Research Paper

Expanding safe fecal sludge management in Kisumu, Kenya: an experimental comparison of latrine pit-emptying services

Rachel Peletz, Andy Feng, Clara MacLeod, Dianne Vernon, Tim Wang, Joan Kones, Caroline Delaire, Salim Haji and Ranjiv Khush

ABSTRACT

Most residents of Kisumu, Kenya, use latrines constructed over basic pits or attached to more durable concrete vaults and septic tanks. Only one-third of fecal sludge generated in the city, however, is safely collected and treated. Programs for improving fecal sludge management among poor households include the development of formal manual emptying organizations that are recognized by local authorities, employ safety procedures, and transport fecal sludge to a treatment site. In this study, we compared the financial structures of these organizations with those of vacuum trucks that primarily serve wealthier households. We also employed an incentives-based strategy to promote the expansion of safe pit-emptying services in a low-income area and compared the performance of three managing groups to coordinate these services: (1) The Association of Wastewater Managers (The Association); (2) a formal manual emptying organization; and (3) a community-based water supplier interested in coordinating emptying services. Vacuum trucks were more cost-effective than the formal manual emptying organization, and The Association was most efficient in servicing poor households. The Association also demonstrated the ability to service low-income areas comprehensively by delegating a fraction of jobs (11%) to formal manual emptiers in locations not serviceable by VTOs, and overall showed the highest potential to achieve pro-poor service delivery at scale.

Key words | fecal sludge management, Kenya, latrines, low-income, sanitation, urban

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HIGHLIGHTS

- Sanitation conditions are of increasing concern for rapidly growing cities of the developing world.
- In Kisumu, Kenya, most residents use latrines constructed over basic pits or attached to more durable concrete vaults and septic tanks. However, only one-third of the fecal sludge generated in the city is safely collected and treated.
- Efforts to improve fecal sludge management among low-income households in Kisumu include the development of formal manual emptying organizations that are recognized by local

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authorities, employ safety procedures and equipment, and transport fecal sludge to the municipal treatment site.

- This study compares the financial structures of these formal manual emptying organizations with those of vacuum trucks that primarily serve wealthier households to determine the feasibility of expanding safe fecal sludge services to low-income areas in Kisumu.
- We employed an incentives-based strategy to compare pit-emptying service provision in a low-income area by three different groups, which include vacuum trucks and formal manual emptiers. We determined that vacuum trucks were more cost-effective than the formal manual emptying organization, and the Association of VTOs was most efficient in providing emptying services to poor households.

INTRODUCTION

Located in Western Kenya and bordering Lake Victoria, Kisumu is the country's third-largest city with an estimated 419,000 inhabitants, of which approximately 60% live in low-income areas (County Government of Kisumu 2018a; Furlong & Jooust 2016). As is the case for many cities in the developing world, sewerage networks are limited in Kisumu, serving only 20% of households. Approximately 70% of households rely on latrines constructed over simple pits and about 5% of households, predominantly in middle- and high-income areas, use latrines linked to underground concrete vaults or septic tanks (Furlong & Jooust 2016). It is estimated that the remaining 5% practice open defecation. These underground containment structures are typically either emptied by vacuum truck operators (VTOs), who mostly serve wealthier households, or informal manual emptiers who remove fecal sludge by hand or buckets and bury it onsite or dispose of it in nearby waterways. Estimates indicate that only one-third of Kisumu's collected fecal sludge is treated at the city's sewage treatment sites, which are managed by Kisumu Water and Sanitation Company (KIWASCO); the remainder is directly discharged into the environment or buried (Furlong & Jooust 2016). Increasing the use of safe and regulated emptying services is therefore critical for improving sanitation in Kisumu.

Recent efforts by the municipality and development partners to promote better fecal sludge management in Kisumu, particularly in low-income areas, have largely focused on the formation of authorized manual emptying services that adhere to safety practices and utilize authorized treatment sites. In 2016, the Kisumu City Partnership for Improved Sanitation in Informal Settlements (KisumuSan), led by the international non-profit organization, Practical Action, trained two community-based organizations, BlueStars and Vukasasa, in safe manual emptying (Practical Action 2016). Prior to joining the KisumuSan program, BlueStars members were informal pit emptiers and Vukasasa members were dedicated to cleaning public and school toilet facilities, cleaning school compounds, and managing an ablution block. In 2018, Water and Sanitation for the Urban Poor (WSUP), an international not-for-profit, implementing organization began collaborating with the Kisumu County Public Health Office to develop Standard Operating Procedures (SOPs) for fecal sludge management (Owako & Renouf 2018). These SOPs provide guidance on emptying practices and equipment that were designed to protect the health of manual emptiers. The SOPs also specify safe methods for transporting and disposing of fecal sludge. In addition, WSUP, in partnership with the Kisumu County Public Health Office and KIWASCO, helped a solid waste management company (Gasia Poa) expand into fecal sludge management (Owako & Renouf 2018; WSUP 2018). WSUP provided Gasia Poa with training in the SOPs and guidance in marketing, branding, and financial management. The three emptying organizations (BlueStars, Vukasasa, and Gasia Poa) now operate in various low-income areas of Kisumu. We refer to these organizations as 'formal' manual emptiers: they are authorized by the Kisumu County Government and the National

Environment Management Authority (NEMA), and they are allowed to dump waste at the KIWASCO fecal sludge treatment site without paying a dumping fee. They typically transfer fecal sludge into barrels (using the hand-operated Gulper mechanical pump or steel buckets with long handles) and then transport the barrels in a pick-up truck to the treatment site.

