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Review

Municipal Solid Waste Collection and Coverage Rates in Sub-Saharan African Countries: A Comprehensive Systematic Review and Meta-Analysis

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Abstract: The annual volume of waste generated in sub-Saharan Africa (SSA) increased from 81 million tonnes to 174 million tonnes per year between 2012 and 2016 and is projected to reach 269 million tonnes in 2030. In 2018, SSA's municipal solid waste (MSW) collection coverage was estimated at 44%. Concerned that the waste generation rate outweighs the collection pace, we conducted a systematic review of studies on MSW collection to examine the current situation in the region concerning the waste collection and coverage rates and to highlight the impediments to rapid progress in waste collection using the lens of four cities. Findings reveal that, despite the involvement of private waste collectors, collection and coverage rates are still below the desired 100% with backlogs of uncollected waste in public spaces, especially in low-income neighbourhoods where coverage remains abysmally low. This study fortifies the systematic discussion on MSW collection and coverage rates by conducting a meta-analysis. The result of the analysis shows that the waste collection and coverage rates are 65% and 67% in SSA, respectively. Aside from the paucity of data on waste generation rate and characterisation, most available data are incongruent. The review further shows that although several studies have been carried out on waste disposal, waste treatment and recycling in SSA studies directly focused on MSW collection are still few, leaving room for more research in this area. The review offers suggestions on how collection and coverage rates can be increased and equally proposes a strategy for reducing scavenging activities in the region's unsanitary landfills, given its concomitant health impacts on the scavengers.

Keywords: municipal solid waste; waste collection rate; waste collection coverage; meta-analysis; source segregation; circular economy

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1. Introduction

Global waste generation, propelled by continuous urbanization, economic development, and an increase in population was estimated at 2.01 billion tonnes per annum in 2016 [1]. This represents an increase of 54.62% from the generation rate of 1.3 billion tonnes [2] per annum in 2012. Unarguably, the rate of waste generation varies across world regions and individual countries, with the rise in per capita waste generation expected to surge in developing nations during economic growth, coupled with high organic contents in municipal solid waste (MSW) streams compared to that of developed nations [3]. Solid waste in the environment, especially where it is openly burned, buried, or indiscriminately dumped, impacts public health [4,5]. Consequently, the collection of MSW remains the most critical aspect of waste management (WM) [6,7], which strains municipal budgets [8]. While the MSW collection rate is estimated at 96% in high-income nations, most least-developed countries (LDC) have a collection rate of about 39%, with low-middle income (LMI) nations reaching about 51% [1].

Sub-Saharan Africa (SSA) is composed mainly of developing countries. Some critical issues contend with sustainable WM in the region at all levels of government such as the lack of political will, the absence of an effective policy on WM, inadequate funding, the lack of environmental education and awareness, a weak infrastructure, and limited collection coverage, among others [9,10]. To ensure public health safety, waste should not be left uncollected; unfortunately, this remains a persistent public health issue in developing countries [5,11]. In many SSA cities, numerous cases of uncollected waste have been documented. For example, uncollected waste in Cameroon, Central Africa, is commonplace in public spaces [12,13]. In Ethiopia, Tassie et al. [14] also observed incidences of uncollected waste in Addis Ababa. Similarly, in Johannesburg, South Africa, piles of uncollected refuse littering some streets have been blamed on corruption and administrative flaws of the municipal authorities [15]. This collection gap has paved the way for scavenging activities on the region's non-engineered landfill sites [16,17]. While it is acknowledged that scavenging in developing nations contributes to the recovery of materials for local recycling industries, the health problems associated with this activity have also been widely researched [18,19]. These different cases of uncollected waste across cities in the region represent a lost opportunity for providing clean recyclable materials to local recycling industries, and this could be a reason for the proliferation of scavenging in the region.

In SSA, MSW is disposed of primarily in uncontrolled landfills [20]. Since segregation is not carried out at the source, organic waste is lumped with recyclables at the dumpsite [21]. Over time, under anaerobic conditions, the organic waste undergoes decomposition, resulting in the release of landfill gas (LFG) with methane (CH4) as the highest component [22]. However, under controlled conditions, CH4 from the LFG could be harnessed for energy generation to meet the acute energy demand in the region, given the high organic content of about 57% in the waste stream. This possibility has been shown in Malaysia [22] where the organic fraction is 45%, lower than in many SSA countries. CH4 captured from some sanitary landfills is being converted to electricity to meet part of the country's energy demand, thereby limiting the use of carbon-intensive energy sources given their attendant environmental and health impacts. Similarly, as shown in a study by Aziz et al. [23], to continually explore the potential of waste as a resource, it is imperative for relevant authorities in developing economies to consider investments in waste recycling facilities to address the mounting volume of the non-biodegradable components in MSW while equally seizing the opportunity of the high organic component to set up waste composting facilities.

Despite the reported myriad of challenges with WM in the sub-Sahara, individual cases of improvements in some countries show that these challenges can be overcome with political will and the commitment to developing local solutions. For instance, the small community of Moshi in Tanzania was able to maintain the status of a 'top clean city' through the efficient collection of waste from its informal settlements, owing simply to the city council's commitment and residents' determination towards the success of the project [11]. In reviewing the literature on MSW collection in SSA cities, we observed that the articles seldom addressed the topic of waste collection directly, compared to the literature on waste disposal, waste treatment methods, and recycling. A similar situation has been reported for low- and middle-income countries [8,24]. This study shows that the scant amount of literature on MSW collection leaves room for more research in this area in SSA. Hence, the article highlights the need for more scholarly work on MSW collection as a way of using science to drive rapid progress in MSW collection in the region. The suggestions offered for increasing the collection rate and coverage as well as the strategy proposed for reducing scavenging activities in the interest of public health, if given the necessary attention by concerned authorities, can be translated into policy statements targeted at making a paradigm shift towards a more sustainable WM system in SSA countries.

2. Description of Study Areas

Ghana and Nigeria are located in West Africa within the SSA region, which comprises 48 countries. The region has an estimated population of 1.107 billion as of 2019 [25], and 34 of these nations are classified as LDC or low-income countries (LI) [26]. SSA is also the most undeveloped among the developing regions in the world, coupled with high infrastructure inadequacy and a world GDP share of 2.23% as of 2014 [27]. The SSA cities examined in this study are Accra and Kumasi in Ghana and Abuja and Lagos in Nigeria.

2.1. Accra and Kumasi

Accra is the capital of Ghana and the Greater Accra Region. It is Ghana's largest city by population [28]. The Accra Metropolitan Assembly's (AMA) WM department is responsible for environmental protection and the promotion of public health. One of its responsibilities is to ensure the efficient collection of MSW in Accra [29]. Kumasi is the second-largest city in Ghana. Like Accra, WM in Kumasi is coordinated by the city's administrative office, the Kumasi Metropolitan Assembly (KMA).

2.2. Abuja and Lagos

Abuja replaced Lagos as Nigeria's Federal Capital Territory (FCT) in 1991 when the capital was moved from Lagos. Abuja Environmental Development Board (AEDB) coordinates WM in the city. Lagos, Africa's largest city by population had a population of 20 million in 2020 [30]. WM in Lagos is coordinated by the Lagos Waste Management Authority (LAWMA), the city's municipal waste authority.

3. Materials and Methods

To access a wide range of literature for this review, the following scientific databases were explored using a combination of some keywords: ScienceDirect, Web of Science, Springer Link and Google Scholar. Apart from government records, publications of international organisations, and references to some unpublished materials with useful information, the bulk of the articles reviewed in this paper were from peer-reviewed journals written in English from 2010 to 2021. The search query, "municipal solid waste collection AND sub-Saharan Africa" entered in the ScienceDirect database returned 632 results after they were refined by year to the period under review. In the titles and abstracts of articles displayed in the results, we looked for the combination of words such as waste collection, municipal solid waste collection, municipal solid waste management, waste bin/receptacles, waste segregation/separation/sorting or recycling. A second search query, "municipal solid waste management AND sub-Saharan Africa" was again entered in the query box and it was noticed that the first five results were the same set of materials as in the first query, while the next 95 materials showed some similarities. Hence, we maintained the results of the first query, given their proximity to the review discourse. We entered the first query above on the SpringerLink database and retrieved 939 materials within the same review window. Using the advanced search function, the Web of Science database was queried with a combination of Booleans, truncation, and field tags viz, TS = (Africa* AND (waste collection OR waste management)). The search returned 981 results for the study period.

To eliminate chances of missing relevant materials, we typed in the query "municipal solid waste collection AND African cities" on Google Scholar, which returned 19,300 results from various scientific databases after refining the results to the period under review. Since most of the results from Google Scholar combined records from the other three above, we mainly selected those considered relevant to our review. It is pertinent to note that we consistently looked for the keywords listed above in all the databases. Then, we read through the abstracts and conclusions to manually select pertinent and non-pertinent materials. Our guiding keywords formed the basis of all articles selected for this review. Additionally, while writing, we made references to all the databases when searching for specific titles. Some pertinent materials which could not be accessed due to the paywall barrier were magnanimously sent by their authors via the "request article" button on ResearchGate—although some did not revert. Cumulatively, 100 peer-reviewed articles published in English from 2010 to 2021 (Figure 1) were cited in this publication.

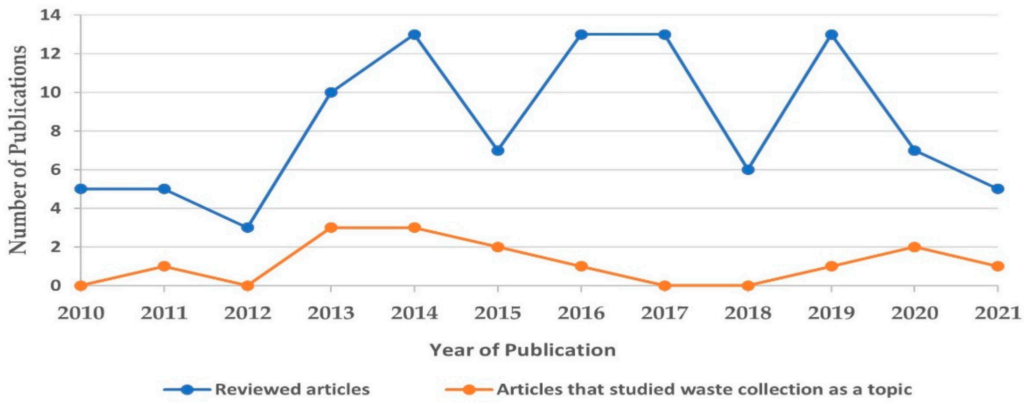

Figure 1. Analysis of peer-reviewed articles and the number of articles that studied waste collection as a topic. The articles that studied waste collection as a topic exclude articles that briefly discussed waste collection under other titles and non-peer-reviewed articles that studied waste collection as a topic.

3.1. Methodology for Meta-Analysis

Meta-analysis is a rigorous review usually employed to aggregate data from various studies to obtain a reliable estimate of findings in previous studies [31,32]. In a meta-analysis, the individual studies are usually assigned a weight, which is a function of the sample size considered in such a study [33]. In this study, the population of the region under investigation at the time of the data collection is used as the sample size. The objective of the meta-analysis conducted in this study is to estimate waste collection and coverage rates in selected SSA countries.

3.2. Selection Criteria for Included Studies in the Meta-Analysis

One important procedure in meta-analysis is defining appropriate inclusion and exclusion criteria for the studies to be included in the analysis. This procedure helps to ensure that only studies that are relevant to the analysis' objective are included. The defined inclusion criteria include (1) studies that present waste collection and coverage rates; (2) studies that highlight the location (i.e., city or country) associated with the data; and (3) studies that focus on SSA countries. Similarly, the exclusion criteria entail (1) studies that do not present quantitative data related to waste collection and coverage rates, (2) studies with no full-text availability, and (3) studies written in other languages apart from English. After this procedure, 12 studies out of the retrieved articles met these criteria.

3.3. Data Extraction for Meta-Analysis

After the selection of the relevant articles, the papers were carefully read to extract the necessary data for the analysis. From each shortlisted article, data relating to (1) the names of the authors, (2) waste collection rate, (3) waste collection coverage rate, (4) year of data collection, (5) region under investigation (i.e., city/country), (6) population of the region at the time of the investigation, and (7) variability measures where available (i.e., standard deviation and error). In a case where the variability measure is not reported in a study, the standard error is estimated based on the guidelines provided by Borenstein et al. [34]. Tables 1 and 2 show the extracted data for waste collection and coverage rates, respectively. While the data used for the collection rate are associated with the four SSA cities (i.e., Accra, Kumasi, Lagos, and Abuja), the data used for the coverage rate are related to SSA countries in general. This disparity is due to the unavailability of sufficient data in the four SSA cities. This generally suggests that there is a low level of research related to waste collection coverage rate in SSA cities.

Table 1. Extracted data for waste collection rate meta-analysis.

