

Valorisation of Biodegradable Solid Waste as a Lever for Reducing Greenhouse Gas Emissions in Yangambi City, DR Congo

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Abstract

Solid waste management is a major environmental challenge in the Yangambi region. The accumulation of waste in landfills, garbage bins, and disposal sites promotes anaerobic decomposition, a process that releases gases such as methane (CH₄) and carbon dioxide (CO₂). A survey was conducted on a randomly selected seven households per axes across five axes roads (35 households). Collected data were processed using Microsoft Excel 2016 and the R software. The results showed that 48% of the surveyed households dispose of their waste in the DR Congo river. While 18.5% buried in their plots of land; and 17% incinerate it. 9.5% threw their waste in the streets and 7% threw it in gutters. Results of waste composition recorded 48.2% organic matter; 25% plastic bags; 14.3% inert waste; 10% paper and cardboard; and 2.5% belonging to the category of other waste. 60% of households' aware of the harmful effects of waste on biodiversity and human health, while 40% unaware. Regarding community involvement in the various waste management processes, opinions are divided: 75% declare that the population is involved; 16% don't know if the population is involved or not; and 9% of households say that the population is not involved.

Keywords

Solid Waste, Methane, Disposal Practices, Community Involvement, Environmental Impact, Yangambi

1. Introduction

Over the past few decades, changes in the global climate system have emerged as one of the major environmental challenges of the 21st century. Climate data indicate a gradual increase in the planet's average temperature since the pre-industrial period, currently exceeding the 1.1 °C threshold. Scientific projections suggest that this temperature rises could reach, or even surpass, the 1.5 °C limit in the near future if anthropogenic pressures persist (Gillett et al., 2021). This climate change is accompanied by increasingly pronounced environmental and socio-ecological disturbances. The intensification of drought episodes, the decrease in water resource availability, the resurgence of wildfires, sea-level rises, the increase in flooding and extreme weather events, as well as the degradation of natural ecosystems, illustrate the magnitude of the impacts associated with climate change (Dahal et al., 2025). One of the major causes lies in the continued increase in atmospheric concentrations of greenhouse gases emissions, particularly carbon dioxide and methane. These compounds, primarily resulting from human activities, disrupt energy exchanges between the Earth's surface and the atmosphere by trapping some of the infra-red after solar radiation emissions. Among these activities, the inadequate management of solid waste, especially biodegradable organic fractions, contributes significantly to methane emissions, a gas with a particularly high warming potential in the short term (Wilson et al., 2024). Furthermore, the intensive use of fossil fuels remains a key driver of increased greenhouse gas emissions worldwide. Burning coal, oil, and natural gas releases significant amounts of carbon dioxide, thus exacerbating the global climate imbalance. In this context, reducing emission sources, combined with the recovery of organic waste, appears to be an essential approach to mitigating the effects of global warming, particularly in developing regions (Filonchuk et al., 2024). Current waste management approaches rely primarily on source separation, recycling, and the recovery of recyclable fractions, with the aim of limiting greenhouse gas emissions associated with uncontrolled disposal. A large proportion of solid waste, especially organic matter, can be used as a resource for renewable energy production through processes such as methanation. Furthermore, this waste can be converted into various value-added products, including compost, biofuels, certain organic acids, biodegradable plastic materials or biopesticides, thus contributing to a circular economy (Wainaina et al., 2020). In this context, the continued increase in waste volumes poses major challenges in terms of public health, natural resource preservation, and threatens the living conditions of the population. In the Democratic Republic of Congo, waste management remains poorly integrated into local development strat-

egies, particularly in secondary urban centers (Okin et al., 2024). The city of Yangambi provides a relevant case study in this regard. Despite its historical recognition as a hub for scientific research and an area of high ecological value, waste management systems there remain poorly structured and insufficiently formalized, thus justifying the interest of this study.

2. Materials and Methods

2.1. Study Environment

Figure 1 below shows the map of the Yangambi region, indicating the different hamlets where the surveys were conducted as well as the main access roads.

