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What is the quantity of consumer goods stocked in a Japanese household? Estimating potential disaster waste generation during floods

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ABSTRACT

This study aims to estimate micro material stock derived from consumer goods using fundamental data such as possession and expenditure of consumer goods in housing, considering the type of housing and class of total floor area of housing. A questionnaire survey of residents living in the eight cities of the Tama river basin was conducted to clarify the possession and expenditure of consumer goods in units of items/housing and JPY/housing. Identified consumer goods were 14 types and 97 items. The questionnaire also asked the storeys on which the consumer goods are installed. Material intensity coefficients (MIC) regarding the weight of consumer goods were calculated based on web–based and statistical surveys in units of kg/item and kg/USD. Micro material stock derived from consumer goods in housing totalled 5.84 t (t) in detached housing and 5.71 t in complex housing. Amount of the micro material stock derived from consumer goods corresponds to 10.9% of the macro material stock derived from detached housing. Reliability and validity of questionnaire results and the MIC were confirmed through two types of sensitivity analysis. As a case study, the total weight of all consumer goods in Kawasaki City was calculated as 3,667,000 t. The disaster waste derived from consumer goods considering the flood damage was estimated based on the total weight of all consumer goods in the city. The resulting estimation was 229,000 t. This estimation is 0.72 times bigger than the above-mentioned result that considered the storeys on which the consumer goods are installed.

1. Introduction

We live our lives surrounded by anthropogenic stock. This anthropogenic stock, also called material stock such as ore, oil and biomass. Anthropogenic stock is classified into two types: macro material stock and micro material stock. The former includes infrastructure and buildings. The latter includes appliances, furniture, clothes, bags, and other small items. The micro material stock is usually stocked in housing as consumer goods. The anthropogenic stock is converted to waste when its lifetime is over. Avoiding the conversion of anthropogenic stock to waste is desirable, according to 3R (Reduce, Reuse and Recycling) thinking and the circular economy (Japan Ministry of Environment (JMOE), 2008; European Commission 2017).

The incident in which anthropogenic stock is converted to waste in a moment is a natural disaster. Natural disasters, such as earthquakes, tsunamis, and floods, cause severe damage to human life and the anthropogenic stock people possess. In addition, a huge amount of disaster waste is generated after such disasters. Disaster waste is derived from anthropogenic stock. After natural disasters, disaster waste is collected and treated for the reconstruction of an affected area. The environmental burden and cost of treating disaster waste are not negligible (Tabata et al., 2017; Wakabayashi et al., 2017). He and Zhung (2016) indicate that loss from natural disasters is determined not only by measures that are taken after the disasters but also by the disaster prevention measures that are taken before disasters. This thinking is also effective for disaster waste management measures. Maryono et al. (2015) identified one of the importance factors in the prevention is understanding of the amount and characteristic of disaster waste. Tajima et al. (2014) also indicate that the disaster waste management planning should be based on research findings and accurate knowledge on disaster agent and response. Fetter and Rakes (2012) and Hu and Sheu (2013) revealed that incentives for the disaster waste recycling reduces total cost of the disaster waste management. When local governments conduct simulations for disaster waste management measures in advance of such disasters to clarify the environmental burden and cost of disaster waste collection and treatment, understanding the amount and type of potential disaster waste is important in generating basic data for the simulation.

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According to the basic disaster prevention plan published by the Japanese government, most of the disaster waste should be reused and/or recycled (Japan Central Disaster Management Council, 2014). This policy is based on 3R thinking and is similar to circular economy thinking. Disaster waste is originally manufactured from natural resources. Although quick treatment of disaster waste is of primary importance for the reconstruction of the affected area, prioritising incineration, and landfill too quickly to reconstruct the affected area might lead to a waste of resources. This is true because plenty of natural resources are consumed in the reconstruction of anthropogenic stock in the affected area. The desirable policy is to utilise disaster waste as secondary materials for reconstruction. According to this policy, 81% of disaster waste and 99% of tsunami debris were recycled for disaster waste treatment generated by the 2011 Great East Japan Earthquakes (JMOE, 2017a).

Understanding the amount and type of disaster waste is effective in investigating disaster waste recycling measures. A popular method of estimating the type and amount of disaster waste is calculating the material intensity coefficients (MIC) of disaster waste generation per housing unit and calculating disaster waste by multiplying the MIC and damage functions. The damage function is determined by the type of natural disaster and degree of damage. Actual data identified by previous natural disasters are usually utilised (Takatsuki et al., 1995; Hirayama and Kawata, 2005, Hirayama et al., 2009; Kung et al., 2012; Xiao et al., 2012; Nakayama et al., 2013; JMOE, 2014; Stolle et al., 2015). However, this method has the following problems: (1) there is a validation date for the MIC because the MIC that were calculated on based on previous natural disasters might not be suitable for estimation against the latest natural disasters. The MIC varies over time because of technical changes in housing structure, such as building materials and (2) the total floor area of housing built in a rural area is usually larger than that of housing built in an urban area. Accordingly, the MIC that are calculated based on cases in an urban area is not suitable for use in a rural area. However, if there were no basic data for rural areas, utilising basic data for an urban area would be the only way. In that case, the problem resulting from the quality of estimation results not being assured would not be negligible.

