Scientific Research Publishing

Journal of Geoscience and Environment Protection, 2024, 12, 218-232
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Evaluation of Solid Waste Disposal in Wa Municipality, Ghana

Patrick Aaniamenga Bowan

Department of Civil Engineering, Dr. Hilla Limann Technical University, Wa, Ghana
Email: p.a.bowan@dhltu.edu.gh

How to cite this paper: Bowan, P. A. (2024). Evaluation of Solid Waste Disposal in Wa Municipality, Ghana. *Journal of Geoscience and Environment Protection, 12,* 218-232.
https://doi.org/10.4236/gep.2024.1212014

Received: October 14, 2024
Accepted: December 22, 2024
Published: December 25, 2024

Abstract

Safe waste disposal is necessary to limit the impact of waste on human health and the environment. This paper evaluates the status of solid waste (SW) disposal in the Wa Municipality, Ghana. The study adopted a descriptive research design and applied quantitative and qualitative research methods. 200 questionnaires were administered to two residential areas, each representing high-income, middle-income, and low-income residential dwellings. The study revealed that the majority of the respondents (33.5%) disposed of their SW in open spaces because any collection service did not cover them and those respondents who were covered by a collection service were not satisfied with the collection service due to irregular collection and inconvenient locations of communal collection containers. In addition, all collected SW in the Wa Municipality are openly dumped in illegal dumping sites across the municipality without any form of processing and treatment. The adoption of an integrated solid waste management system could improve SW disposal in the municipality.

Keywords

Solid Waste, Open Dumping, Solid Waste Disposal, Wa Municipality, Integrated Solid Waste Management

1. Introduction

Effective solid waste management (SWM) is a major challenge to municipal authorities globally. Domestic solid trash, industrial garbage, and construction waste are the three dominant solid waste categories, particularly in most developing countries (Khan et al., 2022a). In many sub-Saharan African countries, including Ghana, few dump sites receive these trashes, but the majority ends up in open areas like streams, drains, and parks. At numerous dumpsites across many urban

areas in these countries, waste is disposed of through open dumping and open burning; the waste is usually burnt to reduce its volume (Das et al., 2018; Ramadan et al., 2022).

With increasing urbanization, population growth, and climate change challenges, SWM is becoming more complicated, as the contemporary urban lifestyles lead to the use of numerous resources, which leads to an increased waste generation, far beyond the management capability of many municipal authorities in some developing countries (Oliveira, Vidal and Ferraz, 2020), with no suitable infrastructure, transportation, and disposal facilities to effectively manage the generated waste. For instance, the majority of Ghana's cities have experienced significant pressure on their waste management infrastructure and services during the past ten years as a result of urbanization (Asibey et al., 2021). The nonexistence of adequate and suitable waste disposal services has given rise to waste build-up and a consequence unsanitary environment in several parts of the country. If nothing is done to ameliorate the current challenges of the waste management systems of many developing countries, the exacerbating solid waste (SW) generation rates shortly would pose greater health and environmental risks.

Globally, many cities produce an average of 1.9 billion tons of SW per year (Maalouf and Mavropoulos, 2023). Meanwhile, many cities throughout the world are facing an enormous challenge of SWM coupled with low economic growth, search for a better way of life, and high consumerism, as the world population is projected to increase to 8 billion by 2025 and to 9.3 billion by 2050, with 70% of people living in urban areas (Gu, Andreev and Dupre, 2021; Onilude and Vaz, 2021). Consequently, 30% - 60% of SW is uncollected, and more than half of the households in some developing countries are not covered by waste collection services (Kwenda et al., 2022; Adedara, Taiwo and Bork, 2023). Uncollected and improper disposal of wastes have been linked to several potentially harmful environmental effects, such as flooding, and the release of gases and chemicals that pollute the air, water, and land.

Notwithstanding these, efforts have been made to achieve effective management of waste, through waste minimization and utilization. For instance, the European Union (EU) has established goals for waste reuse and recycling in its effort to reduce waste; these goals call for a minimum of 65% reuse and recycling as well as a 75% reduction in packaging waste by 2030 (Chioatto and Sospiro, 2023). However, despite the recycling potential of SW, many developing countries have very low recycling rates, ranging from 8% to 11% (Khan et al., 2022b). For instance, in Ghana SW is often predominately made up of organics and inorganics with varying proportion compositions of plastics, paper, metals, and glass (Roy and Tarafdar, 2022). However, lack of waste segregation at the generation points, ineffective waste collection and inadequate recycling systems are hampering effective waste management.

This paper evaluates SW disposal in the Wa Municipality in Ghana, as unsafe disposal of waste can have critical impact on both public health and the

environment. The practice of collecting mixed SW and open dumping the waste at unapproved and approved locations without treatment is common in many developing countries (Bowan, Kayaga and Fisher, 2020). The open dumping of SW as the final disposal option can lead to the contamination of groundwater as leachate seeps into the ground from SW with high moisture content. In addition, when it rains, storm water can transport dangerous substances from the open dump sites into surface water bodies, and thereby polluting the surface water. Furthermore, the open dumping sites attract pests and scavenging animals and offer food and habitation for disease vectors such as rats and mosquitoes. These disease vectors spread waterborne and communicable diseases such as malaria, trachoma and diarrhoeal diseases. Malaria is the most dangerous disease with the greatest economic impact in tropical countries, and the number one killer of children under five years in sub-Saharan Africa (Dao et al., 2021; Gilmartin et al., 2021). Therefore, the study hopes that the evaluation of SW disposal can proffer solutions to the challenges that improper SW disposal poses in the Wa Municipality.

