



## Sustainable Reuse of Food Waste in the Democratic Republic of the Congo for Biocomposite Reinforcement

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### Abstract


This study explores the innovative use of biocomposites as a sustainable solution to waste proliferation in the Democratic Republic of the Congo (DRC), the largest sub-Saharan African country by area. The DRC faces significant environmental challenges due to the high prevalence of organic waste (48% of total waste) and plastic waste (26%). Our research addresses critical waste management issues, contributing to economic growth and public health improvements by recycling and reusing these materials. This study is unique in its focus on using inedible food waste as reinforcement in biocomposites, highlighting the untapped potential for sustainable waste management and circular economy practices in the DRC.

Optimal performance of biocomposites requires extensive research into the thermogravimetric behavior of materials and their environmental interactions. Techniques such as Fourier-Transform Infrared Spectroscopy (FT-IR) are essential for understanding the chemical properties and enhancing the interface between biocomposite components. The recyclability of biocomposites adds another layer of sustainability, allowing materials to be reprocessed for various applications. Our study also emphasizes the importance of public participation and the need for strategic international partnerships with organizations like the World Bank, UNDP, UNEP, and AfDB to enhance waste management capacity and infrastructure. By leveraging these innovative approaches and securing goodwill from governing bodies, the DRC can move towards a greener and more sustainable future, contributing to environmental quality, economic prosperity, and social equity.

**Keywords:** Biocomposites, circular economy, Democratic Republic of the Congo, inedible food waste, sustainable waste management, waste recycling

## Demokratik Kongo Cumhuriyeti'nde Gıda Atıklarının Biyokompozit Takviyesi için Sürdürülebilir Yeniden Kullanımı

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## Özet

Bu çalışma, alan bakımından Sahra Altı Afrika'nın en büyük ülkesi olan Demokratik Kongo Cumhuriyeti'nde (DKC), atık artışına karşı sürdürülebilir bir çözüm olarak biyokompozitlerin yenilikçi kullanımını araştırmaktadır. DKC, organik atıkların (toplam atığın %48'i) ve plastik atıkların (%26) yaygınlığı nedeniyle önemli çevresel zorluklarla karşı karşıyadır. Araştırmamız, bu malzemelerin geri dönüştürülmesi ve yeniden kullanılması yoluyla kritik atık yönetimi sorunlarını ele alarak ekonomik büyümeye ve halk sağlığının iyileştirilmesine katkıda bulunmaktadır. Bu çalışma, yenmeyen gıda atıklarının biyokompozitlerde takviye olarak kullanılmasına odaklanması açısından özgün olup, DKC'de sürdürülebilir atık yönetimi ve döngüsel ekonomi uygulamaları için kullanılmayan potansiyeli vurgulamaktadır.

Biyokompozitlerin optimum performansı, malzemelerin termogravimetrik davranışları ve çevresel etkileşimleri üzerine kapsamlı araştırmalar gerektirir. Fourier-Transform Kızılötesi Spektroskopisi (FT-IR) gibi teknikler, kimyasal özellikleri anlamak ve biyokompozit bileşenleri arasındaki arayüzü geliştirmek için gereklidir. Biyokompozitlerin geri dönüştürülebilirliği başka bir sürdürülebilirlik katmanı ekleyerek malzemelerin çeşitli uygulamalar için yeniden işlenmesine olanak tanır. Çalışmamız ayrıca atık yönetimi kapasitesini ve altyapısını geliştirmek için halk katılımının önemini ve Dünya Bankası, UNDP, UNEP ve AfDB gibi kuruluşlarla stratejik uluslararası ortaklıklara duyulan ihtiyacı vurgulamaktadır. Bu yenilikçi yaklaşımlardan yararlanarak ve yönetim organlarının iyi niyetini güvence altına alarak DKC, çevre kalitesine, ekonomik refaha ve sosyal eşitliğe katkıda bulunarak daha yeşil ve daha sürdürülebilir bir geleceğe doğru ilerleyebilir.

**Anahtar Kelimeler:** Atık geri dönüşümü, biyokompozitler, Demokratik Kongo Cumhuriyeti, döngüsel ekonomi, sürdürülebilir atık yönetimi, yenmeyen gıda atıkları

### 1. Introduction

The Democratic Republic of the Congo (DRC), the largest sub-Saharan African country by area and the 11th largest in the world, is experiencing significant challenges in managing its solid waste, exacerbated by rapid urbanization and population growth. This issue is particularly pronounced in developing countries like the DRC, where inadequate waste management practices lead to severe environmental and public health consequences, including pollution of natural resources and long-term health problems. The ineffective handling of waste in the DRC underscores the need for sustainable solutions that can transform waste into valuable resources.

