

MUNICIPAL SOLID WASTE MATERIAL FLOW IN BALI PROVINCE, INDONESIA

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ABSTRACT

The growing challenge of municipal solid waste management is caused by many factors including the tourism sector developments. The high population growth, increased activity and economy, and urbanization have triggered an increase in the rate of waste generation. Bali Province is one of the most popular tourist destinations in Indonesia that attracts many foreign tourists and certainly produces a high rate of waste generation. Without proper waste management, it will become a complex problem and has a lot of bad impacts on the environment. The solution to the waste problem must be effective and resolve to the root of the problem. Therefore, a study of waste material flow was carried out in the Bali Province to define, evaluate, and analyze the existing condition of waste management to improving solid waste services. Bali Province which consists of 4.2 million local inhabitants and around 4.9 million tourists in a year produces waste around 2,333.1 tons/day which dominated by food waste for around 57.9% WW (Wet Weight) and plastic waste for around 15,67% WW. Around 891.8 tons/day (38.2% WW) of waste is transported directly to the landfill and 547.15 tons/day (23.5% WW) is collected first at the Transfer Depo before transported to the landfill. As much as 120.95 tons/day (5.18% WW) of waste enters the TPS 3R for recycling and there is 19.62 tons/day (0.8% WW) enter the Waste Bank. Furthermore, around 753.7 tons/day (32.30% WW) waste still illegally wasted to the environment. In the end, there is 1,423 tons/day (60.99% WW) of waste processed at the 10 landfills which accommodate Bali Province.

Keywords: solid waste management, tourism sector, Bali Province, material flow

INTRODUCTION

In a developing country such as Indonesia, progress in various aspects and sectors constantly occurs, which includes the tourism sector in Bali Province in particular. Conforming to the increase of population each year, development of economic sector, and growth of activities, the rate of waste generation would also rise. As a matter of fact, population in village of developing country like Indonesia increases approximately 150.000 people every day (UNDESA, 2015). This dynamics of change is extremely delicate in developing country, especially in urban area, that even with changes in socio-economical factors such as education, population, and family composition will affect waste generation (Chen, 2018). That situation alters waste generation and characteristics of the produced waste, which would create new challenges in waste management (Troschinetz et al., 2009). The difficulty that often occurs in developing countries is the fragility of waste management system, lack of financial resource, and limited participation of locals (Makarichi et al., 2018). Bali Province is not exempted of this problematic. The need of good waste management is also one of the objectives of Sustainable Development Goals (SDGs) which aimed to provide universal access for sufficient, secure, and affordable waste management as well as reducing uncontrollable waste disposal and incineration (United Nations, 2015).

Material flow analysis (MFA) is used to investigate the flow and stock from source or environment contaminant in the applied system (Millward-Hopkins et al., 2018; Zhang et al., 2017; Makarichi et al., 2018). MFA is usually utilized in waste flow track analysis which could be applied as a database of waste management development and as a reference for decision making (Stanisavljevic and Brunner, 2014). Through MFA, planned waste management is expected to be effective in solving ensuing problems by making use of opportunities and advantages as well as overcoming weakness and preventing threats which might happen in the system. MFA can also be used to analyze the potential of waste reduction to determine the potential to *reduce*, *reuse*, and *recycling* waste. Therefore, Bali Province,

with its waste management problem which could lead to air, ground, and water pollution that would lead to environmental damage and decline in public health, must conduct MFA analysis as one of the data references in determining the development of waste management which could be applied effectively according to regional characteristics and existing waste management.

MATERIALS AND METHODS

Various activities were conducted to collect data in this research such as primary and secondary data collection. Primary data collection was conducted through direct waste generation sampling. Meanwhile, secondary data collection was conducted to the related institution by reviewing document or literature to know the waste management system and waste handling in 9 (nine) cities/sub-districts of Bali Province.

- a. Data Collection
 - Interview of all stakeholders and subsystem
 - Observation
 - Literature review
 - Direct measurement

- b. Flow Material Calculation

The rate of waste in the source was analyzed to the existing subsystems in Bali Province. The calculation was performed by counting each waste in every subsystem of waste and the result of subtraction was an untreated waste or illegal disposal to the system.

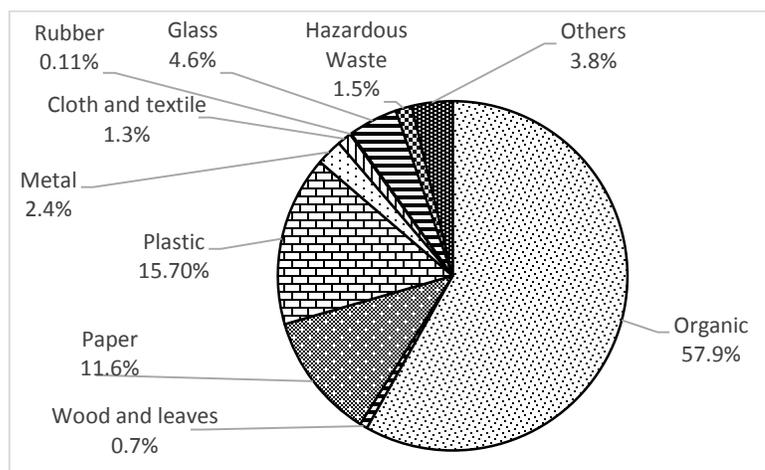
RESULTS AND DISCUSSION

4.1 Amount of Waste in Every Subsystem in Waste Management

Waste generation data of Bali Province for 9 (nine) cities/sub-districts was conducted by literature review of related document and administering waste generation sampling. Referred waste in this research was the result of domestic activities or non-domestic activity such as tourism activity and economic activity such as offices, markets, hospitals, schools, and main road.

