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ORIGINAL ARTICLE

Waste Reduction Effect on Methane Emission in Landfill

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Christia Meidiana, Thomas Gamse: Waste Reduction Effect on Methane Emission in Landfill.

ABSTRACT

Scavenging and composting contributes to waste reduction in Yogyakarta City. Waste reduction in composting centres and in Bendo Landfill done by the scavengers has been observed. The results showed that the recyclable material from Bendo landfill was plastics, paper, metal and glass. Waste reduction done by scavengers was about 7.5% and 12.8% for plastics and for paper respectively. Reduction on metal and glass were very small (below 0.01%) because most of the waste has been sorted by the scavengers before delivered to the landfill. Meanwhile, composting centres has reduced the organic waste from household about 10.33% of total organic waste. However, though the relatively significant waste amount reduction rate because of these two waste treatment methods, the methane emission reduction from 1993 until 2012 is inconsiderable. Without waste reduction, the methane emission is estimated about 8.78E+06 ton CO_{2eq} per year, whereas with waste reduction, the methane emitted from Bendo landfill is estimated about 8.71E+06 ton CO_{2eq} per year. It means that the scavenging activity and composting centers have contributed 1% reduction of methane emission. The small percentage of paper compared to that of organics waste in waste component causes the insignificant methane emission reduction in Bendo landfill, whereas the low capacity of composting centers led to slight contribution. The focus on reduction of organic component in municipal solid waste disposed of in landfill is likely to be an appropriate way to reduce methane emission from the landfill significantly.

Key words: landfill, scavenger, composting, waste reduction, methane emission reduction.

Introduction

The Waste Law no. 18/2008 was enacted in May 2008 by the Government of Indonesia (GoI) and covers issues related to public service principles, waste management, incentives and disincentives mechanism, funding scheme, shared responsibilities among waste authorities, private sectors participation, community based waste management and penalties for disobey. The local government has responsibilities to run the city or regency waste management based on the national and the regional waste law, to foster and to manage as well as to control and to evaluate the local waste management implementation. The local government has also authorities to decide the waste treatment method and final disposal site. The enactment of The Waste Law 18/2008 can be an opportunity, and also a challenge for the local government to improve the local waste management because the law addresses the environmentally sound waste management practices. Article 22 defines this clearly by emphasizing the implementation of environmentally friendly technology for final waste treatment, while Article 44 underlines the requirement of safe landfill practices. It obliges the local governments to have a planning of closing the old open dump site not later than one year after The Waste Law enactment, and to close the final disposal site with open dumping method not later than five years after The Waste Law enactment. Furthermore, Article 20 mentions about reduction recycle and reuse method (3R) for another method in municipal waste management. The Waste Law disobey can cause legal sanction and fines. Local Government of Yogyakarta, as the landfill operator, is required also to meet the law. As the old landfill will be closed in 2012, the government will construct a new landfill in a new site. Based on the previous study, a controlled landfill is appropriate for the new landfill for some local conditions such as high fraction of biodegradable waste and high moisture content, the nature of mixed waste, limited budget, limited infrastructure and equipment, lack of information system and scavenger's involvement (Meidiana, 2011). In controlled landfill, scavenging is allowed and believed as a contribution to waste reduction in landfill which can lead to reduction of methane emission from landfill. Since the Yogyakarta City has interest in reducing the waste tonnage transported to the new landfill,

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there are discussions among local decision makers about the involvement of scavengers in the new landfill. Some believe that reducing the waste by treating it as near as possible to the waste source is more effective than allowing the scavengers to sort the waste at the landfill site. Therefore, this study aims to identify and to analyze the actual condition of waste management in Yogyakarta with focus on scavenging and composting method in reducing waste delivered to the landfill and their impact on methane emission from the landfill. The result can be an input for the local decision maker in determining the policy related to the new landfill in Yogyakarta.

