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Review

Improving Effective Solid Waste Management Systems in Ghana: A Comparative Study of the Cities of Karlsruhe, Germany and Navrongo, Ghana

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Abstract: Effective solid waste management is crucial for protecting public health and the environment. Global concentration on finding sustainable methods of handling waste continue to top the list of most governmental-related project checklists. This paper provides a case study on the management of municipal solid waste in the cities of Karlsruhe, Germany and Navrongo, Ghana as developed and developing countries respectively. This study aimed at comparing and drawing lessons from how these two different cities manage their solid waste. The waste management system in Karlsruhe prioritizes waste separation, recycling, and a pay-as-you-throw system has led to an efficient and sustainable waste management system that minimizes waste and protects the environment. Karlsruhe's adoption of a continual developmental plan structure focused on integrated WM concepts is credited with safeguarding the long-term viability of waste management in the city. In contrast, Navrongo's waste management system faces several challenges, including inadequate resources and infrastructure, traditional waste disposal practices, and the lack of well-planned waste management strategies. To improve effective solid waste management systems in Ghana, a collaborative approach involving the government, local organizations, and the community is necessary. This can include investing in infrastructure, implementing waste separation and recycling programs, and educating the public on the benefits of sustainable waste management practices. Learning from successful models like Karlsruhe can help accelerate the development of sustainable waste management practices in Ghana, and ultimately protect public health and the environment.

Keywords: solid waste; solid waste management; Navrongo; Karlsruhe

Statement of Declaration

Manuscript title: Improving effective solid waste management systems in Ghana: A comparative study of the cities of Karlsruhe, Germany and Navrongo, Ghana

The authors have certified that they have no affiliations with or involvement in any entity with any financial interest or non-financial interest in the subject matter discussed in this manuscript.

Significance statement

This work is important in improving waste management in Ghana by adopting the waste management system in Germany

1. Introduction

Globally, Municipal Solid Waste Management (MSWM) have received environmental conservationists' attention with several proposals of different innovative approaches and technologies in recent times due to the negative consequences waste pose to the environment and its contributions to climate change (Asase et al., 2009). McDougall and Hruska (2000) argued that the main objective of promoting environmental sustainability has ensured human welfare, conserved natural resources, and maximised environmental functions and services. However, the exponential growth of human populations, rise in economic growth, and changing human behaviours and preferences have influenced the creation and use of less recyclable plastic products, and among other factors have increased waste generation rates, creating environmental challenges for MSWM in different cities around the globe (Asase et al., 2009).

In comparison, there are clear use of advanced technologies and highly sophisticated methodologies for MSWM in the developed countries, unlike the developing regions. The public health risk is no longer a key factor in waste management (WM) in the majority of advanced nations; instead, the emphasis placed is on improving WM procedures with a larger focus on environmental sustainability (McDougall et al., 2001; Wilson, 2007). Zurbrügg and Schertenleib (1998) noted that lack of social inclusion, implementation deficits of services, narrow use of recyclables, poor implementation of WM policies and reforms, and insufficient landfill disposal are common characteristics of MSWM in most developing nations. Despite the significant disparities of WM in developed and developing nations, the environmental and financial costs of managing solid waste will continue to rise as developing nations experience population and industrial expansion. An empirical figure by UNEP (2005) suggests that the volume of waste produced often rises in approximately proportional to a country's progress in civilization. Therefore, if a robust management system is not provided, this could lead to higher biodiversity loss and an escalation in the risk to human health. This means that guiding a healthy WM strategy for developing nations is non-negotiable. However, this may take more effort to improve environmental health in more deteriorated ecosystem regions (UNEP, 2005). It is unquestionably true that WM strategies and techniques are far advanced in the first country regions over time through several stages. Wilson (2007) stated that developing nations can draw inspirational benefits from the lessons the developed nations as they work to enhance their current WM systems. This was true when Asase et al. (2009) affirmed that integrated WM strategies give a practical result in the WM system; a system acknowledged by most countries. Nonetheless, the idea of Integrated Solid Waste Management (ISWM) takes a comprehensive plan, and this regulates waste in a manner that is desirable to individuals, financially viable, and ecological success (McDougall et al., 2001). It uses a variety of various local combination treatments and takes into account full solid waste management (SWM).

