

## Research Paper

### The *sanitation arc*: an alternative examination of WASH behavior change

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#### ABSTRACT

A primary goal of the WASH sector is to facilitate transitions from open defecation to improved sanitation. Many residents of low-income countries desire improved sanitation but lack the resources to obtain or maintain access to toilets. For such persons, describing the goal as 'behavior change' implies a deficiency in mindset, failing to capture contextual factors affecting sanitation access. Furthermore, household circumstances affect movement both up and down the sanitation ladder, a phenomenon that the sector tends to overlook. This study, based on interviews with 308 former subscribers to Haitian container-based-sanitation service EkoLakay, tracks household sanitation access at four points in time: prior to subscribing, during the subscription period, immediately upon unsubscribing, and at the time of interview. We describe this movement through time as the 'sanitation arc'. Prior to subscribing, households were more likely to practice open defecation or rely on non-household sanitation, and less likely to have private improved sanitation than the average urban Haitian. This distribution is reversed among former subscribers. Nearly half of former subscribers, however, could not afford continuous access to EkoLakay; 80% of involuntary terminations resulted in loss of access to private improved sanitation, and over one-third of these households reverted to open defecation.

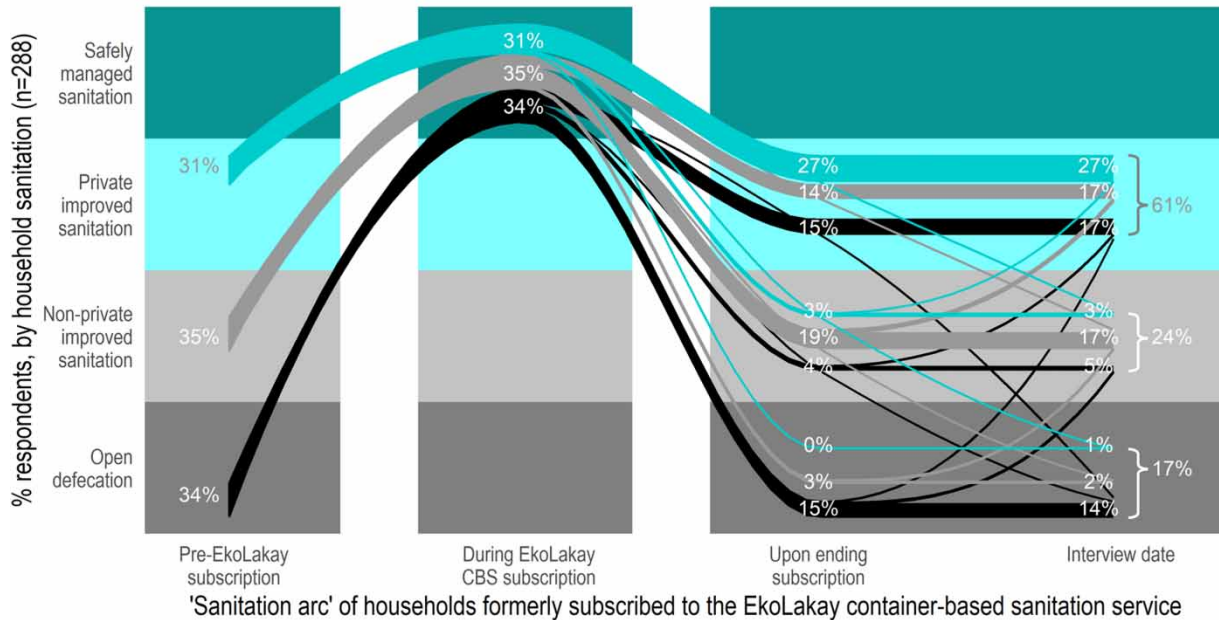
**Key words:** container-based sanitation, improved sanitation, open defecation, sanitation arc, sanitation ladder, transitional sanitation

#### HIGHLIGHTS

- Measuring behavior change omits perspective on resource availability.
- Movement on the sanitation ladder is not always upward.
- The 'sanitation arc' describes household movement up and down the sanitation ladder over time.
- Many households rely on container-based sanitation for sanitation while amassing means to invest in permanent infrastructure.
- Households with economic challenges revert to open defecation when no alternative sanitation is available.

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## GRAPHICAL ABSTRACT

The *sanitation arc*: an alternative examination of WASH behavior change

## 1. INTRODUCTION

## 1.1. Global sanitation challenge and 'behavior change'

As of 2019, only 52% of all residents of low-income countries used improved sanitation (WHO Joint Monitoring Programme 2020). Inadequate sanitation is a major global driver of disease and loss of life, contributing to 432,000 diarrheal deaths annually (WHO 2018). Lost income and medical costs from diarrheal disease exacerbate inequalities, while lack of sanitation facilities reduces educational attainment by girls (Agol *et al.* 2017). For these reasons, the United Nations' Sustainable Development Goal (SDG) 6.2 challenges the world to 'achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations' by 2030 (UN General Assembly 2015).

For decades, the water, sanitation, and hygiene (WASH) sector has worked to alleviate the challenges of inadequate global sanitation, through investment in sanitation technologies, services, and promotion initiatives. A key moment in WASH-sector history was the emergence of community-led total sanitation (CLTS), a practice that has become widespread since guidelines were published in 2005 (Kar 2005). The core principle of the CLTS approach is to promote sanitation and hygiene behavior change in rural communities through demand creation. Since this time, the focus on demand creation has increased across all aspects of the WASH sector. Coupled with evidence of sanitation hardware investments that went unused by the target community, major WASH actors began to assert that sanitation hardware alone would not close the sanitation gap; rather, 'changes in behavior' were key to achieving sanitation objectives (WSSCC & WHO 2005). Over time, the term *behavior change* has taken root within the WASH sector as the operational terminology for describing the adoption of improved sanitation.

