Waste management in integrated waste management facility (TPST) of Piyungan to achieve climate resilience through local institutions

E Y Setyawati1,3,4, MTh S Budiastuti2, M Wijaya2 and P Setyono2

1 Doctoral Program in Environmental Sciences, Graduate School, Sebelas Maret University, Jl. Ir. Sutami 36 A, Keningtang, Surakarta, 57126, Indonesia
2 Lecturer in Environmental Sciences, Graduate School, Sebelas Maret University, Jl. Ir. Sutami 36 A, Keningtang, Surakarta, 57126, Indonesia
3 Lecturer at Kartika Bangsa University of Social and Political Sciences (STISIP) Yogyakarta, Indonesia
4 Corresponding author: yuningtyas06@yahoo.com

Abstract. Greenhouse gases (GHG) such as CH₄ and CO₂ are emitted from wastes at the Piyungan Integrated Waste Management Facility. Integrated Waste Management Facility is called as Tempat Pembuangan Sampah Terpadu in Indonesian, and abbreviated as TPST Piyungan. Both CH₄ and CO₂ gasses are potential to trigger climate change. Therefore, local institutions are required to intensify efforts towards preventing the harmful effect on climate change. This study aimed to determine the involvement of local institutions in handling waste problems in the TPST as one of the strategies to mitigate climate change. A qualitative approach was used to identify three factors of climate resilience including urban systems (infrastructure), social agents (stakeholders), and local institutions while quantitative scoring methods were used, based on the recommendations from the Intergovernmental Panel on Climate Change (IPCC), to determine the waste management strategies. The results showed the Integrated Waste Management Facility in Piyungan has not been able to reduce CH₄ emissions. The urban systems or infrastructure of the facility were found to be in a moderate while the social agents or stakeholders and local institutions were in a good category. However, the participation of local institutions has a major influence on climate change mitigation.

1. Introduction

Methane (CH₄) and Carbon Monoxide (CO₂) are one of the major sources of waste causing global warming. Therefore, waste segregation and the availability of integrated facilities are required to facilitate waste management and reduce the level of greenhouse gas emissions [1].

However, an integrated waste management facility leads to noise, scattered garbage, dust, air pollution, flies, and health problems [2] and poor waste management practices also trigger social conflicts. Climate change is directly or indirectly caused by changes in the composition of the global atmosphere and natural climate variability due to human behavior [3]. Moreover, mitigation of greenhouse gas (GHG) emissions is conducted through integrated climate change interventions and adaptations. However, understanding this concept determines the type of waste management to be implemented [4]. Waste management interventions are conducted through innovative activities oriented towards reducing landfill waste in the Piyungan Integrated Waste Management Facility. These efforts require institutionalization strategies to sort and process upstream wastes.
Climate change mitigation is a resilience effort to slow down or contain greenhouse gas emissions such as CH₄ released into the atmosphere through the optimization of waste [5]. The realization of the climate resilience area requires the successful reduction of greenhouse gas emissions (especially CH₄), the support of urban systems or infrastructure, and the involvement of social agents or stakeholders and local institutions.

Greenhouse gases absorb and reflect solar heat to maintain the proportionality of the earth's temperature and naturally keep it at a livable level. However, the recent increase in the amount of greenhouse gas is decreasing solar heat reflectance and increasing the temperature thereby negatively affecting life on Earth [6]. GHG is a product of the emissions from human activities, one of which is an unmanaged waste. In "Review on The Economics of Climate Change" (2006), Stren [7] argued that unmanaged waste increases GHGs by 3% due to the decay of organic waste to produce methane gas (CH₄) and carbon dioxide (CO₂) while the Ministry of Environment reported that 65% of all wastes are organic. Moreover, CH₄ has a greater adverse effect than carbon dioxide, for example, its heating effect is 23-times higher and it also has a relatively long-life span between 12-17 years.

Methane is produced from the decomposition of organic spoilage through several stages. First, aerobic decomposition is caused by the oxygen level of the waste to produce carbon dioxide (CO₂). Second, anaerobic decomposition due to decreased oxygen levels in the waste where nitrate and sulfate turn into nitrogen and sulfide acid. Third, there is a formation of low molecular compounds such as acetic acid (CH₃COOH) and several other complex organic acids to produce CO₂ and hydrogen. Fourth, there is fermentation of methane or the conversion of acetic acid and hydrogen compounds to CH₄ and CO₂ while the fifth stage includes the release of CH₄ and CO₂ continually. Naturally, CH₄ and CO₂ produced from rubbish heap accumulate in the atmosphere and GHG and after a while its density increases leading to accumulation of solar heat which further causes an increase in global temperature or global warming. However, GHG emissions can be mitigated through the process of reducing, reusing, and recycling (3R).