Despite some progress in global waste management, a substantial gap remains in the reduction and recycling of household waste in developing countries compared to their developed counterparts. Plastic is more in

demand in emerging and especially in poor countries. This is illustrated by the International Energy Agency, which compares the average annual plastic consumption of an African and an American to be approximately 4 kg and 60 g, respectively. Indeed, plastic is relatively cheaper than other materials, and it is both highly durable and lightweight (Ipsesa, 2019). In Kinshasa, approximately 60 Non-Governmental Organizations (NGOs), funded by various agencies including an affiliate of the Ministry of Finance and the City Hall of Kinshasa, are involved in cleaning and recycling efforts, particularly targeting plastic packaging and other urban waste (Ipsesa, 2019).

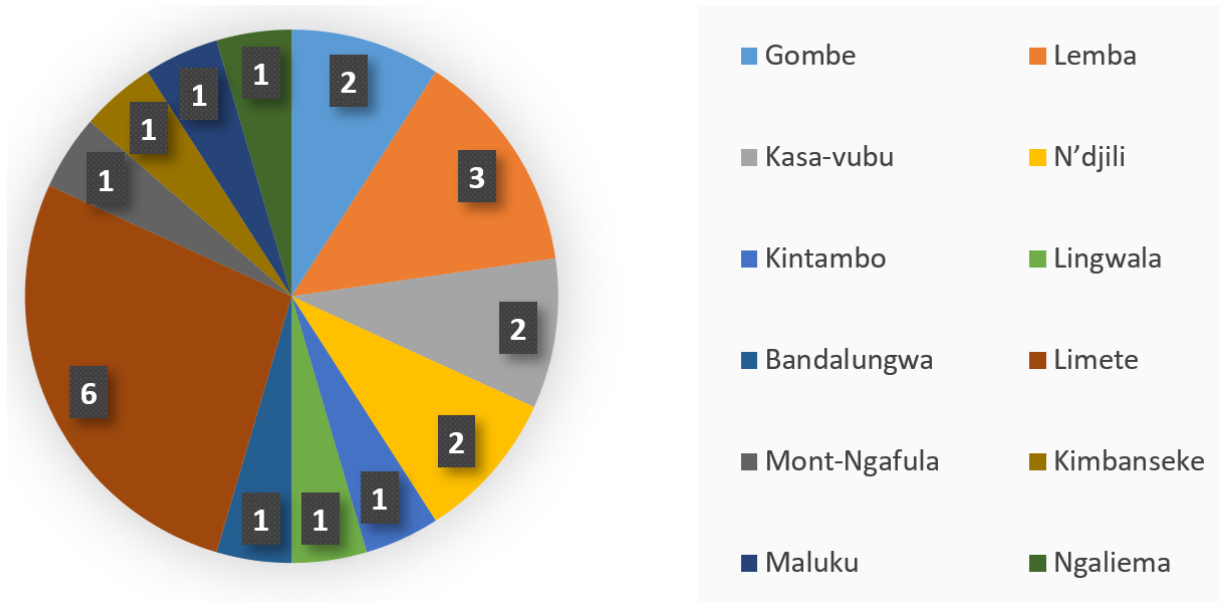
One of the most pressing environmental problems in the DRC is the increase in plastic and inedible food waste. These materials, however, present an opportunity for creative recycling and upcycling, thereby contributing

positively to the circular economy. The civil unrest in the DRC has further complicated waste management by disrupting agricultural production and causing significant migration from rural to urban areas, leading to rapid urban expansion without adequate planning or employment opportunities (Eric et al., 2010)

Food waste, in particular, has profound environmental and economic implications. Globally, approximately 30% of food made for human consuming, valued at an estimated one trillion USD, was wasted (FAO, 2013). In the DRC, the city of Lubumbashi exemplifies

this issue, with an average household producing around 27 kg of compostable waste per month, leading to an annual total of approximately 141,840 tons of compostable waste. This waste contributes significantly to greenhouse gas emissions, with an estimated 9220 tons of methane released annually (Brown, 2013).

Figure 1.1 displays the spread of non-governmental organizations, small and medium-sized enterprises, and businesses participating in the recycling of plastic waste throughout the different districts of Kinshasa.



**Figure 1.1.** Distribution of recycling NGOs, SMEs, and businesses in Kinshasa (Ipasesa, 2019)

In sub-Saharan countries, capitals serve as excellent models for urban studies. In this research, we will focus on two major cities: the capital, Kinshasa, and Lubumbashi. Although only a limited area of each city will be examined, it remains representative, as the findings can be extrapolated to the entire country. Capitals are ideal locations for studying critical urban scenarios.

