MSW handling of top 5 leading waste-producing countries in Southeast Asia

I S Arumdani*, A S Puspita¹, M A Budihardjo¹

¹Department of Environmental Engineering, Faculty of Engineering, Universitas Diponegoro 50275, Indonesia
indahsekar21@gmail.com

Abstract. In 2050, World Bank predicts up to 3.4 tonnes of solid waste generated worldwide. According to Jain (2017), Indonesia, Thailand, Vietnam, Philippines, and Malaysia are the top 5 countries producing enormous waste in Southeast Asia, producing 64, 26.77, 22, 14.66, 12.84 million tons, respectively. Countries in Southeast Asia contribute 1.14 kg/capita/day of waste worldwide; improperly controlled solid waste leads to environmental pollution and generates greenhouse gases. Therefore, this study will discuss further and compare the handling of MSW by the five most waste-producing countries in Southeast Asia. All countries in Southeast Asia produce solid waste dominated by organic waste as much as 50-70% of the total waste. Another waste composition varies between countries. Waste handling in each country, from source to disposal, is different. For example, Malaysia has not implemented waste composting while Indonesia and Thailand is the only country that conducts waste bank program. Above all, waste composition and infrastructure conditions play an essential role in determining the most suitable countries’ waste handling approaches.

1. Introduction
The increase in population growth and high living standards causes the consumption of energy and goods to increase and causes municipal waste to grow. Urban waste can come from households, offices, small-scale institutions, and commercial companies [1]. Increased waste production affects environmental sustainability such as air pollution, water, greenhouse gas emissions. Various efforts to implement environmentally friendly waste management must be carried out for future generations [2]. World Bank predicts that in 2050, up to 3.4 tonnes of municipal solid waste (MSW) generated worldwide [3]. According to Jain [4], countries in Southeast Asia contribute 1.14 kg/capita/day of MSW worldwide. Indonesia ranks first as the largest MSW producer in Southeast Asia with 64 million tons/year, followed by Thailand with 26.77 million tons/year, Vietnam with 22 million tons/year, the Philippines with 14.66 million tons/year, and Malaysia with 12.84 million tons/year.

The composition of urban waste from the five largest producing countries mentioned above varies. According to Nanda and Berruti [1], the composition of urban waste can be from kitchen waste and yard waste originating from biodegradable fractions, cardboard, plastic, metal, glass, inert materials, electronic waste, from non-biodegradable fractions. All countries in Southeast Asia produce municipal solid waste dominated by organic waste as much as 50-70% of the total waste; however, another waste composition varies between countries. For example, Indonesia disposes of more plastic waste with 14% compared to the Philippines, producing only 10.55% of plastic waste from the total waste composition. However, the metal waste produced in the Philippines is 10% more than in Indonesia, which only has
4.3% of the total waste. This variation in the composition of municipal solid waste allows for different handling from source to disposal between countries.

The basic handling of MSW usually consists of three stages: the source of waste production, collection and transfer of waste, treatment, and disposal [1,5].

Handling upstream to downstream must be carried out correctly to prevent adverse effects on health and the environment. Such as in landfills that can pollute the groundwater environment from the formation of harmful greenhouse gases and leachate [6,8]. There are not many studies or articles that discuss the handling of MSW in Southeast Asian countries, even though they contribute a large amount of waste in the world. Therefore, this study will discuss further and compare the handling of MSW by the five most waste-producing countries in Southeast Asia. This study can provide insight for the community and local government on handling MSW from the perspectives of five different countries.

2. Methodology
This study uses a narrative review method from various relevant articles. The main characteristics of this study are discussing and describing the handling of MSW among the five largest waste-producing countries in Southeast Asia. It can compare and summarize the entire study. Articles obtained from 80% of accredited journal sites (such as Google Scholar, Elsevier, Springer and Research Gate) with criteria (i) Indexed journals (ii) open access, (iii) full-text journals, (iv) Publications within the last ten years.

