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DESIGN OF NON-ORGANIC TRASH PROCESSING MACHINE BASED ON SOLAR PANELS IN TOURISM VILLAGE

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Abstract

This research is being carried out to assist in achieving the Sustainable Development Goals (SDGs) through trash management by reducing the household trash volume and environmental pollution. The trash volume is reduced by designing a trash counting device using the Pahl and Beitz design method and the Indonesian National Standard 3242:2008, which is then analysed qualitatively. According to the findings of this study, the trash volume generated in the Cibeusi Tourism Village over the next five years (2022-2026) will be 13-14 m3/person/day. The structure of the trash shredder consists of a trash entrance, trash tank, blade housing, and trash screen. The population in the Cibeusi Tourism Village is taken into account in the trash projected volume analysis, which is adjusted to the formula provisions of the Indonesian National Standard 3242:2008. The shredder machine, on the other hand, has a trash tank size of 55 cm x 52 cm x 15 cm and is supported by 10 disc-shaped cutting blades with a diameter of 17 cm and a thickness of 2 cm. This machine is used to reduce the volume of trash piles by shredding the trash into small pieces. It is expected that this research will support in making the Cibeusi Village community to manage trash directly rather than relying on the government's trash transportation schedule to accelerate trash decomposition as well as reduce air and environmental pollution caused by burning and landfilling activities.

Keywords**:** Environmental, Machine, Trash management, SDGs.

1. Introduction

Currently, one of the major challenges in achieving sustainable development goals is trash. Non-organic trash is the most difficult type of trash to process because non-organic trash is difficult for soil to decompose. Landfills in Indonesia reached 33,113,277.69 (metric tons/year) in 2020 with a managed percentage of 59.3 percent (19,637,279.58 tons/year) [1]. Environmental pollution caused by unmanaged non-organic trash such as plastic, has a negative impact on environmental quality and terrestrial and marine ecosystems health. According to a study conducted in the United States, the volume of trash generated in the United States in 2016 reached 42.0 million tons. Meanwhile, 0.15 to 0.99 million tons of trash was discovered to be inadequately managed or recycled in order to reduce trash accumulation [2]. As a result, trash management is the primary focus in order to maintain ecosystem stability while also considering quality of life, environmental and legal standards, community participation, environmental education, as well as quality management [3].

According to data from the National Trash Management Information System (Sistem Informasi Pengelolaan Sampah Nasional or "SIPSN"), trash management in Indonesia have issues with household trash. This is due to the fact that household trash management is typically handled through a centralized trash management system. All household trash is collected and transported within a certain time frame in a centralized trash management system. Some households, however, manage the system on their own by recycling it into compost or burning it openly [3, 4]. These trash management activities have an impact on environmental quality, including centralized trash management, which contributes to trash accumulation and trash burning, which contributes to air pollution.

Several studies have been conducted to develop trash management technology in order to optimize trash management, particularly household trash. According to Kaszycki et al. [5], trash management in Poland employs bio-based solutions (liquid) to optimize municipal sewage treatment and organic solid trash management. The bio-based solution generates granular soil fertilizer with a higher absorption concentration than regular compost [5].

In contrast, the trash problem in the European Union (EU) is being addressed through campaigns for sustainable consumption and production, reuse, and recycling [6]. Similarly, trash management research in Italy employs a theoretical network model that categorizes trash and manages it. In Italy, trash management is located in each sub-district and trash that requires a more extensive management process is collected at the city [7].

One of the trash-reduction technologies developed is the depolymerization process, which converts chemical energy stored in plastic trash into fuel energy [8]. Plastic trash can also be converted into renewable energy. Taiwan and Nigeria are developing plastic trash industries through network-based collective bricolage in order to improve industrial-level circular economies [9, 10].

This research was inspired by the technology used by several countries to reduce landfill and environmental pollution. The goal of this research is to create a trash counting machine and use microorganisms to reduce the volume of trash accumulation, particularly inorganic trash from households. The descriptive quantitative analysis method was used to support the achievement of research objectives with primary and secondary data collection.

