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Determinants of household waste disposal practices and implications for practical community interventions: lessons from Lilongwe

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Abstract

Open waste disposal has a negative effect on local ecology, economy, and public health. Understanding factors influencing waste disposal decisions is necessary for developing solutions to curb open waste disposal. This paper discusses the associations between household's social demographic and spatial characteristics with preference for domestic waste disposal. The paper also utilizes this knowledge practical community action. This was achieved by gathering and examining a novel dataset of the waste disposal patterns of 200 randomly chosen households in Malawi. We observed that households were likely to dispose of their waste openly when the residential unit was closer to an existing open waste disposal site. A multinomial logistic regression model showed that the likelihood of choosing waste disposal methods, such as private garbage collection services, is higher when the household head is a woman, the housing unit is owned by the occupants, or in situations where a fence is present around the housing unit. We presented these findings to the neighborhood community development committee. A short-term community waste management plan was created using a participatory community planning approach. The plan included co-designing waste disposal solutions with landlords, setting up community waste bylaws, and intensifying civic education activities. In conclusion, our study provides insights into the factors that influence households' disposal behavior. This unique case study highlights a potential approach for developing waste management policies using a bottom-up approach.

1. Introduction

Proper waste management can significantly help to attain the sustainable development goals (SDGs). By contrast, improper waste management, a practice characterized by open disposal of waste in the environment is associated with unpleasant odor, pollution of water resources [1] and present serious threats to marine ecosystems [2] is still pervasive in low-income nations. For example, 70% of the waste produced in sub-Saharan Africa is openly disposed in the environment [3, 4].

The natural ecosystems eventually suffer damage from such practice. These characteristics remain to be barriers to attaining the SDGs, including ensuring healthy lives and promoting well-being for all ages (SDG 3), building sustainable cities and communities (SDG 11), promoting responsible consumption and

production (SDG 12), and protecting life under water (SDG 14). For instance, a study conducted in Pakistan noted that open dumping may cause soil pollution, which could harm crop growth, productivity, and agriculture [5]. Another study from South Africa reported that decomposing waste in landfills has an effect on the local ecology [6]. Additionally, research from several counties reported that open dumping's pollution could have a negative impact on health, exposing nearby residents to both carcinogenic and non-carcinogenic consequences [5–8].

In Malawi, the majority of the population lives in informal settlements and there is limited waste management infrastructure [9]. The national general waste disposal practices include open dumping of waste, waste collection [10], and composting of organic waste [11]. Open dumping typically takes place in open spaces, particularly along the side of road and on bridges [12], whereas garbage collection entails transferring the waste from the location of production for disposal elsewhere (particularly in landfills). The local government and city councils in urban regions of Malawi, such as Lilongwe (Malawi's administrative capital), are responsible for waste collection. However, less than 30% of the generated garbage is reportedly collected by authorities [13]. As a large portion of the population lacks access to waste collection services, the use of private waste collection organizations seems to offer a solution [14]. However, these services come at a cost that exceeds what households are generally willing to pay [14, 15].

In various regions of the nation, waste transfer facilities have been constructed to reduce garbage disposed of at designated dumpsites and to promote local composting and recycling [16]. Such facilities receive and hold waste collected from residences until it can be sent to a final waste disposal or processing facility [17]. According to a research conducted in the northern Malawian city of Mzuzu, the established infrastructure failed to deliver promised benefits due to community resistance [18]. Needless to say, the active engagement of local communities in setting up such infrastructure is needed to prevent such setbacks. Meanwhile, another study in southern Malawi reported that extensive patronage, hierarchical culture, and lack of necessary financial investments hinder the planning and implementation of sanitation programs [19].

Few studies have been conducted in Sub-Saharan Africa to investigate waste disposal-related factors. Alhassan *et al* (2020) investigated the determinants of Ghanaian households' solid waste disposal options. They discovered that the gender, age, income, and employment of the household heads, as well as housing type and attitude towards source separation, all influence household' solid waste disposal options [20]. Another study in Ghana found that similar socioeconomic factors motivate households to use a specific solid waste disposal system [21]. In Cameroon, lack of access to legal alternatives and closer distance to illegal waste dumpsites were reported as motivators for illegal waste disposal [22]. Uma *et al* conducted a gender-differentiated analysis in Nigeria. The study discovered that factors such as education, non-home ownerships, and water availability, are associated with household waste disposal choices [23]. The study also highlighted the gender difference in waste disposal choices [23].

Research conducted in other Sub-Saharan African countries also indicates that factors associated to waste disposal behaviors are country or area specific [20–24]. To our knowledge, in Malawi, there is no published study that provides understanding of the factors associated with household characteristics and waste disposal practices. Therefore, the drivers of different waste practices among households in Malawi remain unknown. In addition, transforming the knowledge related to waste disposal behaviors into policy actions remains a challenge.

