Evidence-Based User Interface Sanitation Technology Selection for Urban Slums: A Multi-Criteria Analysis; The Case of Jimma Town, Ethiopia

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ABSTRACT: Slums are urban areas with insufficient public services and access to sanitation. Evidence-based selection of sustainable sanitation options is critical for addressing the sanitation crisis in slums. This mixed methods study was conducted in Jimma Town, southwest Ethiopia, to assess sanitation status and prioritize sustainable sanitation options for slums. The study was done in 2 phases: quantitative and qualitative. The quantitative cross-sectional household survey aimed to assess sanitation status and the qualitative exploratory method to explore alternative sanitation options and prioritize sustainable alternatives. A total of 310 households were chosen using systematic random sampling methods, of which 302 participated. Data was gathered through interviews, which were supplemented with questionnaires and observation checklists, and 2 focus group discussions (FGD) were held. First, FGD was with expertise in the sanitation sector, and the second was with community members. The state of sanitation was summarized, and multi-criteria analysis (MCA) was used to prioritize sustainable sanitation options. According to our findings, 68% of households had access to improved facilities, and 22.5% didn't have any form of toilet facility. About 7 off-site and on-site user interface sanitation technology options were considered in the selection of alternative sanitation technologies, and each option was evaluated against 17 health, economic, social, technical, and environmental criteria. In the final analysis, the options with the highest scores for the setting were flush to septic tanks, compost toilets, and biogas toilets. Mobilizing such a promising sanitation option is recommended for future interventions.

KEYWORDS: Multi-criteria analysis, selection, sustainable sanitation, urban slum

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Introduction

Sanitation is defined as the access to and use of facilities and services for the safe disposal of human feces and urine.[1] It includes activities aimed at improving and maintaining the basic environmental conditions that affect human well-being.[2] Sanitation access has several positive effects in terms of health promotion and disease prevention.[2] Moreover, unfavorable sanitation contributes to the vicious cycle of poverty, resulting in disease, sickness, and poor productivity.[3] The magnitude of the problem is more visible in urban slums.[4] Slums in cities are areas with limited access to sanitation, deplorable living conditions, and dilapidated housing.

Cities currently house more than half of the world's population.[5] Slum settlements currently host around 1 billion people, accounting for about one-third of the world's urban population, and this number is projected to increase to 3 billion by 2050.[6,7] The biggest sanitation problems among slums are ways to increase demand for sanitation, resilience, and health hazards since most pathogens are of fecal origin.[8,9] Human excreta (urine and feces) are not well treated among many slum dwellers.[10] In such a situation, access to and use of sanitation facilities is more in demand than other commodities.

The sanitation system has a flow of step-wise chains, conventionally named the sanitation value chain.[11] Following the sanitation target, hygienic separation of human feces from human contact and user interface sanitation technologies play the lion's share of a direct user interface in the sanitation value chain. Whatever the system, wet or dry, it can be either safe or worrisome.[3,12] Dry sanitation systems are used in the majority of African countries.[13] Dry systems do not require water for flushing and include a variety of conventional pit latrines, ventilated improved pits (VIP), and new mechanisms that allow for the safe reuse of excreta.[14] The majority of urban slum dwellers use unimproved sanitation choices like traditional pit latrines, flying toilets (the use of polythene bags for excreta disposal that are poured into the local environment), open field defecation practice, and to a limited extent, VIP, and pour-flush toilets by a few high-income earners.[15,16] The trends in urban slum growth have been remarkable over the last decade.[17] Limited investments in the sanitation sector appear to have little impact on the access of urban residents who do not have access to the service, which makes it difficult to estimate when they will reach a greater number of people.[3] It is very unlikely to obtain sanitation solutions that seem to be suitable for people living in urban slums, especially in low-income countries.

Ethiopia has one of the lowest rates of access to safe sanitation services in Sub-Saharan Africa.[18] Poor sanitation and hygiene are significant contributors to Ethiopia's overall environmental concerns. In 2016, approximately 36% of Ethiopians did not have access to sanitary facilities.[19] In Ethiopia, pit

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latrines are the most commonly used alternative. However, different user interface technology options (UISO) are being used in Ethiopian urban slums,[20] which may not be subjected to an evidence-based selection of sustainability criteria.[8] On the other hand, pit latrines require land space. That is not always sufficient in urban slum settlements. In Ethiopia's urban slums, sanitation has remained a challenge. The choice of the sanitation option is more traditional and does not consider many of the factors. To be a rational decision, every sanitation technology option should be consistent with the principle of completely separating feces from human contact.[21] Considering various technical perspectives of the sanitation options are more critical to ensuring the sanitation infrastructure's sustainability and well-performing.

