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Article

Willingness-to-Pay and Costs for Novel Manual Emptying Services for Shared Onsite Sanitation Facilities in an Informal Settlement of Nairobi, Kenya

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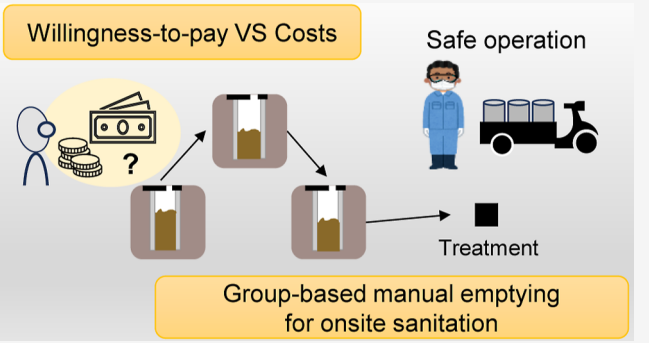
ABSTRACT: Safely managed sanitation is essential for the environment and public health, yet emptying services for onsite sanitation are often unsafe and unaffordable. This study aims to assess the stated willingness-to-pay (WTP) for two safer manual emptying services. The first is referred to as the "Standard Plan", a hypothetical safer manual emptying service, and the second is the "Small-amount Plan", a hypothetical service with a volumetric limit. The service costs were also estimated to assess the financial feasibility. We surveyed 400 households in an informal settlement in Nairobi, Kenya, using a contingent valuation method: respondents answered two dichotomous questions about price bids and then a question about the maximum amount they could pay. The mean WTP for the Small-amount Plan was \$1.4/drum—\$0.2/drum lower than the WTP for the Standard Plan. While the WTP was lower, the estimated cost of the Small-amount Plan where emptiers can visit multiple toilets was \$0.9/drum lower than the Standard Plan where emptiers visit one toilet. Our results suggest that grouping multiple toilets could be a market viable cost-reduction strategy for manual emptying and warrant further research to develop and test this approach, which may increase access to safely managed sanitation in low-income informal urban areas.



KEYWORDS: *sanitation, informal settlement, fecal sludge management, willingness-to-pay, contingent valuation method, cost analysis*

1. INTRODUCTION

Safe sanitation is essential for protecting public health, supporting economic development, and safeguarding the environment, including surface and groundwater.[1,2] Onsite sanitation systems, such as pit latrines and septic tanks, remain a common type of sanitation facility that almost half of the global population used in 2020.[3] In Sub-Saharan Africa, a majority (72%) of the population uses onsite sanitation.[4] Target 6.2 of Sustainable Development Goal 6 calls for universal access to safely managed sanitation by 2030,[5] which will require safe management of onsite sanitation facilities for billions of people.[6]

When an onsite sanitation facility becomes full, it needs to be emptied or sealed.[6] In rural areas, particularly with basic pit latrines, a common practice is to seal the full chamber and abandon it, constructing a new facility instead.[7] In urban areas, sealing and abandoning facilities is rarely safe and/or feasible given the high population density and limited space for reconstruction.[8] Instead, it is necessary to empty and transport the fecal sludge to where it can be disposed of.[8]

In Low- and Middle-Income Countries (LMICs), approximately 60% of the population rely on onsite facilities.[9] Of these, half are emptied manually without mechanical assistance, due to the conditions of fecal sludge and limited access to the facilities.[4,10] Despite the evident need for safe and affordable emptying services given the widespread use of onsite systems, willingness-to-pay (WTP) for formal, safe manual emptying services remains low.[11]

WTP is defined as the maximum amount that a consumer is willing to pay for a service,[12] and it has two types: stated preference and revealed preference, based on how it is measured. Stated preference (or stated WTP) is elicited by asking respondents how they value a good or service without actual payment, while revealed preference (revealed WTP) is

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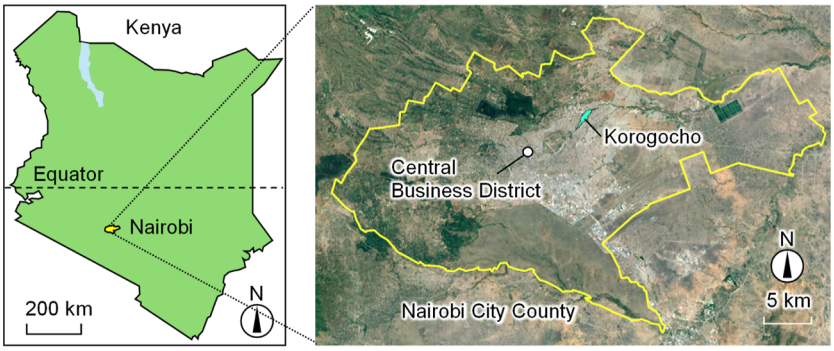

Figure 1. Location of the Korogocho informal settlement in Nairobi, Kenya.

estimated from observed purchase behaviors of a particular population in an actual market or experiment.[13]

WTP for manual emptying services has been investigated in several low- and middle-income countries. In Kenya, Peletz et al. (2020) and Delaire et al. (2021) elicited stated WTP with a contingent valuation method (CVM) in Kisumu and Malindi, reporting that the WTP for formalized manual emptying services covered only 25−49% of their price or costs.[14,15] According to a survey conducted in informal settlements of Kigali, Rwanda, Ross and Pinfold (2017) elicited stated WTP through a bidding game and reported that homeowners' WTP was 50% higher for vacuum truck services than for manual services as they felt the vacuum truck is a more hygienic way of emptying.[16] Harper et al. (2021) also estimated stated WTP with a discrete choice experiment in rural areas of Cambodia and reported that households were willing to pay 263,000 Riel (USD 66) for an emptying service that prevents contact with fecal sludge.[17]