The interplay between poverty and sanitation has long been acknowledged; WASH initiatives assert that sanitation is essential to poverty alleviation (UNICEF & WHO 2020), but many professionals also recognize that poverty can impede access to improved sanitation (Andersson *et al.* 2016; World Bank 2019; Doe & Aboagye 2020). Indeed, many residents of low-income countries desire improved sanitation but lack the resources (finances or space) to obtain or maintain access to toilets. Unlike low-income rural residents who can leverage their labor to construct some form of latrine with minimal resources, urban dwellers living in poverty often lack space for a latrine. In such cases, 'demand' is not the missing piece for sanitation

coverage. While some regional cultural groups express a preference for open defecation (Coffey *et al.* 2014), this is not true of all persons and groups. Rather, resource scarcity and poverty are more common drivers of unsafe sanitation behavior.

In many ways, measuring behavior change is limited in its ability to inform sanitation strategy and policy:

- Many residents of low-income countries desire improved sanitation but lack the resources to obtain or maintain access to toilets (Russel *et al.* 2015; Doe & Aboagye 2020).
- Describing toilet adoption as a behavior can neglect the above-mentioned role of resource availability in sanitation access.
- Household trajectories over time do not consistently demonstrate upward progress on the sanitation ladder (Crocker *et al.* 2017; Orgill-Meyer *et al.* 2019; Ejelonu *et al.* 2020).

For these three reasons, an approach to describing household sanitation evolution with the added dimension of time will provide insight into areas of vulnerability and need. We refer to this movement through time as the *sanitation arc*. Based on a minimum of three temporal data points, the sanitation arc provides a conceptual description of traditional longitudinal survey data, describing transitions in household sanitation access. A household sanitation arc may trend continually upward or may bend downward. The sanitation arc may also undergo repeated rises and falls over the course of time. In many cases, users of a lower-rung sanitation technology gain access to a higher-rung technology only to fall back to a lower-rung over time. Combining household sanitation arcs into a graphical representation can illustrate generalized trends in community sanitation access.

The sanitation arc provides a complementary framework to the sanitation ladder, enabling WASH-sector professionals to describe changes in household sanitation access without presuming a continual upward trajectory on the sanitation ladder. Through this lens, we can explore the factors affecting household movement up and/or down the sanitation ladder, with reference to time periods and events. The multidimensional nature of such analysis will provide richer insights on which to base policy and investments toward achieving SDG 6.

## 1.2. Container-based sanitation and its role in behavior change in Haiti

In Haiti, the sanitation crisis is severe; 20% of the population lacks access to improved sanitation altogether (World Bank, World Development Indicators 2018), and even where toilets or latrines are available, less than 1% of excreta is safely managed. One of the only safely managed sanitation options in Haiti is container-based sanitation (CBS), provided by the EkoLakay service. EkoLakay is a project of SOIL, a nonprofit research and development organization dedicated to sustainable and cost-effective sanitation solutions. Since 2015, EkoLakay has been serving low-infrastructure neighborhoods with private, portable toilets and weekly container exchange for a monthly service fee.<sup>1</sup> Collected excreta is sealed and transported to a semi-centralized site for thermophilic composting (Kramer *et al.* 2011; Figure 1).<sup>2</sup>

At the time of EkoLakay's establishment, a willingness-to-pay study identified widespread desire for household sanitation among potential users. Of these households, 71% given the opportunity to try the EkoLakay toilet opted to pay for continued service after the 3-month pilot period (Russel *et al.* 2015). Over its first 5 years of operation, EkoLakay served 2,331 households in the Cap Haïtien metropolitan area. Of these households, 1,323 ended their subscription. Subscription durations ranged from 1 week to 5 years, and observations by EkoLakay operational staff suggested that attrition factors included both economic progress and strain. The question remained: how did former-subscriber households meet their sanitation needs after ending their EkoLakay subscription? The answer to this question is of interest to the Haitian body governing water and sanitation (DINEPA)<sup>3</sup> as well. DINEPA has expressed a desire for evidence of EkoLakay's role in sanitation 'behavior change' or 'demand creation'.

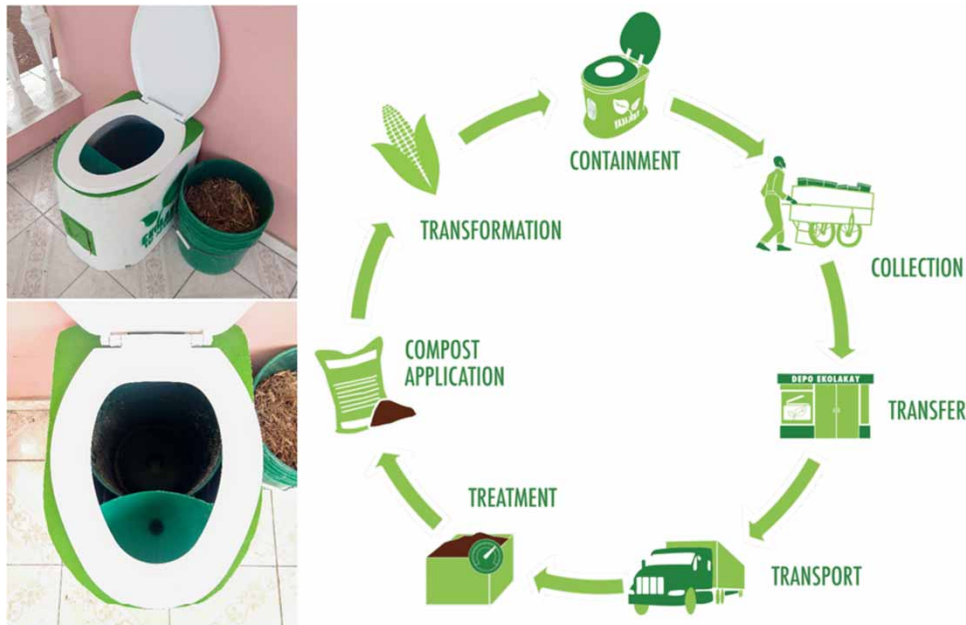
This study set out to characterize the sanitation arc of EkoLakay subscriber households over time and to identify household variables affecting continuous access to improved sanitation.

