SOLID WASTE ANALYSIS AND PROCESSING POTENTIAL IN THE TOURISM SECTOR: CASE STUDY IN NUSA DUA, SOUTH KUTA, BALI

I Made Wahyu Widyarsana¹*, Made Ayu Priyanka², Luhur Akbar Devianto³

¹Environmental Engineering, Faculty of Civil and Environmental Engineering, Bandung Institute of Technology, Bandung, West Java, Indonesia
²Environmental Engineering, Faculty of Civil and Environmental Engineering, Bandung Institute of Technology, Bandung, West Java, Indonesia
³Department of Frontier Sciences for Advanced Environment, Graduate School of Environmental Studies, Tohoku University, Miyagi, Japan

*Corresponding author: imww.research@gmail.com

ABSTRACT

Aims: The study of waste generation and composition in 6 types of tourism facility in Nusa Dua is carried out to analyze the waste processing potential and determine a proper waste management needed for tourism areas.

Methodology and results: The primary data collection methods including field observations for existing waste separation, sampling of waste generation and composition at source, interviews with the facility’s management and characteristics of certain types of waste. Meanwhile, secondary data of waste generation and composition for hotels and the mall is acquired from waste collection services in Nusa Dua and previous studies for typical facilities. Nusa Dua produces around 11 tons of waste per day with hotels being the highest contributor of waste compared to other tourism facilities. The waste produced in Nusa Dua comprises around 70% of organic waste including food and yard waste and the remaining 30% includes paper, plastic, glass, metal, and other waste. Conclusion, significance and impact study: Aside from maximizing waste processing, Nusa Dua should execute campaigns to support the government’s regulation regarding the ban on styrofoam products, plastic bags, and plastic straws which gradually will reduce the amount of non-recyclable waste produced by the area.

MANUSCRIPT HISTORY

- Received November 2021
- Revised February 2021
- Accepted March 2022
- Available online April 2022

KEYWORDS

- Bali
- Tourism
- Waste characteristic
- Waste composition
- Waste generation
1. INTRODUCTION

Bali is an internationally well-known tourism destination, renowned for its natural wonders and culture. It is one of Indonesia’s thirty four provinces, located east of Java and west of Lombok. Bali province consists of Bali Island and a few smaller neighboring islands including Nusa Penida, Nusa Lembongan, and Nusa Ceningan. Annually, the province attracts millions of domestic and foreign tourists which increases throughout the years. In 2017, a total of 5,697,739 foreign tourists visited Bali.

Tourism plays a substantial role in Bali’s development. Over the years, the highest sector contributing to Bali’s GRDP growth is the accommodation and food services sector. However, in spite of the benefits, tourism development creates a great pressure resulting in adverse effects to the environment. One form of environmental pollution by tourist activities originates from the huge amount of solid waste generated.

Solid waste generation in tourism areas is higher than residential areas. Tourists may generate up to twice as much solid waste per capita as locals according to Pham Phu et al., (2018). Therefore, it is a challenge to plan a proper waste management system for tourism areas. Currently, Bali’s waste management implements the conventional collect-haul-dispose system. This system relies heavily on landfills to contain most of the waste generated with minimal efforts of waste processing beforehand. Eventually, the rising quantity of waste from tourism and the lack of proper waste management across the province will overburden landfills in Bali. From the total of 10 landfills in Bali, 5 are almost full now while 2 are categorized as overcapacity according to Widyarsana et al. (2020). Moreover, untreated solid waste possesses a risk to pollute and reduce the quality of tourist destinations, thus discouraging tourists to drop by the area and could lead to economic problems in the future.