There have been several recorded projects toward ISWM in poor nations, most of which were planned by NGOs for cities of some regions. It could be beneficial to provide a comparative study of the creation and establishment of an ISWM system for cities in developed and developing countries to better understand and aid the adoption of the ISWM method on a city-wide base in developing nations (Asase et al., 2009). An implementation framework for an effective ISWM system in developing nations ought to be created using the experiences and lessons learnt. This study aimed to contribute to the conversation about the increasing application of ISWM strategies in developing nations by providing a comparative case from a municipality in a developed nation. Waste management experts and environmental authorities in developing nations can, however, avert missteps by emulating developed countries for their accomplishments in the ISWM sector. According to Magrini et al. (2020), Germany has had success with a variety of WM programs, through effective and efficient WM policies (Olay-Romero et al., 2020). Therefore, this study used Germany and Ghana as developed and developing nations respectively to comprehend and draw an empirical understanding of their WM practices, policies and successes.

It does describe the various components of the MSWM system in Navrongo, Ghana, and Karlsruhe, Germany, as well as analyzes any lessons that could be learned and or adopted from both countries. To better comprehend the two cities' geographical and physical features, contextual

material is offered. The current WM systems are detailed in terms of waste collection, waste disposal methods, waste transportation methods, waste separation and recycling approaches to ensure comparisons between WM in these two cities. Evidence from reports and journal papers found online and in articles was used to describe the WM systems in the two cities – Navrongo and Karlsruhe. The key characteristics and common system drivers revealed in case studies of ISWM studies reported by McDougall et al. (2001) and Asase et al. (2009) are then explored relating to the MSWM systems in Karlsruhe and Navrongo.

2. Descriptions of the City of Karlsruhe and Navrongo

2.1. Background Information on the City of Karlsruhe

In Germany's southwest, close to the French border, sits the old capital of the German state of Baden, Karlsruhe (Figure 1). As of 2008, more than 300,000 people were living in the city. The Federal Law Court (Bundesgerichtshof) and the Federal Constitutional Court (Bundesverfassungsgericht), the top two federal courts in Germany, are both located in Karlsruhe. Karlsruhe is Germany's oldest technological university. The research centre at Karlsruhe and the several Fraunhofer Institutes in Karlsruhe are well known as the hub of an innovative technology region (Schwarz-herion et al., 2008).



Figure 1. Geographical location of Karlsruhe (Schwarz-herion et al., 2008)

2.2. Background Information of Navrongo

Navrongo is a major town in Ghana. The Kassena Nankana District, created in 1988 by LI 1855, was raised to the Kassena Nankana Municipal by LI 2106. It belongs to one of the thirteen municipalities in the Republic of Ghana's Upper East Region. Navrongo serves as the municipality's seat of government and administration. The municipality is positioned roughly between 11°10' and 10°3' North and 10°1' West (Figure 1). Navrongo is bordered to the north by Burkina Faso and the

Kassena-Nankana-West District. It is bordered by Bolgatanga Municipality and Kassena-Nankana West District to the east, Builsa District to the west, and the West Mamprusi District to the south in the Northern Region (GSS, 2014).



Figure 2. Location of Navrongo (Adams et al., 2018)

3. Overview of waste management in Karlsruhe and Navrongo

3.1. Waste management in Karlsruhe and Navrongo

In Karlsruhe, there are numerous governmental and private stakeholders involved in managing solid waste who are each responsible for waste disposal, conveyance, and recycling (Schwarzherrion et al., 2008). The municipal waste transport network, street sweeping, and waste disposal are all handled by the waste management department in Karlsruhe. A private disposer has been assigned to handle waste disposal just in a few of the suburbs. After the various waste types are picked up and transported by the municipal WM officer, they are segregated and treated by various public and private businesses.