2. Literature Review

2.1. Trash management

Trash management is one of the world's most challenging issues, affecting both developed and developing countries [11]. Furthermore, trash generation rises year after year, presenting a major environmental challenge. Every minor error in trash management results in massive environmental losses due to pollution [12]. Trash is defined as the residue of daily human activities or natural processes in the form of semi-solid or solid inorganic or organic substances that can or cannot be decomposed and are discarded by the environment [13]. Trash management is concerned with all types of trash, including biological, domestic, and industrial trash. Organic trash, such as wet or food trash as well as plastic and other materials are commonly generated.

Furthermore, community and industrial activities contribute to an increase in the amount of trash. Furthermore, public places, such as tourist destinations, have a high potential for trash generation [14]. Increased trash in tourism is generally caused by an increase in the number of visitors as well as illegal trash disposal. Dry trash, food scraps, paper, cans, plastic, and other trash are the most common types of trash generation. This trash is easily decomposed and degraded by microbes through natural processes or is biodegradable [15].

2.2. Trash shredder

Trash reduction activities are required to keep up with the growing amount of trash in the environment. The presence of this trash may be hazardous to human health. Several diseases such as cholera, diarrhoea, tapeworm, and fungal daises are caused by trash, as stated by Amir [16]. As a result, trash management requires handling, it can be done using technology that can help answer the community's needs, such as trash copper machines that will dispose of trash in smaller pieces to make the recycling process more efficient [17]. The trash shredder machine is used in conjunction with the initial enumeration process and the crusher system. The crusher model is used to destroy the material structure and reduce its size to small pieces [18].

3. Method

Cibeusi Tourism Village, Ciater District, West Java Province, Indonesia, was the site of this study. Cibeusi Tourism Village is approximately located 3 Km east of the center of Ciater District. The Cibeusi Tourism Village is located on a hill (8.80 miles above sea level), has an air temperature of 32 degrees Celsius, and is located at latitude 6°44'30.64"S and longitude 107°40'21.91"T (Fig. 1).

Within the next five years, the analytical method for projecting the volume of trash uses a qualitative analysis method based on the Indonesian National Standard 3242:2008. The volume of trash generated at the village level is estimated to be 2.5 litres per person per day. The trash pile is assumed to be 200-300 kg/m^3 (0.2-0.3 kg/litre). The following formula can be used to calculate the amount of trash heaped in a given area on a daily basis (see Eqs. (1) to (3)):

$$\text{Trash pile per person (kg/person/day)} = \frac{total\ waste\ weight\ (kg/day)}{number\ of\ sample\ (person)} \quad (1)$$

$$\text{Total trash pile per district (kg/day)} = \text{Trash Volume x Trash Density} \quad (2)$$

$$\text{Trash Density(kg/m}^3\text{)} = \frac{Waste\ Weight\ (kg)}{Waste\ Volume\ (m3)} \quad (3)$$

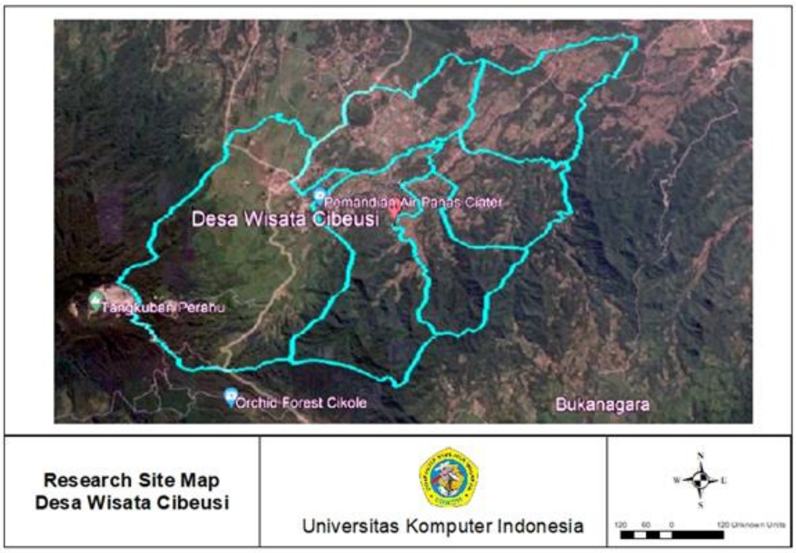

Fig. 1. Research location.