A few studies pertaining to this subject can be referenced. Katumbo et al. (2020) studied household waste management in Lubumbashi, DRC where the authors outline the challenges, practices, and potential

solutions for improving waste collection, segregation, and disposal in the city. Mbadiko et al. (2018) conducted a study on the characterization of the waste produced in the Mbanza-Lemba market, City of Kinshasa in the DRC. The results indicate that waste management in the Mbanza-Lemba market is inadequate as it fails to address the issue of pollution caused by solid waste at the market. Additionally, there is a lack of effective government structures for managing waste from this market. Socioeconomic and demographic traits of the residents, along with how household waste is handled in Katuba municipality in Lubumbashi, DRC. In their paper,

Nahman and de Lange (2013) presented an expanded study to include the expenses related to edible food waste throughout the entire value chain in South Africa, a sub-Saharan country. Saba et al. (2023) characterized and examined the potential valorization of industrial food processing wastes. A model was created to link the characteristics of food waste with the most effective valorization pathway, providing guidance for waste management and informing future analyses of economic and environmental effect. Kubanza and Simatele (2016) criticized the social and environmental injustices in Kinshasa's solid waste management, revealing that the urban poor suffer from poor waste management exacerbated by rapid urbanization, poor governance, and weak institutions, and argues for a pro-poor approach to achieve social and environmental justice. Kubanza et al. (2017) examined environmental justice in solid waste management in Kinshasa, DRC, highlighting the inequitable distribution of waste burdens between rich and poor neighborhoods and arguing for politico-cultural mechanisms to address these injustices, based on qualitative research including literature reviews, system analysis, and stakeholder discussions. They investigated the perception of social and environmental equity in a framework of solid waste management in Kinshasa and crucial factors affecting injustice in this connection where some are happy and some are unhappy. It was recommended that every resident's entitlement, and the rights of each person in an urban area or nation, should be incorporated into a city's development and planning strategies, as well as included in different local and national legal provisions. Simatele & Etambakonga (2015) studied the significant role of solid waste scavenging in supporting the urban food basket, livelihoods, job creation, and environmental sustainability for poor households in Kinshasa, within the context of poverty and political instability, using field data from three sites. It was depicted that solid waste scavenging is often overlooked in urban development and planning policies, but it has a significant impact on the food security of impoverished urban households, like

employment opportunities and environmental sustainability. On the other hand, even though not explicitly stated, some instances of practical application of biocomposites have been referenced by Lukomba and Kahinda (2023), Mangenda et al. (2020) and Ipasesa (2019).

Conventional methods of food waste disposal, such as landfill, incineration, and composting, can have adverse environmental effects, including greenhouse gas emissions and resource wastage (Saba et al., 2023). Food waste not only squanders the resources used in its production but also contributes greenhouse gases accounting for 11% of global emissions (Recycle Track Systems, 2024), such as methane, carbon dioxide, and chlorofluorocarbons, which contribute to climate change.

To mitigate these impacts, innovative approaches such as composting and anaerobic digestion are being explored. Composting transforms food scraps and other organic materials into nutrient-rich soil amendments, while anaerobic digestion produces biogas, a renewable energy source. Another promising avenue is the utilization of mycelium composite, which presents ecological and economic benefits. Research by Akromah et al. (2024) provides valuable insights into this innovative approach, particularly in countries like the DRC.

Our study seeks to elucidate the concept of biocomposites within the context of sustainable solutions to the persistent challenge of waste proliferation in the DRC. Over these past decades, the DRC has grappled with notable environmental threats stemming from the accumulation of waste materials. Our approach involves recycling and repurposing these resources to address the very issues they create. This initiative embodies the principles of waste management and circular economy, leveraging existing expertise in these areas.

The focal point of our research lies in targeting specific types of waste, notably plastic and inedible food waste, which constitute major

environmental concerns. However, with effective management, these waste materials can be transformed into a plethora of valuable products. Such an initiative has a potential to subsidize significantly to a country's economic development, mitigate health risks, and ensure the well-being of the population.

This study represents a pioneering effort in exploring the utilization of inedible food waste such as fruit peels, nut shells, and coffee grounds from the DRC as reinforcement material for biocomposite products. Additionally, we investigate the recyclability of biocomposites, highlighting their potential for reuse. At the end of their lifecycle, manufactured biocomposites can be crushed and reprocessed for alternative applications, while the inclusion of natural inedible food waste fillers promotes biodegradability.

## 2. A Green Perspective to Food Waste in the DRC

Sustainable development endeavors to achieve environment quality, economical welfare, plus social fairness for the present and future generations. The phenomenon of food wastage encompasses both pre-consumer food losses, occurring before food reaches consumers, and post-consumer food waste, which includes both edible and inedible waste (Nahman and de Lange, 2013). Our study primarily focuses on non-edible waste, such as peelings, nut shells, and bones.

Globally, researchers estimate that approximately half of total food product for human consuming is wasted across entire food supply chain, including pre- and post-consumer stages (Lundqvist et al., 2008). Food waste is more prevalent in developed nations compared to developing ones, (Nahman and de Lange, 2013) with consumers in sub-Saharan Africa contributing to only about 3.5% of total food waste (Gustavsson et al., 2011). However, the majority of food waste in the DRC occurs during earlier stages of the food supply chain, before reaching consumers.

