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ABSTRACT

BACKGROUND: The utilization of "on-site excreta decomposition technology" known as "Ecological sanitation (Ecosan)" has a rational use of human excreta. It is a resource-oriented sanitation mostly feasible in areas with rocky soil and prone to agriculture. This technology was implemented in Rwanda for more than a decade. However, little is known about Ecosan utilization in the process of scale-up in the community.

AIM: The study was carried out to determine enablers and barriers associated with the utilization of Ecosan in Burera district, Rwanda.

METHODS: A mixed method study was surveyed in 374 households with Ecosan. A systematic random sampling was used to select respondents and a sample was drawn from the 3 administrative sectors of Burera district. We interviewed 20 key informants that included community leaders and sanitation actors. Bivariate, ordered logistic regression with thematic content analysis were used.

RESULTS: Ecosan users were unable to practice both urine diversion and the use of Ecosan by-products. Only 39.4% of households were better users. As by the survey results, primary and secondary educational status (AOR 2.60, 95% CI 1.11-6.08) and (AOR 3.49, 95% CI 1.02-11.9), frequency of fecal pit emptying (AOR 3.38, 95% CI (2.18-17.91), ash use (AOR 1.65, 95% CI (0.93-4.64) and concrete slab latrine (AOR 7.31, 95% CI (2.94-17.95) were found to be associated with better use of Ecosan. Qualitative findings suggested unaffordable cost, a touch of excreta taboos, and poor maintenance practices as key barriers to utilization.

CONCLUSION: Overall utilization of Ecosan was poor and the majority of households was not able to use Ecosan for both dry separation of urine from feces and reuse in the gardens. Upgrading existing knowledge about Ecosan with greater emphasis on the use of by-products and adopting good maintenance practices through regular training can promote better utilization of Ecosan.

KEYWORDS: Ecosan, excreta, sanitation, technology, utilization

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Introduction

Ecological sanitation (Ecosan) is a complete and sustainable approach to sanitation based on the principles of preventing pollution, sanitizing human excreta, and using urine and feces as resources for agriculture. Ecosan is embedded in the concept of resource reuse-oriented sanitation[1] as dry sanitation system built on the principle of urine diversion from feces during defecation practice. Both fecal matter and urine pass through different holes during defecation practice. The feces pass through a fecal hole and are collected in the fecal vaults, while urine drains into the pipeline to the collection tank.[2] This dry toilet system or Urine Diversion Dry Toilet (UDDT) can reduce 20% to 40% of domestic water use and recycle 80% to 90% of nitrogen, phosphorus, and potassium in excreta into agriculture.[3] These values give Ecosan international credentials from on-site safe excreta treatment to productive sanitation on the part of users.

The utilization of Ecosan technology was reported to be critical in sub-Saharan countries.[4] In these areas, the transfer of Ecosan technology was done by international sanitation

promoters in the formworks of sanitation coverage and input in agriculture.[5] However, studies show that in the areas with low uptake of Ecosan, there was a high decline in number of Ecosan and people have gone back to using the conventional pit latrines.[6] Studies have indicated that improper utilization of Ecosan was strongly related to household and socio-economic factors.[7] Such factors have been widely studied in different similar settings and findings were reported in regard to Ecosan. Research conducted in Tanzania, Malawi, and Uganda highlighted the cost of construction, gender, and religious taboos, as the main challenges for the adoption of Ecosan in these areas.[8-11] This has resulted in a slow down of diffusion of Ecosan pilot project and discontinuance of utilization among the beneficiaries in these cited countries.[12] This is evidence of diverse factors during the diffusion of Ecosan in different social settings, which need to be contextualized wherever Ecosan was implemented.

Furthermore, the proper utilization of Ecosan requires a certain level of operation and maintenance practices on user level. It was noted that foreign sanitation agents are key implementers of Ecosan in Eastern African Countries. Before having Ecosan, beneficiaries were trained to use it and adopted best practices through behavior change programs.[13] However, such trainings were not efficient in areas with high rate of illiteracy and where beneficiaries were not actively fully engaged in Ecosan implementation process.[14] In such trainings, beneficiaries learnt good practices on cleaning of latrine, application of ash, harvesting of urine, feces, and ways of application of such excreta on the garden. However, studies indicated a lack of follow-up and support in maintenance of Ecosan in the areas which implied not long-lasting of Ecosan operation.[15] Studies done in Tanzania, claimed about Ecosan maintenance to be harder compared to the pit latrines.[16] On the part of users, application of ash in the fecal hole after each defecation was reported to be stressful and was not always available within Ecosan latrine.[6] The only swiping practice was locally advisable to avoid any contact of water in the fecal hole of Ecosan latrine made of concrete slabs. However, such sweeping option was not possible in Ecosan latrine made of wood slabs which induces poor sanitation inside the latrine. In Rwanda, the promotion of Ecosan technology filled sanitation shortfalls that existed in areas with agricultural predominance such as Burera district. Since 2006, the United Nations for Children Fund (UNICEF) together with the Netherlands Development Organization (SNV) and local Government have implemented projects for the construction of Ecosan toilets and the provision of slabs and other construction materials in the community.[17,18] Only 20% of farmers started to use Ecosan products on their gardens.[17] However, recent findings show a reduction in the number of Ecosan toilets and their use. For example, 20 blocks of Ecosan toilets built in public places were abandoned, while 16 blocks of toilets in public schools were not operational[19] and provided slabs were being used in the construction of the pit latrine. This misplacement of slabs led to a shortage of households that would have adopted Ecosan technology.[5] The use of protective equipment during the application of Ecosan products in gardens is not a common practice in Rwanda.[18]

Several studies on Ecosan[18-20] have reported about adoption in Rwanda, most of them have overlooked Ecosan through the lens of sanitation options.[18,19] Factors such as the use of ash, sweeping, gender privacy, and collection of Ecosan products were categorized as enablers of better use of Ecosan. However, studies on the use of Ecosan products and associated factors are sparse, which creates a gap in the literature in regard of Ecosan in close proximity to the sanitation and agricultural loophole. Most of the available information on Ecosan utilization in Rwanda is found within institutional reports and not available in a wide scientific domain. This creates a scarcity of long-term monitoring data that have been published on the trends of utilization of Ecosan technology and associated factors in the community. Therefore, a study on utilization of Ecosan considers a wide range of factors in perspectives of sanitation and agriculture so as to inform proper future interventions to boost sanitation coverage and sustainable use of Ecosan in Rwanda.