- How did households meet their sanitation needs prior to subscribing to the EkoLakay CBS system?
- How do households who cease to use EkoLakay meet their sanitation needs after leaving?
- What factors played a role in these transitions?

<sup>1</sup> EkoLakay's cost to the consumer was 200–300 Haitian gourdes (2.11–3.15 USD in August 2019), a rate subsidized by charitable contributions.

<sup>2</sup> Further details on the Cap Haïtien subscription zones can be found in the Supplemental material.

<sup>3</sup> Direction Nationale de l'Eau Potable et de l'Assainissement (DINEPA).



**Figure 1** | EkoLakay toilet technology and the CBS sanitation resource chain (Photographs by FV; Graphics used with permission of SOIL). Please refer to the online version of this paper to see this figure in colour: <http://dx.doi.10.2166/washdev.2021.162>.

This expanded understanding will help us to define the role of the EkoLakay CBS service in aiding urban households' progress up the sanitation ladder and/or maintenance of continuous sanitation access. The answers will provide further insight into the viability of CBS as a component of urban sanitation portfolios in Haiti and similar contexts.

## 2. METHODS

This study used a mixed methodology approach (Greene 2007), deriving qualitative and quantitative data from structured interviews with former subscribers of the EkoLakay CBS service in Cap Haïtien, Haiti. Interview questions addressed respondents' sanitation circumstances over time, and reasons for terminating their EkoLakay CBS subscription. Additionally, the interview collected information regarding household demographics, livelihoods, infrastructure, expenses, and property. The research tool was developed as a collaboration between research institutions in the USA and Haiti, and deployed by a team of Haitian researchers. Interview questions were structured around self-reporting all parameters for the consistency of results regardless of telephone or in-person interview format. All training and tool development were conducted in Haitian Kreyol.

### 2.1. Sample selection, response rate, confidence

SOIL provided the research team with a list of former subscribers for whom telephone contact information was available. We anonymized and randomized this list. Research staff recruited participants by phone, requesting an in-person appointment for an interview. Respondents who had moved away from the Cap Haïtien area, or were unwilling to meet in-person, were offered the opportunity to be interviewed by phone. We recruited one respondent to represent each household who had decision-making input and was 18 years or older.<sup>4</sup>

Due to the high rate of inactive phone numbers, it was necessary to attempt contact with all former subscribers to achieve an adequate sample size. As answering services are uncommon, telephone numbers are often reassigned to new users, and returning calls would place the expense burden on the recipient, recruiters did not leave messages for respondents who did not answer the phone. Recruiters attempted to reach respondents up to five times. Of 1,199 potential former subscribers, we successfully contacted 406; 30 declined to participate, and 68 failed to schedule or complete an interview. We achieved a

<sup>4</sup> SOIL's experience in these communities has found household structures rarely recognize a single 'head of household'; they are more likely to have multiple adult members engage in financial decision-making.

response rate of 33.9 and 75.9% completion rate, for a sample of 25.8% ( $n = 308$ ), a 95% confidence level and a 5% margin of error. Sample sizes vary by analysis because respondents could decline to answer any prompt.

## 2.2. Data collection and analysis

Interviewers visited households and collected survey responses using Qualtrics® (Qualtrics, Provo, UT) on a handheld smartphone. For the first month, 110 household interviews were completed both in-person and over the phone. Due to significant transportation and energy disruption countrywide, the second month of surveys was administered exclusively by telephone for a total of 308 interviews.<sup>5</sup>

Respondents were asked where members of their household ‘did their business’ immediately prior to opening an EkoLakay subscription, immediately upon ending the subscription, and at the time of interview. Interviewers coded responses in the field, using a detailed list. After all data had been collected, investigators aggregated further aggregated codes into qualitative categories. Reports of household sanitation were organized into categories associated with the WHO Sanitation Ladder (Table 1).

Respondents were asked *What were your main reasons for leaving EkoLakay?* They were not prompted or offered potential responses or categories. Interviewers limited participant responses to three ‘reasons’. Many respondents described more than one reason; therefore, total responses often exceed the total respondent count. Responses to this open-ended question were categorized in the field by the interviewer, using predefined codes; interviewers summarized responses that did not fit the available codes. Through an iterative process of team-based coding (Tolley *et al.* 2016), investigators created thematic categories to describe reported factors affecting an EkoLakay subscription termination.

Respondents were asked *Would you want to subscribe to the EkoLakay service again?*, and given three response options: Yes; I don’t know; and No. They were also asked to describe their ideal household sanitation. Responses to this prompt were coded and sorted by the same process used for descriptions of past and present household sanitation.