In Kinshasa, the capital of the DRC, household waste primarily consists of paper,

plastic, and other materials, which constitute approximately 58% of the total waste generated (Kubanza et al., 2017). When assessing different methods for disposing of solid waste in Kinshasa in the study conducted by (Kubanza et al., 2017), biocomposites made from food waste were not even included in the list of most practical options for managing food waste.

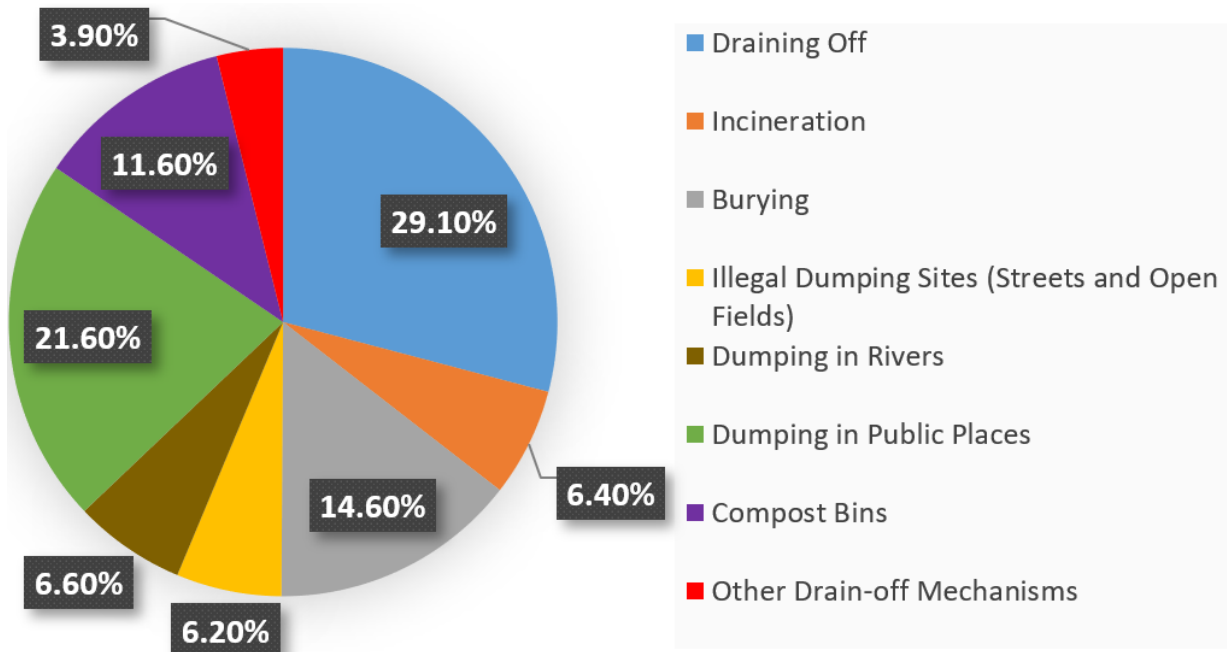
A study by Ipasesa (2019) shows that only five municipalities in Kinshasa housed the majority of formal waste disposal sites, serving just 7.27% of the population in 2020. This means that a significant 92.73% of Kinshasa's population lacked access to sanitation services.

Kinshasa generates over 5,600 cubic meters of waste each day. This amount of refuse stems from a projected population exceeding 12,000,000 and covers an urban area spanning 9,965 square kilometers (Mangenda et al., 2020). The city's yearly production of solid waste is approximately 2 million cubic meters, with only 20 to 30% being gathered and the remainder being disposed of under unsatisfactory circumstances. Unfortunately, the combined daily waste removal/disposal capacity of the National Sanitation Programme and the Department of Roads and Drainage is just 600 m<sup>3</sup>, which amounts to only 6% (Simatele & Etambakonga, 2015). The remaining tasks are managed by the population, who use their own methods of disposal as illustrated in Figure 2.1 adapted from Simatele & Etambakonga's (2015) work.

Householders dispose of 29.1% of their household waste utilizing disorganized disposal methods, whilst 6.4% opt for informal and nonregulated burning. Another 14.6% bury these wastes, and 6.2% exhaust illegal dumping sites such as streets and open fields; meanwhile, 6.6% dump their waste in rivers, with an additional 21.6% resorting to illegal dumping in public areas, 11.6% make use of compost bins for disposal purposes, and the remaining 3.9% utilize other drainage mechanisms for waste management purposes (Simatele & Etambakonga, 2015).

Katumbo et al. (2020) helps understanding that the economic and social conduct of households is crucial for enhancing solid household waste management, but there is a lack of such research in the DRC. The result

of their field surveys work for grasping the understanding of the population about the risks associated with waste are presented in Table 1.



**Figure 2.1.** Waste disposal practices by the population (Simatele & Etambakonga, 2015)

**Table 1.** The understanding of risks associated with waste and the suggestions made by participants concerning waste handling (adapted from Katumbo et al., 2020).