MCA is an approach that considers different criteria for different technical choices of sanitation options.[8,22] The aim is to select evidence-based choices for a particular setting that minimize environmental compliance as well as technically feasible options. Sanitation is a multidimensional issue, and attaining sustainable sanitation in informal settlements, as well as decreasing the considerable challenges connected with sanitation in general, requires evidence-based decisions.[20] However, there is a huge gap in assessing slum residents' sanitation practices in most of Ethiopia's rapidly growing towns, particularly Jimma Town. Previous studies in Jimma town show low sanitation access at the town level,[23] but the information on the urban slum is limited. It is, therefore, necessary to illustrate and identify the practice levels, as well as their negative effects on humans and the environment. Thus, this study aimed to examine sanitation practices and prioritize alternative sustainable UISO for slum dwellers in Jimma town, southwest Ethiopia. The discovery aids sanitation sectors in making evidence-based decisions that facilitate urban sustainable sanitation and the abolition of open-field defecation in urban slums. Moreover, it facilitates choices for urban dwellers to look into the prioritized technology options for their demands.

Methods Materials

Study setting and period

A mixed methods study was conducted from September 2020 to October 2020 in Jimma, about 352 km from Addis Ababa. The town has 195 228 residents,[24] and 17 kebeles (ie, the smallest administrative unit in Ethiopia). Jimma town is located in the Oromia Region's special zone. It is located at a latitude of 7°40′ north and east latitude of 36°50′. The study was done in 2 phases, quantitative and qualitative. First, the quantitative cross-sectional household survey aimed to assess sanitation status and the qualitative exploratory method to explore alternative sanitation options and prioritize sustainable alternatives for the setting.

Sample size and sampling procedures

Household survey. The sample size was calculated using the single population proportion formula,[25] the proportion of households using improved facilities from the previous report among urban slums in Ethiopia,[20] the margin of error at 95% confidence interval, and a design effect of 2, yielding a final sample size of 310 households. However, only 302 households participated in the survey (ie, 8 households were left out after 2 rounds of visits). The kebeles were carefully selected to represent the town's slum conditions. In the household survey, 5 kebeles were used to represent the population under consideration (slum area). Households were randomly selected from slum areas using a systematic random sampling technique. Information was collected from the household heads. To collect data at the household level, interview administered structure questionnaires and observation checklists (Supplemental Table S1) from a similar study that was conducted in the town at the town level were used.[23] To improve the quality of the data, 2 consecutive days of training were given to data collectors before the household survey.

Qualitative. In the FGDs, participants were selected purposefully. The FGDs were held upon participant consent. The user interface sanitation options were listed, and criteria were set by expertise (Supplemental Table S2) and prioritized by the FGDs. The number FGDs was fixed on the base of idea saturation, and 2 FGDs were conducted.

Data processing and analysis

Two approaches were followed in the analysis. First, survey data were entered into Epidata 3.1 software[26] and exported to SPSS version 20,[27] and frequency and percentage analyses were conducted to identify the socio-demographic status of the study participants, sanitation access, and sanitation options in the study area.

The second, a multi-criteria analysis that was adopted from similar studies,[28,29] was used for selecting a UISO. To compile the technology selection, we used an excel-based analysis specifically for this study. It consists of sanitation technology-specific input data and an assessment sheet with technology characteristics adopted from a similar study.[28] The selected technologies were screened further by the use of MCA (Figure 1).