References	Collection Rate	Standard Error	Year of Data Collection	City	Population of City at the Time of Data Collection	Country
[35,36]	0.384	0.03303	2013	Abuja	2,168,000	Nigeria
[1,37]	0.1	0.0085	2015	Lagos	12,239,000	Nigeria
[37,38]	0.277	0.0129	2014	Lagos	11,856,000	Nigeria
[1,39]	0.83	0.0248	2015	Accra	2,290,000	Ghana
[39,40]	0.93	0.185	2006	Accra	1,893,000	Ghana
[40,41]	0.91	0.08	2006	Kumasi	1,628,000	Ghana
[42]	0.799	0.0286	2005	Accra	1,960,797	Ghana
[42]	0.799	0.0263	2010	Accra	2,317,583	Ghana

Table 2. Extracted data for waste coverage rate meta-analysis.

References	Collection Coverage	Standard Error	Year of Data Collection	City	Population of City at the Time of Data Collection	Country
[43,44]	0.4	0.0256	2009	Dar es Salam	3,659,000	Tanzania
[36,45]	0.42	0.0315	2016	Abuja	2,442,000	Nigeria
[43,46]	0.57	0.0366	2009	Bamako	1,825,000	Mali
[43,47]	0.63	0.0376	2009	Lusaka	1,643,000	Zambia
[37,48]	0.63	0.0131	2018	Lagos	13,463,000	Nigeria
[49]	0.7	0.0401	2007	Kumasi	1,300,000	Ghana
[43,50]	0.82	0.0366	2012	Maputo	1,098,000	Mali
[39,51]	0.9	0.0992	2018	Accra	2,439,000	Ghana
[3]	0.95	0.0065	2012	Lagos	11,127,000	Ghana

3.4. Effect Size and Summary Effect

In a meta-analysis, the effect size is the parameter of interest, which indicates each study's outcome or finding [52,53]. In this research, waste collection and coverage rates are the effect sizes. The summary effect is a single estimate that combines the effect size of multiple studies to provide an overall effect. If the included studies are equally precise, the summary effect can be estimated as the weighted average of the effect sizes [33]. However, the studies are not usually consistent due to the variability in the sample size and method of data collection. Hence, weights are assigned to the studies based on their variability measures and sample sizes. The weights of the studies and the summary effect at a specified confidence interval (CI) were computed using a meta-analysis software known as Review Manager 5.4 [54].

3.5. Heterogeneity and Sub-Group Analysis

Heterogeneity refers to the degree of variability between the studies included in the meta-analysis. It may arise due to differences in the sample size, method of data collection and analysis, and other factors that may affect the effect size [34]. Usually, the I2 statistic is used to measure the level of heterogeneity in a meta-analysis. An I2 value of 25% or less indicates that the heterogeneity level is low, while a value between 25–75% is considered moderate. The heterogeneity is considered high when I2 is greater than 75% [55]. A possible cause of heterogeneity should be investigated when the I2 is high. One of the ways of investigating the cause is to conduct a sub-group analysis, which involves dividing the studies included in the meta-analysis into different groups based on a criterion that may affect the effect size. Careful attention needs to be paid to how the studies are divided into groups, as inappropriate criteria may lead to misleading interpretations [33]. In this study, the country where the effect size is estimated is used as a criterion for dividing the studies into groups. This is in agreement with previous studies with similar contexts [33,56,57].

4. Results and Discussion

4.1. MSW Generation, Composition, and Collection in SSA

Some studies in SSA have published data on waste generation and collection in selected countries, either from municipal records or generated through field studies. For example, Miezah et al. [58] generated field data on Ghana's waste composition and generation rate. However, there appears to be a paucity of current and regularly updated data on the aggregate collection coverage of MSW in the entire region, leaving a noticeable gap open. However, after extensive research on the global waste situation, Kaza et al. [1] reported an average collection coverage of 44% for the region. This figure could be higher than 50% in middle- to high-income areas owing to good access roads, high-income level, and willingness to pay. Since collection coverage refers to the number of households (expressed as a percentage) with access to MSW collection service [11], the collection coverage average of 44% implies that waste from 56% of households in SSA could have been lost to the waste stream through indiscriminate dumping, which could accumulate in water bodies and cause blockage to drainage systems [10,59]. This raises concerns about public health [60].

In 2012, waste generation in SSA was estimated at an aggregate of 81 million tonnes per year (Figure 2) by cumulating data obtained from SSA countries [61]. This figure more than doubled to 174 million tonnes per year in 2016 compared to 2012 [1], which means that per capita waste generation has been rising. Of the total waste volume generated in 2012 in SSA from the data provided by Scarlat et al. [61], it can be deduced that a collection rate of 44.3% was achieved for that year. The waste collection rate is the proportion of waste collected for disposal from the volume of waste generated [40]. It is essential to note that although Scarlat et al. [61] estimated that SSA MSW generation would rise to an estimated 172.47 million tonnes per year in 2025, interestingly, this figure had already risen to 174 million tonnes as of 2016 as reported by Kaza et al. [1]. This indicates that estimates of the MSW generation rate might exceed projections for SSA countries, thus calling for urgency on the part of authorities to adopt sustainable WM strategies without further delay. The reported collection coverage of 44% in 2018 (Figure 3) raises a red flag on the region's need to improve the coverage of collection services, as this is still a far cry from the ideal figure of 100% [11]. The MSW in SSA is composed mainly of organics at an average of 57%, comparable to 50% of organics in South Asia [2]. The high organic fraction in the municipal waste stream could be utilized as a waste-to-energy (WTE) option when subjected to further biological treatment [62]. The organics could cushion the region's energy demand or, if co-digested with poultry waste, be used for producing clean energy [63]. The anaerobic digestion of the organic content can contribute to a significant reduction in global warming, as shown in a study on China [64] (something considered desirable for the environment). One challenge with AD, however, is ensuring that the organic fraction is properly separated before being fed into the digester to avoid interference with the biological process in the digester [22]. Hence, a good MSW separation scheme should be in place to separately collect organic waste to maximize the opportunity of this environmentally friendly WTE technology. Unfortunately, the current co-mingling of organic waste with other fractions in SSA impedes these possibilities. Bearing in mind that 2030 is less than a decade away, it has become imperative for SSA countries to take decisive steps towards achieving a sustainable solid WM system.

4.2. Generation, Composition, and Collection of MSW in Accra and Kumasi, Ghana

Ghana's average waste generation rate is 0.51 kg/capita per day [1]. Based on a field study carried out by Miezah et al. [58] in 2015, the waste generation rate in Ghana was estimated at 0.47 kg/capita per day. The annual volume of waste collected in Ghana in 2012 was estimated at 377,000 tonnes of the 444,000 tonnes generated for that year [61]. This translates to an 85% collection rate in 2012. In 2013, Oduro-Kwarteng and Van Dijk [40] had earlier reported a range between 0.35 and 0.75 kg/capita per day as the national household waste generation rate. Though the data from 2013 show some variation compared to the

2015 figure above, the lower value of 0.35 kg/capita per day shows that per capita waste generation in Ghana has been on the rise compared to the situation in 2015. As is typical of developing countries, the organic content of the MSW generated in Ghana comprises 61% organic components, followed by 14% plastics [21]. The data on waste generation rates and their corresponding characteristics are limited and not regularly updated [42,65], as is commonly reported about many least-developed countries. As of the time of writing this review, recent research articles did not report the status of the aggregate collection rate in Ghana; hence, we could not compare the above figures with the situation from 2019 to 2021.

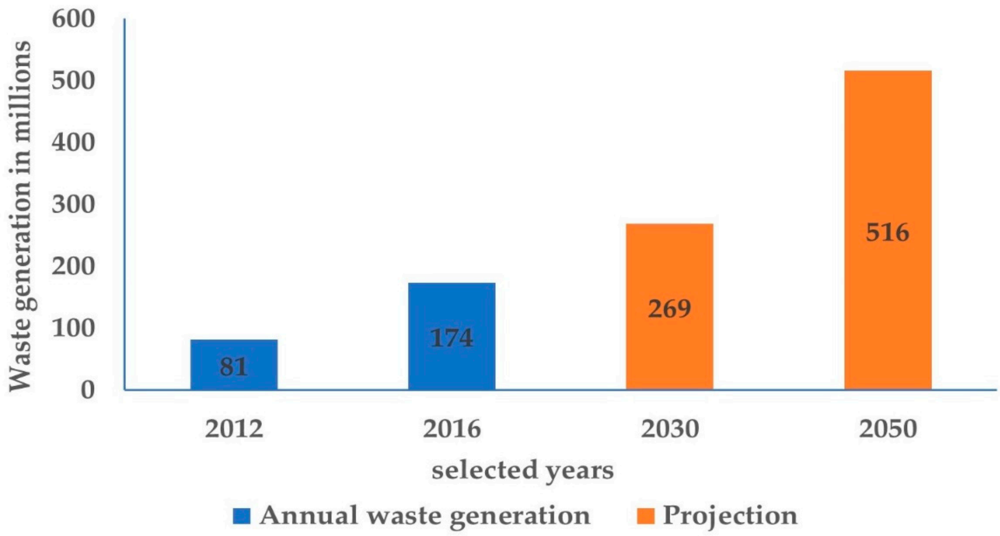

Figure 2. Waste generation in SSA [1,61]. This figure was developed from data published by the cited authors.

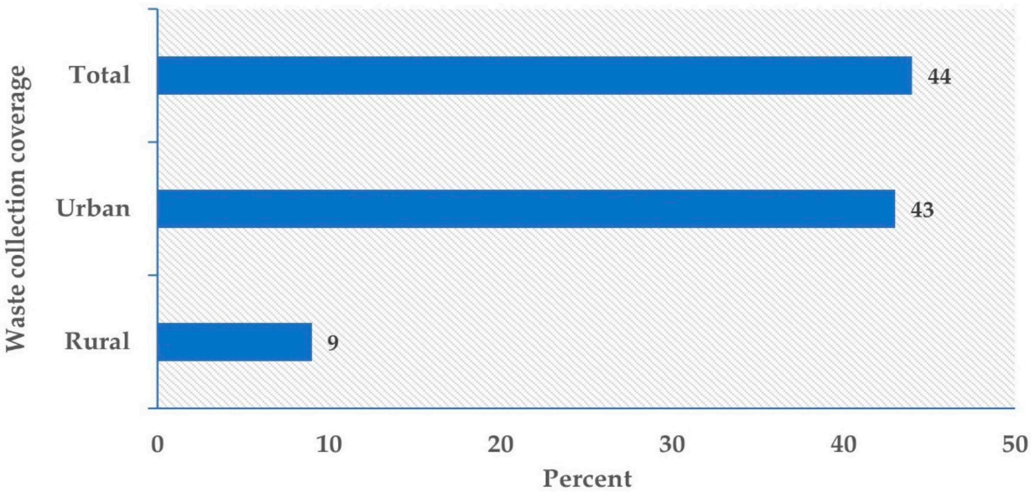

Figure 3. SSA waste collection coverage [1]. Permission to use this figure is granted under the Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO). Reference is cited in the bibliography as advised under the 'Attribution' condition.

4.2.1. Accra Metropolis

Accra's data on waste generation rates are discordant because waste audit reports were unavailable for more than two decades [42]. Following an extensive literature search, the most recent data on waste generation rate from the waste department in Accra found in the peer-reviewed literature is that reported by Sarfo-Mensah et al. [66]. The report states that the environmental protection agency in Accra documented 2800 tonnes per day in 2014 with 2200 tonnes being collected. This implies a collection rate of about 79% (this is in close range with the collection rate of 85% calculated from the 2012 waste collection data provided by Scarlat et al. [61]), although this study also noted that about 30% to 50% are never collected. This casts doubt on the correctness of the figures reported by the environmental agency. Kaza et al. [1] reported an 83% collection rate for Accra while Oduro-Kwarteng and Van Dijk [40] arrived at a much higher collection rate estimate of 93%. A different survey in 2015 [58] showed a value of 1552 tonnes per day and noted that the generation rate was higher in high-class income areas and lowest in low-class income areas. Two studies [42,67] published five years apart seem to agree on waste composition data in Accra. These studies reported 60% for organics while another study [58] published 63%. Interestingly, the figure of 48.8% for organics published in 2017 [68] differs widely. This could mean that waste data are not periodically updated. There are interesting statistics on waste collection coverage for Accra. For example, Frazier [69] reported a collection coverage of 70%; Wilson et al. [43] published a collection coverage of 67%; UNEP [3] documented 80% coverage for Accra. It is pertinent to add that MSW collection coverage improved owing to the engagement of public-private partnerships (PPP), which became necessary because of the increase in waste volume resulting from Accra's population growth.

4.2.2. Kumasi Metropolis

Owusu-Sekyere et al. [70], relying on data from the KMA forecasted waste generation in Accra for 2013 as 591,016 tonnes (we summed up figures from January to December 2013) using monthly waste volume values from 2005 to 2010. Since the waste generation per capita per day is derived by dividing the waste generated per year by the population of the reference year [71], we determined the per capita value for 2013 as 0.32 kg/capita per day using the official population figure of Kumasi metropolis in 2013, which was 1,827,014 according to Ghana Statistical Service [72]. This is in proximity with Ghana's waste generation estimates of 0.35 to 0.75 kg/capita per day as reported by one study [40]. The subsequent year, 2014 showed an increase to an average of 0.75 kg/capita per day [58]. Waste characterisation studies carried out in Kumasi show that the organic component for low- and middle-income communities, respectively, is 59.15% and 65.68% [73]. These figures are not too distant from the organic waste composition of 61% reported earlier for Ghana as a whole.