Although the literature shows that there is demand for cheap and hygienic manual emptying services, in reality, many households rely on lower-cost informal services where workers often operate without protective equipment and indiscriminately dispose of sludge, leading to fecal contamination of surface and groundwater.[18] Our previous qualitative research conducted in the same informal settlement as this study also revealed that financial constraints were one of the major barriers that prevented households from emptying their pit latrines and hindered emptiers from upgrading their operations to make them safer.[19]

Due to the risks posed to service providers, users, and the environment, informal emptying services are often illegal, with regulatory frameworks in place.[20,21] As informal or illegal services are eliminated through regulation and prohibition, there is a growing need for safe and affordable emptying services.[22]

One cost-effective approach is "group-based" emptying which reduces costs by grouping requests for emptying and conducting the work on the same day so that operational costs can be shared and optimized.[23,24] Existing studies have mainly focused on group-based emptying as a supply-based approach—often referred to as scheduled emptying[25,26]—where a local authority mandates periodic emptying in a designated area.[25] However, the economic feasibility of group-based emptying has only been examined for mechanical methods such as vacuum trucks,[23,24] and its applicability to manual emptying services, commonly used in informal settlements, remains unexamined.

In Kenya, a new National Sanitation Management Policy has recently been approved by the Ministry of Water, Sanitation and Irrigation and is about to be endorsed by the parliament.[27] In the new policy, various Fecal Sludge Management (FSM) services across the value chain, including manual emptying, will be recognized, and at the same time, safe operational standards for those services will be defined.[27,28] Although dumping fecal waste into rivers is already illegal in Kenya, the policy will put further regulatory pressure on informal emptying, and provision of emptying services will be the subject of new regulation.[28] In the context of this reform, the aim of our study is to assess the demand and costs of safer manual emptying services in an informal settlement in Nairobi. More specifically, our study addressed two research questions: (i) how much are households willing to pay for the safer manual emptying service? and (ii) is group-based emptying likely to reduce the costs of the safer manual emptying service? To answer these questions, we first conducted a questionnaire survey to assess and compare (a) the fee paid for existing informal manual emptying services, (b) the stated WTP for a hypothetical manual emptying service, from now on termed the Standard Plan, and (c) the stated WTP for the hypothetical service with a three-drum upper limit of emptying, termed the Small-amount Plan. We then estimated the costs for the hypothetical service with a spreadsheet model to see whether the costs are covered by the WTP and if group-based emptying can reduce the cost of manual emptying.

2. METHODOLOGY

2.1. Study Site. This study was conducted in April and May 2024 in the Korogocho informal settlement located in the northern part of Nairobi, Kenya (Figure 1). Nairobi, the capital city of Kenya, had a population of approximately 4.4 million in 2019, with 60% of its residents living in informal settlements.[29,30]

Korogocho is one of the biggest informal settlements in Nairobi, spanning about 1 km.[2,31] A majority (77.6%) of the 34,000 residents use unimproved onsite sanitation facilities such as pit latrines given the limited sewer connection.[32,33] Almost all households in the community share sanitation facilities, resulting in frequent emptying (e.g., more than once a year), especially in the rainy season due to a high water table. The residents are a mix of tenants and landlords. As some landlords own several properties inside or outside the community, tenants and landlords do not necessarily live together in the same compound. Hereafter, we call such landlords "absentee landlords" to distinguish them from live-in landlords.

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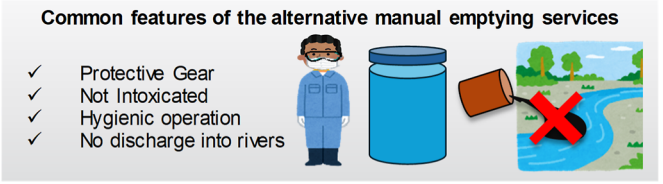

	① Standard Plan	② Small-Amount Plan
Emptying Volume	Unlimited	Up to 3 drums (*200L/drum)
Fee per drum	Standard Fee (no discount)	Reduced Fee

Figure 2. Overview of the two novel manual emptying services.

In Korogocho, manual emptying services are common but not formally recognized by local authorities. The informal emptiers typically collect fecal sludge using a 200 L metal drum covered with plastic sheets and carry it manually with a handcart to a nearby river, where the sludge is dumped.[19] Service fees are usually charged per 200 L drum, and the unit fee per drum is decided by negotiation between customers considering the distance to the nearby river or the sludge thickness.[19] As emptying services in Korogocho generally use 200 L drums, this volume is a common reference value for households. As such, and in relation to how many drums can be collected from their pit and how long a toilet can function, we adopted the 200 L drum as a unit of emptying volume in our questionnaire.

2.2. Study Design. Since we were assessing stated WTP for a hypothetical service not currently available in the local market, this was elicited using the CVM, which is one of the most frequently used stated preference methods for measuring WTP for FSM services.[15,34,35] We also developed a spreadsheet model to estimate the costs of novel safe services and to analyze whether group-based emptying can reduce costs.