National sanitation access statistics were sourced from the WHO Joint Monitoring Programme for comparison purposes. Respondents who reported that their EkoLakay subscription was for non-household use were eliminated from the analysis of household sanitation arc. Differences between national sanitation coverage and respondent averages were compared using a

**Table 1** | Reported sanitation options available in metro Cap Haïtien, Haiti

WHO JMP categories		Options available in Cap Haïtien, Haiti	Study categories
Improved sanitation	Private	Safely managed facilities	Safely managed sanitation
	Non-private	Basic facilities	Private improved sanitation
		Limited facilities	<ul style="list-style-type: none"> <li>• <b>Shared</b> latrine, flush, or dry toilet (no treatment after discharge)</li> <li>• Latrine, flush, or dry toilet through <b>support network</b> (neighbor or family member’s home) (no treatment after discharge)</li> <li>• <b>Public</b> latrine, flush, or dry toilet (no treatment after discharge)</li> </ul>
Unimproved sanitation	Unimproved facilities	<ul style="list-style-type: none"> <li>• Shallow pit</li> <li>• Pit with no slab</li> </ul>	Unimproved sanitation or open defecation
Open defecation	No facilities	<ul style="list-style-type: none"> <li>• In a bag</li> <li>• In a field</li> <li>• By the river</li> </ul>	

<sup>5</sup> The analysis of data showed that this transition did not yield significant differences between groups (full details in the Supplementary material).

one-sample proportions test. Categorical variables were compared against household sanitation using odds ratio analysis. Changes in household sanitation between time periods were compared using a paired *t*-test.

The Institutional Review Boards of Oregon State University, the University of Oregon, and the National Bioethics Board of Haiti reviewed and approved the study protocol.<sup>6</sup> To increase the likelihood of eliciting unbiased feedback from respondents, interviewers clearly identified themselves as affiliates of Oregon State University and not representatives of EkoLakay. They also assured the participants of the steps taken to ensure the confidentiality of their responses. However, it is still possible that bias exists in the findings, due to shame around disclosing open defecation practices or attempts to satisfy the interviewer.

### 3. RESULTS AND DISCUSSION

#### 3.1. Sanitation arc and behavior change

Respondents self-reported the type(s) of sanitation used by their household at four points in time: pre-EkoLakay subscription, during EkoLakay subscription, immediately upon terminating EkoLakay subscription, and at the time of interview (August–October 2019). From before to immediately after an EkoLakay subscription, there is evidence that households are less likely to engage in open defecation ( $p < 0.001$  on a paired *t*-test with 254 df), less likely to use non-private improved sanitation ( $p < 0.001$ ), and more likely to use private improved sanitation ( $p < 0.001$ ). At the time of the interview, compared to the period immediately upon leaving EkoLakay, households were less likely to rely on non-private improved sanitation ( $p < 0.001$ ), and more likely to use private improved sanitation ( $p < 0.001$ ) (Table 2). Figure 2 provides a detailed visualization of movement up and down the sanitation ladder, along the sanitation arcs of former subscribers.

From a WASH behavior perspective, it is encouraging that over 80% of former subscribers use some form of improved sanitation upon leaving the EkoLakay service (an increase of 14% over the pre-EkoLakay stage). DINEPA has highlighted sanitation behavior change as the most important indicator of sustainability for nontraditional sanitation solutions, viewing this as more important than the financial viability of the service (Kramer 2021, personal communication). In total, 20% of former subscriber households transition from open defecation pre-EkoLakay to improved sanitation upon the termination of their subscription, and a quarter of EkoLakay users who leave the service do so only once they have installed or repaired improved sanitation infrastructure in their home. It is important to recognize, however, that while these households continue

**Table 2** | Sanitation access over time (former subscribers only) ( $n = 288$ )

	Respondent count (% of subscribers); value change, <i>p</i> -value					
	Before subscribing to EkoLakayx		Upon terminating subscription		At the time of interview	
Private improved sanitation	88	(31%)	164	(57%)	176	(61%)
Difference from the 'Pre-EkoLakay' stage			26%	$p = 2.53 \times 10^{-16}***$	31%	$p = 1.34 \times 10^{-19}***$
Difference from the previous stage					4%	$p = 0.003**$
Non-private improved sanitation	102	(35%)	73	(25%)	69	(24%)
Difference from the 'Pre-EkoLakay' Stage			-10%	$p = 2.85 \times 10^{-4}***$	-11%	$p = 9.48 \times 10^{-5}***$
Difference from the previous stage					-1%	$p = 0.395$
Open defecation	99	(34%)	53	(18%)	48	(17%)
Difference from the 'Pre-EkoLakay' Stage			-16%	$p = 3.41 \times 10^{-9}***$	-18%	$p = 1.19 \times 10^{-10}***$
Difference from the previous stage					-2%	$p = 0.132$

The **bold** figures report a significant increase from the previous row.