The promotion of formalized manual emptying services in Kisumu and other cities of the developing world is generally based on assumptions that vacuum trucks are not appropriate for low-income areas: it is generally believed that their services are too expensive for poor households, they cannot access households in dense urban settlements, and they are not equipped to remove the solid waste typically found in pit latrines (Chowdhury & Kone 2012; Balasubramanya *et al.* 2017; Mansour Oyaya & Owor 2017). To test these assumptions, we undertook two research activities: (1) we determined the costs of pit-emptying by vacuum trucks and formal manual emptying organizations; and (2) we established an incentives-based latrine pit-emptying program to compare the performance of three managing groups in coordinating the delivery of emptying services in a low-income area of Kisumu.

METHODS

Landscape assessment

We began our comparisons of latrine pit-emptying options in Kisumu by establishing the landscape of existing emptying services: VTOs, formal manual emptying organizations (BlueStars, Vukasasa, Gasia Poa), and informal manual emptiers (Figure 1). To verify business models, establish customer bases, and identify barriers for expansion within low-income areas, we conducted 18 interviews and observations of pit-emptying service providers. Additionally, we reviewed nine policy documents and 25 reports on past sanitation programs and interviewed 17 government and non-governmental stakeholders to understand the regulatory environment (Figure 1). To understand efforts to improve sanitation in other Kenyan cities, we interviewed sanitation service providers in Nakuru (Nakuru Water and Sanitation Services Company), Malindi (Malindi Water and Sewerage Company), and Nairobi (Sanergy, a fecal sludge management organization with for-profit and non-profit operations). Finally, to establish a forum for regularly engaging with local stakeholders, we formed a working committee in Kisumu that included the City and County Public Health Departments, KIWASCO, Great Lakes University Kisumu, and WSUP. The research team met five times with the working committee over the course of the study.

Cost of safe pit-emptying

We used the information collected during interviews with service providers to estimate the costs that they incur per emptying job. We considered both capital expenditures (CAPEX) and operational expenditures (OPEX). For the group of formal manual emptiers, CAPEX included one Gulper (estimated lifetime: 10 years), six 50-L barrels (estimated lifetime: 5 years), and five sets of personal protective equipment (gumboots, helmet, overalls, mask, gloves) with an estimated lifetime of 1–2 years. For a VTO, CAPEX included an 8,000-L exhauster truck (estimated lifetime: 10 years), three 100-feet hoses (estimated lifetime: 1 year), one set of personal protective equipment (gumboots, overalls, gloves) with an estimated lifetime of 1–6 months, annual licenses to the municipality and NEMA, and a one-time registration with the Association of Wastewater Managers. OPEX included labor, truck rental, office costs, and disinfectant consumables for formal manual emptiers; labor, truck maintenance, fuel, a monthly permit to access the treatment facility, and a quarterly membership fee to the Association for VTOs. To estimate costs per emptying job, we first calculated annual costs and then normalized by the approximate annual number of jobs: 2,160 for a VTO (or 6 jobs per day) and 60 for the group of manual emptiers (5 jobs per month), based on currently reported levels of activity.

Managing groups for pit-emptying

Our sanitation landscape assessment and working committee stakeholder consultations identified the need for exploring different management models for pit-emptying services. For our comparative study, we applied the following criteria to select groups that were either already

