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

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Abstract

Several rural technology options exist on the sanitation market with different characteristics, yet project failures in some developing countries were attributable to inappropriate technology choices. Frameworks that are used to select sanitation technology options (hard copy, computer programmes) were developed by researchers and project implementers. They vary in design and application as there is no standard format. This appears to create a gap between science and practice. Frameworks should have some key elements needed to select appropriate sanitation technologies. We evaluated 12 available frameworks (2000–2019) used to select sanitation technologies in rural communities of low- and middle-income countries against 22 assessment criteria derived from literature. Criteria that were not fully addressed by some of the reviewed frameworks (scores of 8–50%) included equity, sanitation demand, sanitation behaviour change, ongoing contact, replicability, framework limitations, personnel selection and flexibility. Addressing such limitations may assist in future framework development.

Keywords: Low- and middle-income countries; rural sanitation; technology selection framework

Introduction

The current global thinking of sustainable development goal (SDG) 6' 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 (2018) urges national governments to prioritise sanitation and explore alternative technology designs as research agenda. There is no one-size-fits-all sanitation technology solution (Palaniappan et al. 2008; Tilley et al. 2014). A single sanitation technology may result in lack of ownership and suspicion among intended users, which influences use (Kvarnström and Petersens 2004).

Evidence-based frameworks have been developed to inform health policy and practice (Morton et al. 2018; Slade et al. 2018). The selection of appropriate sanitation technologies (ASTs) was identified as an important element of the planning process for water, sanitation and hygiene (WASH) interventions (Barnes et al. 2011; Bouabid and Louis 2015). This is because ASTs can improve access to services by beneficiaries (Bauer and Brown 2014). 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 (Palaniappan et al. 2008; Bouabid and Louis 2015), and lack of national sanitation policies in general (Mara et al. 2010). Appropriate technology is an old concept (Karl-Wolfgang 1973) with many subjective definitions. It has

recently been used with a global diffusion of innovation for community development (Kaplinsky 2011; Garniati et al. 2014; Bouabid and Louis 2015) to complement modern technologies rather than being mutually exclusive. Recent studies appear to show renewed interest in the concept (Simiyu 2017; Spuhler et al. 2018) although as a smaller component of the widely used concept 'sustainable technology'.

A review of the global sanitation development by Zhou et al. (2018) 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. Inappropriate sanitation technology options demonstrated poor adoption in some African country interventions (Dakuré et al. 2017; Kamara et al. 2017; Mkhize et al. 2017). Seymour and Hughes (2014) 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 of sanitation services.

The urban environment has emerged as a field of study. Urban sanitation is traditionally integrated into urban planning where several sectors are linked. Planning is mainly influenced by the population growth and density, and availability of space (Lüthi et al. 2011). Urban sanitation in LMICs has mainly been characterised by centralised wastewater treatment systems designed by developed countries, operated and maintained by local municipalities in formally designed settlements. Individual households (technology end-users) have little, or no contribution to select their preferred sanitation systems, therefore, planning is done by experts and engineers. This is different to rural sanitation planning. The differences between urban and rural sanitation planning in communities of LMICs resulted in the development of urban and rural (and at times peri-urban) frameworks for the selection of ASTs. However, some frameworks were reported to be applicable in urban and rural areas (Loetscher and Keller 2002), peri-urban and rural areas (Mara et al. 2007) and small towns and rural areas (Kimera et al. 2013). A number of potential trade-offs may come with these considerations.

We developed a framework assessment criteria from literature due to the lack of a standard or universal procedure. We then used the criteria to assess whether available frameworks address them. Our assumption was that a framework is likely to be applied to select ASTs for successful sanitation interventions in LMICs if it addresses the assessment criteria. However, it should be noted that technology selection is just part of sanitation planning, and as such may not translate into the success of an intervention. A framework worth using considers the multistakeholder and multidisciplinary nature of sanitation. Any bias to one discipline, for example, engineering (technology assessment criteria) may not result in selecting an AST. A critique of existing frameworks for the selection of ASTs was therefore done to identify the available frameworks used to select ASTs in rural communities of LMICs, determine their strengths and limitations, and suggest their implications to research and public health practice.

