Household Solid Waste Management in the Wa Municipality, Ghana

Household Solid Waste Management

Patrick Aaniamenga Bowan[1]
Department of Civil Engineering
Dr. Hilla Limann Technical University
Wa, Ghana
p.a.bowan@dhltu.edu.gh

Sumaya Abdulai[2]
Department of Civil Engineering
Dr. Hilla Limann Technical University
Wa, Ghana
mahyah8888@gmail.com

Edward Boamah[3]
Technical Department
Digital Earth Africa,
Accra, Ghana
nanaboamah89@gmail.com

***Abstract* — Improper solid waste management (SWM) poses serious health hazards, which lead to the spread of diseases. This paper examines household SWM in the Wa Municipality in Ghana. The study adopted an explanatory sequential research design and applied qualitative and quantitative research methods. Correlations tests were performed to observe the correlation between some demographic variables of the respondents and their solid waste disposal method. Digital Earth Platform was also used to observe variations in settlement in the study area. The results revealed that there were no pre-treatment and processing of the collected waste before final disposal. The spatial map findings showed a high variation in settlement (over 50% increase) within five years. A test on the correlation between age, educational level, and waste disposal method produced p > 0.259 and p < 0.201 respectively. The paper proposes the sorting of solid waste at the generation point and the adoption of an integrated SWM system to ameliorate the household SWM challenges in the Wa municipality.**

Keywords—Household Solid Waste; Solid Waste Storage; Solid Waste Collection; Solid Waste Disposal; Waste Segregation; Willingness to Pay; Correlation Test; Digital Earth Platform; Wa Municipality.

I. INTRODUCTION

Solid waste management (SWM) is a local issue with global implications. As the world's population continues to grow, so does the amount of waste being produced. The quantity of solid waste (SW) generated globally per year since 2015 is over two billion metric tons [1]. This number is expected to grow to 3.4 billion metric tons by 2050 [2]. In low-income countries, the amount of waste is expected to increase by more than three times by 2050 [3]. However, cities and local governments face many challenges when it comes to properly managing SW. As a result, it is estimated that at least two billion people live in areas that lack waste collection and rely on uncontrolled dumpsites [4], which present serious risks to human health, the environment, and livelihoods in these areas.

Nonetheless, concerns about sustainable development (SD) have made improving SWM, especially in developing countries, prominent at the current time [5].

Consequently, the United Nations (UN) General Assembly, included SWM in the 2030 Agenda for SD. The specific goals which focus on SWM are sustainable development goal (SDG) 11 - *"make cities and human settlements inclusive, safe, resilient and sustainable"* and properly delineated in target 11.6: "*by 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management*, and SGD 12 – "*ensure sustainable consumption and production patterns*", and appropriately outlined in targets: 12.3 – "*by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses*", 12.4 – "*by 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment*", and 12.5 – "*by 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse*".

However, failing economic models treat resources as if they were infinite and consumption patterns favour their disposal [6], which is making the attainment of the SWM related SDGs, particularly in some developing countries to be a mirage. For instance, the proliferation of plastics has been devastating for the planet and its inhabitants, both current and future. Three-quarters of the vastest open dumps in the world are on the coast, leaching hazardous materials into our oceans [7]. As a result, large marine mammals are washing up on shore dead and their bellies are found to be so full of plastics [8].

One of the cardinal factors responsible for large SW generation, particularly in developing countries, is urbanization, which introduces to society a new and modern way of life. However, when the rate of urbanization gets out of control, it poses a huge challenge to governance and institutional arrangements for effective SWM [9]. Therefore, many communities in developing countries often turn to SW disposal methods that have proven to be destructive to human health and the environment, such as open dumping and burning. However, effective SWM has the potential of contributing to SD [10], [11], through proper SW processing technologies and disposal.

This study examines household SWM in the Wa Municipality of Ghana, focusing on households' SWM practices, households' willingness to pay for SW collection, households' knowledge of waste segregation, and the institutional arrangements for SWM in the municipality. SWM has become a major problem in Ghana, including the Wa Municipality, as indiscriminate dumping, irregular collection, poor storage and inadequate resources are the main problems facing SWM in the municipality [12]. A familiar scene in most suburbs of the municipality is littering, choked drains, heaps of SW, overflowing communal containers, and a general absence of communal collection containers (CCCs) in a good number of neighbourhoods in the municipality [13]. Refuse dumps are seen almost at the back of low-income dwellings, as the proliferation of polythene bags for packaging has compounded the problem of open dumps in the municipality [14].

Nevertheless, waste that is not properly managed poses serious health hazards leading to the spread of diseases. Unattended waste lying around attracts flies, rats and other creatures that spread diseases. In addition, soil contamination is the number one problem caused by improper waste removal and disposal. Some wastes that end up in open dumps excrete hazardous chemicals that leak into the soil. Also, hazardous wastes in the environment leech into the ground, and ultimately, into groundwater.

Groundwater, which is extracted through wells and boreholes is used for many things, from watering the local fields to drinking and other domestic purposes. Toxic liquid chemicals from SW can also seep into water streams and bodies of water. Furthermore, improper disposal of SW can greatly affect the health of the population living nearby polluted areas or open dump sites. Waste workers, including scavengers, are usually at a greater risk. Exposure to improperly handled wastes can cause skin irritations, blood infections, respiratory problems, growth problems, and even reproductive issues [15].

Also, decomposing waste emits gases that rise to the atmosphere and trap heat. Greenhouse gases are one of the major causes of the extreme weather changes that the world is experiencing [16], [17], from extremely strong storms and typhoons to smouldering heat, people are experiencing and suffering negative effects of greenhouse gases [18]. Thus, something needs to be done to ensure effective and sustainable SWM that will avert these dangers.

II MATERIALS AND METHODS

A. The Study Area

The study was conducted in Wa Municipality in the Upper West Region (UWR) of Ghana. The target population was households. The Wa municipality is a middle-sized town with a large rural component. It is one of the eleven District/Municipal Assemblies that make up the UWR of Ghana. It was initially named the Wa District and was upgraded to Wa Municipal in 2004 with Legislative Instrument (LI) 1800 in pursuant to the policy of decentralization which started in 1988. Under section 12 of the Local Government Act 2016 (Act 936), the Assembly exercises deliberative, legislative and executive functions in the Municipality. The Wa Municipal shares administrative boundaries with Nadowli - Kaleo District to the north, Wa East District to the east and to the west, and Wa West District to the south. It lies within latitudes 1º40'N to 2º45'N and longitudes 9º32'W to 10º20'W.