4.3. Generation, Composition, and Collection of MSW in Abuja and Lagos, Nigeria

Estimates of MSW generation rates in Nigeria have been reported by various authors [60,74], but based on our literature review the most current data on Nigeria's MSW generation rate appears to be that reported by Kaza et al. [1] as 0.51 kg/capita per day adjusted to the 2016 population level. Nnaji [75] published data of 0.49 kg/capita per day in 2015, while Oyebode [60] reported a generation rate of 0.43 kg/capita per day in 2018. One would have thought that the national per capita waste generation should be higher in 2018 compared to 2015 since, as noted by Vij [76], urbanization has a direct impact on per capita waste generation, which must have occurred between 2015 and 2018—but again, this could reflect the incongruency in data records. Considering this likely influence, the value of 0.51 kg accurately depicts Nigeria's current waste generation rate. Some authors of articles that reported generation rates before 2010 consistently referred to a particular author's data for over a decade. This again highlights that waste data in the sub-Sahara are not regularly updated to reflect current realities, a trend similar to Ghana, as shown earlier. The composition of MSW in Nigeria is mainly organic, between 60% to 80% [60]. The high organic content in Nigeria is consistent with data reported earlier for SSA. The records of the MSW collection in Nigeria are disparate. It is estimated that only 20–30% of the over 32 million tonnes of annually generated waste are collected [77], while another study [78] reported a collection of 20% to 80%. An older record by Ogwueleka published in 2009 as cited in [75] documented uncollected waste of 30% to 60% before the period under review.

4.3.1. Abuja

In 2010, the waste generation rate in Abuja was estimated at 67,000 tonnes per year [79]. As of 2011, it had increased to 70,000 tonnes per year [80]. The figures for waste generation in Abuja show some disparities. One study [35] reported a generation rate of 0.67 kg/capita per day, while data published in 2015 showed 0.57 kg/capita per day [75]. Two years later, Kadafa [45] documented a range of 0.5 to 1.5 kg/capita per day. There could be reasons for Kadafa's range of figures including the season of the year, the research technique adopted, or the time of data collection [75]. Like other cities in SSA or the urban areas of other developing countries, the per capita waste generation increases with urbanization compared to the rates in rural areas [71]. That effect will increase, with urbanization rates in Africa and Asia projected to reach 64% by 2050 [81]. The composition of MSW in Abuja falls within the range for other cities considered in this review, which is between 52% to 60% organic, followed by plastics at 6.2% (Abuja Environmental Protection Board (AEPB), 2012 as cited in [82]), a trend also observed in the two Ghanaian cities. The MSW collection coverage in Abuja is reported to be insufficient relative to the city's population [83]. In the same vein, the collection rate is low. For example, according to Anyaegbunam [35], the AEPB can potentially collect up to 5000 metric tonnes of waste daily in an ideal situation, but only 1918 metric tonnes (38.4%) are collected, leaving 61.6% uncollected.

4.3.2. Lagos

The MSW waste generation in Africa's most populous city [84] has been rising. The generation rate was reported as 9000 tonnes per day (0.5 kg/capita per day) in 2014 [78,80]. In the same year, a study [85] published a different value of 0.95 kg/capita per day which lies outside the estimated range of 0.5 to 0.8 kg/capita per day for SSA countries [82]. Data published in 2018 estimated 12,000 metric tonnes per day (0.72 kg/capita per day) with a projection to 20,000 metric tonnes per day in 2020 using the estimated population of 30.2 million (LAWMA, 2012 as cited in [48]). Comparing the waste generation per day in 2014 and 2018 shows a 33.3% increase within four years compared to a projected 66.7% surge in the two years from 2018 to 2020. The waste generation rate in Lagos has assumed an alarming scale and calls for increased attention from the municipal authorities. As expected, the organic component of waste generated in Lagos is much higher than other components at 56% [86], although two other studies [48,87] published slightly varied data at 53%. Plastics usually trail behind, as shown in previous figures for other cities, except as reported by Oladepo and Rafiu [86] where the paper fraction came next at 12% with plastics at 10%. However, usually the trend for Ghana and Nigeria shows plastics as the second highest component of MSW. Only a few authors have reported on collection coverage for Lagos within the period under review. We found an article that published 63% collection coverage, mainly in the medium- to high-income areas with better road access, leaving the hinterland poorly serviced [48], a common trend in the sub-Sahara. A low collection rate has also been reported for Lagos. For example, between 2007 and 2013 an estimated 77.76 million tonnes of waste was generated with only 27.7% collected, leaving 72.3% uncollected across the metropolis (LAWMA, 2014 cited in [38]). Like Abuja's values, this figure falls below the estimated collection rate of 44.3% for SSA cities [61]. A similar situation is reported for Nigeria where Adeniran et al. [77] noted that from the over 32 million tonnes of MSW generated nationally, only a meagre 20% to 30% is collected. Notably, the collection rate reported for Lagos in 2018 was 10% [1], which is the lowest we found in the literature. It should be added that, in 2018, Lagos residents feared an epidemic outbreak owing to mounting heaps of uncollected MSW across the city. This was due to the lack of capacity by Visionscape (a foreign waste management company contracted by the Lagos state government) to collect waste across the city, resulting in backlogs over a long period in various parts of the city [88] (Figure 4).

Figure 4. Uncollected waste lining a road median in Lagos. Retrieved from [88]. Used with permission.

4.4. Methods of MSW Collection in Ghana and Nigeria

The literature shows that the common methods of waste collection employed in the examined cities are house-to-house (or door-to-door) and communal (or central) waste collection systems [48,51,80]. These authors also highlighted some of the challenges with these methods in the study areas. The door-to-door waste collection entails the pickup of MSW fractions (sorted waste) at access points from individual dwellings in a locality [89]. In Italy, a study shows, that with more public awareness, door-to-door collection can spur the motivation for waste separation at the source. Thus, the chances of collecting more recyclables are increased [90]. This environmentally friendly approach is captured in the EU waste framework directive (Directive 2008/98/EC). However, the question arises whether this best practice forms part of the ideology of door-to-door collection in SSA. In the communal or central collection system, an area is chosen within a neighbourhood for the placement of waste collection bins. The people from that locality drop their waste for routine pickup by a waste collection company [91,92]. This method is also called the drop-off system. The communal collection is used in a broad sense. The system in Germany (Figure 5) is one variation of the communal method where waste bins are placed at a designated collection point close to apartment buildings [93]. This can also be seen in Maputo, Mozambique, Africa and Bahrain, in the Middle East [43]. It provides a higher service level than the use of communal bins (Figure 6) in the informal settlements of Ghana [43]. The following sections will examine the application of these collection methods and their associated challenges in the SSA focus areas.

Figure 5. A central collection point, near apartments, Berlin, Germany. Author's field photo.

Figure 6. Overfilled communal bin, Accra, Ghana. Retrieved from [94]. Used with permission.

4.4.1. Ghana

Accra and Kumasi's collection methods described above are fraught with some challenges. For example, Boateng et al. [95] reported a low-cost recovery from the communal collection system, which led to the introduction of a 'pay-as-you-dump' (PAYD) cost recovery mechanism, which was successful in the collection system. Unfortunately, as his report indicated, those who could not afford either of the collection services took to illegal dumping, a common trend in the sub-Sahara. However, the study further noted that some community members were willing to pay for either of the methods provided collection is regular, timely, and the appropriate waste collection bins are provided for waste storage. Another issue with communal collection points is the recurring spillover of waste from the skip containers arising from a delayed pickup, usually blamed on faulty collection vehicles [66,96,97]. To substantiate this, we extracted the picture of a skip container in Accra with overflowing waste (Figure 6). In consonance with the findings of Boateng et al. [95] about people's willingness to pay for either PAYD or door-to-door collection, Owusu et al. [98] showed in a Kumasi survey that a higher percentage of the respondents preferred door-to-door collection, followed by PAYD, which, according to him may be due to the timely collection by the waste collection company or the fact that they can afford collection and dumping fees under the PAYD system. In a similar survey, residents were willing to pay a higher collection fee provided collection is consistent and efficient [99].

4.4.2. Nigeria

Ghana and Nigeria have similar challenges with the two prevalent waste collection methods. In Lagos, an article [48] affirmed that the door-to-door collection by the assigned agent is insufficient in coverage, with hinterland Lagos sparsely covered for well-known reasons, including a poor road network to some areas and low cost recovery from people in such locations, among others. Opoko and Oluwatayo [100] and Ojolowo and Wahaba [38] highlighted the issues with irregular door-to-door collection in separate field surveys as the non-provision of communal skip bins in some highly populated low-income areas, as well as demands for waste collection payments when services were not rendered. These inefficiencies push some residents to illegal dumping and open waste burning to rid their homes of accumulated waste, which can potentially harm their health. Chidiebere et al. [101] pointed out another problem as the insufficient capacity of the waste collection agencies to cope with the rising waste volume, which consistently results in a backlog of uncollected waste, especially in the low-income areas of Lagos. This situation is corroborated by Adedara [102] in a study carried out in Lagos where it was noted that Alimosho, the largest local government in Lagos by population, had heaps of refuse in street corners, drains, road medians, and some public spaces—a clear indication that the problem persists. In Abuja, cases of irregular collection, inadequate provision of receptacles for communal or door-to-door collection, and insufficient coverage, among others, have also been reported [83,103,104]. In a field survey, Kadafa [45] noted that non-gated communities outside the Abuja metropolis had neighbourhood open waste dumps as communal collection points. In contrast, the municipal waste collection agency provided gated communities with communal waste bins. This social stratification speaks volumes about the waste authority's attitude to sustainable solid WM. Similar to Ghana, the collection of waste in Lagos and Abuja via the two methods are not in separate fractions that would allow the recovery of recyclable materials. Kadafa [45] also discovered that in Abuja the municipal waste authority initially collected healthcare waste in separate containers but at the dumpsite, they lumped them together with biodegradable and non-biodegradable waste materials, which can constitute a threat to public health, as already established in this article. Moreso, this defeats the environmental benefits of waste segregation at the source. Unfortunately, a similar scenario occurred in Accra where domestic waste was mixed with healthcare waste at the disposal site [105]. This practice, no doubt, portends hazards of injury or disease to scavengers as they scout the site for recyclables, not knowing that such waste materials require special handling [106].

4.5. Private Sector Involvement in MSW Collection—Ghana and Nigeria

Both countries, from the cities examined, engaged the services of the private sector in MSW collection as the municipal waste collection authorities/departments became overwhelmed with escalating waste volume. In Kumasi and Accra, MSW is collected mainly by private companies engaged in a PPP arrangement with the municipal government [107,108]. The waste department only takes care of street sweeping and the collection of bulk wastes [109]. A field study in Kumasi carried out by Awunyo-Vitor et al. [110] concluded that, despite PPP arrangements being in force, piles of refuse were still a common sight in Kumasi. However, according to Oteng-Ababio [111] and Oduro-Kwarteng and Dijk [40], since the introduction of the PPP franchise in Accra and Kumasi, there has been a significant increase in collection coverage (which is higher than the estimated average for SSA countries as shown in Figure 7). On the contrary, Oduro-Appiah et al. [112] are concerned that a collection coverage of 75% in Accra is still a far cry from the desired 100% after the involvement of the PPP arrangement in MSW collection for over 20 years. In Lagos, the private sector participation (PSP) operators and LAWMA share waste collection responsibilities. As in Ghana, the municipal waste collection authority attends to cleaning and waste collection from common city areas, such as highways, major roads, and the like. The PSP operators are assigned to non-public areas, mainly residential premises [48]. In Abuja, the city's environmental board, AEDP, is the main collector of MSW [35,80] with additional services by PSP operators [83,113]. In Lagos and Abuja, waste is collected either once or twice a week, and sometimes twice monthly [114–116]. According to a publication [99], waste from communal waste bins in Accra could be collected up to eight times a day, depending on when they are full. In Lagos, PSP operators do a weekly collection. Irrespective of improvements in collection coverage in Ghana following the involvement of the private sector, there are still complaints of poor service while cases of illegal dumping continue. The waste collection in Lagos by the private waste collectors suffered a setback in 2018 when the government of Lagos state terminated the contracts of PSP operators and replaced them with a foreign waste collection company—the company was overwhelmed by the city's waste volume, which resulted in backlogs of uncollected waste under their watch, as reported earlier in this article. In the case of Abuja, we found that, in addition to complaints of poor service delivery, the city appears to be struggling to meet the average collection coverage for SSA, despite the intervention of private waste collectors.