Methods

Study area

The Burera district is located in the volcanic region of the northern province of Rwanda. The rocky lava soil has challenged the excavation of conventional pit latrines in the area and consequently led to poor sanitation facility coverage in the area.[21] The district was the "implementation site" chosen for Ecosan pilot projects as an appropriate sanitation facility in the area. Burera district comprises 17 sectors with 571 villages. The recent Demographic and Health Survey[22] indicated a total of 336 455 and 73 701 population and households, respectively. Under the promotion of Ecosan projects with the partnership of the local Government, 1000 Ecosan technologies were implemented in households and public places in the district, as indicated in Figure 1.

Study design and population

This is a mixed-methods study identifying factors associated with the utilization of Ecosan among owners and exploring the stakeholders' views on Ecosan. According to Creswell (2006),[24] mixed method research is a research design that combines both quantitative and qualitative approaches for depth understanding of the research questions. In this study, the predominant part was quantitative followed by the qualitative component. Given that a thousand Ecosan was installed in the household. The quantitative component gathered information from the head of household with operating Ecosan excluding households that have used Ecosan for less than 6 months. The study population was household owning Ecosan. The main

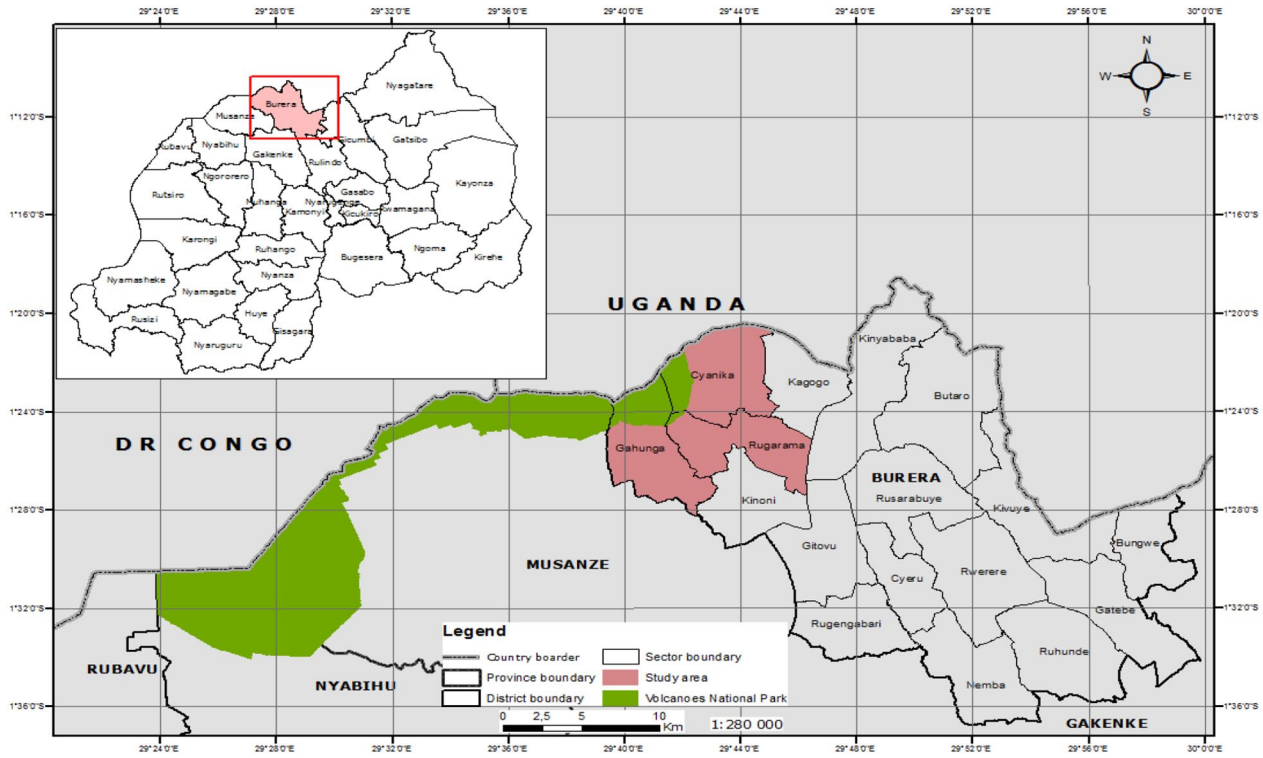

Figure 1. Location of the study area (CGIS-UR, 2018).[23]

respondents were the heads of households, if not available, an adult person above 18 years of age living permanently in the household was interviewed. The qualitative part focused on key stakeholders of Ecosan in Burera district such as community leaders of Rugarama, Gahunga, and Cyanika sectors and sanitation actors of UNICEF and the Netherlands Development Organization (SNV).

Sample size and sampling procedure

The sample size was calculated following a single population proportion formula of Kish Leslie (1965) under the assumptions of the rate of 50% of utilization of Ecosan at a 95% confidence interval, an absolute error of 5% with a design effect of 2, and adding 10% of non-response. A total of 374 households beneficiaries of Ecosan technology participated in the survey. Based on stratified sampling in each sector, we selected 159 households with operating Ecosan in Rugarama sector, 109 households with operating Ecosan in Gahunga sector, and 106 households with operating Ecosan in Cyanika sector. At the household level, the trained masons of Ecosan (locally known as Ecosan supporters) assisted in identifying the location of the targeted household.

A multi-stage sampling technique was used to select the study participants. First, the district of Burera was stratified into sectors. Second, 3 sectors of Rugarama, Gahunga, and Cyanika were randomly selected. Third, study participants were selected using systematic random sampling in proportion to the number of households in each sector. Finally, household beneficiaries of Ecosan were systematic randomly drawn from the existing master list by skipping an interval of one which means the selection of only Odds numbers.