The Standard Plan and the Small-amount Plan had the following common features (Figure 2): (i) manual emptiers are trained, wear personal protective equipment (PPE), and are not intoxicated, (ii) the operation is hygienic and sealable drums are used to prevent spillage, and (iii) fecal sludge is not discharged into rivers but taken to a treatment facility. In the Standard Plan, no upper limit of drums was set when users request emptying, and the fee is decided by the number of drums that users request and a per-drum fee (so-called volumetric pricing). The per-drum fee was a standard fee and no discount was applied. The Small-amount plan applied the same volumetric pricing, but we set an upper emptying limit of three drums (200 L/drum) per service. In return, the Small-amount Plan was supposed to provide a reduced per-drum fee. A benefit of the Standard Plan is that users can entirely empty their onsite sanitation facility at once. To do so, however, they need a budget for the large volume. In contrast, the Small-amount Plan is suitable for households with a smaller budget as it offers a lower fee per emptying drum.

The two plans were developed based on the findings of a previous qualitative study which we conducted in Korogocho involving landlords, tenants, and emptiers.[19] The common features of the plans (e.g., wearing protective gear) were service characteristics that the landlords and tenants wanted for manual emptying services, which were identified through the qualitative study.[19] As the landlords and tenants wanted at least 1−3 drums of sludge to be emptied each time, the emptying limit (∼3 drums) was set to accommodate all the demands.

2.3. Study Population. In Kenya, landlords are generally responsible for emptying their sanitation facilities and the associated cost,[36,37] but they sometimes neglect the role, resulting in tenants bearing the cost.[36] Therefore, the study population included both landlords and tenants as potential users of emptying services (Table 1). We sampled individuals over 18 years of age in Korogocho. We excluded households that were unlikely to use emptying services as they either did not have their own sanitation facilities or their facilities discharged directly to the environment, e.g., to rivers. We excluded participants from a previous qualitative study in the same area,[19] as their participation in that earlier study on the same topic may have biased their responses. From each household, we asked a family member who was likely to make a decision on emptying in the future and then surveyed the decision-maker.

Table 1. Inclusion and Exclusion Criteria of the Study Population

inclusion criteria	exclusion criteria
Landlords or tenants living in Korogocho informal settlement	Those unlikely to empty their toilet(s) due to physical reasons (e.g., do not have toilets, toilets directly connected to a river)
Adults (≥18 years of age)	Participants in our previous study conducted in Korogocho
Those likely to make a decision on emptying	

2.4. Sample Size Calculation. In this study, 400 landlord and tenant households were surveyed, sufficient to elicit WTP for each emptying service plan, for a population size of 34,000 in Korogocho, 5% level of statistical significance, and 5% margin of error.[24] This sample size enabled us to compare the median WTP for the Standard Plan and the Small-amount Plan, with 80% power at the 5% level of statistical significance to detect a small effect size of 0.2 (−) based on a Friedman test. Given that landlords have greater responsibility for toilet maintenance costs, we recruited 75% of the 400 respondents from landlords and 25% from tenants.

2.5. Data Collection. A questionnaire survey was conducted by five local research assistants who were raised or familiar with Korogocho. They visited five or six households per day. The number of landlords and tenants surveyed was counted every day to achieve the targeted ratio described above. The enumerators collected data using Open Data Kit[38] with a tablet. Questions included general household characteristics, financial situation, characteristics related to fecal sludge

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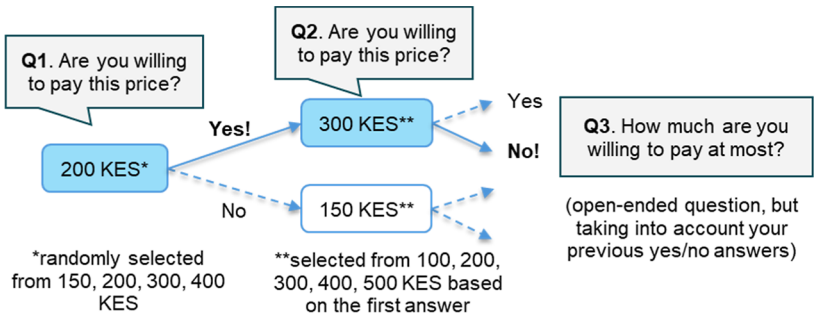

Figure 3. Flow of the double-bounded dichotomous choice method to elicit stated WTP.

management, perception about payment for emptying services, and WTP (Supporting Information S1).

Enumerators first asked participants how much they paid per drum for their most recent informal emptying service and how many drums of sludge they requested to remove the last time. Next, WTP for the hypothetical manual emptying services was elicited using the double-bounded dichotomous choice method with an open-ended question (Figure 3). Enumerators first asked about the Standard Plan and then the Small-Amount Plan. They asked two closed-ended questions on price bids and then asked respondents' WTP in an open-ended form.[15,35] The respondents were asked whether they were willing to pay the first price bid (e.g., 200 Kenya Shillings: KES) which was randomly selected from a range of 150−400 KES by the enumerator. Here, enumerators shuffled four price bid cards (150, 200, 300, and 400 KES) and selected one. Then the second price bid based on the first yes/no answer was posed again (e.g., if they answered yes to 200 KES, then they were randomly shown either 300, 400, or 500 KES). Finally, the respondents indicated the maximum amount that they were willing to pay considering the previously answered price range (e.g., 200−300 KES).

To select participants, Global Positioning System (GPS) coordinates were randomly selected using the open-source software QGIS 3.30.[39] Enumerators went to each GPS coordinate, identified the nearest compound, and interviewed either a landlord or a tenant in each compound. If the landlord did not live in the compound but in another one in Korogocho, enumerators contacted the landlord by phone to make an appointment. If the landlord accepted the appointment, then the enumerator visited the landlord. Absentee landlords were asked about the case of the compound where the enumerator was initially visited.