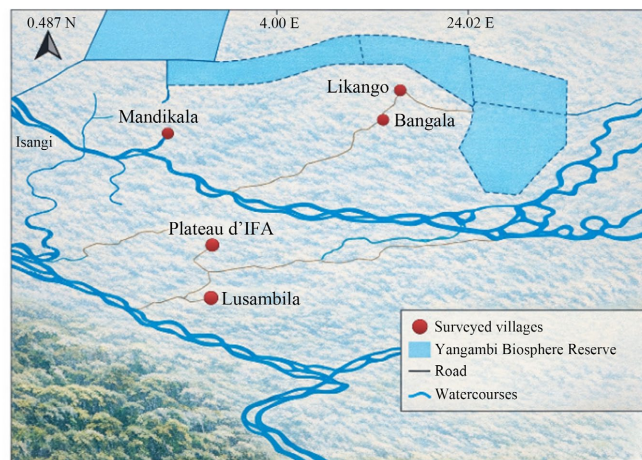


Figure 1. Map of Yangambi and the surveyed hamlets.

This research was conducted in the Yangambi region, located in Tshopo Province, in northeastern DRC, approximately 100 km west of Kisangani, on the right bank of the Congo River. It is home to the Faculty Institute of Agronomic sciences of Yangambi (IFA-Yangambi), agricultural and forested areas, and a thriving commercial center. This region lies within the humid equatorial zone and is characterized by high temperature and significant rainfall throughout the year. Waste production, natural degradation, and local management practices are influenced by these climatic conditions. Yangambi is recognized as a scientific and ecological area due to its vast forested areas and specialized research institutions in forestry and agriculture. However, despite this potential, informal waste management practices persist. The dominant socioeconomic activities in Yangambi are agriculture, small-scale trade, local markets, and households, which constitute the main sources of solid waste production (Yemefack et al., 2018). It is within this context that Yangambi was chosen as our study site to analyze, through direct observation and quantification, the production and management of solid waste.

2.2. Methods

2.2.1. Sampling Technique

Data were collected randomly from seven households located in the following

neighborhoods: Lusambila, Bangala, Mandikala, Likango, the IFA shopping center including the IFA plateau. The sample was constructed using simple random sampling. During data collection, each household in these hamlets was interviewed, with particular attention paid to the female-to-male ratio and age group. The final sample comprised 35 households.

2.2.2. Data Collection

Under the supervision of Professor NDjango NDjimani and Professor Jean Pierre Pitchou MENIKO, interviews were conducted to gather primarily general and contextual information, using an interview guide with closed and open questions. A minimum number of people per household were interviewed, either individually or in groups.

2.2.3. Data Processing and Analysis

Data collection relied primarily on direct observation, quantification of solid waste produced, and management techniques. A camera was used to document waste disposal sites and observed practices in the field. Notebooks were used to record additional information from direct observations. For data processing and analysis, a computer equipped with Excel and R software was used to produce summary tables and graphs, respectively. The collected data were coded and analyzed using R software (version 4.5.1). The analyses performed were exclusively descriptive, including the calculation of frequencies and percentages, and the production of graphs. No inferential analysis was conducted, as the objective of the study was to describe solid waste management practices and the composition of household waste in Yangambi.

3. Results and Discussion

3.1. Results

3.1.1. Waste Sorting Practices

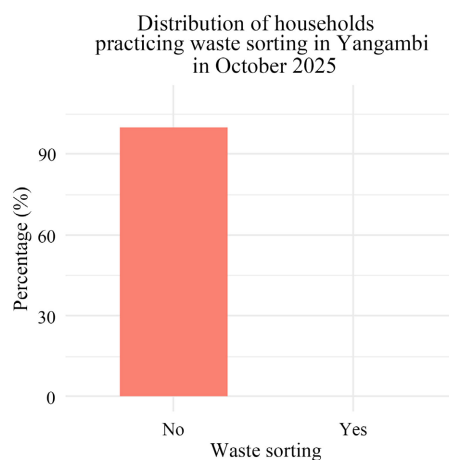


Figure 2. Distribution of households that practice waste sorting.

Results indicated in **Figure 2** showed that entire households (100%) didn't sort their

waste. This explains how waste is thrown in total combining everything disposed.

3.1.2. Waste Collection Services

Results (Figure 3) regarding service that came to their homes to collect waste showed that 93% of households responded that there was no such service, compared to 7% who indicated the existence of public administrations in general managing waste disposal.

Existence of waste collection services in Yangambi (October 2025)

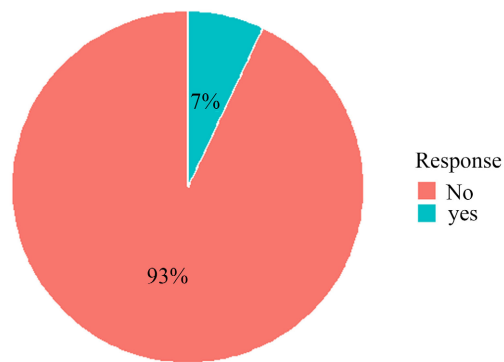


Figure 3. Existence of waste collection services.