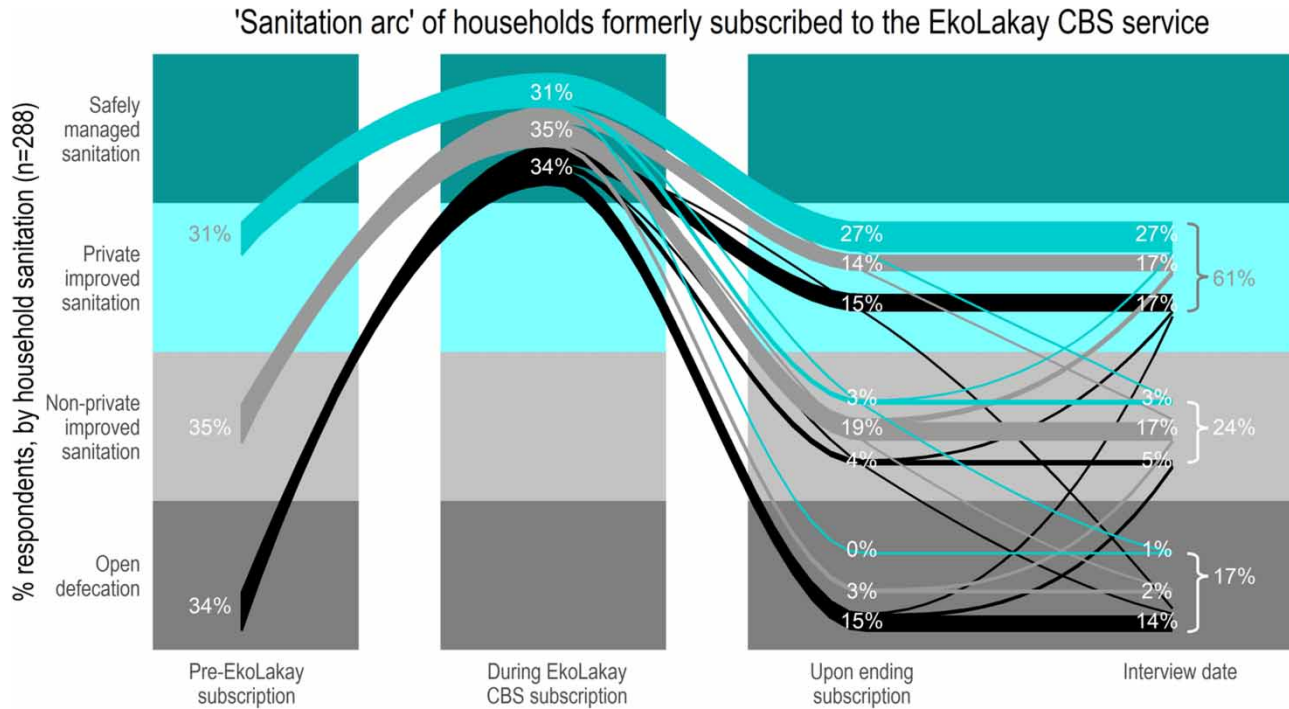
The *italic* figures report a significant decrease from the previous row.

The *p*-values are the result of a paired *t*-test with 254 df;  $H_0: \mu_d = 0$ , where  $\mu_d$  is the difference in subscribers using a given sanitation type at two stages in the sanitation arc;  $H_A: \mu_d \neq 0$ .

The row sums may exceed the respondent count, as respondents could report multiple household sanitation options.

\*Significant at 0.05 level; \*\*significant at 0.01 level; \*\*\*significant at 0.001 level.

<sup>6</sup> Ethics approvals are issued by Oregon State University (IRB-2019-0284), the University of Oregon (IRB 07102019.010), and the government of Haiti (Réf 1819-58).



**Figure 2** | Sanitation arc of former EkoLakay subscriber households at four points in their experience. Please refer to the online version of this paper to see this figure in colour: <http://dx.doi.10.2166/washdev.2021.162>.

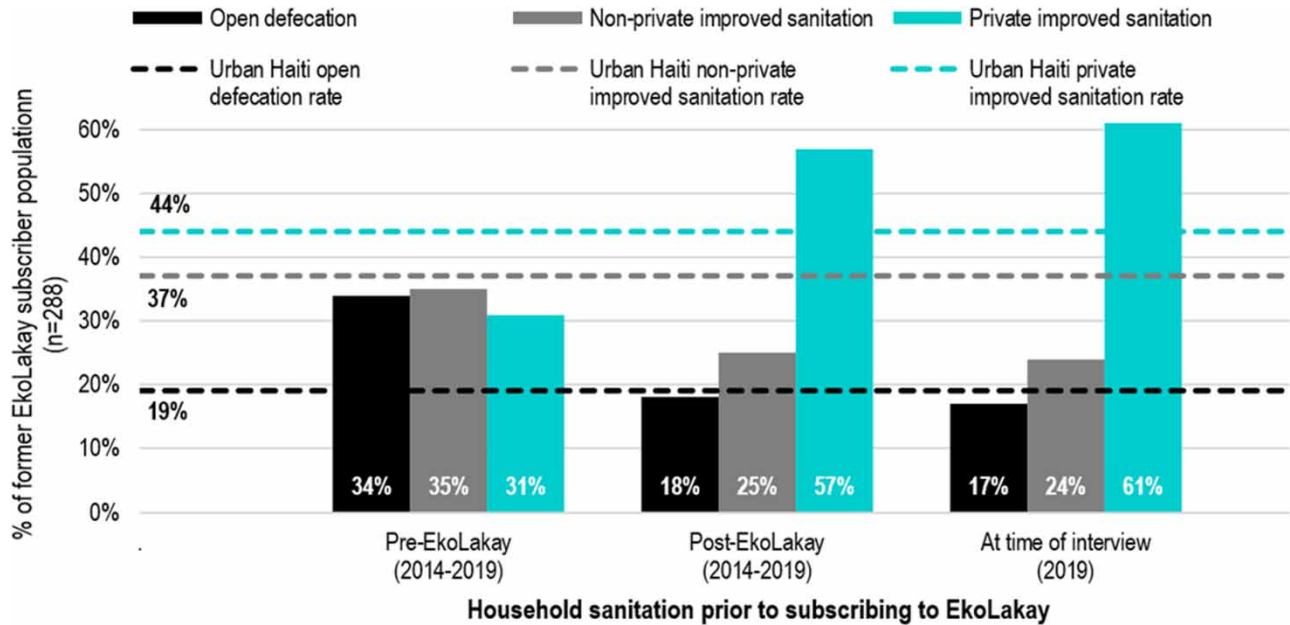
to practice positive WASH behaviors, the overall environmental and public health impacts of this attrition are still problematic. Latrines and flush-toilet cesspools in Cap Haïtien do not function to neutralize pathogens or contain nutrient effluents, nor are their contents treated safely when emptied (WHO Joint Monitoring Programme 2017).