Waste is classified into organic, non-organic, and residue classes. Organic wastes are processed into compost to reduce the level of GHG emissions, while non-organic ones are sorted into recyclable waste and residue. The residue is taken to the integrated waste management facility. Therefore, waste management strategies are conducted to reduce the volume of waste and overcome global warming. This study aimed to determine the involvement of local institutions in handling waste problems in the TPST as one of the strategies to mitigate climate change.

2. Method
The sampling was conducted using purposive sampling which is a selection technique involving the use of certain criteria to obtain a reliable sample. There were 7 informants from the Yogyakarta Environmental and Forestry Office, Sanitation and Urban Water Infrastructure Management Office, the Public Works Office, the Sleman Environment Agency, Bantul Environment Agency, Yogyakarta City Environment Agency, the manager of Piyungan Integrated Waste Management Facility, and the leader of the garbage pickers group.

Qualitative analysis was conducted to identify the characteristics of urban systems, social agents, and local institutions while quantitative analysis was used to calculate the reduction of CH₄ and CO₂ gas emissions using the formula from the Intergovernmental Panel on Climate Change (IPCC). In addition, researchers also scored the characteristics of urban systems, social agents, and local institutions to determine their opportunities in waste management strategies.

3. Result and discussion
3.1. Waste management as a form of climate change mitigation
Wastes are able to produce methane (CH₄) emissions, which are 21 times more dangerous than Carbon Dioxide (CO₂), through the anaerobic decomposition of organic matter. Indonesia's climate change mitigation policy is regulated by Law No.32 of 2009 which involves the handling of climate change as
an effort to support sustainable national development. This is due to the commitment of the Government of Indonesia towards reducing greenhouse gas emissions by 26% independently or 41% with international assistance in 2020 [8]. However, waste mitigation in developing countries is mostly focused on improving waste management systems to ensure the reduction of greenhouse gas emissions is cheap and sustainable [9].

Tyler et al and Moench [10] stated that the realization of climate resilience requires urban systems, social agents (stakeholders), and urban institutions. Urban systems are infrastructure, ecosystem and knowledge systems used as part of intervention measures for climate change. Social agents (stakeholders) are parties involved in waste mitigation and management actions, both individuals (urban residents), households, and organizations (governmental, private, and community institutions) while local institutions are local groups assisting the process in TPST Piyungan.

This study showed the potential amount and economic value of recyclable waste and its effect on reducing methane gas emissions. The recycling optimization conducted by the Surabaya government is able to reduce the cost of waste management, methane gas emissions, and extend the use of wasteland [11].

3.2. Waste management strategy in the integrated waste management facility
The most basic management strategy involves the use of the 3R method of reduce, reuse, and recycle. This is usually conducted to reduce waste from its source, mostly households, and obtain added value socially, economically, and environmentally. It has been reported that ± 40% of the waste in the Piyungan Integrated Waste Management Facility is inorganic which is usually sorted and utilized by the scavengers and collectors. The waste management activities in the facility are conducted by garbage pickers that are members of the Mardiko Community and the people in the Community Self-help Group. At this level, the sustainability and progress of the process are determined by the will and desire of the communities.

3.3. Projections of CH4 and CO2 reduction in climate change mitigation
Methane (CH4) and Carbon Dioxide (CO2) emissions generated from this waste management facility increase with the waste volume. The Comparison of the Business-As-Usual (BAU) value, highest emission level in 2020, and emission value in Non-BAU conditions are shown in Table 1.

| Greenhouse gas from waste | BAU conditions (with a reference for emission reduction) | Standard Maximum Emission Value for 2020 (with a target of 26% of BAU conditions) | Non-BAU Conditions (The existence of waste management) | Percentage of impairment of emissions in non-BAU conditions (intervention) (%) |
|--------------------------|----------------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------|--------------------------------------------------------------------------------|
| CH4                      | 2.160                                                    | 1.932                                                                          | 1.456                                          | 32.59                                                                          |
| CO2                      | 2.410                                                    | 2.135                                                                          | 1.721                                          | 28.59                                                                          |

