International Journal of Electrical and Computer Engineering (IJECE)
Vol. 14, No. 5, October 2024, pp. 4921~4928
ISSN: 2088-8708, DOI: 10.11591/ijece.v14i5.pp4921-4928

The feasibility of processing waste from religious ceremonies in Bali as clean energy

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Article Info

Article history:

Received Apr 15, 2024
Revised Jul 8, 2024
Accepted Jul 16, 2024

Keywords:

Biofuel
Briquettes
Clean energy
Renewable energy
Waste

ABSTRACT

Bali is one of the islands with the largest Hindu religion in Indonesia. This is of course an attraction for tourists to see the culture and natural beauty that the island of Bali has to offer. However, apart from that, there are many religious activities that occur on the island of Bali and the waste produced is something that needs special attention. If this waste is not handled properly, it will threaten environmental sustainability in Bali and indirectly the tourism offered. Therefore, there is a need for a solution to overcome the waste problem. By conducting observations, interviews and literature studies, a way to overcome this problem was found, namely by converting the waste into aromatherapy incense, vermicomposting, briquettes and biofuel. The results of this processing have been studied and of course have the potential to be carried out on the island of Bali. The application of this method also indirectly plays an important role in preserving the environment and economy on the island of Bali.

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1. INTRODUCTION

Bali Island is an area famous for its cultural and natural tourism. This can be seen from the large number of foreign and domestic tourists who visit Bali to see its beauty [1]. Apart from that, Bali is also known as the island of a thousand temples because almost all Balinese people adhere to Hinduism and are indirectly full of religious activities. This religious activity uses ceremonial facilities that were always used by Hindus in Bali.

Data from the National Waste Management Information System of the Ministry of Environment and Forestry shows that the volume of waste generation in Bali reached 1.02 million tons throughout 2022. This waste volume increased by 12.22% compared to 2021 and made Bali a province with the eighth largest waste generation in Indonesia [2]. The Ministry of Environment and Forestry also showed that on average there will be around 2.81 thousand tons of waste generated per day in Bali Province throughout 2022. As much as 60% of the waste is organic waste, 20% is plastic waste, and the rest consists of paper, metal, glass and waste from temples [3]–[9]. The type of waste from temples is mostly waste left over from traditional ceremonial activities. The 3 million Hindus in Bali who pray at temples also influence on the production of waste left over from traditional ceremonies. This increase in waste production has not been accompanied by appropriate waste management efforts. Thus, waste from temples is generally collected and transported to the landfill to be landfilled with other types of waste. The sorting carried out in households is also relatively low, so Canang waste is still mixed with other waste [5]–[7].

Based on regulations set by the government, waste management is carried out in 2 ways, namely reducing and handling waste. Waste reduction can be done using three activities, namely reuse, reduce, recycle (3R) simply in each home. Meanwhile, waste handling is carried out by processing waste in a systematic and integrated manner, starting from sorting, storing, collecting, transporting, processing, to final waste processing. The problem that still occurs is that waste is still mixed up from the source to the landfill, so that most of the waste that should be processed ends up in the landfill. Likewise, with Canang waste, waste collected in temples or households is still mixed and not sorted but is collected and transported directly to the landfill.

As part of Balinese culture, offerings in the form of flowers, leaves, fruit and bamboo are served at almost every traditional ceremony. Worship is a Balinese way of life as part of the three principles that cause happiness or Tri Hita Karana. Worship or Parahyangan is a form of harmonious relationship between humans and their God. These activities are carried out on several holy days, such as the full moon, new moon, Nyepi, Galungan, Kuningan. Offerings generally consist of flowers, leaves, fruit, coconut and other natural ingredients. Processing waste left over from traditional ceremonies, most of which is organic waste, has been carried out by composting. The composition of traditional ceremonial waste, which is dominated by organic materials, has the potential to be used as compost. Based on studies conducted, the average waste generation at Besakih Temple, the largest temple in Bali, reaches 5.06 m^3/day and on traditional ceremony days waste generation increases to 46.71 m^3/day. 79.13% is wet waste which has the potential to be processed into compost. A study of the waste output from Tanah Kilap Temple also revealed that 90.16% organic waste was produced with a weight of 292.36 kg ±2.48 [9]. Apart from that, there are also other waste compositions, such as plastic, cans and paper. People's behavior in using single-use items when going to temples, such as plastic, plastic bags or paper, is still very high, so this waste must be sorted again if it is to be processed or recycled.