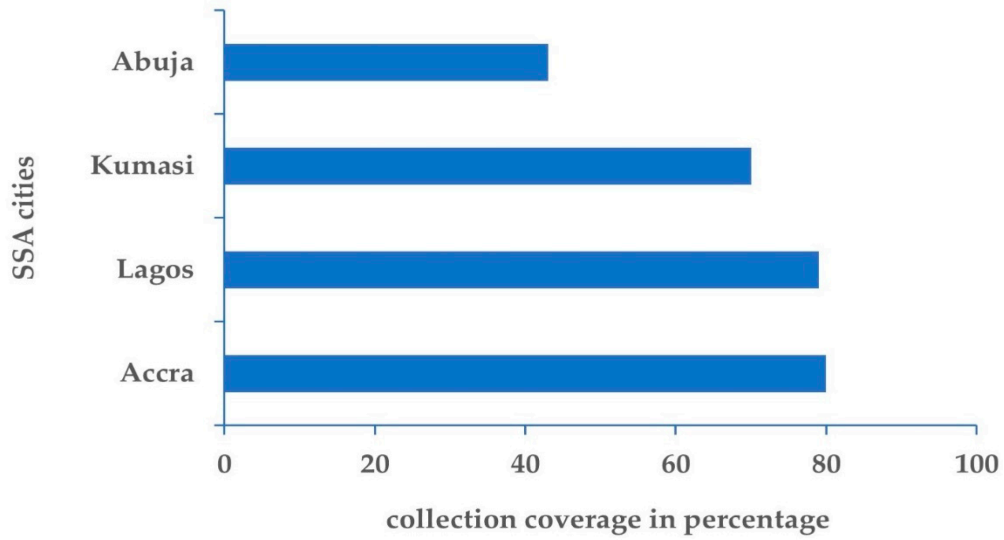

Figure 7. Collection coverage estimates in the four SSA cities [3,45,48,49]. The estimate for Lagos was derived by calculating the average of figures published by [3,48] given their wide disparity and the fact that they were published in the same year.

4.5.1. MSW Storage Receptacles—Ghana and Nigeria

The source separation of solid waste, in line with best practices targeted at environmental protection, including the recovery of quality recyclables, segregation of organics, and reduction of MSW is imperative [117–119]. Therefore, waste storage receptacles at the point of generation should enable the collection of MSW in separate fractions. In Ghana, polythene bags, wheeled plastic bins, baskets, paper boxes, metal containers, old plastic buckets, sacks, and others are commonly used for MSW storage before collection [94,120,121]. Sometimes PPP operators in Ghana give free plastic bins to customers during door-to-door collection [95]. This could be to encourage more sorting towards their next pickup. In other cases, for example in Kumasi, the PPP operators distribute 120-litre plastic bins to households for a fee [109]. Similar types of receptacles are used in Lagos [115] and Abuja [45,80], but in Lagos the wheeled bins are only given to property owners who pay the state's land use charge [122]. The land use charge is a levy imposed on landed property owners in the city [123]. People residing in properties whose landlords are either non-resident in the property they live in or do not pay the levy resort to self-help, which in many cases results in indiscriminate dumping. In addition to the non-separation widely reported for door-to-door collection, wastes were also co-mingled at the skip bins in Ghana [21]. Common problems in all four cities examined are the non-segregation of waste fractions either at the door-to-door collection points or at the communal bins, and the persistent spillover of refuse around the collection bins due to delayed pickup. The co-mingling of waste fractions is not beneficial to the environment and will not facilitate the shift to a circular economy [119].

4.5.2. MSW Waste Collection Vehicles in Ghana and Nigeria

When municipal authorities and private waste collectors choose their waste collection vehicles, they should consider waste density. It varies depending on location, the season of the year, or the type of storage receptacle [8]. We found that a common type of vehicle utilized for door-to-door collection of MSW across the four cities is the compactor truck, in addition to others such as tipping trucks, roll-on-roll-off trucks, rear loaders, and tricycles, among others [48]. During our review, we did not find an article that discussed the technical requirements for the selection of collection vehicles. Instead, issues such as inadequate vehicle fleet or foul odour from obviously decaying biodegradable waste were dominant in papers [38,116,124]. An additional grave concern is the incessant breakdown of collection vehicles due to overloading and sometimes due to poorly surfaced or dilapidated roads [125]. Overloading occurs when the mass of the transported waste is greater than the truck's maximal payload [8]. Vehicle breakdowns remain a daunting challenge coupled with the appalling state of the roads. The engagement of PPP/PSP operators in the cities examined has, no doubt, alleviated the burden of the municipal authorities in waste collection. Nevertheless, the cities are still faced with lingering collection challenges.

4.6. Waste Collection in the Context of a Circular Economy (CE)

According to the Ellen MacArthur Foundation [126], the circular economy (CE), driven by design, promotes the transition from the current linear model of take–make–dispose towards keeping materials in use for as long as possible to reduce the pressure on virgin raw materials, eliminating waste and pollution, and regenerating nature. As developed economies move more intently in the direction of a circular economy (CE), it is imperative for SSA countries to also make a shift in this direction. In this section, we examine how a better understanding of the CE concept can help waste management authorities/departments in SSA countries improve their waste collection systems by taking a cue from the CE drive in Europe and adapting the approaches to local situations. In 2015, the EU presented its policy statement on transitioning to a CE with a review of its waste legislation. It focused on improving the separate collection of waste from households in its bid to increase reuse and recycling among member states while reducing the pressure on finite virgin materials. A critical statement from the document reads, *"there will be no circular economy without good waste separation"*. In the document, the EU expressly emphasized the critical need to separate organic waste from other fractions to ensure a clean collection of recyclables so that recycling industries do not incur increased costs in their operations. It summarised that waste separation could be adapted to local situations in big and small cities [119]. By implication, this could mean that small cities do not need to copy what big cities do directly, but it is necessary to look for ways to improve separate collections within the limits of their size and financial capacity. In the same vein, cities in SSA would have to practice the separate collection of waste in ways locally possible to begin the shift to a CE so that they can increase landfill diversion rate and keep secondary raw materials in circulation. Among other benefits, the regular separate collection of recyclable fractions at the point of generation helps to ensure that local recycling industries have a continuous supply of clean secondary raw materials for their operations, while at the same time reducing the volume of waste disposed of in landfills as shown in a study by Bashir et al. [127]. If this is backed up with an effective waste policy as in the EU, it would no doubt contribute to stemming the tide of indiscriminate dumping in SSA. Non-recyclable waste fractions could be converted to energy with some materials also recovered using incineration as a WTE technology [128]. Although a major issue with incineration is the potential to cause air pollution [76,129], this does not eliminate its potential benefits in energy generation. For example, an empirical study in Palestine [130] showed that incineration generated the highest amount of electricity compared to other WTE technologies. The study further suggested that the combination of AD with incineration will produce more energy with the least damage to the environment. Some other potential benefits of using MSW as a feedstock for energy generation and biofertilizer production, and how these processes contribute to the achievement of some of the sustainable development goals (SDGs) have been thoroughly discussed by Yong et al. [131]. It is essential to add that the state of MSW management in SSA provides a plethora of opportunities for investments in WTE technologies since the raw materials are readily available. These options should therefore be explored by concerned authorities in the region in the shift towards a CE. However, as presented in a study by Yong et al. [22] and Cudjoe [64] in Malaysia and China, respectively, it is essential to carry out an appraisal of the economic viability and environmental implications of various WTE options to decide on which is most viable within a locality as this would guide investors in making an investment choice. As earlier noted, in SSA, organics are co-mingled with other fractions. This is not desirable if the target is high-quality recycling, and it will not attract recycling companies for business since it will increase their operations costs. We reported earlier that there were instances in Ghana and Nigeria where healthcare wastes initially separated at source were co-mingled at the disposal site. This does not align with the CE concept, hence, according to Seyring et al. [90] the separate collection of recyclables at the point of generation is desired. Our take-home observation in the EU document is the commitment of the member states demonstrated through political will, national enforcement, and public awareness. For example, in 2015 Germany made the separate collection of organics a national obligation, although implementation has not been rapid [118]. Policymakers in SSA countries can take a cue from this and enact locally appropriate waste policies targeted at capturing waste resources from the source rather than losing them to the waste stream as it is now. A strong political will and an effective implementation mechanism should follow this. Central and Eastern Europe were assumed to be behind in waste collection, but a field survey established that some cities in those areas emerged as excellent in the separate collection of MSW [90]. Hence, with political will, policies are formulated based on EU guidelines, while public cooperation is sought through public awareness. In SSA, past field studies in Lagos and Accra have established that people are willing to segregate their waste at home and in the office if they are taught how [102,132]. Increased awareness and public education will foster participation in waste separation, even in informal markets [21]. Based on the findings of Gyimah et al. [133], some people indicated a readiness to participate in waste segregation but were demotivated owing to the unavailability of recycling plants to process the waste. This brings another challenge to the fore in SSA: what to do with segregated recyclables when the volume becomes high in the face of an insufficient supply of waste processing companies. There is a need to open the market for local and foreign waste materials processing investments. Given the willingness to be involved in waste separation, as established in this article, the drive towards a CE, in addition to the points raised earlier, can also be achieved via the encouragement of active participation through continuous public awareness. However, caution should be taken to ensure that strategies adopted are tailored towards what is locally possible rather than the direct importation of systems used abroad.

Informal Efforts towards a Circular Economy—Ghana and Nigeria

Proponents of the circular economy (CE) model view waste as an essential resource that powers economic development. Hence, as an important material for the production process, it should be exploited in preference to the extraction of virgin materials [134]. Waste pickers in landfills in SSA are driven by survival [135] but are also informally engaged in re-circulating discarded waste resources for supply to local recycling industries [136]. The scavengers take advantage of the collection gap created through the inefficient collection of MSW by municipal governments that rely mainly on non-engineered landfill disposals. In Ghana and Nigeria, scavenging is common at many dumpsites [49,137]. Some articles [138–140] have reported on the public health hazards associated with scavenging in West African cities, but equally highlighted the contribution of the pickers to the recovery of materials for reuse as well as the supply of materials to local recycling industries, which is in favour of the CE model. In both countries, there are active repair markets for imported E-waste—mostly from the EU—such as mobile phones, TVs, old fridges, and car waste sold as spare parts, among others. Although there is a thriving market for shipped functioning equipment, some materials are damaged beyond repair. These constitute another source of waste and amplify the waste burden in SSA. Especially problematic is the content of hazardous materials in some of these products [141,142]. Even though some E-waste products are damaged beyond repair, useful parts are recovered for the repair of other devices; this contributes to the circulation of secondary raw materials and promotes CE. The quest for survival and the scarcity of jobs mainly drive some unskilled people in developing countries to scavenge at dumpsites [18]. However, it is important to note that these activities indicate that SSA may be well-positioned to begin the shift to a circular economy while it improves on efforts to close the gap in MSW collection, especially in low-income neighbourhoods.

4.7. Result of the Meta-Analysis

This section presents the result of the meta-analysis conducted in this study. As highlighted earlier, the meta-analysis was conducted to obtain an overall assessment of waste collection and coverage rates in sub-Saharan African countries. The subsequent sections discuss the results of the analysis.

4.7.1. Waste Collection Rate

Figure 8 shows the forest plot of waste collection rate in the sub-Sahara African countries generated using the meta-analysis software. A forest plot is often used to denote the result of a meta-analysis graphically. The plot consists of two parts. The first part denotes the included studies, their effect sizes (i.e., collection rate), standard errors, standardized weights given to each study, and their corresponding values at a 95% confidence interval. The other part graphically shows each study's weight, which is represented by the red square. The horizontal line at the centre of the column shows the confidence interval of the weight assigned to each study. For instance, the effect size of the first study in Figure 8 is 0.384, with an upper and lower value of 0.32 and 0.45, respectively, at a 95% confidence interval. The standard error (SE) and the weight of the study are 0.03303 and 10.2%, respectively. The summary effect is represented by the centre of the black diamond, and its 95% confidence interval is denoted by the widths. Quantitatively, the summary effect of waste collection rate in the selected sub-Saharan African countries is 0.65 (i.e., 65%) with a confidence interval of 0.43–0.87. This implies that the waste collection rate in SSA countries is low and less than the desired 100%. The summary effect suggests that there is a significant need for improvement in waste collection practices and policies to reduce the negative environmental and health impacts of uncollected waste.