While EkoLakay subscribers demonstrate a net-positive shift in household sanitation status between their pre- and post-subscription time periods, inertia plays a strong role on a household basis. Of those who transitioned to EkoLakay from a non-private sanitation or open defecation situation, 40–50% returned to their pre-EkoLakay circumstances upon leaving, while the rest experienced a net movement upward on the sanitation ladder. Households with private improved sanitation before subscribing generally maintained access to private sanitation upon terminating their EkoLakay subscription. As seen in upcoming sections, our collective findings suggest that the tendency to fall back to a non-private sanitation or open defecation is shaped more strongly by economic strain than by desires or sanitation values.

It is important to note that the only point along each household's sanitation arc at which their sanitation met safely managed standards was during the EkoLakay subscription period. Fewer than 1% of Haitians have access to safely managed sanitation (WHO Joint Monitoring Programme 2017), and in the Cap Haïtien metro area, no alternative sanitation options connect to treatment services. While CBS may appeal to public officials as a transitional sanitation solution, in the Cap Haïtien context, like many others, CBS is superior in safety to available traditional options. Whether embraced as a transition or long-term sanitation intervention, CBS clearly has an important role in the urban sanitation portfolio.

### 3.2. Sanitation access: comparison to Haitian population

Former subscribers describing their household sanitation situation immediately before accessing the EkoLakay service (dates ranging from 2014 to 2019) reported higher rates of open defecation ( $p < 0.001$  on a one-sample proportion test with 300 df), similar rates of shared or public sanitation ( $p > 0.1$ ), and lower rates of private improved sanitation ( $p < 0.001$ ) than the 2017 Haitian urban average. Immediately after leaving the EkoLakay service (dates ranging from 2014 to 2019), former-subscriber respondents reported equivalent rates of open defecation/unimproved sanitation ( $p > 0.1$ ), lower rates of non-private sanitation ( $p < 0.001$ ), and a higher rate of private improved sanitation ( $p < 0.001$ ) than the 2017 national urban average. At the time of the interview in 2019, former-subscriber respondents reported slightly lower rates of open defecation by their



**Figure 3** | Sanitation of former EkoLakay subscriber households at three points in their experience, compared to urban Haitian population ( $n = 288$ ). Please refer to the online version of this paper to see this figure in colour: <http://dx.doi.10.2166/washdev.2021.162>.

household ( $p > 0.05$ ), lower rates of reliance on non-private sanitation ( $p < 0.001$ ), and higher rates of private improved sanitation than the national urban average ( $p < 0.001$ ) (Figure 3).

These findings suggest that for former EkoLakay subscribers, the service meets household needs during a period, enabling them to achieve the net upward movement on the sanitation ladder over time. This behavior change that follows an EkoLakay subscription appears to be closely related to household resource access, rather than demand alone.

### 3.3. Sanitation upon ending EkoLakay subscription; relationship to reason for subscription cessation

The dominant theme among self-reported factors affecting the termination of an EkoLakay subscription was *economic challenges*; this played a role in over 30% of terminated EkoLakay subscriptions. Respondents mentioning the theme of *economic challenges* among reasons for ending their EkoLakay subscription were more likely to revert to open defecation or non-private improved sanitation, and less likely to use private improved sanitation (Table 3).

CBS subscribers often represent high-vulnerability populations (Russel *et al.* 2019), for whom even the subsidized cost of service may be prohibitive. As a result, financial shocks, resource constraints, and housing instability can disrupt continuity in the service. Our findings indicate that external subsidies to support CBS services for vulnerable households would be necessary for the most resource-insecure users to maintain continuous access to improved sanitation. Cessation of service due to financial difficulties is likely involuntary. Over 80% of EkoLakay attrition attributed to economic challenges resulted in households losing access to private improved sanitation. Nearly 40% of such departures resulted in households practicing

**Table 3** | Odds of citing economic challenges among reasons for ending EkoLakay subscription, by post-subscription household sanitation ( $n = 309$ )

	Odds ratio (95% CI); <i>p</i> -value		
	Open defecation ( $n = 55$ )	Non-private improved sanitation ( $n = 75$ )	Private improved sanitation ( $n = 171$ )
Economic challenges ( $n = 96$ )	<b>4.66 (2.53–8.59)</b> <i>p</i> = $4.86 \times 10^{-7}$ ***	<b>3.56 (2.06–6.15)</b> <i>p</i> = $6.00e \times 10^{-6}$ ***	<i>0.11 (0.06–0.19)</i> <i>p</i> = $7.71e \times 10^{-10}$ ***

The **bold** values indicate a response occurring more frequently than would occur in a random distribution.