Proper solid waste management regulation is critical. The Indonesian government has also set a target for solid waste management through regulations (Bah dan Artaria, 2021). The Presidential Decree of the Republic of Indonesia Number 97 Year 2017 regarding the National Strategy and Policy of Municipal Solid Waste (MSW) stated a target of 30% waste reduction and 70% waste handling by 2025. This regulation also controls commercial solid waste, including solid waste from tourism areas. For that reason, the main objective of this paper is to discuss the reduction, recycling, and processing potential of tourism generated waste which could help initiate a better understanding for the waste management needed in Nusa Dua, Bali.
2. RESEARCH METHODOLOGY

The research is conducted in Nusa Dua, one of the most-visited tourist attractions situated in South Bali. Nusa Dua is a part of Badung Regency, which is the second biggest waste generator that produces 17.36% wet weight of the total waste generated in the province as stated by Widyarsana et al., (2020). Nusa Dua covers a 350 hectare area popular for its high-end resorts, private beaches as well as a venue for international-scale events. Figure 1 shows the location of the Nusa Dua area in Bali Province.

![Figure 1 Location of Nusa Dua in Bali Island](image)

During the last ten years, tourism in Nusa Dua grew significantly by 85% reaching a number of 955,632 tourists in 2018. The great demand for accommodation services led to an increase in the number of rooms by 33%, which equals to 5,140 rooms in 2019, and the current construction of 2 new hotels within 2020. However, the dramatic tourism development did not make any notable changes toward the waste management system or infrastructure. Consequently, the lack of information, planning and regulations on tourism waste management in Nusa Dua may become a threat towards the environment.
2.1 Data Collection Methods

Various activities are carried out to determine the solid waste processing potential from tourist areas in Nusa Dua, including the collection of primary and secondary data. The primary data consists of field observations for existing waste separation, sampling of waste generation and composition at source, interviews with the facility’s management and characteristics of certain types of waste. Meanwhile, secondary data of waste generation and composition for hotels and the mall is acquired from waste collection services in Nusa Dua and previous studies for typical facilities.

Waste sampling is conducted for 3 consecutive days in January 2019. In accordance with national sampling methods stated in SNI 19-3964-1994, a minimal sample of 10% of each category of non-domestic facility is taken. Waste samples are taken from the prayer venue, central parking lot, common area, and offices. Waste is first collected, put in a sampling box and weighed with electronic scales. The waste volume is calculated and then the waste sample is categorized into 9 groups which are yard waste, food waste, plastic, paper, metal, glass, rubber, textile and other types of waste. In order to explore options for waste processing technologies, a more detailed composition from the plastic, paper, and food waste groups are reported. The detailed classification for these 3 groups are as follows.

1. Plastic
   a. PET such as water bottles
   b. LDPE such as plastic bags and bubble wraps
   c. HDPE such as plastic bottle lids and shampoo bottles
   d. PVC such as pipes
   e. PP such as plastic cups
   f. PS such as styrofoam containers
   g. Other plastics such as food wrappings and sachets

2. Paper, include cardboards, office and newspapers, dairy cartons (tetrapak), paperboard/carton and food wrappings.

3. Food waste, include hard putrescible food scraps (bones, fruit seeds, fruit peels with hard materials such as durian) and tender putrescible food scraps (rice, vegetable, fruit leftovers).
Waste sample from the is then mixed and reduced to around 1 kg by the quartering method. The waste sample is analyzed for physical and chemical characteristics such as water content, nitrogen, C-organic and volatile content. Secondary data for hotel waste generation and composition is obtained from waste collection services. Waste generation and composition from two 5-star hotels with a total capacity of 557 rooms, hotel A with 125 and hotel B with 432 rooms, is used to estimate the waste produced by each room.

2.2 Interviews

Interviews were also conducted with the management of hotels, the mall, and offices regarding the implementation of waste sorting, reduction and recycling. Waste generation from the mall was obtained by estimating the need for waste transportation each day since there is no report for the detailed waste generation each day.