Material and Methods

Surveys for primary and secondary data have been carried out twice. The field survey aimed to examine the declared waste treatment in landfill and composting centers, to evaluate their performance and to measure the waste reduction carried out at Bendo landfill and composting centers. The first survey was conducted from January until March 2010 and the second was in October 2010. Data on municipal solid waste were collected from waste authorities in Yogyakarta City to identify the general municipal solid waste condition including the waste characteristic, the rate of waste generation, waste collection and waste transportation to the landfill. Secondary data on waste were mainly sourced from statistics on waste management in 2004 - 2010, Regency's/City's Profile, Waste Status Report 2007-2010, and composting data record in 2009. Survey for primary data was conducted by means of questionnaires to provide more recent data and through interview in order to follow-up the questionnaires answered by the respondents and to get in-depth information related to landfill operation. Questionnaires were distributed to two kinds of respondents. The first respondent represented the stakeholders involved in waste management, and the second respondent represented the scavengers in landfill. Standard-open-ended interviews were selected in which the respondents were asked with same open-ended questions to get detailed information which is easy to be analyzed and compared.

The role of scavenger in waste reduction has been observed by conducting a field survey. The field survey was held for 10 days, beginning from 20 October until 29 October 2010 to measure the recyclable materials from landfill. There were 45 scavengers as respondents who were asked to fill out the questionnaires. The proximate and the ultimate analysis have been carried out using the typical value proposed by Kaiser (1978) since there was no sampling on waste in the landfill.

The methane generation in Bendo Landfill was calculated using Equation 2 according to IPCC Method Tier 2. Since there is no soil covering at Bendo landfill, total methane emitted is the same as generated (IPCC, 2006).

$$CH_{4Emit} = \left[\sum_{x} CH_{4\,generated\,x,T} - R_T\right] * (1 - OX_T) \quad (1)$$

Assumptions and Limitations:

The study focused on reduction of methane emission through composting and scavenging. The related emission calculation and the results are made based on the current situation and do not necessarily reflect the actual prediction of future situations because these can be effected by changes including in waste composition (which was kept constant in this study). There was no field measurement for the waste characteristic investigation. Therefore, some approaches such as the ultimate analysis in determining the waste characteristic and the IPCC Tier 2 for calculating the methane emission have been applied. Due to the lack of input data, the following major assumptions were made:

1. Currency rate is Rp 9,500 for $1 which is the average value of the predicted exchange rate of Rupiah from Central Bank ranging between Rp 9000 - Rp 10,000 in 2010
2. Waste density is assumed 400 kg/m^3 based on typical domestic waste density in Indonesia (Diaz, et.al., 1993). The assumption is made to convert from volume units to weight units.
3. Waste generation rate per person is derived from the average amount of total waste generation and number of population from 2004 – 2010.
4. Waste percentage was kept consistent over the time period.
5. Population growth was the average value over the period and kept consistent for the prediction.
6. All material sorted by the scavengers in landfill will be transported for recycling, while the scavenging in community level is neglected because of unquantifiable data at present.

During the study, some secondary data are required to be processed due to the following limitations:

1. The waste tonnage disposed of in landfill in 2008 and 2009 from Bantul was not complete. Therefore, the calculation was conducted using the percentage from data in 2010.
2. The weighbridge was failure between May until August 2008. The average waste percentage from nearest month was used to calculate the missing data.

3. Different waste classification among the references necessitates modification of existing waste classification to make the physical, proximate and ultimate analysis possible.
4. The percentage from secondary data for metal and glass fraction was consequently used due to minimum obtained data from field survey.

Results and Discussion

3.1 Municipal Solid Waste Management (MSWM) In Yogyakarta:

The City of Yogyakarta is situated on the Indonesian island of Java and has population of approximately 460,000 people in 2009 having grown from 398,000 people in 2000. It is comprised of 14 districts and 45 sub-districts covering a total area of 32.5 km^2. The population growth in Yogyakarta is approximately 1.7% per year (Statistics Yogyakarta, 2007). Meanwhile, the waste generation is increasing approximately 1.8% per year (Environmental Board, 2009[a], 2009[b], 2010). Figure 1 shows that the total waste generation is increasing proportionally to the population growth.