Qualitative data were gathered from 20 key informants made of 18 executive secretaries of the cells in sectors of Rugarama, Gahunga and Cyanika together with 2 workers from Ecosan actors (Unicef and SNV). Participants were purposively selected according to the organizational positions occupied and community influence and their participation in the promotion and follow-up of Ecosan. The informants were community leaders who are responsible for local sanitation enforcement and participated at least in one Ecosan campaign and sanitation actors from UNICEF and SNV who have Ecosan promotion in their responsibilities.

Research instrument and data collection

Five research assistants with a study background in environmental health sciences were recruited and received specific training on the research topic, content, and use of the tools. A 5-day training was carried out by the first author before starting data collection. The last 2 days were characterized by piloting the questionnaire and interview guide for issues of reliability and validity. The questionnaire was reliable at (Cronbach's alpha = 0.785) and was pretested with 30 household heads having Ecosan in Nyabihu District, which is a similar set of study area, with a response rate of more than 90%. The standardized structured household questionnaire on sanitation facilities has been validated.[25] It was adopted

and translated into the local language. It comprises 3 parts: Part 1 was household characteristics (gender, marital status, education status, family size, occupation, and duration of residence). Part 2 was about behavior and socio-economic characteristics (knowledge, attitudes, practices, cultures, economic category, and costs of sanitation). Part 3 was technological factors (Ecosan slabs, privacy and Ecosan construction materials). Quantitative data collection was started from March 2021 to May 2021. As the study area presented a higher prevalence of illiteracy, face-to-face interviews with respondents were conducted and then asked to show and take a photo of Ecosan by a camera in the household.

Since June 2021, qualitative data was collected from implementing partners of Ecosan in Burera district, known as "local community leaders and sanitation actors." By referring to the grounded theory of Ecosan, the first author developed an interview guide using a deductive approach. The open-ended questions were made by the probes to be discussed according to participants' views on the utilization of Ecosan. The questions on barriers and drivers such as social and financial constraints, technology design, maintenance issues, community demands, and motives about Ecosan have been widely discussed. For quality insurance and adequacy of the interview guide, the pretested interview was done with 2 community leaders in Nyabihu district where Ecosan was also implemented. The key informants received an appointment for an interview. After an explanation about the study, they signed a consent form and agreed to participate. The first author was interviewed while a trained research assistant captured tape recording and note-taking in English during interview.

Study variables

Dependent variables. Utilization of Ecosan was considered to be proper when the household was able to divert urine from feces within the technology during defection and able to reuse Ecosan by-products in the garden.

The key independent variables. Socio-demographic characteristics (gender, family size, occupation, educational status, age class, wealth index), personal variables (religion, beliefs, taboos, knowledge, attitude and practices, economic factors (Ecosan products values, income category, capital cost, maintenance cost)

Operation definitions

In this study, *Ecosan technology* was defined as a latrine with a superstructure and substructure made-up either wood, plastic or concrete slab with a urine-diverting squatting pan, which separates urine from feces during defecation for further decomposition and safe reuse. Such separation makes a dry system of fecal matter and gives Ecosan technology a credential to be called "Urine Diversion Dry Toilet (UDDT)."[6]

Utilization of Ecosan is a functional status of making Ecosan operating and usable as a defecation option at the time of data collection.

Ecosan by-products refer to the end-products of urine and feces after on-site treatment and decomposition process through Ecosan technology. Both products are collected separately, treated, and can be applied to the gardens as safe manure.[26]

Data analysis

Quantitative data were entered into the Open Data Kit (ODK Collect V1.25.1). Variables were coded and analyzed in Stata (V.14.2). The utilization of Ecosan technology and socio-demographic variables was expressed by descriptive data. Then, Chi-square was used to test the relationship between variables. Factors with a higher straight of association were considered in the analysis model. Then, the association between the use of Ecosan technology and predictor variables was tested by Odds Ratio (OD). From these, a study categorized the utilization into 3 levels: "poor," "good," and "better." The "poor" level 1 considered households that neither divert urine from feces nor use Ecosan products in their gardens. Level 2 "good" included the households that practiced urine diversion from feces without using Ecosan products in gardens. The households that practiced urine diversion from feces with the use of by-products in their gardens achieved level 3 "better." An ordered logistic regression model was used to calculate the strength of the association between the Ecosan technology utilization levels: "better," "good," "poor," and explanatory factors. Therefore, we compared these ordered categories based on their "good and better" versus "poor" ratings as a reference category. Data were reported in the form of Adjusted Odds Ratio (AOR) and their 95% confidence interval (CI). Data from key informants were recorded, transcribed, and then coded in NVIVO (v.11). The thematic analysis of qualitative data was done according to the context and meaning of the utilization of Ecosan technology. Both quantitative and qualitative data were integrated at the stage of interpretation and therefore, quantitative data were sequentially explained by qualitative data for a better understanding the utilization of Ecosan.

Ethical considerations

The permission to conduct the study was granted by the Burera district administration after submitting an ethical clearance No. 383/CMHS IRB/2019 from the Institutional Review Board of the College of Medicine and Health Sciences, University of Rwanda. Participation in the study was voluntary and participants agreed and signed a written informed consent after explaining the study. The confidentiality of the participants was ensured by using codes instead of their names on the data collection tools.

Table 1. Categories of the utilization of Ecosan according to household characteristics and practices in Burera district.