3. Results and discussion
3.1. The existing condition of waste handling in Indonesia
Figure 1 presents the composition of MSW produced in Indonesia, dominated by organic or food waste, followed by plastic waste. In contrast, the composition of the least waste found in glass waste is 1.7%. Handling of waste starts from collection and storage. The diversity of waste composition requires that waste be separated from the source before it is collected. However, according to Jain [4], the percentage of waste separation in Indonesia is still running at less than 50%. Most people still mix all types of waste. Therefore, the waste bank is currently developed to reduce the waste that goes to the landfill, especially organic waste, which dominates the amount of waste produced. In addition, this program is expected to increase the welfare and public awareness of the environment [9]. In this waste bank managed by local community groups, waste is sorted. Types of organic waste will be processed with composting technology. In contrast, inorganic types will be recycled to become valuable that can be used or resold [10].

Not all waste is taken to the waste bank; some residents choose that the waste they produce is directly transferred using a tricycle motorbike and a cart to a temporary waste disposal site (MRF). Furthermore, the waste is transported to the landfill using trucks provided by the government. A landfill is still the best choice at the final stage of MSW handling because the remaining residue must be disposed of or dumped in the landfill [11]. The residual waste obtained in Indonesia comes from waste that is not recycled or composted and is stored in MRF. Therefore, Indonesia’s recycling rate is less than 50% [4].

Most of the landfills in Indonesia are mainly still using open dumping in order that it has the potential to cause water, soil, and air pollution. In addition, even though it was chosen as an alternative for handling MSW in Indonesia, it does not mean that landfill does not cause other problems. One of them is a decrease in aesthetics due to accumulated waste. Some complaints from the community, such as reducing comfort, endangering health, and limited land, are reasons that can cause social conflict [12].

3.2. The existing condition of waste handling in Thailand
The composition of MSW produced in Thailand is presented in Figure 1, dominated by organic or food waste by 64%, followed by plastic waste, the same as Indonesia. Still, the percentage is almost 4% larger. In comparison, the composition of the least waste found in rubber and grass waste with a percentage of 1%. According to Hayat and Sheikh [13], waste management in Thailand consists of waste generation, separation or processing from source and storage, collection, transportation, processing, and
disposal. Segregation of organic and non-organic waste from each house has become the obligation of the Thai people. However, in some areas, the lack of labelled or coloured waste-can facilities to provide different containers for recycling waste and food scraps causes many residents not to do segregation [14]. In Indonesia, the waste bank method is one way to solve this problem and has been successful in various sectors such as schools, universities, and communities.

Furthermore, temporary waste collection points in Thailand are spread at several points per area. However, the collection points sometimes move, and the schedule is not fixed. People are confused about the location to throw their waste and often put them on the side of the road. Although the waste on the road will later be picked up by the transport truck to the landfill, the waste causes an unpleasant odour and disturbs the view [15].

However, there was also a permanent waste collection point in Bangkok named "transfer station". At that location, workers will separate waste, and organic types will be processed using composting technology. The waste will be transported by truck from the house or building before going to the landfill. Furthermore, the waste is wrapped in plastic to prevent waste from being scattered [16].

The recycling program or 3R has also not been carried out well by Thai residents seeing the relatively low recycling rate and relying on scavengers [16]. This situation is also evidenced by a report from Jain [4], which states that the recycling rate of plastic waste types dominates less than 50% and recycles more waste from construction activities and metal types [4]. Plastic waste in Thailand comes from municipal and industrial waste, increasing by 2 million tons annually over the last decade. So incineration was chosen to destroy plastic waste, and the emission of toxic gases from the combustion caused concern [17]. Another alternative chosen is landfilling; Thailand uses two landfill technologies, namely open dumping and sanitary.

### 3.3. The existing condition of waste handling in Vietnam

Figure 1 presents the composition of MSW produced in Vietnam, dominated by organic or food waste, followed by plastic waste. In contrast, the composition of the least waste found in textile and grass waste is 0%. Waste management in Vietnam consists of minimizing and segregation from source, collection, transport, reuse, recycling, and waste disposal [18]. Segregation of waste from the source should be carried out by every household with facilities in two types of waste bins of different colours, blue for organic waste and grey for non-organic waste [19]. However, according to Thai [20], not all households sort their waste and end up in the landfill.

