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# Investigating the Potential of Landfilled Plastic Waste – A Case Study of Makassar Landfill, Eastern Indonesia

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## ABSTRACT

Society's demands for plastic materials continue to increase, but their impact on the environment cannot be denied due to the long decomposition periods. The destination for plastic waste is mostly in landfills. In the case of Indonesia, the Makassar landfill, the largest landfill in the eastern region of Indonesia, has exceeded its capacity and is currently mixed and buried without treatment (open dumping). The main aim of this study is to identify potential plastic waste buried in the landfill. Sampling was conducted at three landfill locations: location 1 is a non-active landfill zone that is no longer used, and locations 2 and 3 are active landfill zones that are still in operational use. The sampling method uses a Hydraulic Rotary Drilling Spindle, with a drilling depth of 0–18 meters for location 1, 0–17 meters for location 2, and 0–13 meters for location 3. The research results show that at location 1, plastic waste contributes to approximately 31% of the total waste in this old landfill zone, including plastic bags and beverage bottles. Meanwhile, at location 2, approximately 22% of plastic waste was found, and at location 3, about 14%. Testing the calorific value of plastic waste gave an average of 29,862 MJ/ton. The plastic waste found in these landfills has the potential to be recycled but requires intensive cleaning processes. Furthermore, this plastic waste can also be utilized as an energy source due to its relatively high calorific value.

**Keywords:** plastic waste, landfill mining, Eastern Indonesia.

## INTRODUCTION

The demand for plastic use in society has significantly increased over the past few decades. Rapid industrial advancements, coupled with the continuous population growth in large cities, will increase organic and inorganic waste, particularly plastic (Mourshed et al., 2017). The rising demand for plastic materials covers various sectors in modern society, including household products, agriculture, electricity and electronics, medical and health, and packaging industries (Zhou et al., 2014) (Kibria et al., 2023) (Jian et al., 2022) On the other hand, plastic contributes to about 10–13% of inorganic waste in Municipal Solid Waste, in the form of bottles, packaging materials, containers, etc. In another study, disposable plastic materials, such as food packaging and packaging bags, are predicted to contribute approximately 50% to plastic waste and are discarded without processing (Duru et al., 2019). Due to the difficulty in the decomposition process, a significant portion of plastic waste ends up in landfills (Geyer et al., 2017) (Van Roijen & Miller, 2022). This poses a serious environmental threat currently faced in large cities worldwide. The volume of plastic waste from Municipal Solid Waste (MSW) has increased from approximately 2 million tons in 1950 to 8.2 billion tons in 2015 (Mazhandu et al., 2020) (Moharir & Kumar, 2019). Municipal Solid Waste Management that is not optimal can cause pollution problems in water, air, and soil (Khair et al., 2019) (Muis et al., 2021) and can also have an impact on human health (Fariz et al., 2023; Yunus et al., 2019).

As a representative developing country in the world, Indonesia has experienced rapid population growth. In 2021, Indonesia's estimated total national waste reached 68.5 million tons, with 17 percent of it contributed by plastic waste (Ministry of Environment and Forestry, 2021). As one of the major cities and a metropolitan city with a strategic location in the Eastern Indonesia Region, Makassar City had a total population of 1,432.189 people in 2022 (Makassar Bureau of Statistics, 2023). The rapid development and lifestyle changes have led to an increase in waste volume in Makassar City; it's currently averaging 1139 tons a day (Muis et al., 2023). The characteristics of waste in Makassar City are dominated by organic waste, accounting for 55% of the total, while non-organic waste, including plastics, rubber, cane and metal, constitutes 45%. The suboptimal waste management system results in a significant portion of the waste ending up in landfills, with approximately 16% being plastic waste. The amount of plastic waste reached 294 tons per day in 2020, experiencing an increase from the previous year, which was approximately 258 tons per day. (Ahmad Husain, 2021).

Meanwhile, Makassar, the largest landfill in the eastern region of Indonesia known as Tamangapa Landfill, still employs the open dumping method in its operations (Madani, 2023), and waste is mixed and buried without proper treatment. Currently, the landfill has exceeded its capacity. It has become a common understanding that relying on landfills as the primary waste management solution will have long-term environmental implications. Landfill mining has emerged as one scenario to address this issue. Landfill mining is centered around optimizing the resource capacity of landfill sites. Landfill mining is the act of excavating, treating, or recycling waste that has been held in dumps, utilizing waste materials with a high calorific value for recycling purposes. (Krook et al., 2012). Research related to landfill mining has been conducted in various countries (Hermann et al., 2016; Jagodzińska et al., 2021; Pecorini & Iannelli, 2020; Wolfsberger et al., 2015).