Source: Processing Results of 2019

The data above shows a decrease in the value of emissions in 2020 due to the involvement of local institutions in waste processing activities. The volume of garbage entering TPST Piyungan increases by 8.33% per year and the local institutions were observed to have reduced the amount of waste by 20%. The quality of waste management strategies is seen from its success in reducing emissions and the volume of waste entering the facility. In 2020, the volume of waste processed by local institutions will be 5 times greater than without their involvement (table 2). These results have been very helpful in reducing greenhouse gas emissions from non-managed waste methane gas compared to Wijayanti [12], where a third party (Narpati Co. Ltd.) was responsible for waste management by local institution within
the Mardiko community. Emission reductions are still lower, but the Mardiko community as a local institution still has a strategic role in reducing methane gas emissions in Piyungan.

**Table 2.** Comparison of emission value of each waste management strategy

| Years | Standard Maximum Estimated Value in BAU Conditions (standard 26%) | Estimated Value Without Involving Local Institutions | Value of Estimation by Involving Local Institutions |
|-------|---------------------------------------------------------------|----------------------------------------------------|---------------------------------------------------|
|       | CH₄ (Gg / year) | CO₂ | CH₄ | CO₂ | CH₄ | CO₂ |
| 2020  | 1.932           | 2.135 | 2.771 | 3.046 | 2.157 | 2.437 |

Source: Processing Results of 2019

3.4. **Opportunities for Waste Management Strategies in Climate Resilience**

The success of waste management interventions in TPST Piyungan is expected to overcome climate change and create resilience due to the opportunities created through their strategies and supports. The researcher assessed all categories determining the opportunities for each strategy and the results are presented in Table 3.

**Table 3.** Assessment of waste management strategy opportunities without involving local institutions

| Categories               | Criteria                  | Explanation                                                                 | Scores | Total scores |
|--------------------------|----------------------------|-----------------------------------------------------------------------------|--------|--------------|
| *emission reduction*     | emission reduction        | Optimization of waste management strategies has not been able to reduce the value of emissions | 1      | 1            |
| *urban system*           | Flexibility               | There are internal and external influences on the implementation of waste management strategies. However, both can run continuously | 3      |              |
|                          | Diversity                 | The implementation of waste management strategies has a variety of benefits, internally and externally | 3      | 7            |
|                          | Redundancy                | The opportunity to replicate waste management activities is very small       | 1      |              |
| *Responsiveness*         |                            | The waste management intervention strategy can be implemented, even though the mitigation action plan/policy is in the preparation stage | 3      |              |
| *Resourcefulness*        |                            | Funding for waste management is obtained from external parties, there is no new waste management strategy, and there is a lack of cooperation among parties | 2      |              |
| *social agent and local institutions* | capacity to learn | There are plans to optimize waste management and innovation activities (reforestation) | 3      |              |
|                          | local institutions         | The role of local institutions has not been maximized, but there are efforts to develop related policies | 1      |              |

Total 17

Source: 2019 Compiler Analysis Results Modified from Wijayanti [12]
Table 4. Assessment of waste management strategy opportunities in Piyungan integrated waste management facility in creating climate resilience by involving local institutions

| Categories          | Criteria          | Explanation                                                                 | Scores | Total scores |
|---------------------|-------------------|-----------------------------------------------------------------------------|--------|--------------|
| emission reduction  | emission reduction| The optimization of waste management strategies in TPST has not been able to reduce emissions by more than 26%. | 3      | 3            |
|                     | Flexibility       | There are internal and external influences on the implementation of waste management strategies. However, both can run continuously | 2      |              |
|                     | Diversity         | The implementation of waste management strategies has a variety of benefits, internally and externally | 3      | 6            |
| urban system        | Redundancy        | The opportunity to replicate waste management activities is very small      | 1      |              |
| social agent and local institutions | Responsiveness | The waste management intervention strategy can be implemented, even though the mitigation action plan/policy is in the preparation stage | 3      |              |
|                     | Resourcefulness   | Funding for waste management is obtained from external parties, there is no new waste management strategy, and there is a lack of cooperation among parties | 3      |              |
|                     | capacity to learn | The idea of forming a waste management tourism village was hampered by technical and non-technical constraints | 2      | 10           |
|                     |                   | The role of local institutions specifically in dealing with waste management has not been maximized. | 2      |              |
|                     |                   | Total                                                                         |        | 19           |

Source: 2019 Modified from Wijayanti [12]

The assessment in Table 4 shows both waste management strategies have the ability to create climate resilience. However, waste management strategies involving local institutions have greater potential with the rate of 19 while those without is only 17. The strategies have different criteria and they are shown in Table 5.