Materials and methods

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. The search terms were used after preliminary searches using even synonyms of the key search terms (e.g. selection or choosing, framework or model, sanitation technology or option or alternative, LMICs or developing countries, rural community or areas) to find out which combinations yielded the best search results (Table 1). Further, websites of some institutions and reference lists of identified records were consulted. A systematic approach was only used for literature search and inclusion of records to get a clear and comprehensive overview of available evidence on such a broad study area but without analysing the quality of evidence.

Table 1. Literature search terms.

Database	Search terms
BMC Public Health	Framework selection, appropriate sanitation technology, rural, low- and middle-income countries
JSTOR	Framework selection, appropriate sanitation technology, rural, low- and middle-income countries
ProQuest	Framework selection, appropriate rural sanitation technologies, low- and middle-income countries
PubMed	Selection, appropriate sanitation technologies
Science Direct	Framework selection, appropriate sanitation technologies, low- and middle-income countries
Scopus	Selection, appropriate sanitation technologies
Google search	Framework selection appropriate rural sanitation technologies low- and middle-income countries

Applied filters included time period (2000–2019, research articles, journals, book chapters, full text, English

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 summarised for origin, main steps, scope of application and key issues (Table 2). They were analysed using a developed framework assessment criteria (Table 3) from literature on the common components of WASH support tools (Palaniappan et al. 2008; Barnes et al. 2011; Castellano et al. 2011).

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 4). Some assumptions were used to aid authors' judgements. The 22-criteria assessment tool was used to score the 12 included frameworks. All criteria were used to score a framework (category) and the proportion (%) of criteria met by a framework was determined. Further, all frameworks were scored against each criterion. The proportion of frameworks meeting a given criterion was determined. A summary of how each included framework responded to the criteria was prepared. The criteria for framework inclusion were done by two independent investigators, and a third assisted in reaching consensus for any discrepancies identified.

In this work, *appropriate* (sanitation) *technology* refers to a technique, which produces a socially and environmentally acceptable level of service at the least cost (Gunnerson et al. 1978 in Feachem 1980). According to Murphy et al. (2009) 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 (WHO 2018).

Table 2. Summaries of sanitation technology selection frameworks/processes.