2.6. Data Analysis. Statistical analysis was performed with IBM SPSS Statistics 29.[40] Confirming with histograms that the maximum WTP variable was not normally distributed, we did not use mean values for comparison. Instead, median WTPs for the hypothetical services and the fee paid for informal emptying were compared by using the Friedman test followed by the Wilcoxon signed rank test adjusted by the Bonferroni correction at the 5% level of statistical significance. To verify the WTP elicited from the open-ended question, WTP estimated from the dichotomous choices (yes/no answers) was also analyzed by a maximum likelihood estimation[41] (Supporting Information S2).

Multivariate regression modeling was performed taking the maximum WTP for the Standard Plan as the dependent variable. Since the residuals were not normally distributed when using the crude WTP, we log-transformed the WTP after removing an outlier and then confirmed that the residuals were normally distributed from the histogram and P−P plot (Supporting Information S3). We included hypothesized explanatory variables in the regression, including demographic variables (age, sex, self-reported monthly household income, education level) and emptying-related variables (emptying interval, number of households in the surveyed compound, fee paid last time for informal emptying, sludge volume a respondent wants to remove next time, whether there is an agreement on emptying, residential status). The WTP amounts were converted to USD based on the average exchange rate during the survey period of 133.09 KES per USD.[42]

2.7. Quality Control. We selected CVM rather than another method such as discrete choice experiments (DCEs) because, unlike DCE, CVM does not require detailed sets of profiles of a given service to be determined before a survey can be administered.[43] It is crucial since showing several profiles to respondents in addition to the common service features shown in Figure 2 could cause fatigue.[43] Also, among CVMs, a double-bounded dichotomous choice with an open-ended question technique has several advantages including statistical simplicity and fewer zero-answers and outliers.[44]

That said, CVM is also prone to several biases, particularly anchoring bias and hypothetical bias.[12,45] We sought to reduce the risk of biases by adopting a checklist developed by Asian Development Bank.[12,45] To minimize the anchoring bias, a bias where WTP is influenced by the price bids that respondents are shown, the first price bid (150, 200, or 300, 400 KES/200 L drum) was randomly presented to respondents, and then the second price bids that were higher or lower than the first bid (100, 200, 300, 400, 500 KES/200 Ldrum) were presented (Figure 3). To minimize hypothetical bias, where stated WTP is sometimes over- or understated than the actual behaviors observed in a market, enumerators gave a 2-step explanation about the service plans to which respondents were supposed to answer. The enumerators first showed a video about the overview and differences between the two service plans[46] and then provided verbal explanations to make sure that respondents fully understood the content of the video (the transcript of the video is available in Supporting Information S4).

All materials used in the data collection reflected the results of our previous qualitative study conducted in Korogocho.[19] The materials were adjusted and translated into Swahili in consultation with local research assistants for improved clarity and validity.

Before inception of data collection, enumerators underwent 3 days of training that included lectures on the study overview, reading out the survey instruments (e.g., questionnaire sheet), and role-plays. During data collection, quality checks were conducted both in the field and in-office. A senior researcher

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randomly accompanied enumerators, ensuring that they administered the survey correctly and provided feedback when necessary. In addition, survey forms submitted by enumerators were checked daily for the first 3 days and then once in 4 days thereafter.

2.8. Cost Analysis. In our spreadsheet model for financial cost analysis, based on Semiyaga et al., 2022,[47] the emptying service was assumingly performed by three workers and a motorized cargo tricycle with a capacity of 10 drums as commonly used in informal settlements in East African countries.[47] Fecal waste was assumed to be carried from Korogocho to a transfer station at Mukuru in Nairobi, which is the nearest (30−40 min journey from Korogocho) and official disposal site for manual emptiers.[48] For simplification, we assumed that operational costs include wage per drum for workers, fuel, and dumping fee (50 KES/drum),[48] and capital costs include the tricycle purchase, annual loan interest, maintenance, and equipment (PPE, drums, and bucket). Supporting Information S5 gives more details about the calculation.

2.9. Ethical Considerations. Ethical approval was obtained from the London School of Hygiene & Tropical Medicine Research Ethics Committee (ref No. 29690) and AMREF Health Africa's Ethics & Scientific Review committee (ref No. P1547/2023). The study was also approved by the National Commission for Science, Technology & Innovation of Kenya (ref. 815914). Prior to the data collection, we explained the research information sheet to potential participants and gave them time to ask any questions. When they agreed to voluntarily participate in the research, we obtained their written consent for participation.

3. RESULTS

3.1. Characteristics of Participants. In total, 400 residents living in Korogocho participated in the survey, of which 299 were landlords and 101 were tenants (Table 2). Detailed characteristics of participants are presented in the Supporting Information S6. Of the 299 landlords, 79% were live-in landlords, and 21% were absentee landlords. Seventy percent were female respondents. Each compound had 6.4 households on average. Dry pit latrines were used by 91% of the interviewed households, while 9% used pour-flush toilets connected to a pit. Over 80% of compounds where respondents resided had only one toilet, and 98% of households shared their toilet(s) with other households. Given a mean of 5.5 households sharing one toilet and a mean household size of 5.3 people, nearly 30 people shared one toilet on average. Under the criteria of the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP), shared toilets are categorized as "Limited" or "Unimproved" facilities.[49]

