority task area. Various tools were used to evaluate rural sanitation technologies and systems (14-16). Further, available frameworks for the selection of appropriate sanitation technologies (ASTs) for rural areas were reviewed (17,18). Some sanitation technologies and systems have

the potential for resource recovery and reuse (16,19,20). However, faecal sludge management and reuse in rural settings of southern Africa appear poorly reported. Further, water-borne systems in water-stressed regions with high climatic variability and highly unreliable rainfall regime (21) may present operational challenges. Zhou et al. (22) noted that technical innovations, such as the recently developed toilet system in the United Sates, do not meet the actual requirements of the people who need them, thus face adoption challenges.

Appropriate technology emphasises grounding in specific communities, implementation within the constraints of local community-specific socio-cultural and geographical contexts, adaptable, flexible and eliminates environmental threats (23). Indicators of appropriateness of a technology were categorised into socio-cultural, technology, institutional and environmental (24). It is difficult to have a sanitation technology option that is so robust to meet all indicators of appropriateness. Therefore, practically some compromise is made in the selection of ASTs unique to a given local context. Other reviews of literature will be given under specific chapters that address the objective.

WASH interventions reportedly increased latrine coverage for example, in Community-led Total Sanitation (CLTS) approaches (25-27) although the evidence base for the effectiveness of CLTS to inform health practice and its long-term sustainability was regarded weak (28-30). Non-sustained latrine use was identified as a major challenge in post-intervention sanitation evaluations (25,31), attributable to various factors, including socio-cultural norms (32-34). Total sanitation coverage and effective latrine use may be critical to reduce human exposure to faecal pathogens (35).

Frameworks have been developed to inform health policy and practice (36-38). Such decision-making support tools should be flexible to evolve with time in the face of new scientific evidence or emerging contexts so that they remain relevant to new health challenges and suit local conditions and needs. They have to consider impacts of extreme weather events which public health and development through lack of water, poor water quality, destruction of sanitation infrastructure and environmental contamination (39-41). However, climate change provides opportunities for radical action (to improve) that would otherwise not be possible, such as policy review and revision in response to its impacts (42).

Despite there being not a standard approach agreed upon to assess planning frameworks, reviews seem to point that some available decision-making tools do not address important assessment criteria to adapt to local contexts (14,17,18). This may suggest the need to either modify existing frameworks or develop new ones to address unique community sanitation demands, especially factors which influence latrine adoption and sustained use. The current study proposes a framework to select ASTs for rural communities in LMISs, emphasising the local context, based on existing frameworks, informed by community assessment data, and using a Zimbabwean district as a case study.

1.3 Brief background to sanitation in Zimbabwe

Zimbabwe represents a middle lower-income country (recently low-income) in southern Africa which prescribed a home-grown sanitation innovation (ventilated improved pit latrine) found high up the sanitation ladder as a sanitation technology of choice for rural areas (Chapters 4 and 5). The WASH sector is coordinated by the National Action Committee (NAC) which promoted the standardisation of the Blair

ventilated improved pit (BVIP) latrine (and its upgradable designs) for rural sanitation (43).

The country inherited a typically neglected rural sanitation sub sector in 1980 (44,45) which it tried to correct using the Integrated Rural Water Supply and Sanitation Programme (1985 - 2005) with the BVIP latrine. The failed programme was heavily government-subsidised, donor-financed (46,47), tend not to incentivise innovation and enable private sector participation (48). In 2019, the basic rural sanitation coverage and open defaecation in Zimbabwe were estimated at 33.8 and 31.3% respectively (49). About 68% of the country's population live in rural areas (49,50). The growing public expectations and ambitious SDG targets to be met by 2030 (51), and the low rural sanitation coverage in Zimbabwe (33.8%), a policy shift for the provision of rural sanitation or investment package (47) may be inevitable.

1.4 Research statement

Current view in the provision of rural sanitation services is for demand-driven approaches (as opposed to prescribed one-size-fits-all supply-driven approaches), consideration of appropriate alternative technology options for universal coverage and to reduce human exposure to faecal pathogens along the sanitation service chain. These may be met when selected sanitation technologies are accepted and effectively used in the long-term. Reports of failed WASH projects in rural areas of LMICs, especially in Africa (52,53) suggested inappropriate sanitation technology options. Latrine design, structural characteristics and socio-cultural norms were shown to influence sustained effective latrine use (25,33,54). Available frameworks that were developed to select ASTs in rural areas appear not to fully consider social factors (14,17,18) in the local context perceived to influence sustained latrine use.

Therefore, available frameworks and community assessment data may be used to develop a framework to select ASTs to address community contextual settings (conditions and needs) to evolve with socio-cultural challenges promoting non-latrine use.

1.5 Aim and objectives of the study

1.5.1 Aim

To develop a framework for the selection and use of appropriate rural sanitation technologies in low-income settings.

1.5.2 Objectives

(i) To conduct a systematic review of the impact of access to basic sanitation on public health outcomes in low- and middle-income settings (LMISs).

(ii) To review strengths and limitations of available frameworks used to select appropriate rural sanitation technologies in LMISs.

(iii) To determine the implications of prescribing a single or few rural sanitation technology designs in diverse socio-economic and environmental LMISs

(iv) To determine the barriers and enabling factors for sustained use of a prescribed single or few sanitation technologies by rural households in LMISs

(v) To determine how rural communities adapt sanitation services to climate change.

(vi) To develop and validate a framework to select and use appropriate rural sanitation technologies in LMISs.

(vii) To refine and finalise the developed framework to select and use appropriate rural sanitation technologies in LMISs.

1.6 Research questions

Which contextual factors should be included in a framework to select ASTs for rural communities in LMISs to address local sanitation needs and promote sustained latrine adoption and use? The main research question is divided into sub-questions:

(i) What is the strength of association between inadequate access to basic sanitation and public health outcomes?

(ii) What are the strengths and limitations of the available frameworks for the selection of ASTs in rural communities in LMISs?

(iii) What are the experiences and practices of participants in using a prescribed single sanitation technology option (BVIP latrine)?

(iv) Which community assessment factors should be considered to develop a framework to select ASTs to address local contextual settings of rural communities under LMISs?

(v) In which ways does the developed framework add value to the existing ones in selecting ASTs in rural communities under LIMSs?

1.7 Rationale of the study

The findings of this work are relevant for Zimbabwe and other LMICs as the largely preventable diarrhoeal diseases remain widespread and access to basic sanitation in rural areas is limited. The study will provide valuable information for use by sanitation planners, decision making bodies and project implementers. The study may (i) provide an opportunity to explore alternative sanitation technologies in order to increase access to basic sanitation services and eliminate open defaecation, (ii) promote innovation in rural sanitation technologies for different site-specific contexts, (iii) address prescribing of not sustainable rural sanitation options, (iv) demonstrate inequitable access and insufficient government funding for rural sanitation services,

(v) explore opportunities potentially brought about by including alternative sanitation options (e.g. ecological sanitation approaches) (vi) inform sanitation project donors and implementers to consider local contextual settings which influence sustained latrine use and (vii) make decision-making tools evolve with time and remain relevant to changing community demands for sanitation services. It is noteworthy that there are many proven and well-reported sanitation options and frameworks developed to select ASTs. The study does not attempt to 'reinvent the wheel' by doing the same. It proposes a tool to use for the selection of ASTs for rural communities in LMISs to influence sustained latrine use. Therefore, it allows the researcher an opportunity to delve into a widely studied area, yet with a lot of research needs.

1.8 Methods and materials

1.8.1 Description of the study area

The study was done in Mashonaland Central province, Mbire district, Zimbabwe in southern Africa. The province and district were conveniently selected to represent a worst case scenario using poverty and sanitation indicators from national institutions; Zimbabwe Vulnerability Assessment Committee (ZimVAC) and Zimbabwe national Statistical Agency (ZimStat). Details are given in chapters 4 and 5.

1.8.2 Research design

The study assumed a mixed-method approach in a cross sectional study. The qualitative methodology investigated sanitation experiences, practices and perceptions of participants using household interviews, observation and focus groups (55). A quantitative study assessed exposures and outcomes of study participants (56) in a population-based survey (Fig. 1.1) done at household level as described by United Nations (57). Participants were selected for the study based on an inclusion criterion (Chapters 4 and 5).

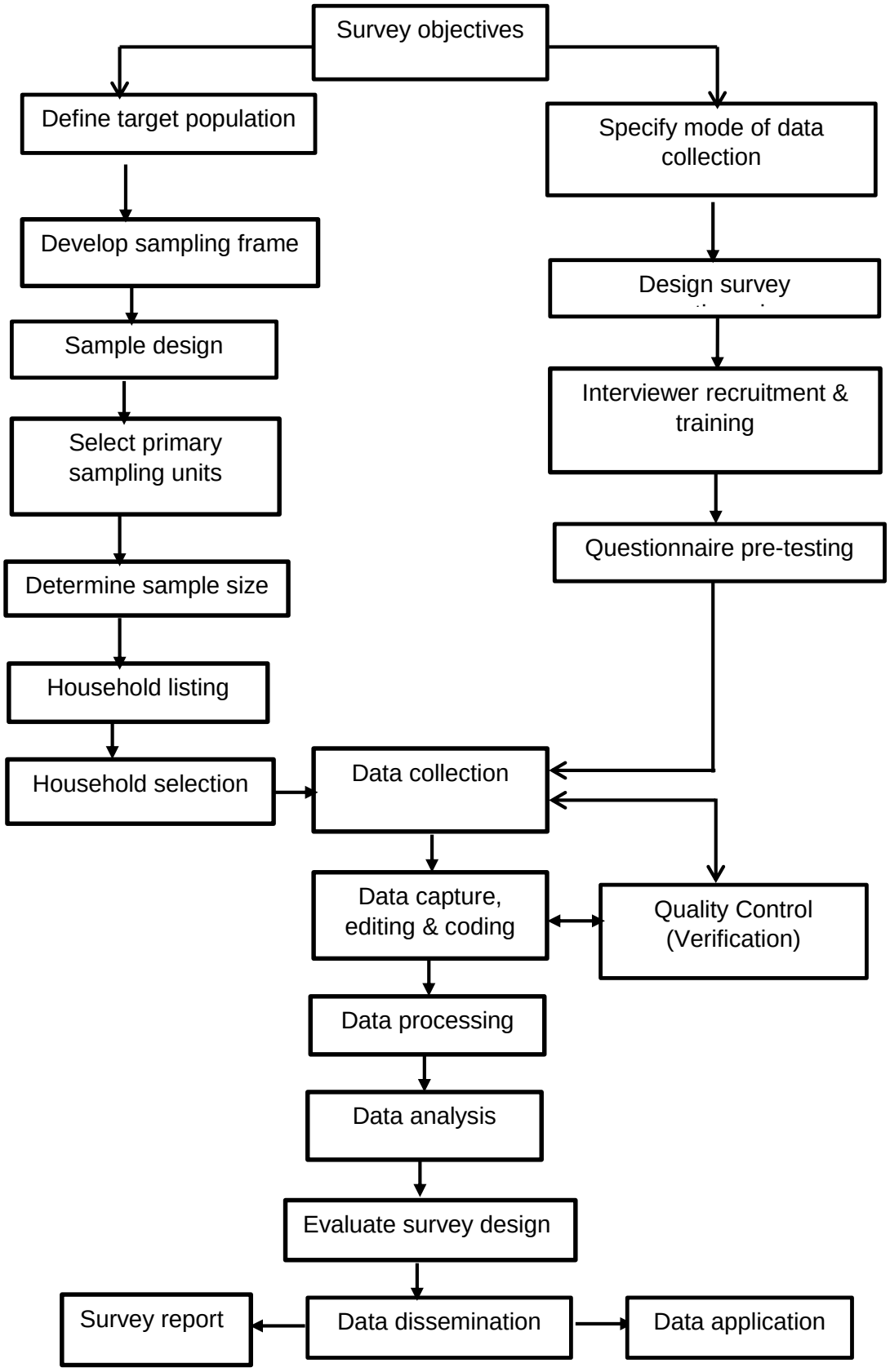


Fig. 1.1 Flowchart of the household survey process modified from United Nations (57).

1.8.3 Determination of sample size

The sample size was determined by using a single population proportion formula (58), considering the design effect (deff) and allowing a contingency for non-response (r) (59), and assuming 95% confidence interval, prevalence of basic latrine of 36.3% in the district, marginal error of 5%, design effect of 2, and a non-response rate of 10%, a sample size was 790 households was determined:

$$n = \frac{Z_{1-\alpha/2}^2 \, p(1-p)}{d^2}$$

n = $(1.96)^2$ * (0.363) (1 - 0.363) / $(0.05)^2$ = 355.3

355.3* (2) ≈ 711 households

Allowing for a non-response rate of 10%, the required sample size is 711 / 0.9 = 790

1.8.4 Measuring instruments

1.8.4.1 Questionnaire

A semi-structured face-to-face interview questionnaire designed by the researcher based on existing instruments was administered by five trained (2 days) and experienced data collectors (Chapters 4 and 5). The approved questionnaire which collected demographic data, rural sanitation services and hygiene, was designed from existing validity and reliability-tested instruments (60) and piloted (60,61). A checklist augmented the questionnaire to collect data on the characteristics (design and use) of the BVIP latrine at household level. A questionnaire was also used in developing and evaluating the questionnaire (Chapter 6).

1.8.4.2 Focus group discussion

Six FGDs were held by a facilitator and assistant with invited participants (Chapters 4 and 5).

A focus group discussion (FGD) recognises the importance of including public opinion in health-care and technology, a reflection of values, attitudes and indigenous knowledge systems important for public policy (62). The FGD procedure described by Nyumba et al. (63) was used (Fig. 1.2). Small groups may cause loss of mutual stimulation amongst participants while large groups may shadow participation of others (64). Training of facilitators, effective recruitment of target participants for particular topics and over-recruitment of participants addresses some of the limitations of the FGD.

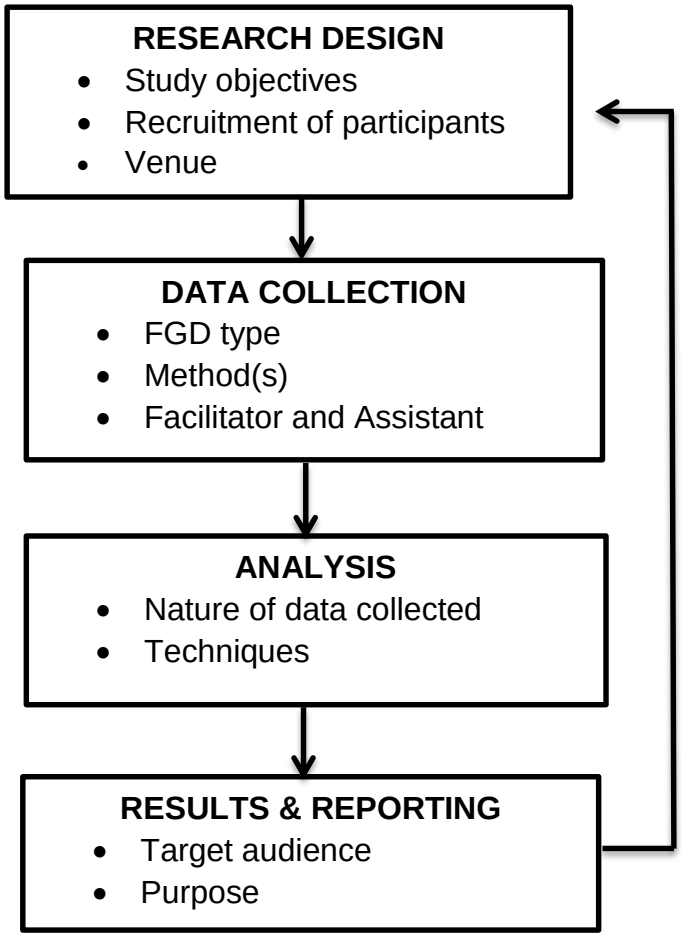


Fig. 1.2 Flowchart of the steps of the focus group discussion technique adapted and modified with written permission from Nyumba et al. (63).

1.8.5 Data analysis and interpretation

Collected data was captured, cleaned (for outliers, completeness and non-existent variables), coded, analysed, summarised and presented in various formats to answer relevant research questions (Chapters 4 and 5). Categorical data was analysed by logistic regression models. Interpretation was based on p-values and odds ratios. Audio-recorded qualitative data was transcribed verbatim and analysed by thematic analysis (65,66). It was coded, categorised, themes generated and reported as narratives (67).

1.8.6 Validity and reliability

1.8.6.1 Reliability

Reliability refers to the consistency (replicability) of the procedures accounting for bias which may have influenced the results (68). It allows for reproducibility (and replicability) by an independent researcher to be able to arrive at similar or comparable findings. Pre-testing or pilot testing of the instruments, and then refining them after identifying sources of error improves reliability (69). In the current study, enumerators were trained to administer the same questionnaire and facilitate FGDs. The questionnaire was developed from existing instruments (70-72) which have repeatedly been practically used in similar settings. A minimum of two independent investigators were involved, with a third for reaching consensus where appropriate.

1.8.6.2 Validity

Validity is the precision in which the findings accurately reflect the data (68). Construct validity is judged by the accumulation of evidence from numerous studies using a specific instrument but content validity is judged by experts in a specific field since there are is no statistical test to determine whether a measure adequately covers a content area or represents a construct (69).

Existing instruments are considered valid and reliable (60). Pilot-testing the questionnaire (to 10% of the sample in this study) adapts it to local contexts (73). In the current study the questionnaire was reviewed by a WASH expert and study promotors. Data cleaning (capture and re-check) for completeness improved data management. Access to the data and records were restricted to the researchers. Training of interviewers allows for the reduction of error and bias (74).

1.8.7 Selection of participants

The survey was done in five randomly selected villages of wards in Mbire district, Zimbabwe. Random selection of households is shown in chapters 4 and 5. The target interviewee was the female or male household head. Randomised household selection excludes selection bias by not considering ethnicity, disability, socio-economic status, educational background, marital status or language. A rural household where consent was given to participate was included in the study. Abandoned households will be excluded. The use of local EHTs would allowed easy communication.

1.8.8 Ethical considerations

The applicable Helsinki guidelines on ethical considerations on research (75), adopted by the World Medical Association, involving human subjects were observed. They include the protection of the privacy of the study subjects, guaranteeing anonymity of participation by using codified household identities and confidentiality of the information shared. The subjects will be informed that they may voluntarily participate and could choose to withdraw their consent at any time of the study without reprisal. They are not to be exposed to physical harm (just to respond to a questionnaire and participate in FDGs). The study protocol was approved by an Ethics Review committee (Chapters 4 and 5).

1.8.9 Framework development and evaluation

A draft framework for selection and use of ASTs was developed based on literature (existing frameworks) and community assessment data. The framework is based on the simple multi-attribute rating technique (SMART) of multi-criteria decision analysis (MCDA) (76). It comprises literature review of existing frameworks, community assessment, MCDA iterative steps and evaluation. Evaluation is four-fold: verification using a checklist from literature, validation with experts through an online survey, sensitivity analysis and a strength, weakness, opportunity and threats (SWOT) analysis (Chapter 6).

1.9 Study assumptions, limitations and delimitations

1.9.1 Assumptions

(i) Selected and volunteered participants would respond honestly after giving their informed consent to voluntarily participate.

(ii) The questionnaire would collect the required information in order to answer the research questions.

(iii) A pilot study oriented the methodologies and instruments and training of data collectors would reduce bias and improve quality data collection.

(iv) Access to appropriate sanitation services promotes effective sustained latrine use.

1.9.1 Limitations

(i) A lot of time and resources are needed for data collection, organisation, capture and interpretation and writing reports.

(ii) Observed sanitation practices, hygiene behaviour and self-reported information may be biased.

(iii) Getting some ‘sensitive information and the involvement of some key stakeholders (e. g. from government) may be lengthy and difficult.

(iv) The BVIP latrine is a jealously guarded home-grown technology innovation by ggovernment. This may impact on data collection and workshop framework validation, and getting general support from proponents of the technology.

(v) Restrictions in movements and contact due to COVID 19 lockdown may affect data collection (timing, sampling design) such as face-to-face in-depth interviews and FGDs, workshop to validate the framework.

(vi) Alternative procedures may be used.

(vii) Evaluation workshops and presentations may not resemble field project planning.

1.9.2 Delimitations

The study aims at developing a framework for selection and use of ASTs for rural communities in LMISs, emphasising local contextual settings. Characteristics which define the scope and boundaries of the study are:

(i) Only trained local EHTs will collect data.

(ii) Only randomly selected participants based on a sampling frame who gave their consent will voluntarily participate.

(iii) Five wards will be selected in a district by simple random sampling.

(iv) Sample households per ward are based on the proportion of the ward relative to the district rural population.

(v) Results of the current study should cautiously be interpreted and not generalised to urban and per-urban settings or other rural areas in different settings, such as in high-income countries.

(vi) Although sanitation is linked to water supply and hygiene, in this study hygiene has to do with handling of faecal matter in the sanitation facility and availability of water for sanitary use will be discussed.

(vii) The study will be done in a district of a purposively selected province targeting rural communities only.

1.10 Expected outputs

The expected outputs from the study are reports on objectives (1, 2, 3, 4 & 5, 6 & 7), a framework for selection and use of ASTs in rural communities of LMISs and a policy brief.

1.11 Thesis structure

The thesis is organised into seven chapters linked to the framework development (Table 1.1).

Table 1. 1 Organisation of the thesis

Chapter	Specific objectives	Overview of activities
1: Introduction	Present background information and description of the study area, problem statement, objectives and the rationale for the study	A brief literature review Drafting the problem statement, objectives and justification of the study Describing the study area, including drawing a map
2: Literature review	1. Systematically review the impact of sanitation on health outcomes in rural communities in LMICs.	Identifying, evaluating and synthesising research results to summarise current evidence, and writing a manuscript for publication
3: Literature review	2. Critically review existing frameworks used for selecting ASTs in rural communities of LMICs.	Identifying relevant frameworks and critique their designs using developed criteria, and writing a manuscript for publication
4: Cross sectional study	3. Determine adaptation of household sanitation needs to a technology option by rural communities under LMICs	Developing a questionnaire, checklist and a focus group interview guide. Data collection using developed tools (community assessment) Writing a manuscript for publication
5: Cross sectional study	4. Determine drivers and barriers to the use of the BVIP latrine as a rural technology option of choice 5. Determine how rural communities adapt latrines to effects of climate change	Developing a questionnaire, checklist and a focus group interview guide Data collection using developed tools (community assessment) munity assessment Writing a manuscript for publication
6: Framework development and evaluation	6. Develop and evaluate a framework to select and use appropriate rural sanitation technologies in LMISs. 7. Refine and finalise the developed framework	Development of a sanitation technology selection framework: Literature review, generate options database, selection criteria, draft framework and its evaluation. Writing a manuscript for publication
7: Conclusions and recommendations	To summarise the main findings, draw conclusions and suggest their implications to sanitation policy, practice and research	Identify and summarise key results (main findings) in the light of relevant literature to give a clear understanding of the work.

References

1. World Health Organisation/United Nations Children's Fund (WHO/UNICEF).Progress on sanitation and drinking water - 2015 update and MDG assessment. Geneva: WHO; 2015. http://files.unicef.org/publications/files/Progress_on_Sanitation_and_Drinking_Water_2015_Update_.pdf. [Accessed 16 January 2018].
2. Ugboko HU, Nwinyi OC, Oranusi SU, Oyewale JO. Childhood diarrhoeal diseases in developing countries. *Heliyon.* 2020; 6:e03690.
3. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, et al. Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An updated analysis with a focus on low- and middle-income countries. *Int J Hyg Environ Health*. 2019; 222:765-777.
4. United Nations Children's Fund [UNICEF]. Childhood diseases. UNICEF: New York, 2020. https://www.unicef.org/health/childhood-diseases. [Accessed 14 October 2020].
5. Cairncross S, Valdmanis V. Water Supply, Sanitation, and Hygiene Promotion. In: Jamison DT, Breman JG, Measham AR, et al. (Eds.) Disease Control priorities in Developing Countries. 2nd ed. Washington DC: World Bank; 2006. pp. 771-792.
6. Freeman MC, Garn JV, Sclar GD, Boisson S, Medlicott K, Alexander KT, Penakalapati G, Anderson D, Mahtani AG, Grimes JET, et al. The impact of sanitation on infectious disease and nutritional status: a systematic review and meta-analysis. *Int J Hyg Environ Health*. 2017; 220(6):928-949.
7. Headey D, Palloni G. Water, sanitation and child health: evidence from sub-national panel data in 59 countries. *Demography*. 2019; 56:729-752.

8. Null C, Stewart CP, Pickering AJ, Dentz HN, Arnold BF, Arnold CD, Benjamin-Chung, J, Clasen T, Dewey KD, Fernald LCH, et al. Effects of water quality, sanitation, hand washing, and nutritional interventions on diarrhoea and child growth in rural Kenya: a cluster-randomised controlled trial. *The Lancet Glob Health*. 2018; 6(3):e316-e329.
9. Contreras JD, Eisenberg JNS. Does basic sanitation prevent diarrhoea? Contextualizing recent intervention trials through a historical lens. *Int J Environ Res Public Health*. 2020; 17:230.
10. Mills JE, Cumming O. The impact of water, sanitation and hygiene on key health and social outcomes: review of evidence. Share/UNICEF: London/New York, 2016. https://www.unicef.org/.../The_Impact_of_WASH_on_Key_Social_and_Health_Outcomes_Review_of_Evidence.pdf. [Accessed 14 October 2020].
11. Mara D, Lane J, Scott B, Trouba D. Sanitation and Health. *PLoS Med*. 2010; 11):e1000363.
12. Trémolet S, Binder D. Evaluating the effectiveness of public finance for household sanitation in the state of Bihar, India. London: WaterAid Report; 2013. www.wateraid.org/evaluatingeffectiveness. [Accessed 31 October 2020]
13. Glassman A, Temin M. Millions saved: New cases of proven success in global health. Washington DC: Center for Global Development; 2016.
14. 14. Skat. Review of Framework for Technology Assessment. (WASHTech Deliverable 3.1) The Hague: WASHTech c/o IRC International Water and Sanitation Centre and Sankt Gallen: Skat; 2011. http://washtechafrica.wordpress.com. [Accessed 27 June 2020].
15. Starkl M, Stenström TA, Roma E, Phansalkar M, Srinivasan RK. Evaluation of sanitation and wastewater treatment technologies: case studies from India. *J Water San Hyg Dev*. 2013; 3(1):1-11.

16. Tilley E, Ulrich L, Lüthi C, Reymond P, Zurbrügg C. Compendium of sanitation systems and technologies. 2nd ed, Swiss Federal Institute of Aquatic Science and Technology (Eawag): Dübendorf; 2014.
17. Palaniappan M, Lang M, Gleick PH. A Review of decision making tools in the water, sanitation and hygiene sector. Environmental change and security programme of the Woodrow Wilson Center and the Pacific Institute; 2008.
18. Barnes R, Roser D, Brown P. Critical evaluation of planning frameworks for rural water and sanitation development projects. *Dev Pract*. 2011; 21(2):168-189.
19. Kumwenda S, Msefula c, Kadewa W, Ngwira B, Morse. Estimating the health risk associated with the use of ecological sanitation toilets in Malawi. *J Environ Public Health.* 2017; 3931802:1-13.
20. Orner KD, Mihelcic JR. A review of sanitation technologies to achieve multiple sustainable development goals that promote resource recovery. *Environ Sci Water Res Technol*. 2018; 4:16-32.
21. Msangi JP. Managing water scarcity in southern Africa: case studies from Namibia. In Msangi JP (Ed). Combating water in southern Africa. SpringerBriefs in Environmental Science, Springer. pp. 21-41. 2014. http://www.springer.com/978-94-007-7096-6. [Accessed 4 March 2019].
22. Zhou X, Li Z, Zheng T, Yan Y, Li P, Odey EA, Mang HP, Uddin SMN. Review of global sanitation development. *Environ Int*. 2018; 120:246-61.
23. Thakaran J. Indigenous knowledge systems for appropriate technology development. In: Venkatesan P. (Ed), Indigenous knowledge, IntechOpen, 2017. pp. 123-134.
24. Bauer AM, Brown A. Quantitative assessment of appropriate technology. *Procedia Eng*. 2014; 78:345-58.

25. Garn JV, Sclar GD, Freeman MC, Penakalapati G, Alexander KT, Brooks P, Rehfuess EA, Boisson S, Medlicott KO, Clasen TF. The impact of sanitation interventions on latrine coverage and latrine use: A systematic review and meta-analysis. *Int J Hyg Environ Health*. 2017; 220(2):329-340.
26. Yeboah-Antwi K, MacLeod WB, Biemba G, Patrick Sijenyi P, Höhne A, Verstraete L, McCallum CM, Hamer DH. Improving sanitation and hygiene through Community-Led Total Sanitation: The Zambian experience. *Am J Trop Med Hyg*. 2018; 100(4):1005-1012.
27. Harter M, Inauen J, Mosler H-J. How does Community-Led Total Sanitation (CLTS) promote latrine construction, and can it be improved? A cluster-randomized controlled trial in Ghana. *Soc Sci Med*. 2020; 245:112705.
28. Ficek F, Novotny J. Comprehending practitioners' assessments of community-led total sanitation. *Health Promot Int*. 2019; 34(6):e129-e138.
29. Venkataramanan V, Crocker J, Karon A, Bartram J. Community-Led Total Sanitation: A mixed-methods systematic review of evidence and Its quality. *Environ Health Perspect*. 2018; 026001.
30. Brown J, Albert J, Whittington D. Community-Led Total Sanitation Moves the needle on ending open defecation in Zambia. *Am J Trop Med Hyg*. 2019; 100(4):767-769.
31. McMichael C. Toilet Talk: Eliminating open defecation and improved sanitation in Nepal. *Med Anthrop*. 2018; 37(4):294-310.
32. Thys S, Mwape KE, Lefèvre P, Dorny P, Marcotty T, Phiri AM, Phiri IK, Gabriël S. Why latrines are not used: Communities' perceptions and practices regarding latrines in a *Taenia solium* endemic rural area in Eastern Zambia. *PLoS Negl Trop Dis*. 2015; 9(3):e0003570.

33. Alemu F, Kumie A, Medhin G, Gebre T, Godfrey P. A socio-ecological analysis of barriers to the adoption, sustainability and consistent use of sanitation facilities in rural Ethiopia. *BMC Public Health*. 2017; 17:706.
34. Lopez VK, Berrocal VJ, Angulo BC, Ram PK, Trostle J, Eisenberg JNS. Determinants of latrine use behaviour: The psychosocial proxies of individual-level defecation practices in rural coastal Ecuador. *Am Soc Trop Med Hyg*. 2019; 100(3):733-741.
35. Clasen T, Boisson S, Routray P, Torondel B, Bell M, Cumming O et al. Effectiveness of rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: a cluster-randomised trial. *Lancet Glob Health*. 2014; 2:e645-53.
36. Oortwijn W, Sampietro-Colom L, Habens F. Developments in value frameworks to inform the allocation of healthcare resources. *Int J Technol Assess Health Care*. 2017; 33(2):1-7.
37. Morton S, Wilson S, Inglis S, Ritchie K, Wales A. Developing a framework to evaluate knowledge into action interventions. *BMC Services Res*. 2018; 18:133.
38. Slade SC, Philip K, Morris ME. Frameworks for embedding a research culture in allied health practice: a rapid review. *Health Res Pol Syst*. 2018; 16 (29):1-15.
39. World Health Organisation [WHO]. The resilience of water supply and sanitation in the face of climate change. Summary and policy implementation: vision 2030. Geneva: WHO; 2009. https://www.who.int/water_sanitation_health/vision_2030_9789241598422.pdf?ua=1 . [Accessed 23 November 2019].
40. Howard G, Calow R, Macdonald A, Bartram J. Climate change and water and sanitation: likely impacts and emerging trends foe action. *Annu Rev Resour*. 2016; 41:253-76.

41. Sorensen C, Murray V, Lemery J, Balbus J. Climate change and women's health: Impacts and policy directions. *PLoS Med*. 2018; 15(7): e1002603.
42. Woodward A. Climate change: disruption, risk and opportunity. *Glob transit*. 2019; 1:44-49.
43. United Nations Children's Fund [UNICEF]. Childhood diseases. New York: UNICEF; 2020. https://www.unicef.org/health/childhood-diseases. [Accessed 14 October 2020].
44. Water and Sanitation Programme [WSP]. An AMCOW country status overview, water supply, sanitation in Zimbabwe: Turning finance into services for 2015 and beyond. WSP; 2011. https://www.wsp.org/sites/wsp.org/files/publications/CSO-Zimbabwe.pdf. [Accessed 23 November 2019].
45. Government of Zimbabwe [GoZ]. The Zimbabwe national sanitation and hygiene policy draft. National Action Committee for rural water supply and sanitation, Harare, 2017.
46. Morgan PR. Technological development in Zimbabwe's rural water supply and sanitation programme. *Zim Sci News*. 1999; 31(1):20-25.
47. Nhapi 1. Challenges for water supply and sanitation in developing countries: Case studies from Zimbabwe. In: Grafton Q, et al. (Eds). Understanding and managing urban water in transition. Global Issues in Water Policy 15. Dordrecht: Springer Science+Business; 2015. pp. 15:91-119.
48. Dondo SM, Scott R. Rural sanitation in southern Africa: A focus on institutions and actors. Human Development Report, Occasional paper 2006/45, Human Development Office. 2006.
hdr.undp.org/sites/default/files/practical_action_consulting_c.pdf.
[Accessed 19 February 2020].
49. Zimbabwe National Statistics Agency/United Nations Children's Fund [ZimStat/UNICEF].

50. Zimbabwe Multiple Indicator Cluster Survey (MICS) findings report. Harare: ZimStat and UNICEF; 2019.
51. Zimbabwe National Statistics Agency [ZimStat]. Zimbabwe Inter-Censal Demographic survey (ICDS). 2017. Harare: ZimStat; 2017.
52. Kruk ME, Gage AD, Arsenault C, Jordan K, Leslie HH, Roder-DeWan S, Adeyi O, Barker P, Daelmans B, Doubova SV, et al. High-quality health systems in the sustainable development goals era: time for a revolution. *Lancet Glob Health*. 2018; 6:e1196-e1252.
53. Dakuré MS, Traoré MB, Sossou SK, Maiga AH. Development of sanitation technologies in African context: how could we make it more sustainable? *IOP Conference series: Earth and Environ Sci*. 2017; 60:012032.
54. Kamara JK, Galukande M, Maeda F, Luboga S, Renzaho AMN. Understanding the challenges of improving sanitation and hygiene outcomes in a community based intervention: A cross-sectional study in rural Tanzania. *Int J Environ Res Pub Health*. 2017; 14;602.
55. Hulland K, Martin N, Dreibelbis R, DeBruicker Valliant J, Winch P. What factors affect sustained adoption of safe water, hygiene and sanitation technologies? A systematic review of literature. London: EPPI-Centre, Social Science Research Unit, UCL Institute of Education, University College London; 2015.
56. Bolderston A. Conducting a research interview. *J Med Imaging Rad Sci*. 2012; 43:66-76.
57. Setia MS. Methodology series module 3: Cross-sectional studies. *Indian J Dermatol*. 2016; 61:261-264.
58. United Nations [UN]. Household sample surveys in developing and transition countries: Studies in methods (ST/ESA/STAT/SER.F/96), New York; 2005. p.34.

59. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? *Indian J Psychol Med*. 2013; 35:121-126.
60. Berhe AA, Aregay AD, Abreha AA, Aregay AB, Gebretsadik AW, Negash DZ, Gebreegziabher EG, Demoz KG. et al. Knowledge, attitude, and practices on water, sanitation, and hygiene among rural residents in Tigray region, northern Ethiopia*. J Environ Public Health*. 2020; 5460168:1-9.
61. Boynton PM, Greenhalgh T. Hands-on guide to questionnaire research: selecting, designing and developing your questionnaire. *BMJ*. 2004; 328:1312-1315.
62. Boynton PM. Hands-on guide to questionnaire research: Administering, analysing and reporting your questionnaire. *BMJ*. 2004; 328: 1372-1375.
63. Rothwell E, Anderson R, Botkin JR. Deliberative discussion groups. *Qual Health Res*. 2016; 26(6):734-740.
64. Nyumba. TO, Wilson K, Derrick CJ, Murkejee N. The use of focus group discussion methodology: Insights from two decades of application in conservation. *Method Ecol Evol.* 2018; 9:20-32.
65. Crawford LM. Marketing research and information systems. (Marketing and Agribusiness Texs-4). Chapter 5: Personal interviews. Food and Agricultural Organisation of the United nations (FAO): Rome; 1997. http//.www.fao.org/docrep/W3241E/W3241E00.htm. [Accessed 5 November 2020].
66. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. 2006, 3(2):77-101.
67. Maguire M, Delahunt B. Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISH-J*. 2017, 9(3):3351-3364.
68. DeJonckheere M, Vaughn LM. Semi-structured interviewing in primary care research: a balance of relationship and rigour. *Fam Med Com Health*. 2019; 7:e000057.

69. Kimberlin CL, Winterstein AG. Validity and reliability instruments used in research: Research fundamentals. *Am J Health-syst Pharm*. 2008; 65:2276-2284.
70. World Health Organisation [WHO]. Ethical principles for medical research involving human subjects. Declaration of Helsinki. World Medical Association Declaration of Helsinki. Adopted by 52nd WMA General Assembly, Edinbrugh, Scotland. *Bull World Health Org*. 2001; 79(4):373-374.
71. World Health Organisation and United Nations Children's Fund. Core questions on drinking water and sanitation for household surveys. Geneva: WHO Press; 2006. https://apps.who.int/iris/bitstream/handle/10665/43489/9789241563260_eng.pdf. [Accessed 13 April 2020].
72. Zimbabwe National Statistics Agency and ICF International [ZimStat/ICF]. Zimbabwe Demographic and Health Survey 2015: Final Report. Rockville, Maryland, USA: ZimStat and ICF; November 2016.
73. United Nations Children's Fund and World Health Organization [WUNICEF/WHO]. Core questions on drinking water, sanitation and hygiene for household surveys: 2018 update. New York: UNICEF and WHO; 2018. https://washdata.org/sites/default/files/documents/reports/2019-03/JMP-2018-corequestions-for-household-surveys.pdf. [Accessed 30 September 2020].
74. Brink HIL. Validity and reliability in qualitative research. *Curationis*. 1993; 6(2):35-38.
75. Ngongo CJ, Frick KD, Hightower AW, Mathingau FA, Burke H, Breiman RF. The perils of straying from protocol: sampling bias and interviewer effects. *PLoS ONE*. 2015; 10(2):e0118025.
76. Couper MP, Singer E. The role of numeracy in informed consent for surveys. *J Empir Res Ethics*. 2009; 4(4):17-26.

77. Dodgson JS, Spackman M, Pearman AD, Phillips LD. Multi-criteria analysis: A manual. London: Department for Communities and Local Government, 2009. http://eprints.lse.ac.uk/12761/1/Multi-criteria_Analysis.pdf. [Accessed 1 November 2021].

CHAPTER 2: EFFECT OF SANITATION INTERVENTIONS ON HEALTH OUTCOMES: A SYSTEMATIC REVIEW OF CLUSTER-RANDOMIZED CONTROLLED TRIALS IN RURAL COMMUNITIES OF LOW- AND MIDDLE-INCOME COUNTRIES

This chapter is a published journal article:

Kanda A, Ncube EJ, Voyi K. Effect of sanitation interventions on health outcomes: A systematic review of cluster-randomized controlled trials in rural communities of low- and middle-income countries. Int J Environ Res Public Health. 2021; 18(16):8313.

2.1 Abstract

A systematic review of published literature (2000–2019) evaluating the impact of sanitation interventions on the prevalence of disease, parasite infestation, and/or child growth using randomized controlled trials (RCTs) was done according to the PRISMA checklist. Earlier reviews indicated mixed evidence citing relatively poor quality evidence from mixed designs. Public health policy and practice appear to rely on evidence from RCTs. Records were searched in six electronic databases. The methodological quality of RCTs was assessed using the Cochrane collaboration risk of bias tool. Fifteen records (2.0%) were included for review. Impact trials were done in rural communities of African and Asian countries. The significant effect of sanitation-focus interventions was found in one trial for the prevalence of childhood diarrhea (14.3%), three trials for parasite infestation (30.0%), and two trials (25.0%) for child growth. Results indicate mixed quality evidence from RCT designs. Evidence is limited and suggestive of the impact of sanitation on parasite infestation and child growth. Further rigorous sanitation intervention trials under varying settings are needed to show what really works and under what settings. Future work may explore sanitation behavior change strategies and latrine options to address the challenges of poor latrine use under high sanitation coverage.

Keywords: basic sanitation; health outcome; low- and middle-income countries; randomized controlled trial.

2.2 Introduction

Sanitation intervention impact research informs public health policy and practice. This could be particularly important for low- and middle-income countries (LMICs) where there is low access to basic sanitation (1), the burden of disease is borne (2) and sanitation remains a major health risk factor (1,3). At the end of the millennium development goals era in 2015, about 32% of the global population (2.4 billion) still lacked access to improved sanitation, 70% living in rural areas (4).

Rural sanitation has become a priority task area. Several studies point to the significant reductions in the prevalence of diarrhea and enteric parasites and child growth with improvements in water, sanitation, and hygiene (WASH). However, it remains not very clear which specific interventions offer the most benefits and under what settings. Evidence from various research designs is mixed and too inconclusive to inform sanitation policy and practice.

A brief review of the literature highlights what is known. A review of 39 studies (1985–2003) by Fewtrell and Colford (5), which evaluated the effect of WASH on diarrhea, found that only one study was on sanitation alone. Wolf et al. (6) identified 11 studies of mixed designs that evaluated the effect of sanitation on health from 1970–2013. Most interventions were implemented as combined WASH. However, the specific effect of a single-focus intervention (e.g., sanitation) cannot be disaggregated from those of the commonly implemented combined WASH interventions (7). A systematic review of the literature up to September 2016 on the effect of WASH on childhood diarrhea (8) identified one study specifically on sanitation alone. The study had no significant effect on childhood diarrhea. Overall estimates showed a 25% mean diarrheal risk reduction compared to a control group without intervention in a review of studies from 1970 to 2016 (9). However, authors noted limited evidence.

Sanitation improvements were found to reduce the prevalence of soil-transmitted helminth (STH) infection in a systematic review and meta-analysis (10). The authors reported that most of the evidence was from cross-sectional studies. Further, no randomized controlled trials (RCTs) were identified in their review.

A similar review of 94 records up to October 2013 identified only five RCTs among the studies on sanitation (11).

Access to sanitation was found to be associated with a decreased likelihood of infection with any STH (odds ratio (OR) 0.66, 95% CI: 0.57–0.76), but not with hookworm. As in other reviews, data were considered to be of low quality due to there being many observational studies. A systematic review and meta-analysis that evaluated 54 studies up to June 2014 found that the availability or use of a sanitation facility was associated with lower odds of infection with *Entamoeba histolytica* or *Entomoeba dispar* (OR 0.5, 95% CI: 0.42–0.74) and *Giardia intestinalis* (0.64, 0.51–0.81) (12). Only two of the studies were RCTs, the rest were observational. This is in agreement with similar work where mixed evidence was attributed to observational studies (13).

Demographic health survey data from 34 countries showed that the disposal practice of child feces in an improved toilet was associated with a 0.12 increase in height-for-age Z-score (HAZ; 95% CI: 0.10–0.15) (14). In a systematic review of the effect of sanitation on childhood (<18 years) growth in LMICs, anthropometric measurements suggested little or no evidence (15). Finally, a systematic review by Freeman et al. (16), which added 64 more studies than in earlier similar work up to December 2015, confirmed positive impacts of sanitation on health outcomes (diarrhea, active trachoma, some STHs, and height-for-age). The authors reported that the overall evidence was generally of poor quality with high heterogeneity.

The use of RCTs to determine the effect of sanitation interventions on health outcomes in rural communities is currently receiving great research attention. Earlier studies used mixed research designs, and they were mainly observational with few rigorous trials and reported mixed findings on the impact of sanitation alone on health outcomes with limited evidence. They lacked rigorous impact estimates due to limited study samples, robust designs, and credible control groups (17). Despite potential methodological limitations, an RCT appears to be the design of choice in healthcare intervention impact research. The effect of an intervention in an RCT is tested by randomly allocating participants to sufficiently large and statistically balanced treatment and control groups (18). A significant difference in the observed outcome is attributed to the intervention (19). The current review includes some new large, rigorous RCTs that were not included in the latest review of various designs (16). In the earlier review, which included 171 records up to the end of 2015, overall evidence suggested that sanitation is protective against diarrhea, active trachoma, some STH, and height-for-age.

The divergence of results and use of evidence from RCTs in sanitation interventions to inform public health policy and practice motivated this work. The review tries to answer the questions: Does new evidence from RCTs on sanitation interventions in rural communities of LMICs show consistent impacts on diarrhea, trachoma, child growth, and intestinal infection with earlier studies? What is the quality of the evidence? The work will be accomplished using evidence only from RCTs that evaluate the effect of sanitation interventions alone (not combined WASH) on selected health outcomes. This is perceived to contribute to the ongoing global research to understand the link between sanitation and health (20).

In this work, *sanitation* refers to having access to and using facilities and services to manage human excreta (20). *Sanitation intervention* is considered to simply mean an increase in access to latrines. An outcome was taken to be a single end-of-intervention point with a linear causal-effect link to that intervention (21). The health outcomes considered were the prevalence of disease or parasite infestation and the condition or state of body (growth) (22).

2.3 Materials and methods

2.3.1 Search strategy, inclusion criteria and data extraction

The preferred reporting items for systematic reviews and meta-analyses (PRISMA) checklist (23) was used to identify, screen, and include records for data extraction and analysis (Fig. 2.1). A systematic review of published peer-reviewed literature was conducted between November 2019 and March 2020 for RCTs that evaluated the impact of sanitation interventions on disease/enteric parasite infestation, child growth, or their combinations as health outcomes indicators. Electronic databases (Cochrane Library Trials (CENTRAL), MEDLINE-Ovid, PubMed, Science Direct, SCOPUS, and Web of Science) were searched for relevant records using appropriate search terms and filters (Table 2.1). The search stream was considered most appropriate after several 'trial and error' attempts. Analysis and synthesis of included records were done by two independent investigators.

The inclusion criteria considered peer-reviewed articles published in English from 1 January 2000 to 31 December 2019 that sought to evaluate the effect of sanitation interventions on health outcomes at rural the community level in LMICs based on RCTs.

Interventions should have been be done at household (not school or hospital) level. Quasi-controlled trials, controlled before-and-after, and uncontrolled studies were excluded. Full-text screening identified the records for data extraction. Data on the selected articles were extracted by two independent investigators. Upon discussion including a third investigator, discrepancies in the eligibility and extraction decisions were removed. A sheet with the characteristics of each study was prepared from the literature (18,24) and used to extract full reference, study area, intervention, participant characteristics, health outcomes, and key findings.

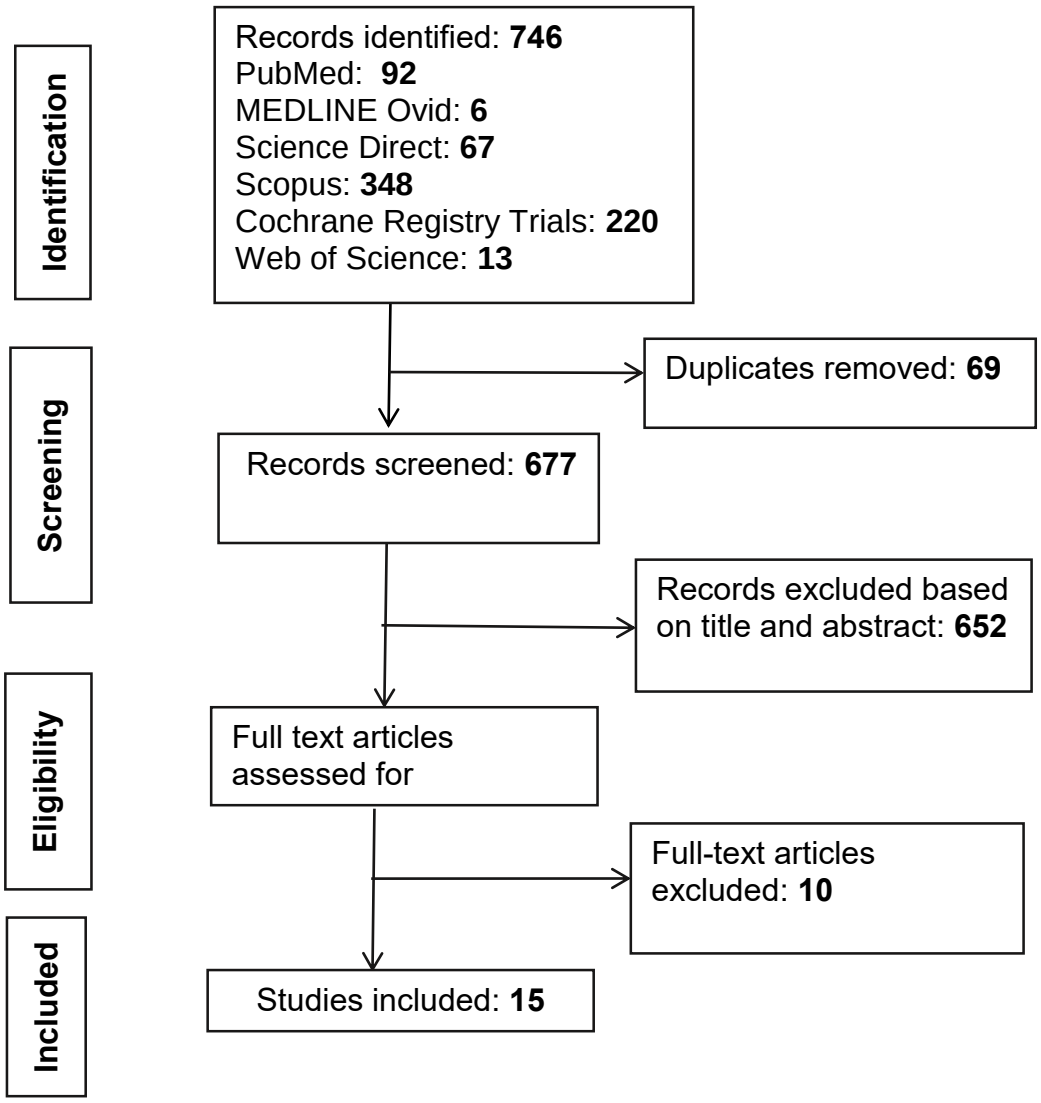


Fig. 2.1 PRISMA flow chart of literature search

Table 2.1 Literature search terms.

Database	Search String	Applied filters
Cochrane Library-Trials	Advanced search: (WASH sanitation randomized controlled trial)	2000–2019 English
MEDLINE Ovid	Advanced search: ((((effect OR impact) AND (sanitation OR WASH) AND interventions AND health AND outcomes) OR (disease OR diarrhoea OR child growth)) AND (randomized AND controlled AND trial) AND (low AND middle AND income AND country))	2000–2019 Article Full text journals
PubMed	Advanced search: (sanitation interventions health outcomes randomized controlled trials)	Full text 2000–2019 RCT
Science Direct	Advanced search: (effect sanitation interventions health outcomes randomized controlled trials low- and middle-income countries)	Research article 2000–2019
SCOPUS	Advanced search: (effect OR impact AND sanitation OR WASH AND interventions AND health AND outcomes OR diarrhoea OR child AND growth AND randomized AND controlled AND trial AND low- AND middle- AND income AND country)	2000–2019 Article English
Web of Science	Advanced search: TS = (effect AND sanitation AND interventions AND diarrhoea AND child AND growth AND randomized AND controlled AND trials)	2000–2019 English

2.3.2 Assessment and analysis of included studies

Qualitative assessment of included studies was done using five considerations: participants, intervention, health outcomes, bias assessment, and key findings derived from similar work (6,8). The Cochrane collaboration risk of bias tool (25) was used to assess bias by two independent investigators who discussed with a third to reach consensus. Narrative synthesis was used for data analysis.

2.4 Results

2.4.1 Characteristics of included studies

The literature search identified 746 studies from six electronic databases. Ten of the 25 full-text articles assessed for eligibility were excluded for not having a stand-alone sanitation intervention arm or the target health outcome indicators.

Finally, 15 peer-reviewed publications from nine unique trails (different clinical registrations) were included (Fig. 2.1). Studies were done in eight countries (five from Africa, three from Asia). About 93% of the studies were published from 2011 to 2019 and 86.7% had clinical registration numbers clearly indicated. Summaries of the 15 reviewed RCTs were categorized into the various characteristics suggested in the methodology and generally used in the literature (Table 2.2).

2.4.1.1 Characteristics of participants

Table 2 shows that the eligibility criteria for enrolment at household level included everyone greater than a given age limit, the presence of at least one child lower than a given age limit, the presence of a pregnant women in a given trimester, and the index child or non-index children within a given age limit at follow-up within the study area.

2.4.1.2 Intervention, adherence, latrine coverage, and attrition at follow-up

All trials were cluster-randomized at village level, except for one at ward level (31). In most cases, a trial profile was provided to show details of the intervention. Community participation in the interventions was mainly in the form of providing labor (such as pit digging and construction) and material for latrine construction (e.g., sand and bricks). Adherence (compliance) to intervention target behavior varied with trials and also during each trial. Baseline-end line sanitation coverage consisted of access to any (private/compound), improved, or functional latrine. Reasons for fall-out at follow-up were reported in 79% of the included studies shown on trial profiles. Follow-up times were from 0.5-2.5 years.

Table 2.2. Summaries of random controlled trials included for the review.