Original name of framework and authors	Origin	Main steps and requirements	Key issues
Strategic planning for Municipal sanitation. guide Tayler et al. (2000)	GHK Research & Training Ltd	Community & technology assessment, Stakeholder identification & training, Technology selection and validation	Developed a collection of guides (tools) for the selection of sanitation technologies. Categorises choices based on nature of system, potential water use and disposal option
Site Sanitation Planning and Reporting Aid (SSPRA) Howard et al. (2001)	Research	Literature review, Community assessment, Framework development and validation	Computer-based planning and reporting aid, and user manual. Integrates sustainability criteria and sanitation selection process, establishes consistent database for use by relevant stakeholders
SANEX Loetscher and Keller (2002)	Advanced Wastewater Management Centre	Literature inventory, identification of sanitation technologies, multi-criterion technology evaluation, affordability and case study evaluation.	Development of a technology selection algorithm to evaluate sustainability and implementability of alternative sanitation systems. Evaluates sanitation alternatives in 2 step (screening & comparison). It is applicable to both urban and rural set-ups.
- Louis and Ahmad (2004)	Department of Systems & Information Engineering, Virginia	Technology assessment, Option scoring and classification, mapping technology to community. Validation.	Technology selection tool – operates by listing, classifying and ranking them to map on a community. Links technology assessment (4 criteria) and community assessment (8 capacity factors). Unscientific procedure.
- Halim et al. (2005)	Department of Sanitary & Environmental Engineering, Egypt	Evaluation of available technologies, economic comparison and selection	Evaluation and selection computer-based tool for sanitation technologies for different site conditions. Evaluates available technologies for a given site based on a selection matrix
- Mara et al. (2007	Department of Civil Engineering, University of Leeds	Technology assessment, sanitation Arrangements technology selection.	Sanitation selection algorithm to select sustainable sanitation Arrangements. Identifies the most appropriate arrangements in any Given situation. Applicable to peri-urban and rural community set-ups
- Henriques and Louis (2011)	Department of Systems & Information Engineering, Virginia	Community capacity level, technology requirement level & matching policy	Capacity factor analysis model for selecting sustainable drinking water supply and grey water reuse system for developing communities to guide selection of appropriate technologies
Technology Applicability Framework (TAF) Kimera et al. (2013)	WASHTech	Technology review, stakeholder KAP survey, tool development and validation	Technology validation and 4-step introduction process based on action Research. Technology applicability based on 6 sustainability dimensions to rural areas and small towns
Capacity Factor Analysis Bouabid and Louis (2015)	Department of General Studies, UAE	Community requirement analysis, Technology requirement level and matching policy	Capacity factor analysis to evaluate water and sanitation infrastructure choices for developing communities
- Ramóa et al. (2015	University of Lisbon, Portugal	Identifying existing sanitation systems, detailing and answering post-selection questions.	System-based decision algorithm for selection of sanitation technologies in a 3-step process requiring detailed knowledge of the local area
- Salisbury et al. (2018)	University of KwaZulu-Natal, South Africa	MCDA to select between a VIP latrine and a UDDT. Weighting of indicators involved a participatory approach	Multi-criteria decision analysis (MCDA) tool for selecting a sanitation option by municipal engineers in South Africa
- Filho et al. (2019)	Department of Sanitary & Environmental Engineering, Dom Bosco Catholic University, Brazil	Tool development, stakeholder selection and participation, and validation	Computer-based sustainable sanitation tool for decision making in isolated areas. Provides computational tool with database connecting guidance in a single reference. Incorporates water reuse and nutrient recovery. Software is compatible with other management tools

All frameworks were developed to select appropriate sanitation technologies (decision making) in low-and middle income settings with the application scope of improving sanitation service delivery.

Table 3. Components of criteria used for analysing frameworks and justification.

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

O & M: Operation and maintenance
a – Palaniappan et al. (2008)
b – Barnes et al. (2011)
c – Castellano et al. (2011)
d – author-derived

Table 4. Scoring system used in the analysis of frameworks.

	Framework assessment method	
Criterion	Score	Definition
Informed 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	No mention of where & who to seek advice from on the framework later on
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

(*Continued*)

Table 4. (Continued).

	Framework assessment method	
Criterion	Score	Definition
User-friendly interface	1	Provides an easy-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 (0), partially addresses it (0.5) and addresses it (1)

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. Validation of a framework with a pilot/case study was assumed to have included government approval/consultation (laws and regulations)
4. Selection of a sanitation technology involved an assessment of its operation and maintenance, and constraints constraints
5. Mere data collection excludes community engagement