Furthermore, the waste is collected using carts (open and automatic transfer system to trucks) with collection times at night to avoid traffic jams and high temperatures during the day. For narrow streets, waste can be collected using a rickshaw. Organic waste that has been sorted is then processed into compost. Each household carries out this processing in rural areas, but factories assist it [21]. Composting takes about 45 days to be used as plant fertilizer, 1 ton of waste can produce 600kg of compost. However, most factories do not operate optimally due to difficulties in marketing compost products [19].

Inorganic waste will be recycled, but scavengers and small household/commercial recyclers will mainly carry this activity. Most households in Vietnam that separate their waste will sell inorganic types to recyclers or craft villages. This activity can reduce waste by 15-20% [20]. Incineration technology is also applied in several areas in Vietnam because it can reduce the volume of waste by 80-90%. Still, it is not widely used because of high investment costs and causing pollution problems. Therefore, landfill technology becomes the choice with open dumping and sanitary methods. Vietnam has 16 sanitary landfills, and the rest is open dumping which is unhealthy. The landfill has a leachate collection system, a gas collection system, and a poor geo-membrane layer. In addition, many cities do not have landfills, so they carry out illegal dumping in rivers, lakes, drainages, and vacant land [21].

### 3.4. The existing condition of waste handling in the Philippines

The composition of MSW produced in the Philippines is presented in Figure 1, dominated by organic or food waste at 52%, followed by metal waste at 14.6%. At the same time, the composition of the least
waste found in rubber and grass waste with a percentage of 1%. Waste management in the Philippines includes separation and collection, transportation, treatment, and disposal, 3R [22,23]. Waste should be separated based on biodegradable and non-biodegradable, so waste cans are provided with different colours [23]. However, according to Camarillo et al. (2021), the facilities provided for waste bins are still lacking. They have become a barrier to the segregation of waste from each house [24].

Waste collection and transportation in the Philippines have criteria that must be met. Officers are encouraged to use PPE, pick up waste on time, and waste collection trucks have lids to avoid pungent odours. These criteria have been met, but due to several things, such as the waste collection site's capacity and the community's poor attitude, officers cannot collect all waste [24]. Most recycling activities are carried out and assisted by primary waste collectors, especially scavengers at landfills. The most collected waste consists of paper, aluminium, plastic, and metal [23]. Most waste generated after organic waste is metal, so processing with refuse-derived Fuel (RDF) to produce fuel has been practiced. According to Semen Global (2013), the waste conversion rate from the Philippines reaches 25-35% [25].

Subsequent waste management is composting, but not many households carry out this activity. As a result of not being facilitated with special training and there is no room for composting. Unprocessed waste will be disposed of in landfills. The Philippines uses sanitary landfills, but their numbers decrease due to a lack of impermeable layers, gas control systems, and adequate ground cover [23]. Meanwhile, controlled landfills are being developed to be sanitary. However, they still require equipment such as non-biodegradable and non-recyclable waste covers [24].

3.5. The existing condition of waste handling in Malaysia

Figure 1 presents the composition of MSW in Malaysia dominated by organic or food waste by 45%. In comparison, the least waste is found in rubber and textile waste with a percentage of 0%. Although it is dominated by organic waste, composting activities are rarely carried out in Malaysia because the market for selling compost is not available [4]. Segregation of waste from sources is divided into recycled and non-recycled waste, carried out voluntarily by each household [26]. Lack of awareness of the environment causes only a few households to sort waste [27,28]. According to Aja et al. (2014), waste collection from each household in Malaysia is carried out with a system of 2 days for residual waste and one day for recycled waste [29]. This system is a door-to-door collection, but the collection schedule has not been correctly regulated for rural areas. Many wastes are left behind and cause people to make their own illegal small waste disposal [28,30]. The waste is then transported by truck to a temporary waste collection point.