The alternative UISO for excreta disposal was presented to the FGDs for ranking. Two FGDs were held. First, community members based on potential information sources on sanitation schemes in the setting, experience, age, and gender (7 individuals participated). The residents were chosen from 2 neighboring communities: Hermata Mentina and Hermata Merkato. Second, FGD was held with sanitation experts as well as those with experience in the study area and those who are currently employed in various sectors of the town. Health workers, social scientists, and urban planners were specifically chosen. Fourteen experts participated in the ranking of the technically feasible sanitation options. In the FGD, the pair-wise method was used for ranking sanitation technologies. Using this structured method, 7 sanitation technologies were compared, each at a

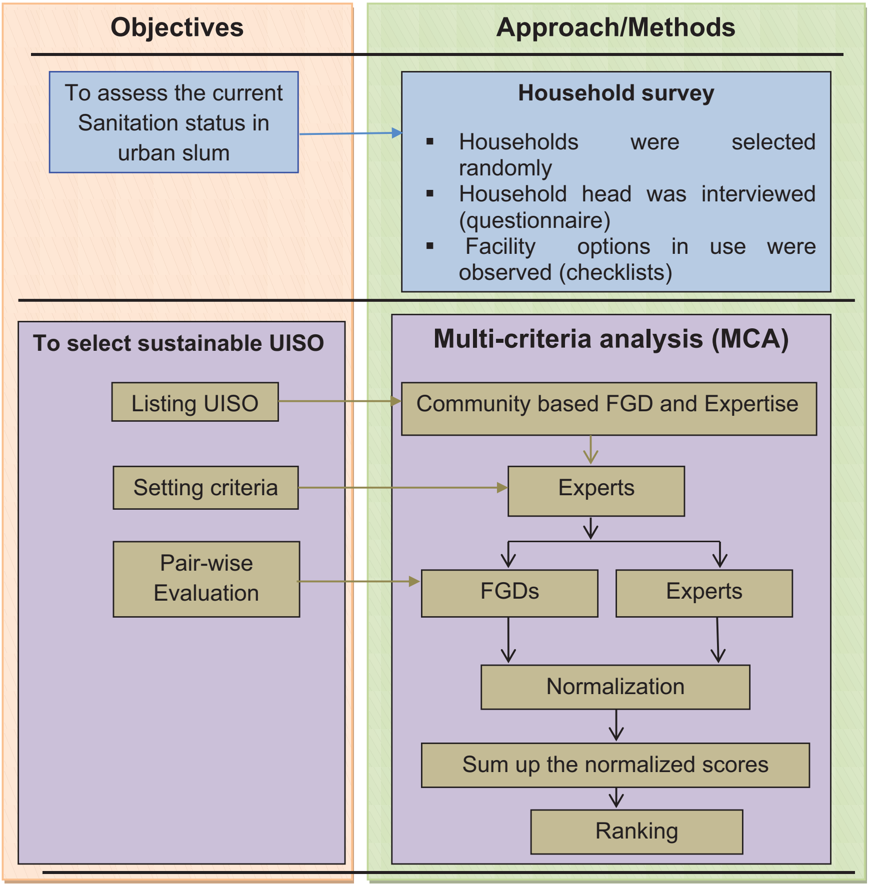

Figure 1. Summary of methods used in this study: MCA.

time, to the 7 technology options. The community-based FGDs were held to establish perceptions and favorites from the communities about the technology options suitable for the study area.

The technologies were presented to the community (represented by FGDs) using IEC (Information, Education, and Communication) materials in a participatory discussion of the merits and demerits of these technologies concerning sustainability indicators before the ranking activity. Individual experts composed of technical and non-technical professionals ranked the technically feasible UISO (Supplemental Table S4).

The final ranking was achieved using the average FGDs scores for the parameters defining sustainability indicators and the weighted scores of the sustainability indicators by the experts. The normalized score of a sustainability indicator was calculated by:

$$F = \sum_{i=1}^{n} \left(\frac{ai}{c} \right) \mathrm{x}\, G$$

Where F is the normalized score of a sustainability indicator, n is the number of parameters defining the criteria for a sustainability indicator, a is the average FGD score of a parameter defining a sustainability indicator, and c is the sum of the average FGD scores for the criteria defining a sustainability indicator, and G is the expert's weighted score for sustainability. The final ranking was based on the sum of the normalized scores (F). This method was adapted from a similar study.[8]

Operational definitions. Sustainable: The definition of sustainable is something that can be continued or a practice that maintains a condition without harming the environment.[30] *Improved toilet facilities*: Improved facilities include flush/pour flush toilets connected to piped sewer systems, septic tanks, or pit latrines; pit latrines with slabs (including ventilated pit latrines), and composting toilets.[1]

Ethical consideration

Ethical clearance was obtained from the Jimma University Institutional Research Ethics Review Committee, Jimma, Ethiopia. Before each interview, data collectors sought written informed consent from each respondent.