According to regulations, the Ministry of Public Works in the Republic of Indonesia (MoPW) establishes the standards for landfill mining, and meeting at least one of these criteria is a prerequisite for conducting landfill mining. The criteria include (1) the landfill causing environmental impact, (2) the government being unable to identify alternative suitable locations for landfills, and (3) The landfill responsible for the management of non-hazardous waste. (Indonesia Ministry, 2013) (Kristanto et al., 2020). The Makassar landfill meets several criteria, with some indications such as groundwater pollution in the surrounding area (Ummu Salmah & Atjo Wahyu, 2023) and unsafe air pollution for human health (Abbas et al., 2019) (Table 1). Also, it has yet to find a new area for waste disposal.

Plastic, as a material derived from non-renewable resources, has become one of the main wastes in mining activities. Plastic waste that pollutes the environment in microplastics can contaminate water sources such as wells because they are recycled using harmful chemicals. In addition, the decomposition process can take a long time, hundreds of years (Haedar et al., 2019). On the other hand, plastic waste has the potential for recycling due to its high calorific value (Krook et al., 2012). Therefore, as an initial step to anticipate threats and harness the potential of plastic waste, research on the investigation of plastic waste through landfill mining methods is needed. The study aims to investigate the potential for plastic waste in the Makassar landfill by drilling

**Table 1.** Area and total waste in Makassar landfill

| Zone | Area (hectares) | Waste volume ($m^3$) |
|---|---|---|
| Old landfill (not survey) | 3.855 | 617,739.47 |
| Zone 1 | 6.38 | 1.444,509.4 |
| Zone 2 | 1.252 | 261,377.84 |
| Zone 3 | 7.34 | 1 695,535.8 |
| Total | 18.827 | 4 019,162.51 |

waste processes in landfills in several zones at still active landfill sites, which have been operating for 25 years, and inactive landfill zones. (yang telah beroperasi selama lebih dari 20 tahun).

## METHODOLOGY

### Study location

This research was conducted in Indonesia at the Makassar City Landfill, located in the eastern part of Makassar, precisely in the Tamangapa area, Manggala Sub-district, Makassar City. Figure 1 shows the map of Indonesia, and the arrow points to the location of the research area (5°10'34.60"S, 119°29'26.90"E).The Makassar City Landfill, namely Tamangapa Landfill, has been in operation since 1993, covering an area of 19.04 hectares (Tabel 1), making it the largest final disposal site in Eastern Indonesia. It is situated at an elevation of 4 to 10 meters above sea level, with a maximum surface pile height of 38 meters above sea level. The Makassar City landfill is divided into four zones. Old landfill zone and zone 1 are zones that are no longer in use. Meanwhile, zones 2 and 3 remain in use (Figure 2).

### Data collection

Quantitative data in this research employs surveys, measurements, and analysis to quantify plastic waste's volume, density, and composition in landfills.