The population of Wa Municipal, according to the 2021 Population and Housing Census, is 200,672 representing 22.3% of the region's total population. Males constitute 49.1% and females represent 50.9%; and about 28.6% of the population reside in rural localities [19]. Furthermore, the Municipality has a household population of 190,962 with a total of 49,500 houses; the average household size in the municipality is 3.9 persons per household [19].

In addition, to understand the SWM practices in the municipality, visualizing and understanding the settlement patterns is essential. Thus, the researchers used Digital Earth Africa's (DE Africa) platform to compare the settlement between 2013 and 2019 in the Wa Municipality, using ESA Climate Change Initiative Land Cover at 300m spatial resolution. The International Panel for Climate Change (IPCC) classification obtained using he De Africa platform for the Wa Municipality focusing on waterbodies, settlement, other land, wetland, grassland, cropland, and forest for 2013 and 2019 indicate a significant change in the settlement in the Wa Municipality as indicated in Figure 1, which makes improving SWM to be a prominent issue in the municipality.

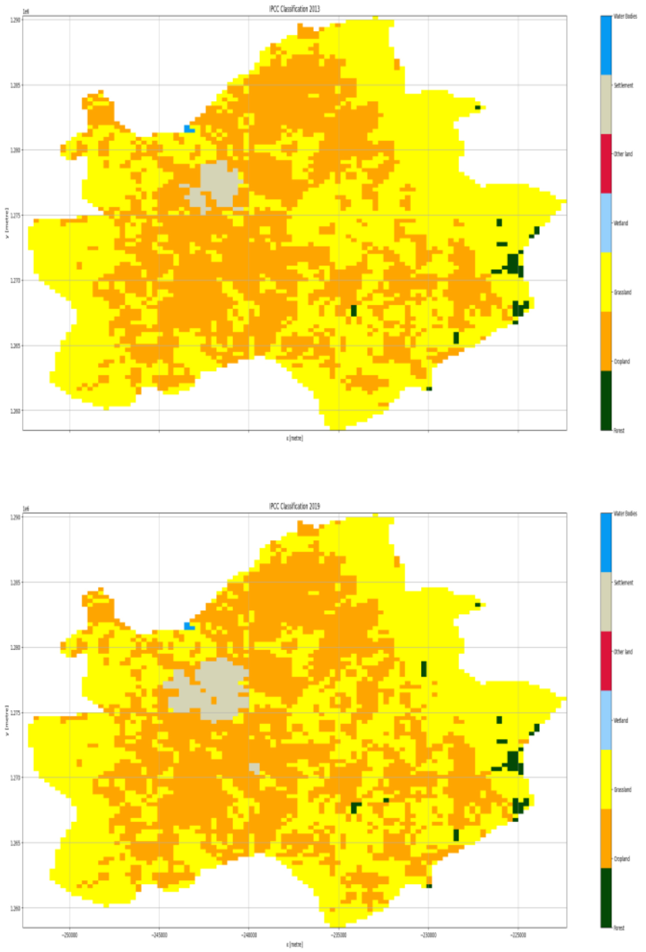

Figure 1: IPCC Classification for the Wa Municipality for 2013 and 2019

The study units selected through stratified sampling, a probability sampling technique were SSNIT and Jahan-Tampaalipaani residential areas, Kpaguri and Konta residential areas, and Jengbeyiri and Zongo residential areas, representing two (2) residential areas in high-income, middle-income, and low-income residential dwellings respectively in the Wa Municipality. The selected residential areas for the study in the Wa Municipality are indicated in Figure 2.

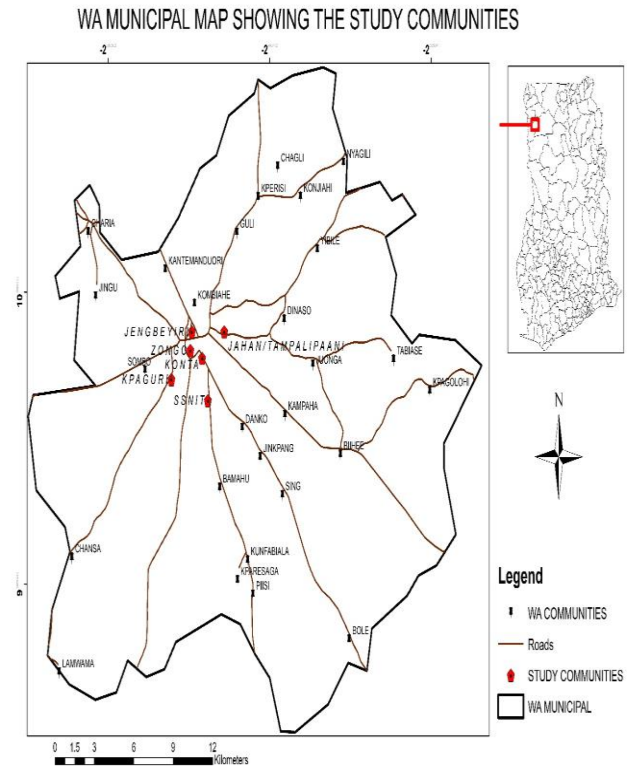

Figure 2: Wa Municipality Map with the study communities

B. Data Collection and Analysis

An explanatory sequential design involving both qualitative and quantitative data collection and analysis was used for the study. Explanatory sequential design involves the procedure of first collecting quantitative data and then collecting qualitative data to help explain or elaborate the quantitative results [20]. Questionnaires and key informants' interviews were used to obtain information on households' attitudes towards SWM practices in the Wa Municipality. Fifty (50) households each from low-income, middle-income, and high-come residential dwellings living in compound-houses, semi-detached, and single-unit dwellings respectively (totaling 150) formed the households sample size. The researchers applied stratified simple random systematic sampling in selecting the 50 uniform households in the various residential dwellings, as a systematic sample is obtained by selecting items at uniform intervals [21]. Though this household sample size was small, as the Wa municipality's household population was 190,962 [19], it was "big enough" to be of scientific and statistical significance [22].