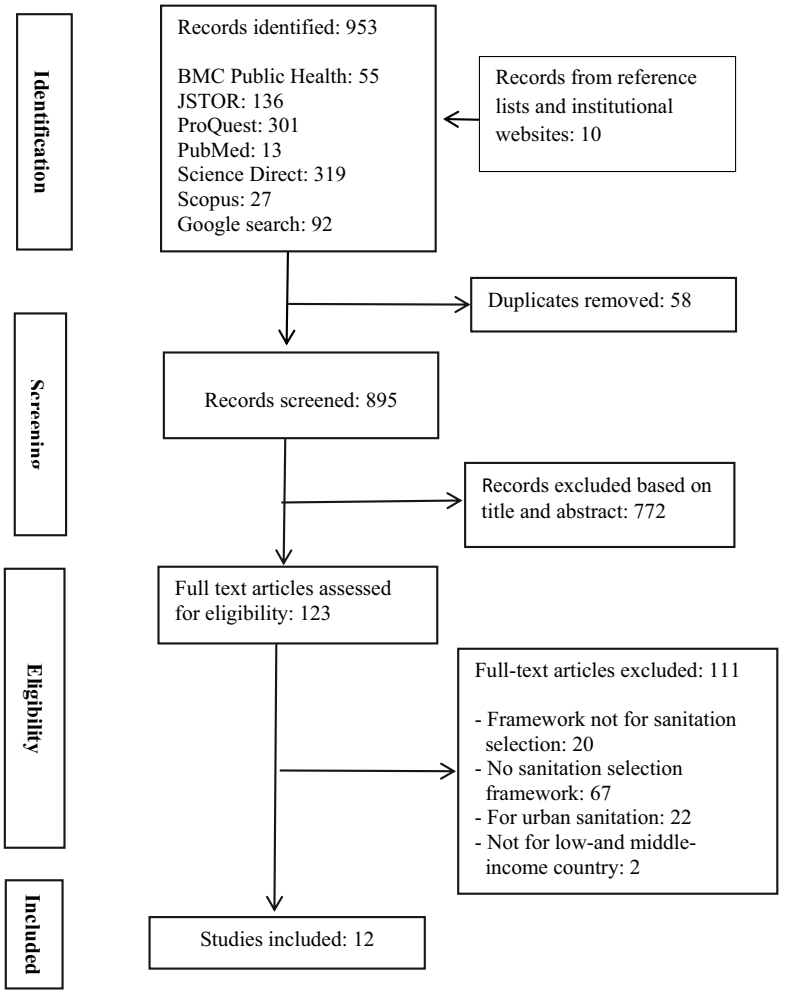

Figure 1. Flow chart of literature search.

Results

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 (Figure 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 only or had sanitation selection frameworks not meant for LMICs. 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 Development Bank, USAID).

Table 5. Scoring procedure applied on included frameworks and results.

	Sanitation selection framework												Score	
Criterion	1	2	3	4	5	6	7	8	9	10	11	12	Possible	Actual %
Informed demand for sanitation	1	1	1	0	0	0	0	0	0.5	0	0	0	12	29
Personnel selection	1	1	1	0	0	0	1	1	1	0	0.5	1	12	63
Technology choice	1	1	1	1	1	1	1	1	1	1	1	1	12	100
Support, legislation & regulation	1	1	1	1	1	0	1	1	1	0	1	1	12	83
Sustainability criteria	1	1	1	1	1	1	1	1	1	1	1	1	12	100
Decision making	1	1	1	1	1	1	1	1	1	1	1	1	12	100
Flexibility	1	1	0.5	0.5	0.5	0.5	0.5	1	0	1	0.5	1	12	67
Ongoing contact	1	1	0	0	0	0	0	1	0	0	0	0	12	25
O & M	1	1	1	1	1	1	1	1	1	1	1	1	12	100
Constraints in technology choice	1	1	1	1	1	1	0	1	1	1	1	1	12	92
Data collection	1	1	1	1	1	0.5	1	1	1	1	1	1	12	96
Communication	1	1	1	1	1	0	1	1	1	0	0	1	12	75
Replicability	0	0	0.5	0	0.5	0	1	1	1	0	0	1	12	42
Community engagement	1	1	1	0.5	0.5	0	0.5	0.5	1	0.5	0.5	1	12	67
Validation	1	1	1	1	1	0	1	1	1	0	1	1	12	83
Transparency	1	0.5	0.5	1	0.5	1	1	1	0.5	1	1	0.5	12	79
Interactability	0	1	1	1	1	1	0	1	1	1	0	1	12	75
Equity	0.5	0.5	0	0	0	0	0	0	1	0	0	0	12	17
Compatibility	0	1	1	1	0	0	1	0	1	1	0	1	12	58
Behaviour change	1	0.5	0	0	0	1	0	0.5	0	0.5	0	0.5	12	33
Framework limitations	0	1	1	0	0	0	1	1	1	1	1	1	12	67
User-friendly interface	0.5	0.5	1	1	1	0.5	1	1	0.5	1	1	1	12	83
Possible score	22	22	22	22	22	22	22	22	22	22	22	22	264	
% actual score	77	86	80	64	59	43	68	82	80	59	57	82		

O & M: Operation and maintenance
1. Tayler et al. (2000)
2.Howard et al. (2001)
3. Loetscher and Keller (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)