Variable	Respondents	Percentage
Risks due to the presence of waste		
Known	102	67.1
Unknown	50	32.9
Sale of recyclable waste		
Never	130	85.5
Some times	18	11.8
Often	4	2.6

According to this study, 96.1% of households did not assign a value to their household garbage. Incineration was the chosen method for waste disposal by 27.6% of the households, while landfill and discharge were selected by 21.1% and 51.3%, respectively, with discharge being the most prevalent option for waste disposal among households. Among respondents, 67.1% demonstrated awareness of the hazards associated with waste presence, while 32.9% lacked such awareness. A significant majority 85.5% of respondents indicat-

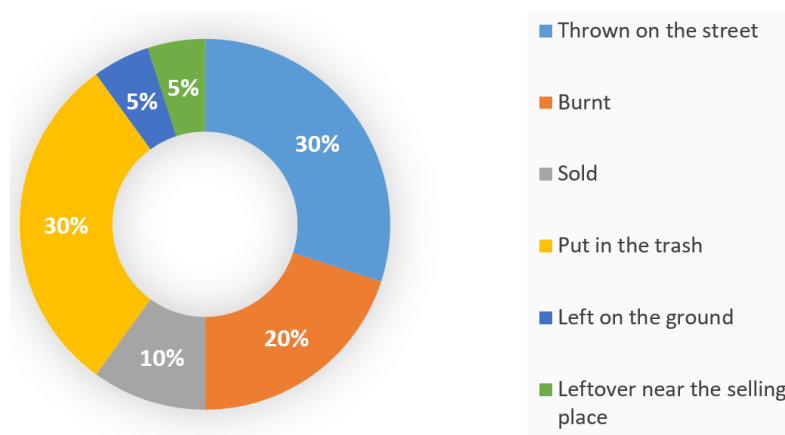
ed no inclination to sell recyclable waste to collectors; however, some individuals 11.8% do engage in this activity occasionally and 2.6% often. The same research demonstrated that just over one-tenth 11.2% of participants engaged in sorting or separating their waste.

Mbadiko et al. (2018) found that there is a lack of effective government structures for managing waste from this market. The inconsistent garbage collection, absence of public

trash bins near sales areas, vendors’ practice of disposing their waste directly on the ground, widespread presence of informal dump sites, and use of basic transportation methods for garbage collection further contribute to these challenges.

In the same study, 95% of sellers believed that the cost of waste collection is reasonable and would not hinder the waste collection process in the market. The irregular waste collection contributes to the uncleanliness observed at Mbanza-Lemba market. 55% of vendors stated that waste collection occurs two times

a week, while 45% indicated it happens three times a week. As pictured in Figure 2.2, the research indicates the ability of vendors to independently handle waste and demonstrates that 30% of vendors gather and discard garbage on a street known as Avenue du Marché, 30% deposit it in an unregulated dump neighboring the market, 20% collate also incinerate these waste out in the uncovered, whilst 10% vend these waste to horticulturists and farmers, with 5% leaving these waste at shop entrances expecting market agents to collect them.



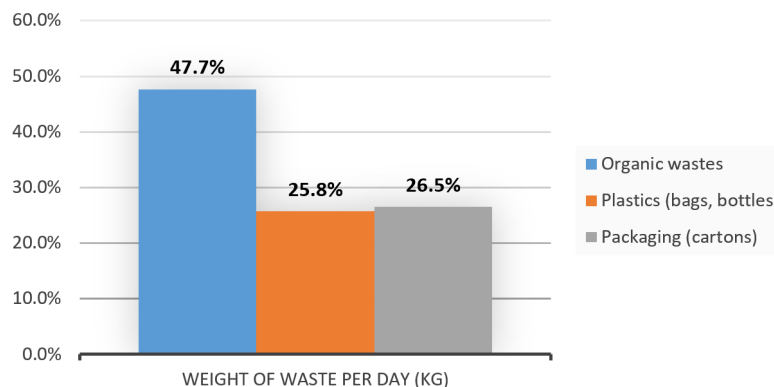
**Figure 2.2.** Vendors’ ability to manage waste individually (Mbadiko et al., 2018)

Figure 2.3 shows the waste characterization of the market.