Accordingly, this study set out in a small community in Malawi to explore associations between household social, economic, demographic and spatial variables with household waste disposal practice. Secondary to this, the study draw upon patterns of association between household characteristics and preference for improper waste disposal practices to engage community leaders in developing community waste management plans.

2. Methods

Figure 1 depicts the scope of our research. First, we gathered household information on waste disposal and other characteristics. The data were collected from randomly selected households in Lilongwe, the administrative capital of Malawi. Second, we conducted both univariate and multivariable analyses to investigate how household characteristics such as socioeconomic factors, proximity to community waste dump sites, and perceptions of waste management responsibility, impact waste disposal choices. Finally, we shared the findings with the local development committees and traditional leaders. A short-term waste management plan was developed based on our results.

2.1. Study community
The study was conducted in Lilongwe, the administrative capital of Malawi. Waste collected in the city is disposed of in Area 38 at a place referred to as 'Ntaya'. The study community, Area 22 B, is a residential area
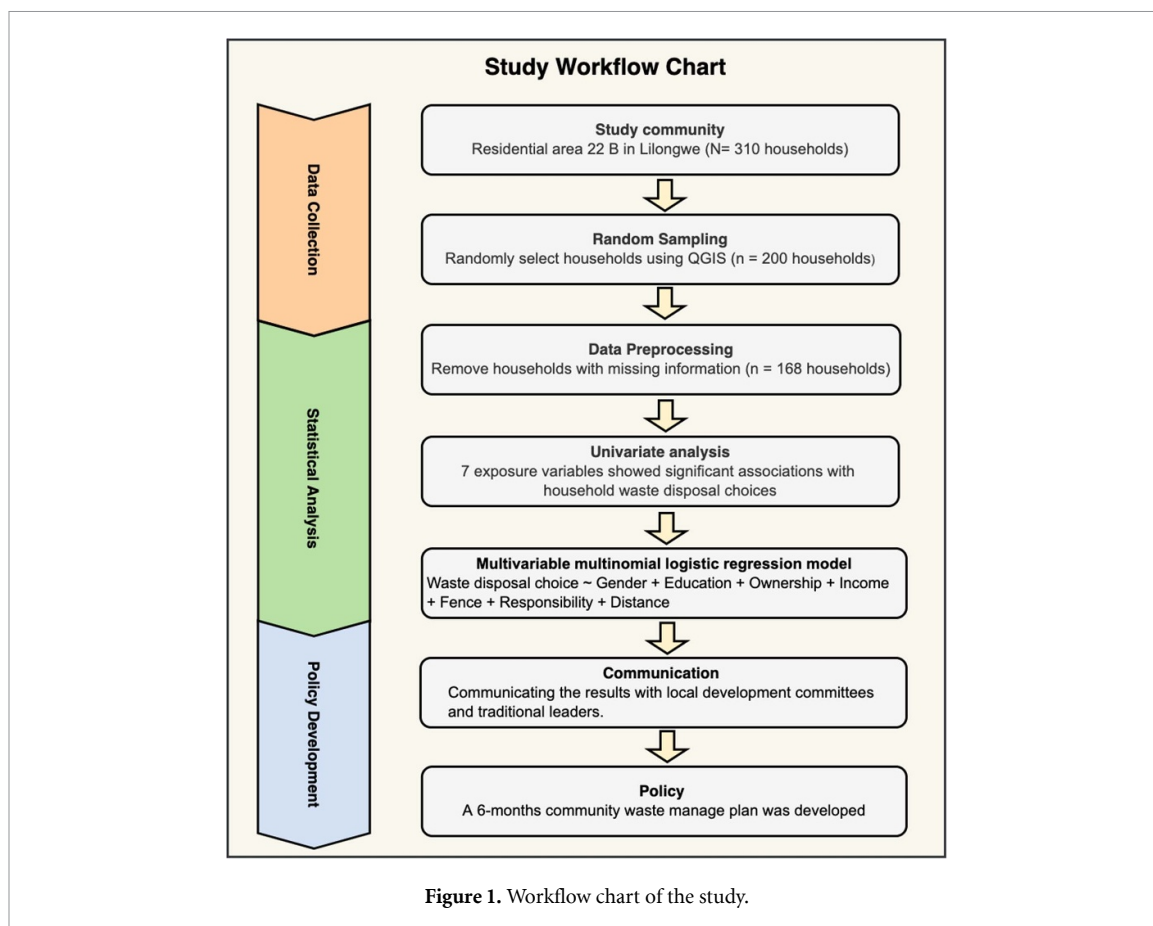
Figure 1. Workflow chart of the study.

within the city of Lilongwe which is located 4 km away from Area 38 (figure 2). The lower left part of figure 2 presents a map of the Africa continent with the study community marked on the map. Within Area 22B, there are waste collection services offered to residents by private waste collection companies. Open dumping of waste into the environment has been previously reported by members of a community environmental club, and the data was shared on an open platform called 'Open Litter Map' [25]. The majority of the dumpsites from the community reported in the Open Litter Map are in close proximity to bridges (https://openlittermap.com/global?lat=−14.013682586605729&lon=33.79969596862794&zoom=16), and as such the river washes the waste down the slope during rainy periods [26]. Some households dig a waste disposal pit for composting organic waste into manure and possibly set up a backyard garden. Other households chose to burn the waste. It was reported that 5.6% of the households in Lilongwe city practice burning domestic waste [27].

