ARTICLE IN PRESS

Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Monitoring environmental burden reduction from household waste prevention

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ARTICLE INFO

Article history:
Received 28 January 2017
Revised 16 July 2017
Accepted 12 October 2017
Available online xxxx

Keywords:
Municipal solid waste (MSW)
Waste prevention
Monitoring
Life cycle approach
Recycling

ABSTRACT

In this study, the amount of prevented household waste in Kyoto city was quantified using three methods. Subsequently, the greenhouse gas (GHG) emission reduction by waste prevention was calculated in order to monitor the impact of waste prevention. The methods of quantification were “relative change from baseline year (a),” “absolute change from potential waste generation (b),” and “absolute amount of activities (c).” Method (a) was popular for measuring waste prevention, but method (b) was the original approach to determine the absolute amount of waste prevention by estimating the potential waste generation. Method (c) also provided the absolute value utilizing the information of activities. Methods (b) and (c) enable the evaluation of the waste prevention activities with a similar baseline for recycling.

Methods (b) and (c) gave significantly higher GHG reductions than method (a) because of the difference in baseline between them. Therefore, setting a baseline is very important for evaluating waste prevention. In practice, when focusing on the monitoring of a specific policy or campaign, method (a) is an appropriate option. On the other hand, when comparing the total impact of waste prevention to that of recycling, methods (b) and (c) should be applied.

1. Introduction

Recently, waste prevention, or 2R (reduce and reuse), was placed at the top of the hierarchy of waste management, and the amount of waste generated is now being monitored (MOEJ, 2012, European Commission (EC) Directorate-General Environment, 2012; Wilts, 2012; Yano and Sakai, 2016). Evaluating not only the quantity but also the quality of activities is meaningful because it aids in understanding the outcome of each activity and comparison with other GHG reduction policies. There have been many studies on life cycle assessments (LCA) of recycling (Laurent et al., 2014) and national indicators of the GHG reduction impact of recycling (European Environment Agency (EEA), 2011, MOEJ, 2012). Then, Cleary (2010) and Nessi et al. (2013) discuss methods to evaluate the environmental impact of waste prevention. Additionally, Gentil et al. (2011), Cleary (2014), Matsuda et al. (2012), Dolci et al. (2016a, 2016b), Martinez et al. (2016), Eriksson et al. (2015), Nessi et al. (2012, 2015) and Salemdeeb et al. (2017) calculated the environmental impact of waste prevention and showed its significant potential. However, in these studies, the amount of waste prevented is based on assumptions. Therefore, these results could not be used as an indicator, unlike recycling impact which is monitored as an indicator by the Japanese Ministry of the Environment (MOEJ, 2015). Yano and Sakai (2016) identified the need to develop a standardized and consistent method for monitoring and quantifying the environmental impacts of waste prevention activities.

In contrast to recycling, quantifying the actual achievement of waste prevention activities is difficult (Yano and Sakai, 2016). Some methods have been proposed for monitoring household waste prevention activities (Zorpas, 2013; Sharp, 2010a). Zacho and Mosgaard (2016) categorized these methods into six types: (1) self-weighing, monitoring, or reporting; (2) use of collection round data (mainly garbage collection data by the local government); (3) use of control and pilot groups to compare changes; (4) attitude and behavior surveys; (5) Point of Sales Data (P.O.S); and (6) hybrid approaches. Some case studies on monitoring waste prevention activities have been reported (Cox, 2010; Sharp,

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https://doi.org/10.1016/j.wasman.2017.10.014
0956-053X/

Please cite this article in press as: Matsuda, T., et al. Monitoring environmental burden reduction from household waste prevention. Waste Management (2017), https://doi.org/10.1016/j.wasman.2017.10.014

2010b). Read et al. (2009) evaluated the waste prevention programs of local governments and summarized their strengths and weaknesses. WRAP (2013) showed the change in food waste generation between 2007 and 2013 as the amount of prevented waste, and concluded that there was a significant impact of waste prevention activities.

These case studies evaluated the amount of prevented waste as the difference from a baseline year. It is similar to the national indicators for waste prevention (Yano and Sakai, 2016). Because it is difficult to know the situation without any waste prevention activities. The amount of waste prevention is relative and subject to social and economic change; on the other hand, the amount of recycling is quantified directly. Therefore the amount of recycling is absolute and less affected by demographics, and it would be inadequate to compare the amount of prevented waste to the amount of recycled waste. This problem also occurs when we compare the environmental impact; this may cause the achievements of waste prevention activities to be evaluated incorrectly.