3.1.3. Waste Disposal Methods

It emerges from this Figure 4 that 48% of households threw the waste produced into the river; 18.5% bury it in the plots; 17% incinerate it; 9.5% throw it in the streets and 7% throw it in the gutters (Figure 4).

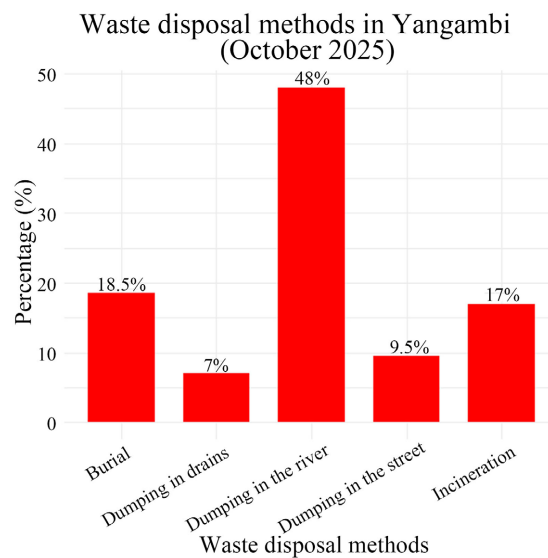


Figure 4. Waste disposal methods.

3.1.4. Composition of Household Waste

Waste encompasses all residues resulting from production, processing, or con-

sumption activities. It consists of substances, materials, or objects that the holder discards or intends to discard. Their nature varies depending on the origin of the human or natural activities that generate them.

Household waste is produced by households as part of their daily activities. It includes both solid waste (food scraps, packaging, paper, plastics, glass, used clothing, small electronic devices, water and beverage bottles) and liquid waste, such as oils and soap residues.

In this context, the analysis of the composition of household waste in Yangambi reveals a predominance of organic waste. As illustrated in **Figure 5**, this waste is composed of 48.2% organic matter, followed by plastic bags at 25%. Inert waste accounts for 14.3%, while paper and cardboard make up 10%. Other types of waste remain marginal and represent only 2.5% of the total.

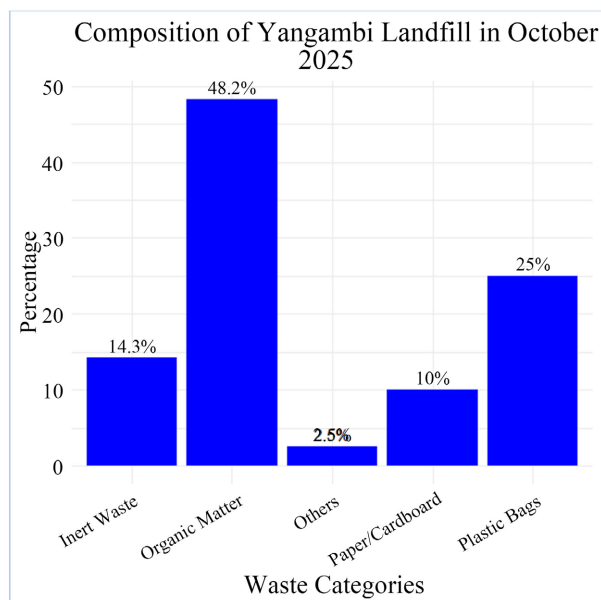


Figure 5. Composition of waste dumps in Yangambi.

3.1.5. Use of the Bin

Figure 6 shows that 70.2% of households use the bin for temporary waste storage and 29.8% do not have one.

Proportion of households using trash bins in Yangambi (October 2025)

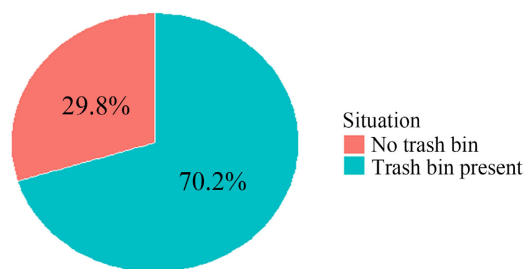


Figure 6. Use of waste bins.