2.2. Data collection

In our study, we used a hypergeometric distribution to calculate the sample size of 200 households because we have a small population of 310 households (figure 2), and the sample size is a significant fraction of the population odel [28]. The hypergeometric distribution is often used in such cases because it takes into account the fact that the sample is being drawn from a finite population without replacement.

The 200 households were randomly selected using the geographical information systems software QGIS (version 3.14.14) as follows. We firstly downloaded the footprints of all buildings within our study area from OpenStreetMap (OSM) [29]. Using the research team's pre-existing knowledge of the area, all known non-domestic structures were removed from the dataset (i.e. community cemetery, maize mills, religious institutions, and schools). Additionally, building footprints with an area of less than 30 m^2 were excluded under the assumption that they were domestic outbuildings such as outdoor kitchens or bathrooms. The remaining polygons were assigned unique identifiers, and 200 polygons were randomly selected. These polygons were uploaded to the ArcGIS Field Map Android app (www.esri.com/en-us/arcgis/products/arcgis-field-maps/overview) to enable the survey team to subsequently locate the selected locations.

The methods employed in this study are similar to those that were previously used in prior studies [20, 22–24]. However slight modifications were implemented. Heads of the households were interviewed using a questionnaire (table S1). A summary of the variables studied in the survey and the outcomes available for
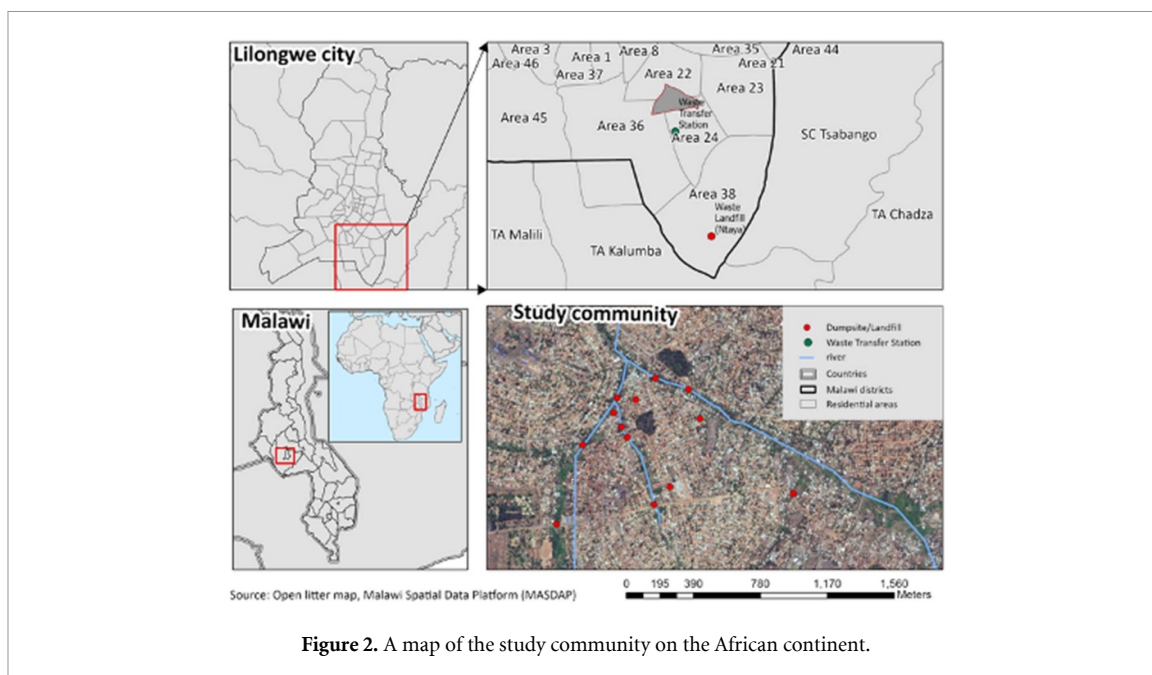
Figure 2. A map of the study community on the African continent.

Table 1. Description of variables and possible outcomes considered in the study.