2. Materials and Methods

2.1. Study Area

The study area, the Wa Municipality, is one of the 11 administrative and political districts in the Upper West Region of Ghana. The municipality is situated between latitudes 1˚40'N and 2˚45'N and longitudes 9˚32W to 10˚20W, covering an area of approximately 23,474 square kilometres, and 32% and 2.56% of the total land area of the region and the country, respectively. The Wa Municipality is located in the southern part of the region, which shares administrative boundaries with the Nadowli-Kaleo District to the north, the Wa East District to the southeast, and the Wa West District to the southwest. Wa, the municipal capital, serves as the governmental and commercial hub of the Upper West Region. According to the 2021 population and housing census, 200,672 people are living in the municipality, including 98,493 men and 102,179 women (Ghana Statistical Service, 2021). The map of Wa municipality with the sampled study communities is shown in Figure 1.

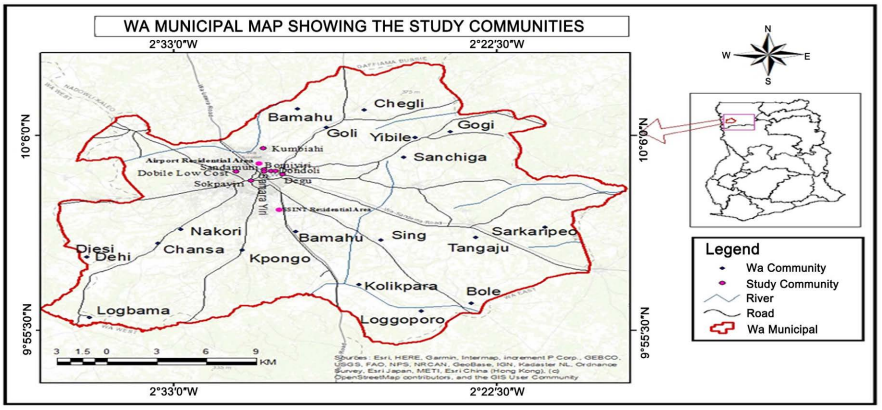

Figure 1. A map of the Wa municipality.

To understand the SW disposal practices in the municipality, visualizing and understanding the settlement patterns is essential. Thus, the researcher 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 300 m spatial resolution because this was readily accessible. The International Panel for Climate Change (IPCC) classification obtained using the 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 2, which makes improving SW disposal to be a prominent issue in the municipality.

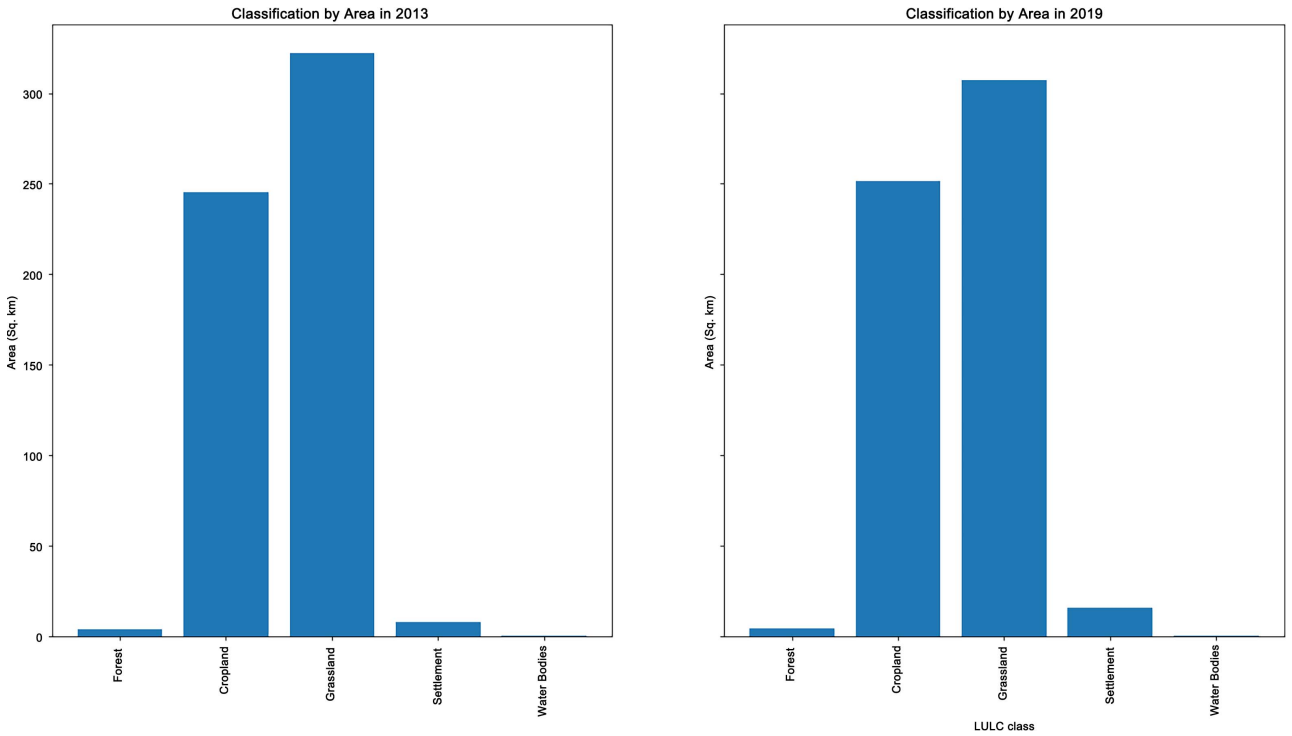

Figure 2. IPCC classification for the Wa municipality for 2013 and 2019.