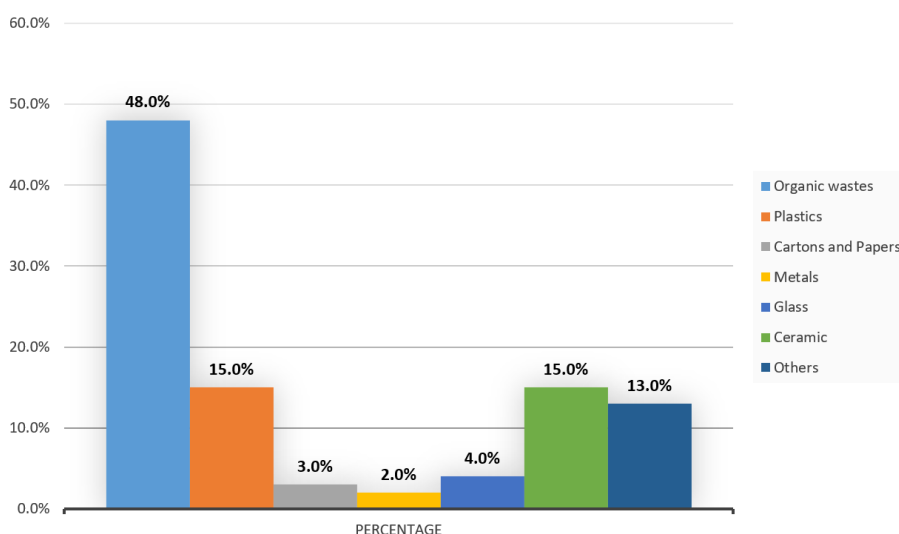
followed by carton packaging at 26.5%, and plastic bottles and bags at 25.8%.

Organic waste, including plant debris and other materials, constitutes the majority of the identified refuse in a specific area of the local market, making up 47.7% of the total daily waste production of 406.8 kg. This is

Ipasesa (2019) presents a bigger picture of the waste distribution in entire Kinshasa based on data retrieved from Kinshasa Sanitation Authority RASKIN, as shown in Figure 2.4.



**Figure 2.3.** Daily waste types per kilogram (Mbadiko et al., 2018)



**Figure 2.4.** Waste produced in Kinshasa (Ipasesa, 2019).

The organic matter content of household waste in Kinshasa averages around 54% (Nzuzi, 2008). Biological methods, such as composting, hold potential for enhancing the value of this organic fraction, providing an organic supplement for agricultural lands. Given the deficiency in organic matter content observed in peri-urban areas and across much of Kinshasa's soils (Mangenda et al., 2020), composting might play a significant role in soil enrichment and fertility enhancement. Composting, as a practice in sustainable agriculture, involves utilizing compost as a soil amendment (Marondji, 2023). The production of biocomposite materials, which entails recycling waste plastic reinforced with inedible food waste within a plastic matrix, embodies a large-scale sustainable solution. These biocomposites can be crushed and repurposed to create new components, offering a circular approach to waste management.

This article focuses on a strategy that integrates the most challenging waste materials, specifically plastics and inedible or spoiled food residues. This approach represents one of the most effective configurations for addressing the current waste management problem.

### 3. Biocomposites as a Sustainable Solution

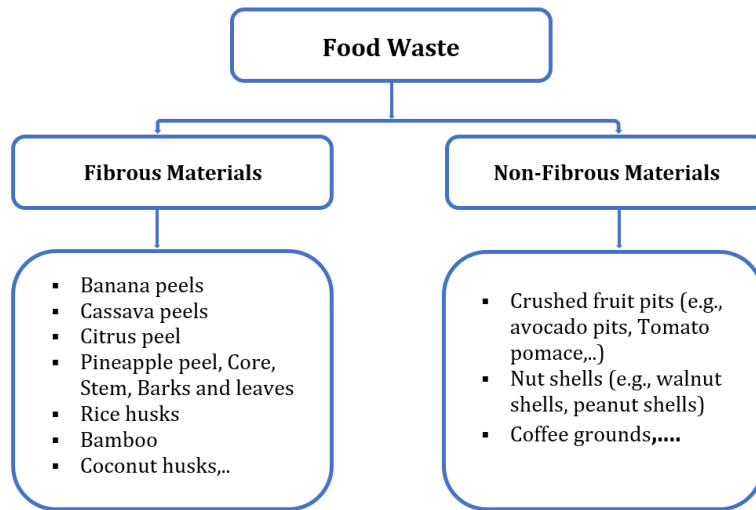
Natural fiber-reinforced polymer compos-

ites, also known as biocomposites, have captivated the attention of researchers for several decades. These biocomposites are being considered as substitutes for synthetic fibers due to their cost-effectiveness, lightweight nature, biodegradability, high specific properties, minimal impact on equipment wear and tear, eco-friendliness, and sustainability attributes. Extensive research has focused on enhancing their mechanical, physical, thermal characteristics, trying out improvements in water resistance to expand their potential applications. As a result, biocomposites have found application in different sectors such as automotive, packaging, renewable energy, construction and more (Mugarura and Çevik, 2023).

The most common approach with plastic recycling is mechanical recycling, where plastic is sorted, cleaned, melted, and reformed into new plastic items. This includes things like bottles and containers, construction materials (fleece for insulation, lumber for decks, panels, roofing tiles), textiles (fleece jackets, carpets), furniture (chairs, benches), art objects, 3D printing filament and more.

Food waste can be split in two as shown in Figure 3.1.