Variables	Description	Outcome
Disposal method	Most used waste disposal method	Improper options, dig waste pits or incinerator burn, or private trash collectors
Gender	Gender of the household head	Female or male
Age	Age of household head	Age in years
Size	Household size	Number of people
Education	Highest education level of household head	Primary education, secondary education, or university or vocational
Ownership	Whether the household owned the house	Yes or no
Income	Household monthly income level	Below MWK 50 000 (USD 48.51), MWK 50 000–10 000 (USD 48.51–98.57), or over MWK 100 000 (USD 98.57)
Fence	The presence of fence around the compound	Yes or no
Responsibility	Perception of responsibility on waste management	City council or household
Distance	Distance to the nearest dump site	Distance in meters

each variable are shown in table 1. Households in the study area were asked to choose the most used method from the four options for waste disposal, namely, digging waste pits, private waste collection collectors, incinerator burn, and other options. From a local perspective, private waste collection collectors, digging waste pits, and incinerator burning are considered proper waste disposal methods. The incidence of incinerator burn was too low in our data set (seven observations). Thus, we combined incinerator burn and the digging waste pits into one category. Other options are considered improper waste disposal methods (e.g. open dumping of waste) that threaten the environment natural ecosystems.

Additional demographic and socioeconomic data captured by the survey included gender of household head, age of household head, the largest household size, household head level of education, ownership of housing unit, household income level, presence of fence around the compound, and perception of responsibility on waste management.

In addition to the variables collected through the questionnaire survey, geographical coordinates for each household were collected and using QGIS, the Euclidian distances to the dumpsites in the community were calculated, and the waste dumpsite with the minimum distance was considered as the nearest dumpsite to the housing unit of the respondent.

2.3. Statistical analysis

Household characteristics were summarized using median (interquartile range) for continuous variables and frequencies (%) for categorical variables. Comparisons between groups were made using Wilcoxon signed rank test and chi-square or Fisher exact test, as appropriate. Using a significant level of 0.05, we then included those variables found to be significant by these comparison methods in a multivariable multinomial logistic regression model [30], with waste disposal options as the response variable.

The resulting estimated associations were reported using odds ratios (ORs) and 95% confidence intervals (CIs), with improper waste disposal as the reference category. Statistical analyses were conducted using R version 4.1.2.

2.4. Communicating the results with the local community

The results were shared with the local development committees and traditional leaders, and possible practical actions were discussed. Here, a facilitator first presented all the research findings and allowed the participants to ask questions in areas that were not clear. This was followed by a discussion based on specific research findings. The participants suggested activities that can be done in the community and were asked to agree on whether it is practical to implement the suggested activities. Activities that were not practical were dropped, and the practical activities were organized into a six-month action plan.

3. Results and discussions

3.1. Description of the outcomes of the sampling process

A total of 1613 polygons were downloaded from OSM. A total of 292 polygons were excluded, and 1321 polygons were retained. All the retained buildings were assumed to be houses, and after applying a random selection algorithm, 200 buildings were selected for data collection.

3.2. Descriptive statistics of household choice of waste disposal options

With regards to gender and age of the households' heads, 52% are females with a median age of 43 (IQR = 19.00) years. Household head's frequently reported that their highest educational level was secondary education (97 [48.5%]) followed by primary education (59, [29.5%]). Only 31 (15.5%) of the sampled household heads had a university or vocational degree. Most of the households (174 [87%]) earn less than MWK 100 000 (USD 98.57) per month. The median household size was 5 (IQR = 2.00) persons per household, and approximately 113 (56.5%) of the household owned their own house. Full descriptive statistics for each of the captured variables are presented in table 2.

Data were not available for all individuals. 15 responses have a missing age; 13 responses have a missing education; 1 response has a missing ownership; 27 responses have a missing income.

(a) Chi-square test was used to determine the *p*-value.
(b) Fisher exact test was used to determine the *p*-value.
(c) Wilcoxon signed rank test was used to determine the *p*-value.

More than half (105, [52%]) of the households had a fence around the compound. A total of 37% ($n = 74$) of the households thought the city councils were responsible for managing/collecting waste to designated locations. The median distance to the nearest dump site was 174 (IQR = 135) meters. Regarding the waste disposal choices, 33 (16.5%) of the households used improper waste disposal methods, 106 (53%) chose to dig a waste pit or burn the waste, whereas 61 (30.5%) chose to use private trash collectors (table 2).

3.3. Multiple factors are associated with household waste disposal choices in univariate analysis

The results of the univariate analysis are also presented in table 2. The households that dispose waste with improper methods have a higher proportion of being male-headed households (63.6% for improper disposal methods vs. 38.7% for digging a waste pit or incinerator burn vs. 55.7% for private trash collectors, $p = 0.015$). Those households also tend to have a younger household head, although the differences are not statistically significant (median = 38.50 years for improper disposal methods vs. 44.00 years for digging a waste pit or incinerator burn vs. 43.50 years for private trash collectors, $p = 0.362$).