3. RESULTS AND DISCUSSION

3.1 Waste Generation

Solid waste generation rates from sampled facilities in Nusa Dua are summarized in Table 1. There are 6 types of tourism facilities sampled in this study. The central parking lot is a 0.9 hectare area consisting of parking areas for buses, mini bus, cars, and similar types of vehicle used by tourist or tour groups. The prayer complex is made up of 5 places of worship including a Pura (Hindu Temple), a Vihara (Buddhist Temple) a Catholic Church, a Christian Church, and a mosque. The common area consists of roads, sidewalks, and gardens surrounding the tourism area. The shopping mall is a semi outdoor building with up to 100 tenants including restaurants, boutiques, book stores which are surrounded by gardens. Hotels which are mostly made up of around 50% gardens, so only 50% of the total hotel area is built to provide rooms and accommodation.

Based on sampling, hotels were the most dominating waste producer, reaching 1,43 kg/room/day or amounting up to 7,3 tons/day in the Nusa Dua area. A study of hotels in Hue City, Vietnam shows that waste generation at a 5-star hotel was 1,61 kg/room/day. There are several factors influencing waste generation in hotels including the capacity of the hotel, the price of the room, the availability of gardens, and restaurant service levels. The second biggest waste generator is the shopping mall, followed by the common area that also produces
a high amount of waste. Other facilities produce a fairly low amount of waste from around 20-50 kg/day.

### Table 1 Waste generation rate of tourism facilities in Nusa Dua

<table>
<thead>
<tr>
<th>Facility</th>
<th>Waste generation</th>
<th>Value</th>
<th>Units</th>
<th>Total waste generated</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices</td>
<td>0.173</td>
<td>2.39</td>
<td>129 employee</td>
<td>22.30</td>
<td>0.31</td>
</tr>
<tr>
<td>Central Parking Lot</td>
<td>0.006</td>
<td>0.04</td>
<td>9,030 m²</td>
<td>52.13</td>
<td>0.38</td>
</tr>
<tr>
<td>Prayer Complex</td>
<td>0.002</td>
<td>0.02</td>
<td>12,930 m²</td>
<td>28.77</td>
<td>0.27</td>
</tr>
<tr>
<td>Common Area</td>
<td>0.004</td>
<td>0.04</td>
<td>339,194 m²</td>
<td>1322.98</td>
<td>12.43</td>
</tr>
<tr>
<td>Mall</td>
<td>0.03</td>
<td>-</td>
<td>67,000 m²</td>
<td>2275.42</td>
<td>11.29</td>
</tr>
<tr>
<td>Hotels</td>
<td>1.43</td>
<td>-</td>
<td>5140 rooms</td>
<td>7370.14</td>
<td>36.57</td>
</tr>
</tbody>
</table>

### 3.2 Waste Composition and Recycling Potential

The composition of waste in an area is needed to determine the best method of waste processing and management. Figure 2 shows the composition of waste obtained from the common area, prayer complex, central parking lot, hotels, and offices in Nusa Dua. Overall, waste found in all facilities is dominated by decomposable material including food waste and yard waste, which amounts up to around 70% of the total waste found in all facilities. This is in line with the fact that 10% of Bali’s landfill is primarily filled with food waste as reported by Widyarsana et al. (2019).

As shown in Table 1, hotels generate the highest portion of waste compared to other types of facilities in Nusa Dua. Because of the large amount of waste, hotels also possess a higher recycling potential. Food waste accounts for 43.8% or 3.2 tons/day amounting up to half of the waste generated, followed by yard waste 28.1% or 2.1 tons/day, paper 17.2% or 1.3 tons/day, plastic 2.4% or 0.18 tons/day, glass 0.9% or 0.07 tons/day, and aluminum 0.5% or 0.04 tons/day. Besides in hotels, food waste also has the biggest portion in offices, amounting up to 39.1%. On the other hand, yard waste constitutes the highest portion of waste in the prayer complex, and common area reaching a number of 80.1%, and 66.3%. Decomposable waste still dominates in the central parking lot however, the food and yard waste ratio are almost equal around 30%.