The quantitative data was collected through a questionnaire survey. This tool captured the required data on awareness, knowledge and practices of households' SWM in the Wa Municipality. In addition, qualitative data were obtained using key informants interview guides with key waste management stakeholders including staff of the waste department of the Wa Municipal Assembly and Zoomlion Ghana Limited (ZGL), the only private waste collection company operating in the Wa Municipality. The data gathered was first coded, categorized and then analysed using SPSS. The results are presented in themes as well as visual presentation in the form of tables and charts. Furthermore, Chi-square bivariate correlation test was performed to determine the correlation between age of the respondents and SW disposal method, and Spearman's correlation performed to determine the correlation between educational level of the respondents and SW disposal method.

III. Results and Discussion

A. *Characteristics of Household Respondents*

Sex of Household Respondents

The majority of the household respondents were female (59.3%) and the remaining percentage of 40.7% of the respondents were male. During the fieldwork, the researchers observed that whereas both males and females could contribute equally to household SWM, majority of the respondents in the Wa Municipality perceived SWM to be the duty of women. However, Schenck *et al.* (2019) [23] posit that women's bodies are more susceptible to health risks from working with waste, and female waste pickers suffer worst health outcomes than their male counterparts.

Age of Household Respondents

Figure 3 illustrates the age groups of the household respondents. The majority of the respondents (42.7%) were in the 21-30 age group and the lowest percentage of the respondents (0.7%) belonged to the 61 and above age group. A test for the significance of age on the SW disposal method using the chi-square test revealed that age had no significance on the SW disposal method, as the test produced a significance level of 0.259, which is above the 5% significant level, as indicated in Table 1. Similarly, A'yunin, Noerjoedianto and Lesmana (2022) found that there was no relation between age and SWM, as their test produced a p-value of 0.928 > 0.05.

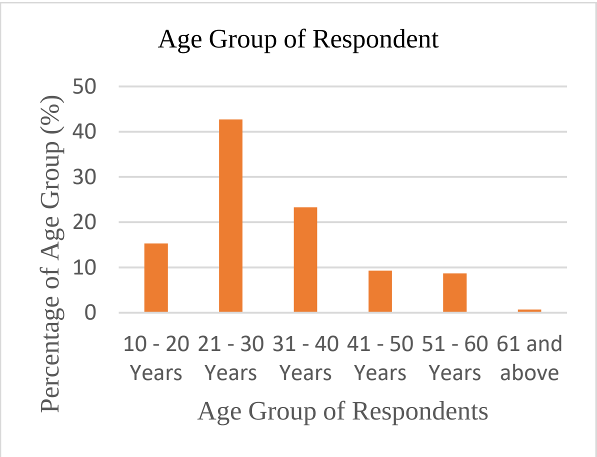

Figure 3: Age Groups of Household Respondents

Table 1: Chi-Square Tests Results for the Significance of Age on the SW Disposal Method

	Value	**df**	**Asymptotic Significance (2-sided**
Pearson Chi-Square	18.061[a]	15	.259
Likelihood Ratio	17.760	15	.275
Linear-by-Linear Association	.365	1	.546
N of Valid Cases	150		

a. 16 cells (66.7%) have an expected count of less than 5. The minimum expected count is .07.

Educational Level of Household Respondents

The majority of the household respondents had no formal education (34.75), whereas the lowest percentage of the respondents (14%) had basic level education (BECE), as indicated in Figure 4. Public education can improve waste management, therefore as 65.3% of the respondents had some formal education, public education on improved waste management practices could easily be undertaken in the Wa municipality to contribute to the attainment of waste management goals. Furthermore, an analysis of the correlation between educational level and waste disposal method showed that educational level did not correlate with SW disposal method, as the correlation coefficient between educational level and SW disposal method was 0.201, which is above the significant level of 5%, as shown in Table 2.

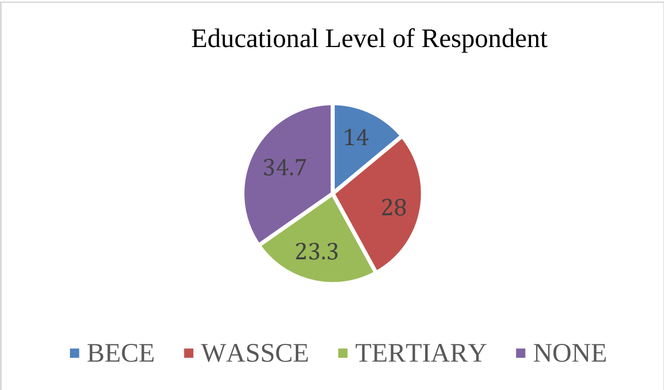

Figure 4: Educational Level of Household Respondents

Table 3: Spearman's Correlation Coefficient of Age and SW Disposal Method

		Value	Asympto-tic Standard Error	Approximate T[b]	Approxi-mate Signifi-cance
Interval by Interval	Pear-son's R	.093	.078	1.131	.260[c]
by Ordinal	Spear-man Corre-lation	.105	.080	.284	.201[c]
N of Cases	Valid	150			

a. Not assuming the null hypothesis
b. Using the asymptotic standard error assuming the null hypothesis.
c. Based on normal approximation

B. *Household Solid Waste Management in the Wa Municipality*

Household Solid Waste Handling and Storage

Households and communal SW storage and handling approaches in the Wa Municipality were myriad. Historically, small communities managed to bury SW just outside their settlements or dispose of it in nearby rivers or water bodies. In recent times, these practices have not changed entirely because waste is collected and stored in temporary refuse containers which do not prevent the spread of pungent odours and diseases before it is buried, burned or carried to the communal collection container (CCC) sites.

The common characteristics of all the containers used in households for SW storage were materials such as plastic bags and containers, metal baskets and paper cartons, with a majority of the households (50.7 %) storing their SW in proper waste bins as indicated in Figure 5. In certain instances, some households kept their SW in hand-dug pits behind their houses. Households who patronized the services of ZGL (the only private waste collection company operating in the Wa municipality) upon registration were given refuse bins with sizes ranging between 12 – 240 litres.