Reference	Country/ Continent of trial/Trial registration	% Access to Basic Sanitation	Sanitation Intervention Group	Intervention Duration (Years)	Sanitation Technology Option(s)	Sanitation Demand	Exposure Pathway(s) Based on the Study	Intervention Subsidy	Reasons for Loss to Follow-up
Emerson et al. (26)	Gambia (Africa) -	3.5	2230 participants in 7 clusters	2	Non-ventilated pit latrine	Not specified	Vector Contact	Government subsidized	travelled, death, declined
Gebre et al. (27)	Ethiopia (Africa) NCT00322972	-	14 189 persons in 12 Subkebeles	2.16	Pit latrine with concrete slab	Not specified	Vector Contact	Government subsidized	-
Stoller et al. (28)	Ethiopia (Africa) NCT00322972	-	14,289 people in 12 Subkebeles	2	Simple pit latrine	Not specified	Vector	Material subsidy	-
Clasen et al. (3)	India (Asia) NCT01214785	9 (any type)	10 014 individuals, including 1919 chn <5 in 50 villages	3.58	Pour flush	Not specified	Water, Contact, Food	Government subsidized	Death, absent, family dropout
Patil et al. (29)	India (Asia) NCT01465204	13.64	1683 chn < 5976 households in 40 villages	Not clear	Various	Not specified	Water, Food, contact	Government subsidized for national TSC	-
Dickinson et al. (17)	India (Asia) -	25 (owned)	1050 HHSs, 1256 chn <5, 40 villages	0.42	Several under CLTS	CLTS triggering	Water	Government subsidized	-
Pickering et al. (30)	Mali (Africa) NCT01900912	22 (control)	2365 HHs, 3508 chn <5, 60 villages	Not clear	Several under CLTS	CLTS triggering	Water	-	-
Briceño et al. (31)	Tanzania (Africa) NCT01465204	49.7	86 villages in 44 wards	2.3	Several under CLTS	CLTS triggering	Water, food contact	-	-
Lin et al. (32)	Bangladesh (Asia) NCT01590095	53 (owned)	696 compounds in 90 clusters	1	Double pit Latrine with water seal	Not specified	Water, contact	Material subsidy	Moved, death, withdrew, no live birth, absent
Luby et al. (33)	Bangladesh (Asia) NCC01590095	54 (owned)	696 compounds in 90 clusters	1	Double pit Latrine with water seal	Not specified	Water, contact food	Material subsidy	Moved, no live birth, absent, refused,
Null et al. (34)	Kenya (Africa) NCT01704105	16	892 HHs 77 clusters	1.5	'Improved latrines'	Not specified	Water, food contact	Material subsidy,	Absent, died refused, no live birth,
Cameron et al.(35)	Indonesia (Asia) -	-	80 villages	-	Several CLTS campaign	CLTS triggering	Contact, food water	-	-
Ercumen et al. (36)	Bangladesh (Asia) NCT01590095	53.4 (owned)	696 women, 90 clusters, 1030 Chn	1	Concrete-lined double pit latrine (seal)	Not specified	Contact, water	Provision of upgraded latrines	Moved, death, absent, no live birth, withdrew
Pickering	Kenya (Africa)	15.7	892 HHs in 77	1.5	Not	Not	Water, food	New latrines	Absent,

et al. (37)	NCT01704105		clusters		specified	specified	contact	& upgrading existing ones	death, refused, no live birth
Stainbaum et al. (38)	Kenya (Africa) NCT01704105	15.7	892 HHs 77 clusters	1.5	'Improved latrines'	Not specified	Water, food contact	Material subsidy	Absent, no live birth, refused, death

(Table 2.2 continued)

Reference	Time when Post-Intervention follow-up done (Years)	Enrolment Criteria	Intervention Adherence (%)	Health Outcome	Study Limitations	Key Findings
Emerson et al. (26)	0.5	Clusters randomly recruited in sets of three	First 0.5 years: 98%	Disease	Study done in low prevalence area. Fly catching without release induces catcher bias (unblinded)	Access to basic sanitation reduced fly eye contact Insignificant reduction in prevalence of trachoma in sanitation intervention
Gebre et al. (27)	2.16	Subkebekes randomly selected	61.5	Disease	No masking, insufficient sample size, no hygiene education	No effect of latrine construction on mortality (under 5 year old children).
Stoller et al. (28)	1 and 2	Subkebekes Randomly selected	67.2	Disease, Parasite	Flies not only transmission route, sanitation control varies in space and time,	Latrine construction offered no protection to prevalence of trachoma
Clasen et al. (3)	1.5	HHH with child < 4 years or pregnant woman	36	Disease, Growth, Parasite	Short follow-up period 1.5 year Self- and care-giver reported bias	No reduced exposure, prevention to diarrhea and STHs or child effect on malnutrition.
Patil et al. (29)	1.75	Villages randomly selected	59	Disease, Growth, Parasite	Short-term follow-up, contamination in the control group and self-reported outcomes	Increased coverage (19%), reduced open defecation 10%) but no improvements on diseases and child growth
Dickinson et al. (17)	0.42	HHH with child < 5 years	-	Disease, Growth	Study under-powered to statistically detect precise effects on diarrhea,	No statistically precise reductions in diarrhea, but increased anthropometric measurements of children <5 years of age
Pickering et al. (30)	1.5	HH with at least a child <10 years old	-	Disease, Growth	Self-reported measure, one follow-up in dry season, no universal access	No reduced diarrhea prevalence, increased child growth (<2) reduced open defecation and stunting (<5). Future work: Sanitation and height
Briceño et al. (31)	1	HHs with a child < 5	-	Disease, Growth	No pre-intervention baseline characteristics, small changes in intermediate outcomes due to isolated interventions	Increased access (49.7–64.8%), reduced open defecation but the final effects of sanitation on child health were absent

Lin et al. (32)	2.5	Pregnant women, Chn ages 18–27 months	85–87	Parasite	*Giardia* genotype not determined, unknown protozoan infection status after intervention initiation but determined before 2 years.	Sanitation intervention reduced Childhood *Giardia* infections (9%)
Luby et al. (33)	1 and 2	Pregnant women, Index chn	'high'	Disease, Growth	Caregiver-reported primary outcomes. Intervention in one socio-ecological zone in times of low prevalence of diarrhea	Sanitation intervention had no effect on child linear growth at year 2 but reduced the diarrhea prevalence (3.5%) than in the control (5.7%).
Null et al. (34)	1 and 2	Pregnant women, other requirements	>70: year 1, < 25: year 2	Disease, Growth	No observable indicators of actual behavior, compound and not community-level, focus on human feces not animal	Sanitation had no effect on diarrhea prevalence and child growth.
Cameron et al. (35)	2	HH with child < 5 years	'low'	Parasite, Growth	Partial compliance to treatment as 13.8% of the control was exposed to treatment	Associated decrease in roundworm infestations but no improvements in child growth.
Ercumen et al. (36)	2.5	Pregnant women in 1st or 2nd trimester, Index chn	54	Parasite	Poor instrumental sensitivity, only relative statistical power to detect relatively large effects, short follow-up for *A. lumbricoides*	Sanitation reduced *T. trichiura* (29%), had borderline effects on hookworm and no effect on *A. lumbricoides*.
Pickering et al. (37)	2	Village with at least 6 pregnant women Index chn	Year 1: 89–90 Year 2: 79–82	Parasite	Imperfect uptake of targeted behaviour, limited power to detect effects on rare parasite infections	Sanitation had no effect on prevalence of *Ascaris* infection, and no reduction in *Giardia*
Steinbaum et al. (38)	2	Village with pregnant women, Index chn	Year 1: 89–90 Year 2: 79–82	Parasite	No precise measures of compound defecation practices. Soil analysis method only optimized for *Ascaris*, not*Trichris* or hookworm eggs	Sanitation had no effect on presence of eggs of total STH, *Ascaris* or *Trichuris*

HHs – Household, Chn – Children, CLTS - Community-Led Total Sanitation, TSC – Total Sanitation campaign

2.4.1.3 Subsidies, sanitation demand and intention-to-treat

Subsidies were provided for in cash or material, either to all participants or to households considered living below the poverty datum line. In some cases where the community-led total sanitation (CLTS) approach was used, material subsidies were provided in a government sanitation campaign.

Participant demand for sanitation was triggered in the demand-side interventions, especially under CLTS or where its approaches were used. Without expressed demand for sanitation, even subsidized interventions (supply-side) e.g., (26,30,31,35) could not achieve total coverage and latrine use. Pit latrines with a plastic/concrete slab or pour flush system were the main technology options used in more than 60% of the interventions. However, different latrines built from local material (mainly unimproved) were constructed under CLTS programs. An intention-to-treat (ITT) was reportedly used to determine the difference between average target health outcomes across the sanitation intervention treatments and the control groups in 85% of the trials.

2.4.1.4 Risk of bias assessment

The authors' risks of bias judgement for the included records are presented in the supporting material 2S.1. The overall assessment of risk of bias for the 15 RCTs is shown in Fig. 2.2. Trials were judged based on the seven domains of the Cochrane collaboration bias assessment tool for undetected bias (low risk), detected bias (high risk), and uncertainty or lack of reported information (unclear risk of bias) (25). Twelve RCTs (80.0%) were rated low risk of bias for sequence generation (selection bias). This means that the assigning of participants into treatment and control groups was randomized.

In nine of them, a computer-generated randomization sequence allocation procedure was used by independent personnel. All studies were rated high risk for not blinding participants and field personnel. However, attempts were made to blind field personnel in some trials (3,30,34).

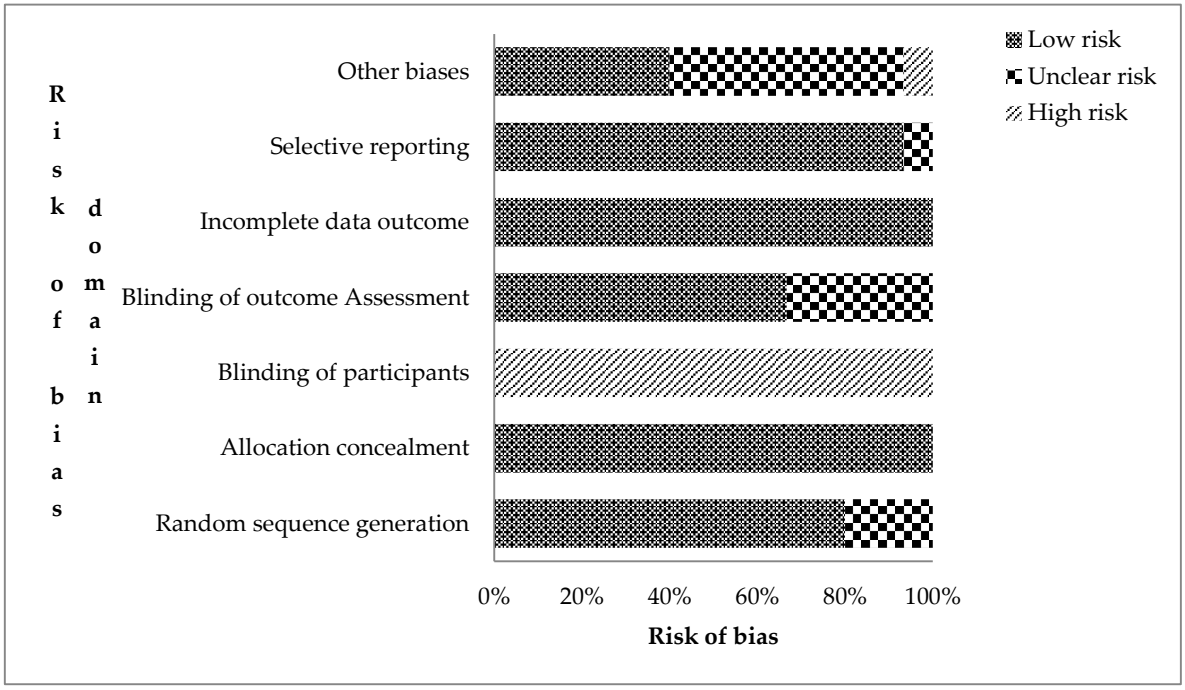


Fig. 2.2 Risk assessment bias for the included cRCTs (*n* = 14) on the effect of sanitation on health outcomes in low- and middle-income countries (Authors' judgement).

Ten trials (66.7%) were judged to have a low risk of detection bias as procedures of blinding outcome assessment were given. Loss to attrition, enrolment at follow-up, and intention-to-treat analysis were explained for all trials, resulting in low risk for attrition bias. Protocols and registered trials with predefined outcomes were available for 80% of the trials. Those without (17,26,35) were rated low risk of bias as the published reports included all pre-specified outcomes. Eleven trials, which relied on caregiver-reported diarrhea as a primary outcome, were judged unclear risk due to reporting bias.

2.4.2 Health outcomes

Health outcomes (whether primary, secondary, or tertiary) upon which the effect of sanitation was assessed in the intervention, as indicated in the included studies, are shown in Table 2.3. Three main outcomes derived from the included studies were the prevalence of disease, parasite infestation, and child growth. Caregiver-reported that diarrhea and active trachoma were the two diseases considered. Parasite infestations were enteric helminths, protozoa, and other (*C. trachomatis*). The prevalence of disease was used in ten (66.7%), parasite infestation in ten (66.7%), and child growth (anthropometric measurements) in eight (53.3%) of the included trials. Only two RCTs (13.3%) considered all the three health outcomes under study in the sanitation impact interventions (3,29).

Results shown in Table 2.4 indicate that there was significant effect on access to sanitation on the prevalence of disease in one study: child diarrhea (3,17,29-31,34), and trachoma (26-28). Reduction in the prevalence of trachoma in one study (26) was considered insignificant. Only one of the seven studies (14.3%) that investigated the impact of sanitation on the prevalence of child diarrhea showed positive results. The Bangladesh trial (33) showed that a 7-day diarrhea prevalence was lower among index children and children under 3 years at enrolment than the control in the sanitation intervention arm (PR 0.61, 95% CI 0.46-0.81).

Only two of the eight trials (25.0%) that assessed the impact of sanitation on child growth showed a positive effect (17,30). The Mali CLTS trial showed that increased access to latrines improved child growth for the < 2 years under conditions of high coverage with mostly unimproved latrines.

CLTS children were taller (0.18 increase in HAZ, 95% CI 0.03–0.32; 2415 children) and less likely to be stunted (35% vs. 41%, PR 0.86, 95% CI: 0.74–1.0) than those from control villages [30]. The difference in mean weight-for-age z score (WAZ) for CLTS and control children was 0.09 (95% CI: −0.04 to 0.22) between groups. A similar trial setting of CLTS in Bhadrak, India, found an improvement in height-for-age z scores (0.37–0.52 and WAZ (0.26-0.31) standard deviations) relative to controls (17).

Three of the ten RCTs (30.0%) that evaluated the effect of sanitation interventions on the prevalence of parasite infestation showed significant positive effects. The sanitation intervention on child enteric protozoan infections in rural Bangladesh (32) showed reduced prevalence of childhood *Giardia* infection in the treatment (26.5%, PR = 0.75 (0.64, 088)) than the control (35.5%) for 2.5-year old children. The CLTS intervention in rural Indonesia (35) showed a 48% reduction in roundworm infestation in treatment children relative to the control. Another trial in rural Bangladesh (36) showed that sanitation improvements reduced *T. trichiura* by 29% (PR = 0.71 (0.52, 0.98), Prevalence difference (PD) = −2.17 (−4.03 to 0.38)).

Table 2.3 Main health outcomes upon which the effect of sanitation was assessed in the intervention as indicated in the included studies.

Reference	Presence of disease		Parasite infestation			Child growth	Main indicator (s) for the outcome					Total outcomes
	Diarrhoea	Trachoma	Protozoan	Helminthic	Other	Anthropometric	Prevalence	Mortality	Height	Weight	Other	
Emerson et al. (26)		✓					✓					1
Gebre et al. (27)		✓			✓			✓				2
Stoller et al. (28)		✓			✓		✓					2
Clasen et al. (3)	✓			✓		✓	✓		✓	✓	✓	3
Patil et al. (29)	✓			✓		✓	✓		✓	✓	✓	3
Dickinson et al. (17)	✓					✓	✓		✓	✓	✓	2
Pickering et al. (30)	✓					✓	✓		✓	✓		2
Briceño et al. (31)	✓					✓	✓		✓	✓		2
Lin A et al. (32)			✓				✓					1
Luby et al. (33)	✓					✓	✓		✓	✓	✓	2
Null et al. (34)	✓					✓	✓		✓	✓	✓	2
Cameron et al. (35)				✓		✓	✓		✓	✓		2
Ercumen et al. (36)				✓			✓					1
Pickering et al. (37)			✓	✓			✓					1
Steinbaum et al. (38)				✓			✓					1

Table 2.4 Summary of results showing the effect of sanitation interventions on disease, parasite infestation and child growth.

Health Outcome		Significant Effect of Sanitation Shown by Randomised Controlled Trial														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Disease	Active trachoma	×	×	×												
	Reported diarrhoea				×	×	×	×	×		✓	×				
Parasite Infection	protozoa									✓					×	
	Enteric helminths				×	×							✓	✓	×	×
	Other		×	×												
Child growth (anthropometric)	Weight				×	×	✓	✓	×		×	×	×			
	Height				×	×	✓	✓	×		×	×	×			
	Other measure				×	×	✓				×	×				

✓- Significant effect; × - No significant effect; 1 - Emerson et al. (26); 2 - Gebre et al. (27); 3 - Stoller et al. (28); 4 - Clasen et al. (3); 5 - Patil et al. (29); 6 - Dickinson et al. (17); 7 - Pickering et al. (30); 8 - Briceño et al. (31); 9 - Lin et al. (32); 10 - Luby et al. (33); 11 - Null et al. (34); 12 - Cameron et al. (35) 13 - Ercumen et al. (36); 14 - Pickering et al. (37); 15 -Steinbaum et al. (38).

2.5 Discussion

We reviewed 14 RCTs that evaluated the impact of sanitation on pertinent health outcomes (diarrhea, trachoma, and child growth and parasite infection) from 2000 to 2019 in rural communities of LMICs. This was to find out whether evidence from RCTs was consistent with earlier findings from mixed design reviews. The latest review (16) considered records up to 2015. The current review adds seven RCTs from then to 2019. A single trial showed a positive impact of sanitation on childhood diarrhea. This could be a chance finding. Improved sanitation services had mixed findings on child growth (height and weight) and parasite infestation.

Participant enrolment based on households with pregnant women in some of the included trials could involve a small proportion of local residents (33). Further, purposively selected countries or states where government interventions were in progress could limit researcher control of the intervention (39). WASH interventions are generally implemented in a participatory manner with communities for sustainability and latrine use concerns (40). Adherence to sanitation behavior helps reduce exposure (34). This should not be assumed as it can distort interpretation of evidence by ignoring access to the sanitation technology-exposure link (41).

High coverage, access to, and functionality of a latrine may not result in its effective use as multi-level factors influence the adoption of a sanitation technology option (42). This could explain the existence of open defecation and unused latrines in CLTS interventions with increased coverage (17,35). Garn et al. (42) revealed a modest impact of sanitation interventions on increasing coverage and use. Higher latrine use was associated with type than low use in poor conditions. However, Massa et al. (43) considered effective latrine use as more important than its state.

Finally, increased coverage remains important as there would be no point of measuring the health effects of a sanitation intervention without a 'reasonable' increase in coverage (44). Post-intervention follow-up time influences the adoption of latrines (45). Long periods introduce administrative treatment challenges such as non-adherence, contamination, and loss to follow-up (46), while short times may introduce the Hawthorne effect. Future work may evaluate optimum follow-up times where expected behavior is observed under given contextual settings.

Risk assessment data showed low risk of bias for most dimensions except for the blinding of participants. Central computer randomization was assumed to sufficiently conceal intervention allocations (low risk) (47). Participants and caregivers are difficult to blind in community-based interventions (48), particularly where visible hardware, such as a latrine, is involved. Further, certification and signage declaring open defecation-free zones in CLTS interventions are visible to all. Self-reported diarrhea could be influenced by this, but intestinal infections and height-for-age were measured precisely to mitigate this concern. Different masked personnel in participant recruitment, data collection, and laboratory analyses strengthens the causal implications of the sanitation intervention on health outcomes (19) and therefore removes performance bias. Participant-reported information potentially suffers from response bias (49). However, the potential effect to outcome assessment could not be ascertained, thus there was an unclear risk of bias. Clinical registration numbers were used as a non-statistical approach to evaluate publication bias (50).

Current health practice appears to rely mainly on evidence from RCTs. Earlier reviews indicated that few studies of mixed designs evaluated the effect of sanitation on diarrhea and child growth (6,8). Improved coverage and reduced open defecation were reported but with limited significant effect to the prevalence of diarrhea and trachoma. Recommendations were the need to achieve total coverage to achieve health gains. However, this may need further enquiry if sustained use is not considered. The provision of sanitation services has to go beyond having access to a facility (hardware) to increase coverage. A latrine has to be accepted and effectively and consistently used, starting at household to the community level in rural areas. Various factors that influence latrine uptake have to be considered, including user preference. Sanitation technologies that include collection, containment, treatment, and disposal of fecal matter at once on site may help reduce multiple human exposure routes through the sanitation service chain. This is because health benefits may be realized by considering the whole sanitation service chain from the interface to disposal, including hygiene. However, other factors influence the selection of such technologies. Hygiene becomes critical in reducing human exposure to fecal pathogens while consistently using latrines. Efforts to end open defecation should also discourage having unimproved latrines at home and unhygienic latrine use.

A consistent lack of significant effect of improved sanitation to the prevalence of diarrhea from RCTs appears contrary to earlier reviews (51) with few such trials. The literature suggests that observational studies were considered to have poor quality evidence as they lack credible control groups, robust research designs, and large samples (17), and they are generally considered subject to bias (52) and cannot demonstrate causality.

Observational studies cannot account for spillovers, a very significant issue in sanitation intervention research. Spillovers are intervention benefits enjoyed by those not directly participating. If spillovers are not accounted for, then the full public health benefits are underestimated.

The systematic review was aimed at assessing the current knowledge on whether there is consistent evidence from RCTs on the effect of sanitation on health outcomes by adding on new trials and identifying methodological limitations that could inform and improve future work. It was done without meta-analysis owing to the few trials available. Limitations to the current review included the use of only three out of the other possible health outcomes (53). Further, the exclusion of records from grey literature and those not reported in the English language, and different combinations of literature search terms used could have left out other studies for inclusion in the review. Exclusion of interventions from grey literature may increase the risk of publication bias and threaten the validity of findings (54). However, bias would most likely favor positive results (bias estimates upwards) whereas much of the findings, especially for the prevalence of diarrhea, show a lack of impact, so bias would not change the qualitative conclusion. The inclusion of multiple publications from the same intervention (with different health outcomes) under the same settings may overestimate the use of RCTs in sanitation interventions. The assessment of bias risk was done using a subjective instrument (Cochrane risk assessment tool), although two independent investigators were involved

2.6 Conclusions

Reviewed trials were done under varying settings such as socio-cultural, environmental, political, sanitation systems, approaches, and follow-up times. However, all RCTs that assessed the impact of sanitation on the prevalence of diarrhea, except one, consistently showed a lack of significant effect despite varying settings and increase in coverage. This may point to the need for combined WASH programming to respond to multiple environmental exposure pathways. However, access to sanitation remains a human right and has other associated benefits. The observed positive impact of sanitation under a CLTS intervention where various technology designs (improved and unimproved) were used may highlight the importance of increased access to a latrine and effective use as opposed to technology design, an area still under scientific enquiry. The provision of targeted subsidy under CLTS approaches may highlight the importance of accessing latrines by the poor.

The review showed that a hybrid CLTS approach with target subsidies was commonly used in the CLTS interventions opposed to the original tenets of the approach. This observation may require further field-based research evidence to inform sanitation practice. Based on the few sanitation-based RCTs available, there is limited and inconclusive evidence of the health benefits of sanitation-specific interventions on child growth and parasitic infestation. It may be difficult to inform sanitation policy and practice on WASH programming for intervention-specific approaches. Rigorous large-scale trials on similar health outcomes are still needed that achieve high sanitation coverage and latrine use. Sanitation behavior change strategies should address low latrine uptake under conditions of high coverage. Future work may consider the extent to which a sanitation intervention facilitates

reduction in the prevalence of parasite infestation and improves child growth in view of the multiple environmental exposure pathways and the optimal time frame when the health outcome is measured.

References

1. Prüss-Ustün A, Bartram J, Clasen T, Colford JM, Cumming O, Curtis V, Bonjour S, Dangour AD, France J.de, Fewtrell L, et al. Burden of diseases from inadequate water, sanitation and hygiene in low- and middle-income settings: A retrospective analysis of data from 145 countries. *Trop Med Int Health.* 2014; 19:894-905.
2. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC. Gordon B, Hunter PR, Medlicott K, Johnston R, et al. Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An updated analysis with a focus on low- and middle-income countries. *Int J Hyg Environ Health.* 2019; 222:765-777.
3. Clasen T, Prüss-Ustün A, Mathers CD, Cumming O, Cairncross S, Colford JM. Jr. Estimating the impact of unsafe water, sanitation and hygiene on the global burden of disease: Evolving and alternative methods. *Trop Med Int Health.* 2014, 19:884-893.
4. World Health Organisation/United Nations Children's Fund. [WHO/UNICEF]. Progress on sanitation and drinking water - 2015 Update and MDG assessment. WHO; 2015. http://files.unicef.org/publications/files/Progress_on_Sanitation_and_Drinking_Water_2015_Update_.pdf. [Accessed 16 January 2020].
5. Fewtrell L, Colford JM. Water, sanitation and hygiene in developing countries: Interventions and diarrhea - A review. *Water Sci Technol.* 2005; 52:133-142.

6. Wolf J, Prüss-Ustün A, Cumming O, Bartram J, Bonjour S, Cairncross S, Clasen T, Colford JM Jr, Curtis V, De France J, et al. Systematic review: Assessing the impact of drinking water and sanitation on diarrhoeal disease in low- and middle-income settings: Systematic review and meta-regression. *Trop Med Int Health*. 2014**;** 19:928-942.
7. Mara D, Lane J, Scott B, Trouba D. Sanitation and Health. *PLoS Med.* 2010; 7:e1000363.
8. Darvesh N, Das JK, Vaivada T, Gaffey MF, Rasanathan K, Bhutta ZA. Water, sanitation and hygiene interventions for acute childhood diarrhea: A systematic review to provide estimates for the lives saved tool. *BMC Public Health.* 2017; 17(4):776.
9. Wolf J, Hunter P, Freeman MC, Cumming O, Clasen T, Bartram J, Higgins J, Johnston R, Medlicott K, Boisson S, et al. Impact of drinking water, sanitation and handwashing with soap on childhood diarrhoeal disease: Updated meta-analysis and meta-regression. *Trop Med Int Health*. 2018; 23:508-525.
10. Ziegelbauer K, Speich B, Mäusezahl D, Bos R, Keiser J, Utzinger J. Effect of Sanitation on Soil-Transmitted Helminth Infection: Systematic Review and Meta-Analysis. *PLoS Med.* 2012; 9:e1001162.
11. Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC. Water, Sanitation, Hygiene, and soil-transmitted helminth infection: A systematic review and meta-Analysis. *PLoS Med.* 2014; 11: e1001620.
12. Speich B, Croll D, Fürst T, Utzinger J, Keiser J. Effect of sanitation and water treatment on intestinal protozoa infection: A systematic review and meta-analysis. *Lancet Infect Dis.* 2016; 16:87-99.
13. Nery SV, Traub RJ, McCarthy JS, Clarke NE, Amaral S, Llewellyn S, Weking E, Richardson A, Campbell SJ, Gray DJ. et al. WASH for WORMS: A Cluster-

Randomized Controlled Trial of the Impact of a Community Integrated Water, Sanitation, and Hygiene and Deworming Intervention on soil-transmitted helminth infections. *Am J Trop Med Hyg.* 2019; 100:750-761.

14. Bauza V, Guest J. The effect of young children's faeces disposal practices on child growth: Evidence from 34 countries. *Trop Med Int Health*. 2017; *22:*1233-1248.
15. Gera T, Shah D, Sachdev HS. Impact of water, sanitation and hygiene interventions on growth, non-diarrheal morbidity and mortality in children residing in low- and middle-income countries: A systematic review. *Indian Pediatr.* 2018; 55:381-393.
16. Freeman MC, Garn JV, Sclar GD, Boisson S, Medlicott K, Alexander KT, Penakalapatia G, Andersona D, Mahtani AG, Grimes JET, et al. The impact of sanitation on infectious disease and nutritional status: A systematic review and meta-analysis. *Int J Hyg Environ Health*. 2017; 220:928-949.
17. Dickinson KL, Patil SR, Pattanayak SK, Poulos C, Yang J-H. Nature's call: Impacts of sanitation choices in Orissa, India. *Econ Dev Cult Chang.* 2015; 64:1-29.
18. Akobeng AK. Understanding systematic reviews and meta-analysis. *Arch Dis Child.* 2005; *90*:845-848.
19. Bhide A, Shah PS, Acharya G. A simplified guide to randomized controlled trials. *Acta Obstet Gynecol Scand.* 2018; *97:*380-387.
20. World Health Organisation [WHO]. WHO Guidelines on Sanitation and Health. Geneva: WHO; 2018.
21. Paterson C, Baarts C, Launsø L, Verhoef MJ, Evaluating complex health interventions: A critical analysis of the 'outcomes' concept. *BMC Complement Altern Med.* 2009; 9:18-18.

22. Beaton DE, Boers M, Tugwell P. Assessment of health outcomes. In: Textbook of Rheumatology, 9th ed.; Firesta GS, Budd RC, O'Dell JR. (Eds). Pennsylvania: Saunders Elsevier; 2017, pp. 496-508.
23. Liberati A, Altman DG, Tetzlaff J, Mulrow CD, Gøtzsche PC, Loannidis JPA, Clarke M, Devereaux P, Kleijnen J, Moher D. The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of studies that evaluate health care interventions: Explanation and elaboration. *PLoS Med.* 2009; 6:e1000100.
24. Moberg J, Kramer M. A brief history of the cluster randomised trial design. *J R Soc Med.* 2015; 108:192-198.
25. Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, Savovićet J, Schulz KF, Weeks L, Sterne JAC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ.* 2011; 343:1-9.
26. Emerson PM, Lindsay SW, Alexander N, Bah M, Dibba S-M, Faal HB, Lowe KO, McAdam KPWJ, Ratcliffe AA, Walraven GEL, et al. Role of flies and provision of latrines in trachoma control: Cluster-randomised controlled trial. *Lancet.* 2004; 363:1093-1098.
27. Gebre T, Ayele B, Zerihun M, House JI, Stoller NE, Zhou Z, Ray KJ, Gaynor BD, Porco TC, Emerson PM, et al. Latrine Promotion for Trachoma: Assessment of mortality from a cluster-randomized trial in Ethiopia. *Am J Trop Med Hyg.* 2011; 85:518-523.
28. Stoller NE, Gebre T, Ayele B, Zerihun M, Assefa Y, Habte D, Zhou Z, Porco TC, Keenan JD, House JI, et al. Efficacy of latrine promotion on emergence of infection with ocular *Chlamydia trachomatis* after mass antibiotic treatment: A cluster-randomized trial. *Int Health*. 2011; 3:75-84.

29. Patil SR, Arnold BF, Salvatore A, Briceño B, Ganguly S, Colford JM. Jr, Gertler PJ, et al. The effect of India's Total Sanitation Campaign on defecation behaviors and child health in rural Madhya Pradesh: A cluster-randomized controlled trial. *PLoS Med*. 2014; 11:e1001709.
30. Pickering AJ, Djebbari H, Lopez C, Coulibaly M, Alzua ML. Effect of a community-led sanitation intervention on child diarrhoea and child growth in rural Mali: A cluster-randomised controlled trial. *Lancet Glob Health*. 2015; 3:e701-e711.
31. Briceño B, Coville A, Gertler P, Martinez S. Are there synergies from combining hygiene and sanitation promotion campaigns: Evidence from a large-scale cluster-randomized trial in rural Tanzania. *PLoS ONE*. 2017; 12:e0186228.
32. Lin A, Ercumen A, Benjamin-Chung J, Arnold BF, Das S, Haque R, Ashraf S, Parvez SM, Unicomb L, Rahman M, et al. Effects of Water, Sanitation, Handwashing, and Nutritional Interventions on Child Enteric Protozoan Infections in Rural Bangladesh: A cluster-randomized controlled trial. *Clin Infect Dis.* 2018; 67:1515-1522.
33. Luby SP, Rahman M, Arnold BF, Unicomb L, Ashraf S, Winch PJ, Stewart CP, Begum F, Hussain F, Benjamin-Chung J, et al. Effects of water quality, sanitation, hand washing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: A cluster randomised controlled trial. *Lancet Glob Health*. 2018; 6:e302-e315.
34. Morris WJ, Tyldesley S, Rodda S, Halperin R, Pai H, McKenzie M, Duncan G, Morton G, Hamm J, Murray N. androgen suppression combined with elective nodal and dose escalated radiation therapy (the ASCENDE-RT Trial): An analysis of survival endpoints for a randomized trial comparing a low-dose-rate brachytherapy boost to a dose escalated external beam boost for high- and intermediate-risk prostate cancer. *Int J Radiat Oncol Biol Phys.* 2017; 98:275-285.

35. Cameron L, Olivia S, Shah M. Scaling up sanitation: Evidence from an RCT in Indonesia. *J Dev Econ*. 2019; 138:1-16.
36. Ercumen A, Benjamin-Chung J, Arnold BF, Lin A, Hubbard AE, Stewart C, Rahman Z, Parvez SM, Unicomb L, Rahman M, et al. Effects of water, sanitation, handwashing and nutritional interventions on soil-transmitted helminth infections in young children: A cluster-randomized controlled trial in rural Bangladesh. *PLoS Negl Trop Dis*. 2019; 13:e0007323.
37. Pickering AJ, Njenga SM, Steinbaum L, Swarthout J, Lin A, Arnold BF, Stewart CP, Dentz HN, Mureithi M, Chieng B, et al. Effects of single and integrated water, sanitation, handwashing, and nutrition interventions on child soil-transmitted helminth and Giardia infections: A cluster-randomized controlled trial in rural Kenya. *PLoS Med*. 2019; 16:e1002841.
38. Steinbaum L, Mboya J; Mahoney R, Njenga SM, Null C, Pickering AJ. Effect of a sanitation intervention on soil-transmitted helminth prevalence and concentration in household soil: A cluster-randomized controlled trial and risk factor analysis. *PLoS Negl Trop Dis*. 2019; 13:e0007180.
39. Lobban F, Postlethwaite A, Glentworth D, Pinfold V, Wainwright L, Dunn G, Clancy A, Haddock G. A systematic review of randomised controlled trials of interventions reporting outcomes for relatives of people with psychosis. *Clin Psychol Rev*. 2013; 33:372-382.
40. Safari J, Mohamed H, Dimoso P, Akyoo W, Odhiambo F, Mpete R, Massa K, Mwakitalima A. Lessons learned from the national sanitation campaign in Njombe district, Tanzania. *J Water Sanit Hyg Dev.* 2019; 9:754-764.
41. Brown J, Hayashi MAL, Eisenberg JNS, Brown J. The Critical Role of Compliance in Delivering Health Gains from Environmental Health Interventions. *Am J Trop Med Hyg*. 2019; 100:777-779.

42. Garn JV, Sclar GD, Freeman MC, Penakalapati G, Alexander KT, Brooks P, Rehfuess EA, Boisson S, Medlicott KO, Clasen TF. The impact of sanitation interventions on latrine coverage and latrine use: A systematic review and meta-analysis. *Int J Hyg Environ Health*. 2017; 220:329-340.
43. Massa K, Kilamile F, Safari E, Seleman A, Mwakitalima A, Balengayabo JG, Kassile T, Mangesho PE, Mubyazi GM. Contributing to the debate on categorising shared sanitation facilities as 'unimproved': An account based on field researchers' observations and householders' opinions in three regions, Tanzania. *PLoS ONE*. 2017; 12:e0185875.
44. Schmidt W-P. Seven trials, seven question marks. *Lancet Glob Health*. 2015; 3:e659-e660.
45. Martin NA, Hulland KRS, Dreibelbis R, Sultana F, Winch P. Sustained adoption of water, sanitation and hygiene interventions: Systematic review. *Trop Med Int Health.* 2017; 23:122-135.
46. Herbert RD, Kasza J, Bø K. Analysis of randomised trials with long-term follow-up. *BMC Med Res Methodol.* 2018; 18:1-9.
47. Nunan D, Heneghan C, Spencer EA. Catalogue of bias: Allocation bias. *BMJ Evidence-Based Med*. 2018; 23:20-21.
48. Rabiu M, Alhassan MB, Ejere HO, Evans JR. Environmental sanitary interventions for preventing active trachoma. *Cochrane Database Syst Rev*. 2012; 2:CD004003.
49. Contzen N, De Pasquale S, Mosler H-J. Over-Reporting in handwashing self-reports: Potential explanatory factors and alternative measurements. *PLoS ONE.* 2015; 10:e0136445.
50. Lin L, Chu H, Murad MH, Hong C, Qu Z, Cole SR, Chen Y. Empirical comparison of publication bias tests in meta-analysis. *J Gen Intern Med*. 2018; 33:1260-1267.

51. Jung YT, Hum RJ, Lou W, Cheng Y-L. Effects of neighbourhood and household sanitation conditions on diarrhea morbidity: Systematic review and meta-analysis. *PLoS ONE*. 2017; 12:e0173808.
52. Bero L, Chartres N, Diong J, Fabbri A, Ghersi D, Lam J, Lau A, McDonald S, Mintzes B, Sutton P, et al. The risk of bias in observational studies of exposures (ROBINS-E) tool: Concerns arising from application to observational studies of exposures. *Syst Rev*. 2018: 7:1-11.
53. Gu G, Zhou Y, Zhang Y, Cui W. Increased prevalence of anxiety and depression symptoms in patients with coronary artery disease before and after percutaneous coronary intervention treatment. *BMC Psychiatry*. 2016; 16:259.
54. Hopewell S, McDonald S, Clarke MJ, Egger M. Grey literature in meta-analyses of randomized trials of health care interventions. *Cochrane Database Syst Rev.* 2007; 2: MR000010.

Supporting material 2S.1 Assessment of risk of bias for 15 RCTs used to determine the impact of sanitation on health outcomes (Adapted from The Cochrane Collaboration's tool for assessing risk of bias)

Reference	Domain	Reviewers' judgement	Support for judgement
Emerson et al. (26)	Random sequence generation	Low risk	Clusters recruited in sets of 3, randomly assigned to treatments/control by drawing from a hat
	Allocation concealment	Low risk	Clusters at community level, their recruitment unlikely to influence participant recruitment
	Blinding of participants & personnel	High risk	One latrine was allocated per household. Difficult to blind when latrine hardware was provided
	Blinding of outcome assessment	Low risk	All participants screened, both eyes inspected, single photograph taken and blinded clinicians
	Incomplete outcome data	Low risk	All clusters participated and were visited 3 times, participants lost to follow-up did not differ
	Selective reporting	Low risk	Active trachoma, primary outcome was reported
	Other biases	Low risk	No clusters were lost at follow up, proportions with active trachoma statistically not different
Gebre et al. (27)	Random sequence generation	Low risk	Randomization sequence was computer-generated in MS Excel
	Allocation concealment	Low risk	Concealment mentioned without details but we judged central randomisation to sufficiently conceal intervention allocations
	Blinding of participants & personnel	High risk	Subkebeles were not masked to the intervention
	Blinding of outcome assessment	Unclear risk	Separate authors did randomisation and participant enrolment. It is not clear who did the statistical analysis and mortality rate calculations (We), and its effect to outcome assessment
	Incomplete outcome data	Low risk	Census updated for deaths and migration, used in calculations. Repeat census to 24 sublevels
	Selective reporting	Low risk	Primary outcome 'age-specific all-cause mortality' pre-specified in the registered protocol reported
	Other biases	Low risk	Masked census auxiliary health workers to treatments and outcome. All sublevels were visited.
	Random sequence generation	Low risk	Randomization sequence was computer-generated in MS Excel for clinical comparisons
	Allocation concealment	Low risk	No detail, but we judged central randomisation to sufficiently conceal intervention allocations

Stoller et al. (28)	Blinding of participants & personnel	High risk	Intensification of an existing latrine programme, prior knowledge of treatment known
	Blinding of outcome assessment	Low risk	Swab samples from randomly selected participants at baseline and follow-up were pooled to detect ocular *C. trachomatis* by blinded laboratory personnel
	Incomplete outcome data	Low risk	Follow-up inclusions and exclusions described. Randomly sampled participants used in data collection. Intention-to treat analysis was done.
	Selective reporting	Low risk	Prevalence of *C. trachomatis* infection in children 0-9 years was reported as primary outcome
	Other biases	High risk	The two treatment groups were well balanced except for antibiotic coverage (cluster imbalance). on-going latrine construction programme (intervention contamination)
Clasen et al. (3)	Random sequence generation	Low risk	Cluster randomisation by computer-generated sequence
	Allocation concealment	Low risk	We judged central randomisation to sufficiently conceal intervention allocations
	Blinding of participants & personnel	High risk	Reported blinding of participants was not possible
	Blinding of outcome assessment	Low risk	Random assignment was by not being involved in data collection or intervention delivery
	Incomplete outcome data	Low risk	Village level clustering was statistically accounted for, adjustments at follow-up due to accounted-for attrition was given (baseline diarrhoea). Intention-to treat analysis was done.
	Selective reporting	Low risk	Primary outcome, 7-day diarrhoea prevalence was compared across treatments and control
	Other biases	Unclear risk	Care-giver self-reported data is prone to reporting bias. Its effect on the outcome is not clear
Patil et al. (29)	Random sequence generation	Low risk	Randomization took place by publicly picking lottery ticket to assign villages to treatments
	Allocation concealment	Low risk	We judged central randomisation to sufficiently conceal intervention allocations
	Blinding of participants & personnel	High risk	Programme implementers and researchers not blinded. Blinded interviewers could identify intervention villages during interviews of block officers or the village secretary.
	Blinding of outcome assessment	Unclear risk	Blinded interviewers could identify intervention villages during interviews. The effect to their data collection is not clear
	Incomplete outcome data	Low risk	No differential attrition by group, no missing data. Intention-to treat analysis was done.
	Selective reporting	Low risk	Study protocol's predefined outcomes were reported
	Other biases	Unclear risk	Care-giver self-reported data is prone to reporting bias. Its effect on the outcome is not clear
	Random sequence generation	Low risk	Randomization took place by publicly picking slips from a bucket to assign villages to treatments

Dickinson et al. (17)	Allocation concealment	Low risk	No detail but we judged central randomisation to sufficiently conceal intervention allocations
	Blinding of participants & personnel	High risk	Researchers/implementers were not blinded
	Blinding of outcome assessment	Unclear risk	Same authors did randomisation, participant enrolment and statistical analysis (We). Same enumerators collected data in base- and end line surveys. The effect to outcome assessment is not clear
	Incomplete outcome data	Low risk	Random subsamples within villages were used for data collection. Loss at follow-up was reported
	Selective reporting	Low risk	Pre-specified outcomes in the protocol were reported relative to the control.
	Other biases	Unclear risk	Care-giver self-reported diarrhoea data is prone to reporting bias. Its effect on the outcome is not clear
Pickering et al. (30)	Random sequence generation	Low risk	Computer-generated algorithm that randomly assigned villages to treatment and control groups
	Allocation concealment	Low risk	We judged central randomisation to sufficiently conceal intervention allocations
	Blinding of participants & personnel	High risk	Participants were not masked to treatment status
	Blinding of outcome assessment	Unclear risk	Although interviewees were blinded, they could infer status during interviews from presence of signage showing village certification of an open defecation-free status, with unknown effect
	Incomplete outcome data	Low risk	Attrition and re-inclusion at follow-up reported with numbers to balance groups.
	Selective reporting	Low risk	Registered study protocol with pre-specified outcomes were reported
	Other biases	Unclear risk	Care-giver self-reported data is prone to reporting bias. Its effect on the outcome is not clear
Briceño et al. (31)	Random sequence generation	Unclear risk	Factorial cluster-randomized control trial, 190 largest wards randomly sampled. Insufficient information about the sequence generation process to permit judgement of low or high risk.
	Allocation concealment	Low risk	Treatment groups knew their assignment, but not controls, unbeknown even to survey teams. but knowing treatment (without controls) concealed knowledge of treatment comparisons
	Blinding of participants & personnel	High risk	Participants were not blinded
	Blinding of outcome assessment	Low risk	Survey firms were never provided information on treatment status of participating wards
	Incomplete outcome data	Low risk	No significant effect. Random subsamples within wards were used for data collection.
	Selective reporting	Low risk	Outcomes pre-defined in the protocol were reported
	Other biases	Unclear risk	Care-giver self-reported data is prone to reporting bias. Its effect on the outcome is not clear

Lin et al. 2018 (32)	Random sequence generation	Low risk	Random number generator used to randomise matched clusters to the double-sized control arm
	Allocation concealment	Low risk	We judged central randomisation to sufficiently conceal intervention allocations
	Blinding of participants & personnel	High risk	Study participants, intervention implementers, and outcome assessors were not masked because the interventions delivered visible hardware
	Blinding of outcome assessment	Low risk	Masked lab technician conducted analyses to detect protozoa infections. Two investigators conducted independent masked data processing and statistical analyses
	Incomplete outcome data	Low risk	Statistical analyses performed for loss and recovery to follow-up. Intention-to treat analysis was done.
	Selective reporting	Low risk	Registered trial protocol available. Pre-specified outcome (tertiary) of interest reported
	Other biases	Low risk	We judged the study to appear free of other sources of bias
Luby et al. (33)	Random sequence generation	Low risk	Clusters randomly allocated to treatment using a random number generator by a co-investigator
	Allocation concealment	Low risk	We judged central randomisation to sufficiently conceal intervention allocations
	Blinding of participants & personnel	High risk	Interventions included distinct visible components so neither participants nor data collectors were masked to intervention assignment
	Blinding of outcome assessment	Low risk	Independent, masked statistical analyses with the true group assignment variable replaced with a re randomised uninformative assignment variable.
	Incomplete outcome data	Low risk	Loss to attrition with reasons and enrolment at follow-up were given. Intention-to treat analysis was done.
	Selective reporting	Low risk	Registered trial protocol available. Pre-specified outcome of interest reported
	Other biases	Unclear risk	Care-giver self-reported data is prone to reporting bias. Its effect on the outcome is not clear
Null et al. (34)	Random sequence generation	Low risk	Clusters were randomly allocated to treatment using a random number generator
	Allocation concealment	Low risk	We judged central randomisation to sufficiently conceal intervention allocations
	Blinding of participants & personnel	High risk	Cluster allocation was communicated directly to the field team, Participants were not blinded
	Blinding of outcome assessment	Low risk	Investigators remained blinded to treatment assignments. 2 blinded biostatisticians independently replicated the analyses following the pre-specified analysis plan
	Incomplete outcome data	Low risk	Monitoring data collected during unannounced visits to a random sample of at least 20% of participants in intervention groups at given time periods after the interventions began. Loss to attrition with reasons at follow-up was given. Intention-to treat analysis was done.
	Selective reporting	Low risk	Registered trial protocol available. Pre-specified outcome of interest reported

	Other biases	Unclear risk	Care-giver self-reported data is prone to reporting bias. Its effect on the outcome is not clear
Cameron et al. (35)	Random sequence generation	Unclear risk	Randomisation stratified at village and sub-village levels with comparison control groups described. Insufficient information about the sequence generation process to permit judgement of low or high risk
	Allocation concealment	Low risk	We judged central randomisation to sufficiently conceal intervention allocations No detail was provided but we judged that interventions included distinct visible components (latrines).
	Blinding of participants & personnel	High risk	Signage and certification of open defecation free zones, sanitation demand triggering sessions so neither participants nor data collectors were masked to intervention assignment.
	Blinding of outcome assessment	Unclear risk	Insufficient information to permit reviewers' judgment of low or high risk
	Incomplete outcome data	Low risk	No imbalances in village characteristics. First and second rounds of visits were done with no details to attrition. We judged no incomplete outcome data due to stratified sampling for analysis
	Selective reporting	Low risk	Although we did not have the trial registration of the protocol, we judged low risk of bias as all outcomes reported
	Other biases	Low risk	We judged the study to appear free of other sources of bias
Ercumen et al. (36)	Random sequence generation	Low risk	Off-site investigator used a random number generator to block-randomize clusters into study arms
	Allocation concealment	Low risk	We judged central randomisation to sufficiently conceal intervention allocations
	Blinding of participants & personnel	High risk	Participants and field staff were not blinded as interventions entailed distinct hardware
	Blinding of outcome assessment	Low risk	Blinded technicians enumerated STH outcomes, blinded analysts independently replicated data management and analysis
	Incomplete outcome data	Low risk	Loss to attrition with reasons, enrolment at follow-up were given and balanced in numbers across intervention groups. Intention-to treat analysis was done.
	Selective reporting	Low risk	Registered trial protocol available. Pre-specified primary outcome of interest reported
	Other biases	Low risk	We judged the study to appear free of other sources of bias
Pickering et al. (37)	Random sequence generation	Low risk	Independent investigator used a random number generator to randomly assign clusters
	Allocation concealment	Low risk	We judged central randomisation to sufficiently conceal intervention allocations

	Blinding of participants & personnel	High risk	Blinding of participants was not possible given the nature of the interventions
	Blinding of outcome assessment	Low risk	Blinded lab technicians analysed samples. 2 authors independently replicated the statistical analyses while blinded to intervention status.
	Incomplete outcome data	Low risk	Loss to attrition with reasons, enrolment at follow-up were given and balanced in numbers across intervention groups. No incomplete data
	Selective reporting	Low risk	Registered trial protocol available. Pre-specified outcome (tertiary) of interest reported
	Other biases	Low risk	We judged the study to appear free of other sources of bias
Steinbaum et al. (38)	Random sequence generation	Unclear risk	Authors referred to “We” in the methodology without indicating independent investigator to randomly assign clusters
	Allocation concealment	Low risk	We judged central randomisation to sufficiently conceal intervention allocations
	Blinding of participants & personnel	High risk	Blinding of participants was not possible as material subsidy was given for latrines. Blinding of the two laboratory technicians who did all sample analyses not clearly spelt status.
	Blinding of outcome assessment	Low risk	The technicians and microscopy expert were blinded to the treatment assignments
	Incomplete outcome data	Low risk	Loss to attrition with reasons reported. No incomplete data
	Selective reporting	Unclear risk	Registered trial protocol available, but a not pre-specified outcome of interest reported. Effect unclear
	Other biases	Unclear risk	Use of not optimised method for other laboratory analyses may introduce ‘other’ unclear bias

CHAPTER 3: FRAMEWORKS FOR SELECTING APPROPRIATE RURAL SANITATION TECHNOLOGY OPTIONS IN LOW- AND MIDDLE-INCOME COUNTRIES: A CRITICAL REVIEW

This chapter is a published journal article:

Kanda A, Ncube EJ, Voyi K. Frameworks for selecting appropriate rural sanitation technology options in low- and middle-income countries: a critical review, Int J Environ Health Res. 2021; Doi: 10.1080/09603123.2021.1963685

3.1 Abstract

Technology selection frameworks should be flexible to local contexts. The review identified available frameworks used to select appropriate rural sanitation technologies in low- and middle-income countries, determined their strengths and limitations, and suggested implications to research and public health practice. Records (2010 - 2019) were searched in eight electronic databases and grey literature between December 2019 and March 2020. They were screened and analysed using predesigned framework assessment criteria. 953 records were identified, 12 were included for review. Eight of the 22 framework assessment criteria (36%) were poorly addressed by individual included frameworks (scored 8 - 50%). These were equity, sanitation demand, sanitation behaviour change, ongoing contact, replicability, framework limitations, personnel selection and flexibility. No single framework addressed all assessment criteria. However, there is need to either upgrade existing frameworks or develop a new one to meet local contextual settings.

Keywords: low- and middle-income countries; rural sanitation, technology selection framework.

3.2 Introduction

The current global thinking of sustainable development goal (SDG) targets to be met by 2030, encourages governments of low- and middle-income countries (LMICs) to review existing or develop new national rural sanitation policies. WHO (1) urges national governments to prioritise sanitation and explore alternative technology designs as research agenda. There is no one-size fits all sanitation technology solution (2,3). A single sanitation technology may cause lack of ownership and suspicion among intended users which influences use (4).

Evidence-based frameworks have been developed to inform health policy and practice (5,6). The selection of appropriate sanitation technologies (ASTs) was identified as an important element of the planning process for water, sanitation and hygiene (WASH) interventions (7,8). This is because appropriate technologies can improve access to services by beneficiaries (9). The purpose of the selection process is to inform decision makers, project implementers and user communities. The high failure rate of WASH projects in developing communities were attributed to approaches for selecting WASH technologies (2,8), and lack of national sanitation policies in general (10).

A review of the global sanitation development by Zhou et al. (11) showed increased research focus shown by publications on sanitation mainly in high-income countries (e. g. United States of America) on technical issues with limited social considerations. Further, Seymour et al. (12) reviewed user preferences of sanitation systems and showed that only 30% of the studies were in rural areas. This makes rural communities of LMICs a priority task area for the provision sanitation services. Inappropriate technology options have demonstrated poor adoption in sanitation interventions in some African countries (13-15). A critique of existing frameworks for the selection of ASTs was therefore done to try and answer the review questions:

- Which are the available frameworks used to select ASTs in rural communities of LMICs?
- What are the strengths and limitations of frameworks included for review?
- What are the implications of the critical review to research and public health practice?

3.3 Material and Methods

3.3.1 Literature search and inclusion criteria

Literature search was conducted between December 2019 and March 2020 in seven electronic databases (BMC Public Health, JSTOR, ProQuest, PubMed, Science Direct, Scopus and Google search) for records, peer-reviewed and grey literature written from January 2000 (start of millennium development goals) to December 2019. It was based on combinations of key terms: framework, selection, sanitation technology, rural (community), low- and middle-income country. Further, websites of some institutions and reference lists of identified records were consulted.

Full text English articles available online with frameworks for the selection of ASTs for rural communities of LMICs were included. Technology selection frameworks designed strictly for urban and peri-urban sanitation, used under high-income settings or used for the evaluation of frameworks only without focus on decision-making were excluded. Records with new (recent, not evaluated in literature) and unproven sanitation technology options were also excluded. Identified records were screened by title, abstract and full-text. They were analysed using a predesigned modified criteria for assessment of frameworks (Table 3.1).

3.3.2 Framework analysis

A scoring system was used where a framework was assigned a score of zero if it did not meet the assessment criterion, one if the criterion was met or a half if the criterion was partially met in some instances and not in others (Table 3.2). A summary of how each included framework responded to the criteria was prepared. The criteria for inclusion and data extraction were done by two independent investigators, and a third assisted in reaching consensus for any discrepancies identified.

Table 3. 1 Criteria used for analysing frameworks

Criterion	Framework assessment method
Community demand for sanitation	Considers community demand for sanitation services
Personnel selection	Guides the selection of agency and local personnel to be involved in planning
Technology choice	Provides guidance on technological options or decision process
Legislation & regulation	Involvement of government departments and sanitation professionals
Sustainability criteria	Considers: social, environmental, technological, economic aspects of the technology selection process
Decision making	Informs policy
Flexibility	Capable of incorporating user remarks, local knowledge and new information sensitive to the local context
Ongoing contact	Encourages ongoing contact between beneficiaries and project implementers
Operation and maintenance	Long-term costs/sustenance associated with technical options
Constraints in Technology choice	Suggests constraints/limitations on the technology option
Data collection	Initial intensive data collection on the local context, with stated methodologies
Communication	Uses appropriate forms of communication suitable to the local context
Replicability	Considers potential replicability/ scalability/ adoption of technology
Community engagement	Considers level of community participation in the planning process
Validation	Provides methodological guidance on validation type and process
Transparency	Tractability of results generated by the system/documentation of the different tasks carried out by the tool
Interactivity	Ease with which end-user can interact with the tool.
Equity	Sanitation needs of vulnerable groups (< 5, > 70, handicapped) and gender
Compatibility	Compatibility of the framework with others
Behaviour change	Links sanitation and hygiene for behaviour change
Framework limitations	Highlights major methodological limitations of the framework
User friendly interface	Provides appropriate user interface to input information and retrieve responses with appropriate technology to meet needs

Modified (2,7,16)

Table 3. 2 Scoring system used in the analysis of frameworks

Criterion	Framework assessment method	
	Score	Definition
Community demand for sanitation	1	Responds to community demand,/describes a stimulation process
	0.5	Demand stimulation advised without methodological guidance
	0	No mention of project initiation or demand–stimulation processes
Personnel selection	1	Advice given on selection of participants or agency representatives
	0.5	Examples of possible participants given without advice on selection
	0	No mention of the significance of personnel selection
Technology choice	1	Full description of decision process and necessary considerations
	0.5	Limited support given to decision making
	0	No guidance on technological options or decision process
Legislation and regulation	1	Government involvement encouraged from the beginning of project
	0.5	Government listed among possible participants
	0	No mention of government involvement
Sustainability criteria	1	Decision considerations grouped according to impact criteria
	0.5	Decision considerations contained several criteria
	0	Impacts of options not discussed/considered across more than one criterion
Decision-making	1	Provides guidance on decision-making and informs policy
	0.5	Provides guidance on decision-making but does not inform policy
	0	No guidance on decision making
Flexibility	1	Tailored to incorporate local contexts, user remarks and new information
	0.5	Tailored to most situations, but does not meet all the three
	0	Difficult to apply to a range of contexts
Ongoing contact	1	Gives detail of where and who to seek advice from on the framework later on
	0	Does not mention where to get support services from
Operation and maintenance	1	Ongoing costs/sustenance for each technical decision
	0.5	Consideration of ongoing costs implied by other instructions
	0	Consideration of ongoing costs required qualitatively or not at all
Constraints in Technology choice	1	Constraints explicitly advised for use in technology choice
	0.5	Constraints implied in a list of decision considerations implicitly
	0	No constraints advised for use in technology choice
Data collection	1	Initial intensive data collection on the local context, with stated methodologies
	0.5	Initial data collection mentioned without methodological detail
	0	Initial data collection not mentioned
Communication	1	Employs creative, culturally appropriate communication methods
	0.5	Creative communication techniques mentioned, no methodological advice
	0	No mention of culturally appropriate communication
Replicability	1	Efforts to induce replication of project in other communities
	0.5	Theoretical agreement with importance of scaling-up interventions
	0	No mention of scaling–up intervention
Community engagement	1	High level of detail regarding community involvement processes
	0.5	Little/moderate level of detail regarding community involvement processes
	0	No methodological detail of community involvement processes
Validation	1	Provides methodological guidance on validation type and process
	0.5	Validation process mentioned without process details

	0	No validation process mentioned
Transparency	1	Results generated are easily handled/manageable
	0.5	Some degree of difficulty in handling results is highlighted
	0	No mention/evidence of transparency is indicated
Interactability	1	Allows interaction with end user. Available tools to support the user
	0	Does not allow interaction with the end user
Equity	1	Considers sanitation needs of vulnerable groups and gender
	0.5	Mentions the sanitation needs of vulnerable groups and gender
	0	Does not consider sanitation needs of vulnerable groups and gender
Compatibility	1	Compatibility of the framework with others with details of application
	0.5	Just mentions compatibility with other frameworks without detail
	0	Does not refer/involve other frameworks
Sanitation behaviour change	1	Provides guidance on how hygiene is linked to sanitation for behaviour change
	0.5	Just mentions the sanitation-hygiene link
	0	Does not mention the sanitation-hygiene link
Framework limitations	1	Describes limitations and their effects to decision making/selection process
	0.5	Mentions limitations of the framework without indicating their effects
	0	Limitations of the framework not mentioned
User-friendly interface	1	Provides an ease-to-use interface to input and retrieve responses e. g software
	0.5	Interface- some degree of difficulty to follow, not straightforward e. g factsheets
	0	Framework has no user-friendly interface

A framework which does not address the factor (zero), partially addresses it (half) and addresses it (full point)

Assumptions:
1. Mention of community assessment or requirement (with procedural reference) included appropriate forms of communication, but not community demand for sanitation
2. Provision of a reference (person, office, website, phone number) was considered an indicator for encouraging ongoing contact, including consultation
3. Mention of institutional arrangements included government, laws and regulations
4. Selecting a technology involved an assessment of its operation and maintenance, and constraints
5. Mere data collection excludes community engagement

In this work appropriate (sanitation) technology refers to a technique which produces a socially and environmentally acceptable level of service at the least cost (17). According to Murphy (18) it incorporates basic needs of users, technical requirements, contextual settings, local participation and gender considerations, affordability, and environmental and social acceptability. Sanitation referred to access to and use of facilities and services for the careful management of human excreta (1).