2.2. Data Collection and Analysis

The study adopted a descriptive research design and applied quantitative and qualitative research methods. The quantitative data was obtained using a questionnaire, whereas the qualitative data was sourced using interviews and observation. In addition, stratified sampling technique was adopted in determining the study communities for the study. All the communities in the Wa municipality were broken down into three (3) strata: high-income residential dwellings, middle-income residential dwellings, and low-income residential dwellings. Two (2) residential areas were selected from each stratum for the study. SSNIT residential area and Degu residential area, Dobile and Kumbiahi residential areas, and Dondoli and Sokpayiri residential areas were selected to represent high-income residential dwellings, middle-income residential dwellings, and low-income residential

dwellings respectively.

Two hundred (200) questionnaires were administered to the residents in these residential areas using simple random sampling techniques. Though this sample size is small as compared to the household population of 190,962 of the Wa municipality (Ghana Statistical Service, 2021), it has scientific and statistical significance, as it is "big enough" (Staller, 2021). The data was coded and fed into SPSS 24 and simple correlation analysis was employed to determine among others the combined effect of age, sex and educational level on the solid waste disposal methods of residents in the study area. Graphs, percentages and tables were also used to analyse the findings. The analysis was undertaken to generate a descriptive picture of the data gathered on such themes as household waste generation and handling practices, services available to households for waste disposal and householders' satisfaction with the quality of service. In addition, informal interviews were held with staff of the waste department of the Wa Municipal Assembly (WMA) and staff of Zoomlion Ghana Limited (ZGL), the only private waste collection company operating in the Wa Municipality, to ascertain SW disposal practices in the Wa Municipality. Furthermore, the researcher made observations of SW disposal practices at various open dump sites, communal collection points, and the operation of informal waste pickers.

3. Results and Discussion

This section deals with the data gathered from 200 questionnaires administered to the six residential areas in the Wa Municipality, namely, SSNIT residential area and Degu residential area, Dobile and Kumbiahi residential areas, and Dondoli and Sokpayiri residential areas representing high-income residential dwellings, middle-income residential dwellings, and low-income residential dwellings respectively. In addition, the responses from interviews held with staff of the waste department of the Wa Municipal Assembly and staff of ZGL to ascertain SW disposal practices in the Wa Municipality are also discussed and the researcher's observation of SW disposal practices are also pictorially presented.

3.1. Demographical Characteristics of Respondents

3.1.1. Gender of Respondents

Gender is a major factor in defining individual responsibilities for waste management at the home and community levels in the Wa Municipality. This is because, as a result of socio-cultural influences, both genders have distinct roles to play in handling sanitation-related concerns. 53.0 percent of the household respondents were women, whereas the remaining percentage of 47 were males. The researcher observed during the fieldwork that women were more interested in matters about waste management in the municipality than men. Accordingly, the Gender and Water Alliance (GWA) (2022) observes that waste management is often regarded as gender-neutral, but gender inequalities and gender-divided roles are deeply embedded in many aspects of current waste management, as there is division of

labour in the waste sector based on conventional gender roles and stereotypes. IETC further posits that whereas men tend to be able to assume positions of higher authority, dealing with the buying and reselling of recyclables, for example, women are often limited to lower-income tasks, such as waste picking, sweeping and waste separation.

3.1.2. Age Group of Household Respondents

The majority of the household respondents (36.5%) were between the ages of 21 and 30 age group, whereas the minority age group, which was between above 51 age range was made up of 3.5% of the household respondents, as indicated in **Figure 3**. Processes associated with ageing could impact waste management behaviour in diverse ways, and impacts are not mutually exclusive (Chen et al., 2021). Accordingly, decreasing self-centredness, as an artefact of ageing, may lead progressively to more positive attitudes and behaviours about individuals' waste management activity (du Plessis, 2017; Cordella and Poiani, 2021). Consequently, Laitala et al. (2021) posit that individuals' diminishing physical capabilities may hamper their ability to repair broken items; failing eyesight and loss of fine motor skills are serious challenges in this regard.

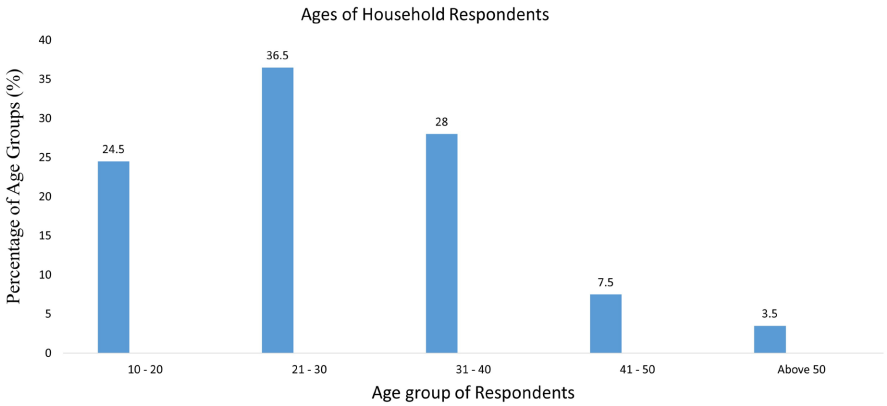

Figure 3. Age group of household respondents.