Contrary to observation by Azunre *et al.* (2021) in a study conducted in some Ghanaian cities, which revealed that both the Municipal Waste Collection Department and the private contractors provide waste bins for their customers upon registration, the waste bins for individual households and corporate entities in the Wa municipality were provided only by the private company, ZGL. Consequently, many households who could not afford the fees charged by ZGL for the provision of the bin and SW collection, resorted to the use of sub-standard waste containers (uncovered containers) for temporary storage and the disposal of their SW in an environmentally unfriendly manner. Nonetheless, both the Wa Municipal Assembly (WMA) and ZGL provided CCCs in most parts of the municipality.

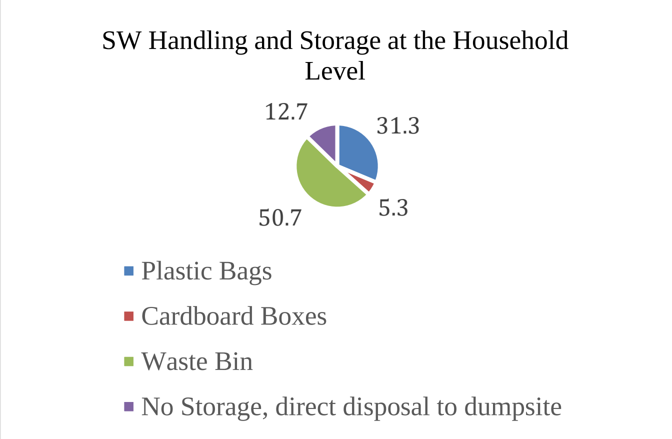

Figure 5: SW Handling and Storage at the Household Level

Time Spent to Dispose-off Waste

The amount of time spent to dispose-off refuse has an influence on the behaviour of waste generators. If the communal container is further away from the waste generator, it reduces the convenience and many waste generators may resort to disposing of waste at places that are convenient to them. The study indicated that the majority of the households (57.7 %) spent between 5 – 10 minutes to dispose their SW in the CCCs as shown in Figure 6. This indicates that most of the CCCs were within an acceptable walking distance of 300 m specified by the WMA. However, the 5.4 % of household respondents reported that they spent between 26 – 30 minutes to arrive at the CCC site, which also indicates that some of the CCCs were located far beyond the acceptable distance.

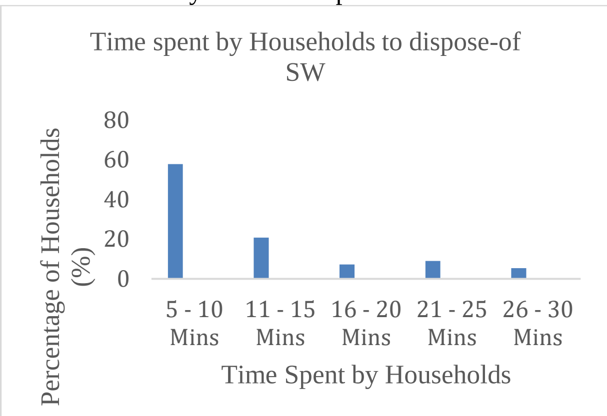

Figure 6: Time Spent by Households to dispose - of SW

Furthermore, the inadequacy of CCCs in the municipality could be attributed to the significant increase in settlement over the period. For instance, the IPCC classification obtained using the De Africa platform for the Wa Municipality with a focus on waterbodies, settlement, other land, wetland, grassland, cropland, and forest for 2013 and 2019 indicates that, whereas there were slight changes in the forest, grassland, cropland, and no change at all in the water bodies cover in the municipality, there was over a 50% variation in settlement in the municipality from 2013 to 2019 as shown in Figure 7.

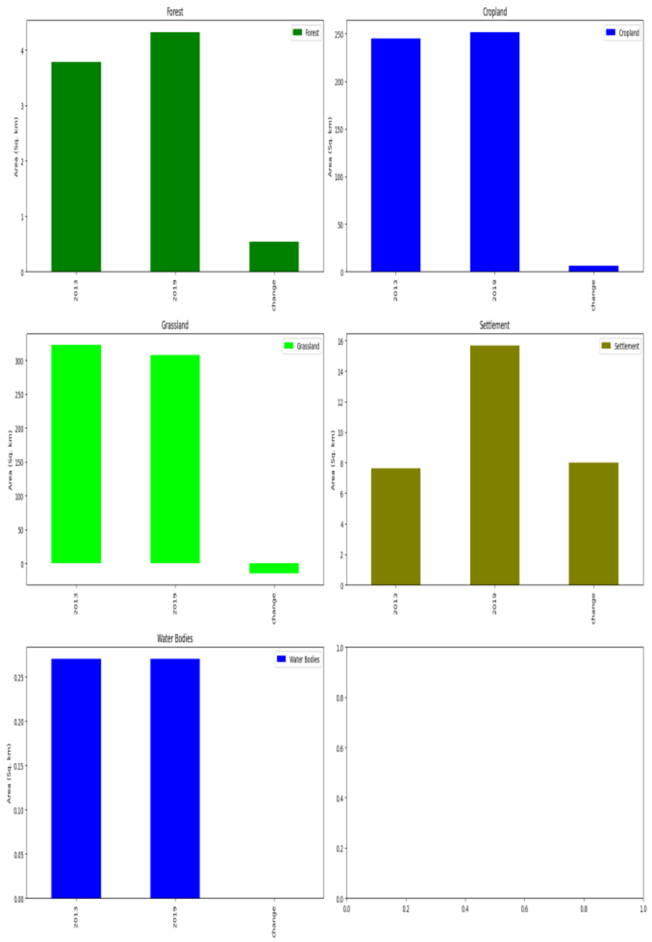

Figure 7: IPCC Classification for the Wa Municipality for 2013 and 2019 with highlight of changes

Solid Waste Disposal by Households

Effective SW disposal is the main goal of the SWM process. Positive externalities exist in proper waste disposal since the whole community receives health and safety benefits from the proper disposal by others [26]. Knowledge of where the households dispose of their domestic SW provides a clear indication of the kind of management system in place for SWM. Figure 8 illustrates households' SW disposal methods in the Wa Municipality.