Compared to households who use private trash collectors, households that chose improper waste dump methods have lower proportions of having a highly educated (university or vocational) head (9.7% vs. 32.7%, $p = 0.001$) and monthly income over MWK 100 000 (USD 98.57) (12.1% vs. 30.0%, $p = 0.002$). A lower proportion of households who own their house chose improper waste disposal options as compared to

Table 2. Household Characteristics Overall and by Waste disposal options.

Characteristic	No. (%)				*P*-value
	Overall ($N = 200$)	Improper ($n = 33$)	Waste pit or burn ($n = 106$)	Private trash collectors ($n = 61$)	
Gender					0.015[a]
Female	104 (0.52)	12 (36.4)	65 (61.3)	27 (44.3)	
Male	96 (0.48)	21 (63.6)	41 (38.7)	34 (55.7)	
Age (median, IQR)	42.94 (19.00)	38.50 (17.75)	44.00 (19.50)	43.50 (16.75)	0.362[c]
Household size (median, IQR)	5.00 (2.00)	5.00 (2.00)	5.00 (2.00)	5.00 (2.00)	0.843[c]
Education					0.001[b]
Primary education	59 (29.5)	10 (32.3)	41 (40.6)	8 (14.5)	
Secondary education	97 (48.5)	18 (58.1)	50 (49.5)	29 (52.7)	
Vocational or college	31 (15.5)	3 (9.7)	10 (9.9)	18 (32.7)	
Ownership					0.036[a]
No	86 (43.0)	19 (57.6)	48 (45.7)	19 (31.1)	
Yes	113 (56.5)	14 (42.4)	57 (54.3)	42 (68.9)	
Income					0.002[b]
Below MWK 50 000	92 (46.0)	13 (43.3)	60 (64.5)	19 (38.0)	
MWK 50 000–10 000	55 (27.5)	13 (43.3)	26 (28.0)	16 (32.0)	
Over MWK 100 000	26 (13.0)	4 (12.1)	7 (7.5)	15 (30.0)	
Fence					<0.001[a]
No	96 (48.0)	21 (63.6)	67 (63.2)	8 (13.1)	
Yes	104 (52.0)	12 (36.4)	39 (36.8)	53 (86.9)	
Responsibility					0.012[b]
Households	126 (63.0)	26 (78.8)	70 (66.0)	30 (49.2)	
City council	74 (37.0)	7 (21.2)	36 (34.0)	31 (50.8)	
Distance (median, IQR)	173.54 (134.92)	123.05 (124.88)	173.55 (135.05)	186.06 (128.05)	0.059[c]

those who do not have the ownership of their house (42.4% vs. 52.3% vs. 68.9%, $p = 0.03$). We also found that households that have a fence around the compound and indicate the city councils are responsible for managing waste are less likely to use improper waste disposal options ($p < 0.001$ and $= 0.012$, respectively).

Households who dump waste using improper methods were closer to their nearest dumpsite in comparison to those who used proper disposal methods (median $= 123.05$ m for improper disposal methods vs. 173.55 m for digging a waste pit or incinerator burn vs. 186.06 m for private trash collectors, $p = 0.059$).

As these differences were borderline significant, we generated violin and boxplots of distance to the nearest dumpsite in three waste disposal categories to explore the difference further. Figure 3 suggests distances to the nearest dumpsite distributions are different among three waste disposal groups. For example, for households that chose improper waste disposal options, the frequency of shorter distances to the nearest dumpsite is higher in comparison to the other two categories (widening of the violin plots near value 0 for improper methods in figure 3). We, therefore, include the distance to the nearest dumpsite in the final model. No significant association was observed between the age of the household head and household size with their waste disposal choices ($p = 0.362$ and 0.843, respectively). These variables were therefore excluded from the multivariable model.

3.4. Determinants of household waste disposal choices in multivariable multinomial logistic regression analysis

Table 3 presents the multinomial logistic regression estimation of the determinants of households' choice of waste disposal, with the improper waste disposal methods as the reference category.