The Pahl and Beitz design method is used for the trash crusher machine design, which includes a product design phase, a product concept phase, a product form phase, and a product detail phase. Solar panels, on the other hand, are used to provide electrical power. Designs and sketches in this study used the Software Invertor 2014 application, the design drawings are made in three-dimensional form.

The phases contained in product design and development are as follows:

(i) Phase 0. Identification phase. This phase identifies the need for tools in managing trash problems in the Cibeusi Tourism Village. The results were gained from direct observations and interviews with village communities.

(ii) Phase 1. Planning phase. This phase discusses the concept and the need for tools in managing trash problems in the Cibeusi Tourism Village. In this phase, the concept is described with the form and function of a product and is usually accompanied by a set of specifications, analysis of competing products, and economic considerations of the project. The concept of a chopping machine in this study applies the concept of a coffee grinder to produce a smaller size of trash, making it easier to manage in a sustainable manner.

(iii) Phase 2. System Level Design. This phase reviews the definition of product architecture and description of the product (subsystems and components). This phase produced a product layout, functional specifications of each product subsystem, as well as a preliminary process flow diagram for the final assembly process.

(iv) Phase 3. Detailed Design. This phase includes the specification completion of the shape, material, and measurement limits of all unit components in the product and identification of all standard components purchased from suppliers. The outputs of this phase are in the form of blueprints or control records for products, drawings for each product component and production equipment, specifications for components that can be purchased, as well as plans for the manufacturing and product assembly processes.

(v) Phase 4. Testing and Improvement. This phase involves the improvement and evaluation of various initial production versions of the product. The initial prototype design (alpha) was made using components with the shape and type of material in actual production, but the design has not yet entered the manufacturing process. This is because the probability of further technical changes should be considered before finalization.

(vi) Phase 5. Initial Production. In phase is the manufacture of products using the system's actual production. The purpose of this initial production was to test the capacity and effectiveness of the shredder machine in solving problems that might arise in the actual production process, and to begin for distribution [19].

4. Results and Discussion

Based on the calculations to determine the amount of Density and Volume, The Indonesian National Standard 3242:2008 stipulates an estimate of the amount of trash produced by each person per day at 2.5 litres. Based on this determination, trash production in the upcoming years is determined with the consideration from the projected population growth (years 2021-2026), which is based on the pattern of population growth in the previous years (years 2018-2020). The projection of the amount of trash in the next five years (2026) has shown to be decreased. This also takes into account the population pattern in Cibeusi Village which decreased from 2018 to 2020 due to the COVID-19 pandemic. The trash pile is estimated to be 11 kg/week in 2026, with a trash volume of 98 m3/person/day (See Table 1). However, this projection could change as the population increases in the future.

Table 1. Trash projection in Cibeusi tourism village.

No.	Description	2021	2022	2023	2024	2025	2026
1	Population Density	5429	5354	5279	5204	5129	5054
2	Trash Volume (m^3/day)	14	13	13	13	13	13
3	Trash Pile (kg/day)	1,6288	1,6063	1,5838	1,5613	1,5388	1,5163
4	Trash Density (kg/m^3)	0,12	0,12	0,12	0,12	0,12	0,12

As a result of the increase in volume and accumulation of trash associated with population growth, a solution is needed to minimize trash accumulation. This is in line with research conducted in North Banjarbaru sub-district, Indonesia which showed that the volume of trash obtained in North Banjarbaru District, Banjarbaru City was 0.4868 kg/capita per day for 50 households [20]. Therefore, trash management activities which consist of a series of activities of sorting, collecting, transporting, processing, and final processing of trash are needed [21].

