JURNAL ILMU LINGKUNGAN
Volume 22 Issue 3 (2024) : 756-765 *ISSN 1829-8907*

Municipal Waste Characterization and Reduction Potential in Singaraja City

Anak Agung Mas Untari[1], I Made Wahyu Wijaya[1*], I GD Yudha Partama[1], and Kailas Deoram Ahire[2]

[1]Regional and Rural Planning Study Program, Universitas Mahasaraswati Denpasar, Denpasar, Indonesia; e-mail: wijaya@unmas.ac.id
[2]Department of Environmental Science, K.R.T. Arts, B.H. Commerce, A.M. Science (KTHM) College, Nashik, Maharashtra, India

ABSTRAK

Tempat pembuangan akhir (TPA) Bengkala merupakan satu-satunya TPA di Kabupaten Buleleng yang kondisi timbunan sampah saat ini telah melebihi kapasitas TPA. Pemerintah daerah telah berupaya untuk mengurangi sampah yang diangkut ke TPA, salah satunya dengan menyediakan pusat daur ulang (PDU) untuk mengolah sampah. Penelitian ini bertujuan untuk menganalisis timbulan dan karakteristik sampah di Kota Singaraja serta potensi daur ulangnya untuk mendukung perencanaan PDU. Metode yang digunakan dalam penelitian ini adalah analisis timbulan dan karakteristik sampah berdasarkan data pengukuran oleh pemerintah daerah Kabupaten Buleleng sesuai dengan SNI 19-3964-1994. Hasil analisis menunjukkan Kota Singaraja menghasilkan sampah sekitar 606.23 kg/hari, dengan kepadatan 0.244 kg/L. Sampah organik mendominasi dengan komposisi 66.31% dari total sampah. Sampah makanan dan dedaunan adalah komponen sampah organik tertinggi yang menunjukkan pentingnya pengurangan sampah makanan, salah satunya melalui pengomposan. Sampah kertas, kayu, plastik masing-masing menyumbang 8.23%, 1.41%, 14.57% dari sampah. Kajian komposisi sampah di Kota Singaraja mengungkapkan adanya peluang dan tantangan dalam pengelolaan sampah dan keberlanjutan. Kota Singaraja dapat mendapatkan manfaat dari inisiatif seperti program pengurangan plastik, daur ulang kaca, dan pengelolaan sampah berbahaya untuk mencapai praktik sampah yang berkelanjutan. Untuk mencapai tujuan ini, diperlukan pendidikan masyarakat, intervensi kebijakan, pengembangan infrastruktur daur ulang, dan kolaborasi pemangku kepentingan.

Kata kunci: Timbulan sampah, Potensi reduksi, Komposisi sampah, Pengelolaan sampah

ABSTRACT

The Bengkala Landfill serves as the sole waste disposal site in the Buleleng Regency, and its current waste accumulation has exceeded the landfill's capacity. The local government has endeavoured to reduce the influx of waste to the landfill by establishing a Recycling Centre (RC) for waste processing. This research aims to analyse the generation and characteristics of waste in Singaraja City, as well as its recycling potential, to support RC planning. The study's method is to look at how much waste is made and what kinds of things are made from it by using measurements made by the local government of Buleleng Regency in line with the Indonesian National Standard (SNI) 19-3964-1994. The analysis reveals that Singaraja City produces approximately 606.23 kg/day of waste, with a density of 0.244 kg/L. Organic waste dominates, constituting 66.31% of the total waste composition. Food waste and foliage are the highest components of organic waste, underscoring the significance of food waste reduction, including composting. Paper, wood, and plastic contribute 8.23%, 1.41%, and 14.57% of the waste, respectively. The study of waste composition in Singaraja City reveals both opportunities and challenges in waste management and sustainability. Singaraja City can benefit from initiatives such as plastic reduction programmes, glass recycling, and hazardous waste management to achieve sustainable waste practices. Achieving these goals necessitates public education, policy interventions, recycling infrastructure development, and stakeholder collaboration.

Keywords: Waste generation, Reduction potential, Waste Composition, Waste Management

Citation: Untari, A., A., M., Wijaya, I. M., W., Partama, I. GD., Y., dan Ahire, K., D., (2024). Municipal Waste Characterization and Reduction Potential in Singaraja City. Jurnal Ilmu Lingkungan, 22(3), 756-765, doi:10.14710/jil.22.3.756-765

1. INTRODUCTION

The management of municipal solid waste has emerged as a critical concern due to its significant environmental implications and potential for adverse effects on both human health and urban aesthetics (Kumar Das & Baishya, 2017). The inadequacies in waste handling not only contribute to environmental degradation but also trigger multifaceted issues

within urban settlements (Kreith & Tchobanoglous, 2002). Among these issues are the onset of malodorous odours, the proliferation of disease vectors, and the erosion of the aesthetic appeal of the surroundings (Huang, Wang, Dong, Xi, & Zhou, 2006; Kohli, 2016). A striking concern lies in the fact that an estimated 60% of urban waste remains untransported to designated treatment and landfill, necessitating a comprehensive approach to both waste disposal and reduction strategies (Adnan, Ainun, & Halomoan, 2018; Paramita, Hartono, & Soesilo, 2018). This highlights the urgency to analyse waste characteristics and investigate potential avenues for waste reduction.

Central to this discussion is the Bengkala Landfill, the sole active landfill in the Buleleng Regency, which contends with a substantial daily inflow of waste totalling 145 tons. Operating since 2008, the Bengkala landfill transitioned to an open dumping approach in 2020, resulting in towering waste mounds that reach up to 15 metres in height. This situation underscores the Buleleng Regency's commitment to bolster waste management strategies, particularly through an infrastructural lens. Singaraja City as capital of Buleleng Regency has the most population in the regency and produce the waste that has been disposed to landfill. The overload capacity condition in Bengkala Landfill is causing some delayed of the waste transport and could not serve the city at the time. It is an urgent situation to handle the waste in Singaraja City to decrease the waste contribution to the landfill.