Study or Subgroup	Collection rate	SE	Weight	Collection rate IV, Random, 95% CI
Anyaegbunam 2013	0.384	0.03303	10.2%	0.38 [0.32, 0.45]
Kaza (2) et al. 2018	0.1	0.0085	10.3%	0.10 [0.08, 0.12]
Kaza et al. 2018	0.83	0.0248	10.3%	0.83 [0.78, 0.88]
Oduro-Kwarteng & Van Dijk (2) 2013	0.93	0.185	8.1%	0.93 [0.57, 1.29]
Oduro-Kwarteng & Van Dijk 2013	0.91	0.08	9.8%	0.91 [0.75, 1.07]
Ojolowo & Wahab 2017	0.277	0.0129	10.3%	0.28 [0.25, 0.30]
Oteng-Ababio (2) 2014	0.799	0.0286	10.3%	0.80 [0.74, 0.86]
Oteng-Ababio (3) 2014	0.799	0.0263	10.3%	0.80 [0.75, 0.85]
Oteng-Ababio 2014	0.8	0.031	10.2%	0.80 [0.74, 0.86]
Sarfo-Mensah et al. 2019	0.79	0.0272	10.3%	0.79 [0.74, 0.84]
Total (95% CI)			**100.0%**	**0.65 [0.43, 0.87]**

Heterogeneity: $Tau^2 = 0.12$; $Chi^2 = 2323.05$, df = 9 ($P < 0.00001$); $I^2 = 100\%$
Test for overall effect: Z = 5.84 ($P < 0.00001$)

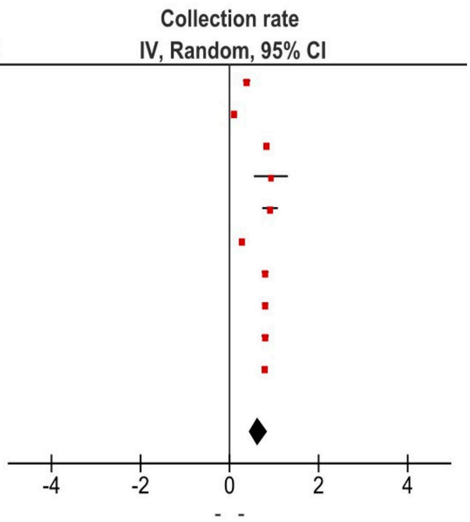

Figure 8. Forest plot of waste collection rate in the selected SSA countries [1,35,38,40,42,66].

Furthermore, the I2 (100%) shows that there is high heterogeneity in the effect sizes of the included studies. Although the random effect model, which caters for variability among the studies, was used for the analysis, a sub-group analysis using the data collection region was conducted to further investigate the heterogeneity. As shown in Figure 9, the summary effect of waste collection in Nigeria is 0.25 (i.e., 25%), while that of Ghana is 0.81 (81%). This shows that the criterion (location of data collection) used for the sub-group analysis is significant for determining the source of heterogeneity, as confirmed by the I2 (98%) of the test for the sub-group difference.

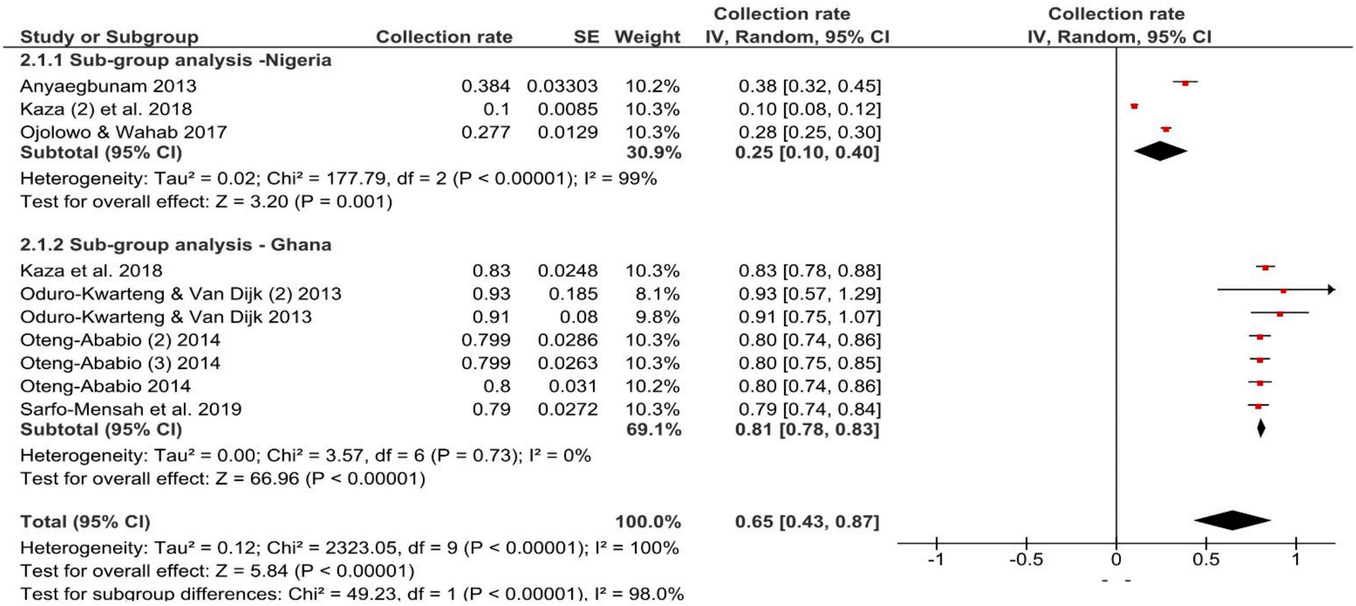

Figure 9. Forest plot of sub-group analysis of waste collection rate based on country [1,35,38,40,42,66].

4.7.2. Waste Collection Coverage Rate

The result of the waste collection coverage rate in SSA countries is represented in Figure 10. The Figure shows the studies included in the meta-analysis, their effect sizes (i.e., coverage rate), standard errors, 95% confidence interval of the effect sizes, and the assigned weights to the studies both numerically and graphically. For instance, the effect size reported in the last study [3] shown in Figure 10 was 0.95, and its 95% confidence interval was found to be 0.94–0.96. Its standard error and assigned weights are 0.0065 and 11.4%. As revealed by the black diamond in Figure 10, the summary effect is 0.67 (i.e., 67%) with a 95% confidence interval of 0.50–0.83. This means that the meta-analysis of previous studies estimated the waste coverage rate in SSA countries to be 67%. The 95% confidence interval of the summary effect shows that the true value of the waste coverage rate in SSA countries is likely to fall within 50–83%.

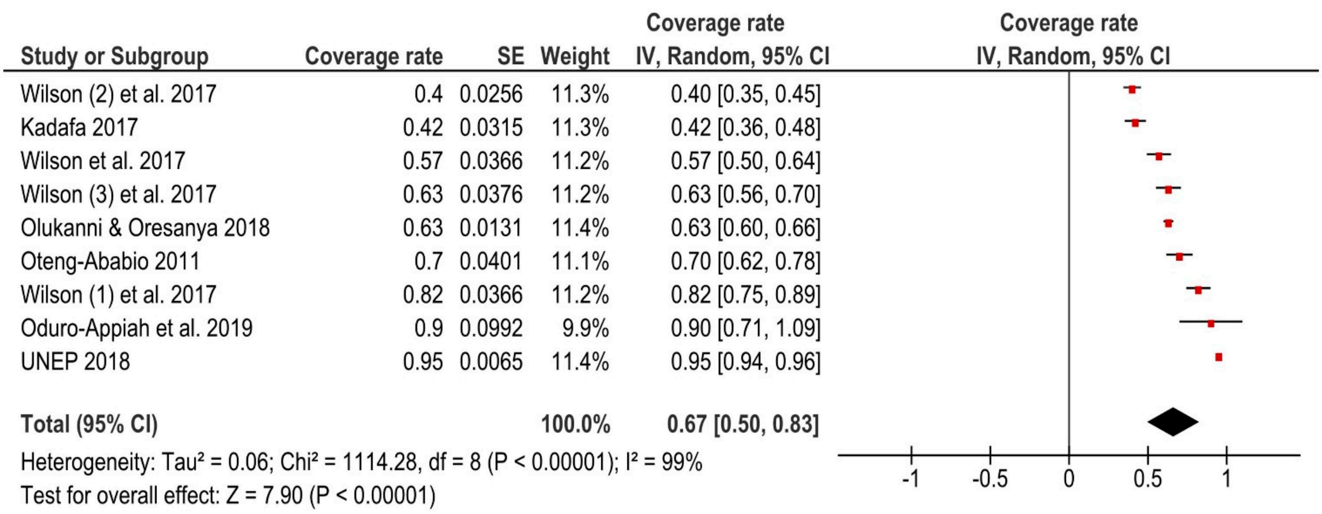

Figure 10. Forest plot of waste coverage rate in the selected SSA countries [3,43,45,48,49,51].

Due to the high heterogeneity (I2 = 99%) in the effect sizes of the studies, sub-group analysis was conducted to investigate the source of the heterogeneity. The result of the sub-group analysis is presented in Figure 11, and it shows that the summary effects of waste collection coverage rate in Nigeria, Ghana, and other countries are 67, 78, and

60%, respectively. This shows that the coverage rate is not statistically different across the three groups as their coverage rate is similar. This is also confirmed by the test for sub-group difference, as the I2 is 0%. Summarily, the waste collection coverage rate in SSA countries is less than the ideal 100%, and it is important to explore potential solutions to improve waste management services availability and accessibility in SSA countries. Potential solutions include (1) investment in waste management infrastructure such as waste treatment facilities, recycling plants, and waste transfer stations; (2) encouraging more public-private partnerships to increase investment in waste management services; and (3) encouraging research and development in waste management technologies that are suitable for the African context.

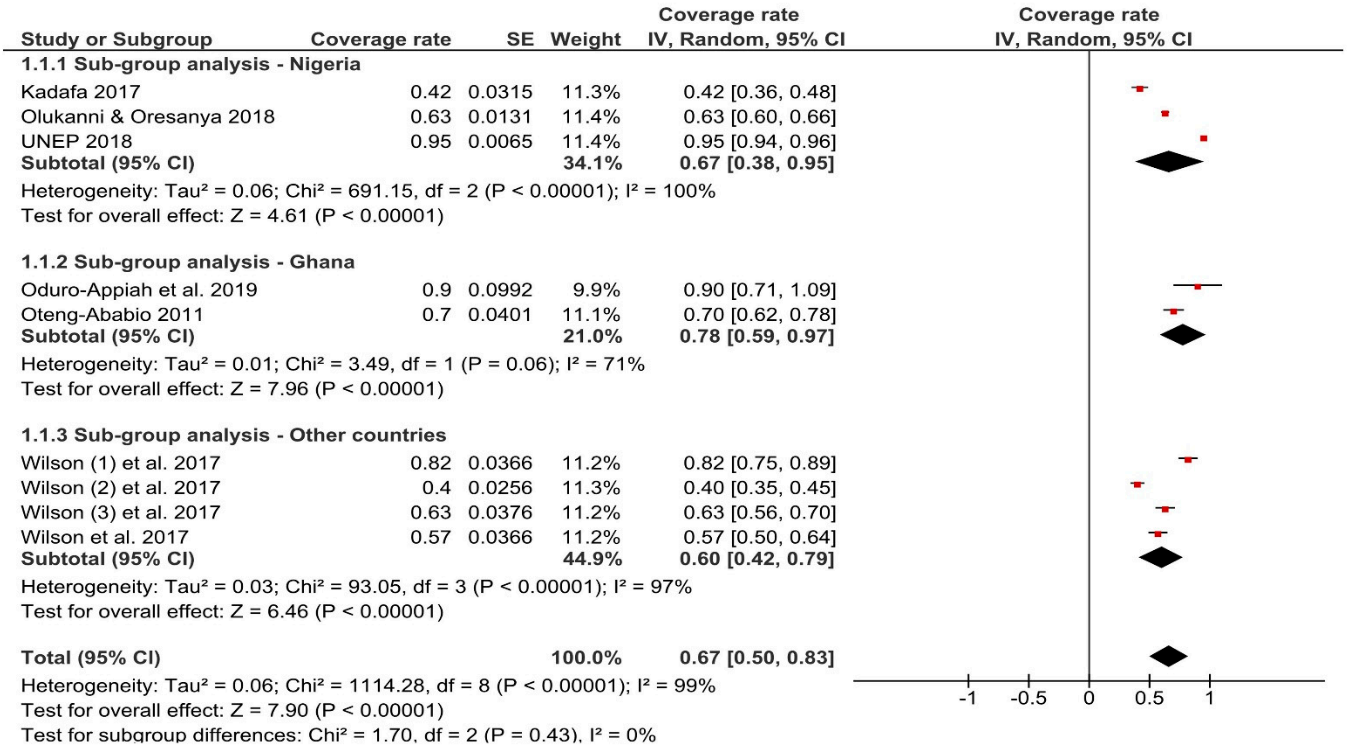

Figure 11. Forest plot of sub-group analysis of waste coverage rate based on country [3,43,45,48,49,51].

5. Conclusions and Recommendations

The review reveals that cities in SSA are currently overwhelmed by lingering backlogs of uncollected waste, with collection rate and coverage still below 100%, despite the involvement of private waste collectors in MSW collection. The meta-analysis result indicates that waste collection and coverage rates are both below 70% in SSA. While several studies have explored the various aspects of waste treatment methods and recycling, only a handful have directly addressed the urgent need to increase the collection rate and coverage of MSW in low-income neighbourhoods with poor sanitary conditions. Hence, there is a pressing need for more research and concerted efforts towards improving WM services availability and accessibility in SSA countries. In some SSA cities, there are instances where waste segregation at source has been practised, but unfortunately, the unavailability or inadequate supply of waste treatment technology for processing the collected waste defeats the purpose of the segregation since the collected waste eventually ends up in the region's mostly un-engineered landfills.

