Municipal solid waste management in small and metropolitan cities in Indonesia: A review of Surabaya and Mojokerto

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Abstract. The increasing urban population has triggered a complex waste problem in Indonesian cities. Since the 1960s, waste generation in Indonesian urban areas has increased exponentially. Considering that municipal solid waste management (MSWM) is a case-by-case issue, MSWM practices vary on the municipal level. This article aims to explore the implementation of MSWM in small and metropolitan cities. By distinguishing cities by their typology, this article hopes to understand the similarities and differences of MSWM characteristics. This study uses a case study approach in which Surabaya represents metropolitan cities and Mojokerto represents small cities. The paper compares the current conditions and challenges of MSWM. This study is based on a literature review but also includes simple statistical analysis to strengthen the arguments in this paper. The review found that there are differences in the implementation of MSWM in Surabaya and Mojokerto in almost all aspects. Surabaya faces more complex problems and challenges and comes up with several solutions such as cooperation with a Japanese city and it is tackling human resources issues. On the other side, MSWM in Mojokerto is mostly government-centered and the city still has to handle institutional limitations such as regulatory issues, limited resources, and lack of participation.

1. Introduction
Over the last decades, rapid urbanization in Indonesia has triggered various environmental issues. One of the most eminent issues is municipal solid waste management (MSWM). In line with Indonesia’s booming urban population since the 1960s [1], waste production in urban areas has increased significantly. Notably, Indonesia’s municipal solid waste (MSW) production has reached 0.8 – 2.1Kg/capita/day [2]. The national government has implemented various regulations to manage this enormous amount of waste. Indonesia has drafted various MSWM policies since the 1970s when the government included MSWM in the third (1979-1984), fourth (1984-1989), and fifth (1989-1994) medium-term development plans. This was followed by the initiation of the Adipura program (the award for the cleanest municipality) in 1989 and the establishment of the Indonesian Environmental Impact Management Agency (Bapedal) in 1990. In brief, waste management issues have been an important issue in Indonesian development plans until the waste management law was enacted in 2008.
(Law 18/2008). This law is operationalized through various operational regulations on the provincial and municipal level [3].

On the municipal level, there are various approaches to MSWM across the country. Numerous studies have addressed how Indonesian city governments deal with waste problems from various perspectives such as sustainability [4–6], management [3,7], community participation [8,9], social aspects [10], and technology [11,12]. Considering that the approach to MSWM is a case-by-case issue and strongly depends on regional characteristics and challenges, studies on MSWM in Indonesian cities have addressed a wide range of issues. Most studies focus on describing the methods and approaches of a certain city in managing solid waste, whereas more general discussions of this issue are still limited.

This research will review MSWM in Indonesian cities based on city size typologies (see Table 1) to address this gap in research. Specifically, the study compares the current MSWM conditions in small and metropolitan cities (consisting of metropolitan and larger metropolitan areas) as well as the challenges. A brief list of several cities as examples of small and metropolitan cities can be seen in Table 2. These typologies are chosen to contrast the different situations and challenges of these city sizes. For instance, small cities are characterized by economic specialization, hinterland stagnation, strong dependence on macro policies, and low investment in public facilities [13,14] while larger metropolitan cities are associated with the opposite. This paper is a descriptive study that relies on qualitative data. The data and information are obtained by reviewing the relevant literature and policies.