After adjusting for other covariates, the gender and education level of a household's head show significant effects on waste disposal choices. Female-headed households were significantly associated with increased odds of both digging a waste pit or incinerator burn (OR $= 3.17$, 95% CI $= (1.19–8.40)$) and using private trash collectors (OR $= 4.13$, 95% CI $= (1.26–13.56)$). This finding is consistent with recent studies conducted in Ghana, Indonesia, and Ethiopia [20, 31, 32]. Studies have indicated that women have modestly stronger pro-environmental values than men [33–35]. In Korea, it was observed that pro-environmental behaviors among females are affected by their lifestyles and social norms [36]. In some societies, responsibilities for domestic waste management and sanitation are expected from women [21]. A similar study in Zimbabwe found that gender was not associated with waste receptacles used by households [37]. It might also be possible that in female headed households less waste is produced and such low quantities of
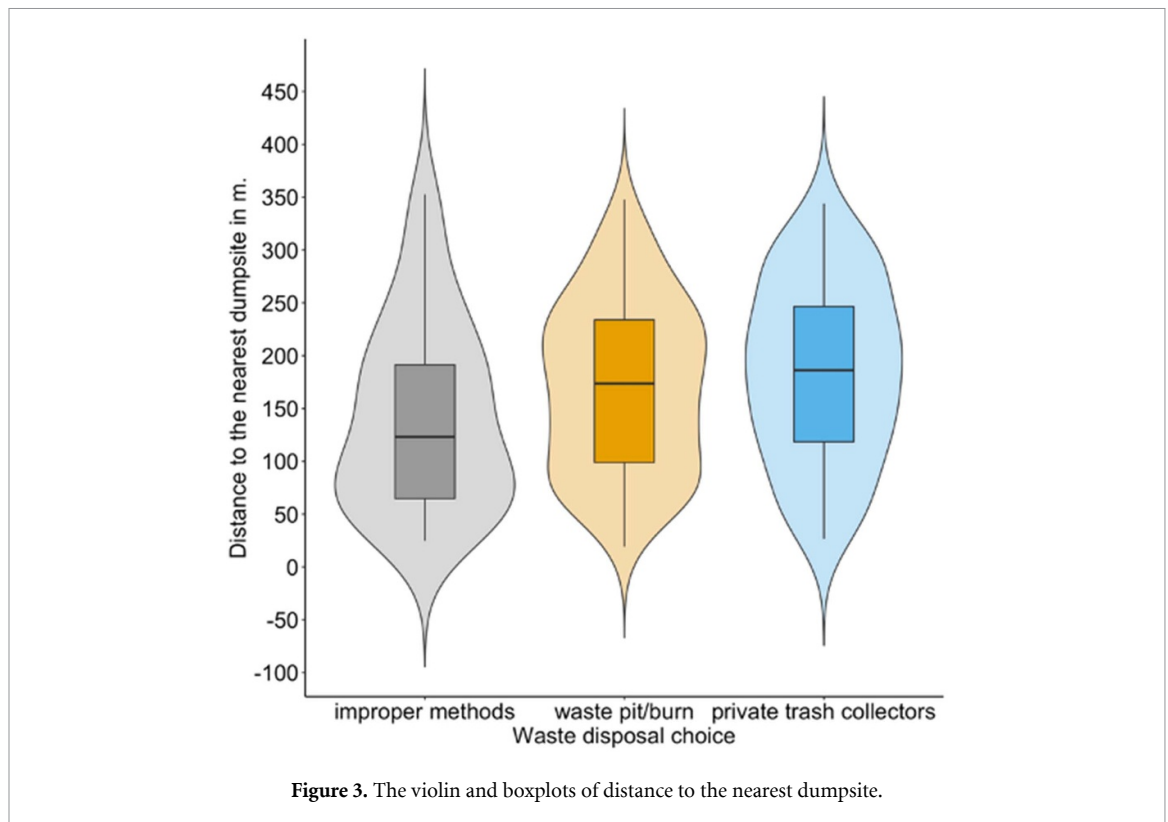
Figure 3. The violin and boxplots of distance to the nearest dumpsite.

Table 3. Multivariable multinomial logistic regression model for waste disposal choices. Asterisks indicate statistical significance: $p < 0.10^*$; $p < 0.05^{**}$; $p < 0.01^{***}$.

	Waste disposal choice			
	Waste pit or burn		Private trash collectors	
Factors	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Gender (female vs male)	3.17 (1.19–8.40)	0.020**	4.13 (1.26–13.56)	0.019**
Education				
Primary education	1 [Reference]	NA	1 [Reference]	NA
Secondary education	0.96 (0.33–2.81)	0.95	2.75 (0.63–12.09)	0.18
University or vocational	1.15 (0.18–7.34)	0.88	4.71 (0.60–37.34)	0.14
Ownership (yes vs no)	3.37 (1.23–9.24)	0.018**	4.07 (1.23–13.39)	0.021**
Monthly income				
Below MWK 50 000	1 [Reference]	NA	1 [Reference]	NA
MWK 50 000 to MWK 100 000	0.39 (0.13–1.17)	0.09*	0.38 (0.10–1.41)	0.15
Over MWK 100 000	0.27 (0.040–1.65)	0.16	0.29 (0.046–1.83)	0.19
Fence (yes vs no)	1.48 (0.46–4.83)	0.51	17.34 (4.11–73.01)	<0.001***
Responsibility (city council vs households)	2.22 (0.72–6.81)	0.16	3.53 (1.00–12.52)	0.05**
Distance (meters)	1.00 (1.00–1.01)	0.13	1.01 (1.003–1.02)	0.006***

waste are easily managed through onsite waste management initiatives. However, it is not clear in literature on whether indeed gender alone can be used as a proxy for possible quantities of waste that is produced by an individual or household. Some studies have reported that females produce less food waste [38] while others indicate the complete opposite with some studies reporting low quantities of waste from male household heads [39, 40]. The associations between gender of the household head on quantity of waste produced and subsequent waste disposal preference should be explored comprehensively.