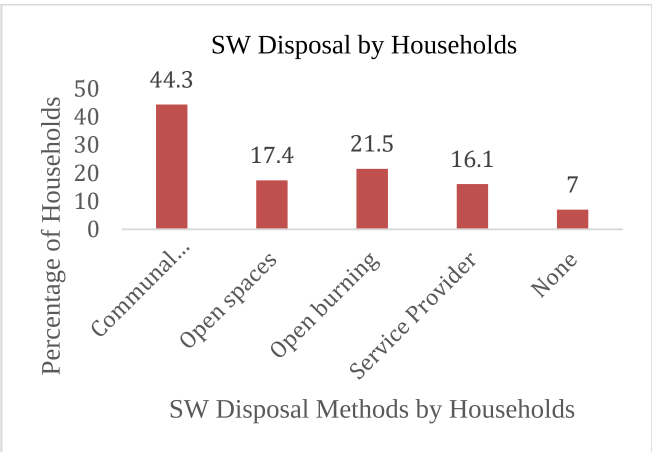

Figure 8: SW Disposal Methods by Households

As high as 17.4 % of the households disposed of their SW at unauthorized places. These include their backyards, open spaces and open depressions, only 16.1 % of households who lived in areas that had good access roads (mainly the high-income residential areas) and could afford to pay the service charges, patronized the private service provider, ZGL for their SW disposal. However, the majority of the households' respondents depended on communal containers (44.3 %) for their SW disposal. This supports other researchers who found out that communal container collection of SW was the common method of SW collection in most parts of Ghana [27], [28].

Nonetheless, some households' respondents (7 %) were not covered by any collection service and therefore resorted to indiscriminate disposal of their SW. This situation has led to households finding various ways to dispose-off their SW, thereby inundating the municipality with polythene bags and other SW. Figure 9 shows an indiscriminate disposal site at Kpaguri in the Wa Municipality. However, the indiscriminate disposal of refuse cannot be wholly blamed on the inadequate communal containers in the municipality. The other cause could be the lack of education on SWM issues in the Wa municipality. According to Brotosusilo *et al.* (2020), good SWM has much to do with changing behaviours and habits, as a person's long-held attitude can only be changed through education.

Unfortunately, 65.3 % of the households' respondents confirmed that there had not been any form of education to enlighten them on SWM practices. Even at some locations, such as 'Zongo' where the CCCs were provided and were at acceptable walking distances from the households, 38.9 % of the households still disposed of their waste indiscriminately, with the excuse that the CCCs location were too far away from their homes.


Figure 9: An indiscriminate disposal site in Kpaguri in the Wa municipality

Awareness of Waste Segregation and Minimization

Some of the respondents were aware of the need for the separation of SW for collection, as 34 % of the respondents said that they were prepared to separate their SW for collection by ZGL if they were given an additional waste bin. In addition, 32.7 % of the respondents acknowledged their awareness about waste minimization and 82.7 % agreed to waste reuse and recycling, as some of the respondents indicated that they used food waste to feed livestock, salvage used plastics and cans, and sachet rubbers, and sell them to informal waste buyers. Notwithstanding this, the collection system in Wa municipality did not support recycling as mixed varied SW were sent to the dumping site for scavengers to scramble for recoverable items in the waste.

Willingness to Pay for Waste Management Services

The willingness of the respondents to pay for improved waste management services was also assessed. 65.3 % of the respondents confirmed their willingness to pay for improved SWM services. However, some of the respondents indicated that a policy on payment for SWM service should be complemented by regulations and enforcement with a punitive measure for indiscriminate SW disposal.

C. *Institutional Arrangements for Solid Waste Management*

As stipulated in Ghana's Local Government Act, Act 963 (2016), the Metropolitan, Municipal and District assemblies (MMDAs) are mandated with oversight responsibilities of SWM in their jurisdictions. Nonetheless, due to the deficiencies in recent times, there has been a paradigm shift in this approach culminating in the assemblies losing that full responsibility. The pressures from international organizations, such as the World Bank and International Monetary Fund (IMF) and globalization forces, have also made the waste management decision-making process more market-based [30]. Again, under the Act, the Assemblies' Waste Management Departments (WMD) and Public Health Departments (PHD) are mandated to provide collection and disposal services. However, Oduro-Appiah *et al.* (2019) observe that due to poor quality of service including the collection of only 60 - 65% of waste generated in most cities in Ghana, it eventually led to a transition to public-private partnerships (PPP), mostly in the form of contracting services out to private operators.

Consequently, in the Wa Municipal Assembly the WMD and ZGL were solely responsible for SW collection and disposal. The ZGL was contracted by the Ministry of Local Government in 2006 to manage SW collection services in the MMDAs in Ghana. The contractual agreement between the Ministry of Local Government for the SW collection in all MMDAs has been shredded in secrecy, and many researchers observe that the elements of competition, accountability, and transparency, which are essential for the involvement of the private sector in SWM, are lacking with the engagement of ZGL [9]. Consequently, an official of the WMA's WMD observes that:

"Nobody at the WMA supervises or monitors the operations of ZGL, as the Assembly does not determine or know the exact amount that ZGL is paid for their services. The payment for ZGL's operations is deducted from the Assembly's Common Fund before the Common Fund is released to the Assembly"

The availability of SWM facilities has a very strong correlation with the level of services that can be provided by waste management authorities [32]–[34]. However, the researchers observed during the fieldwork that except for SSNIT Residential Areas which relied on door-to-door collection operated by ZGL and did not require the services of CCC, the remaining five study communities had one communal container for the disposal of their waste. This was woefully inadequate and therefore always led to a spillover of waste at the CCCs sites, as indicated in Figure 10.

Figure 10: A Communal Container with spillover waste

Furthermore, the regularity of collection is an important component of SW collection [35], though the population of an area, the composition of the waste stream and the volume of the available communal container play important roles in determining how regular the waste is collected, the study showed that the collection of SW in the Wa Municipality was not regular, as a majority of the household respondents (46 %) indicated that their waste was collected once in every two weeks. Consequently, David, John and Hussain (2020) posit that irregular collection of waste leads to the indiscriminate dumping of waste by waste generators. In addition, 28.7 % of the respondents also said that they were not covered by any waste collection service. This could be attributed to the inadequate provision of CCC in the study communities that relied on the communal collection service. The regularity of SW collection in the study communities is indicated in Figure 11.