In Korogocho, 46% of the participants answered that their self-reported monthly household income was below 7500 KES. The vast majority (99%) of participants used the mobile money application, Mpesa.[50]

Median emptying frequency was 3 times/year (four month interval), and 87% had their pit emptied in the last six months. Median volume of fecal sludge removed at the last emptying service was five drums (200 L/drum), while 28% removed three drums or below, which was the upper limit of emptying in the Small-amount Plan. Vacuum truck services were limited and exclusively provided to churches and schools in Korogocho. All landlords and 45% of tenants had used informal manual emptying, while 55% of tenants had never used any emptying services. Half of the landlords and tenants said emptying costs were included in rent, but only 18% of all respondents had an agreement on who bears emptying costs between landlords and tenants. Those who had an agreement reported the following components: how often and how much of the emptying cost tenants and landlords pay; whether the costs are deducted from rent when the emptying event happens; and who is responsible for emptying (i.e., requesting a service and collecting contributions).

Table 2. Characteristics of Participants

category	subcategory	N	percentage
respondent type	landlord	299	75%
	of which live-in landlord	236	
	of which absentee landlord	63	
	tenant	101	25%
sex	male	119	30%
	female	281	70%
sanitation facility type	dry pit	365	91%
	pour-flush latrine connected to a pit	35	9%
number of toilets in a compound	1	329	82%
	2	55	14%
	3	12	3%
	4 or more	4	1%
numbers of households in a compound	1−3	72	18%
	4−6	176	44%
	7−9	104	26%
	>10	48	12%
monthly household income (self-reported)	<5000 KES	81	20%
	5000−7500 KES	103	26%
	7500−10,000 KES	121	30%
	10,000−20,000 KES	78	20%
	>20,000 KES	17	4%
monthly rental income from a compound (n = 299; landlord only)	<5000 KES	100	33%
	5000−7500 KES	76	25%
	7500−10,000 KES	68	23%
	10,000−20,000 KES	50	17%
	>20,000 KES	5	2%

3.2. WTP for Emptying Services. Figure 4 shows the WTP for two novel emptying services and the fee paid for the existing informal manual emptying service. Median and mean WTP for the Standard Plan were 1.50 USD (200 KES)/drum and 1.62 USD (95% confidence interval (CI): 1.56−1.69 USD)/drum, respectively. Given the respondents median emptying volume of five drums, the median WTP for the Standard Plan per emptying event was estimated to be 7.51 USD.

Median and mean WTP for the Small-amount Plan were 1.50 USD (200 KES) and 1.41 USD (95% CI: 1.35−1.47 USD) per drum, respectively. Most landlords (88%) and tenants (76%) preferred to have three drums removed, which was the maximum emptying volume under the Small-amount Plan, while 11% of landlords and 22% wanted to empty two drums. However, the WTP for the Small-amount Plan was not

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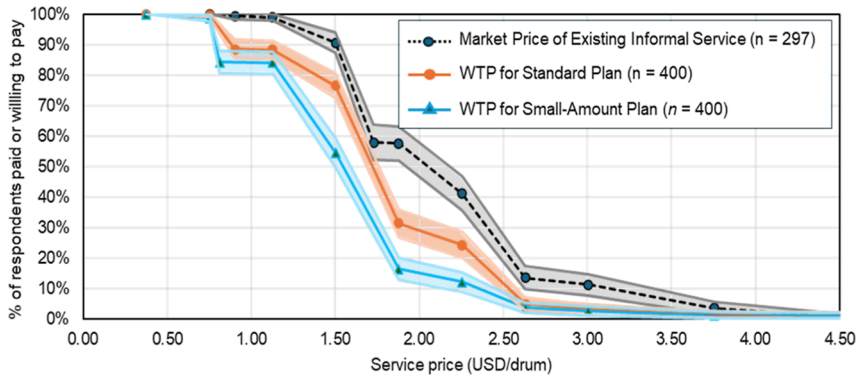

Figure 4. Comparison of WTP for two novel emptying services and the fee paid for the existing informal manual emptying service last time (= market price). The light color shadings show 95% CIs.

Table 3. Results of a Multiregression Model of Log-Transformed WTP for the Standard Plan (R^2 = 0.196, p < 0.001 for the F-Test)[a]

explanatory variable	level	beta	standardized beta	t-value	p-value
(constant)		3.524		10.657	<0.001
age	18−25 (ref)				
	26−35	−0.374	−0.379	−3.532	<0.001
	36−45	−0.366	−0.472	−3.616	<0.001
	46−55	−0.392	−0.490	−3.820	<0.001
	55+	−0.442	−0.532	−4.246	<0.001
sex	male (ref)				
	female	−0.002	−0.002	−0.041	0.967
education level	uneducated (ref)				
	primary_1−4 year	0.061	0.043	0.638	0.524
	primary 5−8 year	0.066	0.092	0.880	0.380
	secondary	0.070	0.092	0.905	0.366
	college/university	0.163	0.130	1.712	0.088
monthly household income	<10,000 KES (ref)				
	10,000−20,000 KES	0.048	0.055	1.063	0.289
	>20,000 KES	0.142	0.085	1.648	0.100
ln (fee paid last time for informal emptying)		0.393	0.363	6.946	<0.001
number of households in the compound		0.008	0.114	2.034	0.043
volume the respondent wants to empty next time (drum)		−0.012	−0.140	−2.468	0.014
respondent lives in the compound	no (ref)				
	yes	−0.081	−0.087	−1.767	0.078
there is an agreement on emptying between landlord and tenant	no (ref)				
	yes	−0.027	−0.030	−0.580	0.562

[a]Note: Since the dependent variable is logged, (i) when the explanatory variable is not logged, the beta (coefficient) is interpreted that for every 1-unit increase in the explanatory variable, the dependent variable increases by beta (%), and (ii) when the explanatory variable is also logged, for every 1% increase in the explanatory variable, the dependent variable increases by beta (%).

correlated with the volume emptied last time (r = −0.143, p = 0.013).