Waste recycling activities in Malaysia are recommended for every household. Lack of adequate facilities and inappropriate recycling locations are why this activity does not run smoothly [28]. In addition, according to Jain (2017), these inadequate facilities also cause the recycling results to decrease in quality [4]. Therefore, Malaysia uses incineration technology to destroy waste [29]. Strict controls must be in place to avoid emitted pollutants that harm human health and the environment. As much as 80% of the remaining waste is disposed of in landfills which causes landfill capacity to reach its limit, land for opening new landfills is difficult to find [31]. Most of the landfills in Malaysia still use open dumping; only 10% are already sanitary landfills [28].
3.6. Comparison of waste handling between five countries in Southeast Asia

The stages of handling municipal waste in various Southeast Asia are similar, and the practice is different. Waste management begins with separation from the source by providing different coloured waste cans for organic and non-organic waste. Implementing these activities in five countries has not been maximized due to the lack of public awareness of the importance of segregation waste for the environment. Meanwhile, in Thailand, Vietnam, and the Philippines, the lack of storage facilities is the main reason for not segregation waste. Therefore, in Indonesia and Thailand, waste banks were developed to solve this problem. Segregation and recycling activities at the waste bank can reduce the accumulation of waste and the carbon footprint in the landfill. Even in one landfill in Indonesia, there is a reduction in the carbon footprint of 72% by recycling 1,865 tons of waste/year [12].

Furthermore, average collecting waste from sources to temporary waste disposal sites (door-to-door collection) using carts, tricycles, and trucks has been going relatively well. Waste collection in Vietnam has a different method done at night to avoid traffic jams and high temperatures during the day. Meanwhile, Malaysia has a 2-day system of collecting organic waste and one day of recycling to be more aware of segregated waste. However, in Thailand, the schedule and location for collection are not fixed, so in some areas such as Bangkok, there are transfer stations that are permanent waste collection points.

Segregation of organic and non-organic waste will lead to composting and recycling. Of the five countries, only Malaysia does not do composting because there is no market to sell the compost. Organic waste is directly disposed of in the landfill. Meanwhile, in the Philippines, it has not been going well due to not being facilitated in advance by training. In addition, in Thailand, compost processing is assisted by factories to keep this processing running in urban areas. Recycling activities are highly recommended but have not been implemented optimally by each household in the five countries. The countries of Indonesia and Thailand do waste recycling with the waste bank program. In addition, in Thailand and the Philippines, more scavengers are assisted. It is also true in Vietnam, where scavengers and craft villages can recycle and reduce waste by 15-20%.

![Figure 1. Comparison of MSW composition between five countries [4].](image-url)
Municipal waste processing by incineration occurs in Malaysia due to recycling activities that are not running smoothly. This condition can happen due to the lack of facilities and locations to decrease the quality of recycled waste. Waste incineration has also been implemented in Vietnam but discontinued due to high costs and environmental problems. In addition, although Thailand does recycling, plastic waste, which dominates, is only recycled with a percentage of less than 50%. So incineration was chosen to destroy the waste. Other waste processing, such as Refuse-derived Fuel (RDF), is widely carried out in various regions in the Philippines. Due to the dominance of metal waste, this processing is carried out to be converted into fuel.

The final stage in managing municipal solid waste in each country is the transportation and final disposal. Transportation to final disposal is carried out using waste trucks provided by the local government. Most of the landfills owned by the five countries are open dumping and controlled landfills; only a tiny proportion use sanitary landfills. Inadequate facilities make the landfill unworthy of being recognized as a sanitary landfill, such as a leachate and gas collection system. In addition, in Vietnam, some areas do not have landfills and carry out illegal disposal. Meanwhile, in Vietnam, the landfill capacity has exceeded the limit, so it has to open up new land. Handling municipal waste in landfills should be given more attention.

4. Conclusion
The purpose of this paper has been achieved, namely to discuss further and compare the handling of waste by the five largest waste-producing countries in Southeast Asia. Although the five countries have a waste composition dominated by organic waste with 50-70% of the total waste, other wastes vary in number. This situation makes a difference in handling waste from source to final disposal. Generally speaking, it consists of segregation, collecting, processing, transporting, and final disposal. However, only Indonesia and Thailand have developed waste bank programs to sort and recycle waste. Meanwhile, in waste processing, the countries of Malaysia and Vietnam choose incineration to destroy plastic waste. In addition, refuse-derived fuel (RDF) processing is widely carried out in various regions in the Philippines because waste is also dominated by metal. Of all countries, only Malaysia does not compost organic waste. It can be concluded that waste composition and infrastructure conditions seem to play an essential role in determining the most suitable of countries’ waste handling approaches.

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