Such an approach emphasises source reduction, efficient utilisation, and comprehensive waste processing, encompassing facets such as Reduce, Reuse, and Recycle Waste Collection Points (3R WCPs), composting facilities, recycling centres, waste recycling units (PDU), and integrated waste processing facilities.

However, the operation of 3R WCPs faces a notable hurdle in the form of high operational costs, which frequently lead to operational discontinuity. The financial burdens associated with effective waste management can undermine the viability of waste reduction initiatives, potentially compromising their long-term sustainability. In response, the Buleleng Regency Government has prioritised the establishment of 3R WCPs in villages, demonstrating a strong commitment to waste management in rural areas. This strategic emphasis aims to ensure the viability of these investments and aligns with the principles of sustainable waste management, where economic feasibility and long-term effectiveness converge (Huang et al., 2006; I. Wijaya, 2014).

Aligned with the Buleleng Sanitation Strategy, certain urban areas within the regency are identified as Grade 3 risk zones due to sanitation concerns. This classification accentuates the repercussions of inadequate waste management, transcending environmental boundaries to impact public health and community well-being. To address these concerns and foster an effective urban waste management framework, the Buleleng Regency Government has planned the establishment of a recycling centre (RC) with a daily capacity of 10 tons. The proposed RC, to be situated on land owned by the Buleleng Regency Local Government and managed by the Department of Environmental Affairs, holds potential as a catalyst for waste reduction efforts. This study's primary focus is to meticulously analyse waste generation patterns and characteristics within Singaraja city. This analysis will provide crucial insights into devising tailored waste reduction and recycling strategies. Furthermore, the study intends to explore the potential for waste reduction through the establishment of a recycling centre (Consonni, Giugliano, & Grosso, 2005; MOELLER, 2019; I. M. W. W. Wijaya et al., 2021). This potential reduction avenue, facilitated by the RC, could significantly enhance waste diversion, and contribute to the evolution of a circular economy framework (Kuniyal, Jain, & Shannigrahi, 2003; Tyagi et al., 2021). In conclusion, the urgency to address waste management challenges underscores the significance of analysing waste characteristics, assessing reduction potentials, and devising context-specific strategies.

As the Buleleng Regency Government endeavours to establish a recycling centre, an in-depth examination of waste generation patterns and characteristics assumes paramount importance to ensure informed decision-making and the establishment of a sustainable waste management paradigm. Additionally, the waste composition analysis aimed to shed light on the diverse array of waste types, further informing effective waste management strategies. The present research aims to comprehensively analyse the generation and characteristics of waste within Singaraja city.

2. METHOD

The study employed the methodology outlined in the Indonesian National Standard (SNI) 19-3964-1994 (SNI 19-3964-1994, 1994), which pertains to the "Method of Sampling and Measurement of Urban Waste Generation and Composition. This standardised approach was selected to ensure methodological rigour and comparability with established practices. The research was conducted on in June – August 2023.

The primary data concerning waste generation was acquired through systematic field measurements. The waste generation was quantified by calculating the waste collected from the city that transported to the Bengkala landfill by the truck. There are 5 trucks that serve the city in the waste transport to the landfill. The study was conducted at the Bengkala Landfill by analysing the waste generation and composition from each truck. The main approach employed in this study entailed the quantification of waste by measuring the amount of waste that was disposed of at the landfill and transported out of the city using trucks. The chosen methodology was

employed to offer a pragmatic and all-encompassing comprehension of the waste environment in urban areas.

The waste composition analysis encompassed the categorization of waste into various types, including organic waste, paper, wood, textile, plastic, leather, metal, glass, hazardous waste, and other. By conducting a detailed analysis of the waste composition, the research aimed to unravel the intricate mix of waste types and their relative proportions within the selected location (Lomelí-Ramírez, Anda, Satyanarayana, Bolzon de Muniz, & Iwakiri, 2018; Turan, Baki, & Ergun, 2016). This process allowed for the identification of dominant waste categories and facilitated informed decision-making regarding waste management strategies. Each waste composition has completed with the waste management strategies that define according to previous references.

3. RESULT AND DISCUSSION

In accordance with the previously delineated comprehensive methodology, this section presents the findings that have been derived from the analysis of waste generation and its corresponding characteristics within the confines of Singaraja city. The findings shed light on the complex interplay of waste accumulation and composition in the urban environment. Following this, the discourse delves into the ramifications of these discoveries, examining their importance within the framework of waste management tactics, environmentally friendly methodologies, and the prospective establishment of a recycling facility (RC).

3.1. Current Situation of Bengkala Landfill

Bengkala Landfill is in the Buleleng Regency functions as an operational final disposal site for waste management activities. According to the Profile TPA Bengkala published by Cleanliness and Gardening Agency of Buleleng Regency (Dinas Kebersihan dan Pertamanan Kabupaten Buleleng, 2020), Bengkala Landfill encompasses a total area of 4.8 hectares and consists of four waste containment blocks, each with its own distinct operational history and associated challenges. It is of significance to mention that Blocks Two, Three, and Four located within the Bengkala Landfill have reached their maximum waste capacity thresholds, thereby requiring the implementation of targeted measures for their effective management. The capacity and existing condition of the landfill blocks is presented on Table 1.

Table 1. Landfill Block Capacity and Current Condition

Blocks	Area (m^2)	Capacity (m^3)	Current condition
Block 1	8.504,76	71.879,78	Overload
Block 2	4.322,37	36.449,53	Overload
Block 3	6.992,22	68.362,71	Overload
Block 4	7.483,69	86.227,27	Overload
Current Block	5.515,48	22.061,92	Overload

The blocks have been subjected to a process of conversion into sanitary landfills, which is a waste management method that incorporates meticulous engineering and stratification techniques to minimise adverse effects on the environment. However, Block One, which was originally intended for soil fill activities to facilitate the operations of the sanitary landfill, assumed a different function. As a result of the excessive utilisation and congestion experienced in Blocks Two, Three, and Four, the decision was made to repurpose Block One for waste management purposes, even though it lacks the necessary impermeable liner mandated for sanitary landfill operations (Dinas Kebersihan dan Pertamanan Kabupaten Buleleng, 2020).