3.1.6. Frequency of Waste Disposal

Agricultural waste consists primarily of plant residues from farming activities, including straw, stalks, husks, and inedible leaves. Most agricultural production systems generate this type of waste, which can have significant impacts on the environment and climate. Indeed, its natural decomposition or disposal through open burning leads to the emission of substantial amounts of greenhouse gases, particularly carbon dioxide (CO₂) and methane (CH₄), as well as polluting fumes. In the Yangambi region, the main crops grown are cassava, plantain, maize, rice, soybeans, and vegetable crops such as amaranth and okra. Due to their size and production volumes, these crops generate considerable quantities of agricultural residues, contributing significantly to the local production of plant-based waste.

Paper and cardboard waste originates primarily from the use of paper-based products in government offices, schools, households, and businesses. It constitutes a significant portion of urban solid waste. Its decomposition also releases carbon dioxide, thus contributing to the overall emissions balance of waste. Analysis of waste disposal practices reveals varying frequency among households. As illustrated in **Figure 7**, 45% of respondents report disposing of their waste twice a week, while 30% do so daily. Conversely, 20% dispose of their waste once a week and 5% three times a week, reflecting a heterogeneity of behavior and a still insufficiently structured local waste management system.

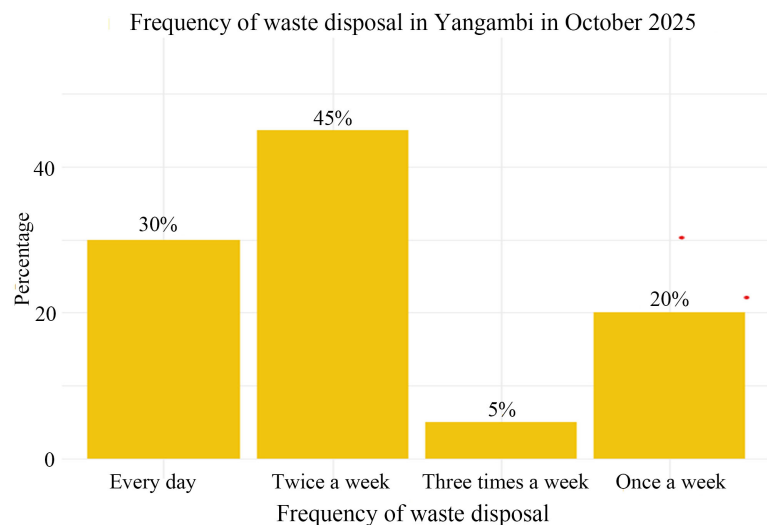


Figure 7. Frequency of waste disposal.

3.1.7. Awareness of the Harmful Effects of Waste on Human Health and the Environment

Waste, whether household, agricultural, industrial, or from healthcare facilities, can pose significant risks to biodiversity and human health when poorly managed. It can lead to soil and water pollution, promote the proliferation of disease vectors, and disrupt local ecosystems. Thus, inadequate waste management constitutes a major environmental and health problem in both urban and rural areas.

Assessing households' awareness of these impacts reveals a contrasting perception.

As shown in **Figure 8**, 60% of households surveyed recognize the negative effects of waste on the environment and human health, while 40% are unaware of them. This significant proportion of uninformed individuals highlights the need to strengthen information and environmental education initiatives to improve waste management practices and reduce its harmful effects on populations and ecosystems.

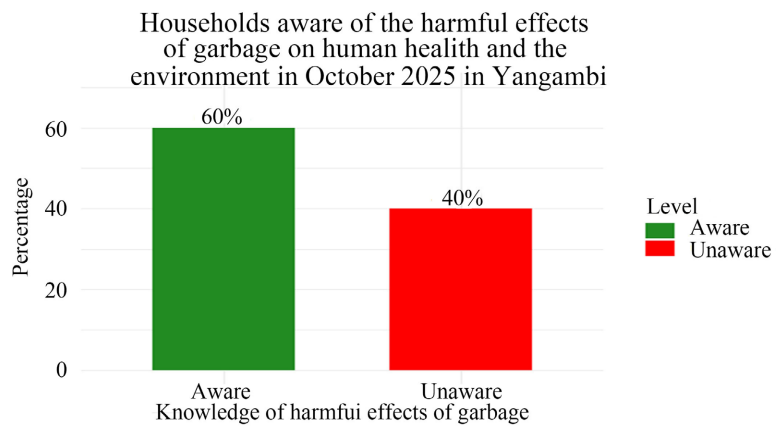


Figure 8. Impacts of waste on human health and biodiversity.