3.3 RESULTS

3.3.1 Records included for the critical review

A total of 953 records were initially identified from the literature search, 12 were included for the critical review (Fig. 3.1). Full text screening of 123 records excluded some articles either because they: had no sanitation selection frameworks, had frameworks not meant for sanitation technology selection, were meant for urban sanitation or had sanitation selection frameworks not meant for LMICs.

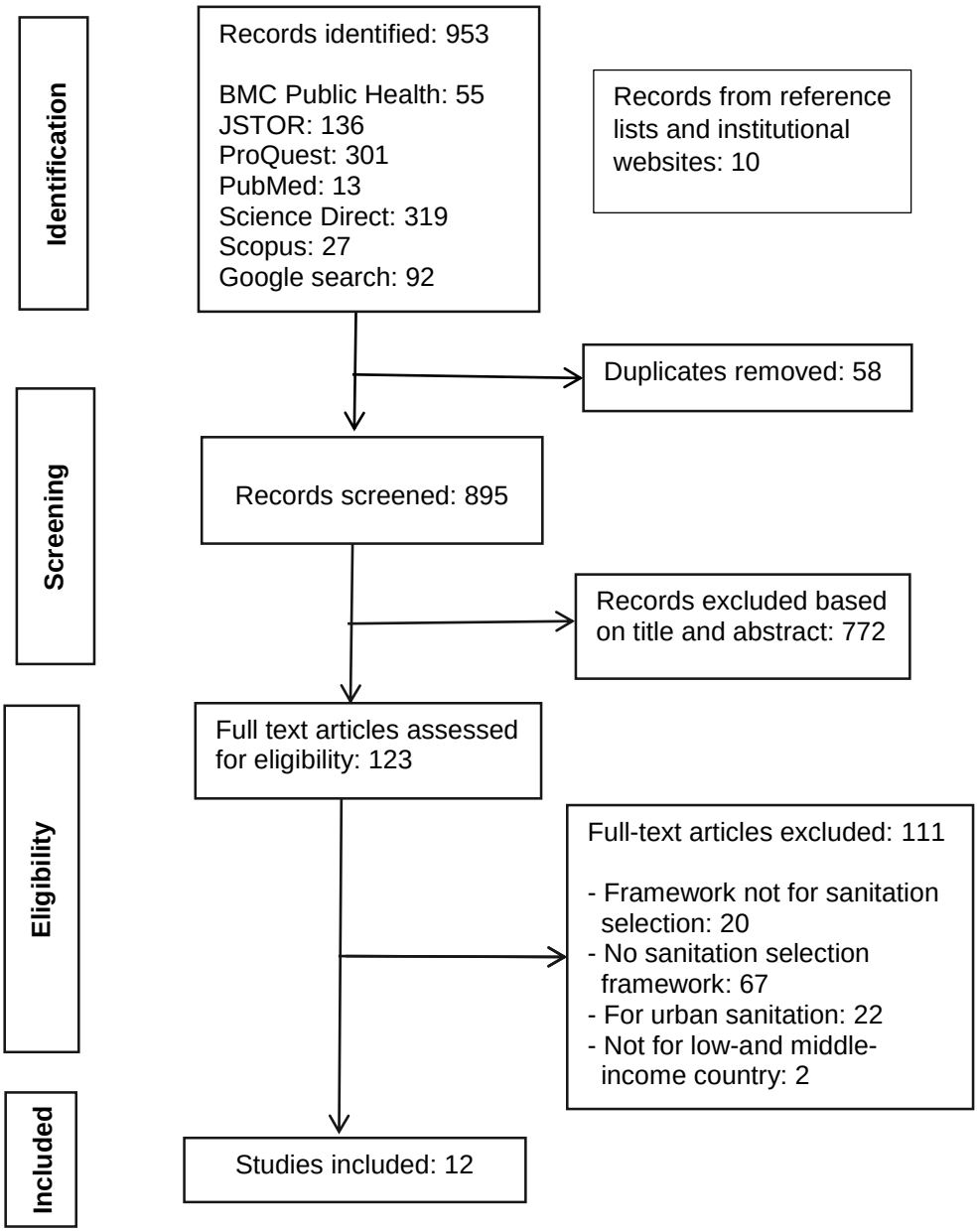


Fig. 3.1 Flow chart of literature search

A summary of included frameworks was presented in the Supplementary file. Published peer-reviewed journal articles constituted 58%, conference papers 25% and institutional reports 17% to the included records. About 83% (10 out of 12) of the records were reported from 2000 to 2015. Initial records identified from the literature search showed that there are various planning frameworks used in WASH interventions by implementing organisations and their partners (e. g. Water Aid, World Vision and DFID) and donor agencies (e. g. The World Bank, Asian Development6 Bank, USAID).

3.3.2 Framework analysis using the scoring method

Table 3.3 shows how included frameworks scored in the assessment criteria. Results show that seven of the assessment criteria (31.8%) were fully addressed by all the 12 included frameworks, showing their strengths. These were technology choice, legislation and regulation, sustainability criteria, decision making, operation and maintenance, constraints in technology choice and data collection. However, some of the included frameworks scored between 62 and 80% in five of the assessment criteria (22.7%). The criteria were validation (83%), communication (79%), interactability and user-friendly (67% apiece), and transparency (63%). Finally, some frameworks scored between 7 - 59%) in the remaining ten of the assessment criteria (45.5%). The least considered assessment criteria among frameworks (contributing 8 - 46%) were: equity, sanitation demand, behaviour change, ongoing contact, replicability and framework limitations. These criteria may form basis for future developments of similar frameworks.

Table 3.3 Scoring procedure applied on included frameworks and results

Criterion	Sanitation selection framework reference												% Score
	1	2	3	4	5	6	7	8	9	10	11	12	
Community demand for sanitation	1	0	1	0	0	0	0	0	0	0	0	0	17
Personnel selection	1	0	1	0	0	0	1	1	1	0	0	1	50
Technology choice	1	1	1	1	1	1	1	1	1	1	1	1	100
Support, legislation and regulation	1	1	1	1	1	1	1	1	1	1	1	1	100
Sustainability criteria	1	1	1	1	1	1	1	1	1	1	1	1	100
Decision making	1	1	1	1	1	1	1	1	1	1	1	1	100
Flexibility	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	1	50
Ongoing contact	1	1	0	0	0	0	0	1	0	0	0	1	33
Operation and maintenance	1	1	1	1	1	1	1	1	1	1	1	1	100
Constraints in technology choice	1	1	1	1	1	1	1	1	1	1	1	1	100
Data collection	1	1	1	1	1	1	1	1	1	1	1	1	100
Communication	1	1	1	1	1	0	1	1	1	0.5	0	1	79
Replicability	0	1	0.5	0	0.5	0	0.5	0.5	0.5	0	0	1	38
Community engagement	1	1	1	0.5	0	0	0.5	1	0.5	0	0	1	54
Validation	1	1	1	1	1	0	1	1	1	0	1	1	83
Transparency	0.5	0.5	0.5	1	0.5	1	0.5	0.5	1	1	0	0.5	63
Interactability	0	1	1	0	1	0.5	0.5	1	0.5	1	0.5	1	67
Equity	0	0	0	0	0	0	0	0	1	0	0	0	8
Compatibility	0	1	1	1	0	0	1	1	1	0	0	1	58
Behaviour change	1	1	0	0	0	1	0	0	0	0.5	0	0	29
Framework limitations	0	1	1	0	0	0	1	0	1	0.5	1	0	46
User interface	0.5	0.5	1	0.5	1	0.5	0.5	1	0.5	0.5	0.5	1	67
Possible score	22	22	22	22	22	22	22	22	22	22	22	22	
% actual score	73	80	80	57	57	48	68	75	75	52	45	80	

1. Tayler et al. (19)
2. Howard et al. (20)
3. Loetscher and Kelly (21)
4. Louis and Ahmad (22)
5. Halim et al. (23)
6. Mara et al. (24)
7. Henriques and Louis (25)
8. Kimera et al. (26)
9. Bouabid and Louis (8)
10. Ramóa et al. (27)
11. Salisbury et al. (28)
12. Filho et al. (29)

Ten of the included frameworks (83.3%) scored between 51 and 81% in the 22 assessment criteria. Only two frameworks scored below 50% (24, 29).The assessment criteria were grouped into four categories, with some overlaps: community (eight), technology (seven), institutional arrangements (three) and framework-based criteria (five). Personnel selection was common for community-based and institutional arrangements-based categories (Table 3.4).

Table 3.4 Categories of criteria used for framework assessment

Community-based	Framework-based	Technology-based	Institutional arrangements
Community engagement	Flexibility	Sustainability criteria	Decision making
Data collection	Transparency	Technology choice	Legislation and regulation
Sanitation behaviour change	Framework limitations	Operation and maintenance	* Personnel selection
On-going contact	User-friendly interface	Technology constraints	
Communication	Compatibility	Scalability	
Equity	Validation	Replicability	
Sanitation demand	Interactability		
* Personnel selection			

* common for community-based and institutional arrangements-based criteria

3.3.2.1 Community-based criteria

All frameworks reported initial intensive data collection on the local context with stated methodologies, nine of them used appropriate forms of communication suitable to the local context (Table 3.3). Community-based criteria met by few frameworks were equity issues (8), community demand for sanitation (19,21), sanitation behaviour change (19,20,24) and ongoing contact (19,20,26,29). On the other hand, about 50% of the frameworks did not consider the level of community participation in the planning process and election of agency, and local personnel to be involved in planning.

3.3.2.2 Framework-based criteria

No single framework fully addressed the framework-based assessment criteria. Only one (27) was capable of incorporating user remarks, local knowledge and new information sensitive to the local context (flexibility criterion) with 10 of the frameworks (83.3%) partially meeting it.

Partial address of the framework-based assessment criteria was also observed mainly for the transparency (7 frameworks) and user-friendly interface (8 frameworks) and interactability (4 frameworks) criteria. Two frameworks (24,27) did not provide methodological guidance on the type and process of validation (validation criterion). Five frameworks highlighted major methodological limitations of the technology selection framework (8,20,21,25,28). However, five of them did not indicate whether the frameworks were compatible with others (19, 23,24,27,28).

3.3.2.3 Technology-based criteria

Table 3 shows that all frameworks fully met four of the five technology-based framework assessment criteria, except for replicability. Only two frameworks (20,29) considered the potential replicability or scalability of the appropriate technology selected. Five of the frameworks had partial scores.

3.3.2.4 Institutional arrangements-based criteria

The two criteria; decision making and legislation/regulation were met by all included frameworks. They were meant to inform policy and consider the involvement of relevant government departments and sanitation professionals. However, 50% of the frameworks (20, 22-24,27,28) did not provide guides for the selection of agency and local personnel to be involved in planning (personnel selection criterion).

3.4 Discussion

Frameworks which addressed the community and technology-based assessment criteria agree well with research trends in the sanitation sub-sector where approaches such as participatory planning, sustainability criteria and community assessment are used in development projects (30,31). The limitations of each framework (Supporting material 3S.1) may be used as source for future framework development or modification.

All frameworks did not explicitly address equity issues in sanitation planning. This remains a critical challenge since few rural sanitation interventions reach vulnerable groups of society (32). To achieve universal access to basic sanitation and end open defaecation, the needs of vulnerable populations should also be addressed. Lack of access to ASTs potentially exposes people to multiple exposure routes and health risks (33,34). Therefore, future work may consider demonstrating how rural sanitation interventions should be done to address equity and universality (35). In some demand-responsive sanitation interventions, targeted financial or material subsidies were provided to households with low social capital (36,37).

Flexibility which scored 50% in 12 frameworks is an important assessment criterion since a decision support tool has to respond to changing environments, challenges and innovation. Aspects of flexibility include the capability to incorporate user remarks, local knowledge and new information that is sensitive to the local context (16). Therefore, there is need for regular updating of a framework (38). Only one framework scored fully for this criterion. Community engagement which scored 54% is critical for a sanitation selection framework as it empowers the community (39). The framework should guide the user on who and how community members should be involved in the intervention. Communities should be involved throughout the project cycle and not just participating in baseline surveys. Higher levels of community participation should be encouraged.

The expression of community demand is important in sanitation interventions. Demand for improved sanitation was defined in a review by Okurut and colleagues (40) as an informed expression of willingness and ability to adapt to a new appropriate service.

It implies the willingness and ability to pay for sanitation services. Communities should be aware that sanitation is a service that has to be paid for. This is well demonstrated in community-led total sanitation interventions which trigger demand. The selection of ASTs should address local sanitation needs of the community to promote effective use and adoption of the selected options. Further, there should be synergy between technology choice and hygiene behaviour. Trends in the sanitation sub-sector appear to show a transition from hardware provision to demand-led approaches with the ultimate goal of behaviour change (10). This is where communities begin to act on their own on given aspects without depending on outside help (40).

The long-term sustainability of sanitation interventions may be ensured when there are support services, community capacity development in operation and maintenance, and hygiene education (2). Therefore, frameworks should address ongoing contact between implementers and end-users of the selected technology options. Similar observations were reported in a review of sanitation planning frameworks with a focus for decision making by Barnes and others (7). The potential scalability of a technology in an intervention may attract donor funding (2). Sanitation technologies with a particular context focus may be difficult to repeat (replicability) elsewhere due to various difference among intended users. The replicability criterion scored 38% with two frameworks getting full scores.

User sanitation preferences in rural communities, sustainability evaluation frameworks for technologies and decision making support resources are well documented in literature. However, the selection of appropriate alternative options appears as a small

component in sanitation planning dominated by the technology evaluation mainly centred on the sustainability criteria or its modified forms (8,41,42). An earlier review of 120 support resources by Skat (38) concluded that there was not a comprehensive decision support tool for the WASH sector. The review recommended the need for a user-interface, financial support and regular updating of the support tool. An analysis of 17 sanitation planning frameworks mainly from institutions (71%) showed that only 41% of them fully provided decision making guidance on appropriate technology choices (7).

There are various frameworks developed by implementing organisation and their partners. However, practice appears to show that such organisations do have, and promote their own WASH planning frameworks to meet their interests. Project implementing organisations have to comply with guidelines of the donor community for funding (43) which may compromise community preferences. On the other hand, research institutions appear to have their own planning resources, potentially creating a gap between researchers and project implementers. Existing frameworks recommended for decision-making by relevant government departments and sanitation professionals in LMICs appear to vary in their criteria and application as they:

- are developed, funded or implemented by various organisations and/or their partners,
- are influenced by sanitation policies of national governments,
- address WASH as a sector, the sanitation sub-sector traditionally receiving limited attention,
- may be disaggregated and skewed to address mainly urban than rural sanitation,

- may ignore local contextual settings, including socio-economic considerations,
- mainly exist in grey literature.

A framework which addressed most of the assessment criteria used in the analysis may be judged likely feasible for application in interventions. However, this assumption was not tested as it was beyond the scope of this review. Further, such frameworks may not necessarily translate into improved sanitation best practice (7).

3.5 Limitations of the critical review

Restrictions such as the exclusion of records not in English language, without full-texts available online, those outside the 20-year study period (2000 - 2019) and search terms could have compromised the comprehensiveness of the critical review. Further, search of grey literature was not as comprehensive which could have possibly omitted other relevant frameworks. The suggested assessment criteria is subjective. However, there were scoring guidelines and it was consistently used across all frameworks.

3.6 Conclusions

Literature has different decision making tools to select AST options for rural communities in LMICs. The included frameworks were mainly based on the sustainability criteria, community and technology assessment, and validation in case studies. Critical issues which appeared not well addressed were equity, behaviour change, replicability of interventions, framework limitations and assessment of sanitation demand. Future framework development work may build on the existing frameworks, or use some of their compatible approaches to address identified methodological limitations. Therefore, there is need to upgrade existing frameworks or develop a new framework to meet the needs of policymakers and practitioners for rural sanitation.

Findings from the current review may inform WASH professionals in on-going studies and interventions, rural sanitation policy on unbundling the sanitation technology basket and the transition from using few prescribed sanitation technology options to alternative designs. The use of appropriate technology in achieving sustainable development still needs further research.

References

1. World Health Organisation. [WHO]. Guidelines on sanitation and health. Geneva: WHO; 2018. https://apps.who.int/iris/bitstream/handle/10665/274939/9789241514705-eng.pdf. [Accessed 31 January 2020].
2. Palaniappan M, Lang M, Gleick PH. A Review of decision making tools in the water, sanitation and hygiene sector. Environmental change and security programme of the Woodrow Wilson Center and the Pacific Institute; 2008.
3. Tilley E, Strande L, Lüthi C, Mosler H-L, Udert KM, Gebauer H, Hering JG. Looking beyond technology: An integrated approach to water, sanitation and hygiene in low-income countries. *Environ Sci Technol*. 2014; 48:9965-9970.
4. Kvarnström E, Petersens E. Open planning of sanitation systems. Stockholm: EcoSanRes programme and the Stockholm Environment Institute; 2004.
5. Morton S, Wilson S, Inglis S, Ritchie K, Wales A. Developing a framework to evaluate knowledge into action interventions. *BMC Services Res*. 2018; 18:133.
6. Slade SC, Philip K, Morris ME. Frameworks for embedding a research culture in allied health practice: a rapid review. *Health Res Policy Syst*. 2018; 16(29):1-15.
7. Barnes R, Roser D, Brown P. Critical evaluation of planning frameworks for rural water and sanitation development projects. *Dev Pract*. 2011; 21(2):168-189.

8. Bouabid A, Louis GE. Capacity factor analysis for evaluating water and sanitation infrastructure choices for developing communities. *J Environ Manage*. 2015; 161:335-343.

9. Bauer AM, Brown A. Quantitative assessment of appropriate technology. *Procedia Eng*. 2014; 78:345-358.

10. Mara D, Lane J, Scott B, Trouba D. Sanitation and health. *PLoS Med*. 2010; 7(11):e1000363.

11. Zhou X, Li Z, Zheng T, Yan Y, Li P, Odey EA, Mang HP, Uddin SMN. Review of global sanitation development. *Environ Int*. 2018; 120:246-61.

12. Seymour Z, Hughes J. Sanitation in developing countries: a systematic review of user preferences and motivations. *J Water San Hyg Dev*. 2014; 4(4):681-691.

13. Dakuré MS, Traoré MB, Sossou SK, Maiga AH. Development of sanitation technologies in African context: how could we make it more sustainable? *IOP Conference series: Earth and Environ Sci*. 2017; 60:012032.

14. Kamara JK, Galukande M, Maeda F, Luboga S, Renzaho AMN. Understanding the challenges of improving sanitation and hygiene outcomes in a community based intervention: A cross-sectional study in rural Tanzania*. Int J Environ Res Pub Health*. 2017; 14:602.

15. Mkhize N, Taylor M, Udert KM, Gounden TG, Buckley CA. Urine diversion dry toilets in eThekwini Municipality, South Africa: acceptance, use and maintenance through users' eyes. *J Water, San Hyg Dev*. 2017; 7(1):111-120.

16. Castellano D, de Bruijne G, Maessen S, Mels, A. Modelling chaos? Sanitation options; support and communication tool. *Water Pract Technol*. 2011; 6(3):wpt2011060.

17. Feachem RG. Community participation in appropriate water supply and sanitation technologies. The mythology for the decade. *Proc R Soc Lond B*. 1980; 209:15-29.
18. Murphy H, McBean EA, Farahbakhsh K. Appropriate technology - A comprehensive approach for water and sanitation in the developing world. *Technol Soc*. 2009; 31:158-167.
19. Tayler K. Colin J, Parkinson J. Tools for Sanitation Choice" in Strategic Planning for Municipal Sanitation. GHK Research and Training, WEDC, and Water and Sanitation Programme for South Asia; 2000. http://www.bvsde.paho.org/bvsacg/i/fulltext/guide/guide.pdf. [Accessed 20 January 2020].
20. Howard JR, Quinn N, Eales K, Douglas S, Quinn N, Voller R. The Development of an on-Site Sanitation Planning and Reporting Aid (Sspra) for the Selection of Appropriate Sanitation Technologies for Developing Communities South African Water Research Commission (WRC) Report Number: 586/1/00; 2001.
21. Loetscher T, Keller J. A decision support system for selecting sanitation systems in developing countries. *Socio-Econ Plan Sci*. 2002; 36(4):267-290.
22. Louis GE, Ahmad T. Technology assessment for sustainable sanitation services low-income communities. 2004. http://www.sys.virginia.edu/techreps/2004/SIE-040008.pdf. [Accessed 31 January 2020].
23. Halim HSA, Abdel-Halim W, Nazih M. Selection and evaluation of appropriate sanitation systems in rural Egypt. Case study in Sohag Governorate, Upper Egypt. ESCWA Conference: Sustainability of Arab cities and security of housing and land tenure and urban governance. Cairo, Egypt, 15-18 December, 2005.

24. Mara D, Drangert J-O, Anh NV, Tonderski A, Gulyas H, Tonderski K. Selection of sustainable sanitation arrangements. *Water Policy*. 2007; 7 (9):305-318.

25. Henriques JJ, Louis GE. A. decision model for selecting sustainable drinking water supply and grey water reuse systems for developing communities with a case study in Cimahi, Indonesia. *J Environ Manage*. 2011; 92:214-222.

26. Kimera P, Smet J, Olschewski A, Parker A. Context specific validation and introduction of technologies for sustainable WASH services. 36th WEDC International Conference, Nakuru, Kenya, 1-5 July, 2013. https://wedc-knowledge.lboro.ac.uk/details.html?id=20770. [Accessed 31 January 2020].

27. Ramóa A, Matos J, Lüthi C. System-based decision trees for the selection of sanitation technologies. In: Shaw RJ. (ed). Water, sanitation and hygiene services beyond 2015 - Improving access and sustainability: Proceedings of the 38th WEDC International Conference, Loughborough University, UK, 27-31 July 2015, pp. 7.

28. Salisbury F, Brouckaert C, Still D, Buckley C. Multiple criteria decision analysis for sanitation selection in South African municipalities. *Water SA*. 2018; 44(3):448-457.

29. Filho FJCM, de Queiroz AAFSL, Machado BS, Paulo PL. Sustainable sanitation management tool for decision making in isolated areas in Brazil. *Int J Environ Res Public Health*. 2019; 16:1118.

30. Lennartsson M, Kvarnström E, Lundberg T, Buenfil J, Sawyer R. Comparing sanitation systems using sustainability criteria. Stockholm: EcoSanRes Programme, Stockholm Environment Institute; 2009.

31. Vidal B, Hedström A, Barraud S, Kärrman E, Herrmann I. Assessing the sustainability of on-site sanitation systems using multi-criteria analysis. *Environ Sci: Water Res Technol*. 2019; 5:1599.
32. Apanga PA, Garn JV, Sakas Z, Freeman MC. Assessing the impact and equity of an integrated rural sanitation approach: A longitudinal evaluation in 11 sub-Saharan Africa and Asian Countries. *Int J Environ Res Public Health*. 2020; 17:1808.
33. Odagiri M, Schriever A, Damelo ME, Wuertz S, Smith W, Clasen T, et al. Human faecal and pathogen exposure pathways in rural Indian villages on the effect of increased latrine coverage. *Water Res*. 2016; 100:231-44.
34. Donovah E, Unice K, Roberts JD, Harris M, Finley B. Risk of gastrointestinal associated with exposure to pathogens in the water of the lower Passaic River. *Appl Environ Microbiol*. 2017; 4(4): 994-1003.
35. Carrard N, Kohlitz J, Soeters S, Halcrow G, Murta J, Willetts J. Reaching all in rural sanitation: experiences from inclusive programming in five countries. *Dev Pract*. 2020; 30(5):609-623.
36. Luby SP, Rahman M, Arnold BF, Unicomb L, Ashraf S, Winch PJ, Stewart CP, Begum F, Hussain F, Benjamin-Chung J, et al. Effects of water quality, sanitation, hand washing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. *Lancet Glob Health*. 2018; 6:e302-e315.
37. Ercumen A, Benjamin-Chung J, Arnold BF, Lin A, Hubbard AE, Stewart C, Rahman Z, Parvez SM, Unicomb L, Rahman M, et al. Effects of water, sanitation, hand washing and nutritional interventions on soil-transmitted helminth infections in young children: A cluster-randomized controlled trial in rural Bangladesh. *Plos Negl Trop Dis*. 2019; 13(5):e0007323.

38. Skat. Review of Framework for Technology Assessment. (WASHTech Deliverable 3.1). WASHTech c/o IRC International Water and Sanitation Centre and Sankt Gallen: The Hague: Skat; 2011. http://washtechafrica.wordpress.com. [Accessed 8 February 2020].

39. Ng E, de Colombian P. Framework for selecting best practices in public health: a systematic literature review. *J Public Health Res*. 2015; 4:157-170.

40. Okurut K, Kulabako RN, Chenoweth J, Charles K. Assessing demand for improved sustainable sanitation in low-income informal settlements of urban areas: a critical review. *Int J Environ Health Res*. 2015; 25(1): 81-95.

41. Barnes R, Ashbolt N. Development of a planning for sustainable rural water supply and sanitation, a case study of a Filipino NGO. *Int Studies Mgt Org*. 2010; 40(3):78-98.

42. Krause A, Köppel J. A multi-caiteria approach for assessing the sustainability of small-scale cooking and sanitation technologies. *Challenges Sust*. 2018; 6(1):1-19.

43. Ngwira C, Mayhew, S. Donor-driven harmonised payment of allowances policy and NGOs' community engagement in Malawi. *Dev Pract*. 2020; 30(1):3-14.

Supporting material 3S.1 Evidence from included articles to aid authors' judgements

Assessment criterion	Ref	Text or phrase from included article used as evidence /lack of it
Assess informed community demand for sanitation	1	To improve sanitation... first establish and inform demand. P 5-6, 5.5: L 1
	2	Basic sanitation needs, Checklist 1. P 53, Assessment level. Fig 5.1
	3	Factors determining the indices … community needs. P 275, Fig 3
	4	Unclear how to adapt to selected sanitation service, No needs assessment
	5	No clear expression to respond to community needs
	6	No mention of sanitation demand stimulation processes
	7	No mention of sanitation demand stimulation processes
	8	No mention of sanitation demand stimulation processes
	9	Sanitation need indicated without methodological guidance. P 337, Fig. 1
	10	No mention of sanitation demand stimulation processes
	11	No mention of sanitation demand stimulation processes
	12	No mention of sanitation demand stimulation processes
Personnel selection	1	Communities, gvt, NGOs, politicians … P 5-8, No. 1 & 2
	2	Participants: selected … broad spectrum of experience and specialisations in sanitation service planning & delivery. Appendix 1B, P 80
	3	… discussions with planners and practitioners (P269, Step 5)
	4	No clear personnel identified. Generally "community" was used
	5	No clear personnel identified. Generally "community" was used
	6	No mention of the significance of personnel selection
	7	Data collection … gvt. offices, community leaders… P218, Section 3.1,
	8	Participation of various stakeholders Abstract: L 7, P 2, L 6
	9	Participation of women (P 341), local organisation (P 339) ….
	10	No mention of the significance of personnel selection
	11	Examples of possible participants given, no advice on selection Abstract, L5
	12	Stakeholders: members & leaders from community, professionals. P 8, Fig 3
Technology choice	1	Detailed technology descriptions given. P C2 –C14
	2	Description of SSPRA in user manual & other information. P 58, Sect 5.2
	3	… sanitation technologies identified were assembled … P269, Step 2
	4	.. list of feasible options and let community decide … 3.1, P 4, Para 1, L 8
	5	Evidence that communities finally make their choice is given. 4.3.2, #
	6	Post-selection check-lists for detailed design. P 316-317, Annex 1,
	7	Description of decision process: model development, P 216 -218.
	8	Full decision process and necessary considerations.
	9	Full description of decision process & necessary considerations throughout
	10	Full description of decision process & necessary considerations throughout
	11	Full description of decision process and necessary considerations
	12	Technologies presented & members voted & chose options. Results: P7, L6
Legislation and regulation	1	Questions effect of legislation& gvt. 'Role in sanitation services'. P C4-12
	2	Sanitation services shared among 6 national departments. 3.3, P 24, L 1-2
	3	Assumption: community assessment and field testing were gvt-approved
	4	Assumption: community assessment and field testing were gvt-approved
	5	Assumption: community assessment and field testing were gvt-approved
	6	No mention of government involvement, just key stakeholders. P 313, L1
	7	Gvt. involvement encouraged. P 218, Section 3.1, bullets 2 & 3
	8	....stakeholders including national gvt and … A-R methodology: P 2, L 21
	9	Assumption: community assessment and field testing were gvt-approved
	10	Gvt. regulation, not involvement, under 'existing regulations' P4, bullet 1
	11	Involvement of local government (eThekwini municipality)
	12	Assumption: community assessment and field testing were gvt-approved

Sustainability criteria	1	Sustainability criteria factors identified. P C3 -3, Key principles, L 15
	2	SSPRA integrates all relevant factors (socio-economic, environmental, technical, financial) in technology selection. P 70, Bullet 1
	3	Sustainability index was calculated by … P 286, 5.2.2. Sustainability
	4	Each technology was evaluated against 4 criteria (sustainability). 3.2 P 4
	5	Criteria of sustainability was used. Section 4.3.2. #1
	6	… fundamental principles for sustainable sanitation. P 306, 1.1 L 1
	7	Capacity factors (P 216 Table 2) include 5 sustainability criteria
	8	Technology assessed on 6 sustainability dimensions. P 4, Figs. 3 & 4
	9	Sustainability criteria considered as part of 8 capacity factors. P 317, L 20
	10	Sustainability criteria suggested in post-selection questions, P 4, bullets 1-5
	11	Fig. 1 Value tree for assessing he sustainability of sanitation systems. P 451
	12	Implied in technology database: technical, environmental, cultural…P 4, L1
Decision making	1	Guide to 'shared decision-making' to sanitation selection. P C3-5
	2	SSPRA - for transparency and accountability in decision-making. P v, L 1
	3	… decision support system SANEX was developed. Abstract, L 3
	4	… help communities make informed decisions about .. Abstract, L 9
	5	… computer-based selection tool … Section 4.3.2. # 1
	6	… useful tool to inform and direct … P 314, Conclusions, bullet #3
	7	.. to guide decision makers in the selection of …. P 216, Para 1, L 7
	8	Tools contribute to technology approval and introduction. Abstract, L 8
	9	CFA: component of decision support. P 337, 2. Proposed approach, L 8
	10	System-based decision algorithm for technology selection … Subtitle, P 3
	11	MCDA was found to provide a guiding framework … Abstract, L 11
	12	… tool was developed … for decision making process. Abstract: L 5
Flexibility	1	Guide can be tailored to suit local contexts, user remarks and new information. Exploring local situation, community responses
	2	Easily updated &applicable to wide range of systems: P 32, 4.2.2, Bull 3&4
	3	Incorporated user remarks but not response to changing environments
	4	Incorporates local contexts but not user remarks and new information
	5	Updated to but no details: local context, user remarks, new information
	6	Tailored to most situations, but not user remarks and new information
	7	Tailored to local contexts and new information but not user remarks
	8	tools … for rural can be applied to urban set-ups. P 6, Recommendations
	9	Difficult to apply to a range of contexts but of comparable capacity profiles
	10	Incorporates local context, user remarks and new information. P 5, Fig. 2
	11	Tailored to local contexts and user remarks but not new information
	12	Decision tree allows flexibility by allowing users to insert … P 11, L 5
On-going contact	1	Gives detail of where and who to seek advice from on the guide later on
	2	Responsibility for actual service delivery to local govt. P 24, L 12
	3	No mention of where & who to seek advice from on the framework later on
	4	No mention of where & who to seek advice from on the framework later on
	5	No mention of where & who to seek advice from on the framework later on
	6	No mention of where & who to seek advice from on the framework later on
	7	No mention of where & who to seek advice from on the framework later on
	8	Webpage (P 2, L 14) and country-specific contacts given (P 6, Contacts)
	9	No mention of where & who to seek advice from on the framework later on
	10	No mention of where & who to seek advice from on the framework later on
	11	No mention of where & who to seek advice from on the framework later on
	12	No team to assist , no local specialists who know difficulties … P 10, L 18
	1	Planned at the beginning, considered throughout. P 4-32. Sect 4.29, L 1-3
	2	Considered in the O & M index. P 33, L 1-2
	3	O & M as criteria determining sustainability P 278, Fig. 6
	4	Technologies assessed … technical … (P 3, L 10). O&M – assumed
	5	Final selection … technical eligibility. 4.3.2: Para 2, L2. O&M – assumed

Operation and maintenance (O & M)	6	User instructions for correct and routine O & M. P 316, Annex 1, # 3
	7	Considers spare parts under technical capacity factor. Fig. 1, P 215
	8	Assumed under technological sustainability criteria. P 4, L 9
	9	Considered under technical CF: O & M. P 339. Sect 4, Para 6, L 2
	10	Assumed under post-selection questions. Bullet 2: Technically appropriate
	11	Assumed under technology sustainability criteria P 451, Fig. 1
	12	Information on technical options (O & M) - found in technology … P 6, L1
Constraints in technology choice	1	Assumed in summary of sanitation technologies. P C2-3
	2	Technology database, post selection questions. P 70, bullet 2
	3	Field testing results showed evidence of constraints. P 287-288 : Rating
	4	Team goes to community with list of feasible options to decide... P 4 , L 8
	5	Final selection ... technical ... for each option. 4.3.2. Para , L2
	6	Post-selection check-lists for detailed design, Annex 1, P 316-317
	7	No constraints advised for use in technology choice
	8	Non-affordability of VIP latrine and UDDT… P 2, Findings & outputs, L8
	9	Finally community evaluates alternatives for …support services. P 342, L 5
	10	Suggested in the post-selection questions. P 4, Sect 2, bullets 1 – 8
	11	Description of VIP and UDDT latrines: summary of results. Table 2, P 454
	12	Assumed in the technology database (DB11) with information. P6, L 1
Data collection	1	Exploring existing situation with given methods. P4 -11; 4.10: Question 1-4,
	2	Field visits, interviews with stakeholders. 4.1 Phase 1, P 29,: 4.1.1 & 4.1.2
	3	Community - source of information for assessing... P 275, bullets 1 & 2
	4	Information- gathered on components of sustainability. P3, after Fig. 3-2
	5	Data was collected and assessed … P 6, 3.1 Assessment …. L 1
	6	Initial data collection mentioned, no methodological detail. P 313, L1
	7	Data was gathered under the supervision of … P 218, Section 3.1, L 8
	8	Participatory process with key stakeholders … field/workshops. P 4, L 11
	9	Profiling a community to get its capacity level. P 338, Sect 3.
	10	Done for identifying systems compatible with existing situation. P 3, # 1/3
	11	Done for final list of criteria used in the MCDA, Table 1. P 452
	12	Done during a pilot study (validation) - rural community. 2.5; P 7, L 1, 26
Communication	1	Standard methods used for data collection. Interviews, FDGs.. 4.4: P C4-19
	2	Assumed done through data collection and community engagement
	3	Assumed done through data collection and community engagement
	4	Assumed done through data collection and community engagement
	5	Assumed done during community assessment
	6	No mention of culturally appropriate communication
	7	Appropriate methods indicated in data collection. P 218, Sect 3.1, L 11
	8	Strong … communication strategy designed. Action-research … P 2, L 9
	9	Assumed done during community assessment
	10	No mention of culturally appropriate communication
	11	No mention of culturally appropriate communication
	12	Assumed done through data collection and community engagement
Replicability	1	No clear evidence of scalability and technology adoption was suggested
	2	No clear evidence of scalability and technology adoption was suggested
	3	Although tested in 9 case studies, adoption of technology not suggested
	4	No clear evidence of scalability and technology adoption was suggested
	5	Considered a starting point … for each village
	6	No mention of scaling–up intervention
	7	Models allows … amenable to expansion as the... Abstract: L 13
	8	… have potential to be applied for urban … Recommendations: P 6, L1-2
	9	Matching done in communities with comparable … P 342, Conc Para 2, L 9
	10	No mention of scaling–up sanitation interventions with the tool mentioned
	11	No mention of scaling–up sanitation interventions with the tool mentioned

	12	Tool can be used in different contexts ….urban, rural, slums … P 11, L 13
Community engagement	1	Community involvement: workshops, FGDs … given. e. g. P 4-17
	2	SSPRA promotes transparency: full user community participation. P 71, L1
	3	… community must be involved in the planning… P 275, bullet 1
	4	Low level of community engagement, not throughout the planning stage
	5	No detail regarding community involvement processes
	6	No methodological detail of community involvement processes
	7	Little detail regarding community involvement processes
	8	Participatory …key stakeholders. Communities: unclear. P 4, L11
	9	For participation of women, validation & village visit. P 339, 4, para 3, L18
	10	Little detail regarding community involvement processes, only 'user'
	11	Little detail regarding community involvement processes, only 'users'
	12	.. discussed with local members, meetings, workshops … P 7, L 18 -28
Framework validation	1	Details of pilot testing technologies were given. P 5-25, Sect 5.28: L 3-4
	2	SSPRA was scenario-tested. 6.2 Scenario testing, P 59
	3	To validate the results, communities … were visited. P 269 Line 2
	4	A case study of Bacoor, Philippines is given. 3.1. Overview
	5	Technique was tested for a group of villages to induce … 4.3.2, #4
	6	No validation process mentioned
	7	Case study validation of the CFA model … in Cimahi. P 216, Para 1, L 9
	8	TAF– field tested in 3 countries. P 2, Action Research Methodology, L13
	9	CFA - used in a village case study in Morocco. P 339, Sect 4, Para 2, L 2
	10	No validation process mentioned
	11	Scenario analyses: S_0- S_{11}. Results, P 453 - 454.
	12	Tool used in a pilot study in Quilombola community. P 3; Methods, L 2.
Transparency	`1	Results generated are easily handled in workshops and to communities
	2	SSPRA – computer-based, integrates all variables for transparency. P v, L 3
	3	Computer-based. Users questioned its results, ignoring theirs. P287-288
	4	Results are easily manageable, community makes final choice. P 4, L 8
	5	Computer-based selection tool, 'simple and ease' 4.3.2, #1. No detail
	6	Selection algorithm transparently considers... P 314, Conclusion, bullet 3.
	7	Results generated are easily handled/manageable
	8	Results generated are easily handled/manageable. TIP given, P 5
	9	Some degree of difficulty… handling results highlighted. P 342, Para 2, L 1
	10	Decision tress provide a transparent … decision process. Abstract, L1
	11	Results generated are easily handled/manageable. P 454, Table 2
	12	Computer-based selection too. Community makes final choice. P 11, L 5
Interactability	1`	No evidence to show user interacts with tool
	2	SSPRA has various PC screens for user to interact with
	3	SANEX - addresses non-interactive shortcoming … P 268, 1.2 Lines 5-6
	4	Computer software allows interaction with end user
	5	Computer software allows interaction with end user
	6	Selection algorithm allows interaction with end user – P 312, Fig. 2
	7	Assists experts & decision makers in final selection... P 218, L 5-6
	8	Allows interaction with end user, TIP Guide support given. P 5
	9	Selection of final candidate… community evaluates options using P 342, L5
	10	End user interacts with tool as directed using available support … P 4, L 2
	11	Does not allow interaction with the end user
	12	Allows user to insert questions in various forms. 2.2 Database mgt: P 4, L 4
	1	Mentions sanitation needs: poor, in low-incomes areas. P 4-7, Box 4.1, # 5
	2	Mentions involvement of poorest & women. P 16, Whose decisions? L 6-7
	3	No clear evidence relating to the sanitation needs of vulnerable groups
	4	No clear evidence relating to the sanitation needs of vulnerable groups

Equity	5	No clear evidence relating to the sanitation needs of vulnerable groups
	6	No clear evidence relating to the sanitation needs of vulnerable groups
	7	No clear evidence relating to the sanitation needs of vulnerable groups
	8	No clear evidence relating to the sanitation needs of vulnerable groups
	9	Assessment of 8 CF... equity….women participation… P 341, Para 3, L1
	10	No clear evidence relating to the sanitation needs of vulnerable groups
	11	No clear evidence relating to the sanitation needs of vulnerable groups
	12	No clear evidence relating to the sanitation needs of vulnerable groups
Compatibility with other frameworks	1	Guide does not refer/involve other frameworks
	2	PHAST – identified to be linked to the SSPRA. P vii, Para 3, L 7
	3	… derived from Multi-attribute Utility Technique. Abstract, Line 5
	4	… adds to Louis' framework for helping … Introduction, P 1, Line12
	5	Does not refer/involve other frameworks
	6	Does not refer/involve other frameworks
	7	Compatible with Community Assessment Framework: P 219, Sect 3.11)
	8	Does not refer/involve other frameworks
	9	Bouabid (2004) guide used in community assessment. P 339, 4. Para 3, L5
	10	Systems …expand /disaggregate …from Tilley (2014). P 2, L 8
	11	Does not refer/involve other frameworks
	12	Software compatible with other tools e.g. 5W2H, Canvas BM. P 11, L24
Sanitation behaviour change	1	Detail on hygiene education given. PC1- C17 e. g. handwashing
	2	Mentions public health education in an index without detail of hygiene. P 37
	3	Does not mention the sanitation-hygiene link
	4	Does not mention the sanitation-hygiene link
	5	Does not mention the sanitation-hygiene link
	6	Hygiene education to induce behaviour change … P 308, Section 2, L 11
	7	Does not mention the sanitation-hygiene link
	8	Just mentions the sanitation-hygiene link. P 2, Action Research …. L 15
	9	Does not mention the sanitation-hygiene link
	10	Just mentions sanitation-hygiene link: anal cleansing material. P 4 , bullet 8
	11	Does not mention the sanitation-hygiene link
	12	Encourage participants reflect on health and hygiene situations. P 10, L 16
Limitations	1	Limitations of the guide were not clearly mentioned
	2	Explained under 7.2.2. Limitations: P 71 - 73, bullets 1 – 5
	3	Results do not allow a definitive judgement of … P 287, 6. Field testing
	4	Limitations of the framework not mentioned
	5	Limitations of the framework not mentioned
	6	Limitations of the framework not mentioned
	7	Limitations and their effects given in 3.2: Scenario validation, P 219-220
	8	Limitations suggested: contextualisation & data collection. P 4, L12, 17
	9	Inaccuracies and subjectivity were discussed. P 342, Para 3, L 1 - 6
	10	Decision trees criticised… (6, L 10), need for detailed knowledge..(P3, L10)
	11	MCDA presents a number of challenges … Conclusions, P 455, L 1, 13, 28
	12	Tool - inapplicable in all contexts. Utility – affected by type and level of community engagement. P 10; L 12, 14
User-friendly interface	1	The guide has not straightforward user-friendly interface e.g. factsheets u
	2	User-interface: Final PC screen, data handling not clear. P 35
	3	User input to the criteria …P 272, *Rating*: Para 2, Line 1
	4	User input information suggested. P 4, L8
	5	Computer-based tool has data entry and output pages. 4.3.2 Figs. 5 & 6
	6	Some degree of difficulty to follow, not straightforward P 312, Fig.2
	7	Ease-to-use interface to input and retrieve responses. P 215, Fig. 2
	8	Ease-to-use interface to input and retrieve responses. P 5, Fig. 5
	9	Not straightforward: CCL score refine choices, finally community evaluates

	`10	...decision algorithm divided … parts which user is directed to. P 5, Fig. 2
	11	Spreadsheet-based MCDA… stakeholder & expert interfaces. Abstract, L5
	12	Allows user to insert questions in various forms. 2.2 Database mgt: P 4, L 4

"Ref" - Reference:

1. Tayler et al. (2000)
2. Howard et al. (2001)
3. Loetscher and Kelly (2002)
4. Louis and Ahmad (2004)
5. Halim et al. (2005)
6. Mara et al. (2007)
7. Henriques and Louis (2011)
8. Kimera et al. (2013)
9. Bouabid and Louis (2015)
10. Ramóa et al. (2015)
11. Salisbury et al. (2018)
12. Filho et al. (2019)

CHAPTER 4: ADAPTING SANITATION NEEDS TO A LATRINE DESIGN (AND ITS UPGRADABLE MODELS): A MIXED METHODS STUDY UNDER LOWER MIDDLE-INCOME RURAL SETTINGS

This chapter is a published journal article:

Kanda A, Ncube EJ, Voyi K. Adapting sanitation needs to a latrine design (and its upgradable models): A mixed method study under lower middle-income rural settings. Sustainability. 2021; 13(23):13444. Doi: 10.3390/su132313444.

4.1 Abstract

Rural households have latrine preferences and unique sanitation needs. An assessment of how rural households adapt their sanitation needs to a nationally encouraged latrine design was done. A cross-sectional survey was conducted among 790 households in a rural district of Zimbabwe from November 2020 to May 2021. Data were analysed using logistic regression. Qualitative data were collected using focus groups and analysed using thematic analysis. Analyses were done in STATA 16 and considered significant at $p < 0.05$. There was low adoption of the Blair ventilated improved pit latrine and its upgradable models. Significant predictor variables of BVIP latrine adoption were mainly contextual and psychosocial at the individual and household levels. They included source and level of household income, residence period, nature of homestead, number of cattle owned, knowledge of sanitation options and perceived high latrine cost. The latrine design was considered not a pro-poor option as it was unaffordable by many rural households resulting in its non-completion, poor-quality designs, alternative options, sharing and open defaecation. Poverty appears the main barrier for latrine ownership. However, a window of opportunity to improve access to sanitation in rural Zimbabwe exists by considering alternative sanitation options and financial investment mechanisms.

Keywords: access; alternative technology; BVIP design; latrine ownership; rural sanitation; sustainable development

4.2 Introduction

Inclusion of sanitation in the unanimously adopted sustainable development agenda by the United Nations (1) demonstrated global concern. Adequate sanitation is perceived to have health and non-health human benefits (2,3). By 2015, ~2.4 billion people still lacked access to basic sanitation (4). Lessons learnt from the millennium development goal target on sanitation (extrinsic issues) in low- and middle-income countries (LMICs) were suggested (5,6) to inform sustainable development Goal 6.2 on sanitation. National governments should include sanitation targets into their policies and strategies considering local context (7).

A systematic review of 44 studies on sustained adoption (8) indicated that (i) the varying definitions of sustained adoption would ideally present behaviour, frequency of behaviour and duration of behaviour measurement; (ii) many studies focused on initial adoption of sanitation behaviour (follow-up times ranged from 6 months to 9 years' post-project intervention); and (iii) factors which influence behaviour practice may be different during and post-project period. The review further stressed the need to describe the context surrounding the adoption, multiple and diversified measurements, and factors that affect sustained adoption. Recent work (9) tried to differentiate between initial and sustained adoption in a longitudinal study with two post-intervention surveys relative to baseline data.

Rural households have latrine preferences (10-12). Several studies indicated poor adoption and non-sustained use of available sanitation facilities (13-15). However, it appears there is no discussion on how rural communities adapt their sanitation needs to a 'standardised' latrine design (considered minimum standard) over a long period. Here, we argue that prescribing a rural sanitation technology option (even including its upgradable models) across a multicultural society in diverse environments potentially impacts on its adoption. We used primary data to support this. It is unclear how rural communities adapt their unique sanitation needs to a technology design.

4.3 Brief background to rural sanitation in Zimbabwe

Zimbabwe had no stand-alone national sanitation policy until 2017 when the sanitation and hygiene policy draft was gazetted (16). After gaining its independence in 1980, Zimbabwe prescribed and promoted the Blair ventilated improved pit (BVIP) latrine design (Fig. 4.1), a Zimbabwean home-grown innovation named after Dr. Blair, was proposed as a technology solution to rural sanitation (17).

The BVIP latrine is an improvement of the simple pit latrine. A vent pipe and fly screen control bad smell and houseflies, respectively. The superstructure (spiral or rectangular brick-lined wall) rests on a concrete slab (with a squat hole) on a brick-lined pit.

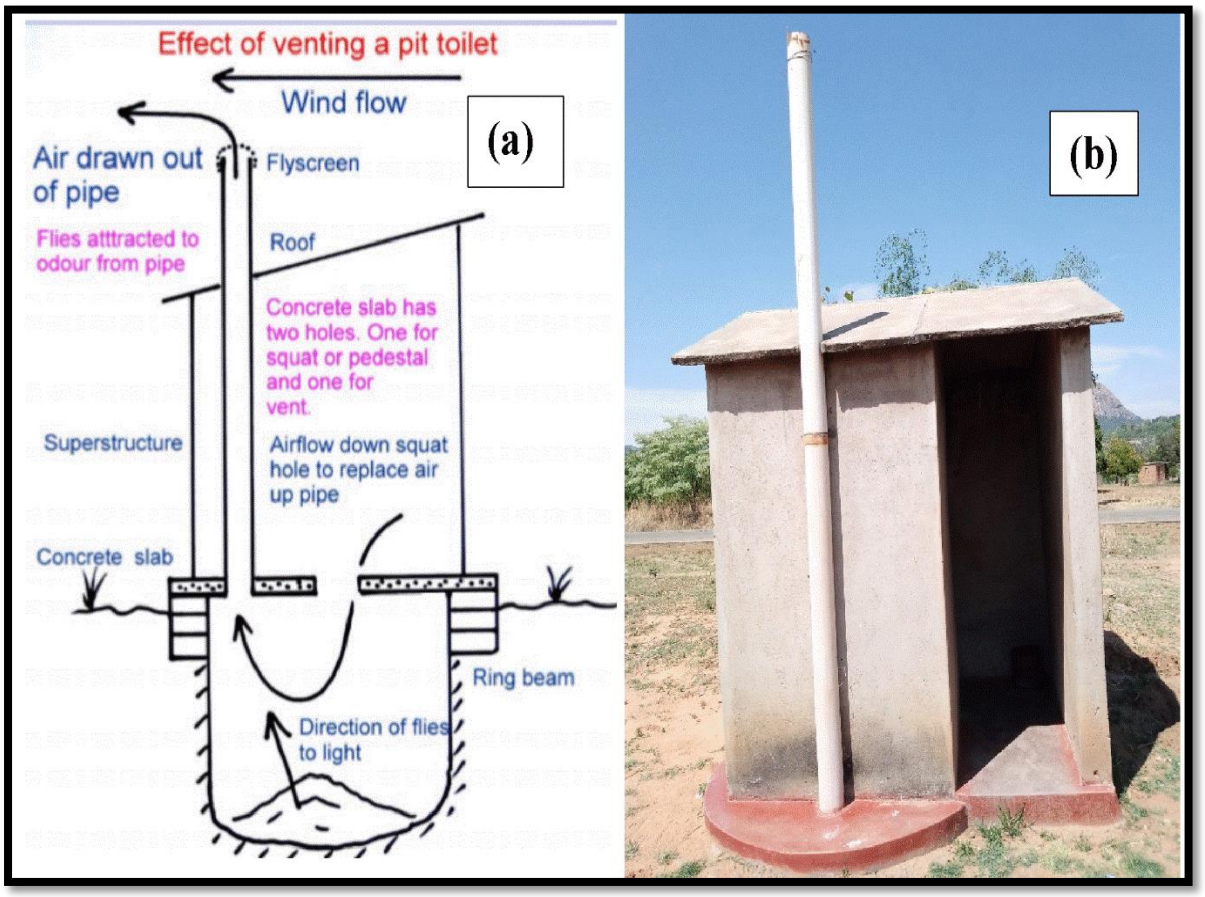


Fig. 4.1 (a) Schematic illustration of the conventional BVIP latrine (23) and (b) photograph of an operational household BVIP latrine taken in the study area (photograph by authors).

The upgradable version of the BVP latrine (uBVIP latrine) maintains the basic brick-lined pit and concrete slab design of the BVIP latrine with the superstructure built in stages and assuming various designs. When completed, it has the vent pipe and fly screen, a form of a BVIP latrine.

The BVIP latrine was used in the integrated rural water supply and sanitation programme (IRWSSP) from 1985 to 2005 to address an inherited pre-independence rural-urban sanitation service disparity (16). The annual production of BVIP latrines declined by 89.1% from 1987 to 2005 (18) when donors exited, coupled with economic recession and a growing population (17). The decline in sanitation and hygiene services contributed to the 2008 - 2009 national cholera outbreak (16) which killed 4287 people (19). In 2015, rural sanitation coverage dropped to 31% (4).

Failure of the IRWSSP culminated in the development of a national sanitation and hygiene strategy (2011 - 2015) in 2010 with a focus to move towards a demand-led sanitation approach and an end to open defaecation (20). A direct lesson learnt from the IRWSSP was that one standard option (BVIP latrine) considered unaffordable by many households (18) was not a solution to address rural sanitation (21). Further, the national water policy of 2012 recommended non-subsidised sanitation services and opted for an upgradable BVIP (uBVIP) latrine (22).

According to Morgan (23), the uBVIP latrine is a basic requirement for a brick-lined pit and a covering concrete slab, which allows the owner to upgrade the superstructure in a sequence of steps to attain the final brick-built BVIP latrine. It was considered more affordable and adaptable as rural families could build a ‘variety of toilets’ including the standardised brick-BVIP latrine. The uBVIP latrine was piloted through the Zimbabwe community approaches to total sanitation (ZIMCATS). However, its uptake outside pilot studies, and completion to get the intended final benefits of the standard BVIP latrine are yet to be reported.

The 2017 sanitation and hygiene policy draft (16) acknowledges the inability of formally preferred sanitation technologies to keep pace with changes and challenges, and the sanitation service chain. A policy principle further acknowledges the need for demand-driven, community-based and context-specific adapted sanitation technologies based on research evidence. However, the policy draft appears to prescribe the uBVIP latrine as the minimum on-site sanitation technology for rural communities. Since 2010, commitment to demand-led sanitation approaches and encouragement of alternative designs are yet to be fully explored. How rural communities adapt their sanitation needs to the BVIP latrine is not well understood against the backdrop of the need to achieve adequate and equitable access and end open defaecation by 2030.

4.4 Materials and methods

4.4.1. Research design and description of the study area

A mixed methods design was used. This consisted of a cross-sectional survey among rural households and focus groups. Mbire is a district found in Mashonaland Central Province, Zimbabwe (between 30.60° and 31.20° E and 15.60° and 16.40° S, lowest altitude 350 m). The projected population was 104 735 in 2020 (24). The study area is characterised by floodplains of the Zambezi River Basin and experience seasonal river flooding. It is a 'communal areas management programme for indigenous resources' (CAMPFIRE) district with ward 1 in wildlife corridors. Therefore, some areas experience human-wildlife conflicts. The district experiences cross border activity by virtue of being near the Mozambican and Zambian borders (Fig. 4.2).