On the other hand, the public landfill and residential burning of solid waste are the two most popular ways to dispose of waste in the Navrongo municipality (GSS, 2014). Nearly 11.8% of householders depend on waste collection services, 17.4% are involved in indiscriminate waste dumping, and 5.3 % use public waste bins. In the urban and rural parts of the Navrongo Municipality (NM), open waste disposal is common. Nonetheless, the rate of careless disposal of solid waste is greater in rural than in urban regions. According to GSS, nearly half of all households in the municipality dump their liquid refuse outdoors or on open lands.

3.2. Waste collection and composition

Primarily, there are three main types of waste bins available at each home in the Karlsruhe; leftover, recyclable items (particularly packaging designated with the green circle), and organic waste

bins (Schwarz-herion et al., 2008). Although residents are responsible for requesting the respective waste bins, this is not a challenge on their part as deliveries are always done and on time. These waste bins are in different colours mostly their lids: red for recyclables, green for organic wastes, and grey for leftover waste to signify different waste storage purposes. The remaining rubbish was collected together. Dry and moist wastes are not to be mixed in the differentiated recyclable waste container systems that Karlsruhe has implemented. Karlsruhe also has introduced the bulky waste collection system as in 2016. This system allows all household and every business which is connected to the municipal residual waste collection to have a bulky waste to be picked up once a year in standard household quantities.

In Navrongo, the narrative is quite different. There is no waste segregation system either at the household or disposal points. Both household and municipal waste are collected together and sent to a landfill for disposal. The Communal Collection System (CCS) entails placing metal containers at predetermined locations, to serve several homes in that neighbourhood. When the containers are full, skip loading vehicles haul and empty them to the final disposal site. There are five different sites for final waste disposal in Navrongo. These sites are Komfosi, Sissala, Zongo, new market and old market waste disposal sites. After the waste has been disposed to the final sites, they are either burned or compacted. Two different private WM companies, Environmental Service Provider Association (ESPA) and Zoomlion Ghana Limited (ZLG), on a separate contract provide WM services to the NM.

3.3. Waste disposal method

The office of Waste Management Karlsruhe (WMK), a regulated company, is in charge of carrying out waste collection services. The city follows the concept of waste separation, which means that waste is separated into different categories before disposal. This is done to ensure that waste is recycled and disposed of in an environmentally friendly manner (Figure 4a). Assorted waste types are delivered to various locations following household waste collection, which is carried out by the department of WMK as a municipal service provider (Rapp, 2008).

In the case of Navrongo, waste disposal is largely poor (Figure 3b). This is due to the insufficient waste bins provided to the public, coupled with limited financial resources and technical know-how confronting the municipal, open waste dump (38.6%), household waste burning (20.2%), indiscriminate dumping of waste (17.4%), the use of waste collection services (11.8%), and public dumpster (5.3%) are encouraged. The indiscriminate dumping of waste in both urban (43.6%) and rural (36.6%) communities are prevalent in the NM. Nevertheless, improper disposal of solid waste is more frequent in rural areas (21.8%) than in urban areas (6.3%). One-fourth (69.8%) of all households in the municipality disposes of their liquid wastes outdoors or on the streets. While 18.9% of people dispose of their waste in compounds, none of the other options accounts for more than 5% of the total disposal of waste (GSS, 2014). The health, sanitization, and growth of the municipality are impacted by the indiscriminate disposal of solid and liquid waste, particularly onto properties, sewers, roadways, and outdoors. The municipality experiences flooding as a result of some of these wastes becoming stuck in the drainage systems.



Figure 3. Disposal of solid waste (b) Navrongo



Figure 4. Comparison of equipment used for waste collection in (a) Karlsruhe (Oertel, 2014) and (b) Navrongo