Supporting Information S3 shows the WTP estimated by the maximum likelihood estimation with dichotomous choices only to confirm the validity of the WTP elicited from the open-ended answers. The mean WTP amounts for the Standard Plan and the Small-amount Plan were slightly higher in the estimates of the maximum likelihood function by 8% and 5%, respectively, but the 95% CIs overlapped for the Small-Amount Plan.

While the median WTP for the two novel services was the same at 1.50 USD (200 KES)/drum, the data sets significantly differed (Wilcoxon-signed rank test, p < 0.001). The mean WTP for the Small-amount Plan was lower by 0.21 USD/drum (or 13%) than that for the Standard Plan with no overlap of 95% CIs, which was considered as a discount rate that respondents expected for the inconvenience of the upper limit of emptying volume. Median and mean fees paid for the existing informal emptying were 1.88 USD (250 KES) and 1.96 USD (95% CI: 1.88−2.02 USD) per drum, respectively, and the median total fee was 9.39 USD. This is more than a quarter of the monthly income for 33% of landlords whose rent income from a compound was less than 37.6 USD (5000 KES) per month.

The fee paid for informal emptying was significantly higher than the median WTP for the two novel services (Wilcoxon-signed rank test, p < 0.001). While the fee paid last time weakly correlated with WTP for the Standard Plan (r = 0.280, p < 0.001) and the Small-amount Plan (r = 0.238, p < 0.001), there was a strong correlation between WTP for the Standard Plan and WTP for the Small-amount Plan (r = 0.690, p < 0.001).

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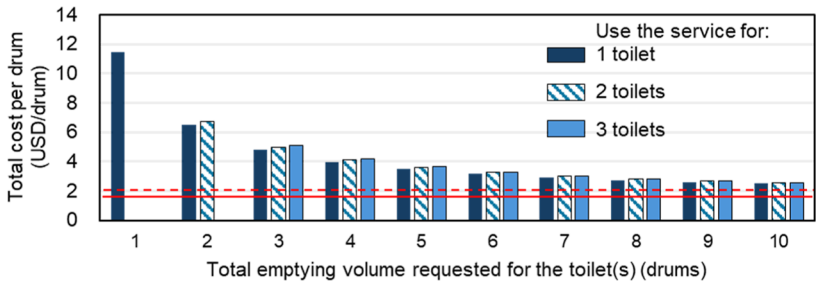

Figure 5. Total cost of the novel emptying service (Standard Plan) per drum when a service provider consecutively visits a different number of toilets. As one toilet needs at least one drum, 2-toilet scenario starts from 2 drums, and 3-toilet scenario starts from 3 drums. The red solid line shows 1.50 USD (200 KES)/drum (median WTP for the Standard Plan), and the red dot line shows 1.87 USD (250 KES)/drum (median fee paid for the existing informal emptying service).

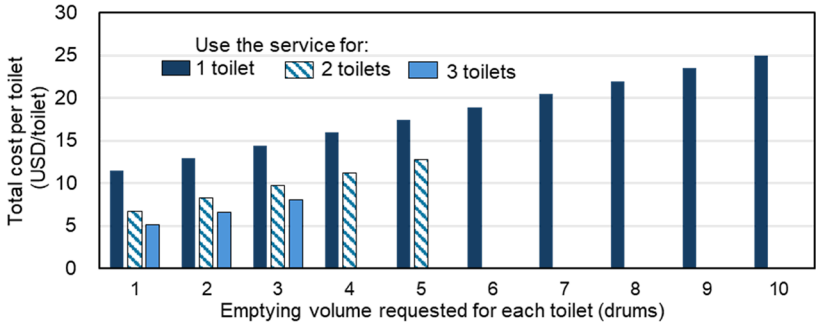

Figure 6. Total cost of the novel emptying service per toilet when a service provider consecutively visits a different number of toilets. Note that the overall number of drums collected is proportional to the number of toilets visited (e.g., if the emptying volume requested by each toilet is one drum, visiting three toilets means three drums are collected overall).

Table 3 shows the results of a multiregression model which examined the influence of demographic and emptying-related variables on the log-transformed WTP for the Standard Plan (adjusted R^2 = 0.196). Regarding demographic variables, age was significantly associated with WTP ($p < 0.001$): the older the age the lower the WTP compared with the reference level (18−25 years old). Age did not correlate with monthly household income. Other demographic variables such as sex, education level, and household income were not associated with WTP. A log-transformed fee paid last time for informal emptying had the biggest impact on WTP ($p < 0.001$), meaning that WTP increased by 0.4% per 1% increase in the fee paid last time. The number of households in the compound ($p = 0.043$) and the volume of sludge the respondent wants to empty next time ($p = 0.014$) also significantly affected WTP, but those factors only led to a 0.8% increase and a 1.2% decrease in WTP per each additional household or drum increase, respectively. The emptying volume had a negative association with WTP ($R^2 = -0.012$, $p = 0.014$), suggesting that respondents expected a reduced price for a larger scale of emptying. Whether the respondent lives in the compound and whether there is an agreement between landlord and tenant on emptying did not affect WTP. We performed the same multiple regression analysis for WTP for the Small-amount Plan and found that the same variables significantly correlated (Supporting Information S7).