Framework analysis using the scoring method

(Table 5) shows how the included frameworks scored in the assessment criteria. Results show that four of the assessment criteria (3.38%) were fully addressed by all the 12 included frameworks, showing their strengths. These were technology choice, sustainability criteria, decision-making and operation and maintenance. However, some of the included frameworks scored between 62% and 80% in 12 of the assessment criteria (54.5%). Finally, some frameworks scored between 17% and 58%) in the remaining six of the assessment criteria (27.3%). The least considered assessment criteria among frameworks (contributing below 50%) were: equity, informed sanitation demand, sanitation behaviour change, ongoing contact and replicability. These criteria may form basis for future developments of similar frameworks.

The assessment criteria were grouped into four categories, with some overlaps: community (8), technology (7), institutional arrangements (3) and framework-based criteria (5). Personnel selection was common for community-based and institutional arrangements-based categories (Table 6).

Table 6. 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

Community-based criteria

(Table 5) shows that 11 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. Community-based criteria that were reportedly met by few frameworks included equity issues (Framework 9), community demand for sanitation (Frameworks 1–3), sanitation behaviour change (Frameworks 1 and 6) and ongoing contact (Frameworks 1, 2 and 8). 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 (Frameworks 4–8, 10, 11).

Framework-based criteria

No single framework fully addressed the framework-based assessment criteria. Five frameworks (1, 2, 8, 10 and 12) managed to incorporate user remarks, local knowledge and new information sensitive to the local context (flexibility criterion). Six of the frameworks partially addressed it. Partial address of the framework-based assessment criteria was also observed mainly for the transparency (Frameworks 2, 3, 5, 9 and 12) and user-friendly interface (Frameworks 1, 2, 6 and 9). Two frameworks (6 and 10) did not provide methodological guidance on the type and process of validation (validation criterion). Eight frameworks

highlighted major methodological limitations of the technology selection framework. However, seven of them did not indicate whether the frameworks were compatible with others.

Technology-based criteria

(Table 5) shows that all frameworks fully met three of the five technology-based framework assessment criteria, except for replicability (Frameworks 7–9, 12) and constraints in technology choice (11 frameworks). Only four frameworks (7–9, 12) fully considered the potential replicability or scalability of the appropriate technology selected.

Institutional arrangements-based criteria

The decision-making criteria were met by all included frameworks. They were meant to inform policy and consider the involvement of relevant government departments and sanitation professionals. However, 41.7% of the frameworks (4–6, 10 and 11) did not provide guides for the selection of agency and local personnel to be involved in planning (personnel selection criterion).

With respect to individual criterion, all frameworks fully addressed the technology-based assessment criteria (except one criterion) but did not similarly meet community-based criteria where frameworks scored from 17% to 42%. Although some of the community factors 'could be hidden' in the technology-assessment criteria, they should clearly be stand-alone key components of a framework. For example, the sustainability criteria may be used on its own. However, it is so broad that it can be interpreted and used differently due to lack of a standard. The social aspects of technology selection ought to be highlighted and assessed independently as they influence technology acceptance and use. With respect to individual criterion, frameworks which did not fully address aspects of community engagement (1, 4–8, 10, 11), framework limitations (1, 4–6) and institutional arrangements (6 and 10) may be less favourable for application in those respects. Overall, frameworks which failed to address 75% of the 22-assessment criteria (4–7, 10 and 11) may be found less favourable for use in the selection of appropriate rural sanitation technologies than those that address most of the criteria.

Discussion

There are various sanitation frameworks developed by project implementers and their partner organisations. However, practice appears to show that such organisations do have, and promote their own WASH planning frameworks to meet their interests, and according to Ngwira and Mayhew (2020), to comply with demands of the donor community for funding. This may deviate from community needs, yet practice is driven by immediate needs for practical solutions (Patel and Kaufman 1998). Under such circumstances, community participation will be at the lowest levels. On the other hand, research institutions appear to have their own planning resources, potentially creating a gap between researchers and project implementers. The result could be the development of various frameworks others of which are never published for use elsewhere. The relationship between theory and practice (beyond the scope of this paper) is a source of debate. Existing frameworks recommended for decision-making by relevant government departments and sanitation professionals in LMICs appear to vary in their criteria and application. Their limitations may be used as source for future framework development to improve sanitation access. Grey literature, generally excluded in academic papers, is a rich source of information, especially government information and institutional

practices. However, most of the reports may remain shelved until may be when need arises without sharing with the wider scientific community.