3.4. Waste transport

The bio-waste is transported to a city-owned composting facility in Karlsruhe. Ordinary waste trucks are used to transport recyclable waste to the segregation facility Karlsruhe Rheinhafen Alba, a private waste disposal facility (Rapp, 2008). The residual waste is transported via an adjustable container system to the waste heating plant in Mannheim. The residual waste remains in the same container from waste collection points until transportation to the waste heating plant. After being emptied, the containers are transported back to Karlsruhe, at their respective places (Rapp, 2008). As posited by Oertel (2014), the use of advanced vehicles (Econic Euro VI), even in the narrow streets of Karlsruhe the dustbins have to be emptied. This Econic (Figure 4a) has additional test equipment on board, Lane Keeping Assist and the three-stage Advanced Emergency Brake System. Karlsruhe's refuse collection fleet includes about 50 refuse collection vehicles. The five new Econics are used primarily for recyclable materials. Every week each of the new trucks covers a distance of about 300 km and collects more than 50 tonnes of refuse. Unlike Karlsruhe, in Navrongo, solid waste is collected from house to house using vehicles, occasionally tricycles, popularly known as 'motor kia', and usually sent to central containers. When the central waste bins are filled up, they are hauled by the Navrongo waste ZLG to a designated landfill (Figure 4b).

3.5. Waste separation and recycling

The city of Karlsruhe engages in waste separation and recycling. Organic waste is converted into composting and filter scraps. These composts are used by the residents as manure for gardening, while another portion is utilized as fertilizers for farmland (Rapp, 2008). Various sorts of separation techniques are used to separate the reusable rubbish that is sent to the private waste processing company, Alba, a subsidiary of the office of waste management in Karlsruhe. When the recyclable garbage has been separated, it is compressed into big bundles and sent to various private recycling centres. On the other hand, the NM does not currently have waste segregation systems in place. Both household and public waste are mixed together. There are no separate waste bins for the collection of different waste forms as in the case of Karlsruhe.

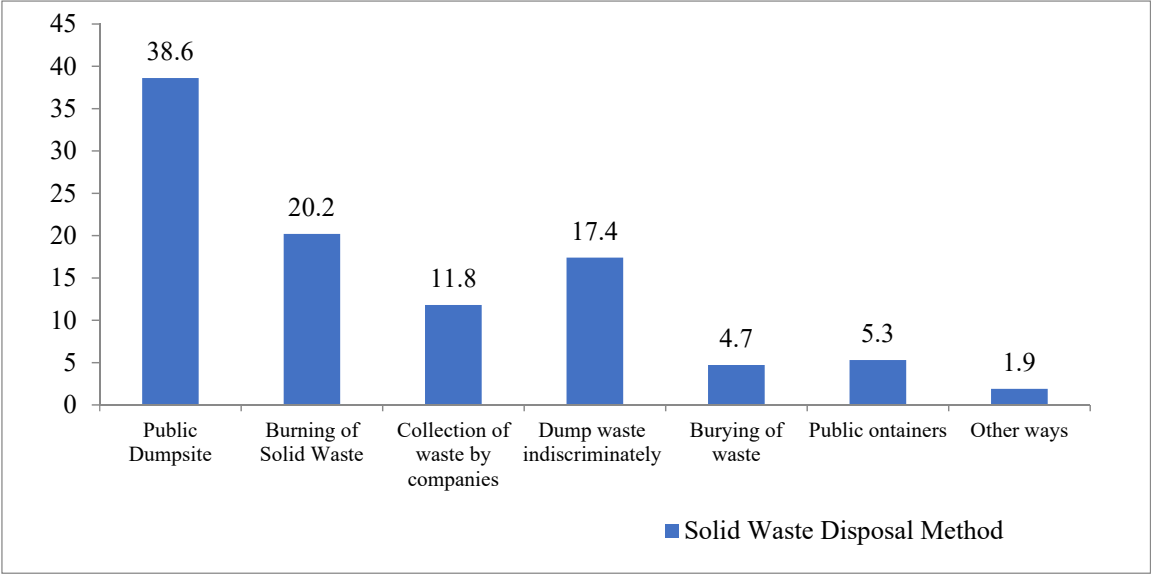


Figure 3. Household solid waste disposal methods in the Navrongo Municipality (GSS, 2014)