The odds of using private trash collectors as opposed to improper methods increase with household heads' education level. The benefit of university or vocational education (OR = 4.71, 95% CI = (0.60–37.34)) is greater than secondary education (OR = 2.75, 95% CI = (0.63–12.09)). The positive but non-significant relationships between proper waste dumping were also reported in the previous studies [20, 22, 24]. Education showed significant impacts on waste disposal decisions in studies with larger sample sizes [23, 41]. The benefits of higher education levels shall be further investigated in future studies.

Our study is the first to explore associations between the presence of a fence and household waste disposal practice. 17-fold increased odds (OR = 17.34, 95% CI = (4.11–73.01)) of using private trash collectors for a household with a fence around the compounds compared with those without a fence was observed after adjusting for other characteristics. The presence of a fence was associated with nearly 50% (OR = 1.48, 95% CI = (0.46–4.83)) increased odds of using a waste pit or incinerator burn, yet the association was not statistically significant.

A possible explanation for this observation is that households with a fence around the compound have enough income to pay for private waste collection services [42]. Indeed, our data suggest households with a fence have higher income levels as compared to those without a fence (table S2; $p < 0.001$). We also found that households with a fence tend to be headed by those with university or vocational degrees (table S2, $p < 0.001$). The presence of a fence can be used to capture the households' socioeconomic status in waste disposal behavior studies when factors such as income and education level are unavailable. There may be factors contributing to this association that were not measured. Future studies are needed to further evaluate the associations between the presence of a fence and household waste disposal practice.

Owing the house was associated with an increased chance of choosing proper waste disposal options over improper ones. The benefits of house units' ownership on digging a waste pit or incinerator burn (OR = 3.37, 95% CI = (1.23–9.24)) and using private trash collectors (OR = 4.07, 95% CI = (1.23–13.39)) are similar. Homeowners have more control over the activities of a land parcel, and they can decide to facilitate the digging of a waste disposal pit, which explains the increase in probabilities of using waste disposal pit. It is worth noting that our observation differs from what was previously reported in Ghana [20]. Unlike Malawi, landlords in Ghana are mandated to register with formal waste collectors that are assigned to the community [20]. This decreases the odds of subscribing to private waste collection services among households staying in their own homes [20]. Therefore, people in Ghana who own their homes have a higher probability of disposing domestic waste in open places [21].

The association between perception of responsibility for waste management and waste disposal choices is another novel finding study. The increased odds were significant for choosing private trash collectors (OR = 3.53, 95% CI = (1.00–12.52)), and non-significant for digging a pit or incinerator burn (OR = 2.22, 95% CI = (0.72–6.81)). No associations between waste disposal choices and monthly income level were observed after adjusting for other factors. Those findings imply that the perception of waste management responsibility does not excuse households from practicing open waste dumping. The perception of waste management responsibility can support local councils to save resources for the management of waste. However, as the city council has the legal mandate for the management of waste in Lilongwe, it is possible that households are indicating the responsibility of the city council in planning and regulating waste management practices on a broader scale.

Compared with households using improper waste dump methods, the distance to the nearest dump site was associated with an increased odds of using a private trash collector. Specifically, 100 m increase in the distance to the nearest dump site increase the odds of using private trash collectors by 100% (OR = 1.01, 95% CI = (1.003–1.02)). No associations between digging a waste pit or incinerator burn and distance to the nearest dump site were observed. Studies in Yaoundé and Ethiopia have reported similar findings [22, 24]. A possible explanation for the positive relationship between choosing private waste collectors and distance from existing open waste dumping locations is convenience. Households that live closer to open dumping locations will have to invest relatively low effort and time to dispose their waste at the open dumpsites.

3.4.1. A short-term community waste management plan

The results were shared with the local actors (local development committees and traditional leaders) to influence localized interventions against improper dumping. This activity brought together key community stakeholders to explore practical community actions. Figure 4 is a photo of the study team presenting the key findings to a community development committee. On the blackboard, there is a template of a table for the development of a short-term community waste management plan.

The stakeholders suggested that based on the findings, it is imperative to necessitate conversations between landlords and local leaders on waste management, including the need to have a proper waste management option for tenants. The committee also highlighted the importance of attracting men to waste management programs in the community. It was also agreed that there is a need for environmental awareness campaigns to discourage community members from disposing waste in open places.

All the suggested activities were tabulated into a short-term (6 months) community action plan. The plan includes working with landlords in co-designing solutions that will minimize waste disposal in the environment by their tenants or customers. In addition, the plan includes disseminating messages to

Figure 4. Presentation of the key findings to a community development committee.

intensify civic environmental awareness. The messages will be disseminated on waste disposal in community meetings and using public address systems. Targeting male household heads in community waste management programs and setting up community waste bylaws are also part of the plan. The proposed activities largely focus on educational campaigns and similar activities were proposed in a different study that was conducted in a context of Europe [43].