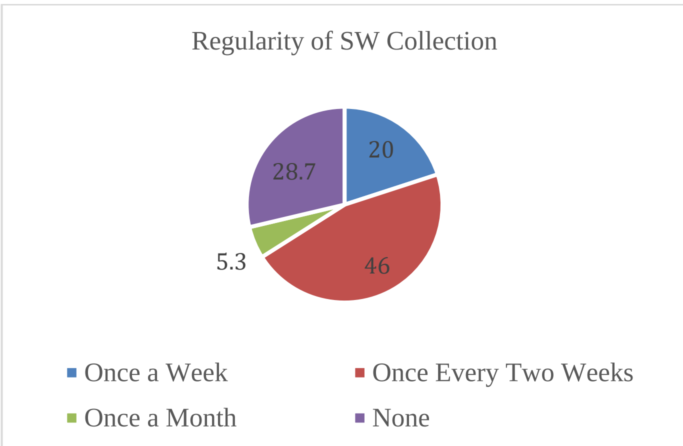

Figure 11: Regularity of SW Collection

D. Final Disposal

The final element in the SWM process is disposal. This can be achieved through the treatment and processing of waste, and eventually final disposal through landfilling or land spreading. Engineered landfills are the most appropriate place of final disposal for SW [37], [38], because no matter the method of SW treatment and processing, landfilling will be required for the final disposal of the residue from the treatment and processing of SW. Notwithstanding this, the SW in the Wa Municipality is neither treated nor properly disposed of. All the collected SW in the Wa municipality was openly dumped at a dumping site located at Siriyiri in the Wa West District.

The Siriyiri community has resisted the dumping of SW in their community since 2004 but to no avail. The transported wastes were deposited at the dumping site without any on-site treatment, which posed a serious public health hazard to the residents of Siriyiri and its environs through polluted air and disease-carrying pests and insects. From time to time, the heap of dumped waste was spread and burned to reduce the volume of the waste on the dumping site to enable the continuous dumping of waste, as shown in Figure 12.

Figure 12: Solid Waste at the Siriyiri dumpsite

As a common practice in most SW dump sites in many developing economies, scavengers informally collect components of the SW such as papers, plastics, glass and metals which they consider valuable due to their economic benefits. These components are sold to individuals who act as middlemen for small recycling units. In the view of Kurniawan *et al.* (2022) [39] even though scavenging activities reduce the volume of waste, the activities of the scavengers make waste collection much more difficult due to how they do the sorting, and thus there is the need to streamline and/or regulate and monitor the activities of the scavengers at the dumping site. However, Dzokpo (2023) posits that financially, waste pickers reduce costs for municipalities by diverting waste from landfill and keeping trash out of drains, that environmentally, waste pickers are recovering materials that can be recycled, reducing the need for raw materials and associated emissions, and in addition, socially, waste pickers are resilient, self-employed and often providing for several family members.

As observed by Bowan, Kayaga and Fisher (2020) [41], the SWM in the Wa municipality consists of some waste collection, transportation and open dumping, where the entire amount of waste is openly dumped without pre-treatment (Figure 13 shows SW flow in the Wa Municipality). The sorting of waste at the generation sources, and the provision of adequate SWM infrastructure, through an integrated solid waste management system, can ensure sustainable waste management in the municipality.

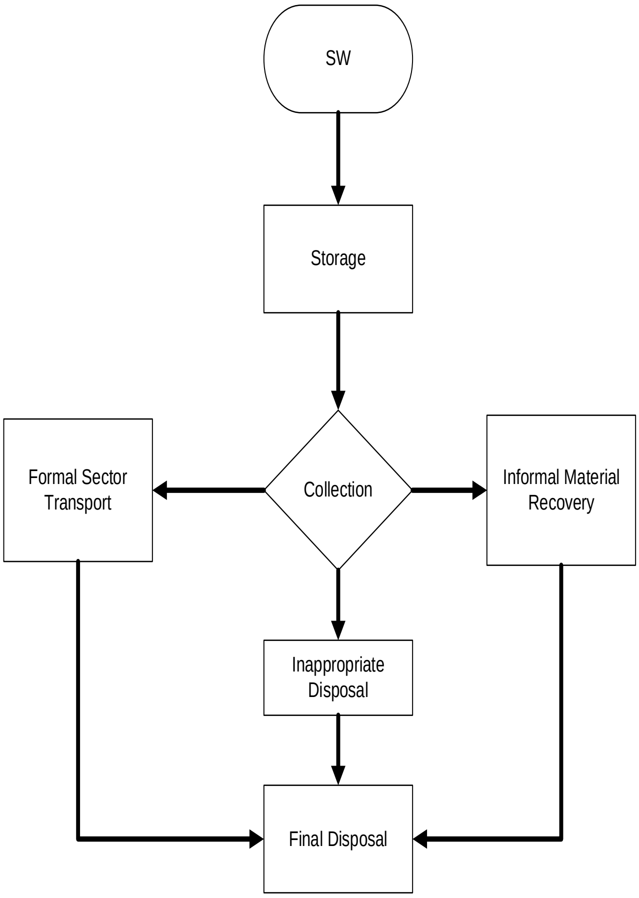

Figure 13: SW flow in the Wa Municipality
Source: adapted from [41]

IV. Conclusion

The paper examined household SWM in the Wa municipality. The examination was focused on the households' SWM practices, households' willingness to pay for SW collection, households' knowledge on SW segregation, and the institutional arrangement for SWM. The study adopted an explanatory sequential research design and applied both qualitative and quantitative research methods. In addition, chi-square correlation and spearman's correlation tests were performed to determine the correlation between some demographic variables of the respondents and their SW disposal method. The results showed that 65.3 % of the respondents were willing to pay for their SW collection and 34 % had knowledge of waste segregation and were prepared to separate their SW for collection if they were given an additional waste bin. Furthermore, there was some collection of household SW in the Wa municipality, though a majority of the respondents (45.8 %) had resorted to improper SW disposal practices such as opening burning and indiscriminate disposal of their SW. There was no pre-treatment and/or processing of the collected SW before the final disposal, as the collected SW was openly dumped and burnt from time to time to reduce the volume of the dumped SW. In addition, the test on the correlation between age, educational level, and SW disposal method produced $p > 0.259$ and $p < 0.201$ respectively, which are above the 5 % significant level. The paper proposes the sorting of SW at the generation point and the adoption of an integrated SWM system to help ameliorate the household SWM challenges in the Wa municipality.