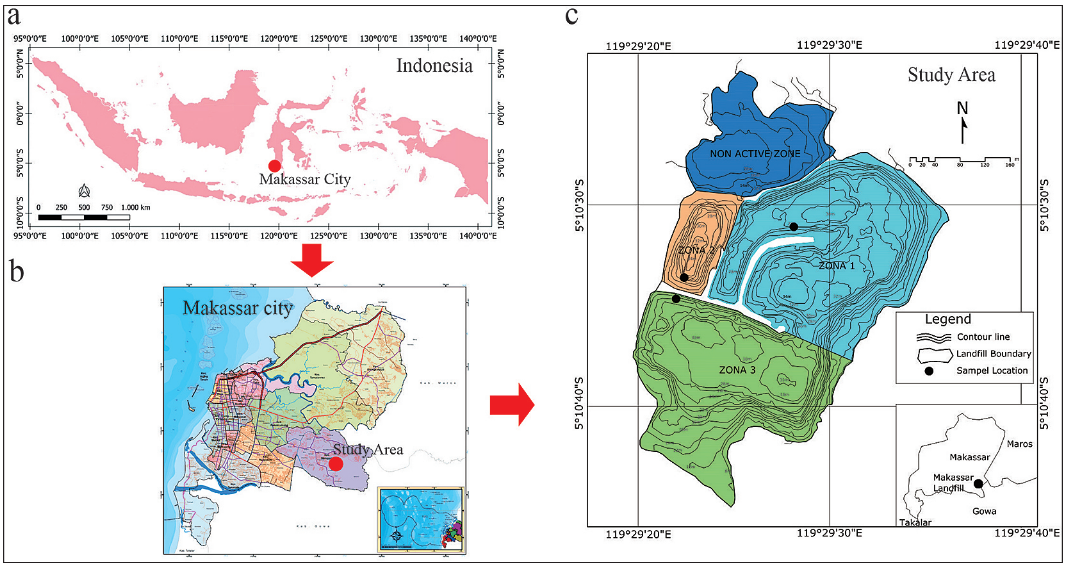


**Figure 1.** The Map of study area: (a) Indonesia, (b) Makassar city, (c) landfill Tamangapa area (the sampling locations)


**Figure 2.** Waste piles in one of the zones in the Makassar City landfill (a), the process of transferring waste from garbage trucks using an excavator (b)

## Sampling methods

The sampling method in this research consists of several stages, namely: the process of drilling waste samples, density calculation, waste composition identification, calorific value calculation, and the calculation of the volume potential of plastic waste. Figure 3 illustrates the flowchart of the research stages.

## Sampling by drilling

The sampling method involved full coring using a Hydraulic Rotary Drilling Spindle with a machine type YBM-05. Samples were taken at three locations. Zone 1 is inactive and no longer in use, containing decomposed waste of over 20 years. Zone 2 and Zone 3 are active zones still in operation, containing decomposed waste in the lower layers and fresh waste stacked on the upper layers up to the present. Samples were taken by excavating material at every meter depth in each zone. Table 2 shows that Zone 1 has an excavation depth of 0–17 meters, Zone 2 has a depth of 0–18 meters, and Zone 3 has a depth of 0–13 meters. This excavation is the maximum depth that can be accessed due to the nature of the waste and the type of equipment used for excavation. The core barrel used at locations 1 and 2 had a diameter of 3 inches and a core length of 100 cm, while location 3 used a core barrel with a diameter of 2.5 inches. The drilling process and the resulting core samples are shown in Figure 3. The next step involves preparing the samples for the determination of density, composition, and calorific value.

## Data analysis

### *Density*

The density of waste samples is measured by considering the diameter and length of the core barrel currently in use. Zone 1 and 2 indicate a waste sample volume of $4.558 \cdot 10^{-3}$ $m^3$ per meter of drilling depth, while location 3 has a waste sample volume of $3.165 \cdot 10^{-3}$ $m^3$ per meter of drilling depth. Before measuring the density, the waste samples were exposed to sunlight for several days at the Landfill Site drilling location. Consequently, the moisture content of the waste samples, particularly the outer core part (defined as wet samples), has decreased. After completing the weighing process, the next step involves redrying the wet samples in an oven for 30 minutes at 100°C. This redrying process facilitates subsequent processes, such as the composition and grinding processes (through mesh 60), for laboratory testing. Before commencing the composition process, the redried samples are weighed again, defined as dry samples.

### *Plastic waste composition*

The method used to determine plastic waste composition in landfills uses the Indonesian National Standard (SNI) 19-3964-1994. This standard

**Table 2.** Sampling locations and depth of drilling

| Location | Sampling point | Depth of drilling (meter) |
|---|---|---|
| Zone 1 (inactive zone) | X: 5°10’31.12”<br>Y: 119°29’28.19” | 0–17 |
| Zone 2 (active zone) | X: 5°10’33.06”<br>Y: 119°29’22.41” | 0–18 |
| Zone 3 (active zone) | X: 5°10’34.6”<br>Y: 119°29’21.4” | 0–13 |