The *italic* values indicate a response occurring less frequently than would occur in a random distribution.

The *p*-values are the result of Pearson's  $\chi^2$  test between the sample and all other respondent-response combinations (1 df); test statistic:  $\chi^2 = \frac{(n-1) \cdot s^2}{\sigma^2}$ , where  $s^2$  is the sample variance and  $\sigma^2$  is the population variance;  $H_0: \sigma^2 = \sigma_0^2$ ;  $H_A: \sigma^2 \neq \sigma_0^2$ .

\*Significant at 0.05 level; \*\*significant at 0.01 level; \*\*\*significant at 0.001 level.



open defecation. These households represent the most vulnerable group in terms of sanitation access and demonstrate the weakness of a behavior change framework that fails to account for resource constraints.

### 3.4. Interest in re-subscribing

Nearly 40% of former subscribers ( $n = 117$ ) indicated that they would be interested in subscribing to EkoLakay again. Respondents whose households practiced open defecation at the time of interview were more likely than the average respondent to express interest in re-subscribing to EkoLakay, as were those using non-private sanitation. Households with private improved sanitation at the time of interview were more likely to express disinterest in re-subscribing (Table 4). Relationships also display a continuous-style trend along the sanitation ladder, with progress from open defecation to private improved sanitation associated with reduced interest in re-subscribing to EkoLakay.

According to the metrics of DINEPA, this suggests that EkoLakay plays a role in demand creation. This is supported by findings during the 2015 pilot study, during which households that were not able to access an EkoLakay toilet expressed dissatisfaction with their situation (Russel *et al.* 2015). At the same time, this provides evidence that demand alone is not sufficient to achieve sanitation coverage in these low-infrastructure urban environments. The public subsidy will be essential to overcome the economic hurdles that stand in the way of demand for improved sanitation. In the Cap Haïtien metro area, basic improved sanitation services are inaccessible to many households. As unsafe excreta management practices have community-wide health implications (Lüthi *et al.* 2011), CBS services like EkoLakay are an essential resource for both individual and public health in Haiti.

### 3.5. Desire for improved sanitation

Over 90% of respondents reported that their ideal toilet would be a private flush toilet (Table 5). This finding is consistent with observations among international scholars and professionals, who describe a widespread preference for water-flushing technologies at the household and sectoral scale, despite its unsuitability in many contexts (WHO 2009).

**Table 4** | Former-subscriber responses to 'Would you want to join the EkoLakay service again?', by household sanitation status at the time of interview ( $n = 299$ )

	Sample odds ratio (95% CI); $p$ -value		
	Open defecation ( $n = 47$ )	Non-private improved sanitation ( $n = 72$ )	Private improved sanitation ( $n = 184$ )
Yes ( $n = 117$ )	<b>3.00 (1.58–5.71)<sup>‡</sup></b> <i><math>p = 9.98 \times 10^{-4}***</math></i>	<b>1.80 (1.05–3.08)<sup>‡</sup></b> <i><math>p = 0.042^*</math></i>	<i>0.36 (0.22–0.59)<sup>‡</sup></i> <i><math>p = 5.85 \times 10^{-5}***</math></i>
I don't know ( $n = 59$ )	1.30 (0.62–1.30) <sup>‡</sup> <i><math>p = 0.625</math></i>	1.09 (0.57–2.11) <sup>‡</sup> <i><math>p = 0.921</math></i>	0.75 (0.42–1.33) <sup>‡</sup> <i><math>p = 0.402</math></i>
No ( $n = 123$ )	<i>0.21 (0.09–0.21)<sup>‡</sup></i> <i><math>p = 1.33 \times 10^{-4}***</math></i>	<i>0.50 (0.28–0.89)<sup>‡</sup></i> <i><math>p = 0.026^*</math></i>	<b>3.56 (2.12–5.98)<sup>‡</sup></b> <i><math>p = 1.71e \times 10^{-6}***</math></i>

The **bold** values indicate a response occurring more frequently than would occur in a random distribution.

The *italic* values indicate a response occurring less frequently than would occur in a random distribution.

The row and column counts may exceed the respondent count, as respondents could report multiple household sanitation options.

\*Significant at 0.05 level; \*\*significant at 0.01 level; \*\*\*significant at 0.001 level.

<sup>‡</sup>The  $p$ -values are the result of Pearson's  $\chi^2$  test between the sample and all other respondent–response combinations (1 df); test statistic:  $\chi^2 = \frac{(n-1) * S^2}{\sigma^2}$ , where  $S^2$  is the sample variance and  $\sigma^2$  is the population variance;  $H_0: \sigma^2 = \sigma_0^2$ ;  $H_A: \sigma^2 \neq \sigma_0^2$ .

**Table 5** | Ideal sanitation, as reported by former EkoLakay subscribers

	Respondent count (% all respondents)		
	Private	Shared	Grand total
Flush toilet	236 (90.8%)	2 (0.8%)	238
Latrine	16 (6.2%)	1 (0.4%)	17
Dry toilet	5 (1.9%)	0 (0%)	5
Grand total	257	3	260

While respondents (and government actors around the world) express a preference for permanent sanitation infrastructure and water-based sewerage in particular (VanRiper 2021), such technologies may be inadequate to meet public health objectives in this context. Centralized sewerage infrastructure can be catastrophically damaged by major geological events (Lüthi *et al.* 2010), which are relatively common in Haiti. Furthermore, extreme flooding, which was observed by the authors during the time of this field research and is only increasing with the onset of climate change, negates the sanitation value of latrine technologies. CBS could buffer these vulnerabilities if incorporated into Citywide Inclusive Sanitation planning, an approach to sanitation delivery that pursues equitable sanitation coverage by shifting the focus from technologies to service outcomes (Schrecongost *et al.* 2020).