Yogyakarta, like many other cities in Indonesia, suffers from an inability to cope with waste generation and disposal. Actually, Yogyakarta has had a regional related-waste law some years before 2008 when The Waste Law No. 18/2008 was enacted. It was The Law No. 22/2002 about community management in Yogyakarta. Still, the low law enforcement causes the ineffectiveness in MSWM. The low waste generation per capita and waste cost per capita characterizes MSWM in Yogyakarta. The waste generation per capita is below 1 kg/cap/day, while the cost for waste management per capita is not more than $1.0/cap/year. Municipal solid waste (MSW) generation in Yogyakarta City is estimated around 313 ton/day (0.67 kg/capita/day) with the level of Service of (LoS) 70% in 2010. Table 1 shows the salient features of solid waste management in Yogyakarta.

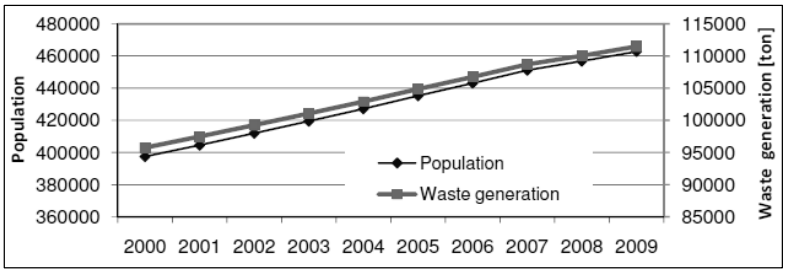

Fig. 1: Waste Generation In Yogyakarta.

Table 1: Salient features of solid waste management in Yogyakarta.

Parameter	Unit	Yogyakarta
Area	km^2	32.5
Population (million)	People	468,000
Waste generation	tons day^{-1} kg cap^{-1} day^{-1}	313 0.67
Waste collection	tons day^{-1}	218.5
Total MSW Cost	Billion Rp $year^{-1}$	3.99
	Million US $ $year^{-1}$	0.42
	Rp cap^{-1} $year^{-1}$	8.45
	$ cap^{-1} $year^{-1}$	0.89
MSW income	billion Rp $year^{-1}$	1.8
	Million US $ $year^{-1}$	0.19
LoS on waste collection	%	70
Currency conversion: US $ 1 = Rp 9,500		

The waste authority in Yogyakarta City claims that about 85% of the waste generated is collected every day. In fact, the record from landfill operator showed that only 218.5 ton waste per day can be collected which is equal to 70% LoS, indicating that not all waste generated was transported to the landfill. The uncollected waste is treated by the community. Referring to the national standard for LoS on waste collection, this percentage represents adequate performance which is upon 60% as the minimum LoS on waste collection (MoSri, 2001).

Most of the waste dumped in Bendo landfill comes from household resulting waste with 77% organic content and 61% moisture content. This is the nature of typical waste in developing countries which has high organic content (about 70%) and high moisture content (about 50%) (Diaz, et.al., 1993). Meanwhile, plastics and paper has the less percentage afterwards followed by other smaller fractions such as glass, metal, textile, rubber, and diapers, as described in Table 2. The waste composition influences the waste's properties in Yogyakarta as shown in Table 3.

Table 2: Waste characteristic in Yogyakarta .

Waste Component	Percentage
Rapid decomposable organic component	
- Kitchen waste	32.66
- Organic waste	21.37
- Paper	5.65
- Garden waste	3.33
Slowly decomposable organic component	
- Textile	2.20
- Napkins	2.37
- Wood	0.72
Non decomposable	
- Plastics	9.96
- Rubber	0.32
- Others	0.72
- Glass	0.34
- Metal	0.19

Table 3: Waste's properties in Yogyakarta (after Kaiser, 1978).