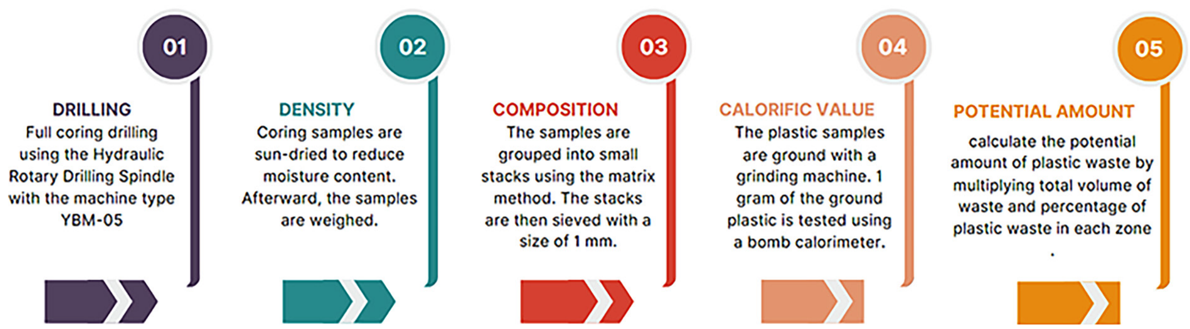


**Figure 3.** Methods flow diagram

provides guidelines related to the methods of collecting and analyzing waste and the classification or composition of various types of waste. After drying and re-weighing, the waste samples are arranged using the matrix method in small stacks. This is done to facilitate the sorting and separation process of compost or soil adhering to plastic or cloth, as illustrated in the figure. The next step involves sieving each small stack with a size of 1 mm to separate the compost from the stack. Subsequently, sorting is done based on categories such as plastic, cloth, wood, stone, glass, rubber, etc. The types of waste that have been sorted are then placed in plastic bags for weighing to determine their composition. This process is repeated for all depths at each sampling point.

### *Calorific value*

To determine the calorific value, a bomb calorimeter test is conducted on the samples. An oxygen bomb calorimeter is used to determine the caloric content of various samples (Trombley et al., 2023). The samples are first pulverized and then refined using a 60-mesh sieve. One gram of plastic powder is tested for its calorific value using a bomb calorimeter.

## RESULT AND DISCUSSION

### Source of plastic waste

Waste accumulated in the landfill comes from various sources. Most of the waste originates from households, constituting approximately 21.33% of the total, including high income settlements, middle-income, and low-income settlements (Makassar City Government, 2021). Waste from city facilities comes from markets, business districts, office areas, educational zones, terminals, railway stations, ports, hotels, hospitals, and facilities of worship (Figure 4). Market waste from trading activities is the most dominant source of waste in urban facilities, accounting for about 15.8%. Other waste sources include industrial areas, open waters, tourist beaches, and parks.

Characteristics of household waste generally contains single-use items. Plastic waste from household waste in Indonesia, including Makassar, consists of plastic bags, plastic packaging from food and product items, and plastic bottles. The composition of plastic waste ranges from 16% of the total waste. The Table 3 provides information about the application of various main plastic materials in household activities and their types.

### Waste composition from drilling

A lot of the waste in the landfill has already decomposed. In Figure 5, core samples at each location are predominantly composed of inorganic waste with various categories including plastic, fabric, rubber, glass, and others. As for organic waste, it consists of food remnants, vegetables, fruit peels, leaves, and grass, which are generally decomposed. Based on the drilling results, Table 4 shows that in Zone 1, the organic and inorganic waste ratio averages 10–20% at

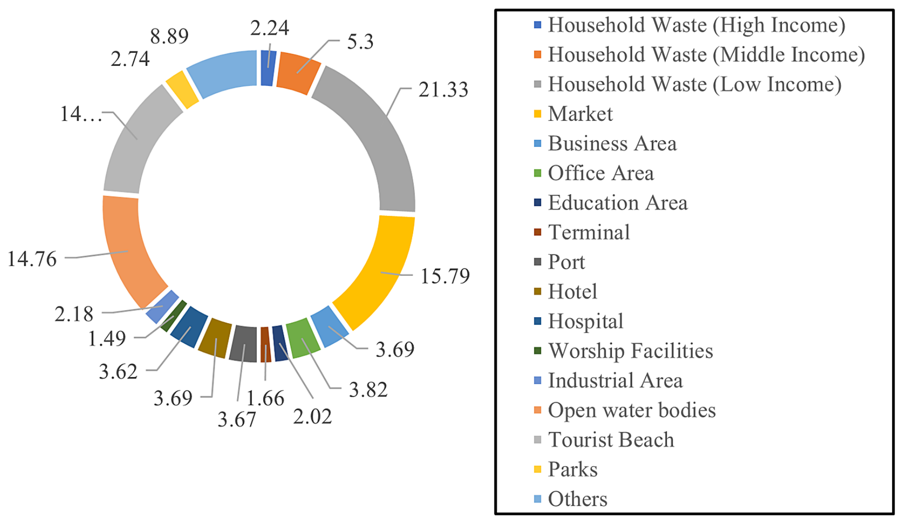


**Figure 4.** Source of waste based on location

**Table 3.** Application of plastic materials in household activities (Gwada et al., 2019)

| Application of plastic materials | Type |
|---|---|
| Salad dressing containers, processed meat packages, water bottles, and plastic soft drink | PET |
| Milk bottles, shampoo bottles, oil jerry cans and toys | HDPE |
| Fruit plastic packaging, sweet trays, and blister packaging | PVC |
| Bread bags, frozen food bags, squeezable bottles, fiber, bottles, furniture, shrink wraps and garment bags | LDPE |
| Margarine and yoghurt containers, cap for containers, and wrapping to replace cellophane | PP |
| Egg cartons, fast food trays, and disposable plastic silverware | PS |
| This includes an item which is made with a resin other than thesix listed above or a combination of different resins | Other |