The absence of a necessary impermeable liner when employing Block One for waste storage gives rise to considerable apprehensions regarding the potential risks of environmental and groundwater contamination. The lack of this liner undermines the effectiveness of containing and managing leachate, which is essential for responsible waste disposal. The scenario highlights the crucial significance of adhering to standardised waste disposal practises and emphasises the need for appropriate investments in infrastructure to guarantee environmental protection. Moreover, the operational roads within the Bengkala Landfill, which were initially designed to facilitate the logistics of waste management, have now been transformed into areas designated for the storage of waste. The accumulation of waste has encroached upon block boundaries, specifically the boundaries between the Existing Block and Block II, as well as Block III and Block IV. The regions, currently occupied by refuse, pose difficulties not only in terms of waste management but also in relation to operational accessibility and safety. The encroachments in Block II and Block III are characterised by waste heaps reaching heights of 15 metres and 10 metres respectively. These dimensions indicate the limited space available and emphasise the pressing need for efficient waste management strategies (Dinas Kebersihan dan Pertamanan Kabupaten Buleleng, 2020; Gede, Yanthi, Rahmawati, Made, & Widiastini, 2022).

The evolving challenges faced by the disposal site of Bengkala Landfill are reflected in the changing methodologies employed in waste management. The progression from a sanitary landfill system to controlled landfill, and eventually to open dumping, reflects the challenges faced, notably the scarcity of fill soil necessary for waste covering. The confluence of these challenges has resulted in the Bengkala Landfill being vulnerable to fire hazards, thereby intensifying the environmental and safety issues related to waste management. Given the gravity of these pressing concerns, the Bengkala Landfill presents itself as a compelling subject of analysis, underscoring the urgency of adopting sustainable waste management strategies and the indispensability of meticulous waste facility planning. The encountered difficulties

highlight the significance of following waste management protocols, maintaining sufficient waste containment capacity, and upholding environmental protection by enforcing regulations pertaining to landfill operations (Dinas Kebersihan dan Pertamanan Kabupaten Buleleng, 2020; Putu, Udayani, Suprihatin, & Made Gunamantha, 2020).

The experiences of Bengkala Landfill offer significant insights into the intricate nature of waste management in urban settings, underscoring the importance of making strategic investments, adhering to environmental safeguards, and implementing proactive measures to mitigate environmental risks arising from inadequate waste disposal methods. The layout of Bengkala Landfill is shown below on Figure 1.

3.2. Waste Characterization

The analysis of waste composition holds significant importance in comprehending the complexities of the waste stream, yielding valuable insights that serve as the foundation for the development of efficient waste management strategies. In the urban area of Singaraja City, there is an increasing focus on waste management, prompting the need for a comprehensive analysis of waste composition. This meticulous examination provides valuable insights that can inform the implementation of sustainable waste management strategies (Consonni et al., 2005). This discourse provides an in-depth examination of the constituent elements of waste, their respective proportions, and the potential ramifications for strategies pertaining to waste management.

The generation and management of waste have emerged as significant global concerns, primarily influenced by the processes of urbanisation, population expansion, and consumption behaviours (Rajendran SM & Sekaran V, 2015; Scarlat, Motola, Dallemand, Monforti-Ferrario, & Mofor, 2015). The management of solid waste in Singaraja City, located in Bali, Indonesia, presents considerable challenges. To establish an efficient waste management system, it is imperative to possess a comprehensive comprehension of the waste stream's composition. This is since various materials exhibit unique characteristics, necessitating specific methods for disposal or recycling. The present discourse examines the composition of waste in Singaraja City, offering an in-depth analysis of the constituent elements of waste and their consequential implications for the development of effective waste management strategies.

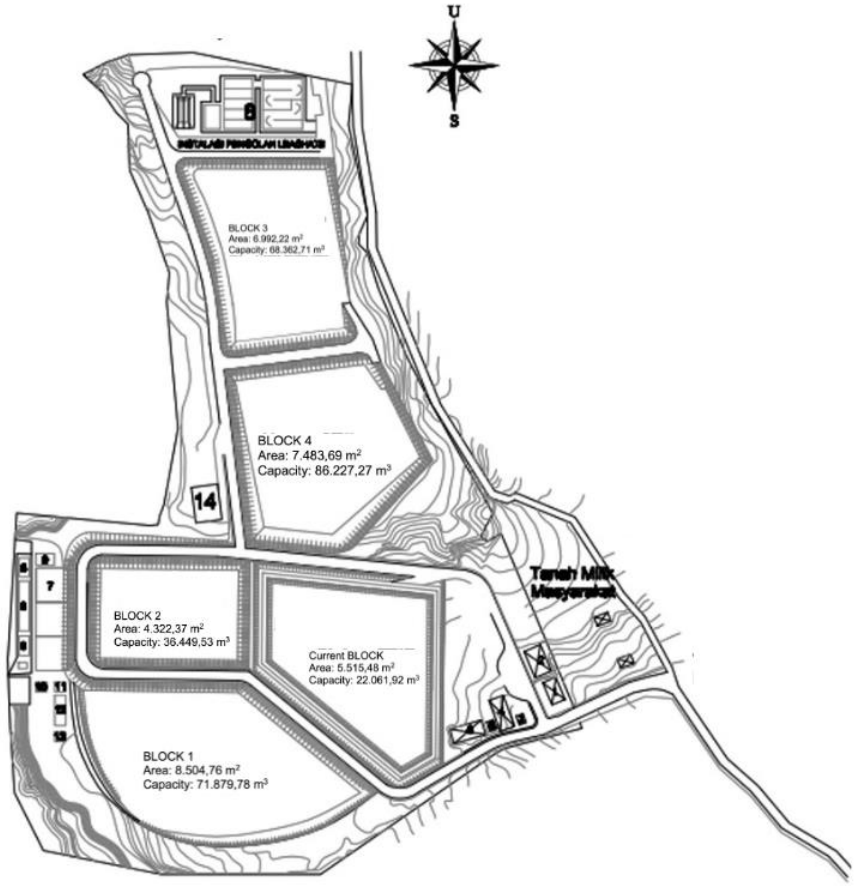

Figure 1. Layout of Bengkala Landfill and the block's capacity (source: (Dinas Kebersihan dan Pertamanan Kabupaten Buleleng, 2020)