There are still not many efforts to reduce waste from waste sources, including waste storage and sorting activities. In this way, all waste is directly transported to the landfill. On the other hand, the use of compost is still not optimal because the general public still prefers to use chemical fertilizers for their plants. Even though compost is sold at a relatively cheap price. Thus, other alternatives are needed that can be applied to process Canang waste and create products of economic value.

For a long time, Bali has known the traditional way of managing organic waste, namely by making food waste as food for pigs and as green manure for plants in rice fields or on dry land/gardens. In the division of yard land which is generally divided into 3 parts (Tri Mandala), the nista mandala section is the part of the yard that is most downstream and is usually used as a place for managing waste, a place for raising livestock and cultivating fruit gardens. As a result of technological developments and rapid population growth, there has been a shift in cultural values which is marked by a decline in the community spirit of mutual cooperation and traditional waste management patterns are no longer possible in urban environments that have high population densities.

One of the goals of the sustainable development goals (SDGs), namely climate action, has a target to reduce greenhouse gas emissions. Waste processing is an effort to reduce greenhouse gas emissions. Waste that is taken directly to the landfill and landfilled will naturally produce greenhouse gases, such as carbon dioxide and methane. By processing waste, the amount of waste stored in landfills can decrease and also reduce greenhouse gas production. Waste from religious ritual activities, consisting of Canang and Upakara remains, is also one of the waste contributors to the landfill. On the other hand, the island of Bali has many temples and carries out routine ritual activities, as well as producing waste from its traditional ceremonial activities [10]–[14].

Based on the above, an effort is needed to process traditional ceremonial waste into products that have economic value. Various methods have been and can be used to process traditional ceremonial waste. Several previous studies have carried out recycling of traditional ceremonial waste by processing it into aromatherapy incense, composting it using vermicomposting techniques, and using alternative energy as briquettes and biofuel materials [4], [15]–[29]. This study was conducted to find out and explore the potential for waste left over from traditional ceremonies in Bali to be reprocessed. Thus, the results of this study can be a reference in efforts to manage waste left over from traditional ceremonies in Bali.

2. METHOD

The method used in this study is a literature study with an emphasis on efforts to recycle waste left over from traditional ceremony activities or their components. In its implementation, observation and interview methods were also used in this activity. A preliminary research was carried out to determine the amount of waste generated from traditional ceremonial activities in households and the composition of this waste. Waste sampling is carried out based on the Indonesian National Standard (SNI), namely SNI 19-3964-

1994, 1994, as shown in Figure 1. This method for collecting and measuring samples of urban waste generation and composition is intended as a guide for development organizers in collecting and measuring samples of waste generation and composition for a city. This method aims to obtain the amount of waste generation that is used in waste planning and management. More clearly, the method of activities carried out can be seen in Figure 1.