Ultimate analysis		Proximate Analysis	
Component	Composition (m% dry basis)	Component	Composition (m% dry basis)
Carbon	51.84	Moisture	61.40
Hydrogen	6.58	Volatile	32.55
Oxygen	33.39	Fixed carbon	4.41
Nitrogen	2.06	Ash	1.62
Sulphur	0.24		

The collected waste is mainly delivered to the landfill and only small fraction of the waste is treated using other methods such as recycling and composting. Waste sorting is done either in community level where the scavengers collect the recyclables door to door or at Bendo landfill where the waste is dumped. In community level, glass and metal is mainly collected by scavengers or sold directly to the waste agent by household. In the meantime, paper and plastics is mainly sorted in landfill (Figure 2).

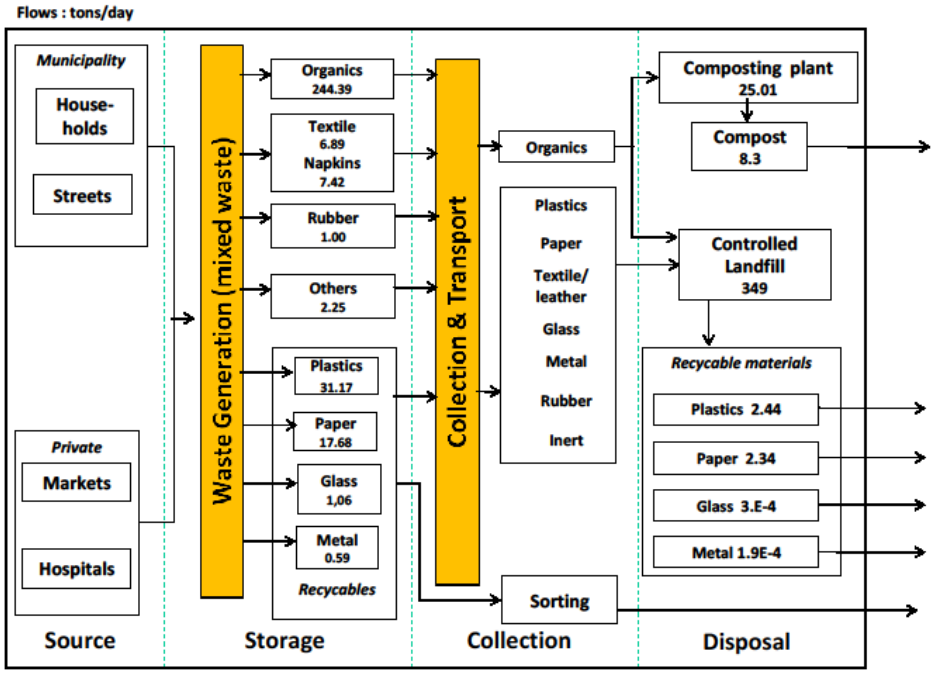

Fig. 2: Waste stream in Yogyakarta City.

Bendo Landfill was opened in 1993 and will be closed in 2012, replaced by a new final disposal site. The total area of Bendo Landfill is about 12.5 ha with depths ranging approximately from 1 meter to 20 meters and divided into 3 zones. The Bendo Landfill has accepted MSW from Yogyakarta, and two other cities, Sleman and Bantul from 1993 - 2010 and will have had the total waste capacity about 2.5 million tons waste by 2012 (Figure 3).

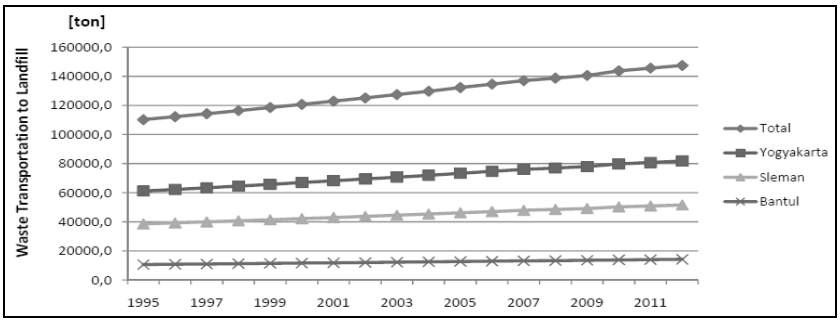

Fig. 3: Waste transportation to Bendo Landfill.