Addressing issues of equity in the provision of rural sanitation services remains a critical challenge as few interventions reach vulnerable groups of society (Apanga et al. 2020). Those not served resort to open defecation, which potentially exposes them to multiple faecal pathogen exposure routes and health risks. Addressing equity and universality in rural sanitation interventions should be considered in future work (Carrard et al. 2020), possibly by selecting appropriate sanitation technology options. About half of the reviewed frameworks did not fully address the flexibility criterion. A framework has to adapt to current sanitation demands, such as responding to effects of climate change, new evidence and local context. If it cannot be updated, a new framework will have to be developed. Current frameworks do not fully address long-term sustainability of sanitation interventions and scalability. The former could partly be due to short (no optimum) follow-up periods after interventions, lack of ongoing contact between implementers and end-users of the selected technology options in the post-intervention phase. The latter could be because sanitation technologies with a particular context-focus may be difficult to repeat (replicate) elsewhere. Where support services, community capacity development in operation and maintenance, and hygiene education are available, long-term sustainability of interventions may be addressed through the government departments responsible.

Current trends from research and practice in the sanitation sub-sector use approaches such as participatory planning and sustainability criteria (Vidal et al. 2019) and participatory health and hygiene education (PHHE). There appears to be a transition from hardware provision to demand-led approaches with the ultimate goal of behaviour change (Mara et al. 2010). However, poor rural households require subsidies if they are to access sanitation facilities, and if universal access and ending open defaecation are really to be achieved by 2030. The provision of subsidies may indirectly show the need for large investments in rural sanitation services by LMICs. They have modified the CLTS concept as indicated in some studies. Therefore, future frameworks should consider the provision of targeted subsidies although communities should be aware that sanitation is a service that has to be paid for. Various levels of community participation are used in WASH interventions. Higher levels of community participation should be encouraged throughout the project cycle and not just in baseline surveys. However, they have their own shortcomings.

User sanitation preferences in rural communities, sustainability evaluation frameworks for technologies and decision-making support resources are well documented in literature. However, a review of 120 support resources by Skat (2011) 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 such a tool.

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 combinations of search terms could have compromised the comprehensiveness of the critical review by leaving out some records. Further, search of grey literature was not as comprehensive which could have possibly omitted other relevant frameworks. The suggested assessment criteria of frameworks is subjective. However, there were scoring guidelines and independently assessed by two of the authors to reach consensus. The criteria were consistently used across all frameworks.

Conclusion

The critical review assessed 12 sanitation selection frameworks using some developed scoring criteria to address methodological limitations for continual improvement in developing future frameworks. Literature has different decision-making tools to select AST options for rural communities in LMICs. Sanitation selection frameworks are indeed needed to choose appropriate technology options from many available alternatives to address unique needs of technology users. This may address situations where inappropriate technologies remain unused even under high sanitation coverage settings. The existence of many frameworks that vary in criteria and application will not inform sanitation policy and practice. The selection of appropriate sanitation technologies should not be viewed as an end-of-pipe solution to sanitation challenges. Sanitation services are provided in a social context influenced by environmental, institutional and economic factors, which a decision-making framework should consider. Critical issues which appeared not well addressed in the frameworks included equity, behaviour change, replicability of interventions, framework limitations and assessment of sanitation demand. The current review may inform WASH professionals in ongoing studies and interventions, rural sanitation policy on considering alternative designs, and the gap between science and practice. It may be very important where transition from prescribed single sanitation options to considering alternatives is imminent.

Disclosure statement

Authors declare no conflict of interest.

Ethical considerations

There are no ethical issues to consider. The paper is a review of literature where no intervention trials including humans or animals were held.

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