Therefore, in order to ensure environmental sustainability, particularly air quality due to trash-burning and the vulnerability to fires due to geographical conditions such as agricultural areas, a trash management system that can be managed without reducing the use of human resources is required (janitors). The concept of a paper chopping machine is used in the design of trash counting technology. The chopping machine also aid in increasing trash holding capacity and is expected to speed up the decomposition process by maggot as Plodia interpunctella (Indian meal worms), Tenebrio molitor (Yellow meal worms) and Galleria mellonella (Greater wax worms) [22].

The trash cutter consists of four main components: the trash inlet, the trash tank, the blade housing, and the trash filter. The result of the trash filter is a smaller size of trash because it has passed through the knife house. The change in the form of trash to a smaller size (2-3cm) is expected to speed up the decomposition process to be used as compost or other recycled goods [23]. The propulsion engine, on the other hand, is powered by a motor engine (See Fig. 2). Trash tank dimensions are 55 cm x 52 cm x 15 cm. There is a gap between the two chopping cylinders in the blade housing where non-organic trash will be destroyed to aid the decomposition process with the help of Galleria larvae. The capacity of the non-organic trash shredder machine in relation to the average density (ρ) of the raw material.

Weight = Density (ρ) × volume (3)

= 28000 kg/m³ x 0.101736 m³

= 2849 kg

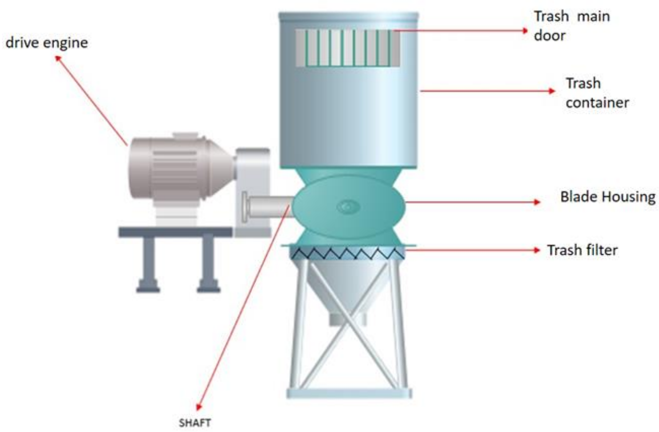

Fig. 2. Trash crusher machine design.

The blade housing contains ten disc-shaped cutting blades made of hard steel, specifically ASSAB 705 (medium carbon steel with a carbon content of 0.38% - 0.43%C), with a diameter of 50 cm and a thickness of 2 cm. By installing a retaining ring with a thickness of 1.7 cm and 10 cm, the counting system will use the concept of rotating 360 degrees, with the distance between one disc and the next disc being 1 cm. The chopping shaft is 55 cm long, and the bearing is 3 cm thick to support the drive shaft, which is connected to one end of the driving motor and driven by a pair of gears (See Fig. 3). The following force will be applied to the inorganic trash shredder machine with a rotating speed of 1400 rpm:

Spin Speed (v) = $\frac{\pi \times d \times n}{60 \times 1000}$ (4)

Spin Speed (v) = $\frac{3.14 \times 500 \times 1400}{60 \times 1000}$

Spin Speed (v) = 36.63 mm/s

Description: *v* = Speed, *d* = Cutting track diameter (mm), and *n* = Motor rotation.

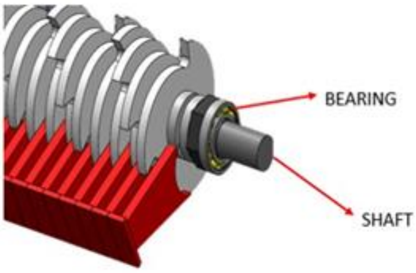

Fig. 3. Shredder knife (blade).