3.2. Waste Reduction:

Scavenging is allowed in Bendo landfill and there are about 400 scavengers registered in landfill operator. Based on the number of registered scavengers, there should be 200 respondents for the survey. However, during pre-survey, it has been identified that only 45 scavengers can be chosen as respondents. Therefore, all 45 scavengers were objected to the questionnaires. The result showed that their activities occurred in the day time, beginning from early morning until afternoon where the fresh waste was recently discarded. Most scavengers (82%) work at least 8 hours per day and do scavenging as their main activities to earn money (58%). They sort the salable used material such as paper, metal, plastic and glass bottles. Weighing and selling the collected waste was conducted inside the landfill area. Most scavengers have income between $ 1.58 and $ 3.6 per day (87%) as shown in Figure 4. Some scavengers build also temporary shelters in landfill area for staying. There was no restriction area and waste type for the scavengers. The valuable wastes sorted by scavengers are plastics, paper, metal and glass. A scavenger can sort approximately 54.3 kg/day plastic and 52.05 kg/day paper waste, contributing to waste reduction in landfill about 7.5% for plastics and 12.8% for paper per day respectively. Reduction on metal and glass is very small (below 0.01%) because most of them have been separated by the scavenger or sold to the waste agent by the households before waste is delivered to the landfill. Figure 5 describes the average amount of plastics and paper waste sorted by a scavenger each day at Bendo landfill.

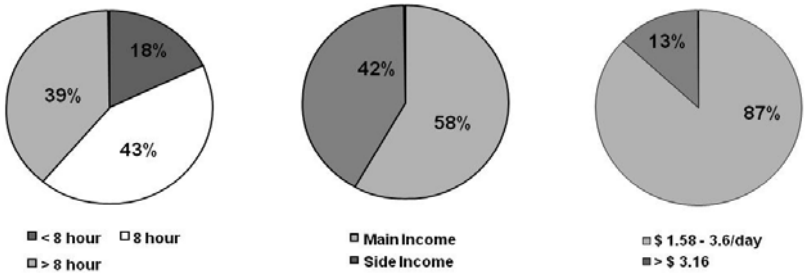

Fig. 4: Data on Scavengers in Bendo Landfill.

Table 4: Waste sorting by scavenger in Bendo Landfill.

Material	Mass [kg/cap/day]	Price [$/kg]	Income [$/kg]
Plastic	54.30	0.02	1.14
Paper	52.05	0.03	1.37
Glass	0.036	0.03	0.00
Metal	0.004	0.03	0.00

In Yogyakarta, composting center is a government-community partnership. There are 14,742 households in Yogyakarta which are involved in community-based-composting centers with the total capacity of 66.33 m^3/day or equal to 25.01 ton/day organic waste based on the typical loose food waste density proposed by CalRecovery (1992) which ranges between 353 - 401 kg/m^3. The current total capacity of waste composting center is about 10.33% of total organic waste generated in Yogyakarta. The treatment process of the organic waste produces 22 m^3/day or 8.3 ton/day compost. If the capacity is increased yearly, there could be a significant waste reduction through composting. Therefore, the local government is targeting to increase the capacity per year by 2.7% (25.7 ton/day) which will produce more compost up to 8,518 kg/day. Though the increasing amount of waste composted in Yogyakarta, the landfill method is still the preference for the local government in treating the MSW.