**Figure 3.1.** Food waste types.

The DRC is a country brimming with culinary traditions. From hearty stews like makemba with smoked fish to starchy staples like fufu and kwanga, these delicious dishes leave behind a significant amount of food

waste. The peels, shells, pulps and cobs of these plants are illustrated in Figure 3.2. This presents a potential goldmine for biocomposite development.



**Figure 3.2.** (a) Ground cassava bagasse and cassava peels; (b) Sweet potato (*Ipomoea batatas*) tubers; (c) Maize cobs; (d) Citrus pulps; (e) Banana peels; (f) Peanut shells (FeediPedia, 2024)

Starchy roots like cassava processing yields large quantities of bagasse (fibrous residue) and peels. Yam peels and even sweet potato peels contribute to the waste stream.

Fruits like mango pits, citrus peels, and even pineapple cores, often discarded after consumption, hold potential for biocomposite reinforcement.

Vegetables like banana or plantain peels, the outer layer of this versatile fruit, are a common waste product. Additionally, vegetable trimmings from okra, green beans, and leafy greens can be utilized.

Legumes like groundnut shells, a by-product of peanut consumption, are a potential source of biocomposite material.

Other sources like palm kernel shells, a byproduct of palm oil production, and even leftover maize cobs offer additional possibilities for biocomposite reinforcement.

There is a huge waste potential in the DRC for biocomposites. This potential once capitalized will allow a reduced reliance on virgin plastics and landfills, a utilization of waste materials for valuable products, an improved environmental footprint compared to traditional materials and potentially lower production costs depending on the specific application.

#### **4. Challenges and Opportunities**

The management of solid waste in urban areas, particularly in the DRC, faces significant challenges and presents unique opportunities for improvement. The widespread existence of unregulated landfills can be attributed to the population's insufficient adherence to regulations due to lack of discipline and the inefficacy of local government bodies in waste collection (Mangenda et al., 2020). Effective solid waste management in the DRC, particularly in Kinshasa, is hampered by high poverty, unemployment, and political instability, which diverts resources from development projects to civil conflict resolution.

This instability weakens institutional and policy frameworks essential for efficient waste management. Structural challenges, including poor governance, economic downturns, inadequate infrastructure, limited recycling facilities, and deficient road networks, further hinder the establishment of an effective waste collection system. Reliance on hand-drawn carts for waste transport to temporary sites exacerbates the issue, highlighting that the struggle is more due to institutional and policy deficiencies than a lack of resources or knowledge (Simatele & Etambakonga, 2015). Research on household waste management by Katumbo et al. (2020) indicates that the municipality of Katuba in Lubumbashi does not have a defined system for categorizing, gathering, recycling, or disposing of household waste. Instead, residents in this area often resort to dumping refuse on the streets or incinerating it. Despite this behavior, there is awareness among the population about the risks connected with improper waste disposal. Increased participation of local government council members in the oversight and control of residential garbage disposal could offer a potential resolution.

The rapid expansion of cities has taken place amidst inadequate institutional structures, deficient urban planning, and a lack of meaningful job prospects. One of the primary obstacles encountered by city officials is the management of household refuse. These challenges manifest in a buildup of domestic waste, proliferation of informal dumping sites, standing water in numerous neighborhoods due to stagnant wastewater and rainwater, as well as limited strategic understanding among residents (Katumbo et al., 2020).

Scouring for solid waste has, in some sense, served as an alternative means of employment and a source of sustenance. Recycling has now evolved into a survival strategy adopted by individuals heavily impacted by unemployment and limited job opportunities (Ipasesa, 2019). In Kinshasa, an approach has been adopted for gathering industrial waste for recycling through a door-to-door

collection system. The collected waste typically includes polyethylene terephthalate (PET), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE), polypropylene (PP), and polystyrene (PS) materials in the form of items such as chairs, utensils, bottles, bags, and other objects.

Despite these challenges, there are significant opportunities to improve waste management in the DRC through strategic interventions and partnerships with international agencies like the World Bank or the United Nations Development Programme (UNDP) for enhancing the waste collector's capacity, increase public awareness and participation, and encouraging creative recycling and up-cycling of plastics and food waste. Partnership with the United Nations Environment Programme (UNEP) or Global Environment Facility (GEF) can secure funding for setting up recycling plants and training the local workforce. The African Development Bank (AfDB) can provide financial and policy support to promote economic growth.

There are some cases of implementation of waste management.

Lukomba and Kahinda (2023) carried out four experiments with different quantities of plastics and slag from the Congolese Gécamines giant mining company, and found that in one sample using a proportion of 6.5 kg of slag and 3.5 kg of plastic (65/35 ratio), the highest compression resistance attained was 50.52 MPa, which proved to be quite satisfactory for the application of their pavers in public areas and walkways. The project's profitability was evaluated, and in order to guarantee its long-term viability, it is suggested that a sales unit be established offering their products at a price of \$20 per square meter.