Using the following formula, the magnitude of the power of the electric motor driving with the rotation of the driving pulley and being driven at 1400 rpm and 2100 rpm, as well as the amount of torque of 9.42 Nm can be determined:

$$P = \frac{t \times 2\pi \times n2}{60} \quad (5)$$

$$P = \frac{9.42 \times 6.28 \times 2100}{60}$$

P = 2070.5 W

Based on the above calculations, it is clear that an electric motor of 2070.5 W is required to operate a non-organic trash shredder with a capacity of 2849 kg. Electric current or solar panels can be used to meet the need for electrical power. The use of solar panels to generate electricity, on the other hand, necessitates an additional 40% of the total power is required. This is because the electrical energy produced by solar power plant cannot be used completely because up to 40% of the electrical energy is lost during the transmission period from the solar panels to the load (electronic devices) [24]. The need for solar power plant is determined as follows:

Total power = Engine power: (100% – 40%) (6)

= 2070.5 W : 60%

= 3451 W

In Indonesia, the optimal photovoltaic process lasts only 5 hours, with the power of solar panels sold in the market generally ranging between 50 and 100 WP, so calculating the number of solar panels required can be done as follows:

Solar Panel = Total Power: Optimal Time s (7)

= 3451 W: 5 hours

= 690 W Peak (7 solar panels, each with a capacity of 100 W)

Batteries can be used directly or by charging from solar panels, allowing those without the need for an energy supply (in the event of a power outage) using a shredder without needing to use the PLN electricity network. However, the use of electrical energy in the battery necessitates an additional 5% reserve of the total battery power. Based on this, it requires a battery with a capacity of 2179 W or four batteries with a capacity of 12 V 100 Ah each. The use of these four batteries to reduce battery life damage. The solar panel's Solar Charge Controller (SCC) power is SCC with a minimum power of 24 A (See Fig. 4). The main parts of solar panel design are as follows:

- Controller: The function is to regulate the current that is charged to the battery and taken from the battery to the load (a device that uses energy) and regulates overcharging (overcharging - because the battery is 'full') and excess voltage from the solar panel.
- Counter: Calculates how much electrical energy is used in a certain period (like an electricity meter).
- Inverter: Functions to convert Direct Current (DC) electrical energy generated by solar panels, into Alternating Current (AC) electricity to be supplied to the load.

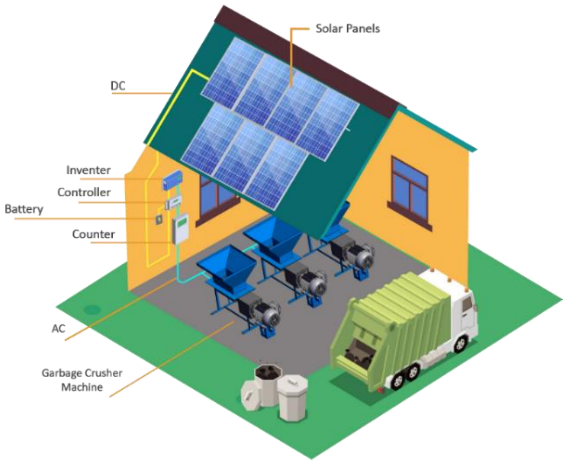

Fig. 4. Solar panel design.

5. Conclusion

This study resulted in designing a non-organic trash counting machine made from household trash in Cibeusi Tourism Village. The trash shredder has a trash capacity of 2849 kg and is outfitted with ten ASSAB 705 (medium carbon steel with a carbon content of 0.38% - 0.43%C) chopping blades with diameters of 50 cm and thicknesses of 2 cm. As for the driving motor, it is powered by solar panels with a total power of 3451 W and a total number of solar panels of up to 7 units (690 W peak). This non-organic trash shredder machine will assist Cibeusi Tourism Village in minimizing trash accumulation and accelerating trash decomposition, thereby preserving environmental quality. The use of solar panels as an energy source can also help to reduce operational costs while also helping to reduce global warming caused by reliance on conventional electricity. As a result, the installation of non-organic trash counting machines in the Cibeusi Tourism Village can assist in the implementation of sustainable development in tourist areas.

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