VARIABLES	CATEGORY	UTILIZATION OF ECOSAN			TOTAL (%)
		POOR (%)	GOOD (%)	BETTER (%)	
Gender	Male	45 (22.6)	74 (37.2)	80 (40.2)	199 (53.2)
	Female	36 (20.58)	72 (41.1)	67 (38.3)	175 (46.8)
Education	Informal	21 (38.2)	18 (32.7)	16 (29.1)	55 (14.7)
	Primary	45 (17.5)	110 (42.8)	102 (39.7)	257 (68.7)
	Secondary	15 (24.6)	18 (29.5)	28 (45.9)	61 (16.3)
Profession	Farmers	80 (26.4)	135 (44.7)	87 (28.8)	302 (80.7)
	Others	1 (1.3)	11(15.2)	60 (8.3)	72 (19.3)
Wealth quintile	Lowest	24 (61.5)	11 (28.2)	4 (10.2)	39 (10.5)
	Middle	53 (20.2)	111 (42.3)	98 (37.4)	262 (70)
	Highest	4 (5.5)	24 (32.9)	45 (61.6)	73 (19.5)
Knowledge	Low	117 (46)	102 (40.2)	35 (13.8)	254 (67.8)
	Moderate	30 (25.4)	44 (37.3)	46 (39.6)	116 (30.4)
Cleaning practices	Mopping	1 (25)	2 (50)	1 (25)	4 (1)
	Sweeping	18 (7.8)	98 (42.6)	114 (49.6)	230 (61.5)
	Both	16 (19.5)	36 (43.9)	30 (36.6)	82 (21.9)
	Not any	46 (79.3)	10 (17.2)	2 (3.4)	58 (15.5)
Use of ash	Yes	63 (17.9)	144 (40.7)	146 (41.4)	353 (67.6)
	No	18 (85.8)	2 (9.5)	1 (4.8)	21(5.6)
Emptying fecal products	Annual	64 (21.5)	123 (41.2)	11 (37.4)	198 (52.9)
	Semi-annual	4 (6.5)	21 (34.4)	36 (59)	61(16.3)
	2 years	13 (92.8)	1 (7.1)	1 (3.6)	15(4)
Ecosan slabs	Wood slabs	39 (62.9)	21 (33.8)	2 (3.2)	62 (16.6)
	Concrete slabs	5 (2.7)	59 (32)	120 (65.2)	184 (49.1)
	Plastic slabs	37 (28.9)	66 (51.5)	25 (19.5)	128 (1.7)
Diverting urine	Yes	-	146 (39)	147 (39.4)	256 (68.4)
	No	81 (21.6)	-	-	81 (21.6)
Use of Ecosan by-products	Yes	2 (0.5)	-	147 (39.4)	149 (39.8)
	No	79 (21.1)	146 (39)	-	225 (60.1)

- means zero case.

Results

The utilization of Ecosan technology in Burera district

Of the total number of 374 participants, 53.2% were males and 80.7% were farmers. Low household income contributed to poor utilization, whereby 61.5% of the respondents belonged to the lowest wealth quantile. According to the knowledge of the respondents, 46% of them are poor users of Ecosan and presented poor knowledge about Ecosan technology.

When considering household sanitation practices, 85% are poor utilizers of Ecosan, as it no longer applies ash. Approximately 65% of the household respondents were classified as better users of Ecosan using Ecosan with concrete slabs, while 62.9% of them were classified as poor users as using Ecosan constructed with wood slabs. Only 39.4% of the household respondents were considered to be better users of Ecosan technology because they practiced urine diversion through Ecosan technology and used Ecosan by-products as indicated in Table 1.

Factors associated with Ecosan utilization

The study revealed that factors such as educational status, wealth quintiles, knowledge of Ecosan, practices, and technological attributes were associated with the utilization of Ecosan in Burera district. There was a strong association of educational status with the utilization of Ecosan technology. Participants with primary (AOR 2.60, 95% CI 1.11-6.08) and secondary education (AOR 3.49, 95% CI 1.02-11.9) were better utilizers compared to those with informal education. The wealth quintiles of households in the high (AOR 2.49, 95% CI 0.50-8.43) and middle categories (AOR 2.07, 95% CI 0.78-7.97) contributed to better use of Ecosan 2 times the odds of being in a low category). The personal factors (knowledge, cleaning practices, use of ash and soil, and emptying practices) are associated with the utilization of Ecosan. People with moderate knowledge about Ecosan contributed to the better utilization of 2 times the Odds (AOR 2.24, 95% CI (1.09-11.6) of those with low knowledge. Sweeping practice (AOR 3.1, 95% CI (2.3-8.47), ash use (AOR 1.65, 95% CI (0.93-4.64) and semi-annual fecal emptying practice (AOR 3.38, 95% CI (2.18-17.91) are closely influencing the proper utilization of Ecosan technology. Furthermore, the concrete slab (AOR 7.31, 95% CI (2.94-17.95) is closely associated with the proper utilization of Ecosan technology (Table 2).

Enablers and barriers to the utilization of Ecosan

To understand the factors that affect the utilization of Ecosan technology in the community, the KII findings were categorized into 4 themes of unaffordable cost, substandard Ecosan latrine design, local demands and success of Ecosan and absence of Ecosan maintenance support, as indicated in Table 3.

Absence of Ecosan maintenance support

The additives; such as ash, are added after defecation practice in the fecal pit hole which contributes to the proper utilization of Ecosan technology. By observation, it was noted that household' users of ash keep the containers in toilets. However, in some households, containers were empty and bad smell and flies inside and around toilets, which justify the irregular use of ash.

The absence of maintenance support, such as poor cleaning practices, additive misuse, and irregular emptying practices, have been problematic issues in the proper utilization of Ecosan. One community leader stated failure of change user' practices toward proper utilization, *"The implementation made by sanitation agencies was not efficient and the practical knowledge of the maintenance of Ecosan for some people was not enough due to limited time, lack of technical support and lack of support from community leaders. For example, SNV constructed Ecosan for poor households in partnership with Burera district without engaging community leaders and people in the excreta emptying practices and the use of Ecosan products as key practices that can push people to continue to use Ecosan as farmers"* (Male, 35 years, community leader).

Table 2. Multivariable regression of factors associated with utilization of Ecosan technology in Burera district.