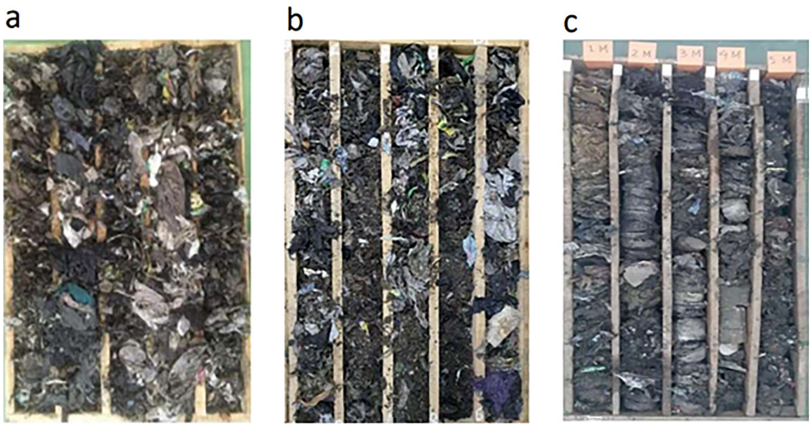


**Figure 5.** Drilling sample Zone 1 (a), Zone 2, (b) Zone 3 (c)

**Table 4.** The ratio organic dan anorganic waste in each locations

| Location | Depth (meter) | Ratio of organic and anorganik waste (%) |
|---|---|---|
| Zone 1 | 0–10 | 10–20 |
| | 11–20 | 20–40 |
| Zone 2 | 0–6 | 10–20 |
| | 6–9.5 | 20–40 |
| | 9.5–15 | 10–20 |
| | 15–17 | 40–60 |
| Zone 3 | 0–5 | 20–40 |
| | 5–13 | 5–10 |

a depth of the first 10 meters and 20–40% at the next 10 meters. The ratio of organic and inorganic waste in zone 2 is as follows: at a depth of 0–6 meters, approximately 10–20% is organic waste; at a depth of 6–9.5 meters, the organic composition increases to 20–40%, at a depth of 9.5–15 meters, around 10–20% is organic waste, and at a depth of 15–17 meters, the organic composition reaches 40–60%. At zone 3, the comparison between organic and inorganic waste is as follows: at a depth of 0–5 meters, the organic proportion reaches 20–40%. Furthermore, at a depth of 5–13 meters, the organic composition ranges from 5–10%.

## Density (kg/m$^3$)

The mass of a type of plastic waste in landfill mining is the measurement of the weight per unit of volume of the plastic waste buried in the landfill site. This type of mass is expressed in weight units (e.g., kilograms) per volume unity. (e.g., meter degree). In the context of landfill mining, the mass of plastic waste type becomes an important parameter as it affects various operational aspects and the sustainability of the waste extraction and management processes. The mass of plastic waste can vary depending on various factors, including the type of plastic, the conditions of degradation, and the level of waste density in the landfill. The average wet density value at zone 1 is 0.451 ton/m$^3$, and the dry sample is 0.426 ton/m$^3$. At Zone 2, the average wet waste density is 0.528 tons/m$^3$, and the dry sample is 0.502 tons/m$^3$. Meanwhile, zone 3 is 0.989 ton/m$^3$ for wet samples and 0.728 ton/m$^3$ for dry samples. The density values per depth at each location are shown in Table 5.