3.1.8. Community Involvement in the Waste Management Process

Population involvement in waste management in Yangambi (October 2025)

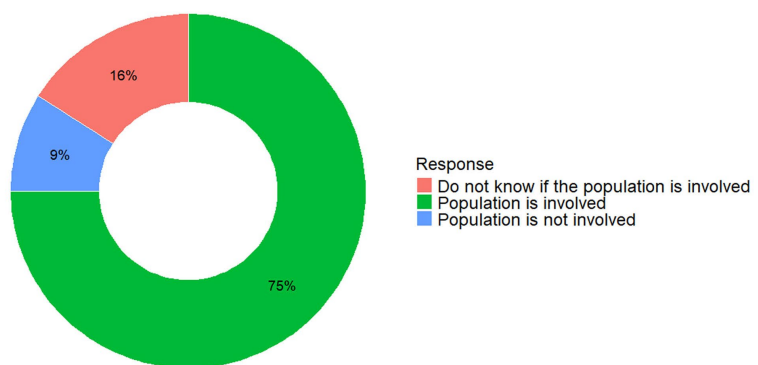


Figure 9. Public involvement in waste management.

The question regarding community involvement in waste management aimed to identify the main actor in this activity: the state, specialized services, or the population itself. The results presented in **Figure 9** show that, for 75% of the households surveyed, waste management relies primarily on the initiative of local residents. This high proportion indicates weak institutional support for the problem and suggests the absence or inadequacy of formal public waste collection and treatment services. Conversely, 16% of respondents stated that they did not know who was actually responsible for waste management, which may reflect a lack of communication or visibility regarding any actions taken by the authorities or specialized organizations. Finally, 9% felt that the population was not involved, sug-

gesting that, in some neighborhoods, no clear organization exists to ensure waste disposal. Overall, these results show that waste management is largely handled by households themselves, rather than by the state or dedicated technical services, highlighting the need to strengthen public policies, sanitation services, and coordination mechanisms with local communities.

3.1.9. Illegal Dumping of Waste

Waste dumped in nature falls into the category of illegal dumps, carrying pathogenic bacteria and fungi that pollute the receiving environment. In Yangambi, the Congo River, the commercial center, and the alleyways are cluttered with garbage, as shown in **Figures 10(a)-(i)**:



Figure 10. Illegal dumping sites observed in the study area. (a) Accumulation of solid waste along the shoreline; (b) Open dumping of mixed household waste in an uncontrolled area; (c) Scattered waste near residential or urban infrastructure; (d) Direct discharge of solid waste into a water body; (e) Waste accumulation along a drainage channel; (f) Uncontrolled dumping of solid waste in a natural depression or open land; (g) Accumulation of solid waste in a vegetated area; (h) Mixed waste dumping in an open environment; (i) Large-scale accumulation of solid waste forming an informal dumpsite.

In this regard, the near absence of controlled landfills in Yangambi is a prime example, and residents resort to unsustainable practices. The deterioration of biodiversity has repercussions on human health, including: impassable roads, deteriorating urban landscapes, dampness in courtyards, and fecal-oral diseases (diarrhea) and fecal-fecal diseases (typhoid fever). This waste releases significant amounts of greenhouse gases into the atmosphere. Effective planning of a household waste management system requires, first and foremost, a thorough understanding of the quality and quantity of waste currently produced and accurate projections for the future (World Bank, 2018).

3.2. Discussion

In Yangambi, as in many cities in the Democratic Republic of Congo, environmental conditions strongly favor the spread of numerous diseases such as cholera, typhoid fever, and malaria. The unsanitary living environment is characterized by poor solid waste management and a virtually nonexistent or ineffective wastewater disposal system, as demonstrated by Gebrekidan et al. (2024). In several neighborhoods of Yangambi, waste is rarely collected. Under the pretext that there is no functioning public garbage collection service, residents are forced to dispose of their waste haphazardly in open spaces or near their homes, in the streets, and in gutters. Studies conducted in Congolese urban areas, particularly in Kinshasa, have shown that exposure to uncontrolled dumpsites is strongly associated with an increase in parasitic infectious diseases (Kitole et al., 2024). Although Yangambi is less urbanized than Kinshasa, the mechanisms of environmental degradation and health risks observed there are similar. Indeed, to reduce the volume of waste, some households resort to open burning. This practice, while common, releases toxic fumes harmful to human health and contributes to air pollution. According to Kouamé et al. (2014), these unhygienic waste disposal methods expose urban and African populations to multiple health and environmental risks. The lack of a structured system for sorting, recycling, and recovering waste makes the situation even more concerning, as highlighted by Thonart et al. (2025). In several cities in developing countries, nearly two-thirds of the population live in unsanitary conditions due to inadequate solid waste management. This reality also applies to Yangambi, where the poor quality of living conditions directly affects the well-being of the population. Thus, the problem of waste management in Yangambi is not only an environmental challenge but also a major public health issue. Finding sustainable solutions, involving both local authorities and the population, appears essential to improving living conditions and reducing the prevalence of diseases related to unsanitary conditions (Okin et al., 2024). Previous studies have shown that the absence of organized waste collection and treatment systems promotes the spread of parasites, particularly roundworm infections, especially among children living in households without collection services (Da Silva et al., 2007). This situation is comparable to that observed in Yangambi, where the majority of households dispose of their waste informally. Children's high exposure to house-