COMPETING INTERESTS

The authors have declared that no competing interests exist.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Patrick Aaniamenga Bowan: Conceptualization, Methodology, Writing, Reviewing and Editing, Data curation, Visualization, Validation, and Supervision. **Sumaya Abdulai**: Investigation and Writing - Original draft preparation. **Edward Boamah**: Software and Visualization.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

[1] A. Maalouf, A. Mavropoulos, and M. El-Fadel, "Global municipal solid waste infrastructure: Delivery and forecast of uncontrolled disposal," *Waste Manag. Res.*, vol. 38, no. 9, pp. 1028–1036, Sep. 2020, doi: 10.1177/0734242X20935170.

[2] J. Lim, C. A. Fernández, S. W. Lee, and M. C. Hatzell, "Ammonia and Nitric Acid Demands for Fertilizer Use in 2050," *ACS Energy Letters*, vol. 6, no. 10. American Chemical Society, pp. 3676–3685, Oct. 2021, doi: 10.1021/acsenergylett.1c01614.

[3] S. Kaza and L. Yao, "At a Glance: A Global Picture of Solid Waste Management," in *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*, The World Bank, 2018, pp. 17–38.

[4] A. Maalouf and A. Mavropoulos, "Re-assessing global municipal solid waste generation," *Waste Manag. Res. J. a Sustain. Circ. Econ.*, p. 0734242X2210741, Jan. 2022, doi: 10.1177/0734242X221074116.

[5] P. A. Bowan, "A Planning Framework for Municipal Solid Waste Disposal Decision-Making," *J. Sustain. Dev. Stud.*, vol. 14, no. 0, pp. 1–17, Dec. 2021, Accessed: Jan. 06, 2023. [Online]. Available: http://infinitypress.info/index.php/jsds/article/view/2030.

[6] T. A. Kurniawan, C. Meidiana, M. H. Dzarfan Othman, H. H. Goh, and K. W. Chew, "Strengthening waste recycling industry in Malang (Indonesia): Lessons from waste management in the era of Industry 4.0," *J. Clean. Prod.*, vol. 382, p. 135296, Jan. 2023, doi: 10.1016/j.jclepro.2022.135296.

[7] Z. Yuan, R. Nag, and E. Cummins, "Ranking of potential hazards from microplastics polymers in the marine environment," *J. Hazard. Mater.*, vol. 429, p. 128399, May 2022, doi: 10.1016/j.jhazmat.2022.128399.

[8] J. R. Jambeck *et al.*, "Marine pollution. Plastic waste inputs from land into the ocean," *Science*, vol. 347, no. 6223, pp. 768–771, Feb. 2015, doi: 10.1126/science.1260352 [doi].

[9] P. A. Bowan, S. Kayaga, A. Cotton, and J. Fisher, "Municipal Solid Waste Management Performance," *Munic. Solid Waste Manag. Perform.*, vol. 19, no. 5, pp. 1–28, 2020, [Online]. Available: infinitypress.info/index.php/jsss/issue/view/128.

[10] S. A. Sarkodie and P. A. Owusu, "Impact of COVID-19 pandemic on waste management," *Environ. Dev. Sustain.*, vol. 23, no. 5, pp. 7951–7960, May 2021, doi: 10.1007/s10668-020-00956-y.

[11] T. Rume and S. M. D. U. Islam, "Environmental effects of COVID-19 pandemic and potential strategies of sustainability," *Heliyon*, vol. 6, no. 9. Elsevier Ltd, p. e04965, Sep. 2020, doi: 10.1016/j.heliyon.2020.e04965.

[12] N. B. Douti, S. K. Abanyie, S. Ampofo, and S. K. Nyarko, "Solid Waste Management Challenges in Urban Areas of Ghana: A Case Study of Bawku Municipality," *Int. J. Geosci.*, vol. 08, no. 04, pp. 494–513, 2017, doi: 10.4236/ijg.2017.84026.

[13] A. Kumar and A. Agrawal, "Recent trends in solid waste management status, challenges, and potential for the future Indian cities – A review," *Current Research in Environmental Sustainability*, vol. 2. Elsevier, p. 100011, Dec. 01, 2020, doi: 10.1016/j.crsust.2020.100011.

[14] C. N. Mama, C. C. Nnaji, J. P. Nnam, and O. C. Opata, "Environmental burden of unprocessed solid waste handling in Enugu State, Nigeria," *Environ. Sci. Pollut. Res.*, vol. 28, no. 15, pp. 19439–19457, Apr. 2021, doi: 10.1007/s11356-020-12265-y.

[15] S. J. Nyeko *et al.*, "The impact of electronic-electrical waste on human health and environment: A systematic literature review," *J. Eng. Technol. Res.*, vol. 15, no. 1, pp. 1–16, Mar. 2023, doi: 10.5897/JETR2021.0726.

[16] R. Panda and M. Maity, "Global Warming and Climate Change On Earth: Duties and Challenges of Human Beings," *Int. J. Res. Eng. Sci. Manag.*, vol. 4, no. 1, pp. 122–125, Jan. 2021, Accessed: Jan. 07, 2023. [Online]. Available: http://journals.resaim.com/ijresm/article/view/478.

[17] B. Mondal, K. Bauddh, A. Kumar, and N. Bordoloi, "India's Contribution to Greenhouse Gas Emission from Freshwater Ecosystems: A Comprehensive Review," *Water (Switzerland)*, vol. 14, no. 19. Multidisciplinary Digital Publishing Institute, p. 2965, Sep. 21, 2022, doi: 10.3390/w14192965.

[18] W. J. Ripple *et al.*, "Many risky feedback loops amplify the need for climate action," *One Earth*, vol. 6, pp. 86–91, 2023, doi: 10.1016/j.oneear.2023.01.004.

[19] Ghana Statisticaal Service, "Population of Regions and Districts," 2021. Accessed: Mar. 17, 2023. [Online]. Available: https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021 PHC General Report Vol 3A_Population of Regions and Districts_181121.pdf.

[20] R. L. Harrison, T. M. Reilly, and J. W. Creswell, "Methodological Rigor in Mixed Methods: An

Application in Management Studies," *J. Mix. Methods Res.*, vol. 14, no. 4, pp. 473–495, Oct. 2020, doi: 10.1177/1558689819900585.

[21] R. Abbott *et al.*, "Population Properties of Compact Objects from the Second LIGO–Virgo Gravitational-Wave Transient Catalog," *Astrophys. J. Lett.*, vol. 913, no. 1, p. L7, May 2021, doi: 10.3847/2041-8213/ABE949.