Although the amount of food waste is fairly high, food waste in Bali has a potential to be redirected and used by pig farmers. Pork is commonly consumed and used in Bali’s tradition and
cere monies. As there is always a demand for pork, pig farms will need a steady supply of food which can be fulfilled through food waste. It can be processed and become a meal for pigs by removing meat products and then boiling the food waste in 100°C for 1 hour to eliminate pathogens. One of the facilities in Nusa Dua that could provide a constant supply of food waste to pig farms is hotels.

Aside from food waste, Nusa Dua also produces a lot of yard waste from the common area and gardens in hotels, mostly consisting of leaves and grass that are compostable. The organic waste processing method preferred for yard waste is composting. Composting reduces the volume of waste while producing a soil enriching material needed by hotels to maintain their garden and lawn. Therefore, creating a closed loop waste management where yard waste from hotels and common areas are collected and processed to become compost and then used in the same area or to be sold. The composting method recommended is aerated static pile composting due to shorter composting time and minimal odor produced.

Plastic and paper also make up a big amount of waste in Nusa Dua. Glass and metal waste are found in fairly small amounts while textile and rubber waste are rarely found. Textile waste is only found in offices and the amount of rubber waste is so small that it is not measurable. From all types of plastic found in tourism facilities in Nusa Dua, PET (plastic bottles), LDPE (plastic bags), and PP (plastic cups) are the most commonly found. These types of plastic are recyclable so they can be collected and sold to waste banks. PET bottle flakes that are crushed beforehand also possess a higher price. On the contrary, plastics in the group of PS (styrofoam), disposable cutlery, plastic food wraps, sachets and straws are also easily found in Nusa Dua.

These types of plastic are not recyclable. Besides that, small size plastic waste like straws and sachets are hard to collect and manage during transportation to landfill, consequently possessing a threat to pollute the environment. In order to prevent further chances of pollution, Bali issued the Bali Governor’s Regulation Number 97 Year 2018 on Single Use Plastic Restriction in which businesses in Bali are expected to replace and stop using single use plastic including plastic bags, styrofoam, and plastic straws. With this regulation, it is expected that the number of non-recyclable styrofoam waste, plastic straws, and plastic bags will decrease gradually.

Recyclable paper waste found in Nusa Dua includes office paper, newspaper, cardboard, and paperboard that can be sold to waste banks. Meanwhile, composite cardboard used for dairy products and food wrapping papers are unlikely to be recycled and offer a potential to be
treated thermally. Glass bottles and aluminum cans can be collected and sold to recyclers. Other non-recyclable waste found in Nusa Dua includes cigarette butts, tissues, sanitary products that are mostly composed of paper or plastic.

![Figure 2 Composition of waste from 5 types of tourism facility in Nusa Dua (wet-weight basis)](image_url)
3.3 Waste Composition and Recycling Potential

Waste characteristics from sampled waste in Nusa Dua is obtained through laboratory testing. Table 2 shows the C/N ratio of food and yard waste obtained. The ideal C/N ratio of waste for composting should be around 25-30 (dry weight) that will decrease to 12-15 (dry weight) when the compost is finished. The C/N ratio found in food waste and yard waste in Nusa Dua respectively is 41.19 and 43.81 therefore another material must be added to lower the C/N ratio needed for optimum composting parameters. Another parameter to support optimum composting conditions is the water content. The optimum water content for composting should be around 50-65%, a lower number will limit the decomposition process while a higher water content can cause anaerobic conditions. Water content for food and yard waste is shown in Table 3. The results show that water content in food waste samples is 83.63% and 71.38% for yard waste.

