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 continues 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. This has led to an efficient and sustainable waste management system that minimizes waste and protects the environment. Karlshrue'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, such as those implemented in Karlsruhe, can help accelerate the development of sustainable waste management practices in Ghana, and ultimately protect public health and the environment.

Subject Areas

Environmental Sciences

Keywords

Solid Waste, Solid Waste Management, Navrongo, Karlshrue

1. Introduction

Globally, Municipal Solid Waste Management (MSWM) has received environmental conservationists' attention with several proposals of different innovative approaches and technologies in recent times due to the negative consequences waste poses to the environment and its contributions to climate change (Asase *et al.*, 2009) [1]. McDougall and Hruska (2000) [2] 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) [1].

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 [3]; Wilson, 2007 [4]). Batista *et al.*, 2021 [5] 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. Turan *et al.* (2009) [6] 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 (Turan *et al.*, 2009) [6]. It is unquestionably true that WM strategies and techniques are far advanced in the first country regions over time through several stages. Wilson (2007) [4] stated that developing nations can draw inspirational benefits from the lessons of the developed nations as they work to enhance their current WM systems. This was true when Asase *et al.* (2009) [1] 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 ecologically successful (McDougall *et al.*, 2001) [3]. 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. An implementation framework for an effective ISWM system in developing nations ought to be created using the experiences and lessons learnt. This study aims 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) [7], Germany has had success with a variety of WM programs, through effective and efficient WM policies (Olay-Romero *et al.*, 2020) [8]. 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.

The study describes 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) [3] and Asase *et al.* (2009) [1] are then explored relating to the MSWM systems in Karlsruhe and Navrongo. In this regard, the purpose of this study was to analyze and draw an empirical understanding of Germany's and Ghana's WM practices, policies, and successes. Germany and

Ghana have been used as developed and developing nations, respectively. Following consideration, the study then suggests German WM techniques that will enhance Ghana's WM techniques.

2. Description 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, situates 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 (Bundesverfassungs-sgericht), the top two federal courts in Germany, are both located in Karlsruhe. Karlsruhe has Germany's oldest technological university. The research centre at Karlsruhe and the several Frauenhofer Institutes in Karlsruhe are well known as the hub of an innovative technology region (Schwarz-Herion *et al.*, 2008) [9].

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 2). 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 Ghana Statistical Service (GSS), 2014 [10].