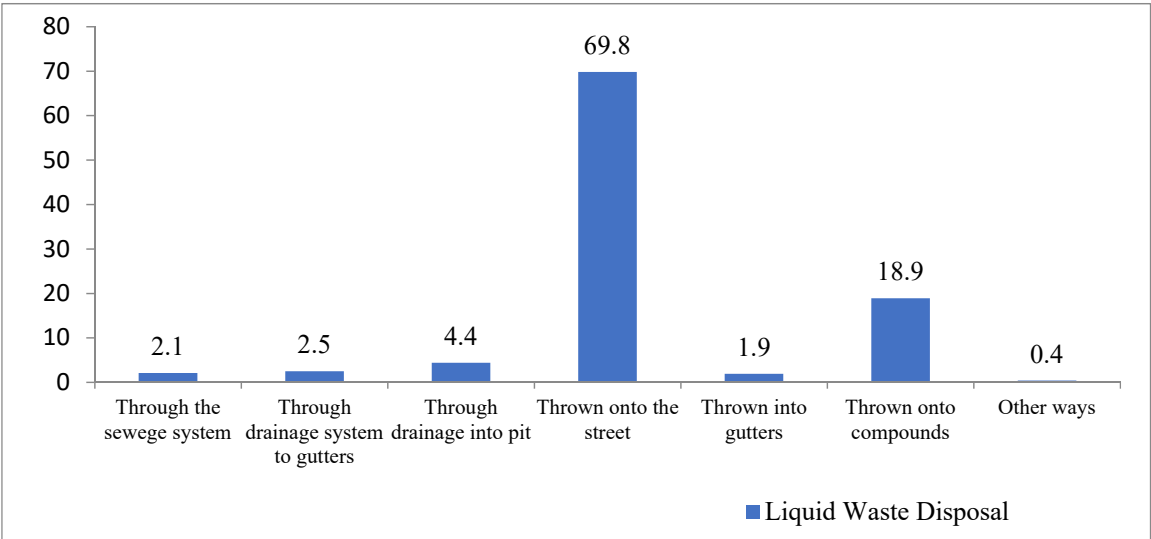


Figure 4. Household liquid waste disposal methods in the Navrongo Municipality (GSS, 2014)

4. Comparison of the waste management systems of Karlsruhe and Navrongo

Karlsruhe and Navrongo have different waste management systems due to differences in resources, infrastructure, and cultural practices. The waste management practices in both towns are manifestations of how industrialized and developing nations handle their waste. Using hygienic

dumpsites, sewage disposal, waste separation and power production from waste, developed countries display a high level of environmental consciousness in their WM. In contrast, waste disposal is unregulated and untreated, and the technology of converting waste into energy is unpopular in underdeveloped nations (Asase et al., 2009).

In Karlsruhe, waste separation is a crucial aspect of the waste management system, and waste is collected separately according to different categories such as paper, organic waste, plastic, glass, and residual waste. The waste is then either recycled or incinerated in waste-to-energy plants. The city also has a pay-as-you-throw system, where residents pay for the amount of waste they produce, which incentivizes them to reduce their waste and recycle more.

On the other hand, Navrongo's waste management system is not as advanced as Karlsruhe's due to the limited resources and infrastructure available. Most waste in Navrongo is collected and disposed of in landfills or open dumps, which can have adverse effects on the environment and public health. However, some local organizations and the government are implementing initiatives to promote waste separation and recycling in the town.

In terms of cultural practices, waste separation and recycling are more common in Karlsruhe due to a greater awareness of environmental issues and a culture of sustainability. In Navrongo, traditional waste disposals practices such as open burning and burying waste are still prevalent, and changing these practices will require more significant efforts in education and outreach.

4.1. Effective waste management strategies

According to UNEP (2005), managerial issues rather than technical ones frequently pose the biggest barriers to efficient and ecologically sustainable WM in poor nations. It is, therefore, crucial to enhancing the operational and managerial skills of individuals and entities engaged in MSWM. A system that has a comprehensive strategy and direction and sustainability is one that has strong system management (Asase et al., 2009). The city of Karlsruhe uses effective, organized, and carefully supervised WM techniques. It has created a tactical plan for accomplishing these aims and has explicitly stated both long-term and short-term objectives with respect to WM. Similar to the context of Africa, the governmental structure of Karlsruhe adds support and prevents needless meddling in the WM system. A city's politicised government, according to Asase et al. (2009), might occasionally obstruct long-term WM initiatives in the city. A concept that can be learned from the city of Karlsruhe, Germany, in order to give Navrongo a stable foundation and a defined route for the establishment of an efficient WM system. Nonetheless, implementing an effective management system will call for clear guidance from a team that is driven and committed to offering real responses to the issues in the city's waste management.