3.3. Cost Analysis. We estimated total costs per drum for the novel emptying services under the condition that a service team visited one, two, or three toilets consecutively for emptying on the same day (Figure 5). At any emptying volume, the total costs exceeded the median WTP for the Standard Plan (1.50 USD/drum) and the median fee for informal emptying (1.88 USD/drum). Even at the lowest cost (2.5 USD/drum), WTP covered 60% of the cost, and there was a gap of about 1 USD/drum between the cost and WTP. The total costs per drum decreased as the number of drums approached 10 as a tricycle capacity of 10 drums was efficiently utilized, while the costs slightly increased with more toilets served due to higher transport costs (A sensitivity analysis is available in Supporting Information S5).

Total costs per toilet were analyzed to assess the effectiveness of visiting multiple toilets on cost. To simplify the comparison, Figure 6 shows the case in which all toilets have the same emptying volume. The more toilets that were visited on the same day, the lower the per toilet cost. For instance, the total cost per toilet when visiting three toilets and emptying three drums each was 44% (about 6.36 USD/toilet or 2.12 USD/drum) lower than that when collecting three drums from a single toilet. In this model, at least a 27% or 0.94 USD/drum reduction was achieved compared to the case of visiting one toilet.

To assess whether a sufficient number of emptying events to be grouped exist in Korogocho, a market scale of emptying services in Korogocho was also estimated. Assuming that one in two toilets is manually emptiable (the rest being directly discharged into rivers),[4] 535 emptiable toilets were estimated to exist. As the median emptying frequency was 3 times/toilet/year, about 1600 emptying events/year were supposed to happen in Korogocho, which means more than four events/day exist within the area.

4. DISCUSSION

We found that informal emptying has a higher market price than WTP for the novel manual emptying services and that the

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WTP did not cover the total costs of the service provision. That said, it was also suggested that costs could be reduced by providing services for multiple toilets consecutively within a day. Based on these findings, this section discusses why there was a difference in the market price of the informal service and WTP for the alternative services, what strategies should be adopted in providing the alternatives, how group-based emptying can be carried out in informal settings, and the limitations of this study.

4.1. Persistent Popularity of Informal Service. The fee paid for informal manual emptying (or revealed preference) was significantly higher than the WTP (or stated preference) for the hypothetical alternatives that give a better outcome for customers and society regarding service hygiene, workers' safety, and the environment. This result suggests three possible interpretations: (i) the influence of biases for stated preference, (ii) informal emptying is highly valued, and (iii) respondents did not care about the outcome of the novel services.

Various biases are known to affect stated preference as respondents need to answer their WTP for a service that they have not used.[45,51] Of the biases, strategic bias could lower WTP: respondents might have intentionally answered WTP lower than they actually thought, thereby attempting to influence the pricing of the service.[44] During the survey, enumerators sometimes pointed out that participants stated WTP which was lower than the price bid that they accepted in the dichotomous choice. Despite enumerators' efforts to remind them of their previous answers and ask about their WTP again in such cases, the bias could have affected the results. That said, the WTP statistically estimated from dichotomous choice answers (Supporting Information S3) was still lower than the market price of existing informal emptying services.

Besides, in Korogocho, most households emptied their onsite facilities using informal services, since other alternatives were hardly accessible. Also, the median emptying frequency (3 times/year) in Korogocho was relatively higher than in other areas where previous WTP studies were conducted.[11] Respondents who have relied on the informal emptying services may have valued the services to some extent more than unfamiliar novel services.

In relation to that, the respondents might take the unhygienic and unsafe services for granted, and the reliance on and frequent use of informal emptying services may have fostered an attitude of resistance to seeking alternative approaches. These may have caused respondents to perceive a limited value for better worker and environmental outcomes. The result that older populations had lower WTP in the multiregression model might also reflect the attitude since elderly people generally reside longer in Korogocho.[31]

Either way, our results revealed that informal services could be competitive with safer alternatives. This implies that introducing safe alternatives should come in tandem with regulations of informal services to eliminate negative externalities such as dumping waste into the open environment.[20]

4.2. Strategies for Introducing Safe Alternatives. Our survey and cost analysis revealed that there was a gap of about 1 USD/drum between WTP for the alternative service and its cost even when the service was most cost-efficiently operated. To close the gap, there could be three strategies: (i) reducing costs, (ii) increasing WTP, and (iii) utilizing subsidies (including cross-subsidies).[11]

For cost reduction, we estimate that visiting multiple toilets consecutively can reduce the cost per toilet (e.g., 44% reduction when one vs three toilets empty three drums each). However, it is important to note that only 28% of households removed three drums or below in Korogocho. This suggests that without a price incentive for small-amount emptying, there may be insufficient demand for them. To enable grouping multiple toilets with smaller emptying demands, an incentive such as a discount price to accommodate a small-amount emptying would be necessary. The Small-amount Plan which set an upper limit of emptying volume obtained 13% lower WTP (0.21 USD/drum difference) than the Standard Plan, but by limiting the emptying volume at each toilet, thereby enabling more toilets to be visited, at least 27% or 0.94 USD/drum of cost reduction was estimated to be achieved. Given that the cost reduction rate outweighed the decrease in WTP, encouraging small-amount emptying at a discounted price and visiting multiple toilets can be an effective cost reduction strategy.