CHARACTERISTICS	COR (95% CI)	AOR (95% CI)
Education status		
Informal education		1.0
Primary education	2.13 (1.22-3.72)	2.60* (1.11-6.08)
Secondary education	2.2 (1.09-4.44)	3.49* (1.02-11.9)
Wealth quintile		
Low		1.0
Middle	6.27 (3.14-12.51)	2.07* (0.78-7.97)
Highest	17.8 (7.92-40.25)	2.49* (0.50-8.43)
Knowledge		
Low		1.0
Moderate	2.68 (1.95-14.3)	2.2* (1.09-11.6)
Cleaning practices		
Mopping		1.0
Sweeping	1.37 (4.7-20.85)	3.1* (2.3-8.47)
Mopping and sweeping	3.92 (2.39-10.9)	1.6* (0.23-10.18)
Not any	0.08 (2.12-4.56)	0.65 (0.02-14.9)
Use of ash		
No		1.0
Yes	2.11 (0.3-4.5)	1.65 (0.93-4.64)
Fecal products emptying		
Once a year		1.0
Twice a year	3.86 (0.41-36.1)	3.38* (2.18-17.91)
2 Years	1.48 (0.16-13.29)	0.045 (0.004-0.50)
Type of slabs		
Wood slabs		1.0
Concrete slabs	41.8 (21.1-82.87)	7.3* (2.94-17.95)
Plastic slabs	4.64 (2.4-8.6)	0.045 (0.004-0.50)
Willing of payment ($)		
Free of charge		1.0
⩽9	3.6 (0.44-28.95)	4.47* (0.7-30.1)
Between 10 and 29	1.1 (0.08-16.01)	1.17* (0.1-14.2)
Between 30 and 49	1.4 (0.40-4.91)	1.52* (0.5-4.7)
Between 50 and 99	7.9 (2.72-23.030)	7.12* (2.9-17.5)
⩾100	23.6 (8.06-69.07)	38.03* (15.3-94.8)

Abbreviations: AOR, adjusted odds ratio; COR, crude odds ratio.
Statistical significance with an association at *$P < .05$.

Table 3. Enablers and barriers to the utilization of Ecosan.

THEMES	SUB-THEMES	DESCRIPTION
Sub-standard design of Ecosan latrines	Declines of functional status	Leakage of urinal pipes and failure to divert urine from feces, which renders a mixture of urine and feces in one fecal vault
	Design-effect	Ecosan latrine with the wooden slabs creates unhygienic conditions with bad smell and flies
Absence of Ecosan maintenance support	Training on Ecosan technology	Misuse of ash and poor fecal pit emptying is a critical point of fecal disease transmission
	Technical support	Sub-utilization of Ecosan due to lack of repairing from trained local masons.
	Supporting supervision	The consistency of poor urination practice in the fecal vault among males undermines the appropriate utilization of Ecosan
	Sharing experiences	No room to share the best practices which make slow the diffusion of Ecosan technology in the community
	Partnership	The role of local leaders was not clear from the start of the Ecosan project
Local demands and success of Ecosan	Replication of Ecosan	Each household claims to have Ecosan or Ecosan slabs
	High demand of Ecosan products	People tend to use any emptied excreta manure without any treatment due to the local high demand
	Local community trainers	A mass of trainers can help to upgrade the local Ecosan context
Unaffordable cost	Usable and repair materials	The urinal collection tanks, repair materials, and other PPE are not locally affordable to small household' farmers

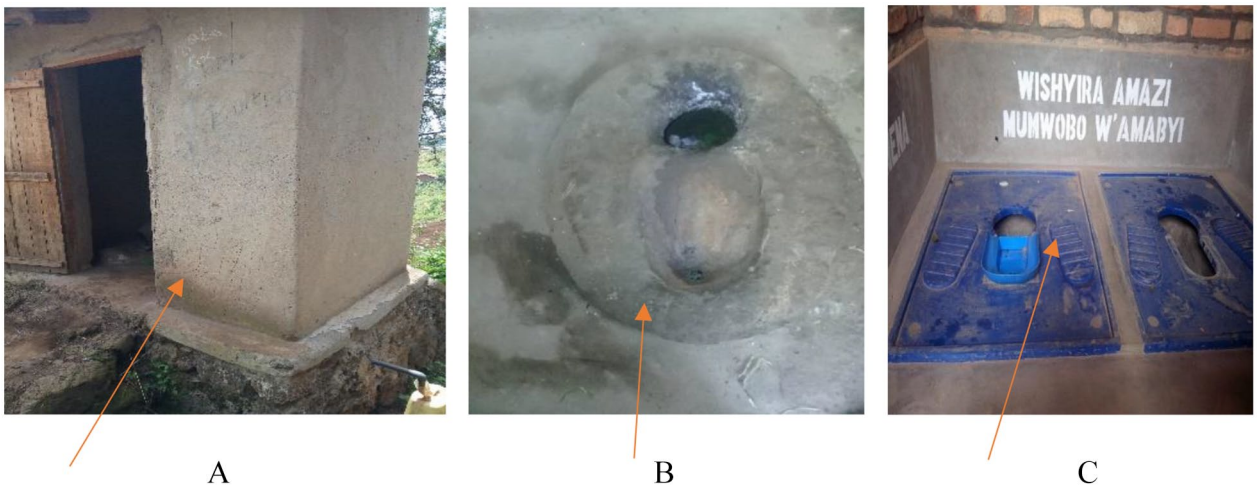

Figure 2. Local Ecosan cabinets with an inside view of slabs: (A) Ecosan superstructure, (B) concrete with cement slab, and (C) plastic slabs.

Sub-standard design

The floor of Ecosan latrines is made of wood, concrete, and plastic slabs, and the slabs variation depends on local providers. According to field observations, SNV has installed Ecosan with concrete slabs; UNICEF has installed the ones with plastic slabs and supplied the same materials to some home builders for themselves. Such a local variation in Ecosan design has confused the local community, creating local dilemma and confusion on proper Ecosan technology, as indicated by Figure 2. Furthermore, leakage of urinal pipes and a mixture of urine with feces created a barrier to better utilization of such technology. In addition, households with Ecosan latrine made up of wood slabs create unhygienic conditions with bad smell and flies.

One community leader confirmed such a dilemma in Ecosan design, *"Having Ecosan technology that can divert urine from feces requires technical skills and regular technical support which are not locally affordable for small household farmers. Therefore, people try to mimic the Ecosan design installed by SNV and then use UNICEF slabs and mix them with wood slabs that make cleaning very hard, a bad smell and attractive to fly"* (Male, 54 years, Community leader).

Local demands and success of Ecosan

People found Ecosan as a holistic solution after the difficulties of local installation of pit latrines in the study area. Ecosan users enjoy sanitation provisions and rely on Ecosan by-products for

yield production that timely replace the local decline of other organic manures and the unaffordable price of mineral fertilizers. The present Ecosan at the home was poorly maintained, which makes its productivity critical safe despite high local demand. From the observed facts, Ecosan built by SNV in households guaranteed better sanitation than Ecosan installed in partnership with UNICEF with community members. SNV built Ecosan with cement-made concrete slabs, while UNICEF installed Ecosan with plastic slabs. It is hard to maintain Ecosan plastic slabs and mixed plastic with wood slabs, as their longevity is shorter and some parts, such as cover holes and squat holes, are easily lost which makes clearing practices difficult.