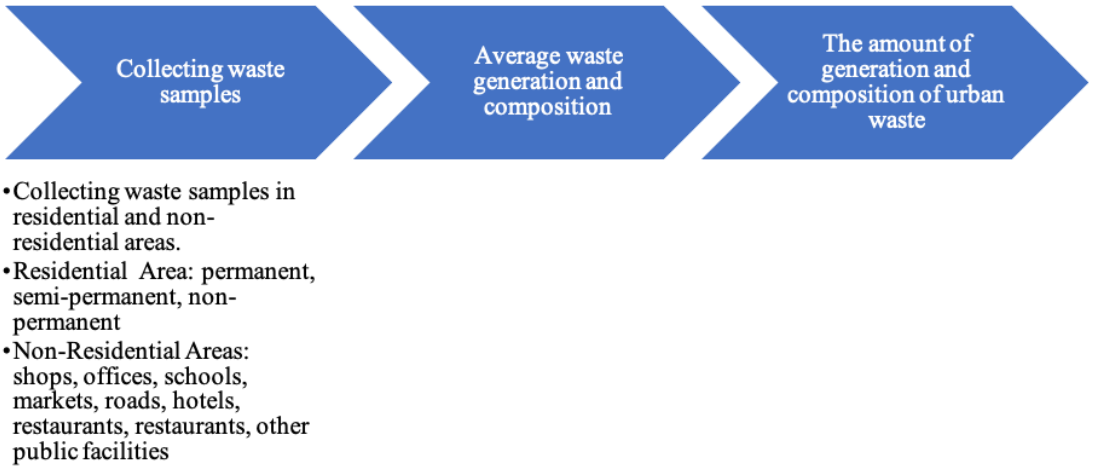

Figure 1. Waste sampling uses the Indonesian national standard

In this article, we will discuss more clearly the things that can be done in managing waste from religious activities in Bali. The process of this waste can be used for aromatherapy (incense), compost, briquettes and biofuel, as shown in Figure 2. Several previous research results have been widely conducted in the management of this waste [16], [21], [30]–[41]. However, this article is designed in such a way as to be able to utilize the waste more optimally. This is considering the condition of Bali as a tourist area that is highlighted by many people and indirectly can be used as an example in managing waste from religious activities that are widely found in Bali.

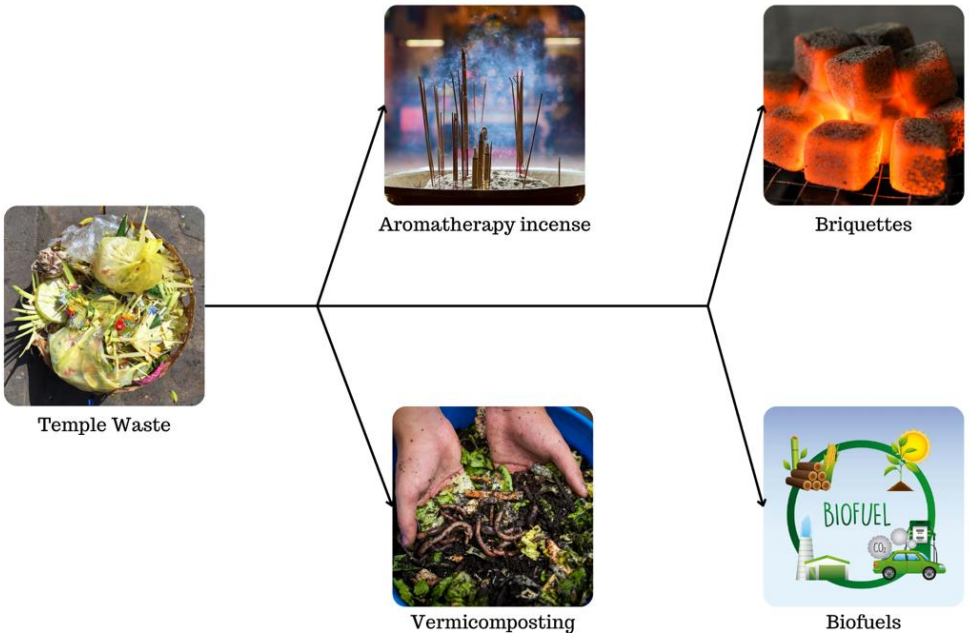

Figure 2. Traditional ceremonial waste processing

3. RESULTS AND DISCUSSION

In general, traditional ceremonial waste generation occurs during traditional ceremonies, prayers or rituals. The amount of rubbish can sometimes exceed the availability of rubbish containers provided at the temple, resulting in a lot of rubbish being scattered. The waste that has been collected is then transported directly to the landfill without any waste processing process first. The lack of availability of waste management facilities means there is energy processing of temple waste, which is generally dominated by organic waste. On the other hand, the composition of temple waste which consists of 79%-91% easily compostable waste is an opportunity to reprocess this waste.