| Table 1. City typologies based on population size [15]. |
|--------------------------------------------------------|
| City Typologies | Population         |
|-----------------|--------------------|
| Small Cities    | 50.000 – 200.000   |
| Medium Cities   | 200.001 – 500.000  |
| Metropolitan Cities | 500.001 – 1.5 mil |
| Larger Metropolitan Cities | More than 1.5 mil |

| Table 2. List of cities. |
|--------------------------|
| Typologies | Cities                  |
|-------------|-------------------------|
| Small Cities | Sawahlunto, Solok, Pariaman, Tidore Kepulauan, Magelang, Kotamobagu, Bukittinggi, Mojokerto, Payakumbuh, Pagaralam, Blitar, Pare-Pare, Tebingtinggi, Bau-Bau, Metro, Langsa, Madiun, Palopo, Tarakan, Prabumulih, Pasuruan, Lhoseumawe, Tanjungpinang, Bitung, Ternate, Lubuklinggau, Probolinggo, Tegal, Banjarbaru |
| Metropolitan Cities | Jambi, Cimahi, Pontianak, Balikpapan, Tasikmalaya, Banjarmasin, Samarinda, Malang, Denpasar, Bogor, Pekanbaru, Batam, Makassar, Palembang, Semarang, Depok, Bandung, Bekasi, Surabaya, Jakarta, Medan |

2. Waste generation
Solid waste management is an inevitable aspect of urban governance. The amount of MSW generated depends on various factors, e.g., economic activities, habits, population size, and the degree of commercial or industrial activities. In general, the amount of MSW in Indonesian cities increases more than twice the rate of population growth [16]. This phenomenon is related significantly to rapid urbanization. However, considering that small cities are unique [14], waste problems in small cities are different than in Indonesian metropolitan cities. In the case of India, MSW generation rates in small cities are lower than in metropoles [17]. The same phenomenon occurs in Indonesia where the rate of MSW generation of small cities is 0.64 kg/capita/day whereas metropolitan cities produce 0.75 kg/capita/day.
Furthermore, two factors that can be clearly observed in comparing waste generation are the standards of livings (Figure 1a) and economic growth (Figure 1b) [18]. These factors indicate the consumption and production of goods and services which will affect waste generation. The correlation is as follows: a higher standard of livings will trigger higher consumption of goods and, therefore, the waste generation will also rise. Whereas higher economic growth means an increasing number of goods and service is produced, which will lead to an increased waste generation.

The Human Development Index (HDI) is a variable that is often used to represent communities’ standard of living. The average HDI value of small Indonesian cities is 74.80. This is lower than Indonesian metropoles which have an average HDI of 77.48. Furthermore, a simple spearman correlation analysis is conducted to see to what extent HDI affects MSW generation rates. The analysis shows a greater correlation value (R=0.301) for metropolitan cities compared to small cities (R=-0.069). Even though the correlation is not significant, this result indicates that citizens in metropolitan cities are more sensitive to an increase in the standard of living. Consequently, for every increase in the standard of living in metropolitan areas, the citizens will consume more goods and generate more waste than in small cities. In contrast, waste generation by the citizens in small cities does not increase significantly with an increase in their standard of living. The same pattern occurs for the economic variable where metropolitan cities show a greater correlation (R=0.504) than small-sized cities (R=0.360).

![Figure 1. MSW generation rates vs HDI (a), and MSW generation rates vs GDP per capita (b) in Indonesian small and metropolitan cities.](image)

### 3. Sources of waste

Besides the amount of waste, the source of waste is another important variable in developing adequate waste management strategies. Data on sources of waste are useful in defining the object of MSWM. Figure 3 shows the proportion of sources of waste for small and metropolitan cities. It can be observed that the sources of waste differ only slightly among the two city typologies. However, the percentage
of each source is quite different for small and metropolitan cities. Households are the largest waste generator in both typologies at 62.50% in metropolitan cities and 63.55% in small cities. Differences can also be observed in other sources such as traditional markets, the commercial sector, and offices. The traditional markets in small cities produce more waste than in metropolitan areas. This is because traditional markets in small cities are still regularly visited [13]. In metropolitan areas, these markets have gradually been abandoned in favor of supermarkets since direct investment in the retail sector was allowed in 1998 [19]. The same phenomenon is observed for offices that generate a greater share of waste in small cities than in metropolitan cities. On the contrary, commercial areas in metropolitan cities generate a larger share of MSW than in small cities due to the density and complexity of activities in metropolitan commercial areas.