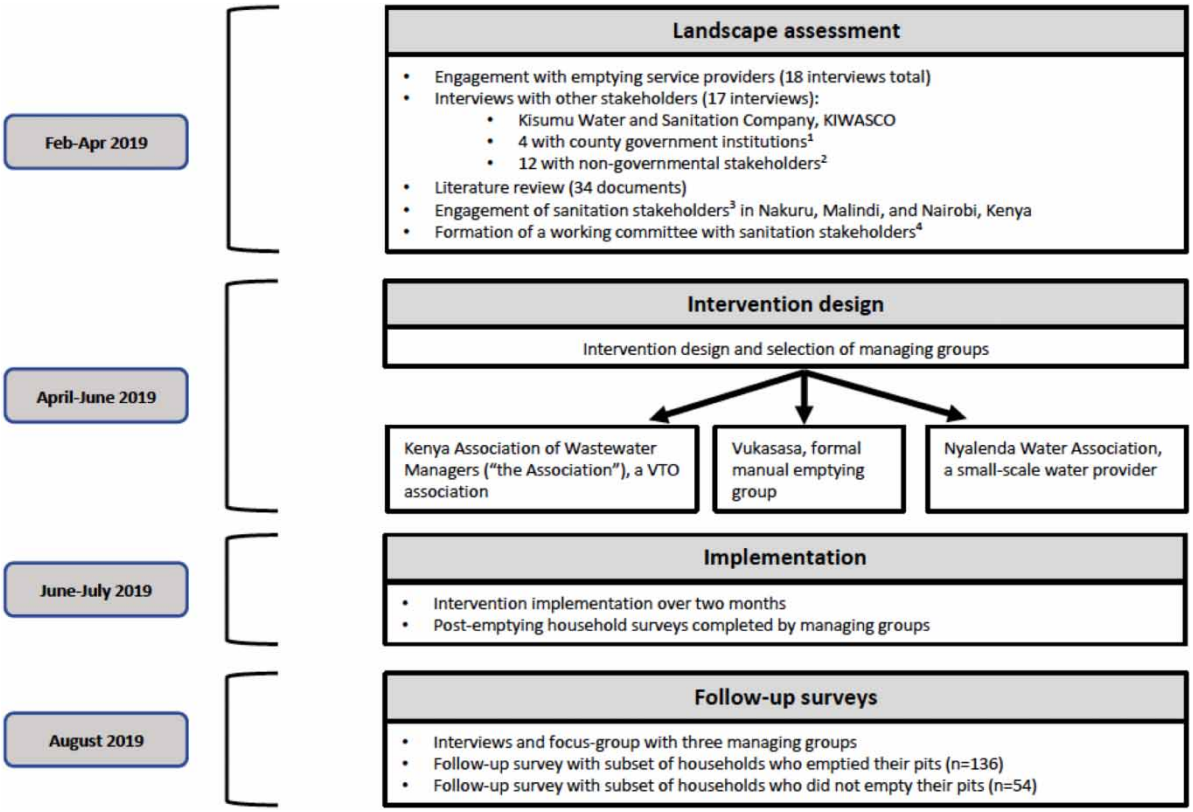

Figure 1 | Study flow diagram. [1]County government institutions include: Kisumu County Public Health Office, Kisumu City Public Health Office, National Environmental Management Authority, and Lake Victoria South Water Service Board. [2]Non-governmental stakeholders include: the Kenya Integrated Water, Sanitation, and Hygiene (KIWASH) program funded by USAID, Kenya Women Finance Trust, ECLOF Kenya (microfinance institution), Kenya Urban Apostolate Program, Umande Trust, Practical Action, Water and Sanitation for the Urban Poor, and Great Lakes University Kisumu. [3]Sanitation stakeholders included Nakuru Water and Sanitation Services Company in Nakuru, Malindi Water and Sewerage Company in Malindi, and the social enterprise Sanergy in Nairobi. [4]The working committee consisted of Kisumu City and County Public Health Departments, Kisumu Water and Sanitation Company (KIWASCO), Great Lakes University Kisumu, Water and Sanitation for the Urban Poor (WSUP).

providing safe pit-emptying services or interested in expanding into pit-emptying: (i) currently operating in the low-income area of Nyalenda within Kisumu, (ii) established business expertise (e.g., experience providing services and managing money), (iii) willingness to participate in a research study, and (iv) concurrence from the working committee. This selection process identified three groups with different cost and management structures: (1) Kenya Association of Wastewater Managers (The Wastewater Association); (2) Vukasasa, the primary formal manual emptying organization operating in Nyalenda; and (3) the Nyalenda Water Association (Nyalenda Water), one of KIWASCO's small-scale water providers responsible for distributing piped water in Kisumu's low-income areas through a delegated management model (Castro 2009; Nzengya 2015; Schwartz & Sanga 2015) (Table 1). Throughout our comparative study, these selected groups managed their delivery of safe emptying services: they were responsible for marketing services, identifying customers, setting prices, and coordinating pit-emptying jobs. All three managing groups could delegate jobs to either VTOs or formal manual emptiers. In the case of the Wastewater Association, delegating a job to a VTO meant to assign it to one of its own members. Similarly, for Vukasasa, delegating a job to formal manual emptiers meant to assign it to its own members.