3.1.3. Educational Levels of Household Respondents

The study indicated that the majority of the household respondents (37.5%) had attained tertiary education, whereas 10% of the respondents did not have formal education, as shown in **Figure 4**. The results indicated that the high-income dwellings in the study area recorded a higher number of respondents who attained tertiary education, while the low-income dwelling recorded a higher number of respondents with no formal education. Education and awareness in the area of waste and its disposal are increasingly important to effective waste management globally. According to Debrah, Vidal and Dinis (2021), people with a high level of knowledge of waste and its management usually undertake actions that ensure effective waste disposal than those with low knowledge of waste and its management. Thus, since majority of the household respondents attained tertiary

education, effective education and awareness creation of good waste disposal practices can lead to sustainable waste disposal in the Wa municipality.

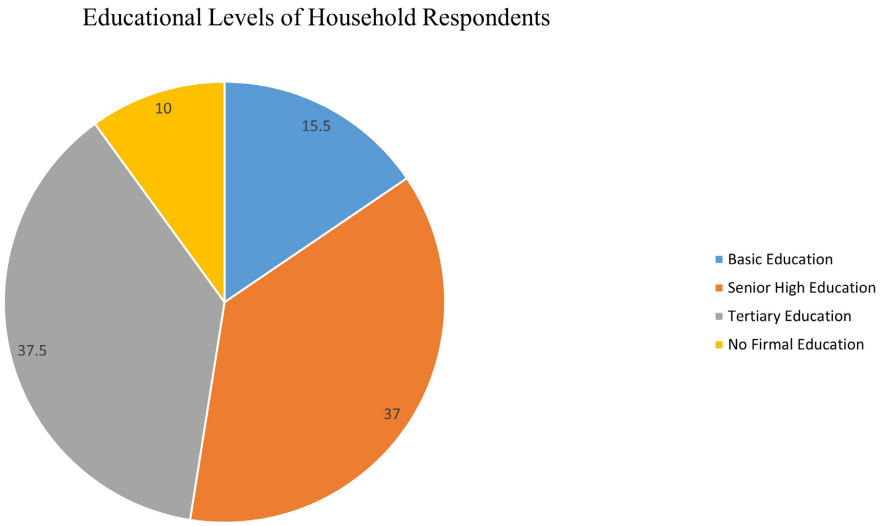

Figure 4. Educational levels of household respondents.

3.2. Solid Waste Disposal Practices in the Wa Municipality

Proper SW collection is essential for the protection of public health and for ensuring good environmental quality. Accordingly, SW collection is regarded as the most labour-intensive activity in SWM and accounts for approximately three-quarters of the entire cost of SWM in most countries globally (Nathanson, 2020), whereas effective SW disposal is the optimum goal of SWM. The study showed that the majority of the household respondents (33.5%) disposed of their SW in open spaces and 11% of the household respondents relied on door-to-door collection, operated by the only private SW collection provider in Wa Municipality, as indicated in **Figure 5**. The high percentage of household respondents who dispose their SW in open spaces (see **Figure 6(a)**) has led to pollution of water bodies and choking of storm drains in the Wa Municipality. These choke drains (see **Figure 6(b)**) serve as breeding grounds for some disease-causing organisms such as mosquitoes. Accordingly, malaria is the leading cause of death among children under five years in sub-Saharan Africa (Obasohan et al., 2021; Sarfo et al., 2023).

Furthermore, there was a low number of household respondents who relied on the door–to–door collection operation by ZGL because the service was limited to areas which had good road network and the ability of the service beneficiaries to pay for the service. This is the most environmentally sustainable waste management approach, as it lays the foundation for the cost and efforts required to separate the waste for various waste treatment processes (Laurieri et al., 2020). Nonetheless, waste segregation was not practised in the Wa Municipality, which makes the downstream waste management activities extremely difficult.

Also, the limitation of the door-to-door collection to suburbs with good road network and beneficiaries' ability to pay for the service had led to many residents

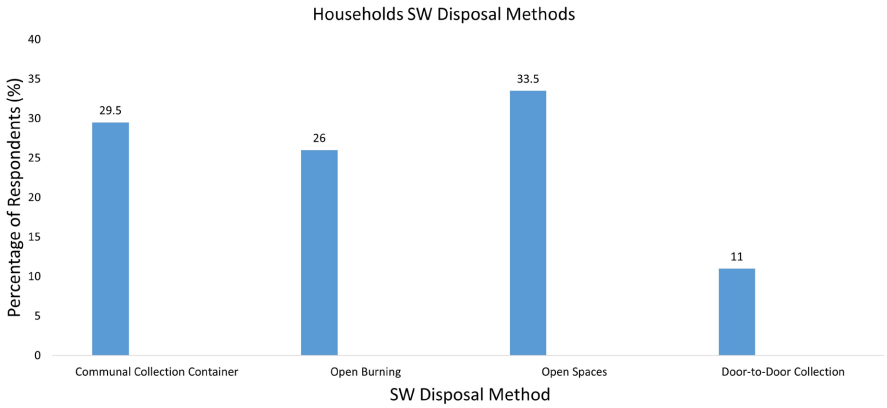

Figure 5. Households SW disposal methods.