Results

In this study, 310 were approached in the survey, and 302 households participated, yielding a response rate of 97.4%. There were 215 (71.2%) male respondents. The mean age was 38 (SD 10.9), 35% of participants had a bachelor's degree or higher, 178 (58.9%) were married, and nearly half (154, 51%) had a family size of fewer than 5 members (Table 1).

Table 1. Socio-demographic characteristics of study participants among urban slums in Jimma town 2021.

VARIABLES (N=302)	FREQUENCY (%)
Head of household	
Male	215 (71.2)
Female	87(28.8)
Age categories of respondent (mean=37.79, SD=±10.89)	
18-24	34 (11.25)
25-29	42 (13.9)
30-34	31(10.25)
35-39	60 (19.9)
40-44	59 (19.5)
45 and above	76 (25.2)
Educational status of study participants	
Can read and write	18 (6)
Primary (1-8)	56 (18.5)
Secondary (9-12)	81 (26.8)
Technical (10+)	41 (13.6)
Collage and above	106 (35.1)
Marital status of the respondent	
Married	178 (58.9)
Single	92 (30.5)
Widowed	14 (4.6)
Separated	15 (5.0)
Divorced	3 (1.0)
Occupation of the head of household	
Farmer	7 (2.3)
Government employee	92 (30.5)
Merchant	51 (16.9)
Housewife	65 (21.51)
Privet worker	65 (21.54)
Day laborer	14 (4.65)
Other	8 (2.6)
Family size (mean=5.55)	
Less than five	154 (51.0)
Above five	148 (49.0)
Family monthly income (mean=11, 896 birrs [230.99$])	
<7000 Birr (135.92$)	126 (41.7)
7000 and above Birr (135.92$)	176 (58.3)

Table 2. Toilet facility options and sanitation conditions among selected households in the urban slum of Jimma town, 2021.

VARIABLES (N=302)	CATEGORIES	FREQUENCY (%)
Do you have a toilet facility?	Yes	234 (77.5)
	No	68 (22.5)
Where are child feces disposed of? (n=177)	Into toilet	60 (33.9)
	Dumped to open field	78 (44.1)
	With other wastes	37 (20.9)
	Buried	2 (1.1)
Type of toilet facility (n=234)	Flush to a lined pit latrine	50 (21.4)
	Pit latrine	53 (22.6)
	Pipes to a septic tank	88 (37.6)
	Flush discharge somewhere	28 (12.0)
	VIP	15 (6.4)
Does it functional? (n=234)	Yes	122 (52.1)
	No	112 (47.9)
Does any household share your toilet? (n=234)	Yes	135 (57.7)
	No	99 (42.3)
Which toilet did you choose for your family?	Water flush	138 (45.7)
	Ventilated improved pit latrine	94 (31.1)
	Pit with slab	64 (21.2)
	Composting toilet	6 (4)
How important to pay for toilet construction?	Very important	188 (62.30
	Somewhat important	94 (31.1)
	Not important	16 (5.3)
	Not at all important	4 (1.3)
Type of toilet facilities	Unimproved	96 (31.8)
	Improved	206 (68.2)

Household sanitation access among selected urban slum dwellers

Of the total 302 households included in the current survey, the majority (234 or 77.5%) of the households had at least one type of toilet facility, while the remaining 68, or 22.5%, did not have any form of toilet facility. About 50 (21.4%) are flushed to a lined pit latrine, traditional pit latrine 53 (22.6%), flushed to septic tanks 88 (37.5%), discharged somewhere 28 (12.1%), and VIP 15 (6.4%). More than half of the 206 (68.2%) had access to improved facilities, while 135 (57.7%) shared facilities with 2 or more households. However, of the existing facilities, nearly half of them (47.9%) were not functional as per the observation report in our survey (Table 2).

Table 3. Score based on sustainability criteria for sanitation option and weighted and final rank for an urban slum in Jimma town, 2021 (weighted and final rank).