Another problem that arises is the use of chemical fertilizers and pesticides on flower plants which are part of the composition of temple waste. Toxic chemical substances will accumulate in the flowers. This will hurt the quality of soil or water bodies if the flower waste is thrown directly into the environment. The impacts that can be caused include odors, sources of disease vectors and water pollution. In addition, this impact can disrupt activities in the temple's holy places.

Based on the results of studies and observations made on the composition of traditional ceremonial waste on a household scale, the average generation of traditional ceremonial waste reaches 0.8 kg/day on weekdays and 2.4 kg/day during holiday ceremonies. The composition of traditional ceremonial waste includes flowers, leaves, coconuts, fruit, bamboo, food waste, cloth and plastic. Usually plastic is used when going to temples as a container for offerings because it is cheap and easy to use, but currently there are several locations that prohibit the use of this plastic. Temple management provides special storage containers for plastic waste to reduce the generation of scattered plastic waste.

When compared with previous research, the waste generation at the temple shrine in Jaypur, India reached 27-300 kg/day with 100% organic material, while the waste output of Pura Tanah Kilap also revealed that 90.16% organic waste was produced weighing 292.36 kg ±2.48. This is due to the ban on the use of single-use plastic if we want to enter the holy site. Pollution by waste from traditional ceremonies if thrown directly into river water bodies can cause impacts in the form of odors and diseases, such as bacteria and flies. This of course has a negative impact on the entire ecosystem.

3.1. Aromatherapy incense

In Bali, worship is a way of life and people offer various offerings to the gods which mostly consist of flowers, leaves, fruits, coconuts, and clothes. Flower offerings are found to be found in large quantities. Therefore, this waste has a unique portion of floral waste in the total waste. After serving their purpose, flowers along with other rubbish are thrown into dustbins or thrown into water bodies or left in the open as rubbish which causes various environmental problems. The flowers most often offered at temples include ylang-ylang, roses, lotus, soka, kenyeri, bougainvillea, frangipani, champaca, alamanda, pandan, and others. This floral waste can be utilized in various ways to produce valuable products and thereby help save the environment from pollution caused by improper disposal of flowers waste. Apart from the vermicomposting process, composting, extraction of natural dyes, essential oils, biogas generation, incense, rose water and handmade paper, this flower waste can also be used to make incense apart from being used for several arts and crafts techniques. Different flower petals can also be used to make handmade paper by extracting the pulp or by adding them to the finished pulp. Temple waste can be utilized and managed to produce valuable products that will lead to a healthier and waste-free environment. Therefore, this technology provides an environmentally friendly way of disposing of floral waste as well as economic benefits.

Dried flower waste has the potential to be used as a mixture for making aromatherapy incense. Flowers left over from traditional ceremonies are dried and ground to obtain dried flower powder. Then mix it with glue powder, oil and natural fragrance. This effort to process flower waste has the potential to produce environmentally friendly products, reduce the generation of flower waste, and can become a community empowerment activity to produce aromatherapy incense. Based on the results of experiments on making aromatherapy incense from leftover flowers, it was found that to make 1 unit of incense you need 6 grams of dried flower flour. With the production capacity of the machine for making dry flower flour being 8 kg of dried flowers per day, and estimated that the amount of dried flowers that can be processed in 1 year reaches 2.92 tons from one temple unit.