This study aims to quantify the amount of prevented household waste in Kyoto city and evaluate its environmental impact using three different methods. For comparison, the environmental impact of recycled waste is also evaluated. Specifically, we estimate the amount of prevented waste as the difference between potential waste generation and actual waste generation. This method allows us to capture the absolute environmental impact of waste prevention activities like recycling.

2. Methods

2.1. Waste management activities

As shown in Table 1, five waste prevention activities and eight recycling activities were considered. The amount of generated waste in Kyoto city is shown in SI.1.

2.2. Calculating the amount of waste prevention

The amount of prevented waste was calculated in three ways, as shown in Table 2. By using the first method (a), we calculate the amount of prevented waste as the relative difference of the amount of waste between a baseline year and the evaluated year. The second method captures the amount of waste prevention as the difference between potential waste generation and actual waste generation. Here, potential waste generation is virtual waste generation when no waste prevention activity is conducted. The result of this method is absolute and independent from the baseline year. The third method also produces absolute values. This method does not needs the data from waste generation. We can calculate the amount of prevented waste from the degree of waste prevention activities collected by the questionnaire survey.

In the present study, we focused on the continuous monitoring of waste prevention. Thus two methods shown in Zacho and Mosgaard (2016) were not considered: “self-weighing, monitoring or reporting” and “use of control and pilot groups to compare changes” due to the difficulty of continuance.

Table 1
Waste management activities considered.

Type of waste	Activities
Prevention	
Plastic shopping bag	Prevention by substitution of reusable shopping bag
Untouched food (when food wasted is equal to more than half of the original quantity of food)	Prevention by optimal food shopping
Leftovers	Prevention by providing an adequate diet
PET bottle	Prevention by substitution of reusable bottle
Non-rechargeable battery	Prevention by rechargeable battery use
Recycling	
Plastic waste	Recycling to secondary plastic
Cooking oil	Recycling to biodiesel oil
Steel can	Recycling to secondary steel
Aluminum can	Recycling to secondary aluminum
Glass bottle	Recycling to secondary glass
PET bottle	Recycling to PET plastics
Used paper	Recycling to copy paper, newsprint, and cardboard
Non-rechargeable battery	Recycling to component secondary metals

2.2.1. Relative change from baseline year

This method was the most frequently used in previous studies (Read et al., 2009; WRAP, 2013). It is classified as the “use of collection round data” according to Zacho and Mosgaard (2016), because it utilizes only waste collection data. This method can be adopted for all waste prevention activities listed in Table 1.

The amount of prevented waste is calculated using Eq. (1). The mass of generated waste (Mw) is calculated by multiplying the total amount of waste generated in Kyoto city by the composition of each type of waste (Kyoto City, 2009–2014). The waste composition was measured by sorting waste sampled from representative districts in Kyoto city (Kyoto City, 2009–2014).

$$\mathrm{Mprv}_i(t) = \mathrm{Mw}_i(t_0) - \mathrm{Mw}_i(t) \quad (1)$$

Mprv: mass of prevented waste (ton/year)
Mw: mass of generated waste (ton/year)
t: year of evaluation
t_0: baseline year
i: type of waste.

2.2.2. Absolute change from potential waste generation

This is the original method used to quantify the amount of waste prevention. In one of the latest reviews (Sakai et al., 2017), we could not find the articles that tried to achieve the absolute amount of prevented waste. It is the difference between potential waste generation and actual waste generation. This method requires both waste collection data and questionnaire survey data and is therefore classified as a “hybrid approach” (Zacho and Mosgaard, 2016). The questionnaire survey was conducted three times in 2008–2013 and the three year data gaps during which no survey was conducted were interpolated linearly. All of the respondents were randomly sampled from Kyoto city by postal code. The outline of the questionnaire survey is shown in SI.2. In the waste prevention activities in Table 1, prevention of PET bottles and non-rechargeable batteries are not considered because of the shortage of questionnaire survey data.

We calculate the amount of prevented waste using Eqs. (2) or (3). Once the amount of potential waste generation (Mpot) has been obtained, either the amount of waste generation or the activity level is required for annual monitoring. Method (ba) shown in Eq. (2) requires only the amount of waste generated in each year. However, to obtain the volume of each type of waste generated, additional waste composition analysis is required. In contrast, method (bb) shown in Eq. (3) requires the activity level, $AL_i(t)$, from a questionnaire survey. In Eq. (3), preventability (Pmax) is the maximum percentage of waste prevention when activity level is 100%.

$$\mathrm{Mprv}_i(t) = \mathrm{Mpot}_i - \mathrm{Mw}_i(t) \quad (2)$$

$$\mathrm{Mprv}_i(t) = \mathrm{Mpot}_i(t) \times \mathrm{AL}_i(t) \times \mathrm{Pmax}_i \quad (3)$$

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