Given the current situation, as a first step, it has become inevitable for countries in SSA to further open up the market of waste collection by enacting a waste policy that allows direct investments in waste treatment technology, which should also licence waste processing companies to collect MSW needed for their plants directly from residential and commercial premises. This would increase competition in MSW collection in the high-, medium-, and low-income neighbourhoods and ultimately result in the quick mop-up of waste backlogs with the overall impact of increasing collection rate and coverage above current levels. It is essential to note, however, that the involvement of waste processing companies in improving the efficiency of the collection system has its associated challenges. One challenge might be the inadequacy of current data on the volume of waste generated by households and commercial premises, which the waste processing companies need to forecast the supply of materials to their processing plants, including planning for personnel and facilities for efficient collection. Where this is not addressed before investing in the market, waste materials supply could fall below what is required for the plants to function at full capacity, thereby affecting the sustainability of the business in the long run. Moreover, the possibility of existing private waste collectors feeling threatened by the entry of competitors cannot be ruled out. This may result in the refusal of older market players to share relevant information with the new entrants at the initial stage. In the interest of public health, the process of upgrading major landfills in the region to the status of "controlled landfills" where a material recovery facility (MRF) is built should be given urgent consideration by municipal governments. Scavengers can be shielded from the potential health hazards associated with their activities by engaging them in the sorting of recyclables in the MRF and then paying them in proportion to the weight of materials sorted, which is the same thing that happens when they sell scavenged materials to local recycling industries. An empirical case that demonstrates this possibility is the revamping of the "Awotan" dumpsite in Ibadan, South-Western Nigeria to the status of a "controlled landfill" where former open dump scavengers now sort about 50 tonnes of recyclables daily in the newly built MRF located at the landfill site [143]. Although it is expected that scavengers would express worries that their means of livelihood is now being threatened with this strategy, as the case was when scavengers were told to vacate the "Awotan dumpsite", their fears could be allayed by ensuring they are co-opted into the new plan at the MRF so that they can continue to earn money while benefiting from safer working conditions.

While more research on MSW collection in SSA is needed, given how critical it is in achieving a sustainable WM system, further research efforts can be focused on monitoring the progress made towards increasing the collection rate and coverage beyond current levels through studies that quantitatively compare the before and after scenarios following the introduction of an intervention in this area. In such studies, research studies should seek to measure the impact of increased competition in the collection system in low-income neighbourhoods where the figures of collection rate and coverage are abysmally low compared to the middle- and high-income areas of the city. Moreso, it would be worthwhile to also quantify the impact of upgrading an open dumpsite to a controlled landfill on scavenging activities within a catchment area as a way of assessing how the government's efforts in this direction are improving public health while ensuring income security for former scavengers and gradually reducing scavenging in SSA. Another aspect aimed at promoting the CE would be to measure the impact of continuous grassroots awareness campaigns targeted at waste reduction and reuse in high-, medium-, and low-income neighbourhoods on the volume of waste generated and disposed of over some time. Specifically, areas with presently low collection coverage should be chosen for this study and checked over two years to compare the results, before and after. A study like this might serve as an insight into how to reduce the waste disposed of in landfills.

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References

1. Kaza, S.; Yao, L.; Bhada-Tata, P.; Van Woerden, F. *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*; World Bank: Washington, DC, USA, 2018.
2. Hoornweg, D.; Bhada, P. *What a Waste 2012—A Global Review of Solid Waste Management*; World Bank: Washington, DC, USA, 2012.
3. UNEP. *Africa Waste Management*; United Nations Environment Programme: Nairobi, Kenya, 2018; ISBN 978-92-807-3704-2.
4. Rodić, L.; Wilson, D.C. Resolving Governance Issues to Achieve Priority Sustainable Development Goals Related to Solid Waste Management in Developing Countries. *Sustainability* **2017**, *9*, 404. [CrossRef]
5. Odonkor, S.T.; Salar, A.M. Correlates of Household Waste Management in Ghana: Implications for Public Health. *Heliyon* **2021**, *7*, e08227. [CrossRef] [PubMed]
6. Pires, A.; Graca, M.; Rodrigues, S.; Gomes, M.I. *Sustainable Solid Waste Collection and Management*; SpringerLink; Springer International Publishing: Cham, Switzerland, 2019.
7. Carlos-Alberola, M.; Izquierdo, A.G.; Colomer-Mendoza, F.J.; Barreda-Albert, E. Design of a Municipal Solid Waste Collection System in Situations with a Lack of Resources: Nikki (Benin), a Case in Africa. *Sustainability* **2021**, *13*, 1785. [CrossRef]
8. UN-HABITAT. *Collection of Municipal Solid Waste in Developing Countries*; United Nations Human Settlements Programme: Nairobi, Kenya, 2010; ISBN 978-92-1-132254-5.
9. Diaz, L.F. Waste Management in Developing Countries and the Circular Economy. *Waste Manag. Res.* **2017**, *35*, 1–2. [CrossRef] [PubMed]
10. Mlilo, P.; Marufu-Dzangare, I.T.; Chigugudhlo, P.N.; Chitongo, L. Waste Management in Cowdray Park Suburb of Bulawayo, Zimbabwe. *J. Public Adm. Dev. Altern.* **2021**, *6*, 48–64.
11. Wilson, D.C.; Velis, C.A.; Rodic, L. Integrated Sustainable Waste Management in Developing Countries. *Proc. Inst. Civ. Eng. Waste Resour. Manag.* **2013**, *166*, 52–68. [CrossRef]
12. Innocent, N.M.; Dieudonné, B.; Jose, S.N. Modeling the Temporal Variations of Municipal Solid Waste Generation for Future Projection in the Douala Municipality, Cameroon. *J. Multidiscip. Eng. Sci. Technol. JMEST* **2016**, *3*, 2458–9403.
13. Mbeng, L.O. Informal Waste Recovery and Recycling: Alleviating Poverty, Environmental Pollution and Unemployment in Douala, Cameroon. *J. Sci. Res. Rep.* **2013**, *2*, 474–490. [CrossRef]
14. Tassie, K.; Endalew, B.; Mulugeta, A. Composition, Generation and Management Method of Municipal Solid Waste in Addis Ababa City, Central Ethiopia: A Review. *Asian J. Environ. Ecol.* **2019**, *9*, 1–19. [CrossRef]
15. Dlamini, S.; Simatele, M.D.; Serge Kubanza, N. Municipal Solid Waste Management in South Africa: From Waste to Energy Recovery through Waste-to-Energy Technologies in Johannesburg. *Local Environ.* **2019**, *24*, 249–257. [CrossRef]
16. Maqhuzu, A.B.; Yoshikawa, K.; Takahashi, F. Estimation of Leachate Generated from Zimbabwe's Municipal Solid Wastes (MSW) Landfills Using a Simple Stochastic Water Balance Model. *App. Envion. Res.* **2018**, *40*, 40–50. [CrossRef]
17. Idowu, I.A.; Atherton, W.; Hashim, K.; Kot, P.; Alkhaddar, R.; Alo, B.I.; Shaw, A. An Analyses of the Status of Landfill Classification Systems in Developing Countries: Sub Saharan Africa Landfill Experiences. *Waste Manag.* **2019**, *87*, 761–771. [CrossRef] [PubMed]
18. Nyathi, S.; Olowoyo, J.O.; Oludare, A. Perception of Scavengers and Occupational Health Hazards Associated with Scavenging from a Waste Dumpsite in Pretoria, South Africa. *J. Environ. Public Health* **2018**, *2018*. [CrossRef] [PubMed]
19. Nambuli, F.; Togarepi, C.; Shikongo, A. Waste Scavenging a Problem or an Opportunity for Integrated Waste Management in Namibia: A Case of Keetmanshoop Municipality, Namibia. *Environ. Pollut.* **2021**, *10*, 47. [CrossRef]
20. Couth, R.; Trois, C. Waste Management Activities and Carbon Emissions in Africa. *Waste Manag.* **2011**, *31*, 131–137. [CrossRef] [PubMed]
21. Agbefe, L.E.; Lawson, E.T.; Yirenya-Tawiah, D. Awareness on Waste Segregation at Source and Willingness to Pay for Collection Service in Selected Markets in Ga West Municipality, Accra, Ghana. *J. Mater. Cycles Waste Manag.* **2019**, *21*, 905–914. [CrossRef]
22. Yong, Z.J.; Bashir, M.J.K.; Ng, C.A.; Sethupathi, S.; Lim, J.W.; Show, P.L. Sustainable Waste-to-Energy Development in Malaysia: Appraisal of Environmental, Financial, and Public Issues Related with Energy Recovery from Municipal Solid Waste. *Processes* **2019**, *7*, 676. [CrossRef]
23. Aziz, S.Q.; Aziz, H.A.; Bashir, M.J.; Yusoff, M.S. Appraisal of Domestic Solid Waste Generation, Components, and the Feasibility of Recycling in Erbil, Iraq. *Waste Manag. Res.* **2011**, *29*, 880–887. [CrossRef]
24. Purkayastha, D.; Majumder, M.; Chakrabarti, S. Collection and Recycle Bin Location-Allocation Problem in Solid Waste Management: A Review. *Pollution* **2015**, *1*, 175–191.

25. World Bank Sub-Saharan Africa | Data. Available online: https://data.worldbank.org/country/ZG (accessed on 23 November 2022).
26. Ministry of Foreign Affairs, Japan. *Chapter 2 Specific Initiatives of Japan's Official Development Assistance. Section 2 Assistance for Each Region*; Tokyo, Japan, 2014. Available online: https://www.mofa.go.jp/files/000119328.pdf (accessed on 21 March 2023).
27. Baumgartner, B. The Position of Sub-Saharan Countries in the World Economy. *Stud. Commer. Bratisl.* **2016**, *9*, 5–16. [CrossRef]
28. World Population Review Population of Cities in Ghana. 2022. Available online: https://worldpopulationreview.com/countries/cities/ghana (accessed on 23 November 2022).
29. *Accra Metropolitan Assembly Republic of Ghana Local Government Bulletin (Bye-Laws 2017)*; 2019. Available online: https://ama.gov.gh/doc/bye-laws.pdf (accessed on 23 November 2020).
30. World Urban Forum. *UN-HABITAT Lagos: Citizen Participation in a Multi-Cultural City Organization*; 2020. Available online: https://wuf10.unhabitat.org/wuf10-programme/voices-cities/lagos-citizen-participation-multi-cultural-city (accessed on 28 November 2020).
31. Mackelprang, A.W.; Nair, A. Relationship between Just-in-Time Manufacturing Practices and Performance: A Meta-Analytic Investigation. *J. Oper. Manag.* **2010**, *28*, 283–302. [CrossRef]
32. Zouine, A.; Fenies, P. The Critical Success Factors Of The ERP System Project: A Meta-Analysis Methodology. *J. Appl. Bus. Res. JABR* **2014**, *30*, 1407–1448. [CrossRef]
33. Salihu, C.; Hussein, M.; Mohandes, S.R.; Zayed, T. Towards a Comprehensive Review of the Deterioration Factors and Modeling for Sewer Pipelines: A Hybrid of Bibliometric, Scientometric, and Meta-Analysis Approach. *J. Clean. Prod.* **2022**, *351*, 131460. [CrossRef]
34. Borenstein, M.; Hedges, L.V.; Higgins, J.P.T.; Rothstein, H.R. Subgroup Analyses. In *Introduction to Meta-Analysis*; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2009; pp. 149–186. ISBN 978-0-470-74338-6.
35. Anyaegbunam, N.C. Environmentally Friendly and Sustainable Municipal Solid Waste Management in Abuja. *Int. J. Eng. Sci. Invent.* **2013**, *2*, 42–50.
36. Macrotrends LLC Abuja, Nigeria Metro Area Population 1950–2023. Available online: https://www.macrotrends.net/cities/21976/abuja/population (accessed on 18 February 2023).
37. Macrotrends LLC Lagos, Nigeria Metro Area Population 1950–2023. Available online: https://www.macrotrends.net/cities/22007/lagos/population (accessed on 18 February 2023).
38. Ojolowo, S.; Wahab, B. Municipal Solid Waste and Flooding in Lagos Metropolis, Nigeria: Deconstructing the Evil Nexus. *J. Geogr. Reg. Plan.* **2017**, *10*, 174–185. [CrossRef]
39. Macrotrends LLC Accra, Ghana Metro Area Population 1950–2023. Available online: https://www.macrotrends.net/cities/21107/accra/population (accessed on 18 February 2023).
40. Oduro-Kwarteng, S.; Van Dijk, M.P. The Effect of Increased Private Sector Involvement in Solid Waste Collection in Five Cities in Ghana. *Waste Manag. Res.* **2013**, *31*, 81–92. [CrossRef]
41. Macrotrends LLC Kumasi, Ghana Metro Area Population 1950–2023. Available online: https://www.macrotrends.net/cities/21108/kumasi/population (accessed on 18 February 2023).
42. Oteng-Ababio, M. Rethinking Waste as a Resource: Insights from a Low-Income Community in Accra, Ghana. *City Territ. Archit.* **2014**, *1*, 1–14. [CrossRef]
43. Wilson, D.C.; Kanjogera, J.B.; Soós, R.; Briciu, C.; Smith, S.R.; Whiteman, A.D.; Spies, S.; Oelz, B. Operator Models for Delivering Municipal Solid Waste Management Services in Developing Countries. Part A: The Evidence Base. *Waste Manag. Res.* **2017**, *35*, 820–841. [CrossRef]
44. Macrotrends LLC Dar Es Salaam, Tanzania Metro Area Population 1950–2023. Available online: https://www.macrotrends.net/cities/22894/dar-es-salaam/population (accessed on 18 February 2023).
45. Kadafa, A.A. Solid Waste Management Practice of Residents in Abuja Municipalities (Nigeria). *IOSR J. Environ. Sci. Toxicol. Food Technol.* **2017**, *11*, 87–106. [CrossRef]
46. Macrotrends LLC Bamako, Mali Metro Area Population 1950–2023. Available online: https://www.macrotrends.net/cities/21818/bamako/population (accessed on 18 February 2023).
47. Macrotrends LLC Lusaka, Zambia Metro Area Population 1950–2023. Available online: https://www.macrotrends.net/cities/23277/lusaka/population (accessed on 18 February 2023).
48. Olukanni, D.O.; Oresanya, O.O. Progression in Waste Management Processes in Lagos State, Nigeria. *Int. J. Eng. Res. Afr.* **2018**, *35*, 11–23. [CrossRef]
49. Oteng-Ababio, M. The Role of the Informal Sector in Solid Waste Management in the GAMA, Ghana: Challenges and Opportunities. *J. Econ. Hum. Geopgraphy* **2011**, *103*, 412–425. [CrossRef]
50. Macrotrends LLC Maputo, Mozambique Metro Area Population 1950–2023. Available online: https://www.macrotrends.net/cities/21910/maputo/population (accessed on 18 February 2023).
51. Oduro-Appiah, K.; Afful, A.; Kotey, V.N.; de Vries, N. 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* **2019**, *8*, 12. [CrossRef]
52. Taiwo, R.; Hussein, M.; Zayed, T. An Integrated Approach of Simulation and Regression Analysis for Assessing Productivity in Modular Integrated Construction Projects. *Buildings* **2022**, *12*, 2018. [CrossRef]