It is not clear how the Government under community partnership has quickly eradicated the traditional grass-covered houses among the poor households by replacing them by modern cost houses in the range of millions of Rwandan francs. Why can the same joint effort be used to build a cheaper Ecosan toilet that can help people to minimize the health burden of human excreta in this area? (Male, 32 years, community leader).

Unaffordable costs

The proper utilization of Ecosan requires regular maintenance of latrines by using sanitary materials and consumables. The sanitation actors with the Government-subsidized the price of some materials at a certain percentage during the installation of Ecosan. The same projects offered the urine tanks at 10$ in the construction phase as well other materials such as PPE such as (gloves, covers, rubber, safety masks) at any cost. After the support of the project,we observed that most received materials got old without replacement and the urinary tanks of 200 L were replaced by Jerri cans of 20 L which are accessible in local shops and affordable by beneficiaries of Ecosan. *"The maintenance of Ecosan evolves the expenses of money of buying some sanitary materials including tanks to collect urine which are more expensive to the users of Ecosan and therefore, we are collaborating with the local government to provide materials on subsidize price"* (Female, 35 years, sanitation actor).

Discussion

Status of utilization of Ecosan technology

The utilization of Ecosan technology was critical and poor to the extent of rejection. Most of the users of Ecosan technology were unable to practice both urine diversion and the use of Ecosan by-products. We assessed the utilization of Ecosan technology among households in relation to its enablers and barriers. The results of the current study show that 78.3% of households with Ecosan technology practiced urine diversion through a squatting plate; only 39.4% of them were able to carry out urine diversion and apply Ecosan by-products on their farms as justification for the low rate of proper utilization. A such extend of poor utilization of Ecosan contributes to the decrease in the number of Ecosan technologies in the home and, hence, to the poor sanitation coverage in the study area.

The level of utilization of Ecosan technology has declined over time after its installation at household level.[9] This slowdown in utilization was due to the poor maintenance practices of Ecosan technology and the failure to use Ecosan by-products among owners. A study conducted at the beginning of the post-implementation of Ecosan in Burera district, Rwanda, in 2014 showed a greater commitment and willingness to use Ecosan technology and by-products among households that received such technology.[19] However, a similar study done in 2016 showed a reluctance in the use of Ecosan technology due to the lack of new sanitary materials and Personal Protective Equipment (PPE) to replace the old ones received during the implementation of the project.[18] It is known that sanitation technology has to prevent the users to be exposed to excreta as well as environmental protection. Such studies attributed to fear of touching human excreta among Ecosan users to such decline of Ecosan in the household. Whereas, the current study did not support such evidence of touching human excreta taboos as among the key factors contributing to the poor utilization of Ecosan in Burera district.

Evidence of a continuous decline in Ecosan utilization was mostly observed in areas where outside sanitation agents installed Ecosan in the communities. This is in line with the findings of similar studies in Tanzania,[8] Malawi,[6,9] and South Africa.[27] However, the current study differs from the cited studies in the conceptualization and operationalization parts of the study outcome and related factors.

Factors of the utilization of Ecosan technology

The utilization of Ecosan technology was closely associated with knowledge of Ecosan technology. Knowledge about the maintenance of Ecosan among owners was found to be low among people who received Ecosan latrines or accessories from NGOs. Such knowledge gaps characterized by Dos and Don'ts in Ecosan were observed in a similar post-project implementation study in Uganda.[28] NGOs' officials offered quick training on latrine cleaning, use of additives (ash, soil, and leaves), urine collection, and use of soaps during Ecosan campaign. Therefore, people have forgotten, with time, some good maintenance practices that aim to maintain a dry sanitation system. According to the study findings, household users with high knowledge of Ecosan technology are more likely to be better users compared to those with low knowledge of Ecosan technology. This correlates with studies of evidence of high knowledge with positive attitudes and proper maintenance practices of Ecosan as the starting point of proper use of Ecosan.[6,29] Sweeping practice has been reported to be an enabling factor for proper utilization among households with concrete slabs. This is in line with previous studies on cleaning practices that discourage the practice of mopping as a risk factor for water entry into the fecal vault, which decreases the rate of fecal decomposition.[6,10,16] This is consistent with the findings from Malawi, in which the addition of dry matter (ash and soil) is a difficult task that requires a higher level of user commitment

and makes the complexity of Ecosan adoption.[9] Ecosan users need regular training to overcome the technological challenges that occur in the sustainable sanitation operation process.

In this study, sociodemographic factors such as education, gender, profession and religion were behind the utilization of Ecosan technology. Participants with secondary education level tend to clean the latrine well as instructed and fear to manipulate poor treated Ecosan products. On the same line of these findings, the more people are educated, they tend to implement the best practices for urine diversion as well as proper utilization of Ecosan technology.[30] However, such a single factor is not enough to allow people to use Ecosan well, but combined factors of gender, and farming activities are drivers of proper utilization of Ecosan. A similar study done in Pakstan[31] on cited factors indicated that females played a role in the selection and utilize sanitation systems,[32] as women are the ones who sit on the slabs of the toilets and have a higher risk of contamination than men, but in the current study there was not enough evidence to support that argument. Being a Muslim was a key factor to reject Ecosan as dry sanitation system[10] as applies water during anal washing and accuse the Ecosan to expose user to his/her excreta. However, this study was not able to show an association between religion and utilization of Ecosan due to the insignificant number of Muslims in the study area.

Standard Ecosan design

It was noted that the material used for the slab influenced the utilization. Households with cement-made concrete slab contribute to better utilization of the latrine 7 times more often than those with latrine with wooden slabs. This correlates with the study on the type of construction material for sustainable use of Ecosan in Burkina Faso.[5] It was found that plastic and wooded slabs are easily broken down, do not support user pressure, and hole covers are easily lost. The shortages of such latrine slabs were widely discussed in study done in Tanzania,[33] it was found the unhygienic design and poor functionality of the slabs hinder sustainable sanitation. Another study described slabs with their cost,[12] and the use of concrete slab made in cement was affordable and sustainable, as it was locally feasible. Part of the subsidies made by UNICEF, the household cannot afford the price of plastic slabs for the construction of Ecosan. Most households have installed local wooden slabs without technical support. This type of Ecosan makes cleaning difficulties that have definitely brought poor sanitation to the home, which could be a source of transmission of excreta borne diseases.