**Table 5.** Density of the samples in each location

| Depth (m) | Density (ton/m$^3$) | | | | | |
|---|---|---|---|---|---|---|
| | Zone 1 | | Zone 2 | | Zone 3 | |
| | Wet | Dry | Wet | Dry | Wet | Wet |
| 0–1 | 0.410 | 0.373 | 0.188 | 0.183 | 0.790 | 0.771 |
| 1–2 | 0.291 | 0.265 | 0.231 | 0.209 | 0.946 | 0.844 |
| 2–3 | 0.308 | 0.273 | 0.362 | 0.350 | 0.941 | 0.926 |
| 3–4 | 0.259 | 0.231 | 0.369 | 0.324 | 1.119 | 1.101 |
| 4–5 | 0.228 | 0.208 | 0.278 | 0.264 | 0.632 | 0.611 |
| 5–6 | 0.258 | 0.228 | 0.290 | 0.255 | 1.093 | 1.056 |
| 6–7 | 0.316 | 0.304 | 0.618 | 0.576 | 0.958 | 0.950 |
| 7–8 | 0.296 | 0.289 | 0.874 | 0.861 | 1.060 | 1.033 |
| 8–9 | 0.284 | 0.274 | 1.018 | 0.970 | 1.083 | 1.060 |
| 9–10 | 0.222 | 0.186 | 0.697 | 0.645 | 1.371 | 1.361 |
| 10–11 | 0.761 | 0.752 | 0.491 | 0.463 | 1.013 | 0.961 |
| 11–12 | 0.670 | 0.651 | 0.690 | 0.673 | 1.119 | 1.096 |
| 12–13 | 0.757 | 0.731 | 0.334 | 0.311 | 0.732 | 0.728 |
| 13–14 | 0.856 | 0.817 | 0.403 | 0.392 | | |
| 14–15 | 0.610 | 0.604 | 0.355 | 0.323 | | |
| 15–16 | 0.693 | 0.647 | 0.667 | 0.634 | | |
| 16–17 | 0.522 | 0.488 | 1.111 | 1.104 | | |
| 17–18 | 0.379 | 0.356 | | | | |
| Average | 0.451 | 0.426 | 0.528 | 0.502 | 0.989 | 0.961 |

## Plastic waste composition

The results of the waste drilling showed that the composition of plastic waste dominated the entire zone in both inactive and active zones. Figure 6 shows that in zone 1, the composition of waste is dominated by plastic waste, with an average value of 31%. Subsequently, the average composition of plastic waste in zone 2 is 22%, and in zone 3, it is 14%. In the inactive zone on the surface of the waste pile at a depth of 1 meter, plastic waste composition is obtained at 51% (Table 6). In this zone, a significant amount of plastic waste is found, with compositions ranging from 16% to 63% up to a depth of 18 meters. In Zone 2, which is an active zone currently in use, the composition of waste at a depth of 1 meter ranges around 41%. Zone 3 is also an active zone currently in use. In this zone, the plastic waste composition is the lowest compared to other zones, ranging from 1% to 26%, observed up to a depth of 13 meters. Previous research at the Nonthaburi about the plastic component ranged from 24.6% to 44.8%, while the soil-like materials accounted for 27.9% to 56.6% of the overall weight. Polyethylene plastic carry bags accounted for the most significant percentage of plastic waste, ranging from 11.9% to 23.4% (Chiemchaisri et