<table>
<thead>
<tr>
<th>Sample</th>
<th>C organic content (% dry weight)</th>
<th>Nitrogen content (% dry weight)</th>
<th>C/N Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food waste</td>
<td>46.75</td>
<td>1.13</td>
<td>41.19</td>
</tr>
<tr>
<td>Yard waste (leaves)</td>
<td>61.39</td>
<td>1.40</td>
<td>43.81</td>
</tr>
</tbody>
</table>

Paper and plastic comprise the second biggest type of waste generated in Nusa Dua. Table 3 shows the water content, dry content, volatile content, and ash content of paper and plastic waste. These characteristics can be used to determine if a thermal treatment is viable to process non-recyclable waste. Suwung Landfill, the landfill which Nusa Dua disposes its waste to, is now developing a waste-to-energy thermal treatment for solid waste. Paper samples have an average water content lower than 13% while plastic waste has a water content lower than 1%. Thus, both types of waste can be processed by thermal treatment without the need of drying. Plastic wrappings, plastic sachets, styrofoam, dairy cartons, sanitary products and food wrappings are some common types of paper and plastic waste that cannot be recycled and propose a potential to be thermally processed in Suwung Landfill. Moreover, dairy cartons and plastic packaging have a volatile content of around 90% which means thermal treatment can be used to eliminate and reduce the volume of the waste. Another characteristic important in
thermal processing of waste is the calorific value. Food wrap papers have a HHV of 4247 Kkal/kg while plastic type PS (styrofoam) has a HHV of 11286 Kkal/kg. Organic waste that is hard to compost such as wood and branches have a HHV of 4716 Kkal/kg thus is suitable to be thermally treated.

Table 3 Physical characteristics of sampled waste in Nusa Dua

<table>
<thead>
<tr>
<th>Sample</th>
<th>Water content (%)</th>
<th>Dry content (%)</th>
<th>Volatile content (%)</th>
<th>Ash content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food waste</td>
<td>83.63</td>
<td>16.37</td>
<td>91.59</td>
<td>8.41</td>
</tr>
<tr>
<td>Yard waste (leaves)</td>
<td>71.38</td>
<td>28.62</td>
<td>85.34</td>
<td>14.66</td>
</tr>
<tr>
<td>Paper</td>
<td>6.51</td>
<td>93.49</td>
<td>88.08</td>
<td>11.92</td>
</tr>
<tr>
<td>Paper board</td>
<td>11.30</td>
<td>88.70</td>
<td>76.19</td>
<td>23.81</td>
</tr>
<tr>
<td>Dairy carton</td>
<td>12.90</td>
<td>87.10</td>
<td>89.10</td>
<td>10.90</td>
</tr>
<tr>
<td>PET plastic bottle</td>
<td>0.61</td>
<td>99.39</td>
<td>99.94</td>
<td>0.06</td>
</tr>
<tr>
<td>Plastic film (plastic bag &amp; sachet)</td>
<td>0.18</td>
<td>99.82</td>
<td>90.28</td>
<td>9.72</td>
</tr>
</tbody>
</table>

4. CONCLUSION

Nusa Dua produces around 11 tons of waste per day as reported by Widyarsana et al., 2019 with hotels being the highest contributor of waste compared to other tourism facilities. The waste produced in Nusa Dua comprises around 70% of organic waste including food and yard waste and the remaining 30% includes paper, plastic, glass, metal, and other waste. Food waste, especially from hotels, possess a potential to be processed and used as pig food. Yard waste, which mostly consists of leaves, can be processed into compost that is needed by the surrounding hotels in the area for their gardens. Wood and branches from garden maintenance could be collected and transported to Suwung Landfill to undergo thermal treatment, considering it has a suitable HHV value for thermal processing. Paper products like cardboards, plastic products like PET bottles, glass, and aluminum cans should be collected, sorted, and sold to waste banks or recyclers. Non-recyclable waste from the plastic and paper groups like dairy cartons and plastic food wraps, as well as other types of waste such as sanitary products, also possess a potential to be treated thermally. Thus, reducing the amount of waste buried in Suwung Landfill. Aside from maximizing waste processing, Nusa Dua should execute campaigns to support the government’s regulation regarding the ban on styrofoam products, plastic bags,
and plastic straws which gradually will reduce the amount of non-recyclable waste produced by the area obtained.

5. ACKNOWLEDGEMENT

This research was financially supported by the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia.

REFERENCES