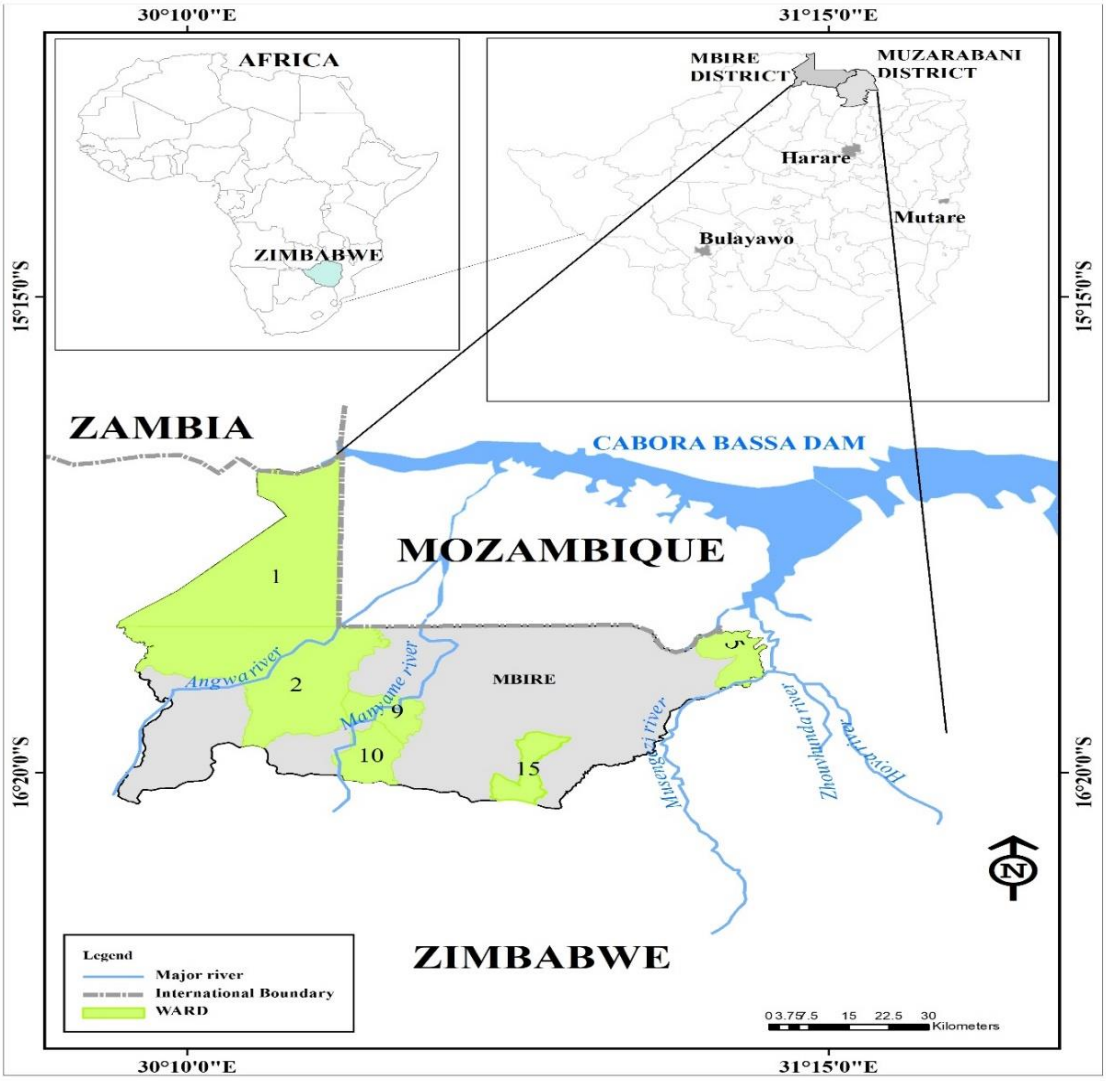


Fig. 4.2 Map of Zimbabwe showing wards in Mbire district selected for the study

Mashonaland Central province represents a worst-case scenario of poverty and low access to basic sanitation in Zimbabwe. In 2019 and 2020, the province had the highest proportion of households with unimproved (20 and 17%) and limited (22 and 20%) sanitation facilities in the country (25,26). It had the highest percentage poverty prevalence (81.6%) and highest percentage extreme poverty prevalence (41.2%) among provinces (27). Similarly, Mbire district was purposively selected to represent a worst-case scenario by having the highest poverty index (90.7%), extreme poverty (64.0%) and poverty severity index (36.6%) among districts in the province in 2017 (27).

Further, the district had the highest proportion of households using water from unimproved sources (32.4%), with 26.6% of the households lacking a sanitation facility [Ibid].

4.4.2 Sample size and research instruments

Multistage cluster sampling was used to select households in the district at ward and village levels (Supporting material 4S.1). Proportional to size allocation was finally used to randomly (lottery method) select households in a village for the study (Supporting material 4S.2). A single population proportion formula (28), considering the design effect (deff = 2), a contingency for non-response (r = 10%) (29), confidence interval (95%), basic latrine coverage for the district (36.3%) and marginal error (5%) was used to determine the sample size. A minimum sample size of 790 households was determined.

A semi-structured questionnaire (Supporting material 4S.3) that was designed based on existing instruments (30,31), reviewed by an independent Water, Sanitation and Hygiene (WASH) specialist and pilot-tested, was administered face-to-face to 790 house heads by five trained and experienced data collectors in vernacular *ChiShona*. The trained data collector was an environmental health technician (EHT) employee from the Ministry of Health with minimum qualification of diploma in environmental health. Five focus group discussions (FGDs) were held one in a randomly selected village of a ward for the five wards. A sixth FGD was held in a ward and village selected by two field supervisors (lottery method).

Nine participants were purposively sampled for each group based on assumed knowledgeable in household sanitation by earlier participation in similar work, augmented by snowballing, through village health workers.

The procedure followed to carry out FGDs was given in literature (32). Topics for discussions allowed participants to share experiences on how they adapt their sanitation needs to the BVIP latrine (and uBVIP models), until saturation was assumed to have been reached for a topic. A FGD guide (Supporting material 4S.4) was used. An assistant audio-recorded the proceedings. The questionnaire recognises the importance of including public opinion in healthcare and technology, a reflection of values, attitudes and indigenous knowledge systems which are important for public policy (33). The integrated behavioural model for water sanitation and hygiene (IBM-WASH) (Supporting material 4S.5) guided the categorisation of determinants for latrine adoption (34).

4.4.3 Study variables and data analysis

The dependent variable for latrine ownership was 'presence of a household BVIP latrine' with two categories: "yes" and "no". The independent (predictor) variables were demographic and technology-derived from the questionnaire. Data were entered into SPSS version 21.0 (35), cleaned and checked for accuracy of capturing by re-entering 10% of the entries before being exported to STATA Vers. 16 (36) for analysis using binary logistic regression. Descriptive cross tabulations were used to summarise participant experiences with the BVIP (and uBVIP) latrine. Thematic analysis was done for qualitative data as described in literature (37,38). An overall analysis of the data set identifying semantic themes to address research questions (deductive thematic analysis) was done. Six audio-recorded FGDs were each transcribed verbatim and translated into English language. Text was coded, clustered into several categories and themes were generated. Analyses were performed in Nvivo 12 (39) and exported to MS Word. Coding was done by two independent researchers and discussed with a third to reach consensus.

4.4.4 Ethical considerations

Ethical approval of the protocol for the study was given by the Faculty of Health Sciences Research Ethics Committee, University of Pretoria and the ministry of Health and Child Care in Zimbabwe. Applicable Helsinki guidelines on ethical considerations on research (40), adopted by the World Medical Association, involving human subjects, were observed. These include the protection of privacy of study participants, guaranteeing anonymity of participation by using codified household identities and confidentiality of the information shared.

Participation was voluntary without any rewards. Participants could choose to withdraw their consent at any time of the study without reprisal. They were informed about the essential elements of the research and understand the information. Participants were not exposed to physical harm (just responded to a questionnaire or attended focus groups). A consent document (Supporting material 4S.6) prepared from literature (40-42) was used to get informed consent.

4.5 Results

4.5.1 Demographic characteristics of survey respondents

Respondents were mainly female (74.3%) and married (89.5%). Approximately 50% of them fell between 36 and 55 years of age. Ethnicity was based on 12 groups dominated by the *korekore* ethno-linguistic group (62.5%). The ethnic category denoted 'other' consisted of nine small ethnic groups. Most of the respondents (71.4%) depended on the sale of garden or field crops to generate household monthly income of less than 50 USD in most households (79.2%). Ten of the demographic variables (Table 4.1) were significantly associated (*p*-values in bold) with the presence of a BVIP latrine at the household ($p < 0.05$).

Table 4.1 Demographic characteristics of respondents and households, Mbire district, Northern Zimbabwe, 2021, showing association with presence of a BVIP latrine (*n = 790*).

Variable	Categories	Count	%	Pearson χ^2-test	
				χ^2-test value	p-value
1. Sex	Female	587	74.3	0.022	0.881
	Male	203	25.7		
2. Marital status	Married	707	89.5	4.904	0.179
	Never married	62	7.8		
	Divorced	7	0.9		
	Widowed	14	1.8		
3. Age group (years)	18 - 25	129	16.3	6.774	0.148
	26 - 35	135	17.1		
	36 - 45	238	30.1		
	46 - 55	155	19.6		
	Greater than 55	133	16.8		
4. Highest educational level	No formal education	108	13.7	10.447	0.015
	Primary	505	63.9		
	Secondary	159	20.1		
	Tertiary	18	2.3		
5. Ethnicity	*Korekore*	494	62.5	5.394	0.145
	Chikunda	179	22.7		
	Foreign	15	1.9		
	Other	102	12.9		
6. Religion	Christianity	613	77.6	6.579	0.087
	Traditional	97	12.3		
	Muslim	18	2.3		
	None	62	7.8		
7. Main source of household income	Employed house head	19	2.4	17.476	0.002
	Sale of crops	564	71.4		
	Small-scale business	123	15.6		
	Paid labour	32	4.1		
	Other	52	6.6		
8. Approximate household monthly income (USD)	Less than 50	626	79.2	41.317	< 0.001
	50 - 100	98	12.4		
	101 - 200	50	6.3		
	Greater than 200	16	2.0		
9. Household size	Less than or equal to 2	63	8.0	5.393	0.067
	3 - 5	360	45.6		
	Greater than 5	367	46.5		
10. Nature of family	Nucleus	456	57.7	0.472	0.492
	Extended	334	42.3		

11. Number of cattle owned	None	625	79.1	9.814	0.020
	Less than or equal to 3	62	7.8		
	4 - 5	61	7.7		
	Greater than 5	42	5.3		
12. Functional TV set present	Yes	50	6.3	16.975	< 0.001
	No	740	93.7		
13. Brick-built house / Iron sheets-asbestos roof	Yes	624	79.0	20.886	< 0.001
	No	166	21.0		
14. Residence period of household /years	Less than 2	48	61.0	7.957	0.047
	2 - 10	233	29.5		
	11 - 20	226	28.6		
	Greater than 20	283	35.8		
15. Know any 3 sanitation options	Yes	402	50.9	24.471	< 0.001
	No	388	49.1		
16. Share latrine with neighbours	Yes	170	28.5	16.779	< 0.001
	No	426	71.5		
17. Enlisted for social support	Yes	482	61.0	4.087	0.028
	No	308	39.0		

Figures in bold denote significant differences ($p < 0.05$).

Using the Integrated Behavioural Model (IBM)-WASH framework (34) predictor variables used in the logistic regression model were categorised (Table 4.2).

Table 4.2 Predictor variables used in the model for latrine adoption using the IBM-WASH framework (34).

Level	Contextual factors	Psychosocial factors	Technology factors
Structural/Environmental			
Community			
Household	Household size, source of income, level of income family set up, number of cattle, residency period	Enlisted for social support	
Individual	For the responding house head: sex, marital status, age group For the male house head: educational level,ethnicity, religion	Knowledge of rural sanitation options	BVIP latrine is expensive
Habitual			

4.5.2 Determinants of BVIP latrine ownership among rural households

Significant determinants of household BVIP latrine ownership were one individual, five household and one technology-based variables (Table 4.3). A participating house head with knowledge of at least three on-site rural sanitation options (e.g., pit latrine, ventilated improved pit latrine, composting toilet, ecosan and flush toilet-septic tank) was significantly less likely to adopt BVIP latrine than one who did not know (OR = 0.493, $p < 0.001$, 95% CI = 0.337, 0.721). There was a significant decreasing likelihood of adopting a BVIP latrine by one who perceived it to be more expensive to construct than one who did not (OR = 0.087, $p < 0.001$, 95% CI = 0.028, 0.273). There was significant less likelihood of adopting a BVIP latrine by a household whose main source of income was paid labour than one with gainfully (self)-employed members (OR = 0.133, $p = 0.011$, 95% CI = 0.028, 0.628). Available evidence shows that increasing household income more than the reference significantly increased the likelihood of adopting a BVIP latrine, the odds being greatest at the highest income.

Having a household income greater than 200 USD was significantly 5.737 times more likely than less than 50 USD to construct a BVIP latrine (OR = 5.737, $p = 0.010$, 95% CI = 1.531, 21.504). There was greater significant likelihood of owning a BVIP latrine for a household with 4–5 cattle than one without (OR = 1.875, $p = 0.038$, 95% CI = 1.034, 3.400). A homestead that had no house built with fired bricks and cement or roofed with iron/asbestos sheets was significantly less likely to own a BVIP latrine than one built with them (OR = 0.455, $p = 0.002$, 95% CI = 0.275–0.755). A household with a residence period of >20 years in the village was significantly 2.883 times more to own a BVIP latrine than one with less than 2 years (OR = 2.883, $p = 0.021$, 95% CI = 1.172, 7.091).

Table 4. 3 Predictors of BVIP latrine ownership among rural households in Mbire district, northern Zimbabwe (n =790).

Predictor variable		Coeff	Wald Statistic	p-value	Odds Ratio	95% CI
Sex of house head (Male)	Female	0.136	0.402	0.526	1.145	0.753, 1.742
Marital status (widowed)	3 Categories		2.424	0.489		
Age group (18 - 25 years)	4 Categories		4.277	0.370		
Educational level (none)	3 Categories		1.133	0.769		
Ethnicity (*Korekore*)	3 Categories		4.860	0.182		
Religion (Christianity)	3 Categories		3.647	0.302		
Source of income (Self / Employed)						
Sale of garden/field crops		-0.881	2.505	0.114	0.414	0.139, 1.234
Small-scale business/trade		-1.003	2.986	0.084	0.367	0.118, 1.144
Paid labour		-2.014	6.503	**0.011**	0.133	0.028, 0.628
Other		-0.666	1.108	0.293	0.514	0.148, 1.776
Monthly HH income/USD (< 50)						
51- 100		0.614	5.123	**0.024**	1.848	1.086, 3.145
101 - 200		1.203	10.032	**0.002**	3.329	1.582, 7.006
> 200		1.747	6.716	**0.010**	5.737	1.531, 21.504
Household size (≤ 2)	2 Categories		3.773	0.152		
Family setup (Nucleus)	Extended	-0.147	0.558	0.455	0.863	0.587, 1.270
Number of cattle owned (None)						
≤ 3		0.226	0.509	0.476	1.253	0.674, 2.332
4 - 5		0.629	4.287	**0.038**	1.875	1.034, 3.400
> 5		0.122	0.098	0.754	1.129	0.527, 2.420
Nature of homestead (Yes)	No	-0.786	9.287	**0.002**	0.455	0.275, 0.755
Residence period/years (< 2)						
2 - 10		0.146	0.115	0.734	1.158	0.498, 2.693
11 - 20		0.239	0.275	0.600	1.271	0.520, 3.107
> 20		1.059	5.318	0.021	2.883	1.172, 7.091
Enlisted for social support (No)	Yes	-0.365	3.038	0.081	0.694	0.460, 1.046
Knowledge of rural sanitation technology options (No)	Yes	-0.707	13.304	**< 0.001**	0.493	0.337, 0.721
BVIP latrine is expensive (No)	Yes	-2.437	17.624	**< 0.001**	0.087	0.028, 0.273
Constant		0.146	0.009	0.922	1.157	

Figures in bold denote significant difference ($p < 0.05$)
Omnibus tests of model coefficients: Chi square (149.250; df = 37; $p < 0.001$)
Hosmer and Lemeshow test: Chi Square (5.258; df = 8; $p = 0.730$)
Overall model classification: 73.9%

4.5.3 Perceptions and practices of respondents on household sanitation

4.5.3.1. Sanitation facility at household

The commonest sanitation facility among households was the BVIP latrine (30.1%) (varying levels of completion and quality) followed by the traditional pit latrine (25.1%). About 23.9% of the BVIP latrines were upgradable versions (uBVIP latrines). The proportion of households without sanitation facilities was 24.6% (Fig. 4.3a).

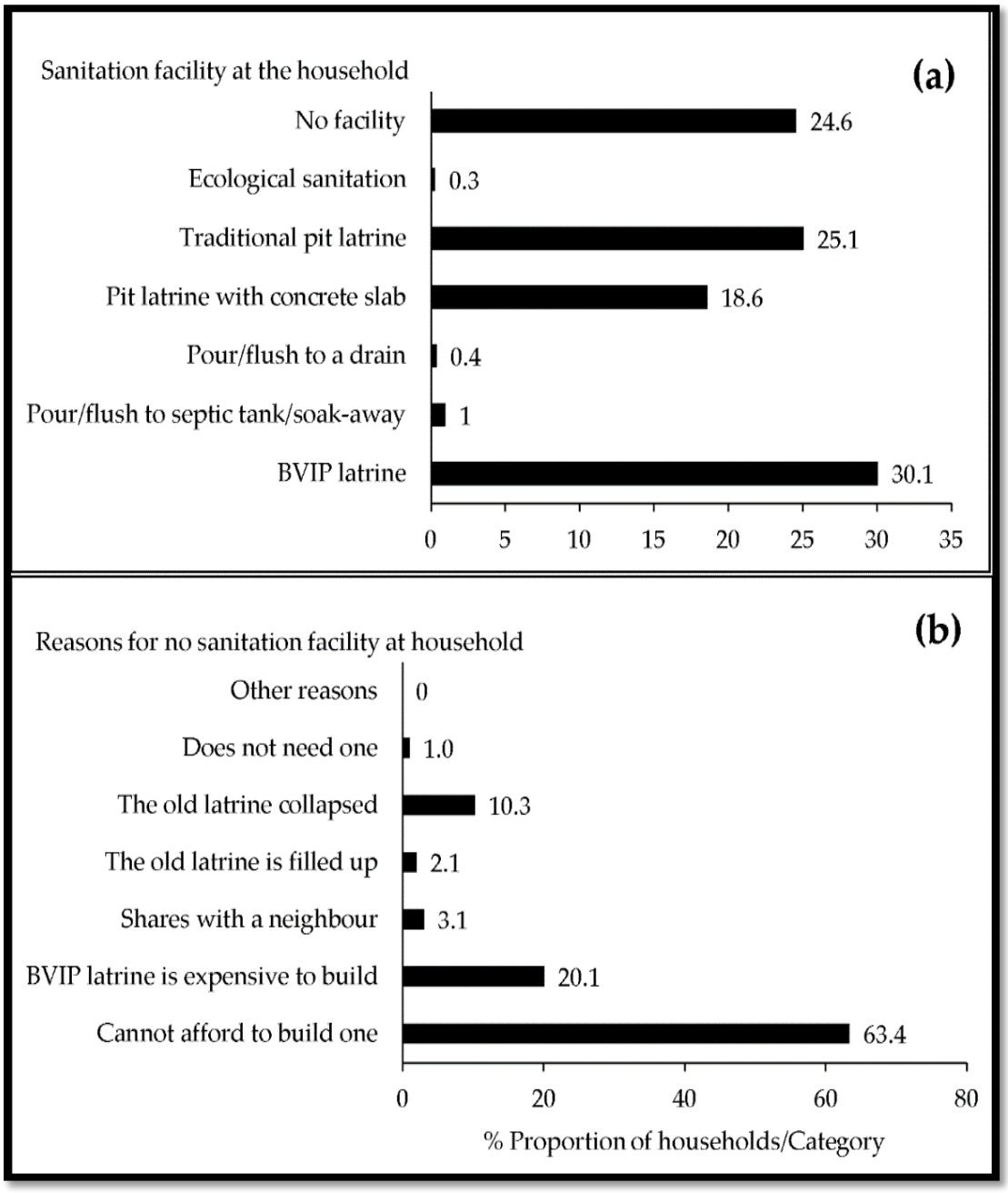


Fig. 4.3 Sanitation facility at the household (a) and reasons for lack of it (b) among rural households in Mbire District, northern Zimbabwe

The main reason (> 80%) for not having a household sanitation facility was lack of finance to construct one (Fig. 4.3b).

4.5.3.2 Access to a Household Latrine

Respondents reported that all household members accessed the available latrine (62.2%) irrespective of its design (Fig. 4.4a). However, others indicated that household members could access latrines at times (22.5%) or never (15.3%). This was due to various reasons (Fig. 4.4b). The main reason (57.5%) for lack of access was the presence of vulnerable groups of society (young children, the old and physically handicapped). Latrine design (42.9%) was a major barrier to access latrines. Those without access mainly contribute to open defaecation even with a latrine at home.

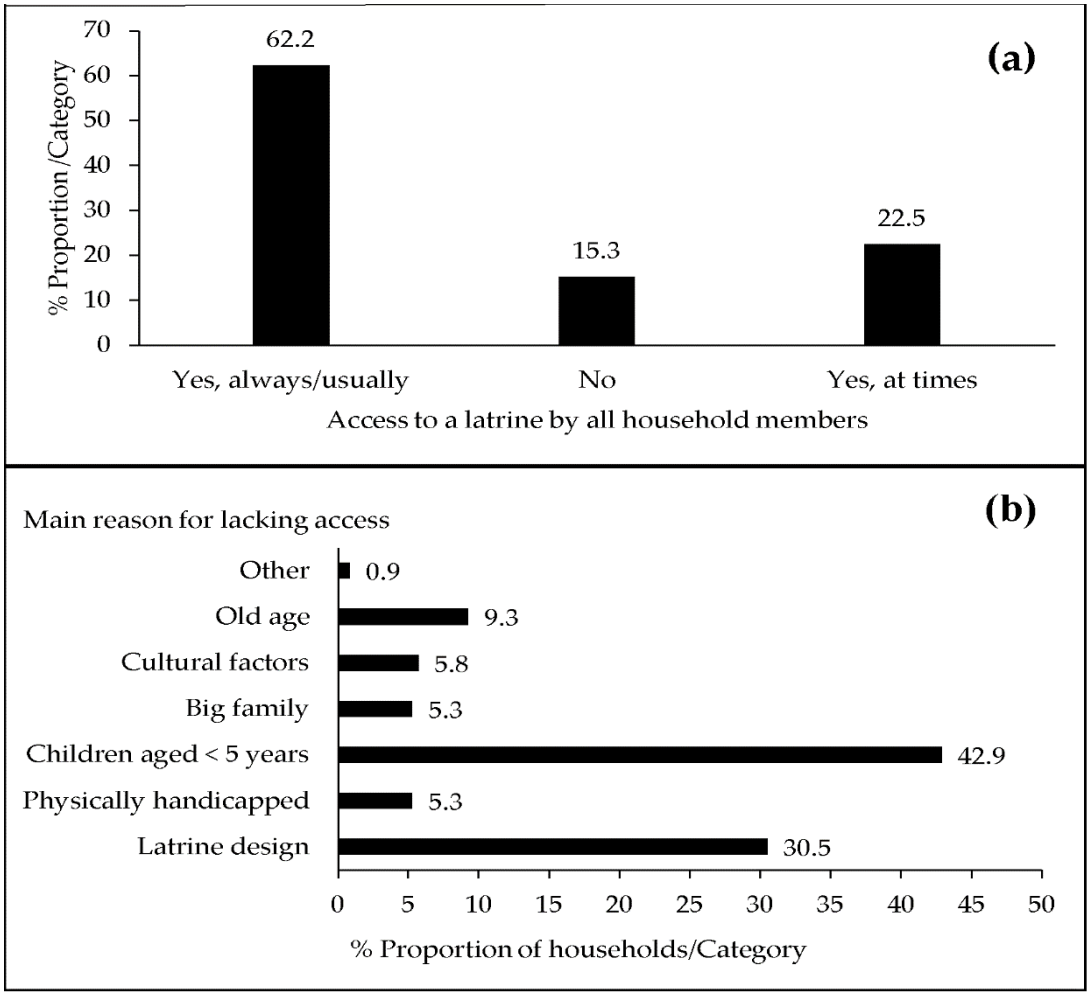


Fig. 4.4 Access to a household latrine (a) and reasons for lack of access (b) among rural households in Mbire district, northern Zimbabwe

4.5.3.3. Latrine references

Most households (69.5%) preferred the BVIP latrine while only a few (1.1%) opted for the traditional pit (1.1%) (Figure 5a). The reasons indicated for preferring a sanitation facility for the household over others were technology-based (Figure 5b). These included durability (27.2%), perceived health benefits (25.3%), hygiene (12.9%) and being user-friendly (11.0%). Only a few respondents (1.1%) preferred a sanitation facility for human excreta reuse opportunities

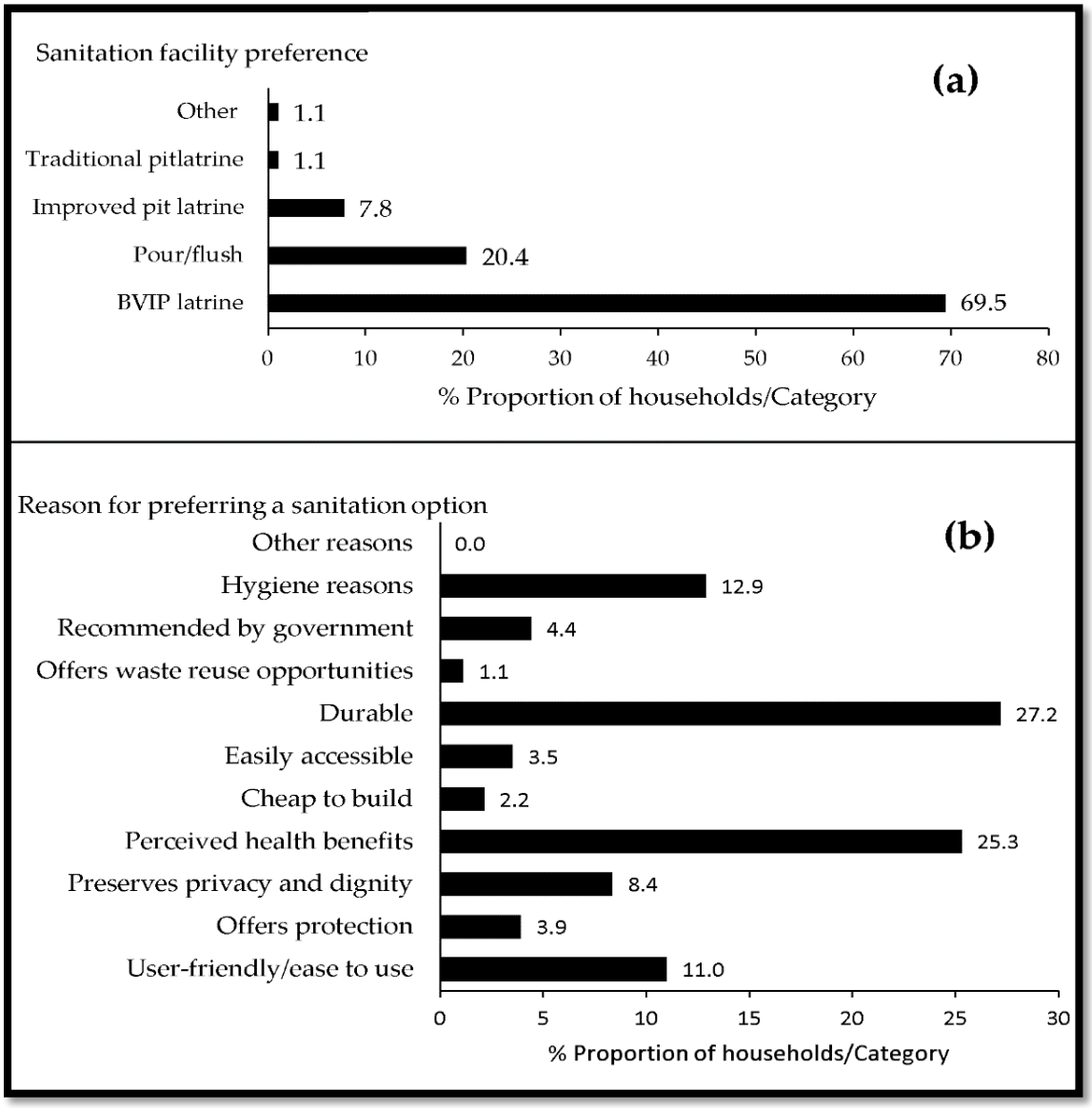


Fig. 4.5 Sanitation preferences among households (a) and reasons for sanitation preferences (b) in Mbire District, northern Zimbabwe (*n* = 790).

In Zimbabwean rural communities, human excreta is considered a waste (and nuisance) rather than a resource, and therefore not used for agriculture (particularly horticulture). Communities commonly use cow dung and decayed vegetative matter. Indirect wastewater reuse for irrigation of non-edible plants (e.g., lawns) is practised in urban environments.

4.5.3.4. Willingness to pay or take up loan for latrine construction or improvements

Respondents expressed their willingness to pay for the construction or improvement of their sanitation facilities (Fig. 4.6a). However, they indicated that since the BVIP latrine is capital-intensive, 39.2% of them suggested that they need micro-credit facilities (loans) which they will repay over time (Fig. 4.6b)

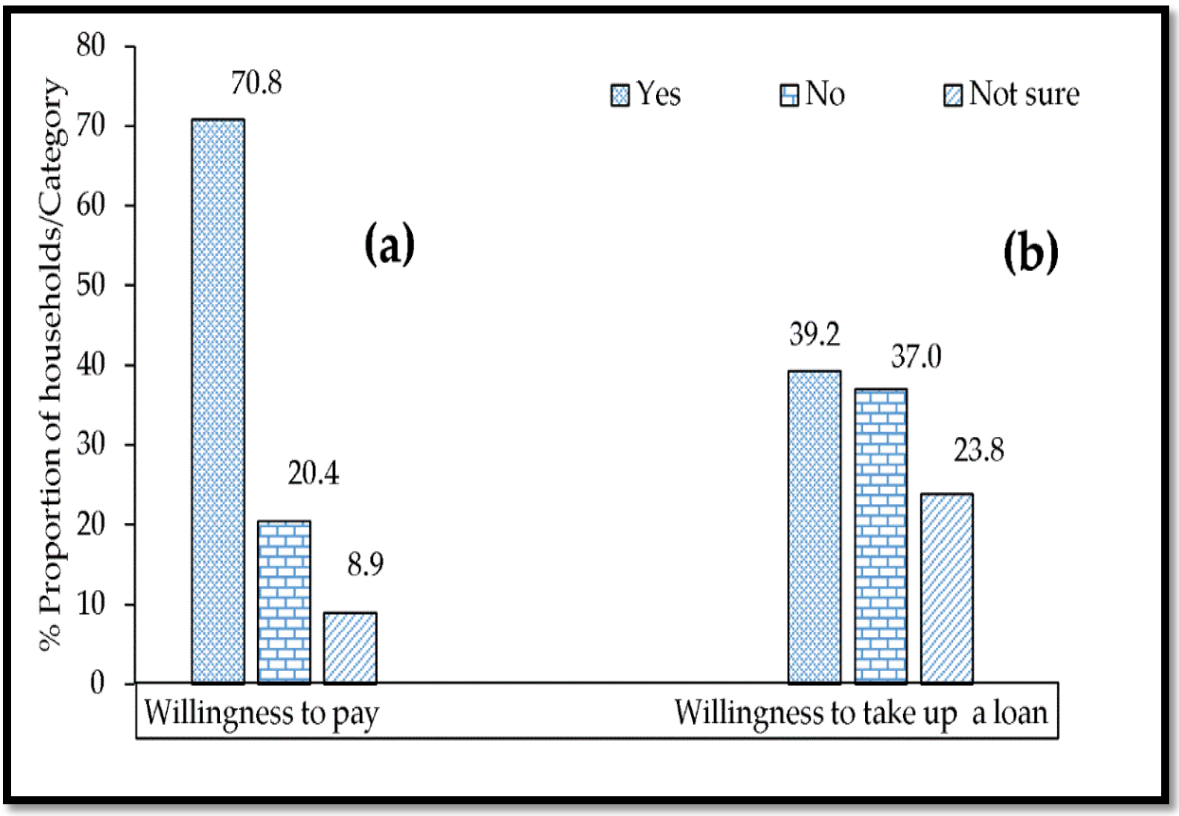


Fig. 4.6 Expression of willingness to pay (a) and willingness to take loan (b) for household latrine construction or improvement

4.5.4 Characteristics of participants in focus groups

Participants in focus groups were either a male or female house head of age above 18 years. Turnout was 72.2%. Twenty-one (53.8%) participants had post-primary education. Discussions were held within 83 minutes (68-83, average: 75.5 min) (Supplementary file 4S.7).

4.5.5 Shared Household Experiences with BVIP Latrines

Experiences shared on the adoption and use of the BVIP latrine were put into three main thematic areas with sub themes (Fig. 4.7). Some coping strategies to challenges presented by the latrine design were discussed.

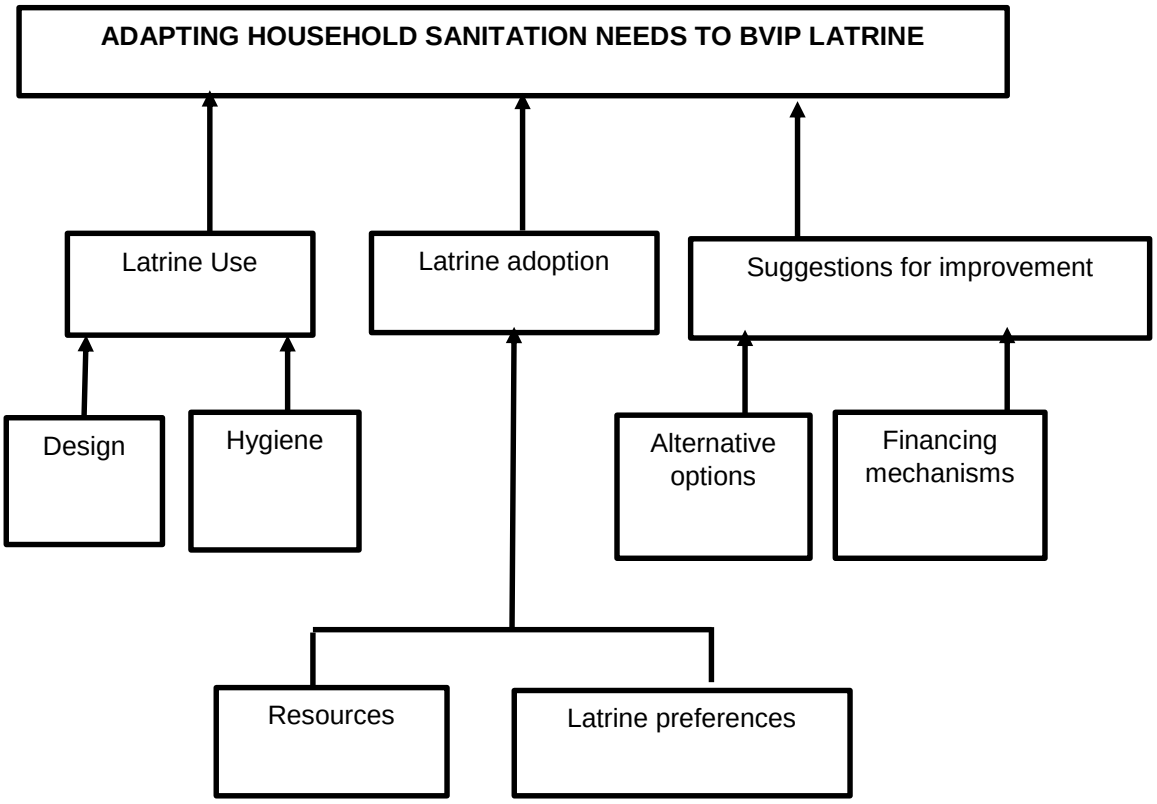


Fig. 4.7 Thematic areas for adapting household sanitation needs to BVIP latrine by households in Mbire District, northern Zimbabwe (6 Focus groups, *n* = 39)

The frequencies that categories were mentioned in the six focus groups are summarised in Fig. 4.8.

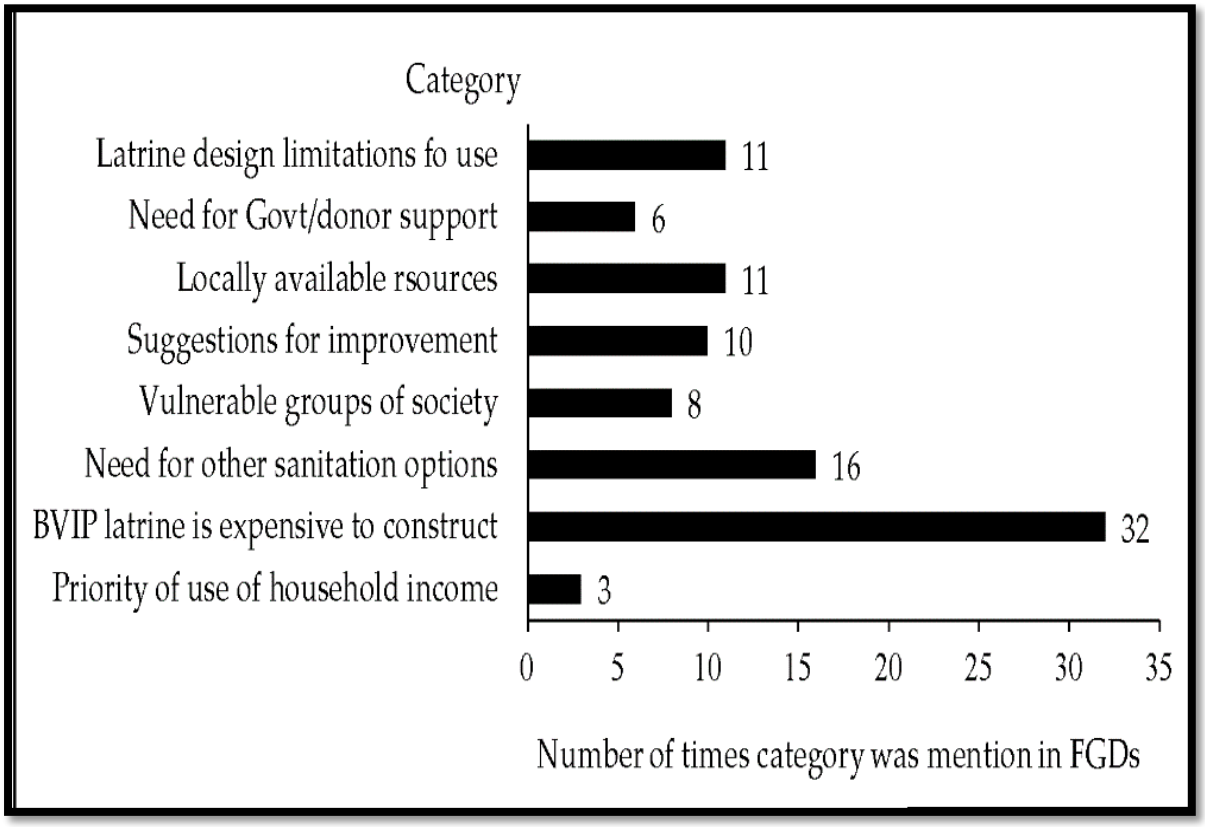


Fig. 4.8 Frequency of a category being mentioned in focus group discussions

4.5.6 Latrine adoption experiences

Participants from all FDGs expressed that the main barrier in adopting a BVIP latrine was its high cost of construction. The financial barrier (lack of money and priority of income use) was mentioned 32 times across the six focus groups. A female participant of 36-45 years of age group from ward 9* quizzed:

> "*A 50 kg bag of cement costs about 12 USD. A standard BVIP latrine needs 6–7 bags of cement. So we need to use 84 USD just to buy cement. What of paying for the builder's services, buying PVC, vent pipe, fly screen and reinforcement material for the concrete slab?*"

Poverty and poor agricultural yields appeared to put pressure on the little household income resulting in priority of use which did not favour latrine construction. A confident female participant from ward 9 (26-35 years of age group) explained:

> "*We have other things that need to be prioritised than building toilets... little to sell. We need to pay for school fees, food, clothes, and other issues that come first before the latrine. After all, we are hungry and do not have anything in our stomachs to empty into the latrines*".

Households try to reduce the cost of constructing a BVIP latrine by providing locally available resources. They also construct other latrine designs to meet their sanitation needs. A participant put it in this way:

> *". . . Although we can mould bricks, supply sand, concrete stones, water and dig the pits ourselves, we cannot buy cement, iron steel rods and PVC vent pipes to build the recommended BVIP latrine. We receive very little rainfall in our area over a short period. So we cannot build water-based latrines. The result is pit latrines with slabs made of logs and mud, and grass or plastic walls without roofs. Most people end-up using the bush*"
>
> (Ward 5, Female, 26-45 years of age group).

In some cases, communities identify vulnerable groups of society and assist them towards having their own BVIP latrines. An elderly female participant greater than 55 years of age from ward 15 remarked:

> "*In some villages, the elderly get assistance from the village for pit digging, supply of water, concrete stones and river sand for the construction of a BVIP latrine. This help can be extended to free latrine construction. If there are relevant interventions, the elderly are the first to receive assistance including a completed latrine...*"

It was indicated that women were not much involved in making decisions on latrine construction. Even if the household gets some income, how it will be used mainly depended on the male house head. A participant noted:

> "*The father has the final say in the sale of goats and cattle, and what to use the money for, whether building a latrine or not. Mothers are not empowered to make such decisions in the home. What we can do* ..."
>
> (W 9*, Female, 36-45 years of age group).

Apart from high construction cost, environmental issues present further challenges for the adoption of a BVIP latrine. The study area mainly has sandy soil. Other households live in rocky places or low-lying areas with high water tables. A concerned young male participant (26-35 years of age) from ward 5 said with displeasure:

> "*A number of BVIP latrines have collapsed … I think this is to do with the sandy soils we have in our area. This is observed especially during the rainy season. If we can have other latrine types*"

Latrines which did not collapse may have their pits float or overflow with faecal matter, especially during the rainy season: A female participant of greater than 45 years of age from ward 9 had this to say:

> "*The pits are filled with water in the rainy season allowing faecal matter to be near the surface of the pit. This results in family members not using the latrine. Also, houseflies can move in and out of the pit freely. This allows diarrhoeal outbreaks.*"

4.5.7 Latrine use

For those who managed to build BVIP latrines, they had to develop coping strategies to overcome challenges associated with bad smell (odour control), fly nuisance (fly control), unhygienic environment and household social issues.

Some simple strategies were described by a male participant from ward 10 as follows:

". . . temperature is very high, household members can bath in the latrine to reduce strong odour by reducing temperature. Alternatively, they can add wood ash into the pit"

(36-45 years of age group).

Households developed coping strategies such as latrine sharing and constructing alternative options so that they meet their sanitation needs:

"*When BVIP latrines collapse or are inaccessible, households can share with neighbours*" (Ward 1, Male, 36-45 years of age group).

"*In situations where sharing of latrines is not a viable option, household members end up using the bush*" (Ward 10, Female, 36-45 years of age group).

The use of alternative sanitation options was mentioned 16 times across all focus groups. With a disapproving countenance, a male participant (36-45 years of age group) from ward 10 had this to say:

"*Construction of the BVIP latrine needs trained experienced builders. They charge high fees … In a similar survey which I was involved in, people expressed dissatisfaction with the BVIP latrine for its high cost proposing to resort to the traditional pit latrine with a slab made of wooden logs and mud*."

Restrictions to latrine use at the household level based on socio-cultural practices were reported. A female participant from ward 1 explained;

"*The latrine may not be suitable for an extended family where in-laws are staying together. Although very few households still practise this culture, health education is removing such taboos*"

(26-35 years of age group).

4.5.8 Suggestions to improve rural sanitation services

Participants suggested financial investments into rural sanitation for increased BVIP latrine adoption or to consider alternative technology options. This was suggested 13 times across focus groups, for example:

> "*We also need to try other latrines other than the BVIP latrine since most people cannot afford it. People need latrines but they cannot afford the BVIP latrine encouraged by environmental health technicians and village health workers. This is why we have a lot of traditional pit latrines and others still using the bush. If we have to construct the BVIP latrine only, then we have to get donors coming in*"
>
> (Ward 10, Male, 36-45 years of age group).

> *" … There can be options of using other cheaper latrines if they are allowed by our EHTs. Or we are given materials or money by donors to build BVIP latrines and government pay for builders. If that is not done, we end up building other latrine designs which we can afford. We can also end up using the bush as a last resort"*
>
> (Ward 15, Female, 36-45 years of age group).

4.6 Discussion

The conventional BVIP latrine design is perceived to have health and non-health benefits. Its cost of construction is beyond the reach of many poor rural households. Although locally available resources may be used to reduce its original cost (43), it remains unaffordable. Therefore, the conventional BVIP latrine is not a pro-poor sanitation option. Failure to construct it resulted in households opting for alternative sanitation options (improved or not), sharing latrines (limited access) with neighbours or open defaecation to meet their sanitation needs.

Reported and observed resultant behaviour after failing to construct a conventional BVIP latrine agrees well with results of a sanitation intervention in Malawi in which a low-cost household corbelled latrine design was implemented. Some households did not adopt it, others opted for open defaecation or shared with neighbours (10). Further, a qualitative study in eastern rural Zambia attributed lack of latrines at households due to the convenience of sharing existing ones with neighbours (44). The quantitative part of the current study indicated that most respondents (97.1%) cited high construction cost of the BVIP latrine as the main barrier to adopting it. Results from the qualitative study justified the high financial requirement for cement, reinforcement material, PVC, fly screen and payment of builders. The observed behaviour prompts the need for research on pro-poor sustainable sanitation technology options and behaviour change strategies that are context-specific, an equity and inclusion policy principle outlined in the 2017 sanitation and hygiene policy draft of Zimbabwe (16).

A systematic review on open defaecation in Ethiopia (45) indicated that incomplete and poorly built latrines as well as financial limitations were associated with the practice. In a separate study, open defaecation was reportedly associated with an ethnic group due to taboos with in-laws and grown-up children of the opposite gender (44). In the current study where an ethnic group is dominant, social taboos which influence latrine adoption and use were mentioned but reportedly being removed by hygiene education. Open defaecation has health, social and psychological impacts on humans (46). It also contaminates drinking water sources with microbial pathogens (47).

Results indicated low and very low uptake of BVIP and uBVIP latrines. Individual level demographic information of house heads (sex, age, marital status, educational level, ethnicity and religion) were not significant determinants of latrine ownership in the current study. This is contrary to some earlier reports from similar studies where the educational level of the responding house head was a significant determinant of latrine ownership (48-50). Households from the current study constantly receive informal education from local EHTs on the BVIP latrine. Further, despite the educational level of the house head, having a child attending school was shown to be associated with latrine adoption (51). However, this predictor variable was not investigated in the current study.

Ethnicity and religion were found as non-significant determinants of latrine adoption. However, their inclusion in sanitation planning remains important considering large proportion of religious households in communities (e.g., 79.9% in the current study) and socio-cultural beliefs of dominant ethnic groups (e.g., 62.5% *korekore* in the current study). Further, these two variables greatly vary with geographical areas. The *Hindu* in sub-national regions of Bangladesh, India and Nepal perform certain rituals of purity which discourage having latrines in close proximity to one's home, promoting open defaecation (52). Knowledge of alternative sanitation options was a significant determinant of BVIP latrine ownership. However, this knowledge was relatively limited among responding house heads (50.9%).

Perceiving the BVIP latrine as expensive to construct was a significant determinant of latrine ownership. This agrees with a report by Hirai and others (49) in a study of six districts of rural Indonesia but using different latrine options. The perception was based on the fact that households were poor and had low monthly incomes.

Ownership of an improved latrine by a poor household could be possible through government subsidies, considering alternative affordable options or microcredit financing mechanisms as households expressed high willingness to pay and take up microcredits for latrine construction or improvements. Subsidies and microcredit financing would require intensive national finance investments, quite unlikely in the current harsh economic environment, unless private micro-financing institutions consider investing in rural sanitation, a seemingly untapped opportunity. This leaves 'alternative sanitation designs' as a viable option when supported by the rural sanitation policy.

Source of household income and monthly income level, and owning cattle were significant determinants of latrine ownership in the study. Study households were poor subsistence farmers with very little surplus to sell to earn less than 50 USD and most of them had no cattle. High climate variability in the Zambezi basin (53) and poor soil in the study area do not guarantee high crop yields. Ownership of improved latrines was reportedly associated with high income households (54), and poverty with open defaecation (55). Few households which opted for the uBVIP latrine ended up with incomplete latrines or poorly built designs which were reported to promote open defaecation (50). Other than the presence of, and accessibility to, a latrine, the quality and other positive attributes sought by the target populations should be considered (56).

Focus groups showed that the little monthly household income had other priority uses than latrine construction. Further, female house heads appeared to have no decision-making autonomy on household spending of income for large projects such as latrine construction.

Similar results were reported in a study of women's role in sanitation decision making in rural India (57). Latrine ownership is considered of lower priority than spending household income for school fees, food, transport and healthcare (56). Further, results indicated lower odds of latrine ownership by a household without a house built with fired bricks and cement or one roofed with asbestos/iron sheets than one with them. This may imply that households would buy cement to build their houses than latrines, favouring a more comfortable living home than an excreta disposal facility.

This study has shown that households have latrine preferences. The low household income has other competing priority uses, not latrine construction. Households would improve their homes before investing in latrine construction. While they are poor, the BVIP latrine is unaffordable. Incomplete uBVIP remained pit latrines with concrete slabs, denying them odour and housefly control benefits of the conventional BVIP latrine which influence use. Households would rather construct alternative sanitation options, practise open defaecation or share latrines with neighbours. The high willingness to pay and take up loans to construct or improve latrines may demonstrate existing sanitation demand, an opportunity to consider other sanitation options for equity and universal access by 2030.

From the qualitative study suggestions for improvement in the provision of rural sanitation services were to consider alternative options and investment financial mechanisms. Although the BVIP latrine was considered not financially sustainable, a compound index considering sustainability criteria, sustainability index (58)] can be used to evaluate its sustainability in comparison to alternative sanitation options before implementation. The index may be useful when policy makers and other key stakeholders want to select an appropriate sanitation technology for a community.

4.7 Limitations of the study

We assumed that long-term (over 30 years) behaviour (practice) exhibited without a recent targeted intervention was sustained behaviour. Results relied on self-reported data and observation spot checks. However, the survey was triangulated with a qualitative study. The studied district has particular context-specific sanitation variables such as ethnicity and religion which may not be generalisable to other districts in the country and other countries. Only completed BVIP latrines built as upgradable designs were considered as uBVIP latrines. Operational uBVIP latrines under construction were considered pit latrines with slabs as their completion of construction was not guaranteed. This conservative approach could potentially reduce the number of upgradable latrines.

4.8 Conclusions

A Zimbabwean district was used as a case study to show how rural communities adapt sanitation needs to a national sanitation technology design under lower middle-income settings. A one-size-fits-all sanitation technology is not a solution to the needs of rural households in multicultural and diverse environments. Alternative latrine designs may meet various latrine user preferences. When upgradable models are not completed, they remain operating as pit latrines without realising the intended odour and fly control benefits of the BVIP latrine design. The BVIP latrine is unaffordable by many rural households. Huge national financial investments are needed as a pro-poor strategy to increase latrine uptake. Alternatively, appropriate sanitation technology options can be selected and piloted under local contextual settings for potential uptake. However, the adoption of new sanitation options by households has its own challenges to be addressed through future research.

4.9 Institutional review board statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Faculty of Health Sciences Research Ethics Committee of University of Pretoria (protocol code 662/2019, 24/10/2019) and the Ministry of Health and Child Care in Zimbabwe.

References

1. United Nations [UN)] United Nations sustainable development summit, 25-27 September 2015. New York: UN; 2015. Sustainabledevelopment.un.org/post2015/summit [Accessed 11 February 2021].
2. Mara D, Lane J, Scott B, Trouba, D. Sanitation and health. *PLoS Med*. 2010; 7:e1000363.
3. Freeman MC, Garn JV, Sclar GD, Boisson S, Medlicott K, Alexander KT, Penakalapati G, Anderson D, Mahtani AG, Grimes JET, et al. The impact of sanitation on infectious disease and nutritional status: A systematic review and meta-analysis. *Int J Hyg Environ Health*. 2017; 220:928-949.
4. World Health Organization; United Nations Children's Fund [WHO/UNICEF]. Progress on Sanitation and Drinking Water-2015 Update and MDG Assessment. Geneva: WHO; 2015. http://files.unicef.org/publications/files/Progress_on_Sanitation_and_Drinkin Water_2015_Update_.pdf. [Accessed 16 January 2021].
5. Satterthwaite D. Missing the millennium development goal targets for water and sanitation in urban areas. *Environ. Urban.* 2016; 28:99-118.

6. United Nations Development Programme [UNDP]. From MDGs to Sustainable development for All: lessons learnt from 15 years of practice; New York: UNDP; 2016. https://www.undp.org/content/undp/en/home/librarypage/sustainable-development-goals/from-mdgs-to-sustainable-development-for-all.html. [Accessed 14 February 2020].
7. United Nations [UN]. Sustainable Development Goal synthesis report 2018 on water and sanitation. New York: UN; 2018. https://www.unwater.org/publication_categories/sdg-6-synthesis-report-2018 on-water-andsanitation/. [Accessed 11 February 2020].
8. Martin NA, Hulland KRS, Dreibelbis R, Sultana F, Winch PJ. Sustained adoption of water, sanitation and hygiene interventions: Systematic review. *Trop Med Int Health*. 2018; 23: 122-135.
9. Legge H, Halliday KE, Kepha S, Mcharo C, Witek-McManus SS, El-Busaidy H, Muendo R, Safari T, Mwandawiro CS, Matendechero SH, et al. Patterns and divers of household sanitation access and sustainability in Kwale County, Kenya. *Environ Sci Technol.* 2021; 55:6052-6064.
10. Holm R, Tembo M, Njera D, Kasulo V, Malota M, Chipeta W, Singini W, Mchenga J. Adopters and non-adopters of low-cost household latrines: A study of corbelled pit latrines in 15 districts of Malawi. *Sustainability*. 2016; 8:917.
11. Simiyu S. Preference for and characteristics of an appropriate sanitation technology for the slums of Kisumu, Kenya. *Int J Urban Sustain Dev*. 2017; 9:300-312.

12. Turrén-Cruz T, García-Rodríguez JA, Peimbert-García RE, Zavala MAL. An approach incorporating user preferences in the design of sanitation systems and its application in the rural communities of Chiapas, Mexico. *Sustainability*. 2020; 12:1024.
13. Routray P, Schmidt W-P, Boisson S, Clasen T, Jenkins MW. Socio-cultural and behavioural factors constraining latrine adoption in rural coastal Odisha: An exploratory qualitative study. *BMC Public Health*. 2015; 15:880.
14. Garn JV; Sclar GD, Freemana MC, Penakalapati G, Alexander KT, Brooks P, Rehfuess EA, Boisson S, Medlicott KO, Clasen TF. The impact of sanitation interventions on latrine coverage and latrine use: A systematic review and meta-analysis. *Int J Hyg Environ Health*. 2017; 220:329-340.
15. Sinha A. Corey L, Nagel CL, Schmidt WP, Torondel B, Boisson S, Routray P, Clasen TF. Assessing patterns and determinants of latrine use in rural settings: A longitudinal study in Odisha, India. *Int J Hyg Environ Health*. 2017; 220:906-915.
16. Government of Zimbabwe [GoZ]. The Zimbabwe national sanitation and hygiene policy draft; National Action Committee for rural water supply and sanitation: Harare, GoZ; 2017.
17. Robinson A. VIP Latrines in Zimbabwe: From local innovation to global sanitation solution; Field note/WSP, No. 4. Nairobi: Water and Sanitation Programme, African Region; 2002.
18. Morgan P. Zimbabwe's Rural Sanitation Programme: An overview of the main events. Harare: Aquamor; 2006.
19. Mukandavire Z, Liao S, Wang J, Gaff H, Smith DL, Morris JG. Estimating the reproductive numbers for the 2008-2009 cholera outbreaks in Zimbabwe. *Proc Natl Acad Sci USA*. 2011; 108:8767-8772.