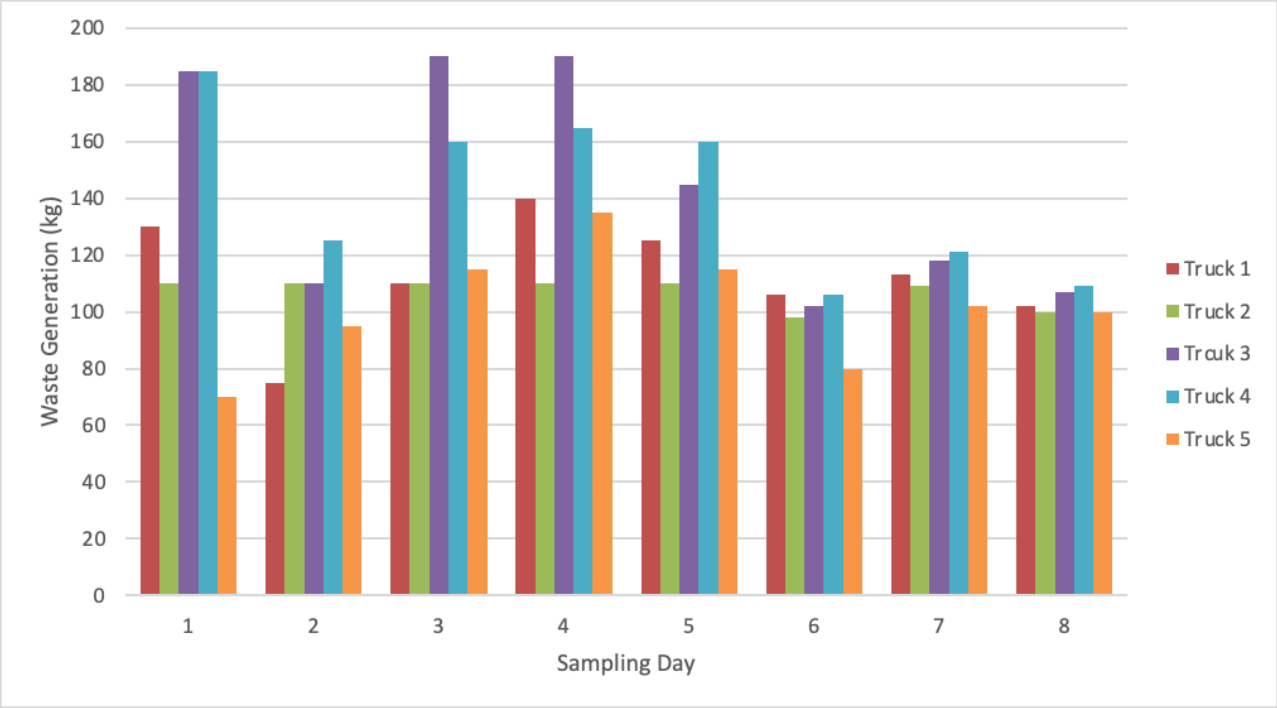

Figure 2. Waste generation sampling at the landfill from the trucks

Prior to conducting a detailed analysis of waste composition, it is imperative to acknowledge the average rates of waste generation and density within Singaraja City. The city, on average, produces a daily waste amount of approximately 606.23 kilogrammes, which is subsequently disposed of in the landfill. The waste demonstrates a mean density of 0.244 kg/L, suggesting a high level of compactness in the waste stream. The sampling result of waste generation is presented on Figure 2. Comprehending these fundamental data points is imperative in evaluating the sustainability of waste management methodologies.

3.2.1 Organic Waste

The waste composition in Singaraja City is predominantly comprised of organic waste, which accounts for approximately 66.31% of the total waste analysed. This category encompasses various organic materials, including food waste, leaves, grass, and other similar substances. It is imperative to comprehend the intricacies inherent in this category, as the proper handling and management of organic waste necessitate the implementation of specific strategies. Food waste, which is a substantial constituent of organic waste, demonstrates fluctuations throughout the observed time intervals. It is imperative to acknowledge that food waste accounts for approximately 17.68% of the overall waste composition. The observed variability implies the presence of dynamic consumption patterns or food disposal practices within the urban area. The significant proportion of food waste underscores the necessity for implementing comprehensive strategies aimed at reducing food waste (Dhanya, Mishra, Chandel, & Verma, 2020). Educational initiatives aimed at enhancing public knowledge regarding food waste and advocating for practices such as composting have the potential to effectively mitigate the environmental consequences associated with the disposal of food waste in landfills.

Leaves and foliage exhibit a consistent presence within the category of organic waste, making a substantial contribution to the overall fraction of waste. They comprise approximately 49.16% of the overall waste composition. The significant abundance of leaves and foliage highlights the potential for the recycling of organic waste through the process of composting (Cokorda, Wijaya, & Paramita, 2022; Ulhasanah et al., 2022; I. M. W. Wijaya & Putra, 2021; I. M. Wijaya, Wiratama, Putra, & Aris, 2023). The implementation of community-based composting programmes has the potential to not only divert a substantial proportion of waste from landfills but also generate valuable compost that can be utilised in local agricultural practices.

Although grass and other organic materials constitute a relatively minor portion within the organic waste classification (approximately 0.12% each), their combined presence significantly influences the overall composition of organic waste. It is important to note that even though these materials may be in small quantities, they should not be disregarded. The integration of these initiatives into composting practices can effectively augment endeavours aimed at recycling organic waste (Suryawan, Rahman, Septiariva, Suhardono, & Wijaya, 2020).