Table 5. The success of each waste management strategy in creating climate resilience

| Waste Management Strategy Without Involving Local Institutions | Waste Management Strategy Involving Local Institutions |
|----------------------------------------------------------------|-----------------------------------------------------|
| The most influential criteria                                  | The most influential criteria                        |
| 1. Urban system (flexibility and diversity)                   | 1. Emission reduction                                |
| 2. Social agent and local institutions (responsiveness and capacity to learn) | 2. Urban system (diversity) |
| 3. Local Institutions                                          | 3. Social agent (responsiveness and resourcefulness) |
| Less influential criteria                                      | Less influential criteria                            |
| 1. Emission reduction                                          | 1. Urban system (redundancy)                         |
| 2. Social agent (resourcefulness)                             | 2. Social agent (capacity to learn)                 |
| 3. Local Institutions                                          |                                                     |

Source: The 2019 Analysis Result
4. Conclusion
The involvement of local institutions of the Mardiko Community in Waste Management in the Integrated Waste Management Facility/TPST Piyungan can reduce the volume of waste and gas emissions of Methane (CH$_4$) and Carbon Dioxide (CO$_2$) as a cause of climate change. Therefore it is necessary to increase the empowerment of local institutions and support from the government and the private sector.

References
[1] Herlambang A, Sutanto H dan Wibowo K 2010 Produksi Gas Metana Dari Pengolahan Sampah Perkotaan Dengan Sistem Sel Jurnal Teknik Lingkungan 11 389-399
[2] Madhav R 2010 Untapped Potential: Securing Livelihoods Dependent on ‘Waste’. A Review of Law and Policy in India WIEGO Final Report
[3] Rahmat A 2013 Gas Rumah Kaca, Dampak, Dan Sumbernya. Pencemaran Udara (Bandung: Teknik Lingkungan, ITB)
[4] Kustiasih T, Setyawan L M, Anggraini F, Darwati S, dan Aryenti 2014 Faktor Penentu Emisi Gas Rumah Kaca Dalam Pengelolaan Sampah Perkotaan Jurnal Perumkan 9 78-90
[5] Klein, Richard J T dan Saleemul H 2007 Inter-Relationships Between Adaptation and Mitigation. Fourth Assessment Report (AR4): Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, UK: Cambridge University Press)
[6] Siahaan J 2016 Prediksi Kondisi Sampah di Tempat Pengelolaan Sampah Terpadu (TPST) Siosar dan Solusi Pemecahan Masalahnya Dalam Upaya Merentasi Gas Rumah Kaca Thesis Magister (Medan: Departemen Teknik Sipil. Universitas Sumatera Utara)
[7] Friedrich E and Trois C 2011 Quantification of greenhouse gas emissions from waste management processes for municipalities–A comparative review focusing on Africa Waste Management 31 1585-1596
[8] Peraturan Presiden Republik Indonesia No. 61 Tahun 2011 tentang Rencana Aksi Nasional Perubahan Iklim
[9] Bogner J, Pipatti R, Hashimoto S, Diaz C, Mareckova K, Diaz L, Kjeldsen P, Monni S, Faaij A, Gao Q, Zhang T, Ahmed M A, Sutamihardja R T, and Gregory R 2008 Mitigation of Global Greenhouse Gas Emissions from Waste: Conclusions and Strategies from The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation) Waste Management and Research 26 11-32
[10] Moench M, Tyler S, and Lage J 2013 Catalyzing Urban Climate Resilience (Asia: Asian Cities Climate Change Resilience Network: Indore Initiative)
Tyler S, Reed S O, Karenmacclune dan Chopde S 2010 Planning for Urban Climate Resilience: Framework and Examples from the Asian Cities Climate Change Resilience Network (ACCCRN) (Colorado: Asian Cities Climate Change Resilience Network)
[11] Suprapto 2016 Peran Daur Ulang Untuk Meningkatkan Pengelolaan Sampah Terpadu Di Kota Surabaya JRL 9 127-142
[12] Wijayanti W P 2013 Peluang Pengelolaan Sampah Sebagai Strategi Mitigasi dalam Mewujudkan Ketahanan Iklim Kota Semarang Jurnal Pembangunan Wilayah dan Kota 9 152-162