53. Tawfik, G.M.; Dila, K.A.S.; Mohamed, M.Y.F.; Tam, D.N.H.; Kien, N.D.; Ahmed, A.M.; Huy, N.T. A Step by Step Guide for Conducting a Systematic Review and Meta-Analysis with Simulation Data. *Trop. Med. Health* **2019**, *47*, 1–9. [CrossRef] [PubMed]
54. The Cochrane Collaboration. Review Manager Web. Version 5.4. 2020. Available online: http://revman.cochrane.org (accessed on 21 March 2023).
55. Higgins, J.; Green, S. *Cochrane Handbook for Systematic Reviews of Interventions*, 1st ed.; Wiley: Hoboken, NJ, USA, 2019.
56. Horman, M.J.; Kenley, R. Quantifying Levels of Wasted Time in Construction with Meta-Analysis. *J. Constr. Eng. Manag.* **2005**, *131*, 52–61. [CrossRef]
57. Taiwo, R.; Wang, K.C.; Olanrewaju, O.I.; Tariq, S.; Abimbola, O.T.; Mehmood, I.; Zayed, T. An Analysis of Employee Motivation in the Construction Industry: The Case of Hong Kong. *Eng. Proc.* **2022**, *22*, 11. [CrossRef]
58. Miezah, K.; Obiri-Danso, K.; Kádár, Z.; Fei-Baffoe, B.; Mensah, M.Y. Municipal Solid Waste Characterization and Quantification as a Measure towards Effective Waste Management in Ghana. *Waste Manag.* **2015**, *46*, 15–27. [CrossRef] [PubMed]
59. Hirpe, L.; Yeom, C. Municipal Solid Waste Management Policies, Practices, and Challenges in Ethiopia: A Systematic Review. *Sustainability* **2021**, *13*, 11241. [CrossRef]
60. Oyebode, O.J. Evaluation of Municipal Solid Waste Management for Improved Public Health and Environment in Nigeria. *Eur. J. Adv. Eng. Technol.* **2018**, *5*, 525–534.
61. Scarlat, N.; Motola, V.; Dallemand, J.F.; Monforti-Ferrario, F.; Mofor, L. Evaluation of Energy Potential of Municipal Solid Waste from African Urban Areas. *Renew. Sustain. Energy Rev.* **2015**, *50*, 1269–1286. [CrossRef]
62. Sechoala, T.D.; Popoola, O.M.; Ayodele, T.R. A Review of Waste-to-Energy Recovery Pathway for Feasible Electricity Generation in Lowland Cities of Lesotho. In Proceedings of the IEEE AFRICON Conference, Jeju Island, South Korea, 1 September 2019; Institute of Electrical and Electronics Engineers Inc.; Volume 2019.
63. Matheri, A.N.; Ndiweni, S.N.; Belaid, M.; Muzenda, E.; Hubert, R. Optimising Biogas Production from Anaerobic Co-Digestion of Chicken Manure and Organic Fraction of Municipal Solid Waste. *Renew. Sustain. Energy Rev.* **2017**, *80*, 756–764. [CrossRef]
64. Cudjoe, D.; Han, M.S.; Nandiwardhana, A.P. Electricity Generation Using Biogas from Organic Fraction of Municipal Solid Waste Generated in Provinces of China: Techno-Economic and Environmental Impact Analysis. *Fuel Process. Technol.* **2020**, *203*, 106381. [CrossRef]
65. Asare, W.; Andrews, A.; Asare, R. Households Solid Waste Generation and Disposal in Some Selected Communities in Ejisu–Juaben Municipality, Ghana. *J. Sci. Res. Rep.* **2015**, *6*, 371–382. [CrossRef] [PubMed]
66. Paul, S.-M.; Kwaku, O.-O.; Albert, A.A.; Theophilus, K.A.; Richard, T.O. Solid Waste Management in Urban Communities in Ghana: A Case Study of the Kumasi Metropolis. *Afr. J. Environ. Sci. Technol.* **2019**, *13*, 342–353. [CrossRef]
67. Osei-Appiah, N.A.; Dioha, M.O. Techno-Economic Assessment of Waste-to-Energy Technologies in Ghana. *J. Sustain. Energy* **2019**, *10*, 112–121.
68. Benedicta, A.; Susanne, H.; Bradl, H.B.; Pishva, D.; Ahiakpa, J.K. Resource Prospects of Municipal Solid Wastes Generated in the Ga East Municipal Assembly of Ghana. *J. Health Pollut.* **2017**, *7*, 37–47. [CrossRef]
69. Frazier, T.J. Opportunities and Challenges for Sustainability in an Urbanizing World: Selections from the UGEC2010 Conference Transforming Accra towards a Sustainable Future: Comprehensive Land Use Planning and the Greater Accra Urban Simulation System (GAUSS). In Proceedings of the UGEC Viewpoints, Tempe, AZ, USA, 15–17 October 2010.
70. Owusu-Sekyere, E.; Harris, E.; Bonyah, E. Forecasting and Planning for Solid Waste Generation in the Kumasi Metropolitan Area of Ghana: An ARIMA Time Series Approach. *Intern. J. Sci.* **2013**, *2*, 69–83.
71. Kawai, K.; Tasaki, T. Revisiting Estimates of Municipal Solid Waste Generation per Capita and Their Reliability. *J. Mater. Cycles Waste Manag.* **2016**, *18*, 1–13. [CrossRef]
72. Ghana Statistical Service. *Ghana Statistical Yearbook*; Accra, Ghana, 2013. Available online: www.statsghana.gov.gh (accessed on 27 November 2020).
73. Oduro-Kwarteng, S.; Anarfi, K.P.; Essandoh, H.M.K. Source Separation and Recycling Potential of Municipal Solid Waste in Ghana. *Manag. Environ. Qual. Int. J.* **2016**, *27*, 210–226. [CrossRef]
74. Atta, A.Y.; Aminu, M.A.Y.; Yusuf, N.; Gano, Z.S.; Ahmed, O.U.; Fasanya, O.O. Potentials of Waste to Energy in Nigeria. *J. Appl. Sci. Res.* **2016**, *12*, 1–6.
75. Nnaji, C.C. Status of Municipal Solid Waste Generation and Disposal in Nigeria. *Manag. Environ. Qual. Int. J.* **2015**, *26*, 53–71. [CrossRef]
76. Vij, D. Urbanization and Solid Waste Management in India: Present Practices and Future Challenges. In *Procedia—Social and Behavioral Sciences*; Elsevier: Amsterdam, The Netherlands, 2012; Volume 37, pp. 437–447.
77. Adeniran, A.E.; Nubi, A.T.; Adelopo, A.O. Solid Waste Generation and Characterization in the University of Lagos for a Sustainable Waste Management. *Waste Manag.* **2017**, *67*, 3–10. [CrossRef] [PubMed]
78. Anestina, A.I.; Adetola, A.; Odafe, I.B. Performance Assessment of Solid Waste Management Following Private Partnership Operations in Lagos State, Nigeria. *J. Waste Manag.* **2014**, *2014*, 1–8. [CrossRef]
79. Roberts, C.L.; Watkin, G.D.; Ezeah, C.; Phillips, P.S.; Odunfa, A. Seasonal Variation and Municipal Solid Waste Composition—Issues for Development of New Waste Management Strategies in Abuja, Nigeria. *J. Solid Waste Technol. Manag.* **2010**, *36*, 210–219. [CrossRef]
80. Ezeah, C.; Roberts, C.L. Waste Governance Agenda in Nigerian Cities: A Comparative Analysis. *Habitat Int.* **2014**, *41*, 121–128. [CrossRef]