The committee acknowledged that there was limited capacity to develop more ambitious plans such as initiating community waste recycling programs and enforcement of regulations on waste disposal practices because of its limited technical, financial, and legal constraints. This suggests that the involvement of other stakeholders such as local government is indispensable.

3.4.2. Study strengths and limitations

This study identified key factors associated with household waste disposal practices and transformed the findings into practical community actions. This is the first study in Malawi to explain household waste disposal practices based on households' socioeconomic attributes and spatial factors. Another strength of our study is that we demonstrated that the findings could be used to guide the development of community waste management plans.

Our study has several limitations. First, only 16.5% of the households were observed to practice open waste dumping. The presence of a self-reporting bias may lead to the underestimation of the occurrence of open waste dumping. In addition, we assume that open waste dumping is practiced only by households that do not choose proper waste dumping methods. There is a possibility for households to choose multiple waste disposal practices. Our assumption needs to be validated with empirical evidence on the effectiveness of proper waste disposal practices. Related to the same, private waste collection is currently done with the intention to dispose the waste in a landfill elsewhere. It is well known that waste disposal in a landfill is associated with generation of leachate, methane in the pit is not necessarily proper.

Second, the 200 households were collected from a single community. Insights drawn from this study need to be validated in different communities. It is therefore recommended that future studies should explore determinants of waste disposal practices by exploring data from multiple and diverse communities in Malawi or other low- and middle-income countries.

Furthermore, the distance between households and waste dumpsites has been computed using Euclidian distance. The use of road distance may provide a more accurate estimate of the influence of distance on waste disposal choice.

One potential limitation of our study is the presence of non-respondents, which raises concerns about self-selection and the potential for bias in the sample. Despite our efforts to use a random sampling approach, make multiple attempts to contact each household, and include a response rate calculation, it is possible that some households may have been more or less likely to participate due to various factors such as their beliefs. The potential threats posed by non-respondents include the possibility that they may differ from respondents in ways that were not measured in this study, such as their attitudes on waste management, religions, or characteristics. This could introduce self-selection bias into the sample, which could affect the accuracy and generalizability of the results. Despite this limitation, the overall high response rate of 84% and the steps we took to address the issue provide a strong basis for the validity and generalizability of our findings.

Finally, the community waste management plan developed during the study needs further investment. The plan primarily focused on targeting stakeholders such as landlords and male household heads. However,

the plan did not specify targets that can help evaluation of changes in general waste disposal practices in the community. In addition, there is a need to strengthen of local governance structures to develop solutions to community environmental challenges. To improve the plan, future work can consider engaging stakeholders such as local government and private waste collectors. Organizing a longer planning session to allow the stakeholders to exhaust all possible actions is another future direction.

4. Conclusions

This study set out to investigate the factors associated with household waste disposal choices in Malawi and explore possibilities of using this knowledge to inform local action. The study has found that female-headed households are more likely than male-headed households to choose onsite waste management practices or private waste collection services. Currently, the majority of sanitation programs target women. However, changes are needed to increase the participation of male household heads in sanitation programs. For example, more waste management programs targeting male household heads should be developed. This may improve waste disposal practice among male household heads. The study also observed similar associations between waste disposal practice and ownership of the housing unit and the presence of a fence. This observation point out the need to expand the participation of households on rented properties in private waste collection programs and onsite waste management practices or proper waste management programs. A mandate on property owners who lease out houses to other to have waste management options can be a good starting point. Another example is to encourage the participation of tenants in waste collection programs [20]. Such action should be taken after proper consultations with local communities. In addition, waste management programs targeting households without fences should be considered. Equally, the findings indicate positive associations between participation in private waste collection programs and households that perceive that waste management is a shared responsibility of both the city councils and local communities. This observation highlights the need for city council to deliberately engage residents of the city on their mandate as an administrative authority, their level of engagement in waste management programs plus the unique role which households in communities can play in managing domestic waste materials. Finally, the distance to open dumpsites in the community was positively associated with participating in private waste collection programs. Despite the expectation that households that live closer to open dumping locations will have to invest relatively lower effort and time to dispose their waste at the open dumpsites, our observation reveals otherwise. Likely, households that live close to waste piles directly experience problems associated with waste piles (for example bad smell, blockage of water channels) and this might have influenced their pro-environmental waste disposal practice. Considering this observation, the challenge is on optimal approach for engaging households in the community on waste management programs based on their proximity to existing waste piles. Regardless, designing of waste management programs that target groups that are likely to openly dispose their domestic waste should be prioritized in the future. Another area for future research is to investigate drivers associated with pro-environmental behavior (characterized by preference towards onsite composting and private waste composting) among female household heads. This can help in identifying opportunities for promoting the same among male household heads.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

Conflict of interest

The authors declared no competing interests.

Ethical statement

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