![Figure 2. MSW sources in Indonesian small cities (a) and metropolis (b).](image)

4. MSWM in small and metropolitan cities: Comparing Mojokerto and Surabaya cases

This paper will review MSWM in small and metropolitan cities by using case studies. Surabaya was selected to represent metropolitan cities whereas Mojokerto represents small cities. These cities will be compared to emphasize the similarities and differences in the implementation of MSWM as well as the challenges related to it.

4.1 Storage and collection

The waste storage and collection processes in Surabaya (as a metropolitan city) and Mojokerto (as a small city) are mostly similar. However, Surabaya applies more advanced waste reduction and processing. In Surabaya, domestic waste is collected from 240 community waste banks [20] and 183 communal bins [21] before being transported to landfills. The waste collection from households is carried out by using carts, motorcycles, or trucks. The waste banks separate and recycle waste to reduce the amount of waste that is transported to landfills. Organic waste is converted into compost using Takakura Home Composting (THC). Surabaya adopted this method as part of a partnership between the local Cleaning Agency (Dinas Kebersihan dan Pertamanan) and Kitakyushu City (Japan). Meanwhile, non-organic recyclable waste will be sorted and processed into valuable goods. Waste collection in waste banks is a communal effort by the community, consisting of sorting, collecting, and saving-sharing. The sorting of waste in communal bins and landfill is mostly done by scavengers and other workers from the Cleaning Agency.

In Mojokerto, the storage and collection of MSW are not as advanced as in Surabaya. In fact, communities just dispose of their waste in a bin in front of their own house. Most of Mojokerto communities are unfamiliar with waste separation and reduction, so only a small number of
communities implements this. Moreover, on the household level, only around 1.1% of households separate waste while 1.9% also tries to reduce the amount of waste that they generate [22].

4.2 Transfer and transport
In general, the transfer and transport of waste are quite similar in small and metropolitan Indonesian cities. In terms of household waste, communities collectively transfer their waste to temporary waste dump sites (TPS) by hiring waste workers who usually use carts or tricycles. However, in some neighborhoods in Surabaya, specifically the upper-middle-income neighborhoods, dump trucks are used to accommodate a greater range of services and a larger amount of waste that is produced. In Mojokerto, the head of the sub-district (camat) and/or the head of the village (lurah) are responsible for the waste collection from household to the TPS [22]. Residents just have to provide a bin in front of their house. After the waste is brought to the TPS, it will be transferred to landfills. This is generally carried out by the government. The size and types of vehicles and transfer frequencies depend on the amount of waste generated and the government’s financial capacities. Surabaya has 173 dump trucks and 630 carts that transport waste on a daily basis [21]. Meanwhile, Mojokerto only has 65 carts, 26 tricycles, and 4 dump trucks [23]. This armada is just enough for collecting around 80% of the generated waste [24]. This condition leads to illegal and unwanted waste practices such as backyard burning and littering [18].

4.3 Landfilling
In Indonesia, landfilling is still considered as the best alternative for ultimate disposal since other options produce residue which must be disposed of in landfills [17]. Moreover, landfilling is relatively cheap compared to other waste management options [25]. Surabaya has one final disposal site in Benowo which has a capacity of 4807 m³. Around 95% of Surabaya’s MSW is disposed of in this landfill [26]. Meanwhile, the remaining waste is composted in communal and household bins or is burned in mini incinerators. Technically, Benowo was designed as a sanitary landfill. However, due to insufficient resources, it has become an open dumpsite with a controlled landfill system. Over 1000 scavengers work daily at the dumpsites, separating and collecting waste [27]. Mojokerto also has a controlled open dumping landfill in Randegan with a capacity of 20m³/day. This is equivalent to around 0.2% of the generated waste in the city.