81. Abomeh Ofobruku, S.; Nkiruka Okafor, C.; Agbaeze, E.K.; Ozioma Obi-Anike, H. Entrepreneurial Potentials of Solid Waste Management in the Federal Capital Territory Abuja, Nigeria. *Niger. J. Soc. Sci.* **2016**, *12*, 1–15.
82. Salami, H.A.; Adegite, J.O.; Bademosi, T.T.; Lawal, S.O.; Olutayo, O.O.; Olowosokedile, O. A Review on the Current Status of Municipal Solid Waste Management in Nigeria: Problems and Solutions. *J. Eng. Res. Rep.* **2018**, *3*, 1–16. [CrossRef]
83. Joseph, F.G.; Folorunsho, J.O.; Yusuf, Y.O.; Aruya, E.I. Assessment of Solid Waste Management Techniques in Maitama, Abuja, Nigeria. *Int. J. Sustain. Dev. Plan.* **2020**, *15*, 227–233. [CrossRef]
84. World Population Review Africa Cities by Population. 2022. Available online: https://worldpopulationreview.com/continents/africa/cities (accessed on 23 November 2022).
85. Aliu, I.R.; Adeyemi, O.E.; Adebayo, A. Municipal Household Solid Waste Collection Strategies in an African Megacity: Analysis of Public Private Partnership Performance in Lagos. *Waste Manag. Res.* **2014**, *32*, 67–78. [CrossRef]
86. Oladepo, A.S.; Rafiu, O.O. Challenges of Waste Management and Climate Change in Nigeria: Lagos State Metropolis Experience. *Afr. J. Sci. Res.* **2012**, *7*.
87. Oyebode, O.J. Solid Waste Management for Sustainable Development and Public Health: A Case Study of Lagos State in Nigeria. *Univers. J. Public Health* **2013**, *1*, 33–39. [CrossRef]
88. Olowookere, D. Investigation Shows How Inexperienced Visionscape Got Lagos Waste Management Deal. Business Post Nigeria. 2018. Available online: https://businesspost.ng/general/investigation-shows-how-inexperienced-visionscape-got-lagos-waste-management-deal/ (accessed on 3 August 2021).
89. Laurieri, N.; Lucchese, A.; Marino, A.; Digiesi, S. A Door-to-Doorwaste Collection System Case Study: A Survey on Its Sustainability and Effectiveness. *Sustainability* **2020**, *12*, 5520. [CrossRef]
90. Seyring, N.; Dollhofer, M.; Weißenbacher, J.; Bakas, I.; McKinnon, D. Assessment of Collection Schemes for Packaging and Other Recyclable Waste in European Union-28 Member States and Capital Cities. *Waste Manag. Res.* **2016**, *34*, 947–956. [CrossRef]
91. Beliën, J.; De Boeck, L.; Van Ackere, J. Municipal Solid Waste Collection and Management Problems: A Literature Review. *Transp. Sci.* **2014**, *48*, 78–102. [CrossRef]
92. Mora, C.; Manzini, R.; Gamberi, M.; Cascini, A. Environmental and Economic Assessment for the Optimal Configuration of a Sustainable Solid Waste Collection System: A Kerbside Case Study. *Prod. Plan. Control* **2014**, *25*, 737–761. [CrossRef]
93. Umweltbundesamt Waste Collection and Transport. Umweltbundesamt. Available online: https://www.umweltbundesamt.de/en/topics/waste-resources/waste-disposal/waste-collection-transport (accessed on 23 November 2022).
94. Owusu, G. Social Effects of Poor Sanitation and Waste Management on Poor Urban Communities: A Neighborhood-Specific Study of Sabon Zongo, Accra. *J. Urban.* **2010**, *3*, 145–160. [CrossRef]
95. Boateng, S.; Amoako, P.; Poku, A.A.; Appiah, D.O.; Garsonu, E.K. Household Willingness to Pay for Solid Waste Disposal Services in Urban Ghana: The Kumasi Metropolis Situation. *Ghana J. Geogr.* **2016**, *8*, 1–17.
96. Abdulai, H.; Hussein, R.; Bevilacqua, E.; Storrings, M. GIS Based Mapping and Analysis of Municipal Solid Waste Collection System in Wa, Ghana. *J. Geogr. Inf. Syst.* **2015**, *7*, 85–94. [CrossRef]
97. Udofia, E.A.; Yawson, A.E.; Aduful, K.A.; Bwambale, F.M. Residential Characteristics as Correlates of Occupants' Health in the Greater Accra Region, Ghana. *BMC Public Health* **2014**, *14*, 224. [CrossRef]
98. Owusu, V.; Boaheng, J.M.; Sundberg, C. Are Households Willing to Pay for Full-Cost Solid Waste Collection? Evidence from Kumasi Metropolis of Ghana. *J. Environ. Stud. Sci.* **2011**, *1*, 144–153. [CrossRef]
99. Oduro-Appiah, K.; Aidoo, D.O.; Graham, S. Fee-Based Solid Waste Collection in Economically Developing Countries: The Case of Accra Metropolis. *Int. J. Dev. Sustain.* **2013**, *2*, 629–639.
100. Opoko, A.P.; Oluwatayo, A.A. Private Sector Participation in Domestic Waste Management in Informal Settlements in Lagos, Nigeria. *Waste Manag. Res.* **2016**, *34*, 1217–1223. [CrossRef]
101. Alban Chidiebere, O.; Abubakar, M.; Shabako, G.J. Municipal Solid Waste Management in African Cities: A Case Study of Lagos State, Nigeria. *Malays. J. Civ. Eng.* **2018**, *30*, 1–12. [CrossRef]
102. Adedara, M.L. Assessment of the Source Separation of Household Solid Wastes in Nigeria (A Case Study of Alimosho Local Government Area, Lagos). Master's Thesis, University of Kiel, Kiel, Germany, 2018.
103. Amasuomo, E.; Tuoyo, O.J.A.; Hasnain, S.A. Analysis of Public Participation in Sustainable Waste Management Practice in Abuja, Nigeria. *Environ. Manag. Sustain. Dev.* **2015**, *4*, 180. [CrossRef]
104. Adeyemi, B. Waste Management in Contemporary Nigeria: The Abuja Example. *Int. J. Polit. Good Gov.* **2011**, *2*, 1–18. Available online: http://www.onlineresearchjournals.com/ijopagg/previousissues.php?jn=22# (accessed on 21 March 2023).
105. Asante, O.B.; Yanful, E.; Yaokumah, E.B. Healthcare Waste Management. Its Impact: A Case Study of the Greater Accra Region, Ghana. *Int. J. Sci. Technol. Res.* **2014**, *3*, 106–112. Available online: https://www.ijstr.org/research-paper-publishing.php?month=mar2014 (accessed on 21 March 2023). [CrossRef]
106. Padmanabhan, K.K.; Barik, D. Health Hazards of Medical Waste and Its Disposal. In *Energy from Toxic Organic Waste for Heat and Power Generation*; Elsevier: Amsterdam, The Nteherlands, 2019; pp. 99–118. ISBN 978-0-08-102528-4.
107. Yeboah-Assiamah, E.; Asamoah, K.; Kyeremeh, T.A. Decades of Public-Private Partnership in Solid Waste Management: A Literature Analysis of Key Lessons Drawn from Ghana and India. *Manag. Environ. Qual. Int. J.* **2017**, *28*, 78–93. [CrossRef]
108. Bosompem, C.; Stemn, E.; Fei-Baffoe, B. Multi-Criteria GIS-Based Siting of Transfer Station for Municipal Solid Waste: The Case of Kumasi Metropolitan Area, Ghana. *Waste Manag. Res.* **2016**, *34*, 1054–1063. [CrossRef]

109. Addo, I.B.; Adei, D.; Acheampong, E.O. Solid Waste Management and Its Health Implications on the Dwellers of Kumasi Metropolis, Ghana. *Curr. Res. J. Soc. Sci.* **2015**, *7*, 81–93. [CrossRef]
110. Awunyo-Vitor, D.; Ishak, S.; Seidu Jasaw, G. Urban Households' Willingness to Pay for Improved Solid Waste Disposal Services in Kumasi Metropolis, Ghana. *Urban Stud. Res.* **2013**, *2013*, 1–8. [CrossRef]
111. Oteng-Ababio, M. Private Sector Involvement in Solid Waste Management in the Greater Accra Metropolitan Area in Ghana. *Waste Manag. Res.* **2010**, *28*, 322–329. [CrossRef] [PubMed]
112. Oduro-Appiah, K.; Scheinberg, A.; Mensah, A.; Afful, A.; Boadu, H.K.; de Vries, N. Assessment of the Municipal Solid Waste Management System in Accra, Ghana: A 'Wasteaware' Benchmark Indicator Approach. *Waste Manag. Res.* **2017**, *35*, 1149–1158. [CrossRef]
113. Ayuba, K.A.; Manaf, L.A.; Sabrina, A.H.; Azmin, S.W.N. Current Status of Municipal Solid Waste Management Practise in FCT Abuja. *Res. J. Environ. Earth Sci.* **2013**, *5*, 295–304. [CrossRef]
114. Idowu, O.B.A.; Omirin, M.M.; Osagie, J.U. Outsourcing for Sustainable Waste Disposal in Lagos Metropolis: Case Study of Agege Local Government, Lagos. *J. Sustain. Dev.* **2011**, *4*, 116. [CrossRef]
115. Ilechukwu, V.U.; Aminu, T.O. Operational Factors Affecting Public-Private Partnership (PPP) in Sustainable Solid Waste Management in Lagos Metropolis. *J. Geogr. Issues* **2014**, *2*, 20–34.
116. Maton, D.J.; Kigun, P.A.; Ogalla, M. Integrated Solid Waste Management—A Palliative to Existing Waste Mgt Challenges in Jabi District, Abuja. *Ethiop. J. Environ. Stud. Manag.* **2016**, *9*, 769–779. [CrossRef]
117. Chen, B.; Lee, J. Household Waste Separation Intention and the Importance of Public Policy. *Int. Trade Polit. Dev.* **2020**, *4*, 61–79. [CrossRef]
118. European Bioplastics the Benefits of Separate Organic Waste Collection—European Bioplastics e.V. Available online: https://www.european-bioplastics.org/the-benefits-of-separate-organic-waste-collection/ (accessed on 23 November 2022).
119. European Commission. *Separate Waste Collection in the Context of a Circular Economy in Europe Charlemagne Building Brussels Draft Conference Report*; 2016. Available online: http://ec.europa.eu/environment/waste/eventspast/separate_waste.htm (accessed on 21 March 2023).
120. Yoada, R.M.; Chirawurah, D.; Adongo, P.B. Domestic Waste Disposal Practice and Perceptions of Private Sector Waste Management in Urban Accra. *BMC Public Health* **2014**, *14*, 697. [CrossRef]
121. Otchere, A.F.; Sarpong, K.O.; Okyere, S. Assessing the Challenges Affecting Solid Waste Management System in the Kumasi Metropolis. *J. Arts Humanit.* **2014**, *3*, 50–63. [CrossRef]
122. Agbesola, Y.O. Sustainability of Municipal Solid Waste Management in Nigeria: A Case Study of Lagos. Master's Thesis, Linköping University, Linköping, Sweden, 2013.
123. Lagos State Government About Lagos—Lagos State Government. Available online: https://lagosstate.gov.ng/about-lagos/ (accessed on 23 November 2022).
124. Fagariba, C.; Song, S. Assessment of Impediments and Factors Affecting Waste Management: A Case of Accra Metropolis Farmers' Climate Change Adaptation Constraints in Ghana: Evidence of Micro Climate Adaptation Strategy View Project Impact of Small Scale Mining on Soil and Water. *Acad. J. Environ. Sci.* **2016**. [CrossRef]
125. Samwine, T. Challenges and Prospects of Solid Waste Management in Ghana. *Int. J. Environ. Monit. Anal.* **2017**, *5*, 96. [CrossRef]
126. Ellen MacArthur Foundation What Is a Circular Economy? Ellen MacArthur Foundation. Available online: https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview (accessed on 23 November 2022).
127. Bashir, M.J.; Jun, Y.Z.; Yi, L.J.; Abushammala, M.F.; Amr, S.S.A.; Pratt, L.M. Appraisal of Student's Awareness and Practices on Waste Management and Recycling in the Malaysian University's Student Hostel Area. *J. Mater. Cycles Waste Manag.* **2020**, *22*, 916–927. [CrossRef]
128. Van Caneghem, J.; Van Acker, K.; De Greef, J.; Wauters, G.; Vandecasteele, C. Waste-to-Energy Is Compatible and Complementary with Recycling in the Circular Economy. *Clean Technol. Environ. Policy* **2019**, *21*, 925–939. [CrossRef]
129. Lam, C.H.K.; Ip, A.W.M.; Barford, J.P.; McKay, G. Use of Incineration MSW Ash: A Review. *Sustainability* **2010**, *2*, 1943–1968. [CrossRef]
130. Salah, W.A.; Abuhelwa, M.; Abusafa, A.; Bashir, M.J.K. The Feasibility of Renewable Energy Recovery from Municipal Solid Wastes in Palestine Based on Different Scenarios. *Biofuels* **2022**, 1–9. [CrossRef]
131. Yong, Z.J.; Bashir, M.J.K.; Hassan, M.S. Biogas and Biofertilizer Production from Organic Fraction Municipal Solid Waste for Sustainable Circular Economy and Environmental Protection in Malaysia. *Sci. Total Environ.* **2021**, *776*, 145961. [CrossRef] [PubMed]
132. Antwi, Y.B.; Koranteng, J.; Odei, S.; Anabila, E. Determinants of an Effective Solid Wastes Collection at the Workplace Accra. *Int. J. Emerg. Sci. Res.* **2020**, *1*, 20–27. [CrossRef]
133. Gyimah, P.; Mariwah, S.; Antwi, K.B.; Ansah-Mensah, K. Households' Solid Waste Separation Practices in the Cape Coast Metropolitan Area, Ghana. *GeoJournal* **2019**, *86*, 567–583. [CrossRef]
134. Savini, F. The Economy That Runs on Waste: Accumulation in the Circular City. *J. Environ. Policy Plan.* **2019**, *21*, 675–691. [CrossRef]
135. Gutberlet, J.; Uddin, S.M.N. Household Waste and Health Risks Affecting Waste Pickers and the Environment in Low- and Middle-Income Countries. *Int. J. Occup. Environ. Health* **2017**, *23*, 299–310. [CrossRef]

136. Kwarteng, I.K.; Kontič, D.; Bizjak, T.; Kontič, B. Assessing the Role of Waste Pickers in the Recycling Industry in Accra Metropolis. *J. Geosci. Environ. Prot.* **2020**, *08*, 73–87. [CrossRef]
137. Ogbonna, A.C.; Mikailu, A. The Role of the Informal Sector in Sustainable Municipal Solid Waste Management: A Case Study of Lagos State, Nigeria. *Int. J. Eng.* **2019**, *17*, 117–122.
138. Ezeah, C.; Roberts, C.L.; Phillips, P.S.; Mbeng, L.O.; Nzeadibe, T.C. Evaluation of Public Health Impacts of Scavenging in Abuja, Nigeria Using Q Methodology. In Proceedings of the International Solid Waste Association World Congress, Lisbon, Portugal, 12–15 October 2009; ISWA: Rotterdam, The Netherlands, 2010; pp. 300–310.
139. Owusu-Sekyere, E. Scavenging for Wealth or Death? Exploring the Health Risk Associated with Waste Scavenging in Kumasi, Ghana. *Ghana J. Geogr.* **2014**, *6*, 63–80. Available online: https://www.ajol.info/index.php/gjg/article/view/111135 (accessed on 21 March 2023).
140. Afon, A. A Survey of Operational Characteristics, Socioeconomic and Health Effects of Scavenging Activity in Lagos, Nigeria. *Waste Manag. Res.* **2012**, *30*, 664–671. [CrossRef] [PubMed]
141. Manhart, A.; Schleicher, T.; Degreif, S. *Global Circular Economy of Strategic Metals—The Best-of-Two-Worlds Approach (Bo2W)*; Oeko-Institut e.V.: Freiburg, Germany, 2014.
142. Manhart, A.; Osibanjo, O.; Aderinto, A.; Prakash, S. *Informal E-Waste Management in Lagos, Nigeria-Socio-Economic Impacts and Feasibility of Inter-National Recycling Co-Operations*; Final Report of Component 3 of the UNEP SBC E-Waste Africa Project; Oeko-Institut e.V.: Freiburg, Germany, 2011.
143. Governor Makinde Commissions Awotan Landfill Project—YouTube. 2021. Available online: https://www.youtube.com/watch?v=COBHAbFIlJ8 (accessed on 15 December 2021).

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