To solve the above-mentioned problems, Tanikawa et al. (2014) developed a method for estimating disaster waste derived from housing using the geographic information system (GIS). The location, type, and amount of housing can be identified using the GIS. This method is advantageous because it does not require MIC calculated on the basis of previous natural disasters, and disaster waste can be estimated from the map data. This method can be applied to any scale of area if there is only map data. Tabata et al. (2016) also developed a method for estimating disaster waste derived from consumer goods, considering 18 types of home appliances and cars. They calculated the MIC for various consumer goods through a web-based survey. The amount and type of consumer goods possessed in housing can be identified using national statistical data and/or a questionnaire survey for consumers. This method can also estimate disaster waste, regardless of the scale of the area. Methods that were developed by Tanikawa et al. (2014) and Tabata et al. (2016) applied the thinking of material flow analysis. They estimated disaster waste using data regarding the macro and micro material stock in the area. These methods created a new approach in the field of disaster waste management.

The above-mentioned methods were originally used to estimate anthropogenic stock. There are two accountings to estimate anthropogenic stock: one is a bottom-up accounting, and the other is a top-down accounting. Gontia et al. (2018) indicates that the bottom-up accounting is also known as a coefficient-based method. According to Gontia et al. (2018), the bottom-up accounting estimates the physical size of the built-environment components in units of m^2 and m^3 and the MIC, also called as basic unit, which is specific to each component, in units of kg/m^2 and kg/m^3 using actual value and national statistical data. There are many studies using the actual data for estimating building material stock. For example, Rincón et al. (2013), Liang et al. (2017), Miatto et al. (2017), Schebek et al. (2017) and Stephan and Athanassiadis (2017) estimated the building material stock utilising spatial data and its lifespan. Gontia et al. (2018) estimated the MIC for the residential buildings in Sweden by using actual architectural data. As the national statistical data, the Japanese government also conducts its‘ National survey of family income and expenditure and family income’, ‘Expenditure survey’, ‘Retail price survey’, and ‘Consumer behaviour survey’. These national statistical data inform us that we should use data such as the amount and types of consumer goods possessed in housing and the annual and monthly expenditures for consumer goods, groceries, education and insurance. The ‘UN Comtrade’ and ‘Trade statistics’ also provide transaction amounts and/or weights of each material and commodity. Chen and Graedel (2015), Lau et al. (2013), Nassar (2017), Oguchi et al. (2008), Tabata et al. (2016), and Tansel (2017) utilise this approach. Schiller et al. (2017) not only estimate consumer goods, but also residential and non-residential buildings. However, these statistical data do not address all the consumer goods stocked in housing. Statistics investigating expenditure trends for only a few months in a year have problems with data integrity. If statistical data regarding trade were utilised, surplus operations, such as the elimination of customs duty from each resource and commodity, were conducted. There are many consumer goods, and it is almost impossible to understand only the statistical data. Understanding these data requires much time and complicated work. For example, imagine counting the clothes at your home. There are various kinds of clothing, and laborious work is required to measure the weight of each. Although Tabata et al. (2016) estimated 18 types of consumer goods, they did not consider the micro material stock because other types of the consumer goods were outside of the study.

Top-down accounting estimates by using an input-output table. The input-output table is a table for understanding industrial activities through monetary flows; anthropogenic stock is estimated by converting monetary data into weight data. Schaffartzik et al. (2013), Eisenmenger et al. (2016), and López et al. (2017) utilise this approach. However, the input-output table is based on industrial activities, and only rough estimation of micro material stock is possible. With this approach, it is also difficult to treat all the consumer goods stocked in housing.

This study aims to estimate all the micro material stock utilising bottom-up and top-down accountings. This study also calculates MIC that can be utilised, irrespective of the scale of the area.

2. Materials and methods

Micro material stock derived from the consumer durables in an area is calculated by the following formulae that are based on Tabata et al. (2016).

$$s_{d,x}^{i} = \sum_{d=1}^{n} (P_{d,x}^{i} \times w_d) \tag{1}$$

$$S = \sum_{i=1}^{n} \sum_{x=1}^{n} (s_{d,x}^{i} \times F_x^{i}) \tag{2}$$

where s denotes the micro material stock derived from the consumer durables in a housing [kg/housing]; P denotes the degree of possession in housing [items/housing or USD/housing]; w denotes the MIC of consumer durables [in either kg/item or kg/USD]; d denotes the type of consumer goods; i denotes the type of housing (detached housing or complex housing); x denotes the total floor area of housing; S denotes the micro material stock derived from the consumer durables in the area [kg]; and F is the number of the housing. Two types of the unit of P are used to query the amount and expenditure of consumer goods that inhabitants possess, using a questionnaire survey.

Key elements in estimating the micro material stock derived from