20. Government of Zimbabwe [GoZ]. The Blair VIP latrine: A builder's manual for the upgradeable BVIP model and a hand washing device. Harare: National Action Committee for rural water supply and sanitation draft: 2011.
21. Water and Sanitation Programme [WSP]. Water supply, sanitation in Zimbabwe: turning finance into services for 2015 and beyond; An AMCOW country status overview. Nairobi: WSP; 2011.
22. Government of Zimbabwe [GoZ]. National water policy; Ministry of Water Resources Development and Management. Harare: GoZ; 2012.
23. Morgan P. The Blair VIP toilet: Manual for the upgradeable BVIP model with spiral superstructure and tubular vent pipe. Harare: Aquamor; 2011.
24. Zimbabwe National Statistics Agency [ZimStat]. Mashonaland Central Province district population projections report; District population projections. Harare: ZimStat; 2020. https://www.zimstat.co.zw/wpcontent/uploads/publications/Population/population/District-Projections/District-Population-Projection-Report-Mashonalandcentral. pdf. [Accessed 3 June 2021].
25. Zimbabwe Vulnerability Assessment Committee [ZimVAC]. Annual update on rural livelihoods 2019 report. Harare: Food and Nutrition Council; 2019.
26. Zimbabwe Vulnerability Assessment Committee [ZimVAC]. Annual update on rural livelihoods 2020 report. Harare: Food and Nutrition Council; 2020.
27. Zimbabwe National Statistics Agency. Zimbabwe Poverty Report 2017; Harare: ZimStat; 2019.
28. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? *Indian J Psychol Med*. 2013, 35:121-126.

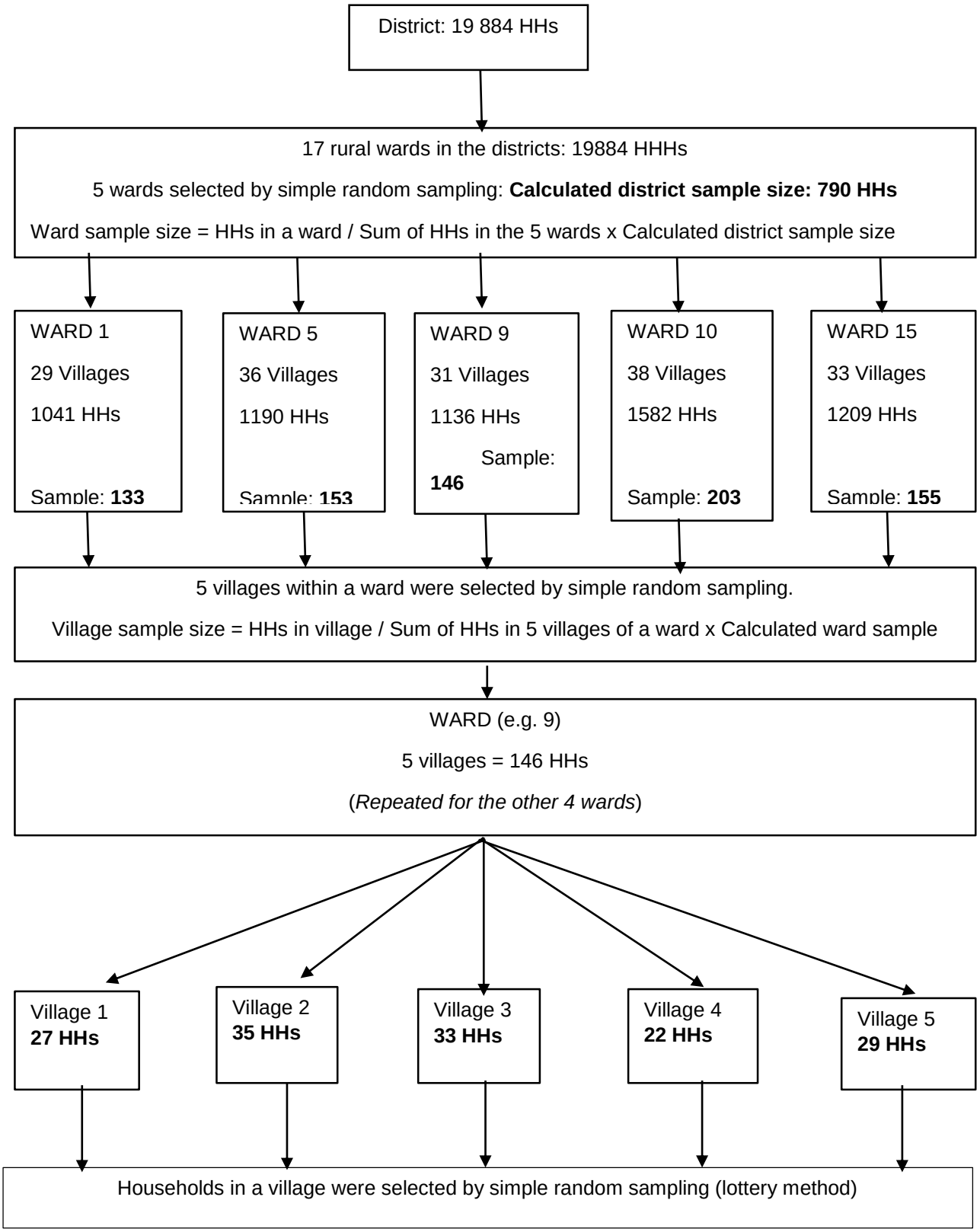
29. Berhe AA, Aregay AD, Abreha AA, Aregay AB, Gebretsadik AW, Negash DZ, Gebreegziabher EG, Demoz KG, Fenta KA, Mamo NB. Knowledge, attitude, and practices on water, sanitation, and hygiene among rural residents in Tigray region, northern Ethiopia. *J Environ Public Health*. 2020; 5460168:1-9.
30. World Health Organization; United Nations Children's Fund [WHO/UNICEF]. Core questions on drinking water and sanitation for household surveys. Geneva: WHO; 2006.
31. Zimbabwe Demographic and Health Survey [ZDHS]. Zimbabwe Demographic and Health Survey 2015 Final Report. Harare: ZimStat; 2016
32. Nyumba TO, Wilson K, Derrick CJ, Murkejee N. The use of focus group discussion methodology: Insights from two decades of application in conservation. *Method Ecol Evol*. 2018; 9:20-32.
33. Rothwell E, Anderson R, Botkin JR. Deliberative discussion groups. *Qual Health Res.* 2016; 26:734-740.
34. Dreibelbis R, Winch PJ, Leontsini E, Hulland KRS, Ram PK, Unicomb L. The integrated behavioural model for water, sanitation, and hygiene: A systematic review of behavioural models and a framework for designing and evaluating behaviour change interventions in infrastructure-restricted settings. *BMC Public Health*. 2013; 13:101529.
35. IBM SPSS Statistics for Windows, Version 21. Armonk: NY, IBM Corporation; 2012.
36. Stata Statistical Software; Release 16. College station, TX, USA: StataCorporation LLC; 2019.
37. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. 2006; 3:77-101.

38. Maguire M, Delahunt B. Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISH J.* 2017; 9:3351-3364.
39. NVivo, Version 12. Melbourne, Australia: QSR International Pty Ltd; 2019.
40. Couper MP, Singer E. The role of numeracy in informed consent for surveys. *J Empir Res Ethics*. 2009; 4:17-26.
41. Fischer BA. A summary of important documents in the field of research ethics. *Schizoph Bull*. 2006; 32:69-80.
42. Länsimies-Antikainen H, Laitinen T, Rauramaa R, Pietilä A-M. Evaluation of informed consent in health research: A questionnaire survey. *Scand J Caring Sci*. 2010; 24:56-64.
43. Keraita B, Jensen PKM, Konradsen F, Akple M, Rheinländer T. Accelerating uptake of household latrines in rural communities in the Volta region of Ghana. *J Water Sanit Hyg Dev*. 2013; 3:26-34.
44. Thys S, Mwape KE, Lefèvre P, Dorny P, Marcotty T, Phiri AM, Phiri IK, Gabriël S. Why latrines are not used: Communities' perceptions and practices regarding latrines in a *Taenia solium* endemic rural area in eastern Zambia. *PLoS Negl Trop Dis*. 2015; 9:e0003570. 45.
45. Abebe TA, Tucho GT. Open defecation-free slippage and its associated factors in Ethiopia: A systematic review. *Syst Rev*. 2020, 9:252.
46. Saleem M, Burdett T, Heaslip V. Health and social impacts of open defecation on women: A systematic review. *BMC Public Health*. 2019; 19:158.
47. Okullo JO, Moturi WN, Ogendi GM. Open defaecation and its effects on the bacteriological quality of drinking water Sources in Isiolo County, Kenya. *Environ Health Insights*. 2017; 11:1-8.

48. Coffey D, Spears D, Vyas S. Switching to sanitation: Understanding latrine adoption in a representative panel of rural Indian households. *Soc Sci Med*. 2017, 188, 41-50.
49. Hirai M, Kelsey A, Mattson K, Cronin AA, Mukerji S, Graham JP. Determinants of toilet ownership among rural households in six eastern districts of Indonesia. *J Water Sanit Hyg Dev*. 2018; 8:533-545.
50. Busienei PJ, Ogendi GM, Mokua MA. Latrine structure, design, and conditions, and the practice of open defecation in Lodwar town, Turkana County, Kenya: A quantitative methods research. *Environ Health Insights*. 2019; 13:1-11.
51. Alemu F, Kumie A, Medhin G, Gasana J. The role of psychological factors in predicting latrine ownership and consistent latrine use in rural Ethiopia: A cross-sectional study. *BMC Public Health*. 2018; 18:229.
52. Vyas V, Spears D. Sanitation and religion in South Asia: What accounts for differences across countries? *J. Dev Stud*. 2018; 54:2119-2135.
53. Banze F, Guo J, Xiaotao S. Variability and trends of rainfall, precipitation and discharges over Zambezi river basin, southern Africa. *Review Int J Hydrog*. 2018; 2:137-140.
54. Kema K, Semali I, Mkuwa S, Kagonji I, Temu F, Ilako F, Mkuye M. Factors affecting the utilisation of improved ventilated latrines among communities in Mtwara rural district, Tanzania. *Pan Afr Med. J*. 2012, 13:4.
55. Njuguna J. Progress in sanitation among poor households in Kenya: Evidence from demographic and health surveys. *BMC Public Health*. 2019; 19:135.
56. O'Connell K. What Influences open defaecation and latrine ownership in rural households? Findings from a Global View; International Bank for Reconstruction and Development. Washington DC: The World Bank; 2014.

57. Routray P, Torondel B, Clasen T, Schmidt W-P. Women's role in sanitation decision making in rural coastal Odisha, India. *PLoS ONE*. 2017, 12:e0178042.
58. Hashemi, S. Sanitation sustainability index: A pilot approach to develop a community-based indicator for evaluating sustainability of sanitation systems. *Sustainability*. 2020; 12:6937.

Supporting material 4S.1 Multistage sampling of households for Mbire district survey, northern Zimbabwe, 2021



Supporting material 4S.2 Summary of selected households for Mbire district survey, Zimbabwe, 2021

Ward			No. of households sampled in selected villages					Selected households/ ward	
Code	Households	Villages	Village 1	Village 2	Village 3	Village 4	Village 5	Number	%
1	1 041	29	25 (36)	29 (41)	19 (28)	33 (47)	27 (39)	133	12.78
5	1 190	36	28 (38)	32 (43)	25 (34)	37 (49)	31 (41)	153	12.86
9	1 136	31	27 (33)	35 (44)	33 (41)	22 (28)	29 (36)	146	12.85
10	1582	38	51 (57)	44 (49)	39 (44)	37 (41)	32 (36)	203	12.83
15	1209	33	36 (48)	31 (41)	34 (45)	30 (39)	24 (31)	155	12.82
Total	6158	167						790	12.83

HH – Household
Number in parentheses ( ) for a village is the number of households in that village

Supporting material 4S.3 Questionnaire for Mbire district, Zimbabwe, 2021

. Questionnaire ID

Adapting sanitation needs to a BVIP latrine (and its upgradable models): a mixed method study under lower middle-income rural settings

Ward: …….. Village: ……. Date: ……

[Institutional and researcher details were purposively removed]

Introduction [On attached Informed consent document]

Instruction
Indicate your response for each by encircling the response number corresponding to your choice.

1. Sex of responding house head	1. Male 2. Female
2. Marital status	1. Married 2. Never married 3. Divorced 4. Widowed
3. Age group (years)	1. 18-25 2. 26-35 3. 36-45 4. 46-55 5. > 55
4. Highest formal educational level	1. None 2. Primary 3. Secondary 4. Tertiary
5. Ethnicity	1. *Korekore* 2. *Chikunda* 3. Foreign 4. Other
6. Religion	1. Christianity 2. Traditional 3. Muslim 4. None 99. Other *If other, please specify*……
7. Main source of household Income	1. Employed member 2. Sale of crops 3. Small-scale business 4. Paid labour 99. Other *If other, please specify* ……
8. Approximate household monthly income (USD)	1. Less than 50 2. 50-100 3. 101-200 4. Greater than 200
9. Household size	1. Less than or equal to 2 2. 3-5 3. Greater than 5
10. Nature of family	1. Nucleus 2. Extended
11. Number of cattle owned	1. None 2. Less than or equal to 3 3. 4-5 4. Greater than 5
12. Brick-built OR iron/asbestos sheets-roofed house	1. Yes 2. No
13. Residence period of household (years)	1. Less than 2 2. 2-10.9 3. 11-20 4. Greater than 20
14. Know 3 sanitation options	1. Yes 2. No
15. Share latrine with neighbours	1. Yes 2. No
16. Enlisted for social support	1. Yes 2. No
17. Presence of functional TV set	1. Yes 2. No
	1. Pour/flush to septic tank/soak-away 2. Pour/flush to a drain

18. Sanitation facility at the household	3. Pit latrine with a concrete slab 4. Traditional pit latrine 5. Ecological sanitation 6. No sanitation facility 99. Other *If other, please specify* ……..……
19. Reason for absence of sanitation facility	1. Cannot afford to build one 2. BVIP latrine is expensive to build 3. Shares with a neighbour 4. The old latrine is filled up 5. The old latrine collapsed 99. Other *If other, please specify*……..…….
20. Latrine preference for the Household	1. BVIP latrine 2. Pour/lush-septic tank/soak-away 3. Improved pit latrine 4 .Traditional pit latrine 99. Other *If other, please specify* ……..
21. Main reason for latrine Preference	1. User-friendly/ease to use 2. Offers protection 3. Preserves privacy and dignity 4. Health benefits 5. Cheap to build 6. Easily accessible 7. Durable 8. Offers waste reuse opportunities 9. Recommended by gvt 10. Hygiene reasons 99. Other *If other, please specify*……..……
22. All household members access the sanitation facility	1. Yes always/usually 2. No 3. Yes, at times
23. Main reason for lack of access to a sanitation facility	1. Latrine design 2. Physically handicapped 3. Young children (< 5) 4..Cultural factors 5. Big family 6. Old age (> 70) 99. Other *If other, please specify*: …….....
24. Willingness to pay for sanitation facility construction/improvement?	1. Yes 2. No 3. Not sure
25. Willingness to take up loan (microcredit) for latrine construction/improvement?	1. Yes 2. No 3. Not sure

Supporting material 4S.4 Focus group discussion guide

[Institutional and researcher details were purposively removed]

Adapting sanitation needs to a BVIP latrine (and its upgradable models): a mixed method study under lower middle-income rural settings

1. Introduction [Not more than 30 minutes]

1.2. Self-introduction (facilitator) and assistant: Thanking participants for coming

1.3. Introduction of the study:

- Purpose and how participants were recruited
- Expected duration, use of information collected
- Setting ground rules: how participants will response, no wrong/correct answers
- Discussions will be audio-recorded

1.4 Self-introductions of participants: First names basis only [Name cards used]

1.5 Informed consent: Consent form is read and consent is indicated

1.6 Asking for clarifications or any other questions

1.7 Filling in short demographic data: ward and village, sex, age group, highest level of education, marital status, community leader/worker, professional qualification

2. Discussion topic [Audio recording starts here]

2.1 Facilitator starts by asking general knowledge about the BVIP latrine (and its upgradable versions) to make respondents comfortable.
"Which one is at your household? What is it? How is it built? How does it work?"
[Not more than 15 minutes]

The facilitator summarises what participants said and adds on to it where necessary, seeking their approval/agreement.

2.2 Main discussion question [About 60 minutes]
How do rural households adapt their sanitation needs to a BVIP latrine (or its upgradable models)?

The facilitator controls the discussions, reflecting probing, and asking participants' experiences, opinions and beliefs where necessary. When participants feel they have exhausted the question, the facilitator may ask for clarifications, any other contributions or questions, and summarises to make sure participants agree

3. Closure

At the end, the facilitator thanks the participants and they depart. [About 3 minutes]

Supporting material 4S.5 The integrated behavioural model for water, sanitation, and hygiene (IBM-WASH) (34)

Levels	Contextual factors	Psychosocial factors	Technology factors
Societal/ Structural	Policy, climate, geography	Leadership, cultural identity	Manufacturing, financing, promotion and distribution of products
Community	Access to markets, access to resources, built and physical environment	Shared values, collective efficacy, social integration, stigma	Location, access, availability, collective ownership, maintenance
Interpersonal / Household	Roles, household structure, division of labour, available space	Norms, aspirations, shame, nurture	Access to product, demonstration of use of products
Individual	Wealth, age, education, gender, livelihoods	Self-efficacy, knowledge, disgust, perceived threat	Perceived cost, convenience, strengths and weaknesses of product
Habitual	Facilitators/barriers to habit Formation	Existing water and sanitation habits, outcome expectations	Ease and effectiveness of routine use of product

Supporting material 4S.6 Informed consent document

Reference number [ ]

INFRORMED CONSENT DOCUMENT

QUESTIONNAIRE/FOCUS GROUP

Researcher's Name: ……..……..……,…….
Physical address: ……..……
Contact details: ……

[Institutional and researcher details purposively removed for review]

Ward: …….. Village: …….. Date: ……..……

Dear participant (Name): ……
"You are kindly invited, by random selection, to voluntarily participate in a sanitation survey and focus groups: *"Adapting sanitation needs to a latrine design (and its upgradable models): a mixed method study under lower middle-income rural settings."* You are being encouraged to participate in the project in order to gather information to look at ways of how alternative rural sanitation technologies in Zimbabwe can be selected to increase latrine ownership and use. This is intended to inform national policy on rural sanitation services.

The project is targeting rural households from 15 villages in five wards of Mbire district. Your participation is by answering questions from an interviewer using a prepared questionnaire on demographic information and household sanitation practices, or by being involved in discussions with fellow community members on a given topic. The questionnaire takes about 15 - 20 minutes, and the focus groups an hour and half. Information shared will remain anonymous as the questionnaire is coded and bears no personal identities. The information will be kept safe to ensure confidentiality. You are free to choose not to participate or terminate your participation anytime when you need to without citing reasons or not respond to questions you consider sensitive. If the information shared is used a publication, your participation cannot be retraced and you identity will remain anonymous.

Consent to participate in the study

1. I confirm that I received, read and understood the nature of the study and how I should participate
2. I was given an opportunity to ask questions, and I have no objections to participate in the study
3. I am aware that information shared, including personal details, will be anonymously processed, presented and/or published
4. I understand that I will not be penalised in any way should I choose to discontinue with my participation in the study and my withdrawal
5. I am ware and have agreed that focus discussions will be audio-recorded.

6. I am participating willingly.

Note: If you have read and understood the information given, please indicate your decision by putting a cross (‘’X”) in the relevant box:

I decided to participate ☐ **I decided NOT to participate** ☐

Signature ……

I sincerely appreciate your assistance.

Yours truly,

……...
Print name

Supporting material 4S.7 Characteristics of participants in focus group discussions, Mbire district, Zimbabwe, 2021 (n = 39)

Characteristic	Ward where a focus group discussion was held						Total	Average
	1	5	9	10	15	9*		
Venue	School	School	Clinic	Clinic	Clinic	Clinic	-	-
Duration (minutes)	68	71	83	81	76	74	437	75.5
Number of participants	6	9	7	6	6	5	39	7
Females	3	3	5	2	4	3	20	4
Highest frequency age group	> 45 (3)	26 - 35 (5)	36 - 45 (4)	36 - 45 (5)	> 45 (3)	36 - 45 (3)	-	-
Post-primary education	3	5	3	5	3	2	21	4
Community leader	0	1	0	1	0	0	2	-
Professionally employed	2	0	2	2	0	0	6	1

Number in parentheses **( )** for the common age group indicates the frequency for that age group
* FDG done by field supervisors

CHAPTER 5: DRIVERS AND BARRIERS TO SUSTAINED USE OF BLAIR VENTILATED IMPROVED PIT LATRINE AFTER NEARLY FOUR DECADES IN RURAL ZIMBABWE

This chapter is a published journal article:

Kanda A, Ncube EJ, Voyi K. Drivers and barriers to sustained use of Blair ventilated improved pit latrine after nearly four decades in rural Zimbabwe. PLoS ONE. 2022; 17(4): e0265077. Doi.10.1371/journal.pone.0265077

5.1 Abstract

Some latrines remain unused even under conditions of high coverage in rural areas of low- and middle-income countries. Not much is known on household latrine use in the long term in the absence of an intervention. The current work assesses drivers and barriers to sustained use of a ventilated improved pit latrine (Blair VIP) design where it originated and how rural households adapt it to climate change. A mixed methods study was conducted from November 2020 to May 2021 among rural households of Mbire district, Zimbabwe. A cross sectional survey of 238 households with Blair ventilated improved pit (BVIP) latrines was conducted using a questionnaire and a latrine observation checklist. Data were analysed using logistic regression. Qualitative data were collected using six focus groups among house heads and analysed by thematic analysis. The latrine has perceived health, non-health and hygiene benefits for its sustained use. However, there are design, environmental and social barriers. The quantitative study indicated that determinants of latrine use were contextual (individual and household levels) and technology (individual level) factors. Focus groups indicated that latrine use was influenced by social, technology and contextual factors at multiple level factors. Interplay of factors influenced the intention to adapt the BVIP latrine to climate change. Local climate change adaptation strategies for the latrine were odour and erosion control, construction of the conventional latrine design and raised structures. The conventional BVIP latrine design is durable and relatively resilient to climate change with high local household use. High construction cost of the latrine causes households to build incomplete and poor quality designs which affect odour and fly control. These are barriers to sustained latrine use. The government should implement the new sanitation policy which considers alternative sanitation options and offer community support for adapting sanitation to climate change.

Key words: BVIP latrine, climate change adaptation, drivers for use, rural Zimbabwe, sanitation behaviour, sustained latrine use.

5.2 Introduction

The global use of safely managed sanitation services in rural areas showed an increase of 1.48 percentage points/year from 2015 - 2020 at the national level, and by 2020 about 3.6 billion people still lacked safely managed services (1). Climate change threatens efforts to serve them (2), potentially worsening the sanitation challenge. Even in areas of high sanitation coverage, latrine use was reported to be low (3,4) indicating that the presence of a latrine does not translate into use. Sanitation coverage refers to the percent proportion of a population using improved sanitation facilities (5).

Most reports of research done on the use of latrines in rural communities of low- and middle-income countries (LMICs) are impact evaluation studies of interventions which use various sanitation options in different settings. They were reportedly done some months to a few years following the intervention end line (6-10). Such evaluations commonly report behaviour change in the short term (11). This could be because behaviour change is difficult to initiate and sustain (12), or that self-reported initial and long-term behaviour change may be difficult to identify. There is no standard approach to evaluate post-intervention latrine use. Further, the reliability of the methods used to assess latrine use is uncertain (7). This could have led to variations in intervention follow-up times in latrine use impact studies, complicating the definition of sustained use. In this work, sustained use refers to the continued use of a sanitation facility at least six months post the intervention period (13).

Some factors which influence sustained use of latrines in rural communities of LMICs reported in literature were based on individual, household, community, technology (latrine) and socio-economic levels. Technology factors included the quality and completion of construction, type, functionality and age of a latrine (14,15). Individual-level perceived benefits of using a latrine were safety, security, privacy and convenience (16). The availability of water also underpinned the use of water-borne sanitation options (14). Local culture, beliefs and attitudes were reported to influence latrine use behaviour (16). The educational level, age, gender and occupation of a house head influence latrine use (17,18). Household-level factors were household size and wealth (15). These were follow-up studies to interventions with different packages and strategies. Despite the reported evidence of improved sanitation services, barriers that influence sustained use of various options remain unclear (13,16,19). An understanding of factors which influence latrine use is important to inform future sanitation practice.

The Blair Ventilated Improved Pit (BVIP) latrine is a dry non-sewer on-site sanitation facility. It is a Zimbabwean innovation of the 1970s (named after Dr. Dyson Blair, former secretary, ministry of health) which got international recognition resulting in many current versions of the ventilated improved latrine (20). The BVIP latrine later became known as the ventilated improved pit (VIP) latrine globally. The conventional design comprises a brick-lined pit, concrete slab with a squat hole, PVC vent pipe, fly screen and brick-built superstructure with a roof to give a semi dark interior (21,22). A vent pipe offers odour control and a fly screen traps flies.

The upgradable version of the latrine maintains the basic brick-lined pit and concrete slab design of the BVIP latrine with the superstructure built in stages (22). Zimbabwe encourages the construction of a local sanitation technology innovation, the BVIP latrine for rural households. The country's sanitation policy draft of 2017 which considers alternative options seems to have ended with pilot studies (e. g. 23) as the BVIP latrine remained the encouraged design in practice.

The sustainability and performance of sanitation technologies are subject to climate change whose potential impact on health outcomes is on the global research agenda (24). Climate change impacts include environmental contamination, groundwater quality impairment, public health risks (2,25), infrastructural damage, and floatation of faecal matter in pit latrines (25,26). Floods damage latrines especially those on loose soil, fill up pits with water and erode soil. They may leave households without permanent sanitation infrastructure and influence latrine use of damaged facilities. In 2015, the Mbire district civil protection department indicated that floods left 60% of the water and sanitation infrastructure destroyed which triggered the outbreak of cholera and typhoid (27). While the use of the BVIP latrine may not be affected by unavailability of water during drought periods (except for handwashing), high air temperature during the summer period (up to 40^{o}C) in this semi-arid area may influence latrine use.

Climate change has been linked to increased potential risk of diarrhoeal diseases (25,26). However, some of the perceived benefits of adapting sanitation to climate change include rationalising the choice of sanitation technologies to be used and unbundling of the sanitation options basket by adopting widely acceptable alternatives (25).

Climate change adaptation refers to accustoming in natural or human systems in response to actual or predicted /expected climatic hazards to prevent or reduce harm, or exploit opportunities (28). Adaptation strategies to climate change may be hard/soft, reactive/proactive or effect-/cause-oriented (29). An understanding of the factors which influence the use of a single sanitation option in different environmental settings in areas prone to climate change impacts may be useful to inform the selection of alternative options as an adaptation strategy.

Currently, there is no assessment report of long-term (over four decades) use of a single latrine option, as a nationally encouraged sanitation option, by households in poor rural communities vulnerable to climate change hazards in LMICs. Locally, no report has been given for the factors which influence the use of the BVIP latrine in under such settings. The research questions for this work were: (i) what are the factors which influence sustained use of the BVIP latrine in rural communities under low- and middle-income settings (LMISs) prone to climate change hazards, and (ii) how do households living under such conditions adapt the BVIP latrine to climate change?

The current work reports a study conducted where no recent targeted intervention had been done. It is assumed to represent a long-term sanitation practice among rural households for over four decades of technology implementation but with low sanitation coverage (~35%). It is centred on the conventional BVIP latrine design because it appears there is no reported empirical evidence of the adoption of its upgradable versions outside pilot studies in Zimbabwe. Investigating factors which influence latrine adoption were not part of this work. However, latrine construction was discussed only as a factor which influences use.

The theoretical framework of the quantitative study was the integrated behavioural model for water, sanitation and hygiene (30) to categorise determinants of latrine use. It composes contextual, psychosocial and technology factors, each with five levels (Supplementary material 5S.1). The framework appears widely used to provide a methodology to analyse multiple levels of influences (13,16,19).

5.3 Materials and Methods

5.3.1 Study design and area

A mixed methods research design comprising a cross sectional survey among randomly selected rural households and focus group participants sampled by snowballing was used for the study conducted in Mbire district found in Mashonaland Central Province, Zimbabwe. Details of the study area of this work were described elsewhere (31). The district was purposively selected. It is mostly rural, and according to a national vulnerability assessment report (32) it represents a worst case scenario of poverty with low sanitation coverage. Understanding a worst-case scenario provides a baseline

condition that allows focusing on conditions that need change, how change may be achieved and transferred to other scenarios. Mbire district is semi-arid, experiences high air temperature (40^{o}C) in summer, low annual rainfall (450 - 650 mm), droughts and floods, particularly further north in the lower middle Zambezi valley. It is representative of how poor households with low access to sanitation services, use the BVIP latrine, adapt their sanitation needs to it even in the face of climate change, and use some climate change adaptation strategies to access their latrines.

5.3.2 Sample size and selection of participants

The current work is part of an on-going study where the selection and recruitment of wards, villages and households, and determination of the sample size were published elsewhere (31). The single population proportion formula (33) was used in a multistage sampling strategy to determine a sample size of 790 households which was used in earlier work. For this particular study, all households with BVIP latrines (238; 30.1%) were selected from the calculated sample size of 790 households. Briefly, five rural wards from the district, five villages from each ward, and households in a village were selected by simple random sampling (lottery method). Numbers of all the wards in the district were written on small pieces of paper and five were picked from a container one at a time without looking at them. This was repeated for villages in a ward for the five randomly selected wards. Proportional to size allocation was used to determine ward and village samples. The number of sample units to select from each stratum was made proportional to the number of sample units (households) within each stratum. In this case, the ward and village were separately treated as strata. A ward sample was determined as: number of households in that ward divided by the sum of households in the selected five wards,

multiplied by the calculated study sample size. This was done for all the five wards and the five villages. At village level the actual households were selected by simple random sampling using a list of households in a village. A rural household where consent to participate was given was included. Abandoned households were excluded and replaced by the next eligible one. The target interviewee to participate in the questionnaire interview at the household was the female house head. If she was not available, then the male house head was recruited. The candidate participant was to be above 18 years of age, not mentally challenged and should have resided at the homestead for more than six months.

Participants for each focus group were adult (> 18 years of age) house heads (male and female) who were sampled by snowballing through village health workers in a village. Those who volunteered to participate by completing consent forms were invited. Selection was based on assumed knowledge in household sanitation indicated by participation in similar work before. Nine participants were invited for each focus group allowing for poor turnout. A heterogeneous group based on sex was used to allow a balanced discussion. Participants shared some previous knowledge and experience that allowed some degree of homogeneity. The focus group comprised male and female participants to allow for some (common male-female) tension that may serve to uncover deeper insights (34) into household sanitation issues.

Data collectors were local personnel from the ministry of health responsible for rural sanitation. It was assumed that they would remove the language barrier and do data collection as part of their routine work. This made it possible for them to do data collection by unannounced household visits to avoid the interviewee being aware beforehand. They were professionally trained in the design, operation, maintenance and use of the BVIP latrine. Further, they had experience in working with communities and project implementers in rural sanitation issues. However, it was impossible to blind them in the field. Data collectors had a 2-day training which ended with pre-testing the research instruments. To help reduce researcher bias some data were collected through the questionnaire, FGD and an observation checklist. Pre-field training with data collectors and regular field debriefing sessions help reduce bias (35).

5.3.3 Variables, data collection and analysis

For the quantitative study, a pre-tested coded questionnaire developed from empirically validated previously used existing tools (36-38) was used (Supporting material 5S.2). It was reviewed by a water, sanitation and hygiene expert, and discussed amongst the authors, and revised. An informed consent document (Supporting material 5S.3) was used to get consent from prospective participants before data collection. The lack of a more uniform method of measuring and reporting latrine use was reported (39). To predict factors influencing latrine use (outcome variable), participants were asked how they frequently used their latrines over the previous week (7,40) using responses ‘Always/Usually used’, ‘Never used’ and ‘Sometimes used’.

Measurement was based on 5-day week latrine recall with ‘Always/Usually used latrine’ (at least once every day, ≥ 5 events), ‘Sometimes used the latrine’ (no use in some of the 5 days, but ≠ 0) and ‘Never used the latrine’ (no use in all the 5 days, 0 events). The ‘Always/Usually used latrine’ category was assumed sustained use. Further, respondents identified the main drivers and barriers to latrine use. Adapting the BVIP latrine to climate change (outcome variable) was investigated by asking participants whether they intended to use any adaptation strategy for their latrines using responses ‘Yes’ or ‘No’. Predictor variables were considered from the questionnaire for latrine use and adaptation to climate change (demography and latrine-based). The ‘Yes’ category was assumed that a household would have the intention to adapt its latrine to climate change. The questionnaire items on local climate change adaptation strategies were derived from literature (41,42) and the authors’ personal experiences working with rural communities in water, sanitation and hygiene interventions.

A latrine inspection checklist (Supporting material 5S.4) on the construction and use of the BVIP latrine was used to determine completeness and correctness of its construction on site. A focus group discussion (FGD) was held in a randomly selected village which did not participate in the quantitative study for each of the five wards. The sixth was held in a ward and village selected by simple random means by two field supervisors. A focus group guide was used (Supporting material 5S.5) following a modified (with written permission) FGD technique framework (Supporting material 5S.6) by Nyumba et al. (43).

Participants discussed perceived drivers and barriers for sustained use of the BVIP latrine, and how they adapt it to climate change based on attitudes, motivations, individual experiences or opinions. A moderator and an assistant facilitated the audio-recorded FGD.

Data from completed questionnaires were entered into SPSS version 21.0 (44), cleaned by double entry and finally by cross checking randomly selected 10% of the completed questionnaires and checklists before being imported into STATA version 16 (45) for analysis. Multinomial logistic regression was used to determine predictor variables for latrine use (the dependent variable had three categories). Binary logistic regression was used to determine predictor variables for intending to adapt a household BVIP latrine to climate change (response variable with two categories). Deductive thematic analysis was used to analyse qualitative data (semantic themes) according to the framework by Braun and Clarke (46) (Supporting material 5S.7). Audio-recorded FGDs were transcribed verbatim, coded, similar codes clustered together into several categories, and themes were generated by organising categories underpinned by a central concept. Analyses were done in NVivo 12 (47) and imported into MS Word.

Coding was done by two independent investigators, discussed and reached consensus with a third. A set of preliminary codes were developed a priori from literature regarding the use of latrines by households and how they behave or act to the effects of climate change on their latrines in rural communities of LMICs.

The codes were applied to transcribed text, reviewed, renamed and merged with others to better capture the data. Others were dropped from the final list of codes used for analysis. The study protocol was approved by an institutional ethics review board (662/2019) and a health ministry at provincial and district levels. All participants provided their informed consent in writing. Participation was voluntary and no compensation was paid.

5.4 Results

5.4.1 Demographic characteristics of respondents in the cross-sectional survey

Households with BVIP latrines were 238 (30.1%). Table 5.1 shows that respondents from households owning BVIP latrines were mainly female (73.9%), married (89.5%), belonged to the 36 - 45 years of age group (30,7%), and were of the *korekore* (60.9%) and *Chikunda* (25.6%) ethnic origins. “Other’ under ethnicity indicates nine small ethnic groups.

5.4.2 Characteristics of inspected BVIP latrines at households

A completed BVIP latrine which was constructed in stages while in use was considered an upgradable BVIP latrine version in this case, otherwise it was generally considered a BVIP latrine in the discussion. Most BVIP latrines (67.2%) had superstructures made of fired farm bricks and cement, and 89.5% of them had concrete slabs (Fig.5.1).

Table 5.1 Demographic characteristics of respondents at households with BVIP latrines, Mbire district, northern Zimbabwe, 2021 (*n* = 238).

Variable	Categories	Frequency	%
1. Sex	Male	62	26.1
	Female	176	73.9
2. Marital status	Married	213	89.5
	Single	25	10.5
3. Age group /years	18 - 25	43	18.1
	26 - 35	47	19.7
	36 - 45	73	30.7
	46 - 55	46	19.3
	> 55	29	12.2
4. Educational level	No formal education	28	11.8
	Primary	142	59.7
	Secondary	58	24.4
	Tertiary	10	4.2
5. Ethnicity	*Korekore*	145	60.9
	Chikunda	61	25.6
	Foreign	1	0.4
	Other	31	13.1
6. Religion	Christianity	197	82.8
	Traditional	23	9.7
	Muslim	6	2.5
	None	12	5.0
7. Approximate monthly household income /USD	Less than 50	159	66.8
	50 - 100	42	17.6
	101 - 200	26	10.9
	Greater than 200	11	4.6
8. Household size	≤ 2	11	4.6
	3 - 5	115	48.3
	> than 5	112	47.1
9. Number of cattle owned by household	None	174	73.1
	≤ 3	22	9.2
	4 - 5	28	11.8
	> 5	14	5.9
10. Residency period /years	< 1	11	4.6
	2 - 10	68	28.6
	11 - 20	57	23.9
	> 20	102	42.9
11. Nature of household	Nucleus	132	55.5
	Extended	106	44.5

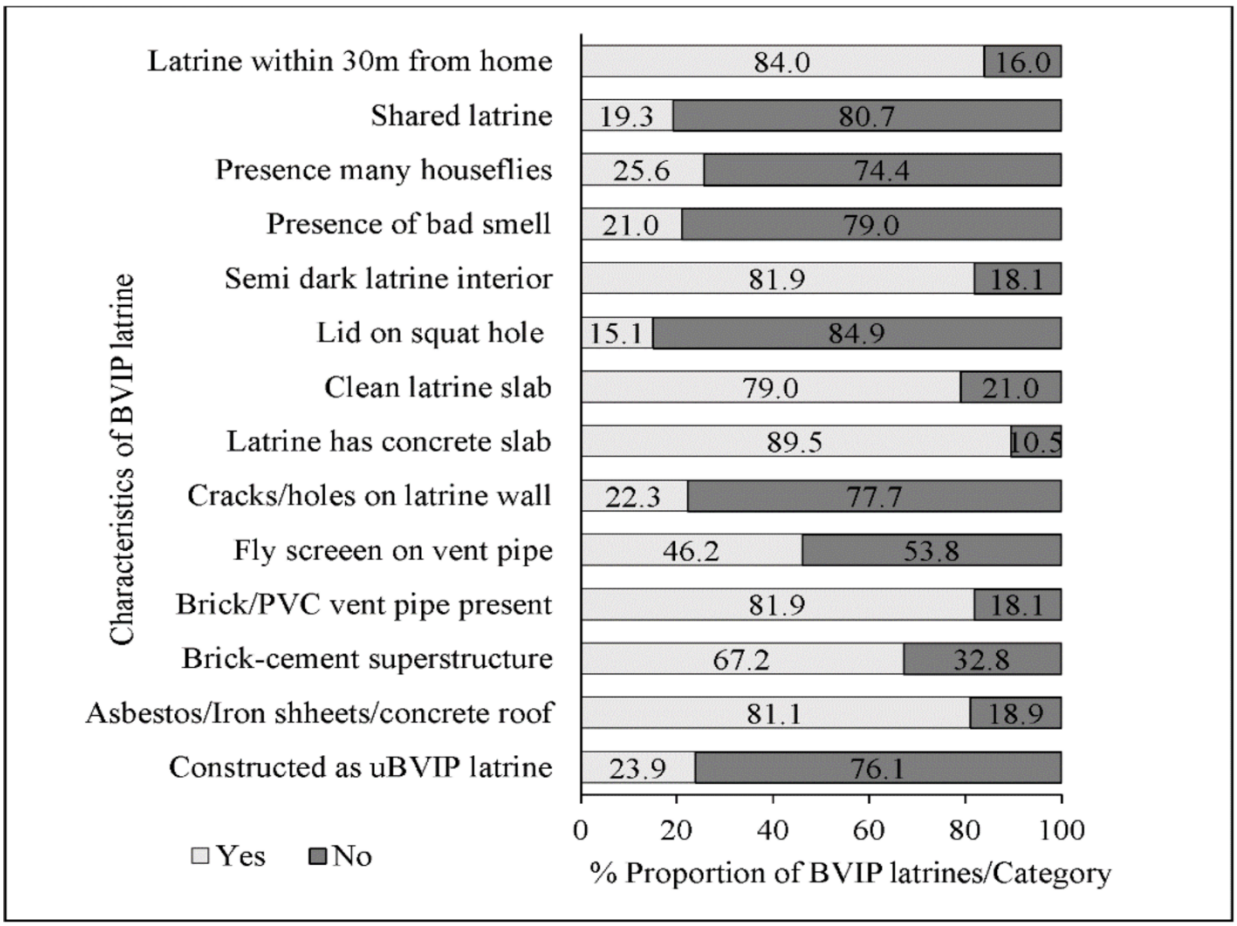


Fig. 5.1 Characteristics of household BVIP latrines in rural villages of Mbire district, northern Zimbabwe, 2021 (n = 238).

Some latrines had no vent pipes (18.1%) or fly screens (53.8%). Squat holes on the slabs had lids in some latrines (15.1%). Thirty-eight latrines (16.0%) were located more than 30 m away from the home. About 40% of the latrines were constructed on sandy soil (Fig.5.2).

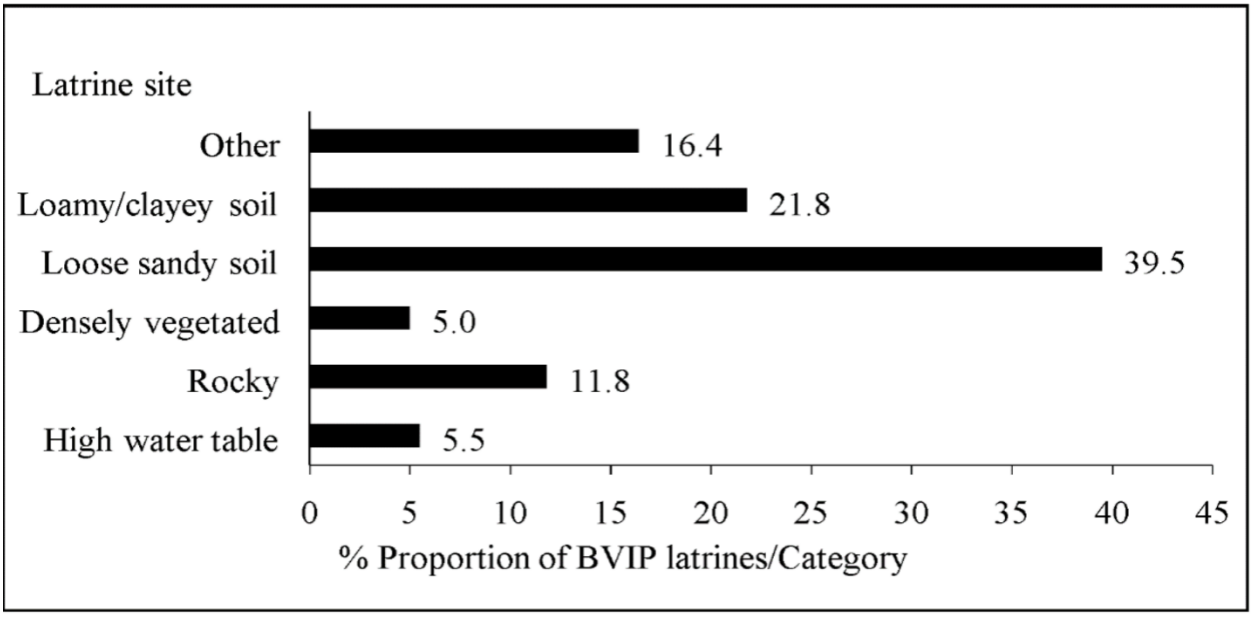


Fig. 5. 2 Description of household BVIP latrine sites in Mbire district, northern Zimbabwe, 2021 (n = 238)

5.4.3 Latrine use patterns

There was moderate self-reported use of BVIP latrines (55.9%) by house heads in the previous week while 20.6% of them never did (Fig. 5.3a). Self-reported drivers to sustained latrine use were completed superstructure and absence of cracks/holes on the latrine, that is, its design (23.1%), hygienic environment (23.1%), perceived health benefits (22.3%) and easy to maintain (16.4%) (Fig. 5.3b). About 27% of the participants indicated that an unclean latrine environment was a major barrier to its use. Other households (19.7%) did not report any barriers to use their latrines (Fig. 5.3c).

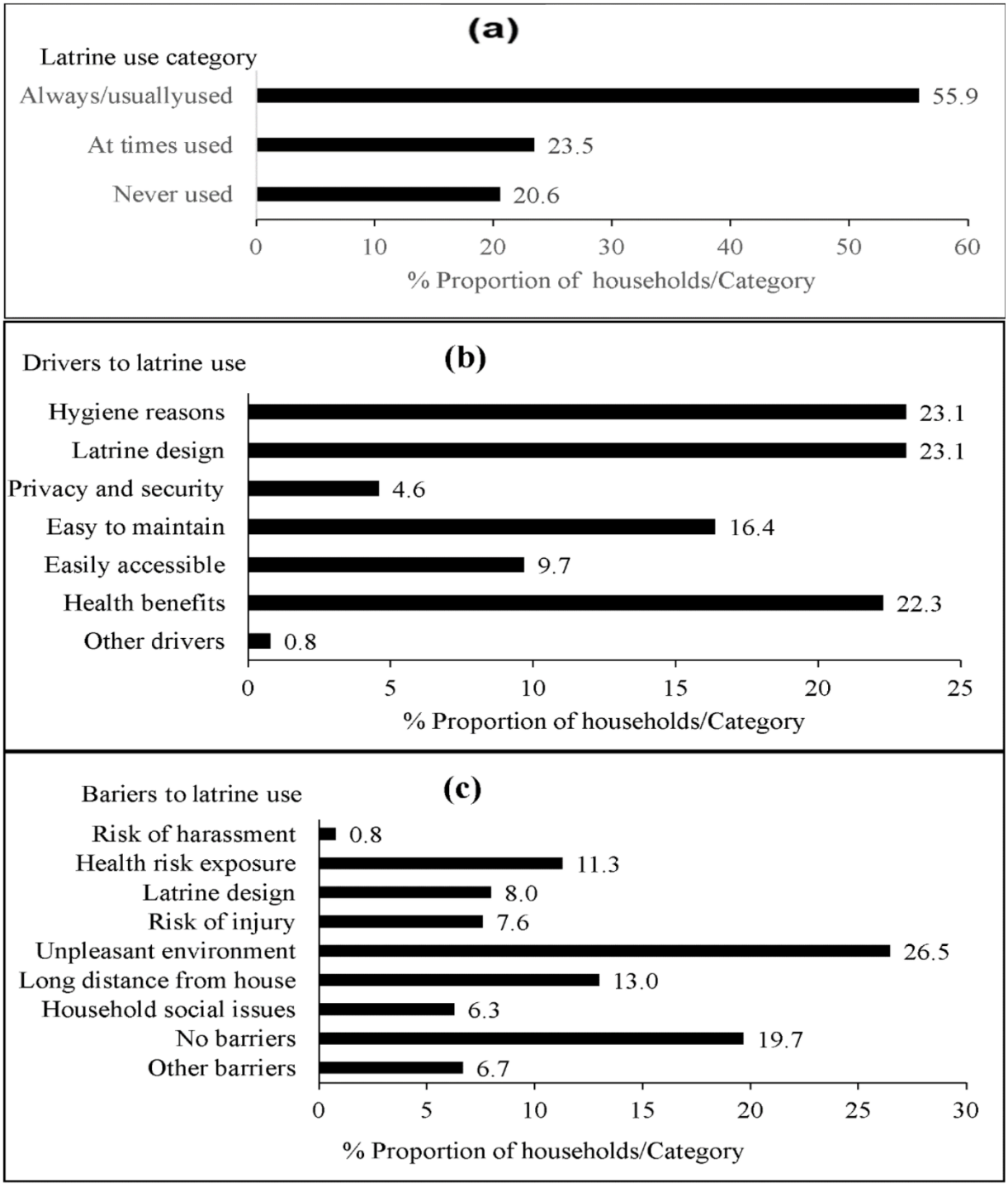


Fig. 5.3 Latrine use in the previous week (a), drivers (b), and barriers (c) to sustained latrine use among households owning BVIP latrines in Mbire district, northern Zimbabwe, 2021.

5.4.4 Disposal of children's stools

More than half of the respondents (53.4%) indicated that they dispose of children's stools into the BVIP latrine (Fig. 5.4). Further, children greater than five years of age were reported to use the latrine (17.6%). A few households (4.2%) reported to use unsafe methods to dispose of children's stools.

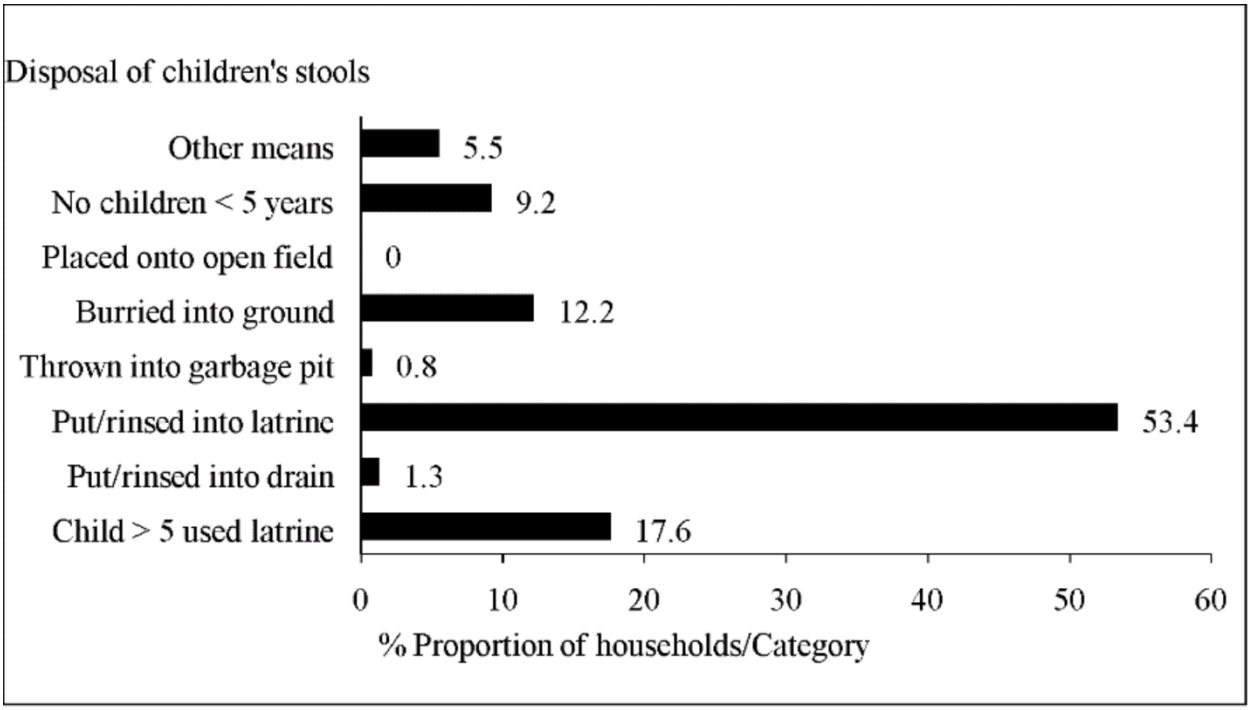


Fig. 5.4 Disposal of children's stools using the BVIP latrine in Mbire district, northern Zimbabwe, 2021 (n = 238)

5.4.5 Determinants of latrine use

Four individual- and seven latrine-based variables used in the multinomial logistic regression model (main effects) were not significantly associated ($p > 0.05$) with latrine use (Table 2). Seven variables which were significant ($p < 0.05$) were used in the *post hoc* analysis (Table 5. 3). Statistically significant ($p < 0.05$) variables have p values (bold).

Two individual-level contextual predictors (age and religion of house head) of latrine use were determined. *Post hoc* results show a significant increased likelihood of reporting *Always/Usually used* the latrine versus *Never used* it for the 26 - 35 years of age group than the reference category of > 55 years of age group (OR = 13.46, 95% CI = 2.01, 89.79, p = 0.007). The 36 - 45 years of age group was significantly more likely to report *Always/Usually used* the latrine versus *Sometimes used* it than the > 55 years of age group (OR = 4.08, 95% CI = 1.07, 15.60, p = 0.04). A house head of traditional religion was significantly more likely than one of none to report *Sometimes used* the latrine versus *Never used* it (OR = 25.28, 95% CI = 0.95, 66.91, p = 0.046).

Table 5.2 Main effects of latrine use

Predictor variable	Likelihood ratio	Chi-Square	df	p-value
Intercept	209.90			
Clean latrine slab without faeces	213.02	3.13	2	0.209
Few houseflies around latrine	212.68	2.78	2	0.249
Latrine inside is dark	212.18	2.28	2	0.320
Open defaecation	210.63	0.73	2	0.695
Build standard BVIP latrine	210.80	0.90	2	0.637
Add wood ash pit	212.05	2.15	2	0.342
latrine is less than 30 m from house	212.04	2.14	2	0.343
Sex	228.88	4.63	2	0.099
Marital status	227.54	3.28	6	0.773
Age group	229.08	4.83	8	0.776
Education level	229.17	4.92	6	0.554

Four household-level contextual predictors (household size, residence period, income and cattle ownership) of latrine use were determined.

The highest household income of > 200 USD was the reference category. A house head from a household with monthly income from all sources falling within the 51 - 100 USD category was significantly less likely than one from the reference to report *Always/Usually used* latrine versus *Never used* it (OR = 0.08, 95% CI = 0.01, 1.07, p = 0.047), similarly for one from the 101 - 200 USD category (OR = 0.06, 95% CI = 0.003, 0.98, p = 0.047). Results show that the smallest household was significantly more likely than the largest (reference) to report Always/Usually used the latrine versus Never used it (OR = 24.99, 95% CI = 1.27, 49.26, p = 0.03).

Having no cattle at the household was found to be both significantly more likely than having more than five to have *Always/Usually used* the latrine versus *Sometimes used* it (OR = 5.19, 95% CI = 1.08, 24.94, p = 0.04), and *Sometimes used* the latrine versus *Never used* it (OR = 31.00, 95% CI = 1.25, 76.66, p = 0.036). There was significantly increased likelihood of a household with ≤ 3 cattle than with > 5 to report *Always/Usually used* the latrine versus *Never used* it (OR = 50.88, 95% CI = 2.09, 124.1, p = 0.020). A household residence period of 11 - 20 years in the ward than > 20 years had a 75% decrease in the likelihood of reporting *Always/Usually used* the latrine versus *Never used* it (OR = 0.25, 95% CI = 0.08, 0.79, p = 0.020), and *Sometimes used* it versus *Never used* the latrine (OR = 0.25, 95% CI = 0.07, 0.93, p = 0.039). A single technology-based predictor (odour) was determined. Perceiving the BVIP latrine as having no obnoxious (bad) smell was significantly 2.46 times more likely than having it, to report *Always/Usually used* the latrine versus *Sometimes used* it (OR = 2.46, p = 0.017, 95%CI = 1.17, 5.17).