3.2. Vermicomposting

Solid waste management is a significant issue in developing countries, particularly in religious places where flowers are used as offerings. The waste is often discarded in water bodies or on land, causing environmental pollution and health hazards. To address this issue, potential management methods include vermicomposting production, composting, extraction of natural dyes, essential oils, biogas generation, incense, rose water, and handmade paper. Vermicomposting is a cost-effective and environmentally friendly waste disposal method that converts organic waste into worm castings, which are valuable commodities for

agricultural, horticultural, and related industries. Vermicomposting is an effective, environmentally friendly, and cheap method of recycling biodegradable waste using selected earthworm species. The process can be carried out using cow dung in different proportions, with the highest bioconversion ratios found in 50:50 and 60:40 ratios. After the vermicomposting process, various physical and chemical parameters are analyzed, revealing that the integrated influence of all nutrients produced increases the growth and yield of tomato plants and improves soil properties. Timing the vermicomposting process between cow dung mixed with solid temple waste and after partial decomposition for 45 days at a temperature of 30 °C can also optimize parameters. The optimum parameters for vermicomposting include temperature of 25 °C, pH 8.0, and electrical conductivity of 200 us/cm. Vermicompost obtained using this method was found to be rich in a C:N energy of 12.3 after 45 days.

A study in the US found that fresh cut flower waste can be used to produce quality compost for vermicomposting in retail flower shops [23]. The results showed that the compost was within normal ranges for the horticultural industry, with levels of arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc well below industry standards. Vermicompost was also tested for 23 herbicides and insecticides, with one herbicide and two insecticides found in trace amounts, well below EPA standards. The research suggests that flower waste collected from retail flower shops can be used in vermicomposting systems to produce quality compost suitable for the horticultural industry. The agricultural revolution integrates technologies across industries to increase yield and efficiency of precision farming, with predictive analytics and the internet of things (IoT) being used to improve agricultural waste management, plant classification, and disease detection.

This activity can of course also be done for the processing of the results of religious activities in Bali. The results of this activity can be directly utilized by the community, and indirectly this activity also helps the community's economy by selling the results of the process. In addition, environmental sustainability can also be achieved with this activity.

3.3. Briquettes

This waste product can also be used in other forms, namely into briquettes. To make your own briquettes, you can use waste products in the form of wood, scalp, and several other possible wastes. The results from waste that become briquettes can provide good economic value too. The same goes for making incense.

Briquettes are small blocks of compacted coal dust, charcoal, sawdust, wood chips, peat, or other biomass materials that are used as fuel and kindling to start a fire. They are commonly used in various applications such as cooking, heating, and industrial processes. The briquetting process usually involves compression of raw materials under high pressure without the use of any binder. This compression produces a dense, dense block that burns efficiently and produces relatively little smoke. Briquettes are valued for their convenience, uniform shape, and high energy density compared to loose biomass materials. This fuel is often used as an alternative to traditional fuels such as firewood or charcoal because of its ease of handling and storage. Additionally, briquettes can be made from renewable biomass sources, making them a more sustainable option than fossil fuels. As a result, this fuel is gaining popularity in both domestic and industrial settings as a cleaner and environmentally friendly fuel source.

In Indonesia, briquettes are commonly produced and used as an alternative fuel source, especially in rural areas where access to traditional fuels such as firewood or charcoal may be limited or expensive. The production and use of briquettes in Indonesia has several goals, such as waste management, energy access, environmental benefits and increasing income. In waste management, briquette production provides a solution for managing waste from religious activities in Bali, such as coconut, bamboo, wood and leaves. These materials are often abundant in temple, and by compressing them into briquettes, they can be used as a valuable fuel source rather than left to rot or burn inefficiently. Briquettes offer an affordable and accessible energy source, especially in rural communities where access to electricity or other modern fuels may be limited. By using briquettes for cooking, heating and other household needs, people can reduce their dependence on fuels that are more expensive or harmful to the environment. In terms of environmental benefits, briquettes offer environmental advantages over traditional fuels such as firewood and charcoal. These materials produce less smoke and harmful emissions when burned, improving indoor air quality and reducing deforestation pressures. Briquette production can also be a source of income for local communities. Small-scale producers often collect and process biomass materials locally, thereby creating employment opportunities and supporting rural livelihoods.

Based on studies that have been carried out, the benefit-cost ratio (BCR) value of processing this waste as an alternative energy source can reach 2.13. This value is based on a benefit value of 8,137,004,146 and a cost value of 3,811,403,609. Meanwhile, for the BCR value, the use of biomass from this waste is considered feasible and profitable because the BCR is >1. The calculated payback period (PBP) value from the use of this waste is 0.82 years or 9.84 months.