Unaffordable cost

The end of funding projects and expensive local expertise have undermined the level of utilization of Ecosan technology among small household users. Most of the poor households in Burera district received Ecosan technology from UNICEF and SNV sanitation agents through a financial support program as free of charge. During the project implementation, the beneficiaries have received urine collection tanks, fecal emptying spades, fecal transport wheelbarrows, and other sanitary materials.[18] However, such materials have gotten old without replacement after the closeout of the project. Moreover, urinal collection tanks, repair materials (urine pipes, Ecosan slabs), and PPE (hand gloves and facemasks) are not locally affordable to the beneficiaries of Ecosan. In the last phase of the project, a subsidy of 90% of the total price of the urinary tanks has motivated households of high and middle income to install the technology themselves using local construction materials such as *sun*-dried *mudbricks* and cement. According to such financial support, they only paid 20$. for a urinary tank of 200 L. After the project, such subsidy was not long applied locally which resulted in the replacement of such big tanks with small Jerri cans at the affordable cost of 1$. This was a fact of poor conditions of storage of urine and timely emptying of untreated urine.

The beneficiaries of Ecosan are not able to afford the cost of regular maintenance of Ecosan . Local expertise is limited and few trained local masons are paid 5$ at each visit and this price can increase when there is a problem with technology. In addition, during harvesting, some household beneficiaries such as old people are not able to do it for themselves and tend to rely on outside fecal pit emptying services on cost of 10$. However, such unfordable costs remain to be a financial burden to the small household beneficiaries as barriers to the utilization of Ecosan. The same findings are in line with studies on the dependency of Ecosan users on external donors with high subsidies from Ecosan installation to maintenance as a key challenge of sustainable use in countries with limited resources.[34,35]

Ecosan is spread throughout the country, mostly in rural areas; therefore, the study findings can be generalized and reliable in similar settings of the study area. In addition, it is among the few studies that establish the contextual factors that affect the utilization of Ecosan among owners after 15 years of initiation in Rwanda. The study assessed the utilization of Ecosan with a focus on the separation of excreta for better treatment and reuse in the gardens. However, no further information on microbial content in Ecosan by-products was indicated. Further studies could investigate the utilization concerning health risks associated with the use of Ecosan by-products.

Contributions to public health

Improper disposal of human excreta is a source of parasitic infections, which continue to threaten a public health.[9] Although Ecosan was implemented as excreta resource-oriented sanitation, its utilization was critical to the extent of rejection in some areas.[1] This study on Ecosan in Rwanda showed a wide range of factors that affect its utilization as sanitation and agricultural option through the reuse of excreta. Such findings on Ecosan demonstrated potential barriers

within a rural context that inform current and future promoters to scale up Ecosan for sustainable reuse of excreta. This could improve public health through sanitation and food security particularly among farmers through relief of the burden of infectious diseases and provision of excreta manure.

Conclusions

The study categorizes the current use of Ecosan technology in households into 3 levels "poor," "good," and "better" and establishes the factors behind this usage. A more than a decade of Ecosan implementation, its utilization was found to be poor in Burera district, Rwanda. Most users of Ecosan were unable to apply both urine diversion and the use of Ecosan by-products. Factors such as education status, Ecosan training, knowledge of Ecosan, sweeping practice, ash application, and frequency of fecal emptying contributed to better utilization. However, latrine with wood slabs, substandard design, unaffordable cost of sanitary materials and PPE, and lack of maintenance support contributed to the poor utilization of Ecosan technology.

According to the above findings, an exploratory study on enablers and barriers to the utilization of Ecosan in a certain time and place can inform future research questions in similar settings and, provides evidence for appropriate Ecosan interventions and sustainable use. A better understanding of the association of these factors with the utilization of Ecosan could support current and future program implementers on how to address these factors to improve the utilization, particularly in households with a low rate of utilization of Ecosan. Moreover, the provision of community-funding opportunities and offering training on skills of Ecosan maintenance at the household level could enhance the proper utilization of Ecosan. Both could increase confidence and trust in Ecosan utilization among owners and their neighbors as facts of scaling up Ecosan in the community and sustainable use in the area.

Author Contributions

BC conceptualized the study idea, designed the search strategy, extracted and analyzed the literature, and drafted the manuscript. NBT contributed in data analysis and revising the manuscript. DM and TN contributed to searching the literature and took part to revise the manuscript. JS and EB revised the final draft and approve the manuscript for submission. GWM assisted in revising and editing the manuscript for English proof reading. The corresponding author also declares that all authors have read and approved the manuscript for publication.

Data Availability Statement

All relevant data are included in the paper and full data and study materials can be available to the corresponding author prior to the request.