(a) (b)

Figure 6. Disposal of SW in open space (a) and a choked drain (b).

in the municipality to resort to improper SW disposal options such as open burning of waste. Open burning of waste is one of the major contributors of greenhouse gases (GHGs) and poses major health hazards owing to the cocktail of air pollutants it discharges into the atmosphere. Mebratu and Mbandi (2022) in a report on the open burning of SW submitted to the Royal Academy of Engineering indicated that "open burning of waste produces 11% of global black carbon emissions, with 26% of global waste burned at a residential level and 15% spontaneously burned at dump sites."

Additionally, there was some provision of CCC at those suburbs that were not covered by the door-to-door collection service, with 29% relying on them as indicated in **Figure 5**. However, the researcher during the fieldwork observed that the CCC were not properly maintained and were deteriorating due to exposure to the weather and burning of waste inside the CCC, as shown in **Figure 7**. CCCs have the potential to solve several waste management challenges in local communities such as reducing wind-blown rubbish, illegal dumping, and ensuring better public health in the overall environment (Ravichandran and Venkatesan, 2021). Furthermore, a survey on households' satisfaction with SW collection services indicated that the majority of the respondents were not satisfied with the collection service

provided by ZGL and the WMA, as 56.5% were not covered by any collection service.

Figure 7. A deteriorated CCC in the Wa municipality.

3.3. Solid Waste Disposal Facilities in the Wa Municipality

SW facilities are facilities where household garbage and other types of SW are collected, processed or stored (Haywood et al., 2021; Khan et al., 2022b). These include household SW storage containers, communal collection containers (CCCs), transfer stations, sanitary landfills, etc. Notwithstanding these, the study showed that only a few household SW storage containers and CCCs were available in the Wa Municipality. The household SW storage containers were mainly provided by ZGL to the residents who relied on its door-to-door collection. The majority of residents/respondents relied on the CCCs provided at vantage points in the municipality. 65% of the respondents indicated that they were not provided with any sort of container for their SW storage/collection, whereas 35% of the respondents indicated that they were provided with CCCs for their SW collection. There were 37 CCCs distributed across the municipality, with 15 and 22 of these CCCs owned and managed by WMA and ZGL respectively. As a result of the uneven distribution of CCCs across the municipality, many residents resorted to indiscriminate disposal of their SW, which could lead to grave environmental and public health challenges.

Furthermore, the majority of the respondents who relied on the CCCs for their SW collection (51%), were not satisfied with the travel time to the CCCs to dispose of their SW, as they claimed they spent 30 minutes to walk to the nearest CCCs to dispose their SW, as shown in **Figure 8**. Meanwhile, an environmental health officer of the WMA in an informal interview indicated that "*the average travel to a CCC to dispose of SW was* 10 *minutes*, *with a spatial distance of* 300 *m for the residents*".

In addition, many of the respondents who relied on CCCs complained that the CCCs were rarely emptied. An environmental health officer at the waste department at the WMA confirmed this by stating that "*we move around to empty CCCs when the WMA provides fuel for our roll-of-on trucks. However, there are instances that the fuel is provided and our trucks are broken down.*" Similarly, ZGL, which has been contracted to collect SW in all metropolitan, municipal and

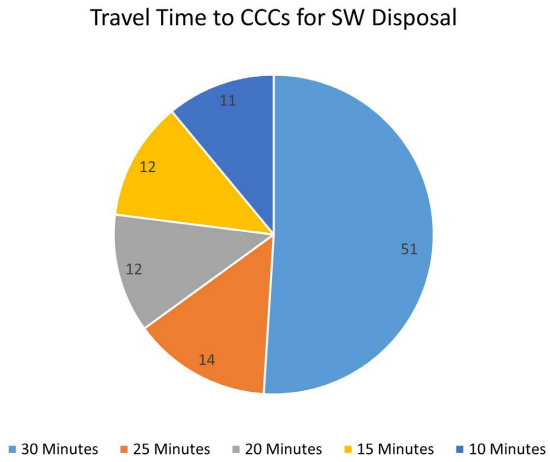

Figure 8. Travel to CCCs for SW disposal.

district assemblies (MMDAs), including the WMA, is undaunted with the volume of SW to be collected in the Wa Municipality, as a staff of ZGL stated that "*we are doing our best in collecting waste in the municipality but there are times the volume of waste is just too much to be collected according to our schedule of collection*." The irregular emptying of the CCCs can be attributed to the inadequacy of collection vehicles and poor routing for SW collection by both ZGL and WMA. Accordingly, Singh (2024) observes that SWM faces increasing demands for efficiency, cost-effectiveness, and sustainability, and that route optimisation has emerged as the best solution to streamline waste collection processes.

3.4. Final Solid Waste Disposal in the Wa Municipality

Disposal is the last step in the SWM procedure, as proper storage/collection, transportation, and processing are supposed to ensure the final effective disposal of SW. Nonetheless, the final disposal of SW in the Wa Municipality follows the principle of "out of sight, out of mind", as all the collected SW is usually disposed of without any processing and/or treatment in various open dump sites scattered across the municipality. Initially, there was a recognised open dump site located at Siiriyiri in the Wa West District for the dumping of SW when the Wa West District was still part of the WMA, however, since the creation of the Wa West District in 2004, the Siiriyiri community has resisted the continual dumping of SW in the community, which has led to creation of illegal dumping sites across the municipality for the dumping of collected SW by ZML and WMA.