[22] K. M. Staller, "Big enough? Sampling in qualitative inquiry," *Qualitative Social Work*, vol. 20, no. 4. pp. 897–904, 2021, doi: 10.1177/14733250211024516.

[23] C. J. Schenck, P. F. Blaauw, J. M. M. Viljoen, and E. C. Swart, "Exploring the potential health risks faced by waste pickers on landfills in South Africa: A socio-ecological perspective," *Int. J. Environ. Res. Public Health*, vol. 16, no. 11, p. 2059, Jun. 2019, doi: 10.3390/ijerph16112059.

[24] Q. A'yunin, D. Noerjoedianto, and O. Lesmana, "Knowledge, Attitudes, Age, Education Level Factors to Waste Management," *J. Appl. Nurs. Heal.*, vol. 4, no. 1, pp. 9–15, Jun. 2022, doi: 10.55018/janh.v4i1.27.

[25] G. A. Azunre, O. Amponsah, S. A. Takyi, and H. Mensah, "Informality-sustainable city nexus: The place of informality in advancing sustainable Ghanaian cities," *Sustain. Cities Soc.*, vol. 67, p. 102707, Apr. 2021, doi: 10.1016/j.scs.2021.102707.

[26] E. P. Kresch, M. Lipscomb, and L. Schechter, "Externalities and Spillovers from Sanitation and Waste Management in Urban and Rural Neighborhoods," *Appl. Econ. Perspect. Policy*, vol. 42, no. 3, pp. 395–420, Sep. 2020, doi: 10.1093/aepp/ppz024.

[27] A. M. Quarshie, S. F. Gyasi, F. A. Kuranchie, E. Awuah, and E. Darteh, "Conceptual Behaviour Underpinning the Occurrence of Nonfaecal Matter in Faecal Sludge in Some Urban Communities, Ghana," *J. Environ. Public Health*, vol. 2021, 2021, doi: 10.1155/2021/2672491.

[28] S. T. Odonkor, K. Frimpong, and N. Kurantin, "An assessment of house-hold solid waste management in a large Ghanaian district," *Heliyon*, vol. 6, no. 1, p. e03040, Jan. 2020, doi: 10.1016/j.heliyon.2019.e03040.

[29] A. Brotosusilo, S. H. Nabila, H. A. Negoro, and D. Utari, "The level of individual participation of community in implementing effective solid waste management policies," *Glob. J. Environ. Sci. Manag.*, vol. 6, no. 3, pp. 341–354, Jul. 2020, doi: 10.22034/gjesm.2020.03.05.

[30] H. Wang, "The New Development Bank and the Asian Infrastructure Investment Bank: China's Ambiguous Approach to Global Financial Governance," *Dev. Change*, vol. 50, no. 1, pp. 221–244, Jan. 2019, doi: 10.1111/dech.12473.

[31] K. Oduro-Appiah, A. Afful, V. N. Kotey, and N. de Vries, "Working with the informal service chain as a locally appropriate strategy for sustainable modernization of municipal solid waste management systems in lower-middle income cities: Lessons from Accra, Ghana," *Resources*, vol. 8, no. 1, p. 12, Jan. 2019, doi: 10.3390/resources8010012.

[32] R. L. S. Fernando, "Solid waste management of local governments in the Western Province of Sri Lanka: An implementation analysis," *Waste Manag.*, vol. 84, pp. 194–203, Feb. 2019, doi: 10.1016/j.wasman.2018.11.030.

[33] I. S. Mir, P. P. S. Cheema, and S. P. Singh, "Implementation analysis of solid waste management in Ludhiana city of Punjab," *Environ. Challenges*, vol. 2, p. 100023, Jan. 2021, doi: 10.1016/j.envc.2021.100023.

[34] M. Massoud, G. Lameh, M. Bardus, and I. Alameddine, "Determinants of Waste Management Practices and Willingness to Pay for Improving Waste Services in a Low-Middle Income Country," *Environ. Manage.*, vol. 68, no. 2, pp. 198–209, Aug. 2021, doi: 10.1007/s00267-021-01472-z.

[35] Z. Wu, Y. Zhang, Q. Chen, and H. Wang, "Attitude of Chinese public towards municipal solid waste sorting policy: A text mining study," *Sci. Total Environ.*, vol. 756, p. 142674, Feb. 2021, doi: 10.1016/j.scitotenv.2020.142674.

[36] V. E. David, Y. John, and S. Hussain, "Rethinking sustainability: a review of Liberia's municipal solid waste management systems, status, and challenges," *Journal of Material Cycles and Waste Management*, vol. 22, no. 5. Springer, pp. 1299–1317, Sep. 01, 2020, doi: 10.1007/s10163-020-01046-x.

[37] G. A. Kristanto and W. Koven, "Estimating greenhouse gas emissions from municipal solid waste management in Depok, Indonesia," *City Environ. Interact.*, vol. 4, p. 100027, Dec. 2019, doi: 10.1016/j.cacint.2020.100027.

[38] S. L. Kareem, S. K. Al-Mamoori, L. A. Al-Maliki, M. Q. Al-Dulaimi, and N. Al-Ansari, "Optimum location for landfills landfill site selection using GIS technique: Al-Naja city as a case study," *Cogent Eng.*, vol. 8, no. 1, 2021, doi: 10.1080/23311916.2020.1863171.

[39] T. A. Kurniawan, M. H. Dzarfan Othman, G. H. Hwang, and P. Gikas, "Unlocking digital technologies for waste recycling in Industry 4.0 era: A transformation towards a digitalization-based circular economy in Indonesia," *J. Clean. Prod.*, vol. 357, p. 131911, Jul. 2022, doi: 10.1016/j.jclepro.2022.131911.

[40] I. K. Dzokpo, "Ghanaian Waste Pickers Call for Government's Intervention | News Ghana," *https://newsghana.com.gh*, 2023. https://newsghana.com.gh/ghanaian-waste-pickers-call-for-governments-intervention/ (accessed Mar. 15, 2023).

[41] P. A. Bowan, S. Kayaga, and J. Fisher, "A baseline scenario of municipal solid waste management," *Int. J. Environ. Waste Manag.*, vol. 26, no. 4, pp. 438–457, 2020, doi: 10.1504/IJEWM.2020.110394.