hold waste, often dumped near homes, increases their vulnerability to diseases related to unsanitary conditions. Poor waste management also has consequences for sanitation infrastructure. In uncontrolled areas, the accumulation of waste in gutters and pits leads to blockages in rainwater drainage, especially during periods of heavy rainfall. This situation exacerbates local flooding, road deterioration, and mosquito proliferation. As several studies have highlighted, irregular waste collection and inadequate maintenance of sanitation infrastructure are closely linked to the degradation of the urban living environment (Echendu, 2023). Faced with this situation, several authors recommend a shift in waste management strategies towards sustainable solutions. Manea et al. (2024) emphasizes the need to significantly reduce landfilling and open-air dumping by promoting recycling and waste recovery, particularly of organic matter.

The results of this study show that nearly half (48.2%) of the household waste produced in Yangambi is organic, suggesting significant potential for biological recovery. On average, a person produces about 0.8 kg of waste per day. For a household of five, this represents approximately 4 kg of daily waste, of which about 1.52 kg is organic matter. Across the 35 households studied, this corresponds to approximately 53.2 kg of organic waste per day. If this figure is extrapolated to the entire city, whose population is estimated at 37,997 inhabitants (Van Vliet et al., 2019), the total amount of household waste could reach approximately 30.39 tonnes per day, of which nearly 11.55 tonnes is organic matter. Assuming a composting efficiency of 40% (Chuma et al., 2024), this organic waste could produce approximately 4.62 kg of compost per day. This compost would be very useful for peri-urban agriculture, improving soil fertility and reducing the need for chemical fertilizers. Furthermore, this organic fraction could be processed by anaerobic digestion to produce biogas, thus providing a local energy source and helping to reduce greenhouse gas emissions associated with uncontrolled landfilling or incineration (Alengebawy et al., 2024). Other types of waste also offer opportunities. Plastics, which are abundant and degrade very slowly, could be recycled mechanically or chemically, thereby helping to reduce environmental pollution (Luo et al., 2024). Inert materials, although non-biodegradable, could be reused in construction or as fill, providing a simple and practical way to recover materials. Paper and cardboard, which are easily recyclable, could be reintegrated into production chains, thus reducing pressure on natural resources. Compared to more advanced sectors, such as the production of organic acids or biopesticides from biodegradable waste, the recovery of inorganic fractions is complementary. It helps to reduce the volume of waste to be managed while generating economic and environmental benefits adapted to the local context of Yangambi, according to the data collected in this study.

4. Conclusion

This study focused on the solid waste management problem in Yangambi. It was found that current waste management practices do not meet waste management

guidelines and standards. Large amounts of waste are dumped in the streets and ravines, and there are numerous piles of illegally dumped garbage. Household waste is also being poured into sewers, resulting in an unsanitary environment. Human health and biodiversity have been affected; global temperatures are rising due to greenhouse gas emissions from landfills. These issues tarnish the city's image. However, the population is aware of the dangers they face, and this situation requires sustainable solutions. It is necessary to implement measures for the sustainable management of solid waste in this area. From the above, the following recommendations can be made: 1) Establishing a structure dedicated to raising awareness about waste management, 2) Convincing the population to adopt the "zero waste" initiative, 3) Providing the mayors of Yangambi with a realistic budget to address the sanitation problem, 4) Implementing the polluter-pays principle, 5) Ensuring the application of Law No. 11/009 of July 9, 2011, concerning fundamental principles relating to environmental protection and regulations in force regarding waste management, 6) Strengthening waste collection infrastructure, 7) Adopting the polluter-pays principle, 8) Transforming plastic waste to produce organic acids, 9) Transforming household waste into compost, 10) Producing biopesticides from waste.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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