The effects of open dumping of SW include pollution of soil, as waste can leak hazardous chemicals into the soil and from there into the food chain (Ajibade et al., 2021; Al-Wabel et al., 2022). Air pollution is another problem of open dumping of SW, as the burning of waste usually to reduce the volume of waste, releases substances into the atmosphere including extremely poisoning dioxins (Siddiqua, Hahladakis and Al-Attiya, 2022). Also, opening dumping of SW leads to the pollution of oceans; accordingly, The World Counts (2024) indicates that 13 million tonnes of plastics end up in the ocean every year due to opening dumping of SW

and that if the dumping of plastics into the oceans continue, by 2050 there will be more plastics than fish in the sea. The World Counts further observes that 280 billion tons of groundwater are being polluted every year by the dumping of SW. These call for the processing, treatment, proper final disposal of SW to ameliorate the effects of open dumping of SW in the Wa municipality. Thus, the adoption of an integrated solid waste management (ISWM) system in the Wa Municipality could lead to effective SW disposal.

According to Memon (2016), ISWM "refers to the strategic approach to sustainable management of solid wastes covering all sources and all aspects, covering generation, segregation, transfer, sorting, treatment, recovery and disposal in an integrated manner, with an emphasis on maximizing resource use efficiency." Consequently, Ravichandran and Venkatesan (2021) observe that an effective ISWM system considers how to prevent, recycle, and manage SW in ways that most effectively protect human health and the environment, and involves evaluating local needs and conditions and then selecting and combining the most appropriate waste management activities for those conditions. Thus, the major activities of WMA's ISWM system could include waste prevention, recycling and composting, combustion (using new technologies such as gasification and pyrolysis), and final disposal in a properly designed, constructed, and managed sanitary landfill. Each of these activities will require careful planning and financing.

Notwithstanding this, many researchers posit that top level political commitment as well as interest and commitment of local authorities is crucial to the success of any ISWM system (Aparcana, 2017; Fernando, 2019; Tobin and Zaman, 2022). In addition, the baseline data that is required for the effective implementation of an ISWM system is usually not available and requires considerable time and resources (Bowan, Kayaga and Fisher, 2020; Kalyanasundaram et al., 2021). Thus, a concerted effort of all stakeholders in waste management would be required for the effective implementation of an integrated sustainable waste management system in the Wa Municipality and other parts of Ghana.

4. Conclusion

The study showed that open dumping of SW in illegal dump sites, without any processing and/or treatment of the collected SW, is the final disposal option of SW in the Wa municipality. This unsustainable SW disposal option poses significant environmental and health risks. The study adopted a descriptive research design and applied quantitative and qualitative research methods. The majority of household respondents (33.5%) disposed their SW in open spaces because they were not covered by any collection service. Also, those respondents who were covered by a collection service were not satisfied with the collection service due to irregular collection and inconvenient locations of communal collection containers. The goal of SW disposal in the municipality seems to be to get the collected SW out of sight. The adoption of an ISWM system to include activities such as waste prevention, recycling and composting, using new combustion technologies such as gasification and pyrolysis, and final disposal in an engineered sanitary

landfill can ameliorate the SW disposal challenges in the municipality. Accordingly, SW management systems that operate successfully in various parts of the world indicate that a single waste management option is not suitable to efficiently handle the full array of SW. Thus, the Wa Municipality and other district, municipal, and metropolitan assemblies in Ghana, which are overwhelmed with SW and do not have a consistent power supply for both domestic and industrial purposes, need to adopt the ISWM concept, including waste-to-energy technologies. Top level political commitment as well as interest and commitment of local authorities will be crucial to the success of the implementation of an ISWM system in the Wa Municipality and other parts of Ghana.

Acknowledgements

The researcher is grateful to all the study participants, particularly the household respondents.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Adedara, M. L., Taiwo, R., & Bork, H. (2023). Municipal Solid Waste Collection and Coverage Rates in Sub-Saharan African Countries: A Comprehensive Systematic Review and Meta-Analysis. *Waste, 1,* 389-413. https://doi.org/10.3390/waste1020024

Ajibade, F. O., Adelodun, B., Ajibade, T. F., Lasisi, K. H., Abiola, C., Adewumi, J. R. et al. (2021). The Threatening Effects of Open Dumping on Soil at Waste Disposal Sites of Akure City, Nigeria. *International Journal of Environment and Waste Management, 27,* 127-146. https://doi.org/10.1504/ijewm.2021.112947

Al-Wabel, M. I., Ahmad, M., Rasheed, H., Rafique, M. I., Ahmad, J., & Usman, A. R. A. (2022). Environmental Issues Due to Open Dumping and Landfilling. In P. Pathak, & S. G. Palani (Eds.), *Circular Economy in Municipal Solid Waste Landfilling: Biomining & Leachate Treatment* (pp. 65-93). Springer International Publishing. https://doi.org/10.1007/978-3-031-07785-2_4

Aparcana, S. (2017). Approaches to Formalization of the Informal Waste Sector into Municipal Solid Waste Management Systems in Low- and Middle-Income Countries: Review of Barriers and Success Factors. *Waste Management, 61,* 593-607. https://doi.org/10.1016/j.wasman.2016.12.028

Asibey, M. O., King, R. S., Lykke, A. M., & Inkoom, D. K. B. (2021). Urban Planning Trends on E-Waste Management in Ghanaian Cities. *Cities, 108,* Article 102943. https://doi.org/10.1016/j.cities.2020.102943