Allowing households to use a service for a small amount can enhance the operational feasibility of group-based emptying. In general, group-based emptying requires a sufficient number of emptying requests in a specific area for efficient grouping.[23] Promoting small-amount emptying, thereby increasing the frequency of emptying (or the number of requests), can help service providers group nearby households and reduce waiting time before being grouped, particularly in areas with low emptying frequency (e.g., once in several years).[8]

Given the financial challenges in Korogocho, providing subsidies would be necessary alongside efforts to close the gap between WTP and the costs. The funding for subsidies can be mobilized from the public sector or within the service provider's business (so-called cross-subsidies).[52] If no intervention takes place, for those who cannot afford even informal emptiers, the only option for empty full pits is voluntary emptying practices by residents such as "flooding out" where they break a part of the pit wall so that the stored sludge can flow out to the open environments.[8,53] When voluntary emptying is not possible for some reason, they may abandon the facility and either use neighbors' facilities and/or defecate in the open. In either case, public health in the community as well as the residents' dignity can be put at risk. To prevent them from happening, subsidizing emptying services for low-income populations would be justifiable.[14,52]

4.3. Group-Based Emptying Based on Household Demand. Existing studies have considered group-based emptying as a top-down approach organized by a local authority.[25,26] While mandatory scheduled emptying is an efficient way to group households, it is less convenient for households which are unable to prepare money on the scheduled date or households whose containment facility fills up before the scheduled date.[26]

If private service providers deliver group-based emptying, they have no control over when and from where households request emptying. Thus, whether a sufficient number of emptying demands exist within a certain area must be assessed. In the case of Korogocho, where 1600 emptying events/year are estimated to happen, it would be feasible for a service provider to visit several toilets a day unless it competes for jobs with other service providers, especially informal emptiers. In cities where emptying frequency is relatively high (e.g., more than once a year), such as Kisumu in Kenya,[14] Freetown in Sierra Leone,[54] and Khulna in Bangladesh[24] among others,

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group-based manual emptying is likely to be more relevant as there will be sufficient emptying requests to facilitate planning and enable efficiency gains. Furthermore, service providers that already employ a group-based approach with vacuum trucks may be able to extend this experience to manual emptying services.[52]

Grouping multiple toilets can lead to another challenge: emptying requests need to be coordinated so that services are provided before pits get full.[19,23] That said, collective action in grouping demand has been successfully implemented in various fields of logistics including municipal solid waste management.[55] To implement group-based emptying based on household demands, IT technologies could help service providers optimize transport routes and vehicle type, taking into account, for instance, household locations, the width of roads, and requested volume of emptying.[23] A call center model, which connects households and service providers, can also play a key role in coordinating the emptying requests.[26,56]

4.4. Limitations. There are several limitations in this study. First, the multiregression analysis explained only about 20% of variation in the dependent variable, WTP for the Standard Plan, suggesting that hidden determinants of WTP as well as biases may exist. Particularly, the WTP was likely affected by a strategic bias despite our efforts to minimize it. Second, our cost analysis had some assumptions (e.g., vehicle type, maintenance costs, etc.) and excluded some costs for simplification (e.g., office rent, tax). With more data, the cost analysis can be more accurate. We assumed in the cost analysis that visiting three toilets and collecting up to 10 drums were manageable within a day for manual emptiers based on our field observation. However, if service providers adapt the model for larger operational scales, then the time feasibility to empty and transport sludge at multiple toilets within a day may need to be assessed. Third, we did not include landlords who live outside of Korogocho due to logistical constraints. Since those landlords are reportedly less cooperative in addressing emptying requests from tenants,[19] the true WTP may be lower if these landlords were included.

5. CONCLUSIONS

To improve emptying services, informal manual emptiers play a key role. Existing informal services seem to affect household preferences for safe novel services and are likely to compete with them as if "better the devil we know than the angel we do not know". Therefore, policymakers should support the transition of informal emptiers to formal services and enforce regulations to eliminate unsanitary operations while simultaneously providing alternative services. We presented the possibility that a group-based approach could be provided not only by a local authority in a mandatory manner but also by the private sector based on household demand. While accepting small-amount emptying requests could improve the economic and operational feasibility of group-based services, further research will be needed to understand how increased emptying frequency is perceived by emptiers, users, and communities for better service delivery.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acsestwater.4c01244.

Questionnaire sheet (English version); verbatim transcript of the video used for WTP survey (English translation); validation of WTP; normality of residuals of the multiregression model; cost analysis; characteristics of participants; and results of a multiregression model of WTP for the small-amount plan (PDF)

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Author Contributions

Conceived by H.T. The data collection was conducted by H.T., B.B.I., and S.S. Analysis was performed by H.T. and IR. The first draft of the manuscript was prepared by H.T. All authors contributed to subsequent drafts. All authors have given approval to the final version of the manuscript. CRediT: **Hiroaki Tomoi** conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, writing - original draft; **Bonface Butichi Ingumba** investigation, project administration, supervision, validation, writing - review & editing; **Sheillah Simiyu** methodology, project administration, supervision, writing - review & editing; **Ian Ross** conceptualization, formal analysis, methodology, supervision, writing - review & editing; **Laura Braun** conceptualization, methodology, supervision, writing - review & editing; **Taeko Moriyasu** conceptualization, methodology, supervision, writing - review & editing; **Oliver Cumming** conceptualization, methodology, supervision, writing - review & editing.

Notes

The authors declare no competing financial interest.

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