To standardize operating conditions for the three managing groups during our study, we selected three separate geographic zones in the Nyalenda area (out of 12 zones that we evaluated) according to the following specifications: (i) inclusion of 500–700 households; (ii) equidistant to the KIWASCO treatment site; (iii) demarcated by clear

Table 1 | Description of the three managing groups selected for the comparative study of pit-emptying

Managing group	Description and structure
The Kenya Association of Wastewater Managers *(referred to as 'The Wastewater Association')*	• An association of VTOs • Serves as an intermediary to link customers to VTOs • Subcontracts jobs to formal manual emptying groups as needed • VTOs operate in all of Kisumu
Vukasasa	• A community-based organization that provides safe manual emptying services • Able to subcontract jobs to VTOs, though rarely applied in practice • Only operates in the low-income area 'Nyalenda'
Nyalenda Water Association *(referred to as 'Nyalenda Water')*	• A small-scale water supplier that provides water in low-income areas • Overseen by Kisumu Water and Sewerage Company (KIWASCO) through a delegated management model • Only operates in the low-income area 'Nyalenda' • No previous experience in sanitation and, therefore, manages pit-emptying by subcontracting jobs to VTOs or formal manual emptiers

boundaries such as roads or rivers; (iv) near the offices of the managing group (did not apply to the Wastewater Association); and (v) approved by the managing groups.

Cash incentives

To encourage participation in our comparative study of pit-emptying services, we provided cash incentives to the managing groups (Figure 2). In addition to the payments that they negotiated with customers, we provided managing groups with a 3,000 KES (30 USD) cash incentive for each emptying job that they completed within their assigned zone during our study period. We selected this amount to address the estimated gap between market prices for VTO and formal manual pit-emptying services in Kisumu and the average willingness-to-pay (WTP) for pit-emptying among poor households, who largely rely on informal manual emptiers (who charge 10–30 USD per job according to our landscape assessment). We measured WTP in a parallel study (Peletz *et al.*, forthcoming). Recognizing that the costs of formal manual emptying were higher than VTOs primarily due to transport, we provided an additional incentive payment of 2,000 KES (20 USD) per trip to the treatment site for pit-emptying jobs completed by formal manual emptiers to support the costs of transporting fecal sludge from the study zones to the KIWASCO treatment site. These incentives were necessary to promote the expansion of formal pit-emptying services into previously

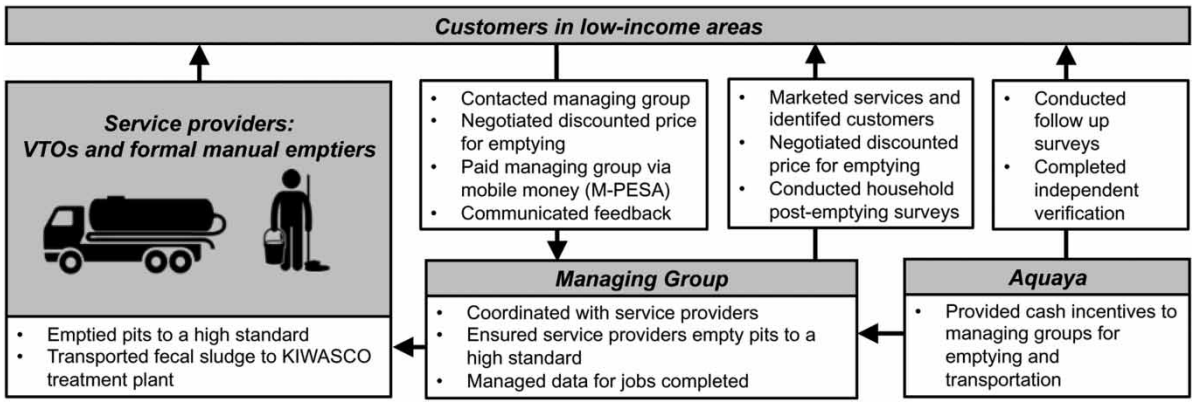

Figure 2 | Comparative study design. Each group's responsibilities are represented by the direction of the arrows. The research team (Aquaya) provided cash incentives to managing groups for emptying and transport.

non-serviced areas. We implemented them for a period of 2 months, as defined by our available budget. This period was sufficient to measure differences in performance between the three managing groups.

Other than defining the zones and providing cash incentives as described above, we did not apply other constraints or guidelines on the three groups. We did not provide capacity building to any of the managing groups. A fundamental element of the research design was giving the groups substantial flexibility to determine key elements of their business model, including choice of provider (VTO or manual), price charged to customer (reflecting the specifics of the job including condition and accessibility of pit), and the price paid to the service provider.

Data collection

We collected data from June to July 2019 to assess the following outcome metrics for each managing group: (i) *safe emptying performance* (i.e., number of households served and volume of fecal waste safely removed), (ii) *financial performance* of managing groups (e.g., prices charged to customers, costs, and net revenues), and (iii) *customer satisfaction*. To capture data electronically, we provided one smart phone (Samsung Galaxy J4, South Korea) carrying the CommCare survey and data management application (DiMagi Inc., Cambridge, MA, USA) to each managing group. After each emptying job, managing groups completed a post-emptying survey to document the toilet type, number of users, volume of sludge removed, number of trips required to transport sludge to the treatment site, customer satisfaction, payment received from the customer, and any payment to a subcontracted emptier. To qualify for our incentive payments, the managing group was required to submit a photo of each emptied pit and receipts that documented their financial transactions with customers and subcontractors, if applicable. We also hired an independent field coordinator to verify 10% of emptying jobs for each managing group, with a minimum of one verification per week per group.