Table 1. Data of waste generation in Bali Province

Cities/Sub-districts	Waste Generation (ton/day)
Badung	523.6
Bangli	210.3
Buleleng	310.3
Gianyar	180.4
Jembrana	126.9
Karangasem	129.4
Klungkung	84.5
Tabanan	177.4
Kota Denpasar	590.3
Total	2333.1



Picture 1. Waste composition in source

Waste composition of Bali Province, in general, was conducted not only in household source but also in non-domestic source. The waste composition was divided into 10 (ten) types, which were: food waste, wood waste, paper

waste, plastic waste, metal waste, cloth and textile waste, leather rubber waste, glass waste, B3 waste, and others. The dominating type of waste in Bali Province was food waste with 57.9% WW (Wet Weight) and plastic waste with 15.7% WW. Waste composition in source is shown in Picture 4. Waste generation in unit weight is displayed in Table 1 while the composition of waste in source is exhibited in Picture 1.

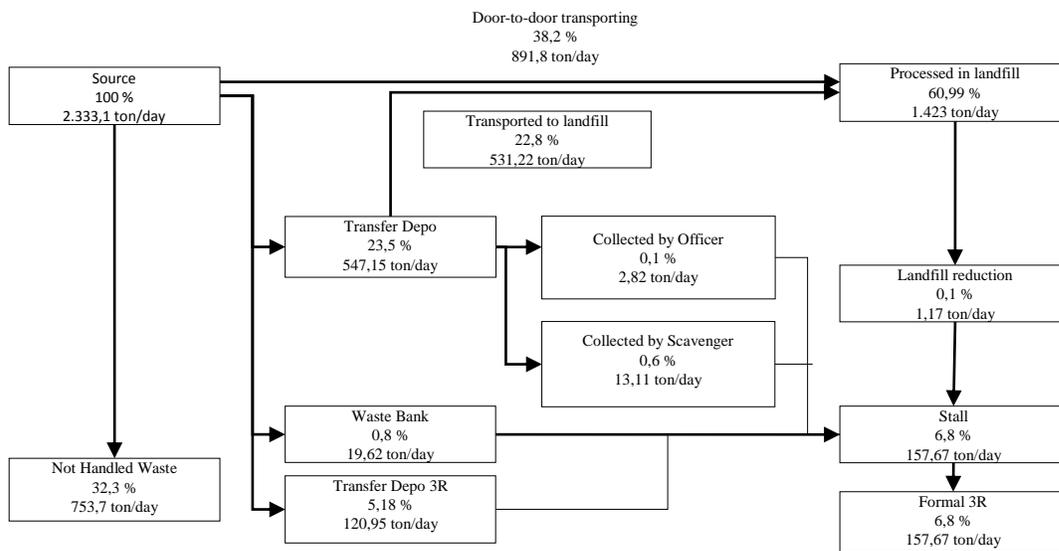
Door-to-door waste transporting service was conducted by the government, namely *Badan Lingkungan Hidup* or Living Environment Agency in each city/sub-district in Bali Province. The highest percentage of waste service was in Denpasar City as the capital of Bali Province with 80% WW and followed by Badung Sub-district with 55.44% WW. Meanwhile, the lowest percentage of waste service was in Bangli Sub-district with 17.26 WW.

Waste handled in TPS-3R and waste bank was conducted by multiplying the average of waste handled in each subsystem with the number of each facilities in Cities/Sub-districts of Bali Province. There were 120.95 ton/day waste in TPS-3R and 19.62 ton/day waste in waste bank which then used as a basic material for recycled goods or resold to waste recycling system in Indonesia or even abroad.

Waste in the landfill was identified by doing a direct observation of waste generation entering 10 landfills in Bali Province. As the final processing site, there were still waste reduction activities by informal parties. There were around 830 scavengers in landfill who were still collecting valuable waste to be resold. Even though their existence was dangerous considering the operating heavyweight machinery in landfill, the waste reduction accommodated by this informal sector helped to reduce 1.175 ton/day of plastic waste.

4.2. Waste Material Flow of Bali Province

The principal of material flow calculation for every stage of the cycle is the total current input must be the same with total current output (Sevign et al., 2015). Based on waste generation data of each subsystem, then waste material flow of Bali Province was displayed in Picture 6.



Picture 6. Waste Material Flow of Bali Province

In the material flow, it could be observed that the condition of waste management in Bali Province was unwell. This was indicated by the amount of waste piled in landfill which was 60.99% or around 1,423 ton/day and untreated waste as much as 32.3% or around 753.7 ton/day which was disposed poorly to the environment. Waste management in landfill which was still using open dumping method also created considerable polluting potential for environment. Thus, the amount of waste generation processed in landfill must be as minimal as possible. Waste disposed to the

environment were waste that was not transported directly by government and also not handled by through TPS-3R and Waste Bank. Therefore, this material flow could serve as an evidence that locals' participation was vital to support good waste management. On the other hand, there was 6.8% waste or around 157.67 ton/day waste handled by business entity to be recycled or resold in the same form as before. The reduction could be maximized through locals' participation in sorting out the waste in source so that the economic value of waste could be increased.

CONCLUSION

Effective and secure waste management is an ideal expected condition of an area, especially in tourism area. Waste material flow in Bali Province is organized to evaluate and analyze the existing condition of waste management. The result of waste material flow analysis attests that there were still setbacks in waste management, but there were also opportunities in waste recycling effort as observed in considerable size of waste generation which was 2,333.1 ton/day with 32.3% system leakage or 753.7 ton/day waste. The waste generation could be managed more optimally and contribute to waste recycling in Bali Province.

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