3.2.2 Paper Waste

The composition of waste includes a comparatively small fraction of paper waste, accounting for approximately 8.23% of the overall waste volume. This category encompasses various types of paper, such as cardboard, duplex, writing paper, Tetrapack, and other paper varieties. Cardboard and duplex materials are significant contributors within the paper waste category, accounting for approximately 0.74% and 6.38%, respectively. The identification of cardboard and duplex materials within the waste stream suggests the possibility of engaging in paper recycling practices. The implementation of effective paper recycling initiatives can significantly contribute to the diversion of waste and the conservation of resources. The inclusion of writing paper and Tetrapack materials in the composition of paper waste is relatively minor, accounting for approximately 0.15% and 0.03%, respectively. It is imperative to consider these materials when implementing paper recycling initiatives, as this will help ensure a comprehensive approach to diverting a diverse array of paper products from ending up in landfills.

3.2.3 Wood Waste

Materials categorised as wood and its counterparts, including bamboo and coconut shells, constitute a negligible portion of the waste stream, representing approximately 1.41% of the overall waste composition. Out of the materials mentioned, coconut shells is the primary contributor, accounting for approximately 0.94% of the total. The utilisation or recycling of coconut shells could potentially yield local economic and environmental benefits, such as the production of charcoal or their use as a material for crafts. Although wood and similar materials are of lesser significance, efficient utilisation of coconut shells holds promise for these purposes.

3.2.4 Textile Waste

Textile waste, which encompasses fabrics and textiles, makes a substantial contribution to the overall waste composition, representing approximately 2.72% of the total waste generated. The present category demonstrates notable variations, wherein the predominant proportion of approximately 2.72% is attributed to contributions from kain, a type of fabric. The implementation of textile recycling initiatives can have a significant impact on diverting these materials away from landfills. Engaging in partnerships with local artisans or textile recycling facilities can offer opportunities for repurposing or recycling textiles, thereby making significant contributions to waste reduction and the promotion of sustainable fashion practices (Martikkala, Mayanti, Helo, Lobov, & Ituarte, 2023; Weber, Weber, Habib, & Dias, 2023).

3.2.5 Plastic Waste

Plastic waste has become a significant and worrisome element within the waste composition, accounting for approximately 14.57% of the overall waste. This category encompasses a range of plastic types, such as plastic bags, multilayer plastics, Styrofoam, Slopan Pouch, and other similar materials. Plastic bags and multilayer plastics are significant contributors to the overall plastic waste category, accounting for approximately 6.84% and 4.57% of the total, respectively. The significant occurrence of plastic bags and multilayer plastics highlights the pressing need to tackle the usage of disposable plastics and advocate for responsible plastic disposal and recycling methods. The implementation of plastic bag bans or the provision of incentives for the use of reusable bags can be regarded as effective strategies (Nyberg, Harris, Kane, & Maes, 2023). The materials known as Styrofoam and Slopan Pouch, despite their relatively limited quantities, make a notable contribution to the overall plastic waste, accounting for approximately 0.26% and 2.24%, respectively. The existence of polystyrene underscores the necessity for alternative options or substitutes. Recycling solutions are imperative due to the persistent nature of environmental pollution. In the context of Slopan pouch materials, the notable presence of such materials indicates a prioritisation of responsible disposal and recycling alternatives for pouch packaging.

3.2.6 Rubber and Leather

Leather and rubber materials constitute a relatively minor proportion of the waste composition, comprising approximately 0.61% of the overall waste volume. Although leather and rubber products make up a relatively small portion, investigating recycling or upcycling possibilities for these materials can have a positive impact on waste reduction and the promotion of sustainable material utilisation (Ding et al., 2023; Mahmood Ali et al., 2023).

3.2.7 Metal Waste

Metal waste, encompassing both ferrous and non-ferrous metals, constitutes an insignificant fraction of the overall waste composition, making a mere 0.21% contribution in aggregate. The limited amount of metal waste suggests that dedicated recycling initiatives targeting metals may not result in substantial waste diversion. Nevertheless, it remains imperative to adhere to responsible disposal practices for metals to mitigate the risk of environmental contamination.

3.2.8 Glass Waste

Glass waste, which includes clear bottles, coloured bottles, and broken glass, accounts for a relatively minor proportion of the overall waste stream, comprising approximately 0.77% of the total waste. Glass pieces constitutes the predominant factor in this classification, accounting for approximately 1.15% of

the total. The recyclability of glass makes it a prime candidate for targeted recycling initiatives. The implementation of collection points and recycling facilities dedicated to glass materials has the potential to yield substantial waste diversion and resource conservation outcomes (Leal Da Cruz Silva et al., 2023).

3.2.9 Hazardous Waste

The waste composition includes a small proportion of domestic hazardous waste, constituting approximately 0.14% of the total. Notwithstanding its relatively small proportion, hazardous waste necessitates specialised procedures for handling and disposal. The implementation of stringent regulatory measures and the promotion of public awareness initiatives have the potential to effectively reduce the potential dangers associated with hazardous waste.

3.2.10 Diverse Components

This study examines a range of components related to medical masks, isolation waste, and miscellaneous items. The purpose is to analyse the various aspects and characteristics of these components within the context of the medical field. By exploring these diverse components, we aim to gain a deeper understanding of their significance and potential impact. These categories encompass a diverse range of waste types, which include medical masks, isolation waste, and miscellaneous items. Collectively, their combined contributions account for approximately 0.92% of the overall waste. The appropriate management and disposal of medical waste, especially in times of health emergencies, are of utmost importance for the well-being and protection of the public. Well-defined guidelines and protocols are imperative. The category denoted "Others" encompasses a variety of miscellaneous waste items, constituting a notable proportion of approximately 2.56%. The diverse and varied characteristics within this category require a comprehensive approach.

In conclusion, it can be inferred that the points provide strong evidence to support the conclusion. The examination of waste composition in Singaraja City unveils a varied waste panorama characterised by unique obstacles and prospects. The composition is predominantly comprised of organic waste, with a particular emphasis on food waste, thereby underscoring the imperative for initiatives aimed at reducing food waste and implementing composting practices. The issue of plastic waste, particularly single-use plastics, presents significant environmental implications and necessitates the implementation of responsible practices for plastic management. Efforts should be directed towards the promotion of textile recycling, glass recycling, and the appropriate management of hazardous waste. Although certain waste components may be present in small quantities, the exploration of recycling or repurposing alternatives can effectively contribute to waste reduction and support local initiatives. To develop effective waste management strategies, it is imperative to thoroughly assess the primary sources of waste generation and subsequently allocate resources to prioritise waste reduction and recycling initiatives.