To audit emptying records and customer feedback reports, we attempted follow-up surveys with all of the customers serviced by Vukasasa (60 households) and Nyalenda Water (44 households) and a random selection of 60% (81/136) of the households serviced by The Wastewater Association. To understand why households did not use the safe emptying services, we conducted follow-up surveys with 54 randomly selected households that did not have their pits emptied by managing groups. We entered household survey responses into the CommCare survey and data management application (DiMagi Inc., Cambridge, MA, USA) on mobile phones (Samsung Galaxy J4, South Korea). We also conducted individual interviews with each managing group and a combined focus group discussion with all three groups to discuss successes, challenges, and recommendations for expanding their businesses in low-income areas.

Data analysis

We analyzed data using the spreadsheet software program Microsoft Excel (Microsoft Corp. Redmond, WA, USA) to examine key outcome metrics previously described. We randomly selected households for follow-up surveys using Excel (for those that received services) and ArcGIS (for those that had not received services, identified using randomly generated GPS points). The exchange rate that we used during our analysis was 1.00 USD = 100 KES (6 June 2019, oanda.com).

Ethical approval

The Western Institutional Review Board (WIRB) (Puyallup, WA, USA) determined that this study was exempt from full ethical review under 45 CFR §46.101(b)(2) of the Federal Common Rule in the USA. In Kenya, we obtained ethical approval for our research from Amref Health Africa (AMREF) (ESRC P493/2018) and a research permit from the National Commission for Science, Technology, and Innovation (NACOSTI) (NACOSTI/P/19/39980/28701).

RESULTS

Costs of safe emptying by different service providers

We analyzed the capital and operating expenses of VTOs and formal manual emptying organizations in Kisumu

prior to beginning our comparative study with the three managing groups (Table 2). Our analyses showed that per emptying job, formal manual emptying was about four times more expensive (6,169 KES or 62 USD) than emptying by VTOs (1,630 KES or 16 USD). Key drivers of this difference were the higher OPEX incurred by formal manual emptiers for labor (25.5 USD per job compared to 11.2 USD per job for VTOs) and for transporting fecal sludge to the treatment site (30 USD per job compared to 3.7 USD per job for VTOs). Economies of scale further improved the cost-effectiveness of VTOs by lowering per-job CAPEX (formal emptying groups performed an average of five pits per month, compared to six jobs per day for VTOs).

Data accountability and misrepresentation

During our comparative study, we found that two of the managing groups misrepresented data and mismanaged funds, despite our efforts to hire an independent field coordinator to verify emptying jobs during the comparative study. Based on our follow-up audit, we estimated that 32% (19/60) of Vukasasa's pit-emptying records and 59% (26/44) of Nyalenda Water's pit-emptying records were invalid: in these cases, households either could not be re-located (according to the recorded GPS coordinates and phone numbers) or did not have their pits emptied. The two managing groups did not provide valid explanations for why, in some cases, we could not re-locate households nor why, in other cases, pits that were not emptied were reported as emptied. In contrast, we determined that only 1% of the Wastewater Association's records (1/81) were invalid. We disregarded the pit-emptying jobs that we could not confirm and reported the total number of jobs accordingly (Table 3). These challenges in data management do not affect the cost analysis in Table 2, which describes expenditures prior to the comparative study.

Safe emptying jobs performed

We confirmed that The Wastewater Association coordinated 135 emptying jobs (removing approximately 1,065,600 L of fecal sludge), Vukasasa coordinated 41 jobs (removing approximately 147,120 L of fecal sludge), and Nyalenda Water coordinated 18 jobs (removing 95,960 L of fecal sludge) during our study period (Table 3). Because our landscape assessment revealed that formal service

Table 2 | Costs of safe emptying and transport: capital expenditures (CAPEX) and operating expenditures (OPEX) incurred by pit-emptying service providers in Kisumu, Kenya

		Formal manual emptying			VTOs		
Cost category		**Cost per emptying (KES)**	**Cost per emptying (USD)**	**Relative costs**	**Cost per emptying (KES)**	**Cost per emptying (USD)**	**Relative costs**
OPEX costs	Truck rental	3,000	30	49%	–	–	–
	Salary/labor (for 1 toilet)	2,550	25.50	41%	1,117	11.17	69%
	Office costs	78	0.78	1.3%	–	–	–
	Disinfectant consumables	245	2.45	4%	–	–	–
	Maintenance	–	–	–	56	0.56	3%
	Fuel	–	–	–	232	2.32	14%
	License/membership				85	0.85	5%
Total OPEX		5,873	58.73	95%	1,489	14.89	91%
CAPEX costs	Registrations	–	–	–	8	0.08	0.5%
	Emptying equipment	77	0.77	1%	125[a]	1.251	8%1
	Safety equipment[b]	220	2.20	4%	8	0.08	0.5%
Total CAPEX		296	2.96	5%	140	1.40	9%
Total costs		6,169	61.69	100%	1,630	16.30	100%

For formal manual emptying, we report data obtained from the Vukasasa organization; costs were similar for the other two formal manual emptying groups.