Bowan, P. A., Kayaga, S., & Fisher, J. (2020). A Baseline Scenario of Municipal Solid Waste Management. *International Journal of Environment and Waste Management, 26,* 438-457. https://doi.org/10.1504/ijewm.2020.10025834

Chen, F., Chen, H., Jin, Y., Wang, F., Chen, W., Wu, M. et al. (2021). Impact of Cognition on Waste Separation Behavior—Nonlinear Moderating Effect by Trustworthiness for Links. *Journal of Cleaner Production, 296,* Article 126525. https://doi.org/10.1016/j.jclepro.2021.126525

Chioatto, E., & Sospiro, P. (2023). Transition from Waste Management to Circular

Economy: The European Union Roadmap. *Environment, Development and Sustainability, 25,* 249-276. https://doi.org/10.1007/s10668-021-02050-3

Cordella, M., & Poiani, A. (2021). Journey Towards the End of Life. In M. Cordella, & A. Poiani (Eds.), *Fulfilling Ageing: Psychosocial and Communicative Perspectives on Ageing* (pp. 721-890). Springer International Publishing. https://doi.org/10.1007/978-3-030-60071-6_8

Dao, F., Djonor, S. K., Ayin, C. T., Adu, G. A., Sarfo, B., Nortey, P. et al. (2021). Burden of Malaria in Children under Five and Caregivers' Health-Seeking Behaviour for Malaria-Related Symptoms in Artisanal Mining Communities in Ghana. *Parasites & Vectors, 14,* Article No. 418. https://doi.org/10.1186/s13071-021-04919-8

Das, B., Bhave, P. V., Sapkota, A., & Byanju, R. M. (2018). Estimating Emissions from Open Burning of Municipal Solid Waste in Municipalities of Nepal. *Waste Management, 79,* 481-490. https://doi.org/10.1016/j.wasman.2018.08.013

Debrah, J. K., Vidal, D. G., & Dinis, M. A. P. (2021). Raising Awareness on Solid Waste Management through Formal Education for Sustainability: A Developing Countries Evidence Review. *Recycling, 6,* Article 6. https://doi.org/10.3390/recycling6010006

du Plessis, C. (2017). Going Beyond Sustainability. In P. S. Brandon, P. Lombardi, & G. Q. Shen (Eds.), *Future Challenges in Evaluating and Managing Sustainable Development in the Built Environment* (pp. 40-54). John Wiley & Sons Ltd. https://doi.org/10.1002/9781119190691.ch3

Fernando, R. L. S. (2019). Solid Waste Management of Local Governments in the Western Province of Sri Lanka: An Implementation Analysis. *Waste Management, 84,* 194-203. https://doi.org/10.1016/j.wasman.2018.11.030

Ghana Statistical Service (2021). *Ghana 2021 Population and Housing Census General Report*. https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021%20PHC%20General%20Report%20Vol%203F_Difficulty%20in%20Performing%20Activities_final_161221.pdf

Gilmartin, C., Nonvignon, J., Cairns, M., Milligan, P., Bocoum, F., Winskill, P. et al. (2021). Seasonal Malaria Chemoprevention in the Sahel Subregion of Africa: A Cost-Effectiveness and Cost-Savings Analysis. *The Lancet Global Health, 9,* e199-e208. https://doi.org/10.1016/s2214-109x(20)30475-7

Gu, D., Andreev, K., & E. Dupre, M. (2021). Major Trends in Population Growth around the World. *China CDC Weekly, 3,* 604-613. https://doi.org/10.46234/ccdcw2021.160

Haywood, L. K., Kapwata, T., Oelofse, S., Breetzke, G., & Wright, C. Y. (2021). Waste Disposal Practices in Low-Income Settlements of South Africa. *International Journal of Environmental Research and Public Health, 18,* Article 8176. https://doi.org/10.3390/ijerph18158176

Gender and Water Alliance (GWA) (2022). *Gender and Waste Management Did You Know…?* http://genderandwater.org/en/gwa-products/capacity-building/no-capacity-to-waste/view

Kalyanasundaram, M., Sabde, Y., Annerstedt, K. S., Singh, S., Sahoo, K. C., Parashar, V. et al. (2021). Effects of Improved Information and Volunteer Support on Segregation of Solid Waste at the Household Level in Urban Settings in Madhya Pradesh, India (I-MISS): Protocol of a Cluster Randomized Controlled Trial. *BMC Public Health, 21,* Article No. 694. https://doi.org/10.1186/s12889-021-10693-0

Khan, A. H., López-Maldonado, E. A., Khan, N. A., Villarreal-Gómez, L. J., Munshi, F. M., Alsabhan, A. H. et al. (2022a). Current Solid Waste Management Strategies and Energy

Recovery in Developing Countries—State of Art Review. *Chemosphere, 291,* Article 133088. https://doi.org/10.1016/j.chemosphere.2021.133088

Khan, S., Anjum, R., Raza, S. T., Ahmed Bazai, N., & Ihtisham, M. (2022b). Technologies for Municipal Solid Waste Management: Current Status, Challenges, and Future Perspectives. *Chemosphere, 288,* Article 132403. https://doi.org/10.1016/j.chemosphere.2021.132403