Asase et al. (2009) assert that placing the citizen at the centre of WM in any city guarantees that both residents and municipal authorities keep one another answerable for the waste management approach chosen, to ensure the sustainability of the system. It is important to let the people of Navrongo understand how the WM system is handled in the NM.

5. Conclusion

A comparative study of the cities of Karlsruhe, Germany and Navrongo, Ghana reveals that the success of waste management systems depends on several factors, including resources, infrastructure, and cultural practices. The substantial progress made by Karlsruhe's in WM is largely attributable to their conviction that an appropriate WM system is premised on sound key principles, powerful delivery service principles, and moving at a fiscally sensitive pace with as many locals as quickly as possible. Karlsruhe's waste management system is a model for sustainable waste management practices, and its success is due to a culture of sustainability, adequate resources, and infrastructure. On the other hand, Navrongo's waste management system faces several challenges, including inadequate resources and infrastructure and traditional waste disposal practices. However, improving waste management systems in Navrongo and other cities in Ghana is possible by adopting a collaborative approach that involves the government, local organizations, and the community. This can include investing in infrastructure, implementing waste separation and recycling programs, and

educating the public on the benefits of sustainable waste management practices. The studies have learned from the suggestion to enhance the Navrongo municipality's solid waste management;

- Creating a city-wide, comprehensive, solid waste plan. The plan should be created while taking into account the city's social and cultural makeup, as well as the origin, features, and amount of waste often generated. All potential WM stakeholders must be consulted while creating this strategy.
- Adopting robust and sufficient national and local regulations to direct WM choices and tactics.
- Assessing the WM system's actual effects: To adequately understand the necessity for implementing suitable countermeasures, it will be beneficial to estimate the amount of ecological harm linked to the current waste management system.
- Implementing culturally relevant strategies to supply solid waste services, thus, guaranteeing that WM machinery is regularly repaired and in excellent state at all times. This might lower the amount of money required for successful service delivery.
- Introduce Waste Separation: One of the key differences between Karlsruhe and Navrongo's waste management systems is waste separation. Karlsruhe has implemented a system of separating waste at source, which has led to more effective waste management. Ghana can adopt this approach by introducing waste separation, which can help to recover valuable materials, reduce the volume of waste going to landfills, and minimize environmental pollution.
- Improve Collection and Transportation: Another critical issue in Navrongo is the inadequate collection and transportation of waste. In contrast, Karlsruhe has a well-organized waste collection and transportation system. Ghana can improve the collection and transportation of waste by investing in waste collection vehicles, creating more efficient routes, and ensuring that waste is collected and transported regularly.
- Encourage Community Participation: Community participation is critical to the success of waste management systems. Karlsruhe has implemented a system where citizens are actively involved in waste management by sorting and separating waste at the source. Ghana can encourage community participation by educating citizens on waste management and providing them with the necessary tools to sort and separate waste.
- Invest in Recycling Infrastructure: Ghana can improve waste management by investing in recycling infrastructure. Karlsruhe has a well-established recycling system, which has helped to reduce the volume of waste going to landfills. Ghana can establish recycling centres and create incentives for companies to invest in recycling infrastructure.
- Increase Government Support: Finally, the government needs to provide more support for waste management in Ghana. This support can be in the form of policy frameworks, funding, and regulations to ensure that waste is managed effectively. The government can also collaborate with private sector stakeholders to develop and implement sustainable waste management practices.

Future research can build upon these findings and explore the following areas:

- Analysis of the socio-economic factors that influence waste management practices in Ghana.
- Evaluation of the effectiveness of waste separation in Ghana.
- Assessment of the environmental and health impacts of inadequate waste management practices.
- Investigation of innovative waste management technologies such as waste-to-energy to reduce the volume of waste going to landfills and generate energy.

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