Thus far, public sanitation investment across the country has been limited to the construction of wastewater treatment plants,<sup>7</sup> subsidized emptying services for some institutional and school latrines, and the construction of public toilet blocks in selected urban areas. At present, national policy dictates that every residence must have a toilet of some kind, but local governments lack the resources to monitor or enforce this mandate (Kramer 2021, personal communication). CBS systems may play an important future role in progress toward satisfactory coverage.

### 3.6. The sanitation arc framework

Movement upward on the sanitation ladder is a widespread topic of research in the WASH sector. However, a small number of investigations on the longevity of sanitation interventions illustrate that deterioration of sanitation infrastructure can reverse this trend (Crocker *et al.* 2017; Orgill-Meyer *et al.* 2019; Ejelonu *et al.* 2020). Backsliding down the sanitation ladder is also observed in households interviewed for this study. Framing such declines in terms of behavior change neglects resource limitation factors affecting sanitation technology use. This illustrates a need for a complementary framework that will enable WASH-sector professionals to explore factors affecting movement up and down the sanitation ladder over time.

Deterioration of infrastructure, lack of political will, and resource constraints may affect long-term sanitation access, resulting in downward trends on a community sanitation arc. Ignoring this reality allows WASH-sector professionals to gloss over unsuccessful sanitation interventions. The causes of such arcs are unlikely to be resolved if implementors assume movement up the sanitation ladder is stable and that backsliding is attributable only to 'behavior change'.

Multiple scholars suggest that a focus on functions/outcomes rather than technologies would provide a more useful means of measuring sanitation quality than the categories presently used to define the WHO sanitation ladder (Kvarnström *et al.* 2011; Gunawardana & Galagedara 2013; Exley *et al.* 2015). As the WASH sector evolves, the sanitation arc framework can flexibly integrate with alternative approaches to describing progress toward privacy and safety of household excreta management.

## 4. CONCLUSION

Our findings indicate that households using the EkoLakay CBS service achieve net progress upward on the sanitation ladder after ending their subscription. Households with few alternatives for sanitation access rely on EkoLakay for longer periods. The details and context of these findings, however, paint a richer picture of the role of CBS in household sanitation access in urban Haiti. The *Sanitation arc* framework provides a useful lens through which to consider the effects of contextual factors when exploring longitudinal household 'behavior change' and movement up and down the sanitation ladder over time.

Since the early days of CLTS, actors in the sanitation sector have conflated behavioral activities like handwashing behavior with the use of toilets. We argue that the latter is more often driven by resource availability than values in urban Haiti. While some regional cultural groups express a preference for open defecation (Coffey *et al.* 2014), this is not true of all persons and groups. Rather, resource scarcity and poverty are powerful drivers of inadequate sanitation behavior. Respondents in this study expressed an inclination toward improved sanitation access and privacy, both associated with fundamental human needs like safety and dignity (Maslow 1943; Taormina & Gao 2013). Many reported that they were unable to maintain access to such sanitation due to economic challenges. When private improved sanitation was unavailable, many of these households accessed improved sanitation through external support networks such as family, neighbors, churches, and schools.<sup>8</sup> Former subscribers' interest in re-subscribing to EkoLakay is strongly related to household sanitation status.

<sup>7</sup> Nationally, four wastewater treatment plants are in the planning or construction stages, and one is operational.

<sup>8</sup> This category of access (sanitation through one's connection to a church, school, workplace, or other support networks) is often not explored in public health research; non-private sanitation is often assumed to fall into either the 'shared' or 'public' category.

Those practicing open defecation or using sanitation outside the home largely express a desire to re-subscribe to EkoLakay, while those with private improved sanitation do not.

Whether intended or not, the term ‘behavior change’ carries assumptions about the values of the subject; as such, it fails to capture contextual factors affecting sanitation access. As the WASH sector endeavors to close the global sanitation gap, demand-creation campaigns cannot replace investments in sanitation services and technologies. Nearly a quarter of respondents in this study, like many residents of low-income urban communities, desire improved sanitation but lack the resources to obtain or maintain access to toilets. ‘Demand’ for improved sanitation among those who lack the resources to realize this goal does nothing to improve health, and much to harm social and emotional well-being.

By tracking the sanitation arc of selected low-income urban households in northern Haiti, we can see that household circumstances affect movement both up and down the sanitation ladder. In low-infrastructure urban zones, areas with unclear land tenure, and geologically insecure environments, CBS is often the only feasible or appropriate improved sanitation option. There are many communities comparable to the EkoLakay subscriber base across Haiti and the world. Given the evident vulnerability of such households, strategies to increase the economic accessibility of this vital sanitation resource are essential.

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## AUTHOR CONTRIBUTIONS

F.V.R. is involved in the conceptualization, methodology, validation, formal analysis, data curation, writing – original draft, writing – review & editing, and visualization. K.C.R. is involved in the conceptualization, methodology, supervision, and writing – review & editing. D.T. is involved in the methodology, supervision, and writing – review & editing. L.A.C. is involved in the supervision and writing – review & editing. J.L. is involved in the methodology, supervision, project administration, and writing – review & editing. E.L. is involved in the conceptualization, project administration, and writing – review & editing. S.K. is involved in the conceptualization, writing – review & editing, and funding acquisition.

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## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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