Note: exchange rate is 1.00 USD = 100 KES (6 June 2019, oanda.com).

[a]For VTOs, the emptying equipment cost includes an exhauster truck and hoses; for formal manual emptiers, the truck price is captured in the truck rental fee.

[b]The amortized cost of safety equipment is higher for formal manual emptying than VTOs primarily because of economies of scale: formal emptying groups were emptying an average of five pits per month, compared to VTOs that were emptying an average of six per day. However, economies of scale would not affect the operating expenditures, which drive the costs for both services: operating costs are 95% of total formal manual emptying costs and 91% of total VTO costs.

Table 3 | Activity summary of managing groups: number of pits emptied, volume of fecal sludge emptied, and types of toilets served based on validated data

Managing group		The Wastewater Association	Vukasasa	Nyalenda Water
Number of pits emptied[a]		135	41	18
Volume of sludge emptied (L)[b]		1,065,600	147,120	95,960
Average sludge volume per job (L)		7,893	3,588	5,331
Number of pits by service provider		120 VTOs, 15 formal manual emptiers	41 formal manual emptiers (Vukasasa)	9 VTOs, 9 formal manual emptiers
Number of trips[c]		120 VTO, 39 formal manual emptier (Gasia Poa)	118 formal manual emptiers (Vukasasa)	9 VTO, 26 formal manual emptiers
Number of toilet facilities serviced[d]	Septic tank (flush/pour-flush)	13 (17%)	2 (5%)	6 (35%)
	Pit latrine (flush/pour-flush)	12 (15%)	7 (17%)	5 (29%)
	Ventilated improved pit latrine	15 (19%)	5 (12%)	1 (6%)
	Dry pit latrine with slab	38 (49%)	27 (66%)	5 (29%)

[a]We excluded all records that were not validated by independent enumerators (e.g., households not found or no emptying done) from analysis: these included 1 record for The Wastewater Association, 19 for Vukasasa, and 26 for Nyalenda Water.
[b]We estimated the volume of sludge removed by VTOs based on exhauster truck capacity. We estimated the volume of sludge removed via formal manual emptying by multiplying the number of barrels used (of either 60, 120, or 210 L capacity) with the number of trips required to transport the sludge to the treatment site.
[c]VTOs conducted one trip per pit, while the formal manual emptiers conducted an average of two to three trips per pit.
[d]Data are based on follow-up surveys: $n = 78$ for The Wastewater Association, $n = 41$ for Vukasasa, and $n = 18$ for Nyalenda water.

providers were largely inactive in the study area prior to the pilot, we can infer that the vast majority of the 1,308,680 L of fecal sludge safely emptied during this study would otherwise have been disposed of unsafely.

Formalized manual emptying required multiple trips to transport all of the fecal sludge from a single pit to KIWASCO's treatment site (generally 2–3 trips per pit): the 41 emptying jobs managed by Vukasasa required 118 trips (Table 3). The Wastewater Association subcontracted 15/135 jobs to the formal manual emptying group, Gasia Poa, which accounted for 39 trips to the treatment site (Table 3). Nyalenda Water subcontracted nine jobs to VTOs and nine to formal manual emptiers (corresponding to 26 trips to the treatment site) (Table 3). Vukasasa delegated all jobs to its members and did not subcontract any jobs to VTOs. We also found that all groups serviced a variety of toilet types (Table 3).

Financial metrics of managing groups

The cash incentives that we provided motivated all three managing groups to reduce the prices of emptying services, and, therefore, served as subsidies for their customers (Table 4). The average price charged by The Wastewater Association (1,375 KES, 14 USD per job) was substantially lower than the average prices charged by the other two managing groups (3,190 KES, 32 USD for Vukasasa and 2,696 KES, 27 USD for Nyalenda Water). These prices were comparable to those charged by illegal manual emptiers (10–30 USD) (Peletz *et al.*, forthcoming), which suggests that the three managing groups were able to compete with informal service providers.

The Wastewater Association showed a lower average net revenue (after incentive payments) per job (1,389 KES, 14 USD) compared to Vukasasa (3,124 KES, 31 USD) and Nyalenda Water (2,474 KES, 25 USD). However, the Association completed substantially more jobs and their total net revenue was higher: 187,486 KES (1,875 USD) for the Association, compared to 128,100 KES (1,281 USD) for Vukasasa and 44,527 (445 USD) for Nyalenda Water.