4.4 Involvement of other parties
Several small and metropolitan cities have involved other parties in MSW management. The most popular scheme is through CSR in which the private sector provides waste management facilities (e.g. waste banks, communal bins, waste processor tools) that are managed by communities. In terms of cooperation, Surabaya is one of the best examples in Indonesia. The city has involved several parties such as communities, environmental cadres, facilitators, NGOs, other government institutions, and the media. A very successful cooperation is with Kitakyushu City concerning education and promoting waste separation on the household level. This scheme implements the converting of organic waste into compost using the Takakura Home Composting (THC) method [28]. Another successful cooperation in Surabaya is between the government, ULI Peduli (a Local NGO) and Unilever Indonesia (a private company). This cooperation aims to promote waste management at the household level by developing waste banks and empowering environment cadres as waste bank operators [27]. Small cities like Mojokerto still lack cooperation in MSWM. In fact, there is no cooperation scheme between the government and other parties or a regulation to arrange this [23]. Thus, despite the government’s limited budget, MSWM in Mojokerto still government-centered. Table 3 presents a comparison of each variable of MSWM in Surabaya and Mojokerto.
Table 3. Comparison table.

| Variables             | Surabaya                                                                 | Mojokerto                                                               |
|-----------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Storage and Collection| • Community waste banks                                                   | • Communities just put their waste in a bin in front of their house     |
|                       | • Waste separation is done by households and waste banks                 | • Lack of waste separation and reduction                                |
| Transfer and Transport| • Collective waste transfer from household to temporary waste dump sites by waste workers | • Collective waste transfer from household to temporary waste dump sites coordinated by the head of the village and/or sub-district |
|                       | • Using carts, tricycles, and dump trucks                                | • Using carts, tricycles, and dump trucks                                |
|                       | • The government is responsible for transporting waste from the temporary dump sites to landfills | • The government is responsible for transporting waste from the temporary dump sites to landfills |
| Landfilling            | • Open dumping site with a controlled system                             | • Open dumping site with a controlled system but with limited capacity |
| Involvement of Other Parties | • Multi-actor cooperation which involves private sectors, NGOs, communities, and government institutions | • No cooperation (government-centered MSWM)                            |

5. MSWM challenges in small and metropolitan cities

MSWM in Indonesian cities is becoming increasingly complex [7]. Numerous researches, projects, and publications have addressed various challenges (e.g. [2]; [7]; [29]; [30]; [31]). This paper views the challenges of WSWM in the context of Surabaya and Mojokerto. In general, the challenges can be grouped into three categories: 1) institutional and financial; 2) technical; 3) community education.

5.1 Institutional challenges

Institutional challenges mostly refer to poor implementation of current policies (national, provincial, municipal level), inter-stakeholder cooperation and insufficient money to funds MSWM programs. Despite several differences regarding MSWM challenges in small and metropolitan cities, these problems occur in most Indonesian cities. Law number 8/2008 on waste management has not specifically regulated MSWM practices on the national level. Hence, there are no specific national MSWM standards and municipal level regulations are often adjusted to the local limitations [7, 31].

The Surabaya government has enacted city regulation 5/2014 which regulates MSWM comprehensively, while Mojokerto still lacks such comprehensive MSWM regulation [23]. Consequently, MSWM in Mojokerto is more of a sectoral business rather than a comprehensive multi-actor movement like in Surabaya. Funding issues are also related to this; due to its established regulations and mechanisms, Surabaya can cooperate with other parties in order to share responsibilities and costs, while Mojokerto cannot. Thus, this paper argues that the institutional challenge of Surabaya is how to make MSWM more efficient and sustainable, especially the approach and mechanisms. Meanwhile, Mojokerto still faces the fundamental problem of how to manage MSW.

5.2 Technical challenges
Inadequate MSWM facilities are an issue in most Indonesian cities. This is caused by the institutional and financial issues that have been addressed above. Technical issues occur in all aspects of MSWM. In terms of waste collection, Surabaya and Mojokerto experience similar problems as most Indonesian cities. Notably, animals thrive in the temporary dumpsites [7,29]. The presence of waste pickers or scavengers also leads to other problems. They often randomly shuffle the waste when searching for recyclable materials [7], scattering the garbage around the temporary dump sites.