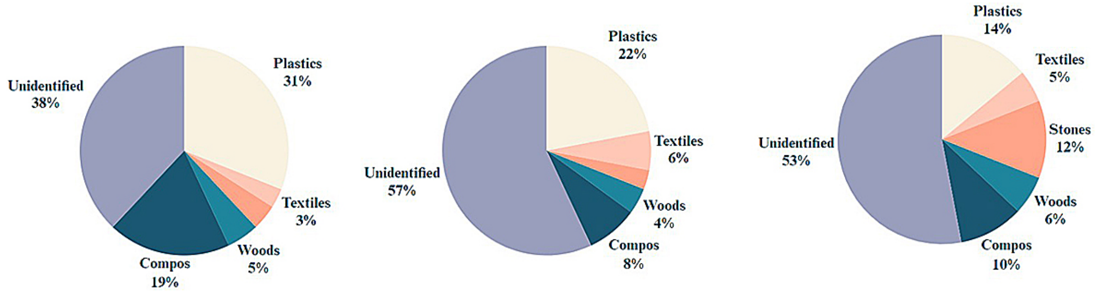


**Figure 6.** Composition of waste in zone 1 (a), composition of waste in zone 2 (b), composition of waste in zone 3 (c)

**Table 6.** Plastic waste composition in each location

| Depth (m) | Plastic waste composition (%) | | |
|---|---|---|---|
| | Zone 1 (inactive zone) | Zone 2 (active zone) | Zone 3 (active zone) |
| 0–1 | 51 | 41 | 21 |
| 1–2 | 42 | 30 | 23 |
| 2–3 | 63 | 34 | 22 |
| 3–4 | 24 | 24 | 7 |
| 4–5 | 22 | 30 | 19 |
| 5–6 | 40 | 26 | 5 |
| 6–7 | 16 | 25 | 10 |
| 7–8 | 40 | 22 | 26 |
| 8–9 | 22 | 14 | 11 |
| 9–10 | 34 | 26 | 1 |
| 10–11 | 27 | 12 | 15 |
| 11–12 | 24 | 9 | 10 |
| 12–13 | 27 | 29 | 10 |
| 13–14 | 19 | 12 | |
| 14–15 | 20 | 21 | |
| 15–16 | 26 | 13 | |
| 16–17 | 16 | 5 | |
| 17–18 | 44 | | |
| Average | 31 | 22 | 14 |

**Table 7.** Composition of combustible waste in each depth

| Depth (m) | Composition of Combustile Waste (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Zone 1 | | | Zone 2 | | | Zone 3 | | |
| | Plastic | Textile | Compost | Plastic | Textile | Compost | Plastic | Textile | Compost |
| 0–1 | 53 | 19 | 28 | 44 | 8 | 49 | 23 | 7 | 71 |
| 1–2 | 45 | 0 | 55 | 32 | 7 | 61 | 23 | 6 | 71 |
| 2–3 | 64 | 2 | 34 | 34 | 28 | 39 | 25 | 11 | 64 |
| 3–4 | 25 | 2 | 74 | 24 | 25 | 50 | 10 | 2 | 89 |
| 4–5 | 24 | 3 | 73 | 31 | 9 | 60 | 19 | 15 | 66 |
| 5–6 | 41 | 10 | 49 | 27 | 2 | 72 | 8 | 2 | 91 |
| 6–7 | 16 | 2 | 82 | 26 | 2 | 72 | 10 | 3 | 87 |
| 7–8 | 40 | 3 | 57 | 22 | 3 | 75 | 29 | 10 | 60 |
| 8–9 | 25 | 0 | 75 | 14 | 0 | 86 | 15 | 5 | 80 |
| 9–10 | 35 | 4 | 60 | 26 | 7 | 67 | 1 | 0 | 99 |
| 10–11 | 29 | 2 | 69 | 13 | 2 | 86 | 18 | 1 | 81 |
| 11–12 | 28 | 1 | 71 | 9 | 1 | 90 | 10 | 2 | 88 |
| 12–13 | 28 | 7 | 65 | 30 | 7 | 64 | 11 | 4 | 85 |
| 13–14 | 20 | 2 | 78 | 13 | 4 | 84 | | | |
| 14–15 | 20 | 0 | 79 | 21 | 4 | 74 | | | |
| 15–16 | 27 | 1 | 72 | 13 | 3 | 84 | | | |
| 16–17 | 17 | 2 | 82 | 5 | 0 | 95 | | | |
| 17–18 | 46 | 1 | 52 | | | | | | |
| Average | 31 | 3 | 64 | 23 | 6 | 71 | 16 | 5 | 79 |

al., 2010). Moreover, plastics exhibit a high level of stability in comparison to other types of waste in municipal solid waste disposal facilities. In European countries, for instance, in Hungary, the proportion of the small fraction is 50%; in Estonia, it is 54%; and in Austria, it is 68% (Faitli et al., 2019) (Bhatnagar et al., 2017). The prevalence of waste packaging (plastic, glass, paper, and metal) is considerably higher in European countries, which is the determining factor. As an illustration, the proportion of packaging in Austria is 15.0%, in Hungary it is 28.4%, and in Estonia it is 23.9% (Wolfsberger et al., 2015) (Bhatnagar et al., 2017), even while taking into account the prohibition on disposing of valuable components in landfills. The composition of combustible waste based on depth is presented in Table 7. The average values of combustible waste composition are shown in Figure 7.

## Calorific value

The calorie value of plastic waste in Tamangapa landfill is ± 29.862 MJ/kg, this value has met European standards but when compared with the results of previous studies this value is still considered low (Table 8). In other studies, obtained Low calorie values that may be due to other materials mixed and high-water content. In a separate study, Chiemchaisri et al. (2010) examined the possibility of utilizing plastic debris from excavated material as refuse-derived fuel (RDF). It was discovered that plastic, particularly plastic bags, has a high calorific value ranging from 27.5 to 38.5 MJ/kg.