Customer feedback

The Wastewater Association's customers reported the highest satisfaction levels: they gave an average rating of 4.3 (on a 5-point scale) and 78% reported that they would use the

Table 4 | Financial metrics for each managing group recorded during our study period

	The Wastewater Association		Vukasasa		Nyalenda Water	
Managing group	**KES**	**USD**	**KES**	**USD**	**KES**	**USD**
Average consumer payment per job	1,375	14	3,190	32	2,696	27
Average payment to service provider per job	(2,986)	(30)	(3,066)	(31)	(3,222)	(32)
Average payment to rental truck driver per job[a]	(578)	(6)	(5,756)	(58)	(2,889)	(29)
Average loss before incentive payment per job	(2,189)	(22)	(5,632)	(56)	(3,415)	(34)
Incentive payment to managing group per job	3,000	30	3,000	30	3,000	30
Average incentive payment for truck rental per job	578	6	5,756	58	2,889	29
Average managing group net revenue per job	1,389	14	3,124	31	2,474	25
Benefit-to-cost ratio	1.39		1.35		1.40	
Number of jobs	135	–	41	–	18	–
Total managing group net revenue	187,486	1,875	128,100	1,281	44,527	445

Numbers in parentheses represent losses.

Exchange rate is 1.00 USD = 100 KES (6 June 2019, oanda.com).

[a]For jobs completed by formal manual emptiers, we provided a 20 USD incentive per trip to the treatment site. The average incentive therefore is equal to the proportion of jobs completed by formal manual emptiers multiplied by the average number of trips to the treatment plant multiplied by 20 USD.

same service again at the same price (Table 5). When the Wastewater Association's customers were asked what they liked about the service, their most common response was price (56%); when asked what they did not like, only 9% responded that their pits were partially emptied and only 3% responded that the solid waste was not removed

Table 5 | Customer satisfaction across the managing groups, based on the independent follow-up survey conducted after the comparative study

		Overall ($n = 136$)	The Wastewater Association ($n = 78$)	Vukasasa ($n = 41$)	Nyalenda Water ($n = 17$)
Customer satisfaction score (5 = best, 1 = worst)		4.1	4.3	4.2	2.9
Intent to use	Yes, through this group, at the same price	70%	78%	61%	53%
	Yes, through this group, not at the same price	18%	14%	20%	35%
	No, not through this group, but at the same price	4%	3%	7%	6%
	No, not through this group, and not at the same price	4%	3%	7%	6%
	Don't know	3%	3%	5%	-
What customers liked	Price	43%	56%	17%	41%
	Quality of service	41%	40%	46%	35%
	Communication	8%	10%	5%	6%
	Proper fecal sludge removal	35%	24%	59%	24%
	Other[a]	28%	24%	30%	40%
What customers did not like	Price change after negotiation	1%	1%	0%	0%
	Pit partially emptied	15%	9%	17%	35%
	Solid waste not removed	2%	3%	2%	0%
	Smell	18%	14%	22%	24%
	Conceal from authority	18%	14%	24%	24%
	Other[b]	18%	14%	22%	24%

[a]Other includes: lack of smell, speed of emptying, and pit fully emptied.

[b]Other includes: service too expensive, sludge buried on site, sludge disposed in open.

(Table 5). Vukasasa received performance ratings comparable to the Association's (average rating of 4.2). Customers particularly appreciated the proper fecal sludge removal (59%) and the quality of service (46%) (Table 4). Nyalenda Water received the lowest average satisfaction rating of 2.9, with 35% of customers complaining that pits were not fully emptied (Table 5). Among households that did not use the subsidized service, 65% (35/54) reported they were not aware of the service, 20% (11/54) reported not needing to empty their pit, and 15% (8/54) reported that the price was too high or they lacked money; however, we did not collect information on whether households used an alternative service.

CONCLUSION

Study summary and key findings

To date, programs for improving fecal sludge management in low-income areas of Kisumu have focused on the development of formal manual emptying organizations that are recognized by local authorities, employ safety procedures and equipment, and transport fecal sludge to the KIWASCO fecal sludge treatment site. However, the respective roles of VTOs and formal manual emptiers in expanding safe sanitation services to low-income areas have not been rigorously investigated. In this study, we compared the economics of VTOs and formal manual emptying organizations. We also employed a financial incentives-based strategy to promote the expansion of safe pit-emptying services in a low-income area and compared the performance of three managing groups to coordinate these services: (1) The Wastewater Association; (2) a formal manual emptying organization; and (3) a community-based water supplier seeking to expand into pit-emptying.