In Kinshasa, RECOVAD company implements a similar initiative to produce pavement blocks from plastic waste and PVC pipes, which are used for coating electrical

wires. It is important to highlight that the production process for these pavement blocks is largely carried out by artisans in the informal sector. The informal sector plays a significant role in the Congolese economy, with 538,300 production units and 692,000 jobs as of 2004. Despite this, only around 5% of daily plastic waste mass is currently being recycled (Ipasesa, 2019). Figure 4.1 illustrates examples of pavement blocks made from waste plastic materials.

Another implementation is the breeding of pigs, poultry, and the manufacture of soaps based on palm kernel oils. The company ELBEMA, which is now absorbed by the Société des Cultures et Agricoles au Mayumbe (SCAM/PKO), had thus found a market for the sale of its two products, namely: Palm Kernel Oils and by-products, called «tourteaux» (Mununzi and Ilunga, 2024).

In Kinshasa, there are currently only three companies working on agricultural waste management. These are Congo Complast, Congolese Solidarity, and ANJ (Ipasesa, 2019).

The first two applications which are very similar, fall under the category of biocomposites without explicitly stating their name. Our approach however involves using food waste as reinforcement. The vast potential of utilizing proliferating waste means that each day without action represents a significant loss for the country. Additionally, the main criterion should not solely focus on material strength; there are numerous other factors to consider. It is imperative to investigate the thermogravimetric (TGA) behavior of both the matrix (recycled plastic) and the reinforcement material (food waste) to evaluate the degradation temperature beyond which the desired outcomes may not be attained. Thermogravimetric behavior of materials refers to how the mass of a material changes as a function of temperature. This behavior is typically analyzed using a technique called thermogravimetric analysis (TGA), where a sample is continuously weighed while it is heated, cooled,

or held at a constant temperature. The resulting data provides insights into the material's composition, thermal stability, decomposition processes, and moisture content, among other properties. TGA is widely used in material science, chemistry, and engineering to study polymers, composites, ceramics, metals, and other materials. Environmental service conditions should also be examined, encompassing the response of the manufactured material to UV radiation, humidity, and water (such as rain). Spectroscopic analyses such as Fourier-Transform Infrared Spectroscopy (FT-IR) are highly recommended. FT-IR furnishes comprehensive insights into the chemical functional groups present in the biocompos-

ite, which are crucial for comprehending the material's properties and potential interactions with its surroundings. The hydrophobic nature of plastic and the hydrophilic nature of natural fiber (derived from food waste) undermine the bond between the biocomposite components. Extensive studies should also be undertaken to enhance the interface between the matrix and the reinforcement, utilizing various methods available in the literature. The list is extensive; thus, ongoing research and development efforts are essential to enhance outcomes, ensuring that the properties of the biocomposite align with the requirements of the intended application, thereby rendering end products more efficient and cost-effective.



(a)



(b)

**Figure 4.1.** (a) Pavement blocks made from plastic waste in Bandalungwa (Mangenda et al., 2020) (b) Pavement blocks made from PET (90%) and hard plastics (10%) in Kintambo (Ipasesa, 2019).

## 5. Conclusion

This study has highlighted the potential of biocomposites as a sustainable solution to the waste proliferation issues in the DRC. By recycling and reusing problematic resources such as plastics and inedible food waste, significant environmental problems can be addressed while promoting economic growth and improving public health. Our research uniquely explores the use of inedible food waste as reinforcement material in biocomposites, a novel approach in the DRC context.

The recyclability of biocomposites further enhances sustainability, allowing materials to be reprocessed for less demanding applications at the end of their lifecycle. However, optimal performance requires thorough investigation into the thermogravimetric behavior of the matrix and reinforcement materials, and the environmental conditions affecting the biocomposites. Techniques like Fourier-Transform Infrared Spectroscopy (FT-IR) are essential for understanding the chemical interactions within the biocomposite, impacting

its properties and environmental interactions. Addressing the hydrophobic nature of plastics and the hydrophilic nature of natural fibers is crucial for improving the bond between components, necessitating extensive research and development.

Strengthening the relationship between municipalities and communities is vital for promoting public participation in waste management. Empowering municipalities through environmental education and employing experts to develop sustainable waste management policies are essential steps.

There are significant opportunities to improve waste management in the DRC through strategic interventions and partnerships with international agencies like the World Bank and the United Nations Development Pro-

gramme (UNDP). These partnerships can enhance waste collectors' capacity, increase public awareness, and encourage creative recycling and upcycling. Collaborations with the United Nations Environment Programme (UNEP) and Global Environment Facility (GEF) can secure funding for recycling plants and workforce training. Additionally, the African Development Bank (AfDB) can provide financial and policy support to promote economic growth.

By leveraging innovative approaches such as biocomposites and composting, securing goodwill from governing bodies, and forming strategic international partnerships, the DRC can move towards a greener and more sustainable future, contributing to environmental quality, economic prosperity, and social equity.

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