Kwenda, P. R., Lagerwall, G., Eker, S., & Van Ruijven, B. (2022). A Mini-Review on Household Solid Waste Management Systems in Low-Income Developing Countries: A Case Study of Urban Harare City, Zimbabwe. *Waste Management & Research: The Journal for a Sustainable Circular Economy, 40,* 139-153. https://doi.org/10.1177/0734242x21991645

Laitala, K., Klepp, I. G., Haugrønning, V., Throne-Holst, H., & Strandbakken, P. (2021). Increasing Repair of Household Appliances, Mobile Phones and Clothing: Experiences from Consumers and the Repair Industry. *Journal of Cleaner Production, 282,* Article 125349. https://doi.org/10.1016/j.jclepro.2020.125349

Laurieri, N., Lucchese, A., Marino, A., & Digiesi, S. (2020). A Door-to-Door Waste Collection System Case Study: A Survey on Its Sustainability and Effectiveness. *Sustainability, 12,* Article 5520. https://doi.org/10.3390/su12145520

Maalouf, A., & Mavropoulos, A. (2023). Re-Assessing Global Municipal Solid Waste Generation. *Waste Management & Research: The Journal for a Sustainable Circular Economy, 41,* 936-947. https://doi.org/10.1177/0734242x221074116

Mebratu, D., & Mbandi, A. (2022). *Open Burning of Waste in Africa: Challenges and Opportunities*. https://raeng.org.uk/news/open-burning-of-waste-in-africa-challenges-and-opportunities

Memon, M. A. (2016). *Integrated Solid Waste Management*. https://sustainabledevelopment.un.org/content/dsd/csd/csd_pdfs/csd-19/learningcentre/presentations/May%202%20am/1%20-%20Memon%20-%20ISWM.pdf

Nathanson, J. A. (2020). *Solid-Waste Management*. https://www.britannica.com/technology/solid-waste-management/Solid-waste-collection

Obasohan, P. E., Walters, S. J., Jacques, R., & Khatab, K. (2021). A Scoping Review of Selected Studies on Predictor Variables Associated with the Malaria Status among Children under Five Years in Sub-Saharan Africa. *International Journal of Environmental Research and Public Health, 18,* Article 2119. https://doi.org/10.3390/ijerph18042119

Oliveira, G. M., Vidal, D. G., & Ferraz, M. P. (2020). Urban Lifestyles and Consumption Patterns. In W. Leal Filho, A. Marisa Azul, L.Brandli, P. Gökçin Özuyar, & T. Wall (Eds.), *Sustainable Cities and Communities* (pp. 851-860). Springer International Publishing. https://doi.org/10.1007/978-3-319-95717-3_54

Onilude, O. O., & Vaz, E. (2021). Urban Sprawl and Growth Prediction for Lagos Using Globeland30 Data and Cellular Automata Model. *Sci, 3,* Article 23. https://doi.org/10.3390/sci3020023

Ramadan, B. S., Rachman, I., Ikhlas, N., Kurniawan, S. B., Miftahadi, M. F., & Matsumoto, T. (2022). A Comprehensive Review of Domestic-Open Waste Burning: Recent Trends, Methodology Comparison, and Factors Assessment. *Journal of Material Cycles and Waste Management, 24,* 1633-1647. https://doi.org/10.1007/s10163-022-01430-9

Ravichandran, C., & Venkatesan, G. (2021). Toward Sustainable Solid Waste Management—Challenges and Opportunities. In R. O. Abdel Rahman, & C. M. Hussain (Eds.), *Handbook of Advanced Approaches Towards Pollution Prevention and Control* (pp. 67-

103). Elsevier. https://doi.org/10.1016/b978-0-12-822134-1.00003-8

Roy, D., & Tarafdar, A. (2022). Solid Waste Management and Landfill in High-Income Countries. In P. Pathak, & S. G. Palani (Eds.), *Circular Economy in Municipal Solid Waste Landfilling: Biomining & Leachate Treatment* (pp. 1-23). Springer International Publishing. https://doi.org/10.1007/978-3-031-07785-2_1

Sarfo, J. O., Amoadu, M., Kordorwu, P. Y., Adams, A. K., Gyan, T. B., Osman, A. et al. (2023). Malaria Amongst Children under Five in Sub-Saharan Africa: A Scoping Review of Prevalence, Risk Factors and Preventive Interventions. *European Journal of Medical Research, 28,* Article No. 80. https://doi.org/10.1186/s40001-023-01046-1

Siddiqua, A., Hahladakis, J. N., & Al-Attiya, W. A. K. A. (2022). An Overview of the Environmental Pollution and Health Effects Associated with Waste Landfilling and Open Dumping. *Environmental Science and Pollution Research, 29,* 58514-58536. https://doi.org/10.1007/s11356-022-21578-z

Singh, S. (2024). *Route Optimization for Solid Waste Management—Ultimate Guide in 2024*. https://nextbillion.ai/post/route-optimization-in-solid-waste-management

Staller, K. M. (2021). Big Enough? Sampling in Qualitative Inquiry. *Qualitative Social Work, 20,* 897-904. https://doi.org/10.1177/14733250211024516

The World Counts (2024). *Global Waste Problem*. https://www.theworldcounts.com/challenges/planet-earth/waste/global-waste-problem

Tobin, S., & Zaman, A. (2022). Regional Cooperation in Waste Management: Examining Australia's Experience with Inter-Municipal Cooperative Partnerships. *Sustainability, 14,* Article 1578. https://doi.org/10.3390/su14031578