Table 5.3 Parameter estimates of the multinomial logit latrine use model showing the effect of individual, household and technology-level predictors on sustained use a BVIP latrine rural households in Mbire district, northern Zimbabwe (n=238)

		Always/Usually Vs. Never			Sometimes Vs. Never			Always/Usually Vs. Sometimes		
Variable (Reference category)	Categories	Odds Ratio	95% CI	p value	Odds ratio	95% CI	p value	Odds ratio	95% CI	p value
Age group / years (> 55) (Nearest 1)	18 - 25	1.34	0.23, 7.69	0.75	0.55	0.08, 3.59	0.53	2.45	0.51, 11.9	0.27
	26 - 35	13.46	2.01, 89.79	**0.007**	4.75	0.64, 35.20	0.13	2.84	0.67, 11.96	0.16
	36 - 45	2.38	0.56, 10.20	0.24	0.58	0.12, 2.94	0.51	4.08	1.07, 15.6	**0.04**
	46 - 55	2.31	0.47, 11.29	0.30	0.96	0.17, 5.37	0.96	2.41	0.59, 9.82	0.22
Household monthly income /USD (> 200)	≤ 50	0.22	0.02, 2.91	0.25	1.60	0.06, 41.65	0.78	0.14	0.01, 1.52	0.11
	51 - 100	0.72	0.04, 12.43	0.82	8.83	0.26, 29.57	0.22	0.08	0.01, 1.07	**0.047**
	101 - 200	0.06	0.003, 0.98	**0.047**	0.15	0.004, 5.88	0.31	0.38	0.02, 6.38	0.50
Religion (None)	Christianity	2.30	0.32, 16.61	0.41	13.02	0.81, 20.97	0.07	0.18	0.02, 2.0	0.16
	Traditional	7.59	0.58, 98.87	0.12	25.28	0.95, 66.91	**0.046**	0.30	0.02, 4.09	0.37
	Muslim	0.13	0.01, 2.6	0.18	0.57	0.01, 24.48	0.77	0.23	0.01, 8.32	0.42
Household size (> 5)	≤ 2	24.99	1.27, 49.26	**0.03**	7.27	0.20, 26.27	0.28	3.44	0.33, 35.73	0.30
	3 - 5	1.70	0.65, 4.42	0.28	1.30	0.45, 3.74	0.63	1.31	0.59, 2.92	0.51
No. of cattle owned (> 5)	None	7.02	0.90, 54.55	0.06	1.35	0.19, 9.72	0.76	5.19	1.08, 24.94	**0.04**
	≤ 3	50.88	2.09, 124.1	**0.02**	31.0	1.25, 76.66	**0.036**	1.64	0.28, 9.77	0.59
	4 - 5	4.98	0.52, 47.76	0.16	2.36	0.25, 21.93	0.45	2.11	0.35, 12.69	0.41
Residence period /years (> 20) (Nearest 1)	< 2	0.16	0.02, 1.58	0.12	0.06	0.003, 1.42	0.08	2.63	0.19, 36.39	0.47
	2 - 10	0.40	0.12, 1.29	0.12	1.04	0.29, 3.75	0.96	0.38	0.14, 1.03	0.06
	11 - 20	0.25	0.08, 0.79	**0.02**	0.25	0.07, 0.93	**0.039**	1.02	0.38, 2.77	0.97
No odour from latrine (No)	Yes	0.49	0.22, 1.08	0.078	1.21	0.52, 2.83	0.67	2.46	1.17, 5.17	0.017

5.4.6 Predictors of adapting a household BVIP latrine to climate change

Two individual-level variables (sex and age group) were significant in predicting the intention to adapt a latrine to climate change (Table 5.4). Category in brackets ( ) after the predictor variable denote reference category. The Hosmer and Lemeshow test gave a Chi-square value of 6.209, df = 8, p = 0.624. The model specificity was 54.3% while its sensitivity was 82.9%. Overall classification was 71.8%. P values in bold denote statistically significant ($p < 0.05$). Female house heads were 2.293 times significantly more likely than their male counterparts to express an intention to adapt household BVIP latrines to climate change (OR = 2.293, p = 0.038, 95% CI = 1.046, 5.027). Older house heads, 36 - 45 years of age group had significantly greater likelihood than the 18 - 25 years of age group to indicate the intention to adapt their latrines to climate change (OR = 4.477, p = 0.007, 95% CI = 1.516, 13.204), so was the 46 - 55 years of age group than the reference category (OR = 4.445, p = 0.012, 95% CI = 1.406, 15.483). Although the oldest group (> 55 years of age group) had greater likelihood than the 18 - 25 years of age group of intending to adapt, it was not statistically significant (OR = 2.444, p = 0.207, 95% CI = 0.609, 9.809).

Household-level predictors included households with a monthly income of 51 - 100 USD which were significantly 4.79 times more likely than those with less than 50 USD to demonstrate the intention to adapt their latrines to climate change (OR = 4.790, p = 0.002, 95% CI = 1.775, 12.927). Increased likelihood of the intention to adapt the BVIP latrine was evident on larger household sizes than smaller ones, for 3 - 5 than ≤ 2 members (OR = 5.177, p = 0.039, 95% CI = 1.087, 24.655) and > 5 members than the reference category (OR = 6.247, p = 0.029, 95% CI = 1.209, 32.282).

A decreased likelihood of households with 3 - 5 cattle than those with none was observed for the intention to adapt latrines to climate change (OR = 0.299, p = 0.021, 95% CI = 0.018, 10.833).

Table 5.4 Binomial logistic regression model showing the effect of individual, household and technology-level predictors on the intention to adapt a BVIP latrine to climate change for rural households in Mbire district, northern Zimbabwe (n = 238).

Predictor variable (Reference category)	Categories	B	Wald statistic	p value	Odds Ratio	95% CI
Sex (Male)	Female	0.830	4.294	**0.038**	2.293	1.046, 5.027
Marital status (married)	Single	0.473	0.696	0.404	1.605	0.528, 4.880
Age group /years (nearest 1) (18 - 25)	26 - 35	0.328	0.388	0.533	1.388	0.495, 3.898
	36 - 45	1.498	7.362	**0.007**	4.477	1.516, 13.204
	46 - 55	1.540	8.332	**0.012**	4.665	1.406, 15.483
	> 55	0.894	1.589	0.207	2.444	0.609, 9.809
Household income in USD (< 50)	51 - 100	1.566	9.582	**0.002**	4.790	1.775, 12.927
	101 - 200	0.046	0.008	0.929	1.047	0.379, 2.889
	> 200	0.665	0.652	0.419	1.945	0.387, 9.779
Household size (≤ 2 members)	3 - 5	1.644	4.263	**0.039**	5.177	1.087, 24.655
	> 5	1.832	4.780	**0.029**	6.247	1.209, 32.282
Number of cattle owned (none)	≤ 2	- 0.671	1.550	0.213	0.511	0.178, 1.470
	3 - 5	- 1.206	5.338	**0.021**	0.299	0.108, 10,833
	> 5	0.600	0.668	0.414	1.822	0.432, 7.684
Open defaecation (No)	Yes	0.279	0.701	0.402	1.322	0.688, 2.543
Built raised latrine (No)	Yes	0.063	0.033	0.856	1.065	0.538, 2.111
Built conventional BVIP (No)	Yes	0.079	0.056	0.812	1.082	0.565, 2.073
Add wood ash into pit (No)	Yes	0.212	0.354	0.552	1.236	0.616, 2.479
Bath in the latrine (No)	Yes	0.881	6.580	**0.010**	2.414	1.231, 4.733
Latrine built on raised ground (No)	Yes	- 0.993	9.039	**0.003**	0.370	0.194, 0.708
Constructed emergency latrines (No)	Yes	- 0.056	0.028	0.968	0.946	0.489, 1.829

A technology-level predictor established was bathing in the latrine (also behaviour-level predictor). Households bathing in the latrine were significantly more likely to indicate intention to adapt it to climate change than those which did not (OR = 2.414, p = 0.010, 95% CI = 1.231, 4.733). Further, there was evidence of significantly decreased likelihood of households with latrines built on raised ground than those without to adapt it to climate change (OR = 0.370, p = 0.003, 95% CI = 0.194, 0.708).

5.4.7 Reasons for not adapting the BVIP Latrine to climate change

About 38.7% of households with BVIP latrines indicated that they had no intention of adapting their latrines to climate change. Fig. 5.5 shows that most reasons that were given by house heads were lack of knowledge of latrine adaptation to climate change (35.9%), perceived high cost associated with adaptation strategies (27.2%) and others viewed the BVIP latrine as a strong design that does not need adaptation to climate change (14.1%).

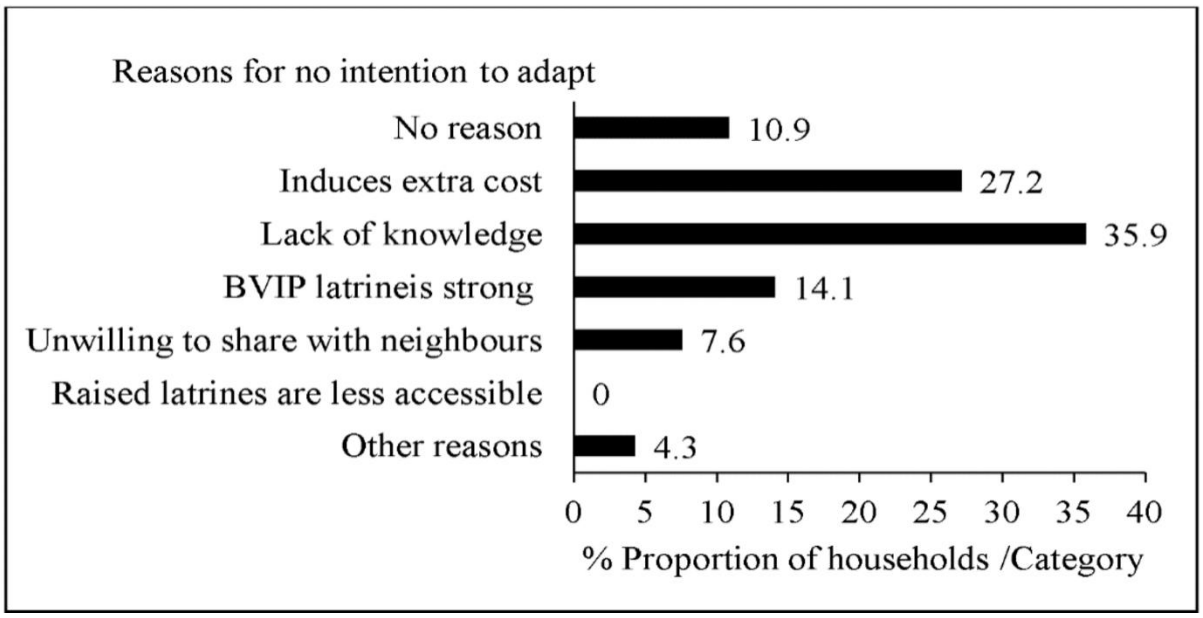


Fig. 5.5 Reasons for no intention to adapt household BVIP latrines to climate changes in Mbire district, northern Zimbabwe, 2021 (n = 92).

5.4.8 Adaptation strategies of BVIP latrine to climate change among households

Addition of wood ash into the latrine pit and bathing in the latrine (69.3%) to control bad odour emerged the commonest climate change strategies (Fig.5.6). Most respondents indicated that the standard BVIP latrine design was resilient to climate change effects (61.3%). Due to additional cost associated with improving the latrine design, some households indicated that they would opt for open defaecation (63.0%). Sharing of latrines with neighbours was the least common climate change adaptation strategy of the BVIP latrine (19.3%).

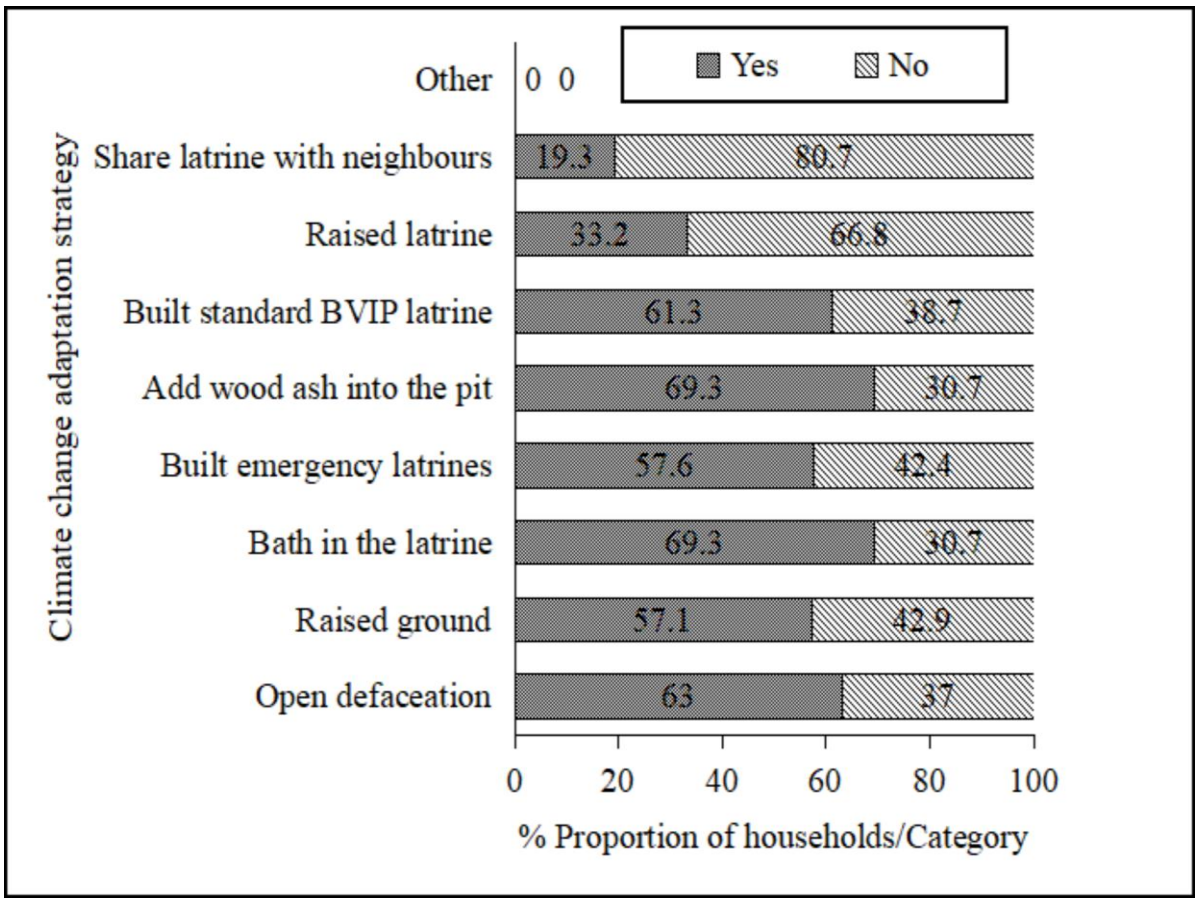


Fig. 5.6 Reported adaptation strategies (survey) of household BVIP latrines to climate change in Mbire district, northern Zimbabwe, 2021 (n = 238)

5.4.9 Characteristics of participants and focus groups in the qualitative study

Table 5.5 indicates that 39 house heads (72.2%) participated in focus groups (ave. 7 participants). About half of the participants (51.3%) were female. Audio-recorded FGDs were held within 85 minutes (68 - 83, ave. 75.5 minutes). FDG denoted 9* throughout this report denotes it was done by field supervisors.

Table 5.5 Characteristics of participants in focus groups, Mbire district, northern Zimbabwe, 2021 (n = 39).

	Ward where a focus group discussion was held							
Characteristic	1	5	9	10	15	9*	Total	Ave
Venue	School	School	Clinic	Clinic	Clinic	Clinic	-	-
Duration (minutes)	68	71	83	81	76	74	437	75.5
Number of participants	6	9	7	6	6	5	39	7
Females	3	3	5	2	4	3	20	4
Highest frequency age group	> 45	26 - 35	36 - 45	36 - 45	> 45	36 - 45	-	-
Post-primary education	3	5	3	5	3	2	21	4
Community leader	0	1	0	1	0	0	2	-
Professionally employed	2	0	2	2	0	0	6	1

5.4.10 Sustained BVIP latrine use: evidence from focus groups

Three main perceived multilevel drivers (health, non-health and hygiene) and three barriers (design, environmental and socio-cultural) with sub-factors in some instances, were determined from FGDs (Fig. 5.7) and summarised in Table 5.6.

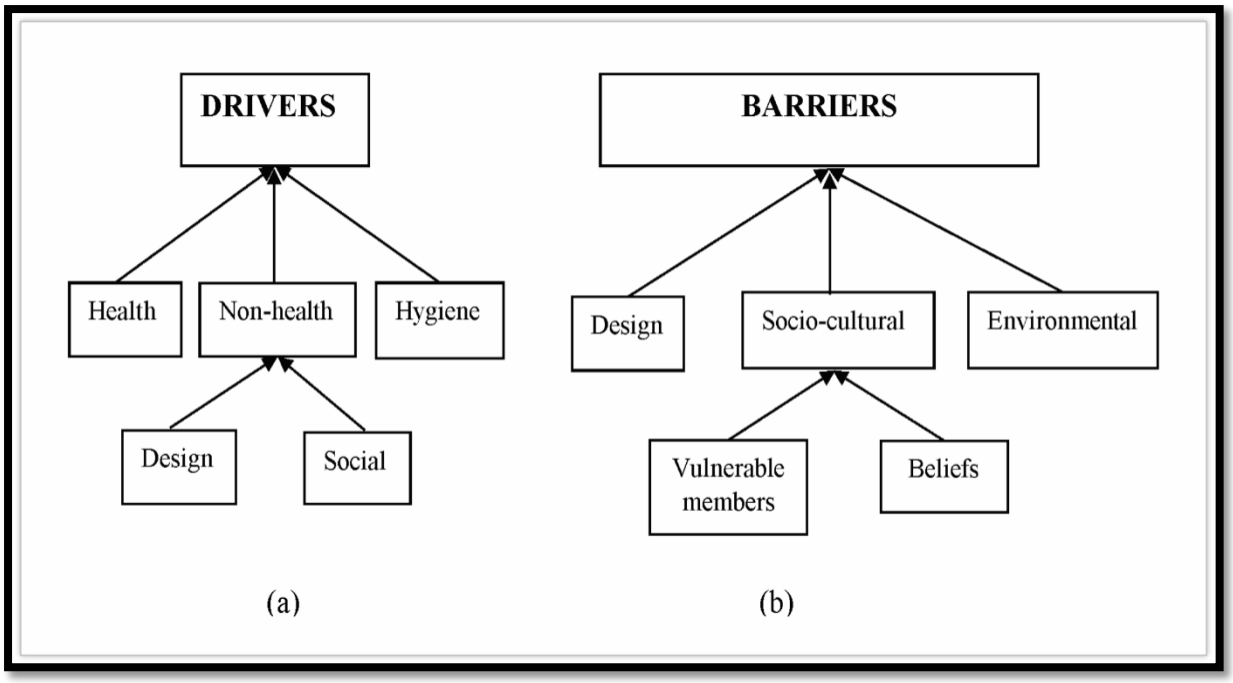


Fig. 5.7 Focus group perceived drivers and barriers to users of the BVIP latrine, Mbire district, northern Zimbabwe, 2021.

Table 5. 6 Summary of perceived drivers and barriers (multi-level) to users of BVIP latrine from focus groups, Mbire district, northern Zimbabwe 2021

Perceived drivers	Perceived barriers
Offers dignity, privacy and security	Not always used when distant from the home
Prevents contracting diarrhoeal diseases to the family	Instils fear of collapse if latrine has observable cracks
Containment of faecal matter gives a clean home environment	Semi-dark interior scares users for fear of snakes, bats and mosquitoes
Prevents contamination of food and water with faecal pathogens	May not be suitable for extended families with in-laws (especially one unit)
Controls odour and houseflies	Faecal matter on slab prevents use
Long life and strong when well built	Cannot be used without odour and fly control
Flexible to be built over time (upgradable) using local resources	May not be accessible to the elderly, very young and physically handicapped
Can alternatively be used as a bathroom	
Concrete slab is easily cleaned	
Safe disposal of children's faeces	

5.4.11 Drivers to latrine use

Results from the FGDs indicated that sustained latrine use seem to be driven by perceived health, non-health and hygiene benefits. The non-health driver was subdivided into two; latrine design and social considerations (Fig. 5.7a). All the three factors were summed in a statement by a female participant (greater than 45 years of age) from ward 1 as follows:

> "The BVIP latrine prevents diarrhoeal diseases, offers privacy, security, dignity, and is easy to clean".

Another participant added the potential of latrine for fly control and excreta containment which provide a hygienic environment to motivate the user:

> "The BVIP Latrine kills houseflies and prevents them from getting into house, provides a hygienic environment. It allows disposal of children's faeces" (Ward 5, Female, 26 - 35 years age group).

5.4.12 Barriers to latrine use

Three main barriers were identified for sustained latrine use. The Socio-cultural barrier was subdivided into two (Fig. 5.7b)

5.4.12.1 Environmental barrier

The use of a BVIP latrine is faced environmental challenges. Pits were reported to fill up with water especially during the rainy season. A participants had this to say:

> "*The pits are filled with water in the rainy season allowing faecal matter to float near the surface of the pit or overflow. This result in family members not using the latrine. Also, houseflies can move in and out of the pit freely. This allows diarrhoeal outbreaks*" (Ward 9, Female, > 45 years age group).

5.4.12.2 Latrine design

Despite owning a BVIP latrine, participants expressed that its design presents barriers to access it, instils fear and has security threats. Participants gave examples of the latrine design barrier:

> "The elderly, children and physically challenged may fail to access the BVIP latrine" (Ward 1, Male, > 45 years age group).

> "The dark interior of a BVIP latrine is scary to users, especially during the night. There are reports of having snakes and bats being harboured in the latrine. Further, in malarial areas, the BVIP latrine harbours mosquitoes" (Ward 15, Female, 18 - 25 years age group).

The use of a latrine was reported limited when it is located further away from the home and not accessible by all including vulnerable members of the household. A male participant (aged > 45 years) from ward 1 noted:

> "My BVIP latrine is built some distance away from the house as we could not find an appropriate site near the house. I have observed that at night not all of us use it for fear of darkness. This also happens when it is raining" (Ward 1, Male, > 45 years age group).

5.4.12.3 Socio-cultural barrier

Staying with in-laws as an extended family was observed as a barrier to latrine use in two focus group discussions. A participant explained:

> "The latrine may not be suitable for an extended family where in-laws are staying together. Although very few households still practise this culture, health education is removing such taboos" (Ward 1, Female, 26 - 35 years age group).

5.4.13 Adaptation of the BVIP latrine to climate change from focus groups

Results from focus groups suggest that most BVIP latrines were not of the 'standard 5 - 7 bag cement model' expected to operate well and easily cleaned. Fig. 5.8 shows the main thematic areas and Table 7 the adaptation strategies of how rural households adapt BVIP latrine to climate change.

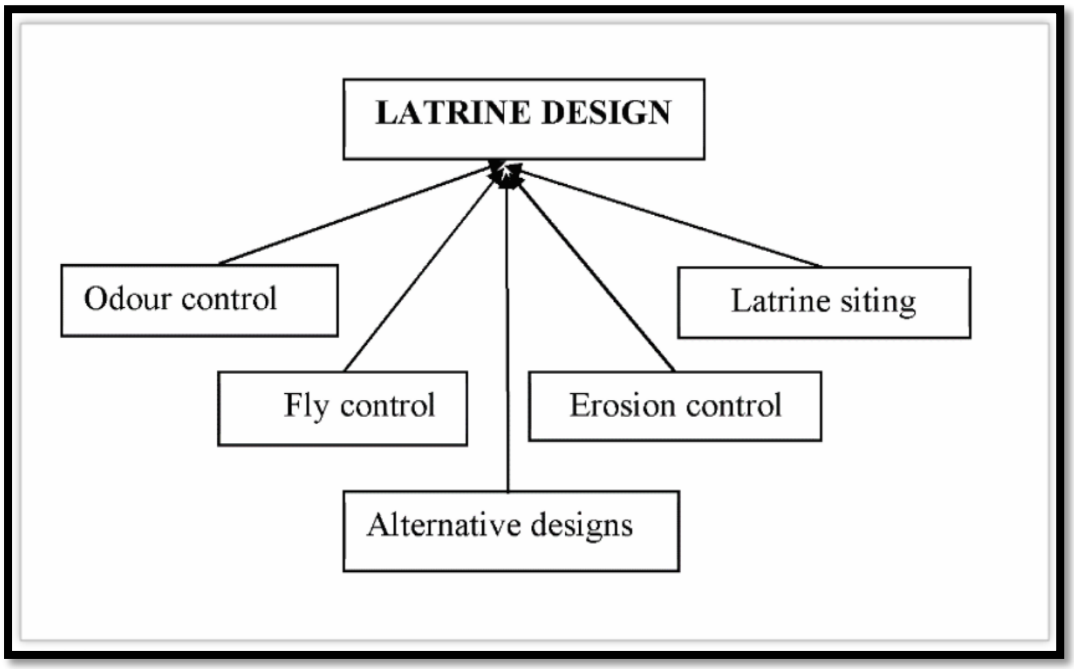


Fig. 5.8 Adaptation strategies of the BVIP latrine to climate change from focus groups, Mbire district, Zimbabwe, 2021.

Table 5.7 Adaptation strategies of BVIP latrine to climate change, Mbire district, northern Zimbabwe (Focus groups), 2021.

Adaptation strategy	Approaches by households
Latrine design	Raised slab level
Latrine design	Site latrine on raised ground
Latrine design	Construct standard 5 - 7 bag cement latrine
Latrine design	Site latrine on firm soil
Latrine design	Construct concrete latrine roof and brick latrine vent pipe
Latrine design	Construct superstructure with fired brick and cement
Odour control	Addition of wood ash in latrine pit
Odour control	Bathing in the latrine adding water into the pit
Erosion control	Build a concrete pavement around the latrine
Erosion control	Construct a contour around the latrine
Insect control	Spraying chemicals on walls to kill houseflies and mosquitoes
Alternative options	Temporary pit latrines, cat sanitation and the bush/field
Alternative options	Share latrine with neighbours

5.4.13.1 Latrine design: Construction of the conventional design

The BVIP latrine has 'a conventional 5 - 7 bag cement' design and several upgradable models. Adaptation strategies to climate change are central to its design:

> "*We used to build only the latrine pit with cement, the outer wall with dagga then plaster with cement. With the changing climate, we are reverting to the standard 5-bag cement BVIP latrine which uses cement throughout. This gives a strong structure to withstand rainfall and strong winds*" (Ward 10, Male, 36 - 45 years age group).

Adequate cement is needed to prevent latrines from collapsing. The standard 5 - 7 bag cement is considered strong. However, if households build modified design with less cement it is subject to collapsing. Collapsing of latrines was mentioned five times across FGDs. A participant noted:

> "*When built on sandy soil without adequate cement and reinforcement, BVIP Latrines collapse in the rainy season*" (Ward 1, Male, 36 - 45 years age group).

5.4.13.2 Odour and housefly control

Participants mentioned adding wood ash and bathing in the latrine and to control odour and houseflies. The addition of wood ash into the latrine pit appears to be common practice mentioned eight times across FGDs. They explained:

> "*In summer where temperatures are very high, we bath in the latrine to reduce strong odours by reducing temperature. Alternatively, we add wood ash into the pit*" (Ward 10, Male, 36 - 45 years age group).

Further, spraying chemicals was also mentioned:

> "*In hot weather and the rainy season we may experience large numbers of houseflies which can move in and out of the pit easily. So we spray chemicals into the pit and latrine interior to kill them*"

(Ward 9*, Female, 36 - 45 years age group).

5.4.13.3 Erosion control

Participants explained that trenching and paving the ground around the latrine with concrete were two ways of controlling erosion:

> "C*onstruct a shallow diversion trench around the latrine in the rainy season so that water flows away without filling the pit*", (Ward 9, Female, > 45 years age group), and "*I have seen some households using extra cement to pave the surrounding of the latrine with concrete to avoid soil erosion which leads to collapse of the latrine*".
>
> (Ward 1, Male, 36 - 45 years age group).

5.4.13.4 Latrine siting

The BVIP latrine should be constructed on firm soil and raised areas to prevent it from collapsing and the pit filling up with water. Two participants had this to say:

> "*To make latrines accessible in times if heavy rainfall, during construction, raised latrines can be used, or construct latrines on raised areas*" (Ward 10, Male, 36 - 45 years age group).

Another participant added:

> "W*e construct raised BVIP latrines in places where the pit cannot be deep enough (rocky) or low-lying places which can allow runoff to accumulate*" (Ward 15, Male, > 45 years age group).

5.4.13.5 Alternative sanitation options

Participants identified 'cat sanitation' and the bush (open defaecation) as alternative sanitation options to using the BVIP latrine when made inaccessible by climate change effects. A few households shared sanitation facilities with their neighbours.

A participant explained:

> "*In situations where sharing of latrines is not a viable option, household members end up using the bush, practising open defaecation*" (Ward 10, Female, 36 - 45 years age group).

In another focus group, a participant indicated:

> "*In times of high rainfall events or at night, the cat sanitation is used instead of the BVIP latrine*"
>
> (Ward 1, Female, 36 - 45 years age group).

5.5. Discussion

The current study presents one of the few, or first report on perceived drivers and barriers of sustained use of a ventilated improved pit (VIP) latrine design (locally called BVIP latrine) for over four decades of technology implementation in rural Zimbabwe. This was because of a long-standing policy which encouraged the implementation of this home-grown innovation without considering appropriate alternative sanitation options to suit different environmental settings, even in the face of climate change. This is envisioned in the new national sanitation policy draft of Zimbabwe (48). Focus group discussions appear to unearth more latrine use drivers and barriers of a social nature, not found significant in the quantitative study. Results from the quantitative study show that contextual factors at the household level appeared to influence latrine use in the study area.

From the quantitative study it was found that some households did not use their BVIP latrines. This is consistent with previous reports where various latrine designs were not used (6,15,49). Reasons for non-use of latrines varied from technology, socio-cultural to hygienic latrine environment at individual and household levels (30). Old age and lack of a religion appeared not to favour always using a latrine. The age of all

household members, as opposed that of the house head in the current study, were shown to influence latrine use (10,15). In rural Ecuador, elderly men were found less likely to use a latrine (50). This could be explained by attitude or beliefs. Religion was not selected as a predictor variable in most studies evaluating latrine use.

High household income and a long residence period were found to increase the likelihood of latrine use. No cause-effect relationships were established and these predictor variables were rarely used in similar study settings. Current results corroborate with the general observation that latrines with bad odour are not 'always' used. Odour from human excreta influences latrine use due to social, moral, aesthetic, and disease-related concerns (51). Detection of odour form a well-constructed and functional VIP latrine indicates faulty odour control due to poor maintenance. Other studies indicated that socio-cultural factors at the household level were considered the main latrine use predictors (50) while an interplay of the technology, social and contextual factors was attributed to latrine use (52).

Participants in the quantitative study had either no formal (11.8%) or primary (59.7%) education but indicated high latrine use. Results show that education was not a significant predictor of BVIP latrine use. A similar conclusion was arrived at by Sinha (15) in a CLTS evaluation study. However, this finding is contradictory to other findings (16-18,49). A possible explanation could be that other than formal education, environmental health technicians (EHTs) stationed at rural health centres in the study area and village health workers staying in the villages freely give awareness and knowledge on the use of a BVIP latrine as part of their routine work. This arrangement augurs well for community support especially where household heads lack knowledge or awareness on sanitation issues.

Results from the qualitative study indicated that a hygienic latrine environment (absence of foul odour, houseflies and faecal matter on the slab) was a driver for sustained latrine use. This is consistent with a wide literature (17,50,53). Possible reasons for an unclean latrine environment could be bad attitude, use by young children or pit floatation with excreta especially in the rainy season. The presence of faeces on the latrine floor was reported to provoke open defaecation (54). The concrete slab of the BVIP latrine can easily be cleaned to provide a hygienic environment for use.

The dark interior and poor quality of the latrine were mentioned in focus groups as barriers to latrine use. A poorly-built BVIP latrine may compromise its design (strength, life, durability) and operation (odour and fly control) which influences its use. Results from the observation checklist showed that some latrines lacked vent pipes or fly screens, and had odour and many houseflies. If local communities ignored the special design specifications of constructing conventional VIP latrines for odour and fly control, then such latrines may not the best options for the area (55). Instead, latrine modifications or alternative options may be suggested for sustained use. Despite being mentioned in focus groups, hygienic latrine environment, its design and educational level of the house head were not determinants of latrine use from the quantitative study. Therefore, a mixed methods study appears useful to explore experiences by households which could otherwise not be unearthed by a questionnaire alone.

Sandy soil contributed to latrine pit floatation with faecal matter, especially in the rainy season. Loose soil that does not support strong constructions was considered a barrier for latrine use (56).

Although socio-cultural factors were mentioned in focus groups as potential barriers to latrine use, it was indicated that the practice was disappearing due to health education. Results from the quantitative study indicated that characteristics of the house head (sex and age), household (income and size) and the latrine (bathing in the latrine and siting it on raised ground) were determinants of the intention to adapt the BVIP latrine to climate change. The study area for this work falls within the Zambezi valley which experiences frequent flooding and high air temperature (up to 40^{o}C) in summer, particularly further north. Adapting the BVIP latrine to climate change by bathing in the latrine which is assumed to lower down latrine air temperature has consequential environmental implications. The BVIP latrine is a dry technology such that the addition of bathwater may pose operational challenges of odour control, potential groundwater contamination and pit filling.

Results from the focus groups indicate that most of the adaptation strategies of the BVIP latrine to climate change are central to the technology design. Addition of wood ash into the latrine pit to control odour appears a widely reported common practice (51). Scientific empirical evidence for odour control using wood ash appears not readily available. Bathing in the latrine has potential impacts were discussed above. Barriers to climate change action in rural sanitation include the challenge to interface it with sanitation and hygiene programming (already complex) and that its data is perceived to be too confusing and discouraging to engage by practitioners (57). This area still needs further research.

There is limited literature to discuss findings on sustained BVIP latrine use. Most studies in literature (i) are post-intervention evaluation studies, (ii) evaluate interventions at varying follow-up times in the post intervention period,

(iii) use different sanitation options in interventions (at times unimproved, (iv) indicate participants were house heads or all household members, and (v) were done in different settings.

5.6 Limitations of the study

The study potentially had interviewer-interviewee and researcher biases. Self-reported sanitation behaviour could have been over-reported. Local data collectors may know participants but could not be blinded. Interviewer-interviewee bias could have been avoided and/or minimised by (i) training data collectors, (ii) using pre-tested data collection instruments, (iii) review of the questionnaire by a WASH expert, (iv) administering the questionnaire in unannounced household visits and (v) physically checking on specified indicators of latrine use and characteristics using an inspection checklist. Potential researcher bias could have been avoided/minimised by triangulation in the mixed methods study (58). It appears there is limited literature on the sustained use of a VIP latrine design outside intervention impact studies over long periods of time (e. g. 40 years) and using a standardised national sanitation option for fair comparison with the current results. This may limit the generalisation of the findings.

5.7 Policy implications and future research

Poor construction of BVIP latrines affects their operation for odour and fly control which in turn influence use. The long-observed unaffordability of the latrine design by poor households may indicate the need for speedy implementation of the new national sanitation policy draft to consider alternative options. However, it not certain how the identified factors influence sustained use of the BVIP latrine, which needs further scientific enquiry.

There are opportunities to do a similar assessment in diverse rural settings with a wider selection of potential predictor variables which influence latrine use. Policy implications of adapting sanitation to climate change may include the selection of appropriate technologies to help build resilience based on the existing experiences under specified contexts (22). Modifying or extending the life of existing technologies may also adapt them to climate change to some extent (41). Since households responded to climate change impacts on their sanitation facilities through some adaptation strategies, the provision of sanitation services in vulnerable rural areas may incorporate aspects of climate change. Further studies may be done to investigate household perceptions about climate change in vulnerable environments.

5.8 Conclusions

The current study demonstrates high sustained use of the BVIP latrine, a national sanitation innovation for rural communities after four decades of implementation, not as a post-intervention evaluation study. Further, it shows a widening gap between local sanitation practice and review policy requirements, and the need to unlock the sanitation basket to allow for alternative options to address equity and universal access. The results show quite encouraging high sustained use of the BVIP latrine despite its perceived use barriers and low adoption due to unaffordability. The quantitative study shows that contextual factors were determinants of latrine use at the individual and household levels. Findings from the focus groups indicate that technology and social factors at the individual, household and community levels influence latrine use. Therefore, an interplay of multiple- level factors influence sustained latrine use. This is important as the country is about to consider other sanitation options. Climate change adaptation strategies that were implemented were central to the latrine design.

They pose an extra cost to the capital requirements of constructing a BVIP latrine. There is need for community support in this respect. Alternative sanitation options and hygiene education may be needed to address unique household sanitation needs of a multicultural society in diverse environments and influence latrine use.

References

1. World Health Organisation/United Nations Children's Fund [WHO/UNICEF]. Progress on household drinking water, sanitation and hygiene 2000-2020: Five years into the SDGs. Geneva: WHO/UNICEF, 2021.
2. Dickin S, Bayoumi M, Giné R, Andersson K, Jiménez A. Sustainable sanitation and gaps in global climate policy and financing. *Clean Water*. 2020; 3:24.
3. Clasen T, Boisson S, Routray P, Torondel B, Bell M, Cumming O, et al. Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: a cluster-randomised trial. *Lancet Global Health*. 2014; 2:e645-53.
4. Garn JV, Sclar GD, Freeman MC, Penakalapati G, Alexander KT, Brooks P, et al. The impact of sanitation interventions on latrine coverage and latrine use: A systematic review and meta-analysis. *Int J Hyg Environ Health*. 2017; 220:329-340.
5. World Health Organisation/United Nations Children's Fund. [WHO/UNICEF]. Joint monitoring programme for water supply and sanitation, progress on sanitation and drinking water: 2010 update. Geneva: WHO; 2010.
6. Kema K, Semali I, Mkuwa S, Kagonji I, Temu F, Ilako F, et al. Factors affecting the utilisation of improved ventilated latrines among communities in Mtwara Rural District, Tanzania. *Pan Afr Med J*. 2012; 13(1):4

7. Sinha A, Nagel CL, Thomas E, Schmidt WP, Torondel B, Boisson S, et al. Assessing latrine use in rural India: A cross-sectional study comparing reported use and passive latrine use monitors. *Am J Trop Med Hyg*. 2016; 95(3):720-727.
8. Hussain F, Clasen T, Akter S, Bawel V, Luby SP, Leontsini E, et al. Advantages and limitations for users of double pit pour-flush latrines: a qualitative study in rural Bangladesh. *BMC Public Health*. 2017; 17:515.
9. Gebremariam B, Hagos G, Abay M. Assessment of community led total sanitation and hygiene approach on improvement of latrine utilization in Laelay Maichew District, North Ethiopia. A comparative cross-sectional study. PLoS ONE. 2018; 13(9):e0203458.
10. Srinivasan S, Mary D, Tannirkulam, A. Measurement of latrine use in rural India, final report. 3ie Impact Other Evaluation Report. New Delhi: International Initiative for Impact Evaluation (3ie); 2019.
11. Schmidt W-F, Chauhan K, Bhavsar P, Yasobant S, Patwardhan V, Aunger R, et al. Cluster-randomised trial to test the effect of a behaviour change intervention on toilet use in rural India: results and methodological considerations. *BMC Public Health*. 2020; 20:1389.
12. McMichael C, Robinson P. Drivers of sustained hygiene behaviour change: A case study from mid-western Nepal. *Social Sci Med*. 2016; 163:28-36.
13. Hulland K, Martin N, Dreibelbis R, DeBruicker V, Winch P. What factors affect sustained adoption of safe water, hygiene and sanitation technologies? 3ie Systematic review summary 2. London: International Initiative for Impact Evaluation, (3ie); 2015.
14. Barnard S, Routray P, Majorin F, Peletz R, Boisson S, Sinha A, et al. Impact of Indian total sanitation campaign on latrine coverage and use: a cross-sectional

study in Orissa three years following programme implementation. *PLoS ONE*. 2013; 8(8):e71438.

15. Sinha A, Nagel CL, Schmidt WP, Torondel B, Boisson S, Routray P, et al. Assessing patterns and determinants of latrine use in rural settings: A longitudinal study in Odisha, India. *Int J Hyg Environ Health*. 2017; 220:906-15.
16. Tamene A, Afework A. Exploring barriers to the adoption and utilization of improved latrine facilities in rural Ethiopia: An Integrated Behavioral Model for water, sanitation and hygiene (IBM-WASH) approach. *PLoS ONE*. 2021; 16(1): e0245289
17. Gebremedhin G, Tetemke D, Gebremedhin M, Kahsay G, Zelalem H, Syum H, et al. Factors associated with latrine utilization among model and non-model families in Laelai Maichew Woreda, Aksum, Tigray, Ethiopia: comparative community based study. *BMC Res Notes*. 2018; 11:586.
18. Leshargie CT, Alebel A, Negesse A, Mengistu G, Wondemagegn AT, Mulugeta H, et al. Household latrine utilization and its association with educational status of household heads in Ethiopia: a systematic review and meta-analysis. *BMC Public Health*. 2018; 18:901.
19. Alemu F, Kumie A, Medhin G, Gebre T, Godfrey P. A socio-ecological analysis of barriers to the adoption, sustainability and consistent use of sanitation facilities in rural Ethiopia. *BMC Public Health*. 2017; 17:706.
20. Robinson A. VIP latrines in Zimbabwe: From local innovation to global sanitation solution. WSP, Field Note 4. Africa Region: Vanana Mehra; 2002.
21. Morgan P. Zimbabwe's rural sanitation programme. An overview of main events. Harare: Government of Zimbabwe, 2006, updated 2010.
22. Morgan P. The Blair VIP toilet. Manual for the upgradeable BVIP model with spiral superstructure and tubular vent pipe. Harare: Aquamor, 2011.

23. Ahmad A, Jonga M, Nyamuranga S, Shirihuru N, Kinyanjui V, Mashingaidze HR. Rolling out Zimbabwean approach to demand-led sanitation in most vulnerable communities. 39th WEDC International Conference: Ensuring availability and sustainable management of water and sanitation for all. Kumasi, Ghana, Refereed paper 2427, 2016.
24. World Health Organization [WHO]. Guidelines on sanitation and health. Geneva: WHO, 2018
25. Howard G, Calow R, Macdonald A, Bartram J. Climate change and water and sanitation: likely impacts and emerging trends foe action. *Annu Rev Resour*. 2016; 41:253-276.
26. Arnell NW, Halliday SJ, Battarbee RW, Skeffington RA, Wade AJ. The implications of climate change for the water environment in England. *Prog Phys Geogr*. 2015; 39(1):93-120.
27. Mucherera B, Mavhura E. Flood survivors' perspectives on vulnerability reduction to floods in Mbire district, Zimbabwe', *Jàmbá: J Disast Risk Stud*. 2020; 12(1):a663.
28. International Panel on Climate Change [IPCC]. Climate Change 2001: Synthesis Report. Summary for policy makers. Contribution of Working Groups I, II and III to the Third Assessment Report of the IPCC, Geneva. New York: Cambridge University Press; 2001. p. 365. https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_TAR_full_report.pdf. [Accessed 14 January 2020].
29. Selseng T, Klemetsen M, Rusdal T. Adaptation confusion? A longitudinal examination of the concept ''Climate change adaptation'' in Norwegian municipal surveys. *Climate Weather Soc*. 2021; 633-648.

30. Dreibelbis R, Winch PJ, Leontsini E, Hulland KRS, Ram PK, Unicomb L. The integrated behavioural model for water, sanitation, and hygiene: a systematic review of behavioural models and a framework for designing and evaluating behaviour change interventions in infrastructure-restricted settings. *BMC Public Health*. 2013; 13(1):1015.
31. Kanda A, Ncube EJ, Voyi K. Adapting sanitation needs to a latrine design (and its upgradable models): A mixed method study under lower middle-income rural settings. *Sustainability*. 2021; 13(23):13444.
32. Zimbabwe National Statistics Agency [ZimStat]. Zimbabwe poverty report 2017. Harare: ZimStat; May 2019.
33. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? *Indian J Psychol Med*. 2013; 35:121-6.
34. Roller MR, Lavrakas PJ. Applied qualitative research design: A total quality framework approach. Chapter 4: Interview method - Focus group discussions. New York: The Guilford Press; 2015. p.108.
35. Bergen N, Labonté R. "Everything is perfect, and we have no problems": Detecting and limiting social desirability bias in qualitative research. *Qual Health Res.* 2020; 30(5):783-792.
36. World Health Organisation/United Nations Children's Fund [WHO/UNICEF]. Core questions on drinking water and sanitation for household surveys. Geneva: WHO Press; 2006.
37. Zimbabwe National Statistics Agency/ICF International [ZimStat/ICF]. Zimbabwe Demographic and Health Survey 2015: Final Report. Rockville, Maryland, USA: ZimStat and ICF; Nov 2016.

38. United Nations Children's Fund/World Health Organization [UNICEF/WHO]. Core questions on drinking water, sanitation and hygiene for household surveys: 2018 update. New York: UNICEF/WHO; 2018.
39. De Buck E, Van Remoortel H, Hannes K, Govender T, Naidoo S, Avau B, et al. Promoting handwashing and sanitation behaviour change in low- and middle-income countries: a mixed method systematic review. 3ie systematic review 36. London: Initiative for Impact Evaluation (3ie); 2017.
40. Alemu F, Kumie A, Medhin G, Gasana J. The role of psychological factors in predicting latrine ownership and consistent latrine use in rural Ethiopia: a cross-sectional study. *BMC Public Health*. 2018; 18:229.
41. United Nations Framework Convention on Climate Change [UNFCCC]. Technologies for adaptation to climate change. Climate Change Secretariat, UNON Publishing Services: Nairobi, 2006. https://unfccc.int/resource/docs/publications/tech_for_adaptation_06.pdf. [Accessed 27 January 2020].
42. Oates N, Ross I, Calow R, Carter R, Doczi J. Adaptation to climate change in water, sanitation and hygiene: assessing risks, appraising options in Africa. London: Overseas Development Institute, January 2014. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8858.Pdf. [Accessed 27 January 2020].
43. Nyumba TO, Wilson K, Derrick CJ, Murkejee N. The use of focus group discussion methodology: Insights from two decades of application in conservation. *Method Ecol Evol*. 2018; 9:20-32.
44. IBM Corp. IBM SPSS Statistics for Windows, Version 21.0. Armonk, New York: IBM Corp; 2012.

45. StataCorp. Stata Statistical Software: Release 16. College Station, TX, StataCorp LLC; 2019
46. Braun V, Clarke, V. Using thematic analysis in psychology. *Qual Res Psychol*. 2006; 3(2):77-101.
47. QSR International Pty Ltd. NVivo (Version 12). 2018
48. Government of Zimbabwe [GoZ]. The Zimbabwe national sanitation and hygiene policy draft. National Action Committee for rural water supply and sanitation. Harare: GoZ; 2017.
49. Yimam YT, Gelaye KA, Chercos DH. Latrine utilization and associated factors among people living in rural areas of Denbia district, Northwest Ethiopia, 2013, a cross-sectional study. *Pan Afri Med J*. 2014; 18:334.
50. Lopez VK, Berrocal VJ, Angulo BC, Ram PK, Trostle J, Eisenberg JNS. Determinants of latrine use behavior: The psychosocial proxies of individual-level defecation practices in rural coastal Ecuador. *Am Soc Trop Med Hyg*. 2019; 100(3):733-741.
51. Rheinländer T, Keraita B, Konradsen F, Samuelsen H, Dalsgaard A. Smell: an overlooked factor in sanitation promotion. *Waterlines*. 2013; 32(2):107-112.
52. Nunbogu AM, Harter M, Mosler H-J. Factors associated with levels of latrine completion and consequent latrine use in northern Ghana. *Int. J. Environ. Res. Public Health*. 2019; 16:920.
53. Budhathoki SS, Shrestha G, Bhattachan M, Singh SB, Jha N, Pokharel PK. Latrine coverage and its utiisation in a rural village of Eastern Nepal: a community-based cross-sectional study. *BMC Res Notes*. 2017; 10:209.
54. Busienei PJ, Ogendi GM, Mokua MA. Latrine structure, design, and conditions, and the practice of open defecation in Lodwar town, Turkana County, Kenya: A quantitative methods research. *Environ Health Insights*. 2019; 13:1-11.

55. Dumpert JW, Paterson KG, Emerson P. Performance assessment for the VIP toilet in the Upper West Region of Ghana. *Waterlines*. 2009; 28(3):250-259.
56. Dickin S, Dagerskog L, Jiménez A, Andersson K, Savadogo K. Understanding sustained use of ecological sanitation in rural Burkina Faso. Sci Tot Environ. 2018; 613-614:140-148.
57. Kohlitz, J, Iyer R. Rural Sanitation and climate change: Putting ideas into practice. Frontiers of Sanitation: Innovations and Insights 17, Brighton Institute of Development studies. 2021. Doi: 10.19088/SLH.2021.002
58. Shaya G, Selvam SDB. Empirical research: A study guide. Nairobi: Paulines Publications Africa; 2017.

Supporting material 5S.1 Integrated behavioural model for water, sanitation and hygiene (30)

Levels	Contextual factors	Psychosocial factors	Technology factors
Societal/Structural	Policy, climate, geography	Leadership, cultural identity	Manufacturing, financing, promotion and distribution of products
Community	Access to markets, access to resources, built and physical environment	Shared values, collective efficacy, social integration, stigma	Location, access, availability, collective ownership, maintenance
Interpersonal/Household	Roles, household structure, division of labour, available space	Norms, aspirations, shame, nurture	Access to product, demonstration of use of products
Individual	Wealth, age, education, gender, livelihoods	Self-efficacy, knowledge, disgust, perceived threat	Perceived cost, convenience, strengths and weaknesses of product
Habitual	Facilitators/barriers to habit formation	Existing water and sanitation habits, outcome expectations	Ease and effectiveness of routine use of product

Supporting material 5S.2 Latrine use household questionnaire

No:

Drivers and barriers to sustained use of the BVIP latrine, and its adaptation to climate change in rural Zimbabwe (Mbire district)

Date …… Ward: …… Village: ……..……

Note: Institutional and researcher details were purposively removed. This tool is used after getting informed consent

Instructions to the enumerator

- ✓ The questionnaire will only be administered after getting informed consent.
- ✓ Please do not prompt or read answers to the respondent, unless where it is indicated.
- ✓ This questionnaire is to be administered to the mother/female head of the household. If she is not available then you can administer it to male house head.
- ✓ Please circle one response and/or clearly write down responses where appropriate.

1. Sex	1. Male 2. Female
2. Marital status	1. Married 2. Single
3. Age group (years)	1. 18 – 25 2. 26 – 35 3. 36 – 45 4. 46 – 55 5. > 55
4. Educational level	1. No formal education 2. Primary 3. Secondary 4. Tertiary
5. Ethnicity	1. *Korekore* 2. *Chikunda* 3. Foreign 99. Other *If other, please specify: ……...……..*
6. Religion	1. Christianity 2. Traditional 3. Muslim 4. None 99. Other *If other, please specify*: ……
7. Monthly household income /USD	1. Less than 50 2. 50 – 100 3. 101 – 200 4. Above 2000
8. Household size	1. ≤ 2 2. 3 – 5 3. > 5
9. Nature of household	1. Nucleus 2. Extended
10. No. of cattle owned	1. None 2. ≤ 3 3. 4 - 5 4. > 5
11. Residence period of household (years)	1. < 1 2. 2 – 10 3. 11 - 20 4. > 20
12. Latrine option at the household	1. Upgradable BVIP 2. BVIP
13. Latrine has a clean concrete slab	1. Yes 2. No
14. Latrine has no bad smell	1. Yes 2. No
15. Latrine has a few houseflies around it	1. Yes 2. No
16. Latrine interior is dark	1. Yes 2. No
17. Latrine is < 30 m from the homestead	1. Yes 2. No
18. Frequency of latrine use (5week days)	1. Always/Usually used 2. Sometimes used 3. Never used

19. How were children's (<5 years old) stools disposed of last time?	1. Children < 5 years old used latrine 2. Put/rinsed into drain 3. Put/rinsed into latrine 4. Thrown into garbage pit 5. Burried into ground 6. Placed into open field 7. No children < 5 years old 99. Other means *If other, please specify* ……..
20. Main driver for use of the BVIP latrine	1. Hygienic environment 2. Latrine type 3. Easy to maintain (e. g. clean) 4. Easily accessible 5. Health benefits 6. Privacy and security 99. Other drivers *If other, please specify* ……
21. Main barrier for use the BVIP latrine	1. Health risk exposure 2. Design of the latrine 3. Risk of injury 4. Unclean environment 5. > 30 m from the homestead 6. Household social issues 7. None 99. Other barriers *If other, please specify* ……..
22. Do you intent to adapt your BVIP latrine to climate change?	1. Yes 2. No
23. Reason for not intending to adapt your BVIP latrine to climate change	1. No reason 2. Induces extra cost 3. Lacks knowledge 4. BVIP is strong 5. Large family to bath 6. Unwilling to share with neighbours 7. Raised latrine affects accessibility 99. Other reasons *If other, please specify* ……..…….

Would you adapt the BVIP latrine to climate change using the following strategies (24 – 31)?

24. Open defaecation?	1. Yes	2. No
25. Build a raised latrine?	1. Yes	2. No
26. Build a standard BVIP latrine?	1. Yes	2. No
27. Add wood ash to the latrine pit?	1. Yes	2. No
28. Bath in the latrine?	1. Yes	2. No
29. Build latrine on raised ground?	1. Yes	2. No
30. Build an emergency latrine?	1. Yes	2. No
31. Share BVIP latrine with neighbours	1. Yes	2. No

END OF THE QUESTIONNAIRE

Supporting material 5S.3 Informed consent document

Drivers and barriers to sustained use of the BVIP latrine, and its adaptation to climate change in rural Zimbabwe (Mbire district)

Principal investigator: [*Information was intentionally withheld*]
Contact details: *[Institutional details were intentionally withheld*]

Date: …….. Time: ……

Dear prospective participant: ……..

Hello. My name is (*Interviewer name*). I am working with the Ministry of Health and Child Care district and provincial offices. You are invited to volunteer to participate in a research study for [*Institutional details removed*]. The purpose of the survey is to determine the drivers and barriers to sustained use of the BVIP latrine, and its adaptation to climate change in rural Zimbabwe (Mbire district). The initiative is develop a framework to select appropriate rural sanitation technology options. The final aim is to inform government policy to respond to global call to improve access to basic sanitation services for all in 2030.

Your participation is by responding to questions regarding yourself, household and sanitation facility. This is either at household level or through a small group where you meet your fellow community members to discuss the topic. If you have any questions you are free to ask. I can also refer you to our district office. Volunteering to participate will not expose you to any physical harm. However, if you feel you are not comfortable to respond to some of the questions you are free to indicate so.

Your name will not be used or connected to the information shared, recorded, presented at a conference or published. All data shared will be treated a s confidential. You will not be compensated for voluntarily participating in this study. Whatever is discussed in focus groups will have to be treated confidential by all members. During the interview I will also need your consent to inspect your sanitation facility (latrine) if available.

Informed consent

1. I confirm that I was told details of the study, how I should participate and understood it.
2. I was told of the risks or discomforts, and potential benefits of the study.
3. I was given adequate time to ask questions and I have no objections to participate.
4. I am aware that the information shared including personal details, will be Anonymously processed and presented when reporting the results.
5. I understand that I may withdraw my consent to participate any time without being affected
6. I understand and give my consent that focus group discussions will be audio-recorded.
7. I am participating willingly.

Participant …… OR put a cross (x) in the box ☐ Date: ……..……
Signature

Data collector: …… Signature: …….. Date: ……...
Please print name

Supporting material 5S.4 Blair ventilated improved pit latrine construction checklist

Drivers and barriers to sustained use of the BVIP latrine, and its adaptation to climate change in rural Zimbabwe (Mbire district)

[Institutional and researcher details were purposively removed]

Introduction

Informed consent statement

Instruction: Please indicate your response for each question by putting a cross

	Checklist item	Response
1	BVIP latrine constructed as an upgradable design?	1. Yes 2. No
2	Latrine roof made of asbestos/iron sheets of concrete?	1. Yes 2. No
3	Superstructure made of fired bricks and cement?	1. Yes 2. No
4	Does the latrine have a vent pipe (brick/PVC)?	**1.** Yes 2. No
5	Does the vent pipe have a fly screen?	**1.** Yes 2. No
6	Does the latrine wall have cracks or holes?	**1.** Yes 2. No
7	Does the latrine have a concrete slab?	**1.** Yes 2. No
8	Is there a lid on the squat hole?	**1.** Yes 2. No
9	Description of the location of the latrine	1. High water table
		2. Rocky/hilly
		3. Densely vegetated
		4. Sandy soil
		5. Loamy/clayey soil
		99. Other

If other, please specify

……..