3.4. Biofuels

Biofuels, which are derived from biomass, are used to address energy, environmental, waste management and socio-economic problems in the food sector. These products include bioethanol, biomethanol, biodiesel, biogas, biosynthesis gas (bio-syngas), bio-oil, bio-char, Fischer-Tropsch, and biohydrogen. Biofuels, a renewable, biodegradable, and environmentally friendly alternative to fossil fuels, are growing in popularity due to increasing global population, industrial activity, commercialization, and consumption of fossil fuels. Investments in human resources, energy, and infrastructure are needed to encourage man-made biofuels to improve environmental health, encourage sustainable consumption, and reduce greenhouse gas emissions. Various types of biomass, such as lignosulfose, oilseeds, and animals, have been studied for their composition and potential. Microalgae, a very efficient source of biofuel, can be used as a biomass base for biofuel production due to its organic carbon content and ability to absorb CO_2 and release oxygen quickly. More modern activities focus on biomass-based biofuels to meet energy needs in transportation while considering fossil fuels as alternative energy sources and economic development. However, it needs to be taken into consideration because apart from biofuels providing positive energy output, they also have negative externalities in land use and resource conservation.

In waste products from religious events in Bali, the lignin content in flower waste can be used to make biofuel. The fermentation process using free yeast cells produced the highest ethanol yield from the 48 hour fermentation process. This can also utilize leftover traditional ceremonial flowers to produce biofuel. Biofuels are increasingly being used to address energy scarcity, climate change and socio-economic development. Most countries use biomass as a raw material for biofuel production, thereby reducing costs and providing benefits to poor communities. Energy has a major focus on biomass energy, with the 2014 energy development law issued by the government revealing the potential of biomass energy. Biofuels have the potential to help achieve the target of net zero emissions by 2050 if technical and economic improvements are achieved. Biofuels are expected to be a significant economic driver in the 21st century, contributing to 28% of global energy demand by 2050.

Developments in biofuel production and consumption in six Southeast Asian countries have also been carried out, with a focus on environmental degradation and the impact of biofuel consumption. Use of panel analysis with four main models, namely consumption, production methods, labor force, capital investment and capital expenditure. Activities to explore the potential of biofuels can reduce environmental degradation and increase renewable energy production.

In the energy sector, an energy efficiency assessment model can be carried out by evaluating projected energy consumption in 2020-2050 and carbon-intensive energy systems. The results show that by 2050, renewable energy sources will dominate the list of renewable energy sources, with biomass-based sources reaching 36.35 GW. This can emphasize the importance of using fossil fuels with renewable energy to reduce carbon emissions and meet the country's energy needs, especially in regions with limited national renewable energy resources.

The Indonesian government has also set a target of 100% electricity, but many new energy sources are still being used, causing tension between the government and local communities. Local biomass distribution is unsustainable 4926uet o lack of planning, incentives and government support. Biomass contributes to national energy production, but there are challenges in implementing and developing biomass energy. The Covid-19 pandemic has an impact on global energy production, prioritizing renewable energy and achieving national energy production targets.

4. CONCLUSION

Traditional ceremonial waste is a waste problem in Bali that really needs to be addressed. This is because this waste is one of the contributors to landfill which, if not processed properly, will have a negative impact on environmental sustainability. To overcome this, waste management from religious activities can be further processed in several ways, such as making incense, making vermicompost, and turning it into briquettes and biofuel. The results of this processing activity can be reused to increase the economy around the temple area and the surrounding community. However, this needs to be reconsidered because apart from biofuels providing positive energy output, biofuels also have negative externalities in land use and resource conservation. This can of course be material for further study for the development and use of renewable energy considering that the use of fossil energy is not good for the environment.

ACKNOWLEDGEMENTS

Thanks are given to the Marine and Fisheries Polytechnic of Kupang, Institute of Business and Technology Indonesia, and for all their help and support in this research.

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