SANITATION OPTIONS	SCORE BASED ON EACH SUSTAINABILITY CRITERIA FOR SANITATION OPTION (NORMALIZED)					TOTAL SCORE	RANK
	SOCIO-CULTURE (0.13)	TECHNICAL (0.29)	HEALTH AND ENVIRONMENT (0.13)	ECONOMICS (0.29)	INSTITUTIONAL (0.16)		
VIP	0.10	0.13	0.10	0.44	0.12	0.89	6
Compost toilet	0.07	0.23	0.12	1.16	0.12	1.69	2[a]
Biogas	0.13	0.29	0.10	0.58	0.40	1.50	3[a]
Flush to septic tanks	0.10	1.02	0.65	1.02	0.10	2.88	1[a]
Flush with sewer line/ networked	0.11	0.24	0.10	0.44	0.16	1.05	5
Pit latrine with slab	0.05	0.23	0.05	0.29	0.10	0.72	7
UDDT	0.11	0.26	0.13	0.73	0.14	1.37	4

[a]Flush to septic tanks, compost toilet, and biogas toilet is 3 alternatives ranked first in the study area.

Sustainable user interface sanitation technology selection

The selection of sanitation technology in this study was made by expert choice based on the scenario of sustainable sanitation options for urban slums. Important components of the sustainability criteria were health benefit, social acceptance, and economic feasibility; availability of skills in the technology; technical feasibility; and ease of expansion (Supplemental Table S3). Different types of user interface sanitation options were considered. A total of 7 sanitation options were evaluated by expertise and FGDs: VIP, compost toilet, biogas toilet, flush to septic tanks, centralized sewer networked toilet, pit latrine, and urine diverting dry toilet (UDDT). The criteria used in the final evaluation were determined from the values given by experts (Supplemental Table S4) and FGDs (Supplemental Table S5). The result of the multi-criteria analysis shows that flushing to septic tanks, compost toilets, and biogas toilets were the 3 top alternatives for this particular study area (Table 3).

Discussion

The current study demonstrated the sanitation status and prioritized the alternative user interface sanitation options for the slum areas of Jimma town. A total of 7 sanitation options were evaluated and ranked.

The finding revealed that most households (77.5%) had at least one form of toilet facility, while 22.5% did not have any toilet facilities. This level of coverage is consistent with findings from a similar study conducted in Addis Ababa.[20] Even though more than half of households (68.2%) had access to improved facilities, approximately half (47.9%) of the existing toilet facilities were non-functional, according to the observation, and approximately 57.7% shared facilities between 2 or more households. This finding is higher than that of a similar survey from Addis Ababa,[31] in which 94.5% of urban slum dwellers used unimproved toilet facilities. This variation could be attributed to differences in town size as well as intervention in urban slums.

The multi-criteria analysis result showed that flushing to septic tanks, compost toilets, and biogas toilets were the 3 alternatives ranked in the final analysis for this particular study area. Flushing to a septic tank is a user-interface sanitation technology option that supports a safe containment approach because it facilitates the easy emptying of fecal matter; if well designed, it can facilitate onsite treatment. Similar research has found that this technology is a relatively acceptable option in African urban slums.[8,32] On the other hand, composting toilets and biogas-integrated technologies are resource-conscious options that facilitate nutrient and energy recovery.[33,34] The biogas toilets have benefits in reducing wood biomass fuel use by bio-gas substitution (reducing deforestation) and enhancing soil amendments through bio-fertilizer; which are resource-oriented options shift the shits to opportunities. Despite the benefits of those alternatives, they are uncommon in Ethiopia, and many households rely on non-sustainable sanitation alternatives.

The alternative ranked technology options in our case are new for the setting, except for flush to septic tanks, which were in use by a few householders. This requires stakeholders to concentrate their efforts on mobilizing, demonstrating, and assisting the community effort with sustainable sanitation options such as shifting to resource-recovery-oriented sustainable technology, which may lead to a long-term solution to the urban sanitation crisis. Moreover, standardizing the sanitation options specific to the local setting, making regulatory frames for sanitation interfaces, and evidence-based choice may help the sanitation sector to step forward to achieve sustainable development goals targeted in urban sanitation. Furthermore, in multi-criteria analysis, some options would be better against one criterion but worse against another in the matrix.[35] This study handled such cases using weighted ranking, but it is limited in making inter-temporal comparisons of options that point to future work.

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Author Contributions

DO and TK have designed the survey, trained the research team, oversaw the fieldwork, and participated in drafting the manuscript. WZ, AB, and GT participated in the design of the survey, approved the survey, and oversaw the critical revision of the manuscript. All authors read and approved the final version of the manuscript.

Availability of Data and Materials

The datasets used during the current study are available in the manuscript.

Supplemental Material

Supplemental material for this article is available online.

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