As for technical challenges related to transfer and transport, improper vehicles and transport infrastructure are considered as the main issues. Surabaya has larger service coverage (86%) than Mojokerto (around 50%). Yet, there are still areas in both cities with no MSWM, especially in low-income neighborhoods or slum areas where roads are too narrow for waste vehicles [7]. In some cases, these issues can be overcome when waste officers manually collect waste by walking through the slums. However, in other cases, this issue leads to unwanted waste practices such as backyard burning (mostly in Mojokerto) and littering in the river or the drainage system in metropolitan slum areas. This is exacerbated by the limited number of transport vehicles, particularly in Mojokerto because of limited financial resources, and irregular transport schedules.

Other technical problems relate to the ultimate disposal. Notably, most Indonesian landfills do not meet the standards for controlled landfills nor - in most cases - sanitary landfills [30]. Leachate from the Benowo Landfill (in Surabaya) and the Randegan Landfill (in Mojokerto) cause environmental problems in the surrounding areas. In Benowo, leachate is caused by leakage of pipes [32] whereas in Randegan, it is due to improperly management [22].

5.3 Educational challenges

Another major problem in all Indonesian cities is a lack of awareness, knowledge, and expertise in sustainable MSWM practices. From the waste generation perspective, low public awareness of the importance of waste separation and 3R (Reduce, Reuse, Recycle) hinders the implementation of these programs in most Indonesian cities [33]. However, Surabaya is a success story of waste separation and 3R implementation after the city started building public awareness by conducting community training programs [8]. This will boost the effectiveness of waste management systems by increasing communities’ sensitivity and willingness to participate in waste management programs [18,34]. From the perspective of MSWM service provision, the capacity of waste officers is also important. In many cases, the limited capacity of the personnel inhibits the implementation of technology and more complex waste management programs [29]. As Surabaya did, this human resource issue is the first aspect government must address to achieve a more efficient MSWM system. Conversely, Mojokerto does not pay much attention to this issue. This can be seen from the percentage of the community that participates in waste separation and reduction programs which is only around 1% [22].

| Challenges       | Surabaya                                                                 | Mojokerto                                           |
|------------------|--------------------------------------------------------------------------|------------------------------------------------------|
| Institutional    | • Establishing sustainable and efficient cooperation mechanisms          | • Lack of comprehensive regulations                  |
|                  | • Maintenance of waste facilities                                        | • Limited resources and financial capacities         |
|                  | • Implementation of technological improvements to reduce negative impacts| • Inadequate facilities and infrastructure            |
| Technical        | • A rapid increase in waste generation                                   | • Reducing illegal waste practices                    |
|                  | • Implementation of technological improvements to reduce negative impacts| • Unmanaged landfills                                  |
| Educational      | • Upscaling local movements                                              | • Lack of knowledge and awareness of waste generation|
|                  |                                                                         | • Lack of trained waste officers                      |

Table 4. MSWM challenges in small and metropolitan cities.
6. Conclusion
The aim of this paper was to identify the current conditions and challenges of MSWM practices in small and metropolitan cities in Indonesia. By studying two case studies, Surabaya and Mojokerto, the paper found that metropolitan cities like Surabaya face more complex problems than small cities like Mojokerto. This is due to the complexity of activities and the significant increase in waste generation. To tackle these problems, Surabaya has implemented various approaches in almost all aspects of MSWM including institutional and funding mechanisms, participative schemes, and the application of technological improvements. On the other side, Mojokerto still struggles to provide adequate MSWM because of limited resources. Mojokerto even lacks the most fundamental aspect, i.e., a comprehensive regulation that can serve as the basis for MSWM. This causes MSWM in Mojokerto to be government-centered.

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