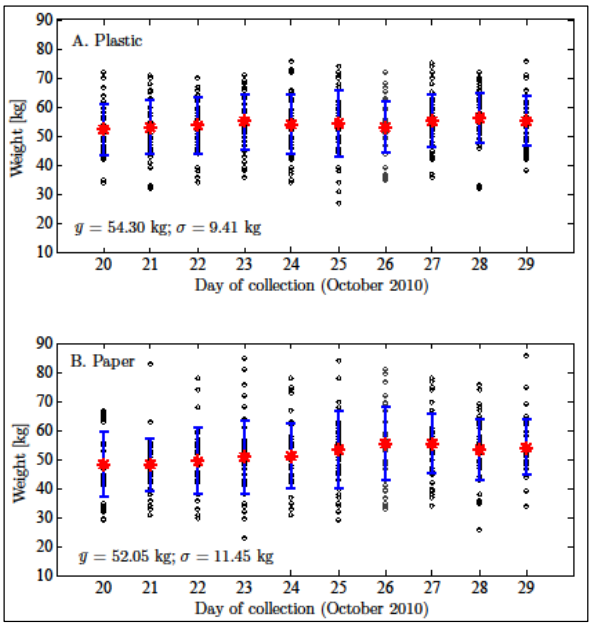

Fig. 5: Waste reduction done by a scavenger at Bendo landfill.

3.3. Estimation of Methane Emission:

The estimation of methane emission is made for two conditions, namely without waste reduction and with waste reduction which is done by the scavengers in landfill and by composting centres. The result showed that without waste reduction, the total methane emission produced in Bendo landfill from 1994 until 2012 is about 8.78E+06 ton CO_{2eq}. If it is assumed that all the registered scavengers (400 scavengers) work optimally, the amount of methane emitted will be 8.57E+06 ton CO_{2eq} (2.3% emission reduction). However, since there are only 45 scavengers in Bendo Landfill who work optimally, the methane emission will reduce to 8.71E+06 ton $CO_{2eq.}$ It means there is about 1.8% emission reduction due to the current scavenging and composting activity. It is obvious that the involvement of 45 scavengers in methane emisson reduction in Bendo landfill was not significant. The slight decrease of methane emission will occur if it is assumed that all registered scavengers are optimally involved in scavenging (Figure 6). The same effect was also indicated in Figure 7 that neither the current nor the targeted composting rate had an important influence on methane emission reduction. A significant methane emission can be achieved if the composted waste has a higher percentage and all of the registered scavengers separate the waste optimally. In this case, it is assumed that it would be 50% composting rate of kitchen and organic waste. Estimation of methane emission of each case is shown in Figure 8.

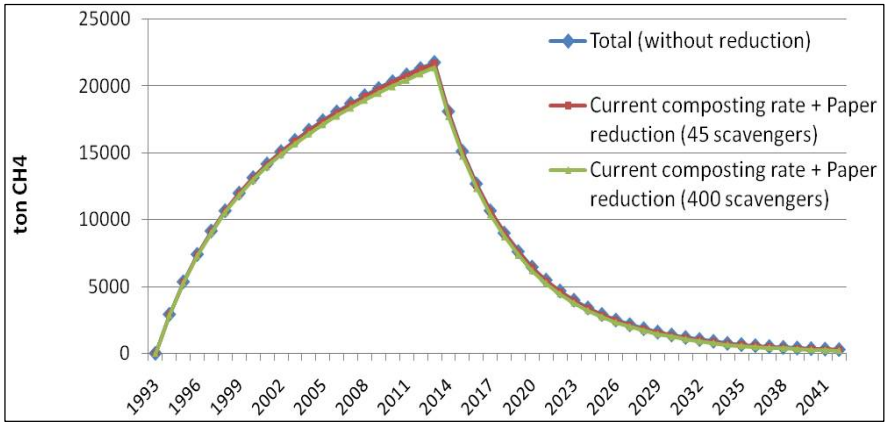

Fig. 6: Methane emission reduction in Bendo Landfill.