Supporting material 5S.5 Focus group discussion guide

[Institutional and researcher details were purposively removed]

Drivers and barriers to sustained use of the BVIP latrine, and its adaptation to climate change in rural Zimbabwe (Mbire district)

1. Introduction

1.2. Self-introduction (facilitator) and assistant: Thanking participants for coming
1.3. Introduction of the study:
(a) Purpose and how participants were recruited
(b) Expected duration, use of information collected
(c) Ground rules: how participants will response, no wrong/correct answers
(d) Discussions will be audio-recorded
1.4 Self-introductions of participants: First names basis only
1.5 Informed consent: Voluntary participation, confidentiality, anonymity, right to withdraw, how to disclose findings (publications)
1.6 Asking for clarifications or any other questions
1.7. Signing of consent form/verbal agreement to participate
1.8. Writing of name cards (first name basis)
1.9. Filling in short demographic data: Sex, age group, highest level of education reached, marital status, community leader/worker, professional qualification.

2. Discussions

2.1 Question 1: What are the drivers for you to use the BVIP latrine?

Facilitator starts by asking general knowledge about the BVIP latrine to make respondents comfortable (What is it? How is it built? How does it work? e. t. c) …
At the end facilitator summarises what participants said and adds on to it where necessary.

(a) Drivers
(b) *Barriers*

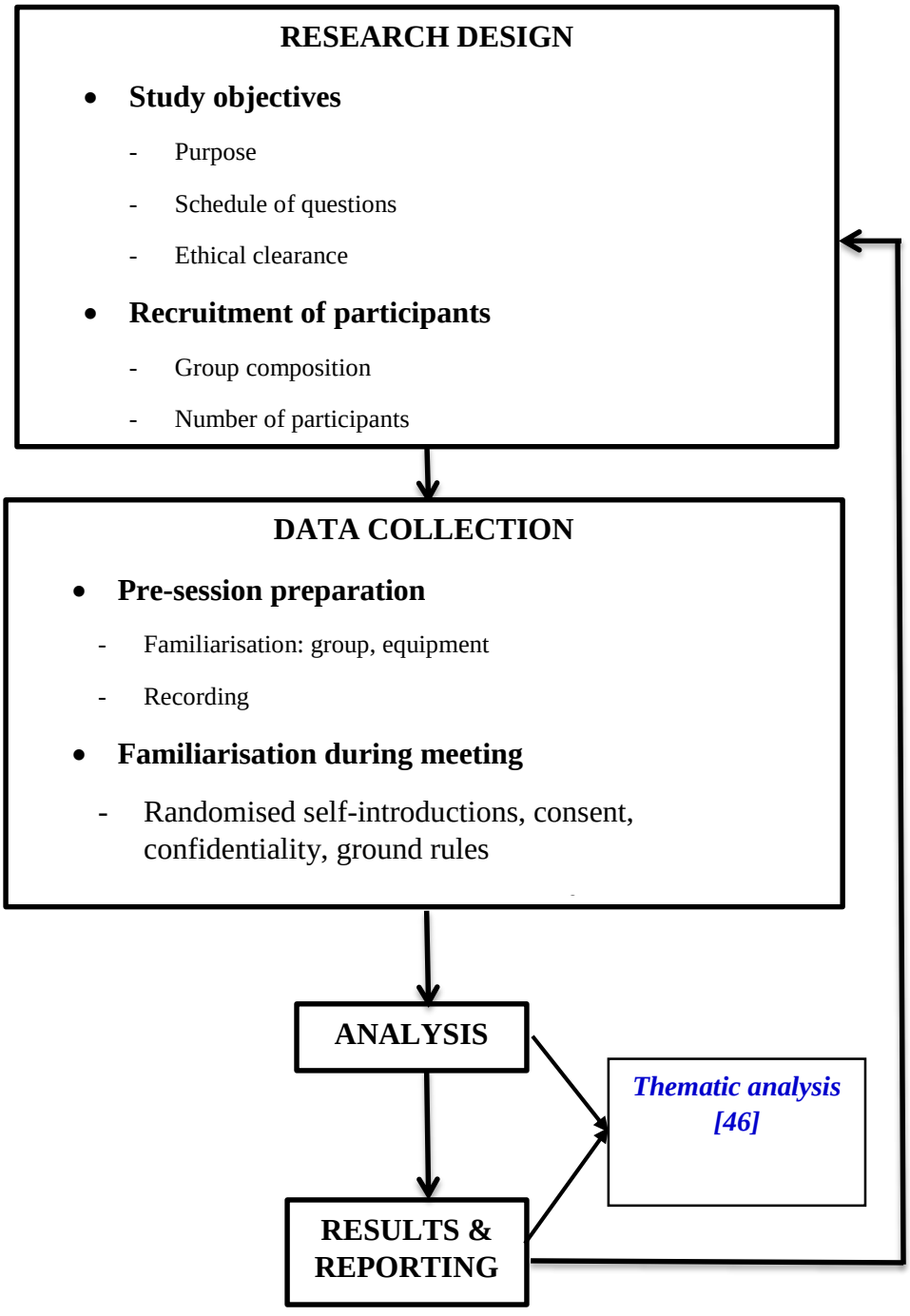
Facilitator controls the discussions, reflecting probing, asking participant experiences, opinions, beliefs where necessary. When participants feel they have exhausted the question, the facilitator may ask for clarifications, any other contributions or questions, and summarises to make sure participants agree

2.2. Question 2: How do households adapt the BVIP latrine to climate change?

Facilitator explains climate change and asks participants to give examples and potential risks related to sanitation.
Group discussion (as in question 1)

2.3. Closure: At the end, the facilitator thanks the participants and they depart.
Supplementary file 5. Modified flow chart of the steps of the focus group discussion technique with permission [43]

Supporting material 5S.6 Modified steps of the focus group discussion technique with permission (43)



Supporting material 5S.7 Phases of thematic analysis (46)

	Phase	Description of the process
1.	Familiarizing yourself With your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2.	Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3.	Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4.	Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5.	Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6.	Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

CHAPTER 6: DEVELOPMENT AND EVALUATION OF A FRAMEWORK FOR SELECTNG AND USE OF APPROPRIATE SANITATION TECHNOLOGIES IN LOW-AND MIDDLE-INCOME SETTIGS

This chapter is a published journal article published as:

Kanda A, Ncube EJ, Kuku Voyi K. Selection of appropriate on-site household sanitation options for rural communities of Zimbabwe – case of Mbire district, Zimbabwe, Int J Environ Health Res. 2023.
Doi: 10.1080/09603123.2023.2166021

6.1 Abstract

Selecting an appropriate sanitation option involves multiple stakeholders with often conflicting objectives. A multiple criteria decision analysis (MCDA) framework was developed to inform decision makers on selecting appropriate sanitation options for rural communities. Criteria established from literature were evaluated and weighted on-line by stakeholders. A performance matrix was developed by assigning weights to criteria and scoring alternatives. Selection of alternatives was based on a composite appropriateness index from a rank using the simple multi-attribute ranking technique. The framework was evaluated by verification, validation and sensitivity analysis. Five alternatives were evaluated on 14 decision criteria. The first preferred alternative was the urine diverting dry toilet (72.54) then the Blair ventilated improved pit latrine (67.10). The framework was commented as reasonable and robust. A simple and transparent MCDA framework was developed considering local conditions in a participatory manner to select appropriate alternatives for rural sanitation where a single option is encouraged.

Keywords: alternative options; appropriate technology; rural communities; sanitation planning

6.2 Introduction

Rural sanitation in low- and middle-income countries (LMICs) is still faced with old challenges of under-prioritisation and inappropriate technical standards challenges (1). A review of available technology selection frameworks for rural communities of LMICs (2) indicated lack of prioritisation of rural areas. There is a need for prioritisation of rural sanitation since that is where (i) most intervention

trials are done (3), (ii) access to safely managed sanitation services is low, (iii) open defaecation is still practised (1) and (iv) the burden of childhood diarrhoeal diseases is mainly borne (4).

Inappropriate technical sanitation options caused intervention failures (5). An appropriate technology incorporates social acceptability, financial affordability, institutional acceptance and physical feasibility (6). The development of frameworks to assist decision makers to select appropriate technologies appears to favour urban sanitation (2). Although frameworks appear to stem out from the World Bank model for planning sanitation programmes (7) which encouraged multidisciplinary and multi-stakeholder approaches, such insights including the cultural dimension, are yet to be sufficiently operationalised and implemented in sanitation development (8). The development of decision options is often left to engineers (9) which introduces shortcomings in technology-based on experts with little local ownership (10).

Multi-criteria decision analysis (MCDA) is an approach (also group of techniques) which can be coupled with a problem structuring method (11) and be used as an integrated framework to aid decision-making. It is used to identify the most preferred alternative, rank different alternatives or distinguish acceptable from unacceptable ones. MCDA techniques such as outranking methods, analytic hierarchy process and multi-attribute value theory were applied in evaluating sanitation alternatives. Simple multi-attribute ranking technique (SMART), a type of multi-attribute utility theory (MAUT) measurement (12) has been used in sanitation planning alone, modified or combined with other techniques. A simple

and transparent MCDA framework based on the SMART procedure is proposed to inform decision-makers in selecting appropriate sanitation technologies (ASTs) in a participatory manner for rural communities in LMICs. As Zimbabwe proposes to consider alternative sanitation options which are available on the sanitation market, appropriate ones should be selected considering all relevant stakeholders to address the sanitation needs of the local people, requiring an integrated technology selection framework. A strength, weakness, opportunities and threats (SWOT) analysis is a strategic planning tool that is used to evaluate decision making (13) such as MCDA.

6.3 Materials and methods

6.3.1 Research approach

The framework to select ASTs was developed in an iterative process of literature review of available frameworks (2), data collection through household surveys (14,15), generating sanitation options and technology selection process including its evaluation. The study was done in Mbire district, Mashonaland central province, Zimbabwe. Details of the study area were described elsewhere (14,15). Data collected were used to develop a MCDA framework based on the simple multi-attribute rating technique (Fig. 6.1)

6.3.2 Stakeholder identification

Three members from each of the six stakeholder groups identified from literature (16) were invited to participate in an online survey. These have been used in similar work.

6.3.3 Situational analysis

Since the 1980s Zimbabwe encouraged the use of the Blair ventilated improved pit (BVIP) latrine as a technical solution for rural sanitation. It was not affordable

to many rural households. In 2020, the country had a low rural sanitation coverage of 31% (1).

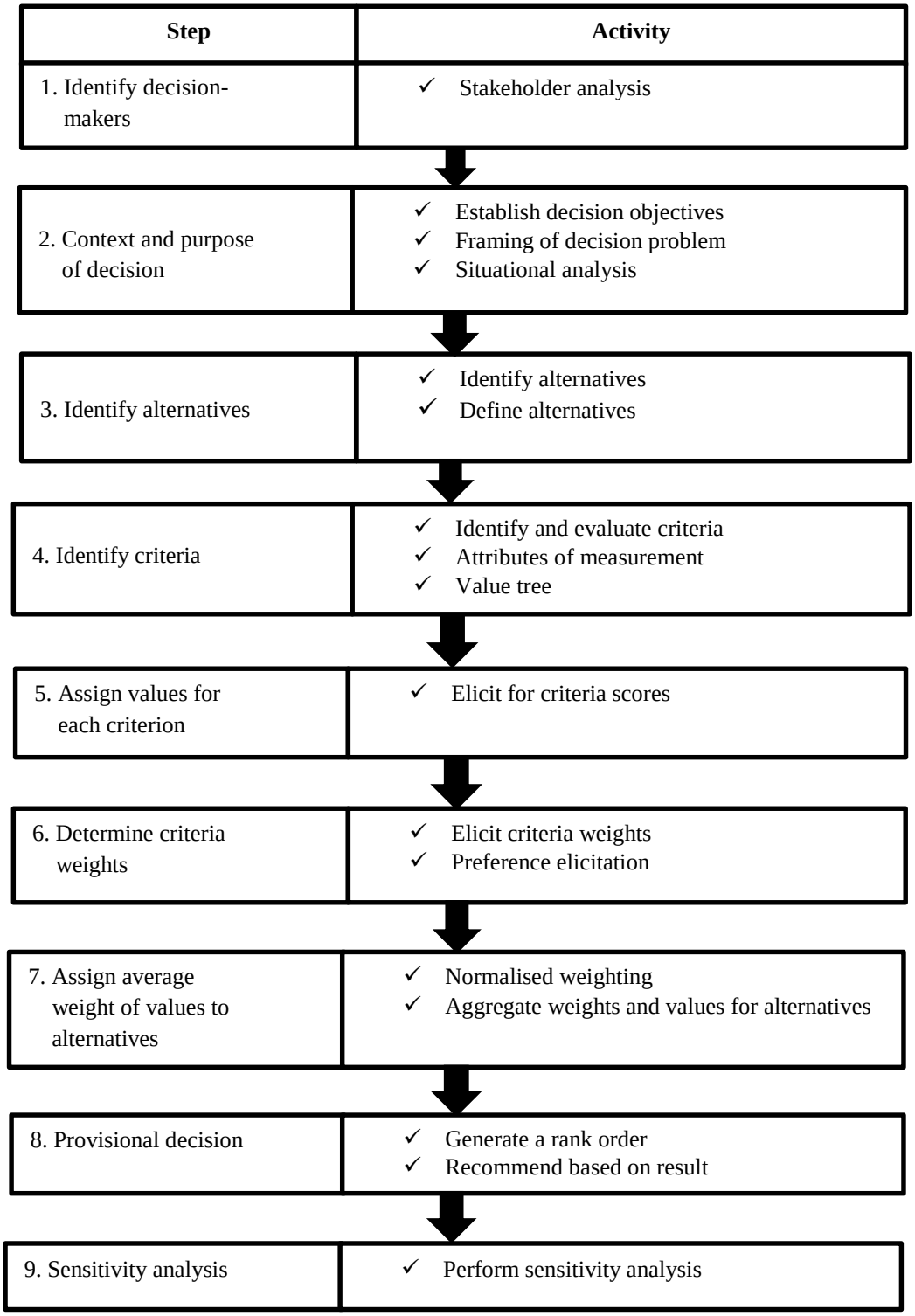


Fig. 6.1 Steps in value measurement of the SMART framework

The national sanitation and hygiene policy draft gazetted in 2017 proposed considering alternative sanitation options (17). The overall aim of the decision-maker is to choose ASTs from a list based on preferences (ranking problem). The decision is influenced by consequences of technology selection in economic, social-cultural, environmental and technical contexts (18).

6.3.4 Decision alternatives

On-site sanitation options which were adopted and sustainably used in rural communities of LMICs were identified from literature (19), independent of stakeholder consultation for preferences. Theoretically generated 'perfect systems' or 'technically functional systems' from an engineering perspective were excluded. Performance measurements were done and literature was used where data were not available. Most of the alternatives were not used in the study area limiting the availability context-specific data and the application of data-intensive collection tools such as life cycle assessment (LCA) and quantitative microbial risk assessment (QMRA).

6.3.5 Decision criteria

An initial list of indicators (here-in referred to as criteria) (Supporting material 6S.1) established from literature (20) was screened by the authors and sent to a pre-selected group of stakeholders for evaluation on-line from February to May 2022. A final comprehensive list of criteria was selected based on requirements for completeness, mutual exclusiveness, operationality and decomposability (21). Respondents were asked to include, exclude or modify criteria. Individual follow-ups with them produced an agreed final list which was used to develop a value tree.

6.3.6 Score and weight elicitation

Subjective methods elicit weights from decision-makers while objective ones use data-driven weights (22). Subjective MAUT methods include direct rating, SMART, SMART-Swing (23). SMART was used for weight and performance score elicitation in the current study based on its advantages stated by Neméth et al. (23):

- its low resource requirement,
- no software requirement,
- relatively moderate chance of bias,
- low complexity,
- ability to handle relatively high number of criteria and
- the decision-making context being a LMIC setting where resources are limiting.

A pre-tested questionnaire (Supporting material 6S.2) was administered on-line to respondents to rank and score selected criteria, and assign weights to alternatives against each criterion (23,24). Ranked criteria were scored from the most important, 100 at the top to the least important, 10 at the bottom. Respondents were asked to assign weights to alternatives against each criterion; 0 - 100, using criteria definitions and value scales provided. After assigning 0 and 100 value points, then relative weights were assigned. Final scores and weights were a result of repeated consensual consultations. SMART becomes liable to inconsistency when different experts are consulted and potential bias if experts have an interest in the decision outcome (24). Scenarios with suggested scores

associated with them and a sensitivity test were suggested improvements to this limitation.

6.3.7 The MCDA technique

SMART uses the multi-level function (12):

$$u_i = \sum_{j=1}^{k} w_j \, u_{ij} \qquad Eq.1$$

Where wj: weight (importance) of criterion j, uij: Performance (preference) for alternative i on criterion j, and ui is the overall utility (preference) for alternative i. Normalisation of criteria weights to get a weighted value was done as described by Dodgson et al. (24):

$$\frac{w_j}{\sum w_j} \qquad Eq.2$$

Where wj: weight value of criteria and ∑wj: total weight of all criteria.

The weighted score was determined as a product of the utility score for each alternative by the normalised criteria value (uiwj). The sum of the weighted criteria scores gave a total utility value for an alternative which was used for ranking. The SMART procedure produced a rank order with the highest total utility value representing the provisionally recommended alternative to decision-makers. Computations were carried out in Microsoft Excel spreadsheets.

6.3.8 Framework evaluation

According to Qureshi et al. (25) model (framework) testing consists of verification (model built with a specific methodology), validation (correctness of model to mimic real world) and sensitivity analysis (extent of variation in predicted model performance). A checklist (Supporting material 6S.3) from literature (26) was

used for model verification. Sources of uncertainty requiring a sensitivity analysis include parameter (e. g., performance of alternatives), structural (e. g., choice of criteria) and heterogeneity in performance among sub-groups (27). A sensitivity test was done to determine the effect of small changes on assigning criteria weights on the final ranking of alternatives. Four scenarios were described: (i) removing 10 value points from each of the socio-cultural criteria, (ii) adding 10 value points to each of the technical criteria, (iii) assigning 50 value points to environmental criteria, and (iv) assigning 50 value points to all the 14 criteria. The SMART procedure was re-run in Microsoft Excel.

Face validity of the framework is considered a relevant validation technique where no real system data is locally available (25). A questionnaire (Supporting material 6S.4), summary of procedures and results were sent on-line to seven pre-identified experts (including the three initially invited for weighting and scoring) familiar with sanitation planning or MCDA. They were identified through snowballing. Expert views were sought on the reasonableness of the framework. Finally, the authors did a SWOT analysis of the framework and results.

6.4 RESULTS

6.4.1 Stakeholder analysis

Relevant stakeholder groups identified represented the authority, policy maker, technology user, and technology implementer and researcher groups (Supporting material 6S.5) in the sanitation sub-sector. An initial low response rate of 61.11% was achieved which decreased during subsequent consultations. No response was received from the private sector.

6.4.2 Alternatives, evaluation criteria and performance values

Table 6.1 shows the five alternatives, final list of 14 evaluated criteria and performance scores of the alternatives. A value tree (Supporting material 6S.6) was developed from the criteria. The characteristics of alternatives used were summarised (Supporting material 6S.7 and 6S.8). The relative importance of a criterion was shown as a percentage proportion of normalised weights (Fig. 6.2).

Table 6.1 Performance matrix for sanitation alternatives against decision criteria

Criteria	Weight (%)	A1. Simple pit with slab	A2. VIP latrine	A3. Pour flush septic tank + soak away	A4. Pour flush double leach pit	A5. UDDT
C1. Control of exposure to pathogens	100	40	60	90	90	70
C2. Investment costs	100	100	75	25	50	75
C3. Convenience	100	25	50	100	100	50
C4. Durability	90	50	50	75	100	100
C5. Cultural acceptance	80	100	100	100	100	50
C6. Water source protection	70	25	25	25	25	100
C7. Current legal acceptability	60	100	100	100	25	25
C8. Local availability of materials	50	100	100	75	75	50
C9. Local availability of skilled labour	50	100	100	0	0	100
C10. Need for ease of excavation	40	25	25	0	0	100
C11. O & M costs	30	75	75	50	50	75
C12. Water for operation	20	100	100	25	25	100
C13. Robustness	20	50	50	25	50	100
C14. Nutrient recovery	10	0	0	50	50	75
Total	820					

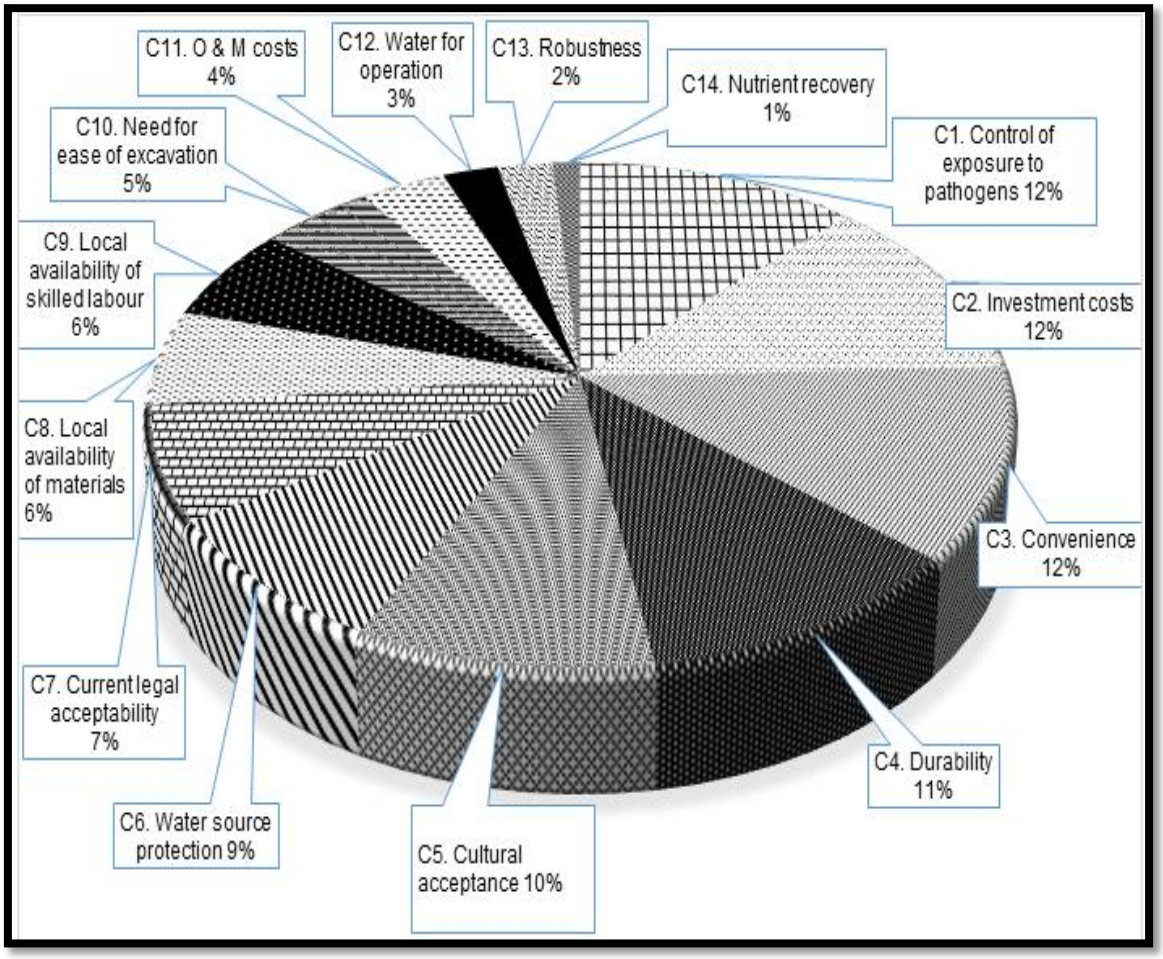


Fig. 6.2 Normalised criteria weights (%)

6.4.3 Criteria weights, normalisation and utility scores

Table 6.2 shows criteria weights, their normalised weights and utility scores for alternatives. The values were read off from an output of computations done in MS Excel (Supporting material 6S.9). Based on the assumptions that were made in the SMART model, alternative A5, the urine diverting dry toilet (UDDT) was ranked number 1 with a total utility score of 72.54. Alternative A2, the BVIP latrine was ranked second with a total utility score of 67.10.

Table 6.2 Aggregation to estimate utility and total utility scores for alternatives

Criteria	Normalised value $\frac{w_j}{\sum w_j}$	Utility score of alternative				
		A1	A2	A3	A4	A5
C1. Control of exposure to pathogens	0.122	40	60	90	90	70
C2. Investment costs	0.122	100	75	25	50	75
C3. Convenience	0.122	25	50	100	100	50
C4. Durability	0.110	50	50	75	100	100
C5. Cultural acceptance	0.098	100	100	100	100	50
C6. Water source protection	0.085	25	25	25	25	100
C7. Current legal acceptability	0.073	100	100	100	25	25
C8. Local availability of materials	0.061	100	100	75	75	50
C9. Local availability of skilled labour	0.061	100	100	0	0	100
C10. Need for ease of excavation	0.049	25	25	0	0	100
C11. O & M costs	0.037	75	75	50	50	75
C12. Water for operation	0.024	100	100	25	25	100
C13. Robustness	0.024	50	50	25	50	100
C14. Nutrient recovery	0.012	0	0	50	50	75
Total	**1.000**	**64.66**	**67.10**	**61.93**	**62.86**	**72.54**
Rank		**3**	**2**	**5**	**4**	**1**

A1: Simple pit with slab, A2: VIP latrine A3: Pour flush septic tank + soak away A4: Pour flush double leach pit, A5: UDDT

The socio-cultural criteria category, followed by the technical category contributed most to the overall utility values for an alternative (Fig. 6.4).

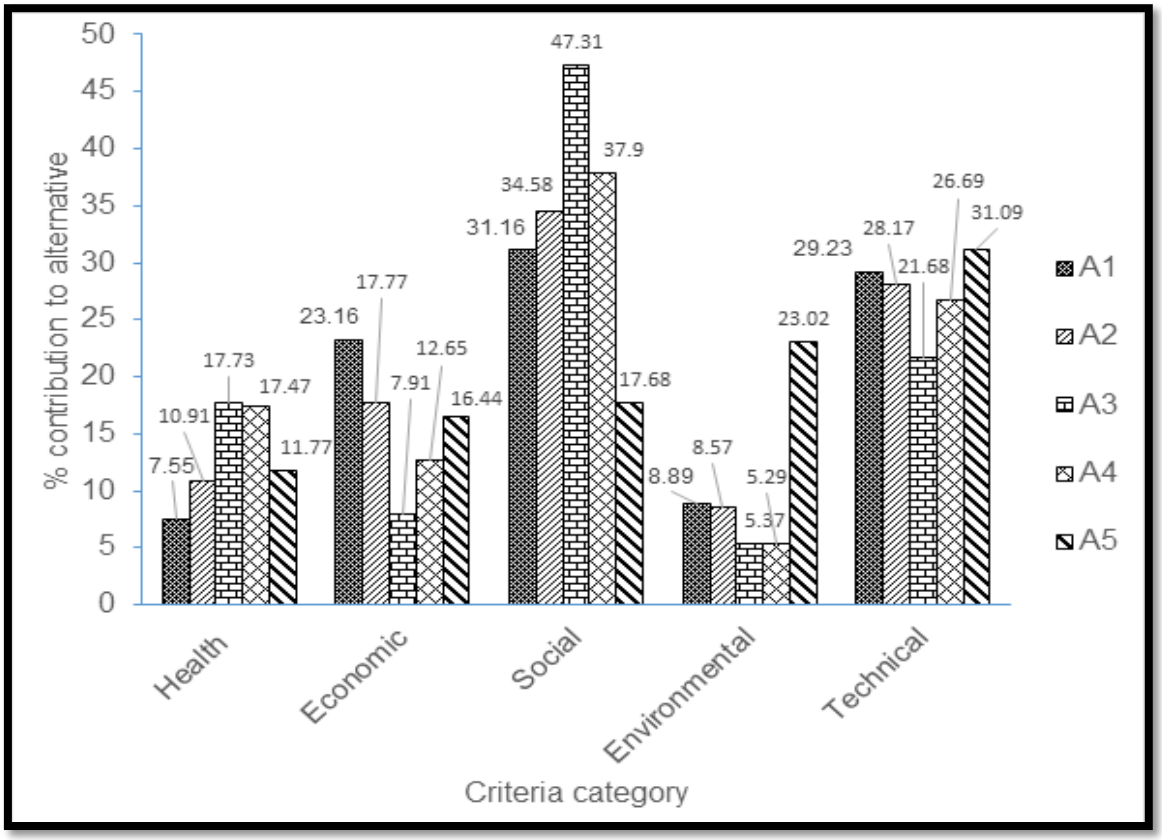


Fig. 6.3 Percent contribution of criteria category to alternative selection.

The environmental criteria contributed the least. For the UDDT, the percent contribution of criteria categories to the selection of the alternative decreased in the order: Socio-cultural (37.90) > technical (26.69) > human health (17.47) > economic (12.65) > environmental (5.29).

6.4.4 Framework evaluation

Small changes in criteria weights for the four different scenarios did not affect the rank order of the original model for ranks (Table 6.3). The model appeared to be robust.

Table 6.3 Results of sensitivity analysis

Scenario	Description of change in criteria weight	A1		A2		A3		A4		A5	
		value	rank	value	Rank	value	rank	Value	rank	value	rank
(i)	Original MCDA framework criteria weights	64.66	3	67.10	2	61.93	5	62.86	4	72.54	1
(ii)	Small reductions in social criteria	61.89	3	64.02	2	58.23	5	60.06	4	71.04	1
(iii)	Small additions in technical criteria	68.29	3	70.73	2	64.02	5	65.55	4	78.66	1
(iv)	Assigned 50 value points across all criteria	54.27	3	55.49	2	45.12	5	45.12	5	65.24	1

A1: Simple pit with slab, A2: VIP latrine A3: Pour flush septic tank + soak away A4: Pour flush double leach pit, A5: UDDT

Framework verification using a pre-designed checklist indicated that all the steps of the framework were followed with details provided in each step of the procedure.

Expert opinion indicated that the framework was reasonable with a score of 59.6% (Supporting material 6S.10). Three invited experts did not respond (57.1% response rate). Responses to experts' comments were explanations to their concerns some of which were used to improve the framework. Item Q1: The decision problem was framed together with decision objectives and situational analysis of the SMART (Fig. 6S.1) which made it long. However, a ranking decision was investigated. Item Q3: A sanitation exclusion strategy was described in the methodology. Stakeholder preferences were not elicited for alternatives since a single solution was prescribed for rural sanitation. Information on various alternatives was assumed to be only available to experts.

Item Q4: Measurements for material flows are usually done for nutrients, energy, water, wastewater and gaseous emissions. Without nutrient reuse, quantitative nutrient recovery was not considered. Instead, potential for recovery was qualitatively used. No energy is used in all the alternatives. Water requirements were quantitatively considered. The main public health objective for a sanitation facility is to prevent human contact with faecal pathogens. The economic benefit of sanitation is usually determined considering relevant national economic variables. Zimbabwe is currently operating in a hyper-inflationary environment (above 200%) making it difficult to determine cost-effectiveness as variables are not fixed. Item Q5: Criteria weights are subjective (MCDA approach).

However, stakeholders were given an interval scale, guides and characteristics of alternatives. Further, a sensitivity test was done to check for consistency.

Item Q11: Introducing a new alternative and using a scenario analysis are different approaches to sensitivity analysis. The current study used criteria weights. Further, verification and validation were also done. Item Q12: It is a characteristic of the SMART procedure being flexible to adding an alternative. It does not affect the criteria weights and the scoring, hence the overall utilities of the other alternatives. Adding criteria can be done to a manageable number in MCDA but it changes criteria weights which means that the overall utility computations are affected. The whole procedure is started.

6.4.5 Results of SWOT analysis

A SWOT analysis showed the strengths, weaknesses, opportunities and threats of the framework and the final results (Supporting material 6S.11). Most of the strengths were identified with the technical, environmental and economic advantages of the UDDT alternative, and the SMART. Similarly, associated weaknesses were the limitations of the alternative and the MCDA approach used. Critical threats included cultural acceptance of ecological sanitation, exposure to pathogens and potential reduced adoption of the BVIP latrine.

6.5 Discussion

Considering only adopted and sustainably used sanitation options for the MCDA resulted in a relatively short database of candidate on-site options. This shortened the generation of potential alternatives. The pour flush toilet is generally used as an in-house unit locally. The BVIP latrine and UDDT are commonly out-house structures from literature. Sanitation

alternatives evaluated in the current study were reportedly used in urban and peri-urban settings (28). The UDDT is an ecological sanitation technology where waste reuse is encouraged. Thousands of units were constructed and are used in South Africa (29), Zimbabwe's neighbour. Other than nutrient recovery, the technology can be built in rocky areas, high water table environments or in loose soils where the BVIP and simple pit latrine may not be applicable. Provided there is political will, the UDDT may be piloted including participatory health and hygiene education (PHHE) to safeguard human health. The technology was piloted in some urban Zimbabwean areas but no full studies were published. Considering alternative technical alternatives may improve access to sanitation in diverse environments and may potentially increase latrine use when local preferences are prioritised.

The BVIP latrine was second on the selection rank closely followed by the pit latrine with a slab. The simple pit latrine with a concrete slab is considered an upgradable BVIP latrine in Zimbabwe (14,15). It becomes important to upgrade than build a new one to meet regulatory requirements. Existing facilities may reflect local socio-cultural preferences, economic and technical capacities (30). However, in the absence of a facility, an appropriate one should be selected from potential alternatives. A recommendation from a baseline survey of the study area was that the adoption and completion of the upgradable BVIP latrine need to be studied outside pilot studies (14).

Considering that the BVIP latrine has been the technical solution to rural sanitation in Zimbabwe for the past four decades (15), having the UDDT as the first preference was

an unexpected result. Existing preferences and local values were reported to potentially influence results with alternatives likely to be assessed unfavourably (31). Moving from the first preferred alternative (UDDT) to the second (BVIP latrine) will be favourable as the latter has no cultural restrictions and construction materials are locally available. However, the disadvantages to be faced include ground excavation requirement, lack of nutrient recovery (based on local practice), and potential groundwater pollution. These are environmental issues which were observed in this study to contribute the least to the overall utility for an alternative.

Engaging different groups of stakeholders in developing the current MCDA framework allowed an integrated analysis of multiple stakeholder objectives which are often conflicting. However, a low response rate was achieved, particularly in follow-up engagements. This could happen with the SMART procedure (32). The format in the online survey that forced respondents to answer each question in order to proceed through the questionnaire could explain the low response rate (33). A workshop or focus group discussions may be ideal. The categories of criteria used in the current study have been used in literature as principles, main objectives or criteria. From these categories, sub-criteria, attributes, indicators are derived which basically refer more or less the same thing, measurable variables. Although many indicators of sanitation technology appropriateness (or sustainability in some cases) are available in literature (6,10,34), only a comprehensive list for use in MCDA are considered.

The selection of criteria (21) reduces them to a manageable number for use in MCDA. Qualitative criteria used involving ethical and moral principles, and environmental

considerations could not be easily condensed into a monetary or economic value as observed by Kiker et al. (35).

The sensitivity analysis results indicated that the SMART was robust. Verification of the framework using a checklist from literature indicated that all the steps of the SMART were verified to show consistency. Experts' opinion suggested reasonableness of the SMART procedure despite some experts not scoring some questionnaire items for lack of readily available data, e. g., the description of the study area was referred to some references in the text. A literature-based SWOT analysis was performed to support the decision situation.

6.6 Limitations of the study

The study was done in a country anticipating a policy review towards using other sanitation alternatives for rural communities. It had over four decades using a single sanitation option for rural sanitation. These may limit the generalisability of the findings to other areas although useful to inform the selection of appropriate alternatives process. The framework was not tested by using it for sanitation planning in the study area as there was no intervention taking place. It was based on the current sanitation regulatory framework while awaiting the finalisation of the 2017 policy draft which encourages considering alternatives. The assessment of performances of alternatives, particularly those not used locally, could have been very theoretically grounded, therefore subjective. However, they were based on literature.

Other methodological limitations include low response rates and long response times from selected participants, lack of resources and timing of the study. Data collection was affected by the COVID 19 guidelines which included restrictions of movement and gatherings, at times resorting to on-line surveys. This was worsened by prolonged approval of field visits by the local health ministry.

6.7 Policy implications

The transition from a national sanitation technology to acceptable alternatives may be faced with some challenges. For Zimbabwe, potential challenges could be: (i) high level of community involvement without necessary awareness, knowledge and experience on acceptable alternatives (15), (ii) lack of political will which creates an enabling operational environment. The BVIP latrine is a Zimbabwean home-grown innovation which received extensive government support and forms part of the national educational curricula. Change may be met with some resistance. (iii) The BVIP latrine, encouraged for rural Zimbabwe, is found high up the rungs of the sanitation service ladder. Reverting to alternatives with perceived lower benefits than itself may not be readily acceptable, even though the current technology may not be considered appropriate in other contexts. Further, (iv) technologies often yield different levels of service and different expected benefits.

6.8 Conclusions, recommendations and future outlook

A simple, consistent and transparent MCDA approach was developed involving locals and sanitation experts in an open consultative process to be contextually relevant, an improvement to other sanitation frameworks. A list of criteria for judging the performance of alternatives and a selection procedure of alternatives were established. The framework

was evaluated by verification, validation and sensitivity testing. It was considered reasonable by expert opinion (face validity) and robust by a sensitivity test. The urine diverting dry toilet (UDDT) was ranked first, and the currently used technology (BVIP latrine), second.

Criteria and alternatives are dynamic and therefore expected to change with settings. The developed framework should be a living document which would require updating and in view of new evidence in future. Revision of the framework every five years is recommended. Future work should address the identified weaknesses and threats for strategic sanitation planning, particularly cultural acceptance of ecological sanitation, including the whole sanitation chain and potential public health risks. Novel or innovative alternatives maybe considered later. Further work on may be done on the appropriateness of the water-tight BVIP design (modification of the local innovation) which involves pit emptying when handling of human waste becomes universally acceptable.

References

1. World Health Organisation/United Nations Children's Fund [WHO/UNICEF]. State of the world's sanitation. A call to transform sanitation for better health, environments, economies and societies. Geneva/New York: WHO/UNICEF, 2020. https://www.unicef.org/reports/state-worlds-sanitation-2020. [Accessed 1 November 2021].
2. Kanda A, Ncube EJ, Voyi K. Frameworks for selecting appropriate rural sanitation technology options in low- and middle-income countries: a critical review. *Int J Environ Health Res*. 2021; Doi: 10.1080/09603123.2021.1963685.

3. Kanda A, Ncube EJ, Voyi K. Effect of sanitation interventions on health outcomes: A systematic review of cluster-randomized controlled trials in rural communities of low- and middle-income countries. *Int J Environ Res Public Health*. 2021; 18(16):8313.
4. Troeger C, Blacker BF, Khalil IA, Rao PC, Cao S, Zimsen SRM, Albertson SB, Stanaway JD, Deshpande A, Zegeye A-G, Nelson AAT et al. Estimates of the global, regional, and national morbidity, mortality, and aetiologies of diarrhoea in 195 countries: a systematic analysis for the global burden of disease study 2016. *Lancet Infect Dis*. 2018; S1473309918303621.
Doi: 10.1016/S1473-3099(18)30362-1.
5. Dakuré MS, Traoré MB, Sossou SK, Maïga AH. Development of sanitation technologies in African context: how could we make it more sustainable? *IOP Conf Ser Earth Environ Sci.* 2017; 60:012032.
6. Simiyu S. Preference for and characteristics of an appropriate sanitation technology for the slums of Kisumu, Kenya. *Int J Urban Sustain Dev*. 2017; 9(3):300-312.
7. Kalbermatten JM, Julius DS, Gunnerson CG, Mara DD. Appropriate sanitation alternatives - A planning and design manual. World Bank Studies in water supply and sanitation, Vol. 2. Baltimore: The Johns Hopkins University Press, 1980.
8. Workman CL, Cairns MR, de los Reyes FL, Verbyla ME. Global water, sanitation, and hygiene approaches: anthropological contributions and future directions for engineering. *Environ Eng Sci*. 2021; 38(5): 402-417.

9. Spuhler D, Lüthi C. Review of frameworks and tools for urban strategic sanitation planning: a structured decision-making perspective. *J Water Sanit Hyg Dev*. 2020; 10(4):768-785.
10. Spuhler D, Germann V, Kassa K, Ketema AA, Sherpa AM, Sherpa MG, Maurer M, Lüthi C, Langergraber G. Developing sanitation planning options: A tool for systematic consideration of novel technologies and systems. *J Environ Manage*. 271, 111004.
11. Belton V, Stewart T. Problem structuring and MCDA. In: Trends in multiple criteria decision analysis. Ehrgott M, Figueira R, and Greco S, (Eds)., US: Springer, 2010. pp. 209-239.
12. Bakus GJ, Stillwell WG, Latter SM, Wallerstein MC. Decision making: with applications for environmental management. *Environ Manage*. 1982; 6(6):493-504.
13. Kim Y-J, Park J. A sustainable development strategy for the Uzbekistan textile industry: The results of a SWOT-AHP analysis. *Sustainability*. 2019; 11, 4613.
14. Kanda A, Ncube EJ, Voyi K. Adapting sanitation needs to a latrine design (and its upgradable models): A mixed method study under lower middle-income rural settings. *Sustainability*. 2021; 13(23):13444.
15. Kanda A, Ncube EJ, Voyi K. Drivers and barriers to sustained use of Blair ventilated improved pit latrine after nearly four decades in rural Zimbabwe. *PLoS ONE*. 2022; 17(4):e0265077.
16. Cairncross S, Bartram J, Cumming O, Brocklehurst C. Hygiene, sanitation, and water: What needs to be done? *PLoS Med*. 2010; 7(11), e1000365.

17. Government of Zimbabwe [GoZ]. The Zimbabwe national sanitation and hygiene policy draft. National Action Committee for rural water supply and sanitation. Harare: GoZ; 2017.
18. Chitescua RI, Lixandru M. The influence of the social, political and economic impact on human resources, as a determinant factor of sustainable development. 3rd Global conference on business, economics, management and tourism 26-28 November 2015, Rome, Italy. *Procedia Econ Fin*. 2016; 39:820-826.
19. Tilley E, Ulrich L, Lüthi C, Reymond PH, Zurbrügg C. Compendium of sanitation systems and technologies. 2nd revised Edn. Dübendorf: Swiss Federal Institute of Aquatic Science and Technology (Eawag), 2014.
20. Turrén-Cruz T, García-Rodríguez JA, Peimbert-García RE, Zavala MÁL. An approach incorporating user preferences in the design of sanitation systems and its application in the rural communities of Chiapas, Mexico. *Sustainability*. 2020; 12(3), 1024.
21. Habenicht W, Scheubrein B, Scheubrein R. Multiple-criteria decision making. In: Optimisation and operation research, Derigs U (Ed). Vol. IV. Oxford: UNESCO-EOLSS Publishers Co. Ltd., 2009, pp. 257-279.
22. Canella M, Kadziński M, Gonzalez M, Słowiński R. How to support the application of multiple criteria decision analysis? Let us start with a comprehensive taxonomy. *Omega*. 2020; 96:102261.

23. Neméth B, Molnár A, Bozóki S, Wijaya K, Inotai A, Campbell JD, Kaló Z. Comparison of weighting methods used in multicriteria decision analysis frameworks in healthcare with focus on low- and middle-income countries. *J Comp Eff Res*. 2019; 8(4):195-204.
24. Dodgson JS, Spackman M, Pearman AD, Phillips LD. Multi-criteria analysis: A manual. London: Department for Communities and Local Government, 2009. http://eprints.lse.ac.uk/12761/1/Multi-criteria_Analysis.pdf
[Accessed 1 November 2021].
25. Qureshi ME, Harrison SR, Wegener MK. Validation of multicriteria analysis models. *Agric Syst*. 1999; 62:105-116.
26. Marsh K, IJzerman M, Thokala P, Baltussen R, Boysen M, Kaló Z, Lönngren T, Mussen F, Peacock S, Watkins J, Devlin N. Multiple criteria decision analysis for health care decision making -Emerging good practices: Report 2 of the ISPOR MCDA, Emerging good practices task force. *Value Health*. 2016; 19(2):125-137.
27. Thokala P, Devlin N, Marsh K, Baltussen R, Boysen M, Kalo Z, Longrenn T, Mussen F, Peacock S, Watkins J, Ijzerman M. Multiple criteria decision analysis for health care decision making - An introduction: Report 1 of the ISPOR MCDA Emerging good practices task force. Value in Health. 2016; 19(1):1-13.
28. Kumwenda S, Msefula C, Kadewa W, Ngwira B, Morse T. Estimating the health risk associated with the use of ecological sanitation toilets in Malawi. *J Environ Public Health*. 2017; 1-13.

29. Mkhize N, Taylor M, Udert KM, Gounden TG, Buckley CA. Urine diversion dry toilets in eThekwini Municipality, South Africa: acceptance, use and maintenance through users' eyes. *J Water Sanit Hyg Dev*. 2017; 7(1):111-120.
30. Brikké F, Bredero M. Linking technology choice with operation and maintenance in the context of community water supply and sanitation. A reference document for planners and project staff. Geneva: WHO/IRC Water and Sanitation Centre, 2003, p10; 103-126.
31. Barnes R, Ashbolt N. Development of a planning framework for sustainable rural water supply and sanitation. *Int Stud Manag Organ*. 2010; 40(3):78-98.
32. Ma W, Du Y, Liu X, Shen Y. Literature review: Multi-criteria decision-making method application for sustainable deep-sea mining transport plans. *Ecol Indic*. 2022; 140, 109049.
33. Sischka PE, Décieux JP, Mergener A, Neufang KM, Schmidt AF. The impact of forced answering and reactance on answering behavior in online surveys. *Soc Sci Comput Rev*. 2022; 40(2):405-425.
34. Kvarnström E, Bracken P, Ysunza A, Kärrman E, Finnson A, Saywell D. Sustainability criteria in sanitation planning. 30th WEDC International Conference, Vientiane, Lao PDR, 2004. People-centred approaches to water and environmental sanitation, 2004, pp. 104-107.
35. Kiker GA, Bridges TS, Varghese A, Seager TP, Linkov I. Application of multicriteria decision analysis in environmental decision making. *Integr Environ Assess Manage*. 2005; 1(2):95-108.

Supporting material 6S.1 Initial list of decision criteria and criteria definition

Criteria	Sub-criteria (indicator)
Human health protection	Control of exposure to pathogens
Environmental protection	Water for operation
	Water source protection
	Nutrient recovery
	Need for ease of excavation
	Soil permeability
	Air emissions
Economic viability	Investment cost
	O & M costs
	Break-even time
	Cost effectiveness
	Willingness to pay
Socio-cultural acceptance	Cultural acceptability
	Regulatory requirements
	Convenience
	Information requirement
	Odour/fly nuisance
	Institutional requirements
	Local skill for construction
	Local skill for maintenance
	Compatibility

Technical feasibility	Robustness
	Availability of resources locally
	Durability
	Adaptability
	Treatment efficiency

Explanation of terms

A. *Explanation of decision objectives* (34)

1. Human health protection: Protect and promote human health (prevent contact with excreta) considering the whole sanitation service chain.
2. Technical acceptability: Robustness- ability to receive varying loads and externally able to withstand varying extreme environmental conditions and user abuse.
3. Socio-cultural acceptance: Cultural acceptance, institutional requirements and perceptions on sanitation technology including aspects of user convenience.
4. Economic viability: The willingness and capacity to pay for sanitation services among the users define within what range the costs, both of construction and O&M, can vary and services be sustained financially by the population.
5. Environmental protection: Emissions to different recipients (water, soil and air), efficiency of treatment for potential reuse and resource use by alternatives (construction, operation).

B. Explanation of decision criteria characteristics (21)

1. Completeness: All relevant aspects for the assessment of alternatives to be covered/included by the system of criteria
2. Mutual exclusiveness/non-redundancy: Criterion should measure aspects of the problem not measured by any other to avoid double entry/duplication.
3. Reliability/operationality: Each criterion should assess *precisely* the aspect it is intended to measure
4. Decomposability: Performance of an alternative to be assessed independently, without considering its performance on other criteria
5. Minimum size: The criteria list should be kept simple and small yet still including all relevant criteria

Explanation of decision criteria (6,10,34)

Sub-criteria/Indicator	Description
Controls exposure to pathogens	Potential health risk by pathogens through excreta contact
Local availability of skilled labour	Local skill for construction and maintenance
Local availability of materials	Materials for construction of technology and/or operation and maintenance
Durability	Life time
Robustness	Sensitivity to shock loads/user abuse, extreme weather
Soil permeability	Rate at which water infiltrates into soil
Air emissions	Contribution to global warming
Adaptability	To user and existing environmental conditions, e.g. geology
Treatment efficiency	Capacity for treatment and disposal, reduce human contact
Water for operation	Water requirement for discharge/disposal/treatment of excreta

Water source protection	Risk of emission of pollutants (nutrients) to water sources
Nutrient recovery	Possibility of nutrient recovery and recycle to land
Need for ease of excavation	Ease with which soil can be dug out of the ground
Cultural acceptance	Compatible with local priorities, needs, norms and values
Institutional requirements	Involves key leaders and organisational structure
Convenience	Accessible to all, security, comfort, dignity, odour, fly nuisance
Current legal acceptance	Acceptable to a functional legal system / policy
Investment costs	Initial costs related to the construction of the sanitation system
O & M costs	Costs associated with O &M (recurring costs for service)
Willingness to pay (WTP)	Financial effort for full investment cost) of the facility
Break-even time	Point at which you will have returns enough to cover all costs

Supporting material 6S.2 Questionnaire for elicitation of criteria and performance scores

Introduction

Zimbabwe gazetted a sanitation and hygiene policy draft in 2017 to consider alternative sanitation options for rural communities backed by scientific research evidence. Once the draft is finalised into policy, different options are needed to address the needs of communities due to unique sanitation demands and local contextual settings. A decision-making aid may inform decision-makers when selecting appropriate sanitation technologies. You have been selected as a stakeholder in the study to develop such an aid because of your involvement in WASH activities. All ethical concerns will be observed. Do not indicate your name. You will need at least 20 minutes to complete the questionnaire.

An appropriate sanitation technology (latrine) has to protect public health and the environment, be socially and institutionally acceptable, economically viable and technically feasible.

SECTION A: Brief demographic information

Please indicate (highlight, put a 'x' or otherwise) your response

1. *Type of stakeholder you are in national WASH activities*:
    1. Community member
    2. Academic/researcher
    3. Gvt. professional
    4. NGO
    5. Private sector

6. National Action Committee/ National Coordination Unit

2. *Sex*:
    1. Male
    2. Female
3. *Age group (years*):
    1. < 26
    2. 26 - 35
    3. 36 - 45
    4. > 45
4. *Highest academic qualification obtained*:
    1. High school certificate
    2. Diploma
    3. Undergraduate degree
    4. Master's degree
    5. PhD
5. *Highest level of operation in WASH activities:*
    1. Household
    2. Ward
    3. District.
    4. Province
    5. National
    6. International

SECTION B: ranking and scoring criteria

In the table below rank number 1 – 14, and score the 14 criteria (used when selecting an appropriate technology) from most important; 100 at the top, to least important; 10 at the bottom. Criteria may share the same score. The rest of criteria are weighted between 10 and 100 relative to the first 2 in order of importance going down. Definitions of criteria and interval scale are given at the end if you need them.

Criteria	Rank (1-14)	Score (10 – 100)
Controls exposure to pathogens		
Local availability of skilled labour		
Local availability of materials		
Durability		
Robustness		
Water for operation		
Water source protection		
Nutrient recovery		
Need for ease of excavation		
Cultural acceptance		
Convenience		
Current legal acceptance		
Investment costs		
O & M costs		

SECTION C: Performance scores

Assign weights to alternatives against each criterion 0 (least preferred) to 100 (most preferred. Assign scores to the rest using values between 0 and 100. Use criteria definitions and value scales provided.

Criteria	Pit latrine with slab	BVIP latrine	Pour flush septic tank -soak away	Pour flush, 2 leach pits	. UDDT
Controls exposure to pathogens					
Local availability of skilled labour					
Local availability of materials					
Durability					
Robustness					
Water for operation					
Water source protection					
Nutrient recovery					
Need for ease of excavation					
Cultural acceptance					
Convenience					
Current legal acceptance					
Investment costs					
O & M costs					

Definition of criteria

Criteria	Definition
Controls exposure to pathogens	*100-point scale ranging 0 – 100* 0 = very poorly controls exposure to pathogens 100 = Controls human contact with faces
Local availability of skilled labour	*100-point scale ranging from 0 - 100* 0 = Needs professionals for construction or maintenance 100 = Can be constructed or maintained by local trained masons
Local availability of materials	*100-point scale ranging from 0 - 100* 0 = All materials need to be bought elsewhere and be transported 100 = All materials are readily available locally
Durability (years)	0 = < 5; 25 = 5 - 10; 50 = 11 - 15; 75. 16 – 20 100 = > 20
Robustness	*100-point scale ranging from 0 -100* 0 = Cannot withstand user abuse / shock loads / environmental forces 100 = Able to withstand abuse by user /shock loads / environmental forces
Water for operation (L/d/person)	0 = > 30; 25 = 20 - 30; 50 = 11 - 19 75 = 1 - 9 100 = 0
Water source protection	*100-point scale ranging from 0 - 100* 0 = Readily releases nutrients/pathogens to nearby water sources 100 = Does not release nutrients or pathogens to nearby water sources
Nutrient recovery	*100-point scale ranging from 0 - 100* 0 = No nutrients are recovered from waste streams 100 = Large quantities of nutrients are readily recovered
Need for ease of excavation	*100-point scale ranging from 0 - 100* 0 = Ground excavation for more than one pit is always needed 100 = No ground excavation is required during construction
	100-point scale ranging from 0 - 100

Cultural acceptance	0 = Local culture does not accept the technology 100 = The are no cultural restrictions to technology acceptance
Convenience	*100-point scale ranging from 0 - 100* 0 = Very low; 25 = Low; 50 = Medium 75 = High; 100 = Very high
Current legal acceptance	*100-point scale ranging from 0 - 100* 0 = Not acceptable by current regulatory frameworks 25 = Some restrictions by current regulatory frameworks 100 = No restrictions for adoption by current regulatory frameworks
Investment costs (US$)	*100-point scale ranging from 0 - 100* 0 = ≥ 900 25 = 600 - 899 50 = 400 - 599 75 = 200 - 399 100 = < 200
O & M costs*	*100-point scale ranging from 0 - 100* 0 = A relatively lot of money is needed for operations and maintenance 100 = Very little to negligible amount of money is needed for O & M

* Qualitative assessment as no values were established

END OF QUESTIONNAIRE

Thank you for your participation

Supporting material 6S.3 Verification of MCDA framework procedure. Good practice guidelines checklist for an MCDA framework (26)

	MCDA step	Recommendation	Comment
1	Defining the decision problem	Develop a clear description of the decision problem	Use of a single sanitation option in diverse areas – need alternatives to increase rural sanitation access
		Validate and report the decision problem	Assessment data: nationally 31% rural sanitation access
2	Selecting and structuring criteria	Report and justify the methods used to identify criteria	Literature review and community assessment data
		Report and justify the criteria definitions	Criteria definitions were provided as supplementary material
		Validate and report the criteria and the value tree	18 final criteria agreed on selected by stakeholders on a value tree
3	Measuring performance	Report and justify the sources used to measure performance	Alternatives were characterised from literature (data provided)
		Validate and report the performance matrix	Performance of alternatives on each criterion given as results
4	Scoring alternatives	Report and justify the methods used for scoring	Scoring by SMART- several criteria,
		Validate and report scores	Scores agreed upon by stakeholders and reported as results
5	Weighting criteria	Report and justify the methods used for weighting	Weighting by SMART
		Validate and report weights	Weights assigned by stakeholders and reported as results

6	Calculating aggregate scores	Normalisation method used	Normalisation done by weight divided by weight total for a criterion
		Report and justify the aggregation function used	Additive aggregation method used
		Validate and report results of the aggregation	Computations in MS Excel, output reported as results
7	Dealing with uncertainty	Report sources of uncertainty	Subjectivity of assigning of criteria weights by stakeholders
		Report and justify the uncertainty analysis	Sensitivity analysis done using three scenarios. Results given
8	Report MCDA method & findings	Report the MCDA method and findings	Findings were given as results
		Examine the MCDA findings	Findings were examined by a discussion of results

Supporting material 6S.4 Questionnaire for experts to validate the MCDA framework

Introduction

A MCDA framework was developed following the nine steps of the SMART approach to select appropriate sanitation options for rural communities in low- and middle-income countries. Six groups of stakeholders, criteria and sanitation alternatives were identified from literature. Stakeholder preferences were considered in ranking and weighting criteria, and scoring alternatives against criteria. Normalisation was done by diving criterion weight by the sum of all criteria. Utility values were calculated as the product of the normalised criteria a weight and the score of the alternative, whose sum gave the overall utility value used for ranking alternatives. The framework was evaluated by verification, validation and sensitivity analysis. Results indicated that the urine diverting dry toilet (UDDT) was ranked first, followed by the Blair ventilated improved pit (BVIP) latrine.