Our economic analysis showed that VTOs were about four times more cost-effective than formal manual emptying organizations (Table 2). The main contributors to higher operating costs for formal manual emptying included truck rentals for transporting fecal sludge to the KIWASCO treatment site and labor expenses (Table 2). The Wastewater Association was more efficient in coordinating emptying services in low-income areas than the formal manual emptying organization and the community-based water supplier, both in the numbers of pits emptied and in the numbers of trips required to transport fecal sludge from an emptied pit to the treatment site (Table 3). The Wastewater Association also received the highest customer satisfaction ratings (Table 5) and maintained the most reliable records of business activities. These findings challenge the assumption that VTOs are not appropriate solutions for servicing low-incomes areas, at least in Kisumu, Kenya. On the contrary, VTOs can effectively service a large proportion of low-income households in Kisumu, using formal manual emptiers as a substitute in the fraction of cases where they cannot technically operate.

Service delivery model with potential to scale: sanitation 'switchboard'

The strong performance of The Wastewater Association in our comparative study was likely driven by multiple factors: their substantially lower operating costs and price points, their greater experience in marketing their services, their higher capacity for performing jobs through their membership of VTOs, and their adherence to accurate record keeping. On a pilot scale, the Association's service delivery model was successful in delivering safe sanitation: pits were safely emptied at a price point low enough to eliminate informal, unsafe pit-emptying as a viable economic substitute and households were satisfied with the Association's services. The key elements of this service delivery model were: (1) a competent local organization serving as a 'switchboard' between households and suppliers; (2) broad flexibility given to that organization to assess pits, set prices, choose appropriate suppliers, negotiate supplier payments, coordinate timing and terms, and ensure customer satisfaction by resolving disputes; (3) holding the organization accountable by careful monitoring of high-level outcomes and customer satisfaction; (4) providing an outcome-based incentive.

Our study clearly demonstrated that the choice of the organization matters. The organization needs to be visible and trusted by the community but also quite sophisticated in its business practices; experience in sanitation service provision is also critical. Another key element of the model is to entrust operational decisions to the organization,

rather than be prescriptive from the top down (for process, such as selecting suppliers, setting prices, marketing activities, etc.). For example, The Wastewater Association outsourced 11% (15/135) of their emptying jobs to the formal manual emptying group, Gasia Poa, because vacuum trucks could not reach the pits, or because the pits contained solid waste that required manual removal, or a combination of both factors (Table 3). This 'hybrid' service delivery approach combines the strengths of the two types of service providers and potentially promotes investments by the VTOs in the manual emptying organizations. The 'switchboard' model has substantial potential to scale in Kisumu (with the Wastewater Association) and beyond. Comparable 'switchboard' models in Dakar, Senegal, and Dhaka, Bangladesh, have shown promising results in expanding safe pit-emptying services in low-income areas, with the municipal utility and/or a private entity acting as the 'managing group' (ONAS 2014; FSM4 2017). The most appropriate organization to operate as a switchboard on a large scale will likely vary from city to city; the selection, training, and monitoring of this organization require careful consideration.

Addressing affordability

Service providers applied our payment incentives to subsidize their emptying fees: for example, despite estimated costs of 6,169 KES (62 USD) for formal manual pit-emptying, Vukasasa charged customers an average of 3,190 KES (32 USD) during our comparative study (Tables 2 and 4). These subsidies likely expanded their markets during the study period, as poor households are typically unable to afford safe pit-emptying services (Burt Sklar & Murray 2019; Peletz et al., forthcoming). Our study thus validated that financial incentives are effective at promoting the expansion of formal pit-emptying services in low-income areas. Identifying the optimal incentive amount to support regulated pit-emptying service delivery models at scale will require accurate measurements of WTP for pit-emptying among poor households and careful consideration of the prices charged by informal manual pit emptiers (J-PAL 2012; Daudey 2017). Further, identifying sustainable resources for these subsidies, whether from donor funds, government budgets, pro-poor sanitation surcharges imposed on utility bills, or higher fees charged to the wealthy (cross-subsidies), is an essential political consideration, if Kisumu is committed to improved fecal sludge management (Blackett & Hawkins 2017; Acey *et al.* 2019). For example, the cities of Wai and Sinnar in India finance inclusive scheduled desludging services through a surcharge on property taxes (Mehta Mehta & Yadav 2019).

Expanding treatment capacity and regulation

As a final political consideration, we emphasize the importance of increasing Kisumu's capacity and regulation of fecal waste treatment, both for disposal and reuse. As noted in the introduction, estimates indicate that the KIWASCO treatment site only receives about one-third of the fecal sludge generated in the city (Furlong & Jooust 2016). Programs to increase safe pit-emptying services will likely require augmentation of Kisumu's fecal sludge treatment and disposal infrastructure, including additional staff, drying fields, and standards for chemical use (e.g., odor neutralizers) during pit-emptying. The development of the Kisumu County Environmental Sanitation and Hygiene Policy and the Kisumu County Environmental Health and Sanitation Bill are promising steps for increased regulation for fecal sludge treatment (County Government of Kisumu 2018a, 2018b).

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DATA AVAILABILITY STATEMENT

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

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