The achievement of sustainable waste management in Singaraja City necessitates the implementation of a comprehensive strategy that includes various components such as public awareness campaigns, policy interventions, the establishment of recycling infrastructure, and the fostering of collaborative relationships among relevant stakeholders. Singaraja can progress towards a more sustainable and environmentally responsible waste management system by considering the distinctive attributes of each waste component and devising strategies accordingly.

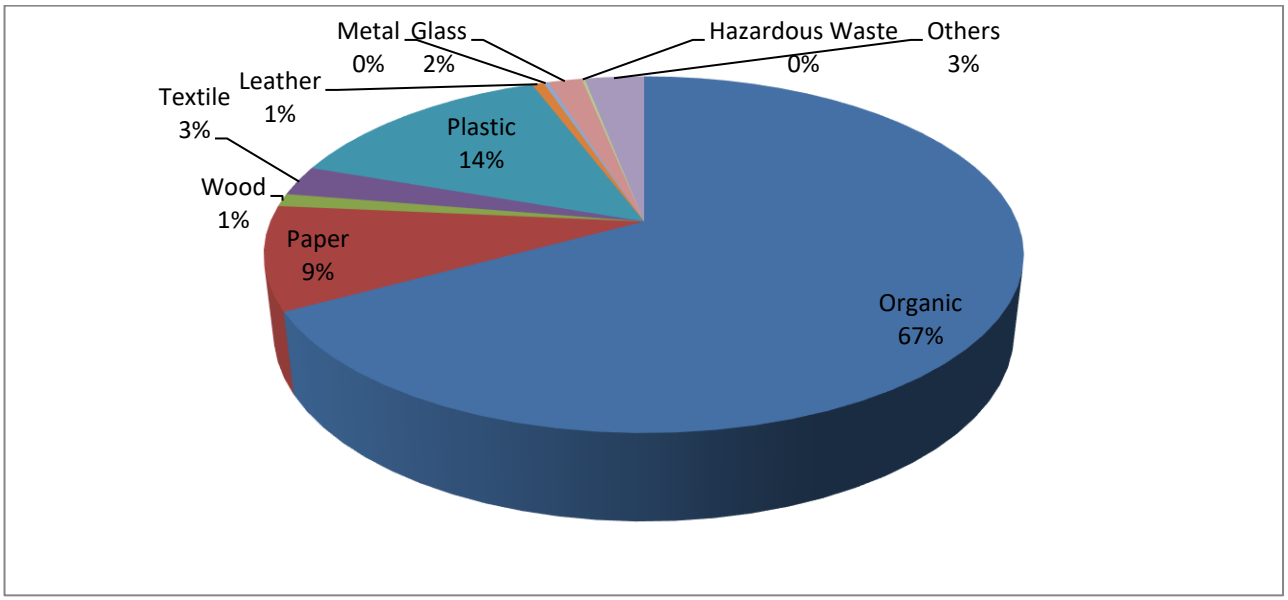

Figure 3. Waste composition at the Bengkala Landfill

3.3 Potential Waste Reduction

The potential waste reduction percentages for different waste components in Singaraja City reveal significant opportunities and challenges. Organic waste, with a high potential reduction percentage of 99.66%, can be diverted from landfills through composting and other strategies. This suggests that promoting composting, educating the public about food waste reduction, and establishing composting infrastructure could lead to a substantial reduction in organic waste sent to landfills(Habib, Kaur, Sharma, & Talwar, 2023; Malefors, Secondi, Marchetti, & Eriksson, 2022)

Paper waste has a potential reduction of 77.48%, suggesting opportunities for improved recycling and waste reduction practices. Initiatives such as paper recycling programs, paperless alternatives, and efficient use of paper resources could significantly reduce paper waste generation. Wood waste has a 100% potential reduction, indicating that all wood-related waste materials could be repurposed, recycled, or reused (Diggle, Walker, & Adams, 2023; Milbrandt, Zuboy, Coney, & Badgett, 2024). Metal waste has a 0% potential reduction, indicating a significant challenge in reducing textile waste. Innovative approaches such as textile recycling facilities, upcycling initiatives, or extended product lifecycles may be needed. Plastic waste has a 49.13% potential reduction, suggesting substantial progress can be made in reducing single-use plastic consumption, promoting recycling, and addressing plastic pollution (Cecere et al., 2024; Ng & Yang, 2023).

Leather waste has a 0% potential reduction, indicating challenges in reducing leather product waste. Metal waste has a 100% potential reduction, highlighting the importance of metal recycling programmes, responsible metal disposal, and efforts to recover valuable metals from waste streams. Glass waste has a 100% potential reduction, indicating that recycling programs and responsible disposal practices can lead to complete diversion from landfills. Hazardous waste has a 0% potential reduction, highlighting the challenge of managing hazardous materials safely and ensuring proper disposal (Diggle et al., 2023; Feng et al., 2023; Yousefi et al., 2023). Comprehensive waste audits and tailored strategies are essential for achieving these waste reduction goals.

4. CONCLUSION

The study of waste composition in Singaraja City reveals both opportunities and challenges in waste management and sustainability. Organic waste, plastic, and paper are the most prevalent, with high potential for reduction. Implementing composting, paper recycling, sustainable wood practices, and metal recycling can contribute to waste diversion and resource conservation. However, textile and leather waste have minimal potential for reduction, necessitating innovative approaches and consumer education. Singaraja City can benefit from initiatives like plastic reduction programmes, glass recycling, and hazardous waste management to achieve sustainable waste practices. Achieving these goals will require public education, policy interventions, recycling infrastructure development, and stakeholder collaboration.

Acknowledgement

The authors gratefully acknowledge the support and funding provided by the Ministry of Education, Culture, Research, and Technology of Republic of Indonesia, Directorate General of Research, Technology, and Community Empowerment, Indonesia under Master Research Sheme.