Figure 1. Geographical location of Karlsruhe (Schwarz-Herion *et al.*, 2008) [9].
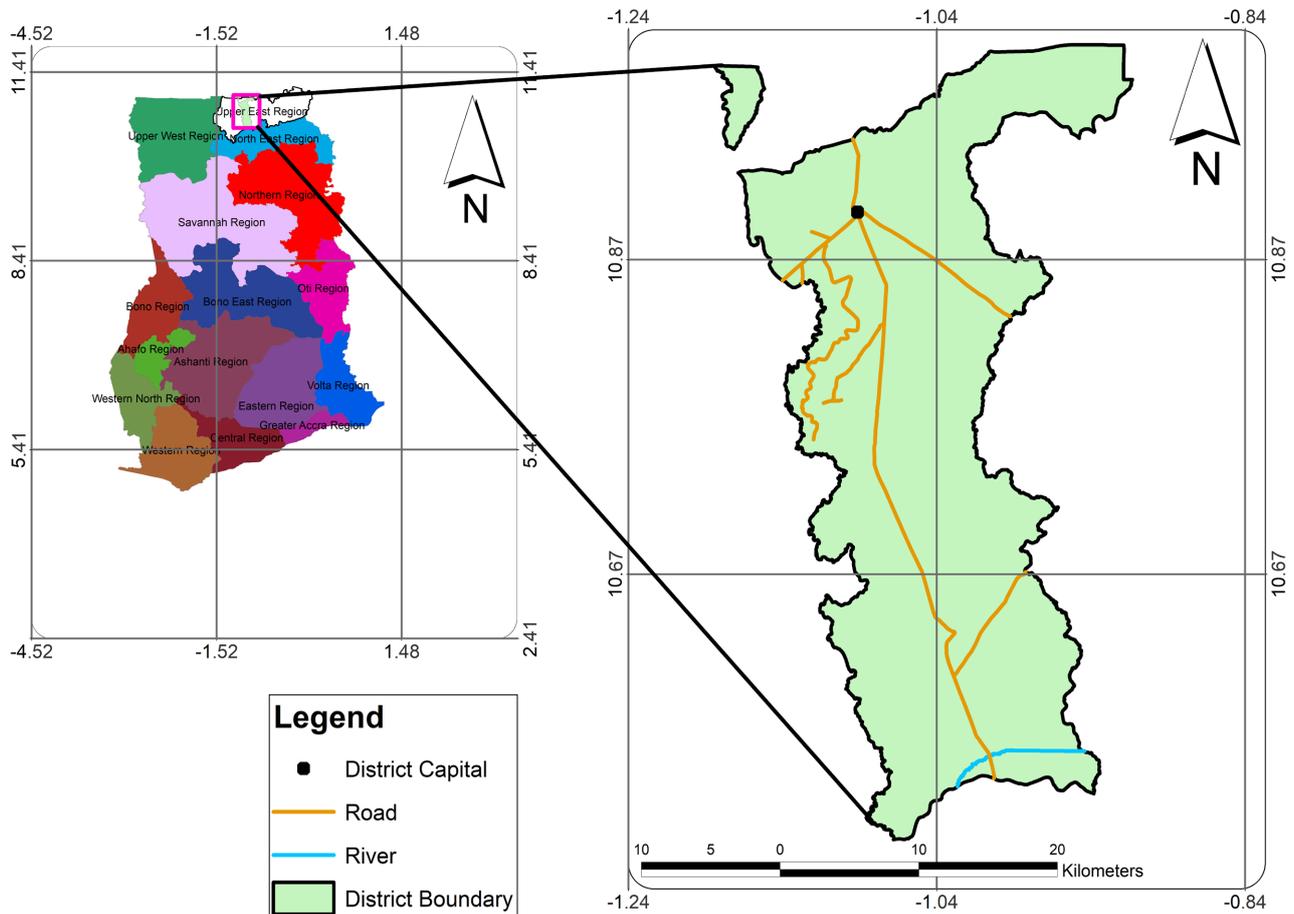
Figure 2. Map of Ghana (left) and Kassena Nankana East Municipal (right). Source: Field work.

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 (Schwarz-Herion *et al.*, 2008) [9]. 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 Ghana Statistical Service (GSS), 2014 [10]. 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. Accord-

ing 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) [9]. 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 waste is 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 households and businesses which are connected to the municipal residual waste collection to have 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 or communal skip for disposal. The Communal Collection System (CCS) entails placing metal containers (skips) 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 eight different sites for final waste disposal in Navrongo with skips. These sites are Basina, STC, COS Park, Nogsenia, Sissala lane, Kaabania, Hospital gate and new market waste disposal sites. After the waste has been disposed to the final sites, it is either burned or compacted. Two different private WM companies, Environmental Service Provider Association (ESPA) and Zoomlion Ghana Limited (ZLG), on separate contracts, 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. 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) [11].

In the case of Navrongo, waste disposal is largely poor (Figure 3(a) & Figure 3(b)). This is due to the insufficient waste bins provided to the public, coupled with limited financial resources and technical know. Dominant waste disposal practices in Navrongo are open waste dump (38.6%), household waste

Figure 3. Disposal of solid waste: (a) a major dumping site, (b) a skip and a dumping site.

burning (20.2%), indiscriminate dumping of waste (17.4%), the use of waste collection services (11.8%), and public dumpster (5.3%). 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) [10]. 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 this waste becoming stuck in the drainage systems.

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) [11]. 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) [11]. As posited by Oertel (2014) [12], Karlsruhe uses advanced vehicles known as Econic Euro VI. This Econic (**Figure 4(a)**) 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 (**Figure 4(b)**). When the central waste bins are filled up, they are hauled by the Navrongo waste ZLG to a designated landfill.

Figure 4. Comparison of equipment used for waste collection in (a) Karlsruhe (Oertel, 2014) [12] and (b) Navrongo.

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 farmlands (Rapp, 2008) [11]. Various sorts of separation techniques are used to separate the reusable waste 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. Nonetheless, the method of separation is traditionally done by locals in Navrongo. They separate their organic waste and use them as organic fertilizers in their backyard gardens. Generally, 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.

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 rarely available in underdeveloped nations (Asase *et al.*, 2009) [1].

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 disposal practices such as open burning and burying waste are still prevalent, and changing these practices will require more significant efforts in education and outreach.