You were selected to participate in validating the framework based on your expertise in sanitation through research and/or participation in sanitation interventions with experience of more than 5 years. Confidentiality of information shared through your voluntary participation is guaranteed. May you please answer the following 13 questions by indicating Yes or No. You may add comments after your response.

Validation of MCDA framework (face validity)

1. Was the decision problem reasonably articulated? Yes/No

Comments: ……

2. Do stakeholder groups identified reasonably relevant? Yes/No

Comments: ……..……

……..……

3. Are alternatives identified reasonably feasible for the described study area? Yes/No

Comments: ……..

……

4. Do the 14 selected criteria chosen reasonably define appropriateness of an alternative?

Yes/No.

Comments: …..…….

…….

5. Are assigned criteria weights reasonable to compare the alternatives? Yes/No

Comments: ……

…….

6. Was the interval scale used reasonable to score alternatives? Yes/No

Comments: …….

……

7. Is the SMART reasonably useful in this type of decision problem? Yes/No

Comments: ……..

……..

8. Is the first ranked alternative expected for the described study area? Yes/ No

Comments: ……..…….

……

9. Are the socio-cultural, technical and human health criteria categories expected to contribute most to the first ranked alternative? Yes/No

Comments: ……..

……

10. Is there a procedural trail of the framework? Yes/No

Comments: ……..

……

11. Is the framework robust? Yes/No.

Comments: ……

……

12. Can the framework be flexible to adding new alternatives/criteria? Yes/No.

Comments: ……

……

13. Was the evaluation of the framework reasonable? Yes/No.

Comments: ……..

……

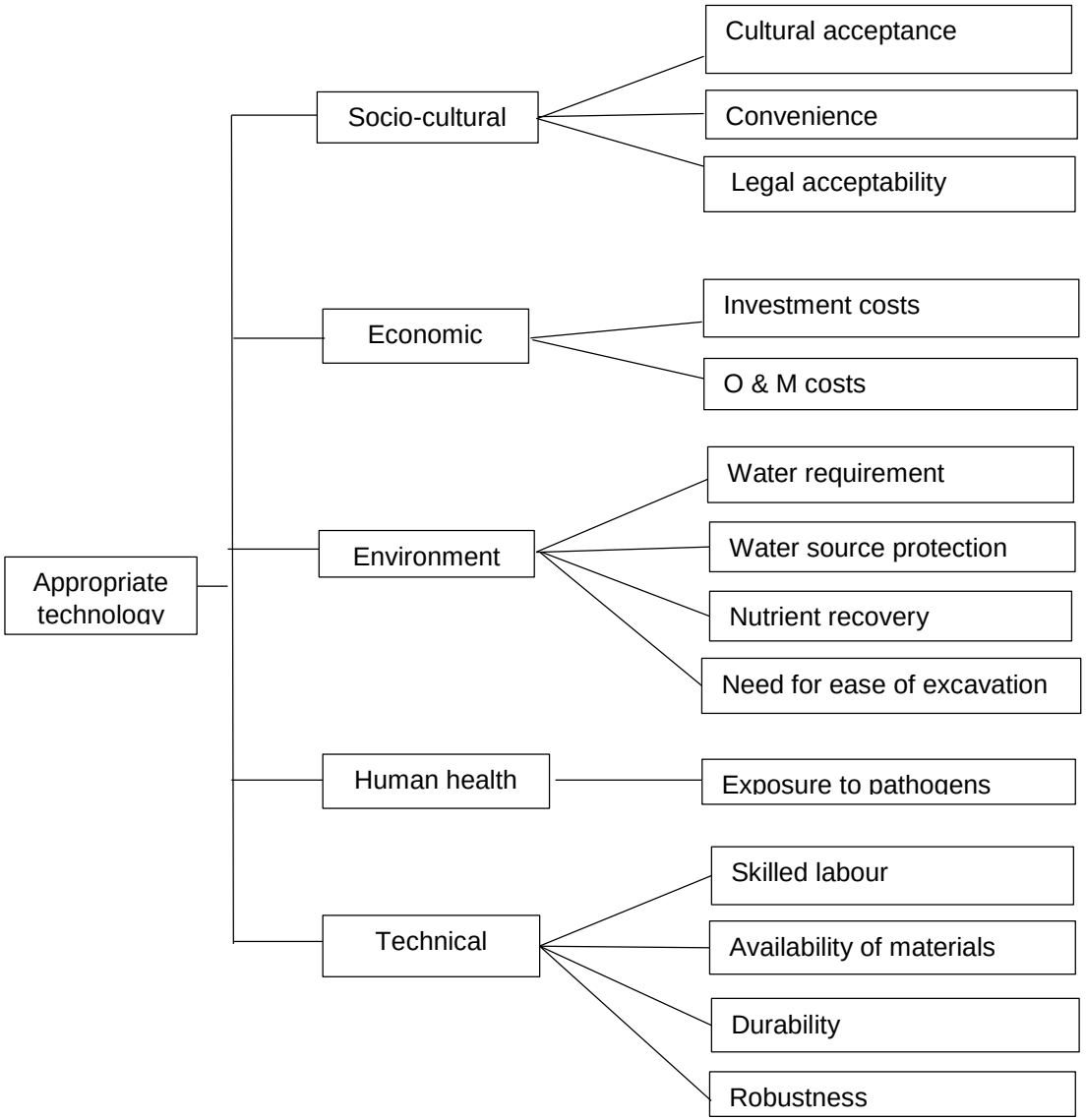
End of Questionnaire

Thank you for your participation

Supporting material 6S.5 Stakeholders involved in evaluation of criteria, and elicitation of scores and weights

Variable	Category	Academic	Government professional	NGO	Community representatives	Policy maker	Total (%)
Sex	Male	2	1	2	2	1	8 (72.73)
	Female	-	2	-	1	-	3 (27.27)
Age group (years)	< 26:	-	-	-	-	-	-
	26 – 35	-	1	-	-	-	1 (9.09)
	36 – 45	1	1	2	2	-	6 (54.55)
	> 45	1	1		1	1	4 (36.36)
Highest academic Qualification	High school Certificate	-	-	-	2	-	2 (18.18)
	Diploma	-	-	-	1	-	1 (9.09)
	BSc	-	2	1	-	1	4 (36.36)
	MSc	-	1	-	-	-	1 (9.09)
	PhD	2	-	1	-	-	3 (27.27)
Response rate (%)		66.67	100.00	66.67	100.00	33.33	11 (61.11)
Level of operation	Ward	-	1	-	2	-	3 (27.27)
	District	-	1	-	1	-	2 (18.18)
	Province	-	1	-	-	-	1 (9.09)
	National	-	2	1	-	1	4 (36.36)
	International	2	-	1	-	-	3 (27.27)
Total: # (%)	All	2 (18.18)	3 (27.27)	2 (27.27)	3 (27.27)	1 (9.09)	11 (100%)

Supporting material 6S.6 Value tree



Supporting material 6S.7 Characteristics of alternatives based on local application

Criteria	A1. Simple pit with slab	A2. VIP latrine	A3. Pour flush to septic tank-soak-away	A4. Pour flush to double leach pits	A5. UDDT
Controls exposure to pathogens	Flies, dirty slab	Dirty slab	Pit emptying	Pit emptying	Vault emptying
Local availability of skilled labour	Trained locals	Trained locals	Professional	Professional	Trained locals
Local availability of materials	Readily available	Readily available	Available	Few exceptions	Few exceptions
Durability	15	15	20	25	25
Robustness	Problems with high water table	Problems with high water table	Succumb to blockages	Succumb to blockages	Very robust system
Water for operation	0	0	11-15	11-15	0
Water source protection	Pollutes much in loose soil	Pollutes much in loose soil	Pollutes much in loose soil	Pollutes much in loose soil	No infiltration
Nutrient recovery	None	None	In septic tank	In leach pit	Urine and faeces
Need for ease of excavation	Single pit	Single pit	2 pits	2 pits	No excavation
Cultural acceptance	No restrictions	* No restrictions	* No restrictions	* No restrictions	Some restrictions
Convenience	Limited	Some restrictions	No restrictions	No restrictions	Some restrictions
Current legal acceptance	Accepted	Accepted	Accepted	May be considered	May be considered
Investment costs	185	352	882	489	368
O & M costs	Negligible -hygiene	Negligible - hygiene	Hygiene, anal cleansing	Hygiene, anal cleansing	[#] Very low

* Assuming no reuse [#] Assuming household does own emptying

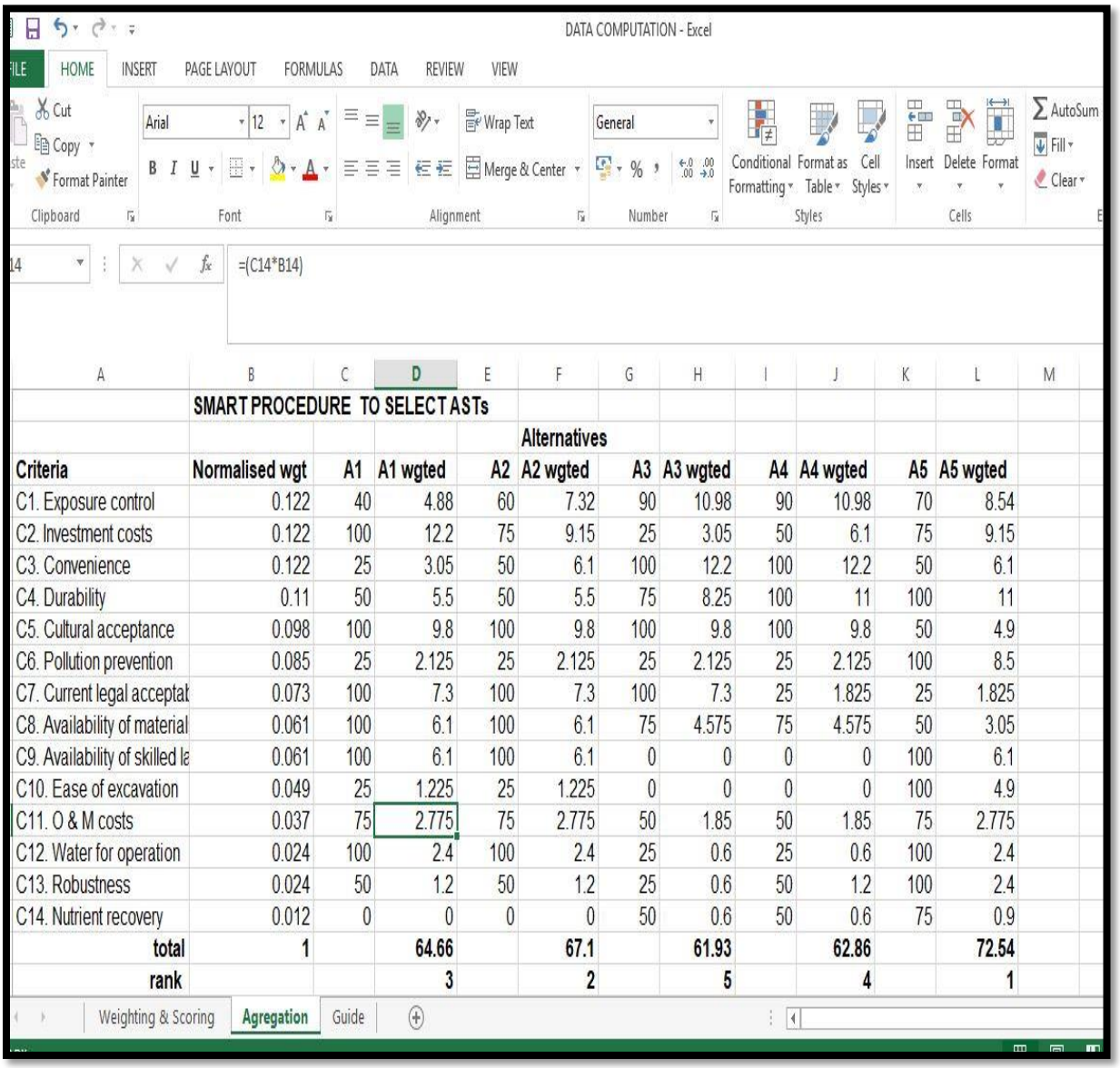
Supporting material 6S.8 Estimates of investment costs of alternatives (US$)

Alternative	Description of item	Quantity	Unit cost	Total cost
Pit latrine with Concrete slab (assessment)	Fired farm bricks, 9”	600	35/1000	21
	Transport bricks (load)	600	20/1000	20
	Cement (32.5%)	2	12	24
	Transport cement	2	1	2
	Quarry (wheel barrow)	5	1	5
	River sand (wheel barrow)	5	1	5
	Transport river sand (wheel barrow)	5	1	5
	Deformed steel rod (6 m x 12”)	2	12	24
	Mesh wire	2	2	4
	Labour - pit digging (3 m depth)	1	5/m	15
	Labour – construction	1	60	60
	Total	-	-	185
Conventional BVIP latrine (assessment)	Pit: Material and labour costs up to the slab	-	-	185
	Superstructure labour	1	80	80
	Fired farm bricks, 9”	500	35/1000	18
	Transport bricks (load)	500	60/2600	10
	Cement (32.5%) + transport	3	12 +3	39
	Quarry - roof + transport (wheel barrow)	1	1 + 1	2
	Mesh wire	2	2	4
	Deformed steel rod (6 m x 12”)	1	12	12
	Fly screen	1	2	2
	Total	-	-	352
Pour flush toilet + septic tank + soak away (assessment)	*(a) Pour flush toilet* (in-house structure)			
	Pan and cistern	1	85	85
	Pan connector (110 mm polythene)	1	5	5
	T connector (110 mm polythene)	1	5	5
	Vent valve	1	4	4
	Y connector (110 mm polythene)	1	6	6
	450 bent	1	4	4
	ABC /road-way	1	4	4
	Labour	-	-	100
	Sub - total			213
	(b) Septic tank (3 x 1.8 x 3) m^3			
	Polythene pipe (Length = 6 m x 110 mm)	1.5	20/length	30
	Main hole cover (cast iron)	1	70	70
	T connector (110 mm)	2	5	10
	ABC road-way	1	3	3
	Cement (32.5%)	10	12	120
	Cement transport	10	1	10
	River sand (wheel barrow) + transport	12	1 + 1	24
	Quarry (wheel barrow) + transport	12	1 + 1	24

	Fired farm bricks, 9”	1500	35/1000	53
	Transport bricks (load)	1500	20/1000	30
	Deformed steel rod (6 m x 12”)	3	12	36
	Mesh wire	6	2/m	12
	Sub-total	-	-	422
	(c) soak away (3 x 1.8 x 3) m^3			
	Pit digging	-	-	25
	Rough stone (load)	2	40/load-	80
	Transport of rough stones (load)	2	60/load	120
	Black polythene cover	6	2/m	12
	3m polythene pipe (110mm x 6m = Length)	0.5	20/length	10
	Sub total	-	-	247
	Total cost of system	-	-	882
Pour flush + 2 leach pits (estimated)	*(a) Pour flush toilet (from above)*	-	-	213
	(b) Leach pit No pre-fabricated rings			
	Pit digging *(1.3 x 2.4 x 1.8) m^3*	2	10/pit	20
	Cement (32.5%) + transport	4	12 + 4	52
	Fired farm bricks, 9”	800	35/1000	28
	Transport bricks (load)	800	20/1000	20
	Deformed steel rod (6 m x 12”)	2	12	24
	River sand + transport (wheel barrow)	6	1 + 1	12
	Mesh wire	4	2/m	8
	Polythene pipes 75mm x 6m = length)	1.5	8/length	12
	Labour	-	-	100
	Sub - total	-	-	276
	Total cost of system	-	-	489
UDDT Out-house, literature) Excl. polythene container	Assumption: BVIP superstructure)	-	-	167
	Assumption: Pit latrine slab			71
	UDDT squatting pan	1	60	60
	Pipes (75 mm x 6 m = I length)	0.5	8/length	4
	Vault compartments (materials and labour)	-	-	66
	Total	-	-	368

Costs can significantly be reduced based on availability of local household labour and pre-fabricated material, and negotiated labour costs.

Supporting material 6S.9 An output of utility values and rank order from computations in Microsoft Excel spreadsheet



	SMART PROCEDURE TO SELECT ASTs											
					Alternatives							
Criteria	**Normalised wgt**	**A1**	**A1 wgted**	**A2**	**A2 wgted**	**A3**	**A3 wgted**	**A4**	**A4 wgted**	**A5**	**A5 wgted**	
C1. Exposure control	0.122	40	4.88	60	7.32	90	10.98	90	10.98	70	8.54	
C2. Investment costs	0.122	100	12.2	75	9.15	25	3.05	50	6.1	75	9.15	
C3. Convenience	0.122	25	3.05	50	6.1	100	12.2	100	12.2	50	6.1	
C4. Durability	0.11	50	5.5	50	5.5	75	8.25	100	11	100	11	
C5. Cultural acceptance	0.098	100	9.8	100	9.8	100	9.8	100	9.8	50	4.9	
C6. Pollution prevention	0.085	25	2.125	25	2.125	25	2.125	25	2.125	100	8.5	
C7. Current legal acceptat	0.073	100	7.3	100	7.3	100	7.3	25	1.825	25	1.825	
C8. Availability of material	0.061	100	6.1	100	6.1	75	4.575	75	4.575	50	3.05	
C9. Availability of skilled la	0.061	100	6.1	100	6.1	0	0	0	0	100	6.1	
C10. Ease of excavation	0.049	25	1.225	25	1.225	0	0	0	0	100	4.9	
C11. O & M costs	0.037	75	2.775	75	2.775	50	1.85	50	1.85	75	2.775	
C12. Water for operation	0.024	100	2.4	100	2.4	25	0.6	25	0.6	100	2.4	
C13. Robustness	0.024	50	1.2	50	1.2	25	0.6	50	1.2	100	2.4	
C14. Nutrient recovery	0.012	0	0	0	0	50	0.6	50	0.6	75	0.9	
total	**1**		**64.66**		**67.1**		**61.93**		**62.86**		**72.54**	
rank			**3**		**2**		**5**		**4**		**1**	

Supporting material 6S.10 Summary of feedback of validation of the framework through expert opinion (n = 4; 57.1%)

Questionnaire item	Response	Comments
1. Was the decision problem reasonably articulated? Y/N.	Yes: 3/4	(i) To make it clear it could have been stated in a few sentences rather than paragraphs.
2. Do stakeholder groups identified reasonably relevant? ? Y/N.	Yes: 4/4	No concerns raised
3. Are alternatives identified reasonably feasible for the described study area? Y/N.	Yes: 1/4	(i) Two experts highlighted that the study area was described in a separate publication therefore not readily available to comment. (ii) One commented that if the alternatives considered were not in use locally, why were other alternatives left out? (iii) Why were alternatives not suggested by stakeholders to express their preferences?
4. Do the 14 selected criteria chosen reasonably define appropriateness of an alternative? Y/N	Yes: 2/4	(i) Need for more quantitative indicators and suggested material flows (ii) Need for more indicators on the health category with only a single criterion (iii) Another concern was the economic benefit which was left out under economic category
5. Are assigned criteria weights reasonable to compare the alternatives? Y/N.	Yes: 3/4	(i) Since these came from different groups and reflect consensus (trade-offs), it's difficult to comment. This is subjective.
6. Was the interval scale used reasonable to score alternatives? Y/N.	Yes: 3/4	No concerns.
7. Is SMART reasonably useful in this type of decision problem? Y/N.	Yes: 3/4	(i) Yes, but it could be used with other techniques or its modified forms.
8. Is the first ranked alternative reasonably expected for the study area? Y/N.	Yes: 1/4	(i) Two experts: The prescribed option was expected since it was not being used.
9. Are socio-cultural, technical and human health criteria categories reasonably expected to contribute most to the first ranked alternative? Y/N.	Yes: 2/4	(i) Two experts concur: Socio-cultural – No, since it's based on waste reuse. Where excreta is considered unsightly or handling it a taboo, it will be scored low by community representatives

10. Is there a reasonable procedural trail of the framework? Y/N	Yes: 3/4	No concerns
11. Is the framework reasonably robust? Y/N	Yes: 2/4	(i) A new better-performing alternative (even hypothetical) could have been introduced to check on the model sensitivity (ii) Different scenarios could also be used to check on model sensitivity.
12. Can the framework be flexible to adding new alternatives/criteria? Y/N	Yes: 1/4	This was not demonstrated.
13. Was framework validation reasonable? Y/N	Yes: 3/4	No concerns.

Supporting material 6S.11 SWOT analysis for the MCDA framework and results

Strengths ✓ Local context and stakeholder participation ✓ Clear procedures for selection of criteria and alternatives ✓ Clear weight and score elicitation ✓ Transparent procedure based on MCDA framework ✓ Interdisciplinary multi-stakeholder involvement ✓ Inclusion of social aspects which influence technology use were included ✓ Advantages of the UDDT explained in text (technical, environmental, economic)	*Weaknesses* ✓ Requirement to be pilot-tested in the real-world ✓ Framework does not consider whole sanitation system ✓ Lack of awareness and technical skill ✓ Weaknesses of the SMART procedure (explained in text)
Opportunities ✓ Unbundle sanitation technology basket ✓ Sanitation policy review ✓ Introduce ecological sanitation for waste reuse and recycling ✓ Allow for innovation and wider research focus ✓ Potential improved access to improved sanitation services ✓ PHHE and political will may lead to cultural diffusion into accepting ecological sanitation	*Threats* ✓ Potential reduced adoption of local innovation (BVIP) ✓ Inability to predict human behaviour: resist adoption and use of new appropriate sanitation options ✓ Potential public health risks of urine and excreta handling ✓ Policy requirement for ecological sanitation

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

- An integrated multi-criteria decision analysis (MCDA) framework was developed to select appropriate rural sanitation technology options in low- and medium income settings based on the simple multi-attribute rating technique. This is a step-wise iterative, multi-stakeholder and multi-dimensional procedure based on the principles of public health and environmental protection, economic viability, social acceptance and technological feasibility. The framework was developed based on review of relevant literature, community assessment data, database of available sanitation options and stakeholder consensus considering the local context.
- The impact of sanitation on the prevalence of diarrhoeal diseases, child growth and infestation of internal parasites based on randomised controlled trials appeared inconclusive due to suggestive and mixed evidence.
- The absence of a standard framework used to select appropriate sanitation options appears to create gap between science and practice. Existing frameworks appeared to have shortcomings by not fully address established criteria e.g., on sanitation demand, behaviour change, framework limitations and flexibility.
- Households have latrine preferences. When a prescribed sanitation option which is unaffordable, households adapt by constructing incomplete and poor designs of that prescribed option, adopt alternatives (improved or not), share latrines among households or practice open defaecation which may potentially expose households to faecal pathogens.

- An understanding of drivers and barriers to sustained latrine use inform the development of a framework on criteria and option preferences. The use of a latrine use was shown to be influenced by an inter-play of various factors (e.g., latrine design, social considerations) at the individual, household and contextual levels.
- Computations in MS excel spreadsheet using MCDA equations produced a ranking of alternatives based on total utility values: urine diverting dry latrine then the BVIP latrine.
- Evaluation of the framework verified that a laid down development methodology was followed. The framework was considered robust based on criteria weight changes and also deemed reasonable based on expert opinion.

8.2 Recommendations

- Further trials and the use of a standard evaluation procedure for RCTs are recommended so that high quality evidence is used to exclude chance or opportunistic results of a single finding. The link between sanitation and health outcomes has been placed on the global research agenda in 2018 by the World Health Organisation.
- There is need for guidance in sanitation programming to avoid the use of various frameworks based on implementing agency or donors. There is need for research-based evidence to guide practice. Identified limitations of available frameworks may be used to inform future work as frameworks should be flexible to respond to new evidence and changing human sanitation needs.
- Sanitation options should be considered to meet household preferences and 'leave no one behind'. Countries still having a single rural sanitation option should review standing policies or craft new ones to embrace alternatives.

- Local research in this regard be funded and shared at multi-stakeholder platforms such as workshops or conferences to be debated to reach consensus among stakeholders.
- Research in sanitation, such as pilot studies require huge financial investments and long study times as behaviour change takes time. Governments are therefore recommended to come up with comprehensive financing mechanisms, sound institutional arrangements and regulatory frameworks.
- The SMART techniques used is a very simple, transparent yet comprehensive procedure which can be used by decision-makers not experts in MCDA. It is recommended based on its simplicity, ability to handle several criteria, flexibility, low resource requirement, being highly multi-stakeholder dependent and ability to be used with other decision-making tools. This suits resource-constrained area. Decision-makers are recommended to use the framework only as an aid without replacing them.

APPENDIX 1: Academic Advisory Board Approval

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

19 August 2019

Mr A Kanda
(19240865)
PhD (Public Health)

Dear Mr Kanda

SHSPH Academic Advisory Committee: Protocol

Your protocol titled "*Framework for selection and use of appropriate rural sanitation technologies in low –income settings*" served at the Academic Advisory Committee (AAC) meeting via e-mail on 15 August 2019.

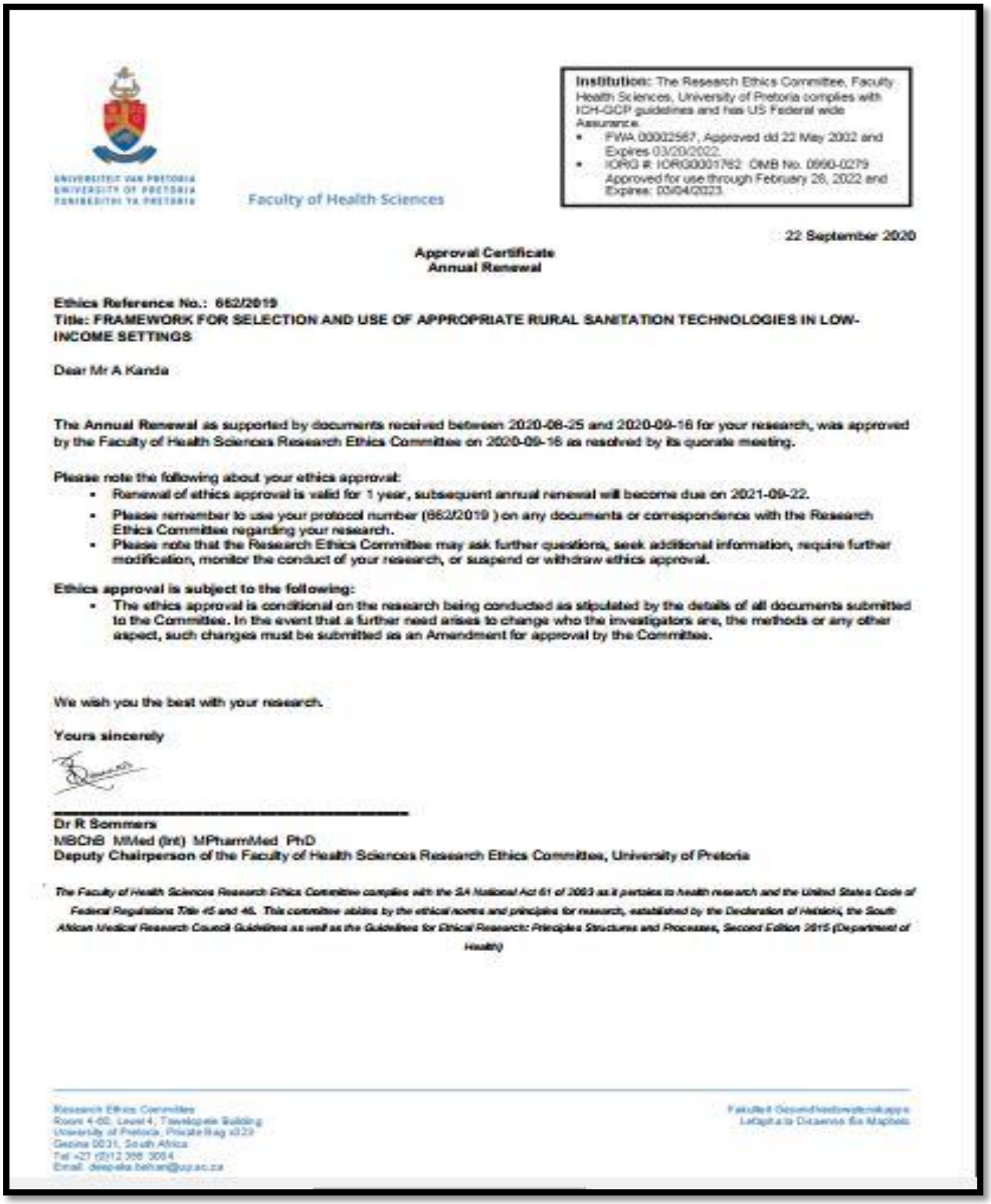
You can now submit to ethics.

Sincerely

Dr J Shirinde
Chairperson
SHSPH Academic Advisory Committee

cc Dr E Ncube
Prof K Voyi
Mrs René de Waal
Mrs Annette Welman

APPENDIX 2. SHSPH Ethics approval. Reference No.: 662/2019



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IORG #: IORG0001762. OMB No. 0990-0279 Approved for use through February 28, 2022 and Expires: 03/04/2023.

22 September 2020

Approval Certificate
Annual Renewal

Ethics Reference No.: 662/2019
Title: FRAMEWORK FOR SELECTION AND USE OF APPROPRIATE RURAL SANITATION TECHNOLOGIES IN LOW-INCOME SETTINGS

Dear Mr A Kanda

The Annual Renewal as supported by documents received between 2020-08-25 and 2020-09-16 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2020-09-16 as resolved by its quorate meeting.

Please note the following about your ethics approval:

- Renewal of ethics approval is valid for 1 year, subsequent annual renewal will become due on 2021-09-22.
- Please remember to use your protocol number (662/2019) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers
MBChB MMed (Int) MPharmMed PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)

Research Ethics Committee
Room 4-60, Level 4, Tswaipoele Building
University of Pretoria, Private Bag x323
Gezina 0031, South Africa
Tel: +27 (0)12 356 3084
Email: deepeka.behari@up.ac.za

Fakulteit Gesondheidswetenskappe
Lefapha la Ditsaense tsa Maphelo

APPENDIX 3: Permission by the ministry of health and child care (Provincial director) to carry out research in Mbire district, Zimbabwe

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Health Sciences

RESEARCH PROPOSAL FOR APPROVAL

(Ministry of Health and Child Care - **Mashonaland Central Province**)

TITLE: FRAMEWORK FOR SELECTION AND USE OF APPROPRIATE RURAL SANITATION TECHNOLOGIES IN LOW-INCOME COUNTRIES

By

Artwell Kanda

Student Number: 19240865

Supervisor: Dr. E.J. Ncube

Co-Supervisor: Prof. K. Voyi

Principal researcher: Mr. Artwell Kanda, E- mail:alzkanda@gmail.com

Contact information

Mr. Artwell Kanda
Bindura University of Science education
Astra Campus, alongTrojan Mine Road,
Bag 1020
Bindura, Zimbabwe

Cell: +26377277356
+263712098483

University of Pretoria
Faculty of Health Sciences
School of Health Systems and Public Health

Authority granted

MIN. OF HEALTH & CHILD CARE
PROVINCIAL MEDICAL DIRECTOR
MASHONALAND CENTRAL
26 OCT 2020
P.O. BOX ... BINDURA
ZIMBABWE

RESEARCH PROPOSAL

Framework for selection and use of appropriate rural sanitation technologies in rural Zimbabwe

Brief background information

Despite the progress made in increasing access to improved sanitation services during the Millennium Development Goals (MDGs) (1990 - 2015), rural areas still lagged behind urban areas. In low- and middle-income countries, 842 000 deaths are caused by inadequate WASH, representing 58% of total diarrhoeal deaths, and 1.5% of the total disease burden (1). In 2015, about 32% of the global population (2.4 billion) still lacked access to improved (now basic) sanitation (7 out of 10 living in rural areas) and about 13.5% of which still practiced open defecation (9 out of 10 living in rural areas) in 2015 (2). Diarrhoea has been identified as one of the principal causes of morbidity and mortality among children in the developing world (3). It is the second leading cause of death in children under five (525 000/year) (4) but is largely preventable through safe water supply, adequate sanitation and hygiene interventions (5).

Lack of access to appropriate sanitation technologies may expose people to health risks mainly through the faecal-oral route due to open defaecation, unsustained latrine use, poor hygiene behaviour and degradation of food and drinking water quality (6,7). Sustainable Development Goal Target 6.2 to achieve access to sanitation and hygiene and end open defecation is meant to address sanitation needs of the previously unserved and new populations. There are many proven and established sanitation technologies on the sanitation market which are at different rungs of the sanitation ladder. Appropriate ones should be selected for defined contexts to influence adoption, effective and sustained use, and therefore, the intended health gains, opposed to a single standardised option (one-size-fits-all). The new global thinking (SDG targets to be met by 2030) puts pressure on national governments to review policy on rural sanitation.

Zimbabwe's water, sanitation and hygiene (WASH) sector is managed by the National Action Committee (NAC). The Ministry of Health and Child Care (MoHCC) is responsible for rural WASH. The NAC agrees that sanitation has been lagging

1

APPENDIX 4: Clearance letter from the biostatistician

Date: 23/08/2019

LETTER OF CLEARANCE FROM THE BIOSTATISTICIAN

This letter is to confirm that the student, with the Name(s)

ARTWELL KANDA (Student Number 19240865)

Studying at the University of PRETORIA

Discussed the Project with the title:

"FRAMEWORK FOR SELECTION AND USE OF APPROPRIATE RURAL SANITATION TECHNOLOGIES IN LOW-INCOME SETTINGS"
with me.
I hereby confirm that I am aware of the project and also undertake to advise on the Statistical analysis of the data generated from the project. The analytical tool that will be used will be:
Data analysis will follow a mixed methods approach. Collected qualitative data will be coded, analyzed and summarized. Coded data will be used to group data into classes/categories that summarize it for easy interpretation. This allows identification of emerging themes or patterns from data. Narrative and discourse analyses will be used for FGD-collected data to understand the way in which communities think and behave when responding to interview questions or discussions. For quantitative data, descriptive statistics will be used to summarize data: (a) for categorical data, frequency distribution tables showing counts and percentages will be done as well as bar and pie charts to display data and (b) for numerical data, means and standard deviations will be used for symmetrical data whereas skewed data will be summarized using medians and ranges. Multivariate logistic regression model will be used to establish relationships between the binary outcome variable and a group of predictor variables using Stata version 15 statistical software and the output will be interpreted. The predictor variables are responses from questionnaire items. In the current study, logistic regression analysis, as opposed to linear regression, will be used because the dependent variable is binary.

Name: Dr Alfred Musekiwa **Date: 23/08/2019**

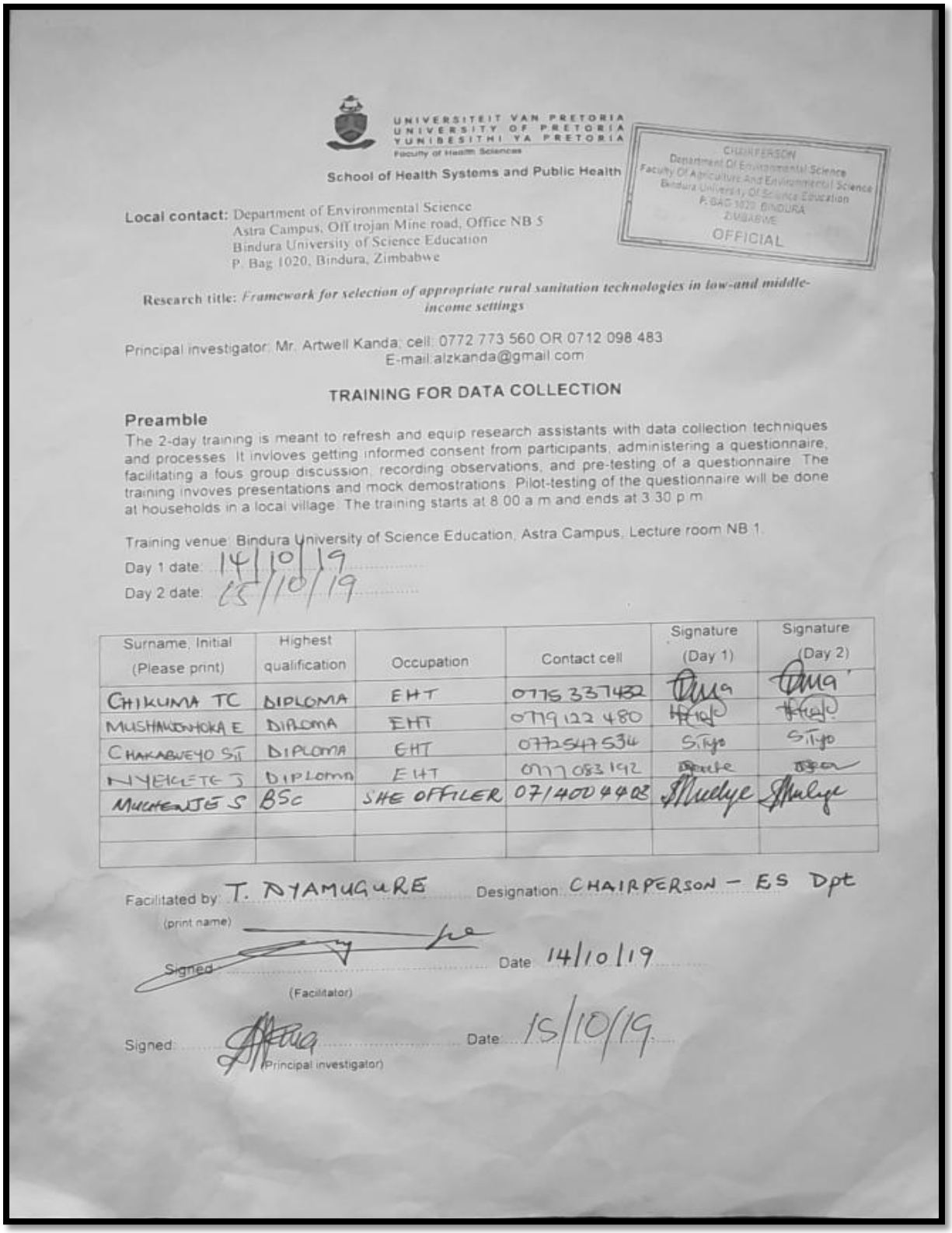
Signature  **Tel: 012 356 3253**

Department or Unit: SCHOOL OF HEALTH SYSTEMS AND PUBLIC HEALTH

Letter compiled by:

Dr Alfred Musekiwa

APPENDIX 5: Two-day training of enumerators for data collection



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Faculty of Health Sciences

School of Health Systems and Public Health

CHAIRPERSON
Department Of Environmental Science
Faculty Of Agriculture And Environmental Science
Bindura University Of Science Education
P. BAG 1020 BINDURA
ZIMBABWE
OFFICIAL

Local contact: Department of Environmental Science
Astra Campus, Off trojan Mine road, Office NB 5
Bindura University of Science Education
P. Bag 1020, Bindura, Zimbabwe

Research title: *Framework for selection of appropriate rural sanitation technologies in low-and middle-income settings*

Principal investigator: Mr. Artwell Kanda; cell: 0772 773 560 OR 0712 098 483
E-mail:alzkanda@gmail.com

TRAINING FOR DATA COLLECTION

Preamble

The 2-day training is meant to refresh and equip research assistants with data collection techniques and processes. It invloves getting informed consent from participants, administering a questionnaire, facilitating a fous group discussion, recording observations, and pre-testing of a questionnaire. The training invoves presentations and mock demostrations. Pilot-testing of the questionnaire will be done at households in a local village. The training starts at 8.00 a.m and ends at 3.30 p.m

Training venue: Bindura University of Science Education, Astra Campus, Lecture room NB 1.

Day 1 date: 14/10/19

Day 2 date: 15/10/19

Surname, Initial (Please print)	Highest qualification	Occupation	Contact cell	Signature (Day 1)	Signature (Day 2)
CHIKUMA TC	DIPLOMA	EHT	0775 337432		
MUSHAMBONOKA E	DIPLOMA	EHT	0779 122 480		
CHAKABVEYO ST	DIPLOMA	EHT	0772 547 534		
NYEKETE J	DIPLOMA	EHT	0777 083 192		
MUCHENJE S	BSc	SHE OFFICER	0714004403		

Facilitated by: T. NYAMUGURE (print name) Designation: CHAIRPERSON – ES Dpt

Signed: ..... (Facilitator) Date: 14/10/19

Signed: ..... (Principal investigator) Date: 15/10/19

APPENDIX 6: EVIDENCEOF PUBLISHED ARTICLES

Effect of Sanitation Interventions on Health Outcomes: A Systematic Review of Cluster-Randomized Controlled Trials in Rural Communities of Low- and Middle-Income Countries

Artwell Kanda *, Esper Jacobeth Ncube and Kuku Voyi

Faculty of Health Sciences, School of Health Systems and Public Health, University of Pretoria, Private Bag 323, Pretoria 0007, South Africa; encube@randwater.co.za (E.J.N.); kuku.voyi@up.ac.za (K.V.)
* Correspondence: alzkanda@gmail.com; Tel.: +263-772-773-560

Abstract: A systematic review of published literature (2000–2019) evaluating the impact of sanitation interventions on the prevalence of disease, parasite infestation, and/or child growth using randomized controlled trials (RCTs) was done according to the PRISMA checklist. Earlier reviews indicated mixed evidence citing relatively poor quality evidence from mixed designs. Public health policy and practice appear to rely on evidence from RCTs. Records were searched in six electronic databases. The methodological quality of RCTs was assessed using the Cochrane collaboration risk of bias tool. Fifteen records (2.0%) were included for review. Impact trials were done in rural communities of African and Asian countries. The significant effect of sanitation-focus interventions was found in one trial for the prevalence of childhood diarrhea (14.3%), three trials for parasite infestation (37.5%), and two trials (25.0%) for child growth. Results indicate mixed quality evidence from RCT designs. Evidence is limited and suggestive of the impact of sanitation on parasite infestation and child growth. Further rigorous sanitation intervention trials under varying settings are needed to show what really works and under what settings. Future work may explore sanitation behavior change strategies and latrine options to address the challenges of poor latrine use under high sanitation coverage.

Keywords: basic sanitation; health outcome; low- and middle-income countries; randomized controlled trial

check for updates

Citation: Kanda, A.; Ncube, E.J.; Voyi, K. Effect of Sanitation Interventions on Health Outcomes: A Systematic Review of Cluster-Randomized Controlled Trials in Rural Communities of Low- and Middle-Income Countries. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8313. https://doi.org/10.3390/ijerph18168313

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Frameworks for selecting appropriate rural sanitation technology options in low- and middle-income countries: a critical review

Artwell Kanda, Esper Jacobeth Ncube & Kuku Voyi

To cite this article: Artwell Kanda, Esper Jacobeth Ncube & Kuku Voyi (2021): Frameworks for selecting appropriate rural sanitation technology options in low- and middle-income countries: a critical review, International Journal of Environmental Health Research, DOI: 10.1080/09603123.2021.1963685

To link to this article: https://doi.org/10.1080/09603123.2021.1963685

Article

Adapting Sanitation Needs to a Latrine Design (and Its Upgradable Models): A Mixed Method Study under Lower Middle-Income Rural Settings

Artwell Kanda *, Esper Jacobeth Ncube and Kuku Voyi

Faculty of Health Sciences, School of Health Systems and Public Health, University of Pretoria, Private Bag 323, Pretoria 0007, South Africa; u99130590@up.ac.za (E.J.N.); kuku.voyi@up.ac.za (K.V.)
* Correspondence: alzkanda@gmail.com; Tel.: +263-772-773-560

Abstract: Rural households have latrine preferences and unique sanitation needs. An assessment of how rural households adapt their sanitation needs to a nationally encouraged latrine design was done. A cross-sectional survey was conducted among 790 households in a rural district of Zimbabwe from November 2020 to May 2021. Data were analysed using logistic regression. Qualitative data were collected using focus groups and analysed using thematic analysis. Analyses were done in STATA 16 and considered significant at $p < 0.05$. There was low adoption of the Blair ventilated improved pit latrine and its upgradable models. Significant predictor variables of BVIP latrine adoption were mainly contextual and psychosocial at the individual and household levels. They included source and level of household income, residence period, nature of homestead, number of cattle owned, knowledge of sanitation options and perceived high latrine cost. The latrine design was considered not a pro-poor option as it was unaffordable by many rural households resulting in its non-completion, poor-quality designs, alternative options, sharing and open defaecation. Poverty appears the main barrier for latrine ownership. However, a window of opportunity to improve access to sanitation in rural Zimbabwe exists by considering alternative sanitation options and financial investment mechanisms.

Keywords: access; alternative technology; BVIP design; latrine ownership; rural sanitation; sustainable development

check for updates

Citation: Kanda, A.; Ncube, E.J.; Voyi, K. Adapting Sanitation Needs to a Latrine Design (and Its Upgradable Models): A Mixed Method Study under Lower Middle-Income Rural Settings. *Sustainability* **2021**, *13*, 13444. https://doi.org/10.3390/su132313444

PLOS ONE

RESEARCH ARTICLE

Drivers and barriers to sustained use of Blair ventilated improved pit latrine after nearly four decades in rural Zimbabwe

Artwell Kanda*, Esper Jacobeth Ncube☯, Kuku Voyi☯

Faculty of Health Sciences, School of Health Systems and Public Health, University of Pretoria, Pretoria, South Africa

☯ These authors contributed equally to this work.
* alzkanda@gmail.com

Abstract

Background

Some latrines remain unused even under conditions of high coverage in rural areas of low- and middle-income countries. Not much is known on household latrine use in the long term in the absence of an intervention. The current work assesses drivers and barriers to sustained use of a ventilated improved pit latrine (Blair VIP) design where it originated and how rural households adapt it to climate change.

Methods

A mixed methods study was conducted from November 2020 to May 2021 among rural households of Mbire district, Zimbabwe. A cross sectional survey of 238 households with Blair ventilated improved pit (BVIP) latrines was conducted using a questionnaire and a latrine observation checklist. Data were analysed using logistic regression. Qualitative data were collected using six focus groups among house heads and analysed by thematic analysis.

Check for updates

OPEN ACCESS

Citation: Kanda A, Ncube EJ, Voyi K (2022) Drivers and barriers to sustained use of Blair ventilated improved pit latrine after nearly four decades in rural Zimbabwe. PLoS ONE 17(4): e0265077. https://doi.org/10.1371/journal.pone.0265077

Editor: Alison Parker, Cranfield University, UNITED KINGDOM

Received: October 11, 2021

Selection of appropriate on-site household sanitation options for rural communities of Zimbabwe – case of Mbire district, Zimbabwe

Artwell Kanda, Esper Jacobeth Ncube and Kuku Voyi

School of Health Systems and Public Health, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa

ABSTRACT

Selecting an appropriate sanitation option involves multiple stakeholders with often conflicting objectives. A multiple criteria decision analysis (MCDA) framework was developed to inform decision makers on selecting appropriate sanitation options for rural communities. Criteria established from literature were evaluated and weighted on-line by stakeholders. A performance matrix was developed by assigning weights to criteria and scoring alternatives. Selection of alternatives was based on a composite appropriateness index from a rank using the simple multi-attribute ranking technique. The framework was evaluated by verification, validation and sensitivity analysis. Five alternatives were evaluated on 14 decision criteria. The first preferred alternative was the urine diverting dry toilet (72.54) then the Blair ventilated improved pit latrine (67.10). The framework was commented as reasonable and robust. A simple and transparent MCDA framework was developed considering local conditions in a participatory manner to select appropriate alternatives for rural sanitation where a single option is encouraged.

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APPENDIX 7: POLCY BRIEF: ALTERNATIVE SANITATION OPTIONS FOR RURAL ZIMBABWE: NEED FOR LOCAL RESEARCH-BASED EVIDENCE

Box 1: Summary

The Blair ventilated improved pit (BVIP) latrine (commonly called VIP elsewhere) is a Zimbabwean innovation used for rural sanitation since the 1980s. Many rural households could not afford it. It is not applicable to all contexts. A national sanitation and hygiene policy draft, yet to be approved, proposes to consider other options supported with research evidence. This policy brief advocates for policy shift from a single to other sanitation options, and the need for research evidence to select appropriate sanitation options.

Fig. 1 Latrines in a rural district of Zimbabwe

Box 2: What is at stake?

To achieve sustainable development goal target 6.2:

- Universal and equitable access to sanitation services,
- Pay specific attention to the sanitation needs of women and girls,
- End open defaecation

Key findings

- Field research in rural Mbire district indicates a wide gap between sanitation policy and practice.
- Households' adaptation strategies to the BVIP latrine included construction of poor designs, alternative options (improved or unimproved), latrine sharing and open defaecation.
- High use of the BVIP latrine but very poor adoption.
- Need for alternative options but general lack of knowledge of them.
- High expressed sanitation demand and willingness but low ability to pay due to poverty.
- Study participants expressed need for government support.

Introduction

The Blair ventilated improved pit (BVIP) latrine has been a technology design of choice for rural Zimbabwe since the 1980s. However, it proved unaffordable to many rural households resulting in its poor adoption and low rural sanitation coverage which was 30% in 2020 (1). A sanitation and hygiene policy draft of 2017, yet to be approved in

2022, proposes to consider other sanitation options for rural communities. The current policy brief advocates for a policy shift and presents to policy makers and practitioners, proposed candidate sanitation alternatives for rural Zimbabwe. It highlights the importance of local research to inform decision-making using literature, community assessment data and professional experience. Local research evidence is needed to suit local conditions as findings are not always transferrable to other settings. Latrine selection, adoption and use are influenced by an interplay of environmental, economic, socio-cultural, technological, and institutional factors (2).

The study

Household surveys, focus groups and key informants were used to gather information amongst 790 selected rural households in 15 villages of Mbire district, Zimbabwe. Data collected was to determine commonly constructed latrines and their sustained use, adaptation strategies to a single option, and the selection of appropriate ones considering the local conditions (2,3).

Alternative sanitation options

Common sanitation options and their various modifications in rural communities include the ventilated improved latrine, simple pit latrine, urine diverting dry toilet, pour flush latrine with leach pits or septic tank and soak-away. Their designs, operation and use, application and modifications are available in literature. The current policy brief recommends alternatives that do not rely on water (except for handwashing) considering that most rural areas in Zimbabwe, and Sub-Saharan Africa, are arid and semi-arid with low seasonal and unreliable rainfall.

Discussion points

The selection of appropriate sanitation options

An approach that involves all relevant actors with different interests is used to reach consensus based on a composite index involving relevant factors of technology

appropriateness (4). Stakeholders include government, sanitation experts, policy and decision-makers, technology users, private sector, researchers, implementing organisations and funding institutions. A multi-stakeholder platform allows consensus and timely use of data by decision makers for planning and advocacy to stimulate sanitation demand, political commitment and investment. Evidence shows that inappropriate sanitation technology options were poorly adopted in interventions (5,6).

Sustained behaviour change

Sanitation services should go beyond the provision of a technology and consider sustained hygienic latrine use. Socio-cultural factors influence latrine preference and use (7). The case study in this policy brief demonstrated that participating households were dominated by an ethnic group (60.1%). They have different social norms (customs, taboos and laws) and values (what is good, right and just). Handling of faecal matter may be considered a taboo by one ethnic group to exclude ecological sanitation options. However, this finding cannot be extended to other ethnic groups, if it is institutionally acceptable. The general lack of knowledge of alternative options may suggest the need for intensive government mobilisation and support for awareness and knowledge of potential technology users and regulating departments.

Enabling environment

Despite being appropriate, a technology needs to be implemented in an enabling environment to ensure that it reaches out to all including vulnerable groups. Despite being unaffordable to many rural households, the success of the BVIP latrine was due to government commitment, willingness and support. To change from a single to alternative sanitation options, an enabling environment should be built and strengthened by approving the policy draft, crafting frameworks for regulation, monitoring, evaluation, financing, capacity building capacity and partnerships based on sound capacitated institutional arrangements. The current National Action

Committee responsible for rural sanitation in Zimbabwe appears to lack this. Local government support prioritises other public health services such as health and education ahead of rural sanitation. Political commitment, financing and supervision of interventions increase latrine coverage (8).

Recommended sanitation option

The urine diverting dry toilet (UDDT) is recommended ahead of the BVIP latrine based on a composite index of several factors of technology appropriateness (Chapter 6) derived from a local district case study. Despite some potential reservations for reuse of human waste for agriculture raised by some participants and the requirement of frequent operation and maintenance, the technology scored high for being (i) applicable in diverse environments such as high water table, loose soil and rocky environments as it does not require pit digging, (ii) socially convenient offering privacy and security for women and girls, (iii) low risk of polluting water sources, (iv) less sensitive to shock loads and extreme weather events, (v) long life of up to 20 years and (vi) high potential of nutrient recovery and recycling for agricultural use. Where the technology is not acceptable, the second-ranked option, the BVIP latrine with its modifications can be used, with government support to overcome high initial investment cost.

Policy implications

- Lack of community knowledge and awareness on alternative options may influence their acceptance and use.
- Institutional acceptability of ecological sanitation: need for regulatory and operational technical support to protect public health. In urban South Africa, government took over pit emptying.
- Weak enabling environment: lack of capacity and large initial financial requirement.

- Lack of rigorous research-based evidence fails to inform decision-making of what works, how and where. Local research findings may not be over-generalised for scaling up. What works in a local context may not work elsewhere.
- Need for monitoring and evaluation frameworks and multi-stakeholder data sharing platforms.

Conclusions

- No one-size-fits all solution to sanitation challenge, alternatives are needed to cater for the expressed sanitation demand.
- A multi-stakeholder approach is needed to select appropriate sanitation alternatives.
- Policy transition is a long-term process with opportunities and threats.
- Mixed financing models are needed to meet expressed willingness to pay

References

1. World Health Organisation/United Nations Children's Fund [WHO/UNICEF]. Progress on household drinking water, sanitation and hygiene 2000 - 2020. 5 years into the SDGs. Geneva: WHO; 2021. https://apps.who.int/iris/bitstream/handle/10665/258617/9789241512893-eng.pdf. [Accessed July 28 2021].
2. Kanda A, Ncube EJ, Voyi K. Drivers and barriers to sustained use of Blair ventilated improved pit latrine after nearly four decades in rural Zimbabwe. *PLoS ONE*. 2022; 17(4): e0265077.
3. Kanda A, Ncube EJ, Voyi K. Adapting sanitation needs to a latrine design (and its upgradable models): A mixed method study under lower middle-income rural settings. *Sustainability*. 2021; 13(23):13444.

4. Bauer AM, Brown A. Quantitative assessment of appropriate technology. *Procedia Eng*. 2014; 78:345-358.
5. Dakuré MS, Traoré MB, Sossou SK, Maiga AH. Development of sanitation technologies in African context: how could we make it more sustainable? *IOP Conf Ser Earth Environ Sci.* 2017; 60:012032.
6. Kamara JK, Galukande M, Maeda F, Luboga S, Renzaho AMN. Understanding the challenges of improving sanitation and hygiene outcomes in a community based intervention: a cross-sectional study in rural Tanzania. *Int J Environ Res Pub Health*. 2017; 14(6):602.
7. Routray P, Schmidt W-P, Boisson S, Clasen T, Jenkins MW. Socio-cultural and behavioural factors constraining latrine adoption in rural coastal Odisha: an exploratory qualitative study. *BMC Public Health*. 2015; 15: 880.
8. Odagiri M, Cronin AA, Thomas A, Kurniawan MA, Zaina lM, Setiabudi W, Gnilo ME, Badloe C, Virgiyanti TD, Nurali IA, et al. Achieving the Sustainable Development Goals for water and sanitation in Indonesia - Results from a five-year (2013–2017) large-scale effectiveness evaluation. *Int J Hyg Environ Health.* 2020; 230:113584. Doi: 10.1016/j.ijheh.2020.113584.