REFERENCES

Adnan, H., Ainun, S., & Halomoan, N. (2018). [STUDI KAJIAN DENSITAS SAMPAH BERDASARKAN ALAT ANGKUT DAN SUMBER SAMPAH DI TPA JALUPANG KABUPATEN KARAWANG] [STUDI OF WASTE DENSITY BASED ON CONVEYANCE AND SOURCES OF WASTE IN JALUPANG LANDFILL OF KARAWANG DISTRICT]. In *Jurnal Teknik Lingkungan* (Vol. 24).

Cecere, G., Bottausci, S., Esposti, A. D., Magrini, C., Mazzi, A., Camana, D., … Rigamonti, L. (2024). The role of life cycle thinking-based methodologies in the development of waste management plans. *Waste Management*, *173*, 109–117. https://doi.org/10.1016/j.wasman.2023.11.005

Cokorda, J., Wijaya, I. M. W., & Paramita, A. A. I. I. (2022). Produksi Kompos melalui Pengelolaan Sampah Rumah Tangga Menggunakan Composter Bag di Desa Ayunan, Kabupaten Badung. *Lumbung Inovasi: Jurnal Pengabdian Kepada Masyarakat*, *7*(4), 479–488. https://doi.org/10.36312/linov.v7i4.824

Consonni, S., Giugliano, M., & Grosso, M. (2005). Alternative strategies for energy recovery from municipal solid waste: Part A: Mass and energy balances. *Waste Management*, *25*(2 SPEC. ISS.), 123–135. Elsevier Ltd. https://doi.org/10.1016/j.wasman.2004.09.007

Dhanya, B. S., Mishra, A., Chandel, A. K., & Verma, M. L. (2020). Development of sustainable approaches for converting the organic waste to bioenergy. *Science of the Total Environment*, *723*. https://doi.org/10.1016/j.scitotenv.2020.138109

Diggle, A., Walker, T. R., & Adams, M. (2023). Examining potential business impacts from the implementation of an extended producer responsibility program for printed paper and packaging waste in Nova Scotia, Canada. *Circular Economy*, *2*(2). https://doi.org/10.1016/j.cec.2023.100039

Dinas Kebersihan dan Pertamanan Kabupaten Buleleng. (2020). *Profil TPA Bengkala*.

Ding, X., Li, Y., Chen, J., Huang, X., Chen, L., & Hu, Z. (2023). Sustainable utilization of finished leather wastes: A novel collagen hydrolysate-based gypsum additive with high-retarding performance. *Process Safety and Environmental Protection*, *172*, 451–461. https://doi.org/10.1016/j.psep.2023.02.040

Feng, S. J., Li, J., Zheng, Q. T., Zhang, M. L., Yu, Y., & Zhao, Y. (2023). Utilization potential of waste residue and dust powder from C&D waste. *Case Studies in Construction*

Materials, *19*. https://doi.org/10.1016/j.cscm.2023.e02513

Gede, L., Yanthi, E., Rahmawati, P. I., Made, N., & Widiastini, A. (2022). Source Based Waste Management at the Environment Department of Buleleng Regency. *Budapest International Research and Critics Institute Journal*, *5*(3), 20832–20844. https://doi.org/10.33258/birci.v5i3.6102

Habib, M. D., Kaur, P., Sharma, V., & Talwar, S. (2023). Analyzing the food waste reduction intentions of UK households. A Value-Attitude-Behavior (VAB) theory perspective. *Journal of Retailing and Consumer Services*, *75*. https://doi.org/10.1016/j.jretconser.2023.103486

Huang, Q., Wang, Q., Dong, L., Xi, B., & Zhou, B. (2006). The current situation of solid waste management in China. *Journal of Material Cycles and Waste Management*, *8*(1), 63–69. https://doi.org/10.1007/s10163-005-0137-2

Kohli, R. (2016). Management of Flower Waste by Vermicomposting. *International Conference on Global Trends in Engineering, Technology and Management*, 34–38.

Kreith, F., & Tchobanoglous, G. (2002). Handbook of Solid Waste Management. In *Waste Management Research* (Vol. 13). https://doi.org/10.1006/wmre.1995.0050

Kumar Das, D., & Baishya, P. (2017). Municipal Solid Waste Management: A Case Study of Kamakhya Devi Temple, Assam, India. *International Research Journal of Engineering and Technology*. Retrieved from www.irjet.net

Kuniyal, J. C., Jain, A. P., & Shannigrahi, A. S. (2003). Solid waste management in Indian Himalayan tourists' treks: A case study in and around the Valley of Flowers and Hemkund Sahib. *Waste Management*, *23*(9), 807–816. https://doi.org/10.1016/S0956-053X(03)00027-8

Leal Da Cruz Silva, T., Santos Carvalho, E. A., Sales Barreto, G. N., Perim da Silva, T. B., João da Cunha Demartini, T., & Fontes Vieira, C. M. (2023). Characterization of artificial stone developed with granite waste and glass waste in epoxy matrix. *Journal of Materials Research and Technology*, *26*, 2528–2538. https://doi.org/10.1016/j.jmrt.2023.08.045

Lomelí-Ramírez, M. G., Anda, R. R., Satyanarayana, K. G., Bolzon de Muniz, G. I., & Iwakiri, S. (2018). Comparative Study of the Characteristics of Green and Brown Coconut Fibers for the Development of Green Composites. *BioResources*, *13*(1). https://doi.org/10.15376/biores.13.1.1637-1660

Mahmood Ali, A., Khan, A., Shahbaz, M., Imtiaz Rashid, M., Imran, M., Shahzad, K., & Binti Mahpudz, A. (2023). A renewable and sustainable framework for clean fuel towards circular economy for solid waste generation in leather tanneries. *Fuel*, *351*. https://doi.org/10.1016/j.fuel.2023.128962

Malefors, C., Secondi, L., Marchetti, S., & Eriksson, M. (2022). Food waste reduction and economic savings in times of crisis: The potential of machine learning methods to plan guest attendance in Swedish public catering during the Covid-19 pandemic. *Socio-Economic Planning Sciences*, *82*. https://doi.org/10.1016/j.seps.2021.101041