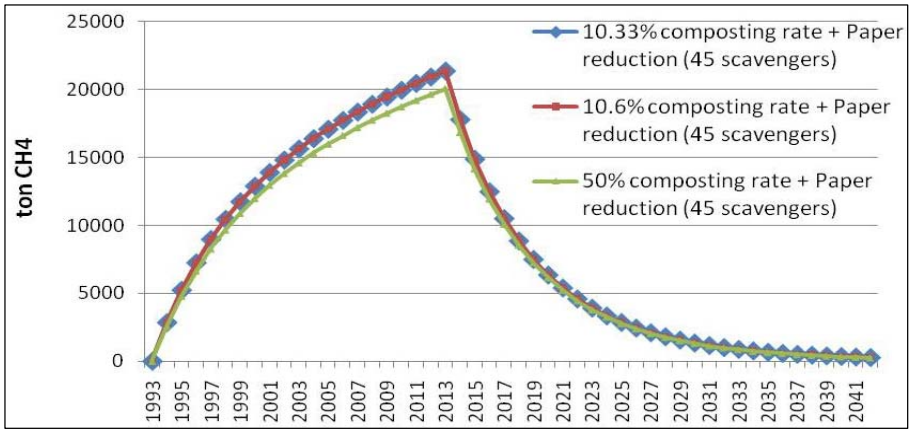

Fig. 7: The impact of composting rate on methane emission reduction.

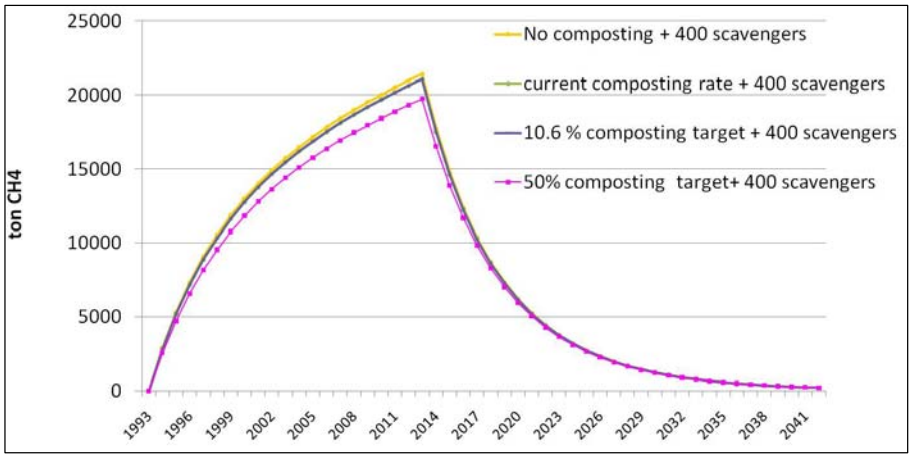

Fig. 8: Methane emission reduction through composting and scavenging.

Conclusions:

Scavenging in Bendo Landfill and composting in community based composting centers in Yogyakarta City have reduced the amount of waste delivered to the landfill. There is about 12.8% reduction of paper waste and 10.33% reduction of organic waste delivered to Bendo landfill. However, since the major part of municipal solid waste is degradable materials and only small percentage of them has been reduced, the methane emission reduction through scavenging and composting is not significant (1.8% methane emission reduction). A significant contribution to methane emission reduction can be achieved if the percentage of organic component in waste is reduced considerably.

Recommendations:

Bendo Landfill is approaching to the end year operation and will be closed in year 2012. The local government has planned to build a new landfill which will be a controlled landfill. Since the result showed that the waste picking activities has impact on waste reduction causing methane emission reduction in Bendo landfill, the following recommendations can be considered:

- The involvement of scavengers in new landfill should be accommodated
- Scavenging management should be improved to optimize waste separation in landfill
- Weighing fee charged to the scavenger should be eliminated as an incentive.

Furthermore, the capacity of community based composting centers should be increased to reduce the organic waste transported to Bendo landfill. The less organic fraction transported to the landfill, the higher methane emission reduction can be reached.

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