According to Turan *et al.* (2009) [6], 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) [1]. 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) [1], might occasionally obstruct long-term WM initiatives in the city. This is 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) [1] 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. Conclusions

A comparative study of the cities of Karlsruhe, Germany and Navrongo, Ghana reveals major different ways of solid waste management. In Karlsruhe, waste is segregated and treated by various public and private businesses and every household and every business which is connected to the municipal residual waste collection to have bulky waste to be picked up once a year in standard household quantities. While in Navrongo, both household and municipal waste are collected together and sent to a landfill or communal skip for disposal. The study reveals that:

- The success of waste management systems depends on several factors, including resources, infrastructure, and cultural practices. The substantial progress made by Karlsruhe 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.

- 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.

6. Recommendations

Having evaluated the effective and efficient solid waste management practices in Karlsruhe, the researchers recommend the following strategies:

- Creating a city-wide, comprehensive, solid waste management 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.

- Implementing culturally relevant strategies to render solid waste management 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.

- 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.

Funding

Statement of Declaration

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.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Asase, M., Yanful, E.K., Mensah, M., Stanford, J. and Amponsah, S. (2009) Comparison of Municipal Solid Waste Management Systems in Canada and Ghana: A Case Study of the Cities of London, Ontario, and Kumasi, Ghana. *Waste Management*, **29**, 2779-2786. https://doi.org/10.1016/j.wasman.2009.06.019

[2] McDougall, F.R. and Hruska, J.P. (2000) The Use of Life Cycle Inventory Tools to Support an Integrated Approach to Solid Waste Management. *Waste Management and Research*, **18**, 590-594. https://doi.org/10.1034/j.1399-3070.2000.00159.x

[3] McDougall, F., White, P., Franke, M. and Hindle, P. (2001) Integrated Waste Management: A Life Cycle Inventory. Second Edition, Blackwell Science, Oxford, UK.

[4]   Wilson, D.C. (2007) Development Drivers for Waste Management. *Waste Management and Research*, **25**, 198-207. https://doi.org/10.1177/0734242X07079149

[5]   Batista, M., Caiado, R.G.G., Quelhas, O.L.G., Lima, G.B.A., Leal Filho, W. and Yparraguirre, I.T.R. (2021) A Framework for Sustainable and Integrated Municipal Solid Waste Management: Barriers and Critical Factors to Developing Countries. *Journal of Cleaner Production*, **312**, Article ID: 127516. https://doi.org/10.1016/j.jclepro.2021.127516

[6]   Turan, N.G., Çoruh, S., Akdemir, A. and Ergun, O.N. (2009) Municipal Solid Waste Management Strategies in Turkey. *Waste Management*, **29**, 465-469.

[7]   Magrini, C., D'Addato, F. and Bonoli, A. (2020) Municipal Solid Waste Prevention: A Review of Market-Based Instruments in Six European Union Countries. *Waste Management & Research*, **38**, 3-22. https://doi.org/10.1177/0734242X19894622

[8]   Olay-Romero, E., Cervantes, E., Hernández-Berriel, M., Cortázar, A., Cuartas-Hernández, M. and Rosa-Gómez, I. (2020) Technical Indicators to Improve Municipal Solid Waste Management in Developing Countries: A Case in Mexico. *Waste Management*, **107**, 201-210. https://doi.org/10.1016/j.wasman.2020.03.039

[9]   Schwarz-Herion, O., Omran, A. and Rapp, H.P. (2008) A Case Study on Successful Municipal Solid Waste Management in Industrialized Countries by the Example of Karlsruhe City, Germany. 266-273. https://annals.fih.upt.ro/pdf-full/2008/ANNALS-2008-3-46.pdf

[10]   Ghana Statistical Service (GSS) (2014) 2010 Population and Housing Census. https://www2.statsghana.gov.gh/docfiles/2010_District_Report/Upper%20East/KASENA%20NANKANA%20EAST.pdf

[11]   Rapp, H.P. (2008) Overview on Solid Waste Management in Karlsruhe City. Conversation Conducted by Dr. Odile with Dipl. Ing. Hans Peter Rapp, Representative CEO of the Office for Waste Management, Karlsruhe, Department Leader Street Cleaning.

[12]   Oertel, F. (2014) Efficient and Quiet, Ergonomic and Safe: The New Euro VI Econic Quickly Proved Its Worth for Refuse Collectors in Karlshruhe. https://special.mercedes-benz-trucks.com/en/econic/waste-management/no-waste-disposal.html