Martikkala, A., Mayanti, B., Helo, P., Lobov, A., & Ituarte, I. F. (2023). Smart textile waste collection system – Dynamic route optimization with IoT. *Journal of Environmental Management*, *335*. https://doi.org/10.1016/j.jenvman.2023.117548

Milbrandt, A., Zuboy, J., Coney, K., & Badgett, A. (2024). Paper and cardboard waste in the United States: Geographic, market, and energy assessment. *Waste Management Bulletin*, *2*(1), 21–28. https://doi.org/10.1016/j.wmb.2023.12.002

MOELLER, D. W. (2019). Solid Waste. In *Environmental Health, Third Edition*. https://doi.org/10.2307/j.ctvjz80w7.13

Ng, K. S., & Yang, A. (2023). Development of a system model to predict flows and performance of regional waste management planning: A case study of England. *Journal of Environmental Management*, *325*. https://doi.org/10.1016/j.jenvman.2022.116585

Nyberg, B., Harris, P. T., Kane, I., & Maes, T. (2023). Leaving a plastic legacy: Current and future scenarios for mismanaged plastic waste in rivers. *Science of The Total Environment*, *869*, 161821. https://doi.org/10.1016/j.scitotenv.2023.161821

Paramita, W., Hartono, D. M., & Soesilo, T. E. B. (2018). Sustainability of Refuse Derived Fuel Potential from Municipal Solid Waste for Cement's Alternative Fuel in Indonesia (A Case at Jeruklegi Landfill, in Cilacap). *IOP Conference Series: Earth and Environmental Science*, *159*(1). Institute of Physics Publishing. https://doi.org/10.1088/1755-1315/159/1/012027

Putu, L., Udayani, D., Suprihatin, I. E., & Made Gunamantha, I. (2020). EFEKTIVITAS PENGOLAHAN LINDI (TPA BENGKALA) DENGAN KOMBINASI TRICKLING FILTER DAN ELEKTROKOAGULASI. In *Cakra Kimia (Indonesian E-Journal of Applied Chemistry* (Vol. 8).

Rajendran SM, & Sekaran V. (2015). Generation, Characteristics and Treatment of Municipal Wastewater in Madurai City. *International Journal of Civil Engineering and Technology*, *6*(69), 58–70.

Scarlat, N., Motola, V., Dallemand, J. F., Monforti-Ferrario, F., & Mofor, L. (2015). Evaluation of energy potential of Municipal Solid Waste from African urban areas. *Renewable and Sustainable Energy Reviews*, *50*, 1269–1286. https://doi.org/10.1016/j.rser.2015.05.067

SNI 19-3964-1994. (1994). *Metode pengambilan dan pengukuran contoh timbulan dan komposisi sampah perkotaan*. 16. https://doi.org/10.2989/16085906.2013.815406

SURYAWAN, I. W. K., RAHMAN, A., SEPTIARIVA, I. Y., SUHARDONO, S., & WIJAYA, I. M. W. (2020). Life Cycle Assessment of Solid Waste Generation During and Before Pandemic of Covid-19 in Bali Province. *Journal of Sustainability Science and Management*, *16*(1), 11–21. https://doi.org/10.46754/jssm.2021.01.002

Turan, N. G., Baki, O. G., & Ergun, O. N. (2016). Municipal solid waste characteristics and management in Sinop, Turkey. *Environmental Engineering and Management Journal*, *15*(1), 13–18. https://doi.org/10.30638/eemj.2016.002

Tyagi, V. K., Kapoor, A., Arora, P., Banu, J. R., Das, S., Pipesh, S., & Kazmi, A. A. (2021). Mechanical-biological treatment of municipal solid waste: Case study of 100 TPD Goa plant, India. *Journal of Environmental Management*, *292*. https://doi.org/10.1016/j.jenvman.2021.112741

Ulhasanah, N., Sarwono, A., Yosafaat, M., Filippi, D., Suryawan, I. W. K., & Wijaya, I. M. W. (2022).

Composting of Banana Leaves and Coconut Leaves Using EM4 Bioactivator. *Advances in Tropical Biodiversity and Environmental Sciences*, *6*(1), 8. https://doi.org/10.24843/atbes.2022.v06.i01.p02

Weber, S., Weber, O., Habib, K., & Dias, G. M. (2023). Textile waste in Ontario, Canada: Opportunities for reuse and recycling. *Resources, Conservation and Recycling*, *190*. https://doi.org/10.1016/j.resconrec.2022.106835

Wijaya, I. (2014). *DESIGN OF SOLID WASTE MANAGEMENT FACILITIES OF EKS PELABUHAN BULELENG BEACH RESORT, BULELENG REGENCY*. Institut Teknologi Sepuluh Nopember Surabaya, Surabaya.

Wijaya, I. M. W., & Putra, I. K. A. (2021). POTENSI DAUR ULANG SAMPAH UPACARA ADAT DI PULAU BALI. *Jurnal Ecocentrism*, *1*(1), 1–8.

Wijaya, I. M. W. W., Indunil, K. B., Ranwella, S., Revollo, E. M., Ketut, L., Widhiasih, S., … Junanta, P. P. (2021). *Recycling Temple Waste into Organic Incense as Temple Environment Preservation in Bali Island*. *19*, 365–371. https://doi.org/10.14710/jil.19.2.365

Wijaya, I. M., Wiratama, I. G. N. M., Putra, I. K. A., & Aris, A. (2023). Refuse Derived Fuel Potential Production from Temple Waste as Energy Alternative Resource in Bali Island. *Journal of Ecological Engineering*, *24*(4), 288–296. https://doi.org/10.12911/22998993/161015

Yousefi, M., Khosravani, F., Farzadkia, M., Mahvi, A. H., Kermani, M., Esrafili, A., & Gholami, M. (2023). Sustainable management of alkaline battery waste in developing countries by waste reduction and metal recovery development: A cost-benefit study based on waste flow analysis to select the optimum scenario. *Arabian Journal of Chemistry*, *16*(10). https://doi.org/10.1016/j.arabjc.2023.105140