REFERENCES

1. Simha P, Ganesapillai M. Ecological sanitation and nutrient recovery from human urine: How far have we come? A review. *Sustain Environ Res*. 2017;27:107-116.
2. Magri ME, Philippi LS, Vinnerås B. Inactivation of pathogens in feces by desiccation and urea treatment for application in urine-diverting dry toilets. *Appl Environ Microbiol*. 2013;79:2156-2163.
3. Jonah A. *Ecological Sanitation (Ecosan) and the Kimberley Experience*. Master's Thesis, Linköpings Universitet; 2007.
4. Robinson BE. *Household Adoption of Ecological Sanitation: An Assessment of Agricultural Value and User Perspectives in Nyanza Province, Kenya*. Master's Thesis, Massachusetts Institute of Technology; 2005.
5. Dickin S, Dagerskog L, Jiménez A, Andersson K, Savadogo K. Understanding sustained use of ecological sanitation in rural Burkina Faso. *Sci Total Environ*. 2018;613-614:140-148.
6. Kumwenda S, Msefula C, Kadewa W, Ngwira B, Morse T, Ensink JHJ. Knowledge, attitudes and practices on use of fossa alternas and double vault urine diverting dry (DVUDD) latrines in Malawi. *J Water Sanit Hyg Dev*. 2016;6:555-568.
7. Pearson J, Mcphedran K. A literature review of the non-health impacts of sanitation. *Waterlines*. 2008;27:48-61.
8. Aloyce WM, Twaha M. Challenges of adoption of urine-diversion dry toilets technology as sanitation option by coastal communities of Mkuranga District in Tanzania. *Afr J Environ Sci Technol*. 2015;9:482-492.
9. Chunga RM, Ensink JH, Jenkins MW, Brown J. Adopt or adapt: Sanitation technology choices in urbanizing Malawi. *PloS one*. 2016;11:e0161262.
10. Richard C. *Sanitation Technology Preferences & Drivers of Demand for Ecological Sanitation*. PhD Thesis, University of London, July 2015.
11. Drangert JO, Nawab B. A cultural–spatial analysis of excreting, recirculation of human excreta and health—The case of North West Frontier Province, Pakistan. *Health Place*. 2011;17:57-66.
12. Fry D, Mideksa D, Ambelu A, et al. Adoption and sustained use of the arborloo in rural Ethiopia: A cross-sectional study. *J Water Sanit Hyg Dev*. 2015;5:412-425.
13. Kefeni EG, Yallew WW. Communal latrine utilization and associated factors in Addis Ababa, Ethiopia: A community-based cross-sectional study. *J Water Sanit Hyg Dev*. 2018;8:319-324.
14. Bhardwaj P, Gupta R, Shukla JP, Mishra D, Mudgal M, Amritphale SS. The connection between female literacy and technology adoption in rural societies: Exploring female literacy and technology adoption for promoting the usage of water-based toilets in India. *Technol Soc*. 2017;50:44-49.
15. Ganiron TU Jr. Design and management features of ecological sanitation. *Int J u- e-Service Sci Technol*. 2015;8:41-54.
16. Trimmer JT, Nakyanjo N, Ssekubugu R, Sklar M, Mihelcic JR, Ergas SJ. Assessing the promotion of urine-diverting dry toilets through school-based demonstration facilities in Kalisizo, Uganda. *J Water Sanit Hyg Dev*. 2016;6:276-286.
17. Ekane N, Nykvist B, Kjellén M, et al. Multi-level sanitation governance: understanding and overcoming challenges in the sanitation sector in sub-Saharan Africa. *Stock Environ Inst*. 2014;4:1-18.
18. Ekane N, Mertz CK, Slovic P, Kjellén M, Westlund H. Risk and benefit judgment of excreta as fertilizer in agriculture: an exploratory investigation in Rwanda and Uganda. *Hum Ecol Risk Assess*. 2016;22:639-666.
19. Mukasine B. Ecological sanitation in Rwanda: A baseline study to identify challenges and opportunities. *Conf Proc*. 2014; 2:1-10.
20. Banamwana C. Application of human excreta on the farms as an effective. *Eng Technol Environ*. 2020; 3:1-17.
21. USAID. *Assessment and Improvement of Sanitation and Hand Washing Supply Chain in Burera, Musanze, Nyabihu and Rubavu Districts in Rwanda: Main Assessment Report February 2015*. USAID; 2015; 2:1-89.
22. National Institute of Statistics of Rwanda (NISR) [Rwanda], Ministry of Health (MOH) [Rwanda], and ICF International. *Rwanda Demographic and Health Survey*, 2014-2015.
23. CGIS-UR. *Mapping the Administrative Boundaries of the Burera District, a Geographic Information Survey*. 2018.
24. Creswell J. Choosing a mixed methods design. *Book chapter*. 2006;58-89.
25. UNICEF. *A Latrine That Meets Our Household Needs. Instruction for Latrine Construction*. UNICEF; 2019.
26. Nimanya C, Achiro B, Ssewanyana D, et al. Ecological Sanitation in Uganda Inspirational success stories from the field. *Netwas-U*. 2011;1-36.
27. 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;7:111-120.

28. Tumwebaze IK, Niwagaba CB. Ecological sanitation uptake, knowledge, beliefs and practices in Kabale Municipality, Kabale District. Paper presented at: The Future of Water, Sanitation and Hygiene in Low-Income Countries : Innovation, Adaptation and Engagement in a Changing World : 35th WEDC International Conference; 2011: 0-6, Loughborough, UK.
29. Simha P, Lalander C, Vinnerås B, Ganesapillai M. Farmer attitudes and perceptions to the re–use of fertiliser products from resource–oriented sanitation systems – the case of Vellore, South India. *Sci Total Environ*. 2017;581-582:885-896.
30. Lamichhane KM, Babcock RW Jr. Survey of attitudes and perceptions of urine-diverting toilets and human waste recycling in Hawaii. *Sci Total Environ*. 2013;443:749-756.
31. Nawab B, Nyborg ILP, Esser KB, Jenssen PD. Cultural preferences in designing ecological sanitation systems in North West Frontier Province, Pakistan. *J Environ Psychol*. 2006;26:236-246.
32. Mugure A, Mutua BM. Norms, attitudes and gender perspectives in ecological sanitation. Water, sanitation and hygiene: sustainable development and multisectoral approaches. Paper presented at: 34th WEDC International Conference, United Nations Conf Centre; May 18-22, 2009:491-495; Addis Ababa, Ethiopia.
33. Jenkins MW, Cumming O, Scott B, Cairncross S. Beyond 'improved' towards 'safe and sustainable' urban sanitation: assessing the design, management and functionality of sanitation in poor communities of dar es Salaam, Tanzania. *J Water Sanit Hyg Dev*. 2014;4:131-141.
34. Zhou C, Liu J, Wang R, Yang W, Jin J. Ecological-economic assessment of ecological sanitation development in the cities of Chinese Loess Plateau. *Ecol Complex*. 2010;7:162-169.
35. Uddin SMN, Muhandiki VS, Sakai A, Al Mamun A, Hridi SM. Socio-cultural acceptance of appropriate technology: identifying and prioritizing barriers for widespread use of the urine diversion toilets in rural Muslim communities of Bangladesh. *Technol Soc*. 2014;38:32-39.