## The potential amount of plastic waste in landfill

Calculating the potential volume of plastic waste in a landfill is a mathematical process to determine how much plastic waste can be extracted from a specific zone in a landfill site. The total volume of waste in landfill is 4 019,162.51 $m^3$, with the largest volume in Zone 3 being 1 695,535.8 $m^3$. Zone 3 is the largest area, with an area of 7.34 ha, and is still in use to this day. Next is zone 4, with a volume of 1 444,509.4 $m^3$. The area of zone 4 is 6.38 ha, and it is an inactive zone. The size and volume of waste in each zone are shown in detail in Table 9. Table 9 shows that the amount of plastic waste in zone 1 was 447,797.91 $m^3$, in zone 2 it was 57,503.12 $m^3$ and in zone 3 it was 237,375.01 $m^3$. The total amount of plastic waste in Makassar landfull is 742,676.05 $m^3$. These values are high and potentially to be used both as raw materials and mixed materials. The plastic waste found at these landfills has the potential to be recycled but requires an intensive cleaning process of the adjacent soil. Besides, based on the potential calorie value, plastic waste can be used as RDF. However, to obtain a high calory value, a drying process on the plastic waste material is required to remove the water content. Current trends in the reuse of plastic waste have spread to the construction sector, including as mixed materials for concrete, railway, bench, deck, fence, sheet, garden products, sidewalks, components for bridges, pipes, and gates (Bajracharya et al., 2014).

**Table 8.** Calorific value of all materials in landfill

| Sample | Calorific value (MJ/kg) |
|---|---|
| Zone 1 | |
| Compost | 2,879 |
| Zone 2 | |
| Compost | 3,864 |
| Zone 3 | |
| Compost | 2,929 |
| Plastik in all zone | 29,862 |
| Textile | 18,945 |

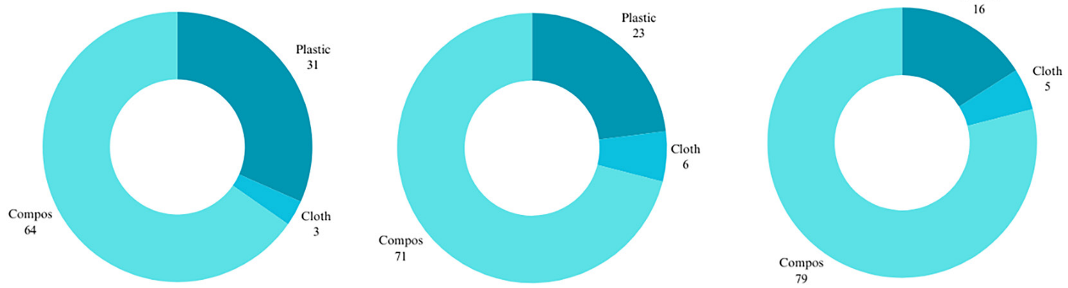


**Figure 7.** Composition of combustible waste in Zone 1, (a) composition of combustible waste in Zone 2 (b), composition of combustible waste in Zone 3 (c)

**Table 9.** The volume and potential of plastic garbage in each zone

| Zone | Volume of waste ($m^3$) | Plastic waste potential volume ($m^3$) |
|---|---|---|
| Old landfill | 617,739.47 | not survey |
| Zone 1 | 1 444,509.40 | 447,797.91 |
| Zone 2 | 261,377.84 | 57,503.12 |
| Zone 3 | 1 695,535.80 | 237,375.01 |
| Total | 4 019,162.51 | 742,676.05 |

## CONCLUSIONS

This research shows that in landfill waste mining, the composition of plastic waste is the most dominant of the other waste materials. In Zone 1 (inactive zone), plastic waste contributed to about 31% of the total waste in this old landfill area, including plastic bags and beverage bottles. Meanwhile, in location 2, about 22% of plastic waste was found, and in location 3, about 14%. At zone 1, the average wet density is 0.451 ton/$m^3$, while the dry density is 0.426 ton/$m^3$. The average wet trash density in Zone 2 is 0.528 tons/$m^3$, and the dry sample density is 0.502 tons/$m^3$. Zone 3 is currently 0.989 ton/$m^3$ for wet samples and 0.728 ton/$m^3$ for dry samples. Testing the calorie value of plastic waste after drying obtained an average result of 29.862 MJ/kg. The total potential volume of plastic waste in Tamangapa landfill is 742,676.05 $m^3$. Plastic waste found at these landfills has a variety of potentials but requires treatment processes to get maximum results.

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