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Environmental and economic evaluation of pre-disaster plans for disaster waste management: Case study of Minami-Ise, Japan

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ABSTRACT

Although it is important that disaster waste be demolished and removed as soon as possible after a natural disaster, it is also important that its treatment is environmentally friendly and economic. Local municipalities do not conduct environmental and economic feasibility studies of pre-disaster waste management; nevertheless, pre-disaster waste management is extremely important to promote treatment of waste after natural disasters. One of the reasons that they cannot conduct such evaluations is that the methods and inventory data required for the environmental and economic evaluation does not exist. In this study, we created the inventory data needed for evaluation and constructed evaluation methods using life cycle assessment (LCA) and life cycle cost (LCC) methodologies for future natural disasters. We selected the Japanese town of Minami-Ise for the related case study. Firstly, we estimated that the potential disaster waste generation derived from dwellings would be approximately 554,000 t. Based on this result, the land area required for all the temporary storage sites for storing the disaster waste was approximately 55 ha. Although the public domain and private land area in this case study is sufficient, several sites would be necessary to transport waste to other sites with enough space because local space is scarce. Next, we created inventory data of each process such as waste transportation, operation of the temporary storage sites, and waste treatment. We evaluated the environmental burden and cost for scenarios in which the disaster waste derived from specified kinds of home appliances (refrigerators, washing machines, air-conditioners and TV sets) was transported, stored and recycled. In the scenario, CO_2, SO_x, NO_X and PM emissions and total cost were 142 t, 7 kg, 257 kg, 38 kg and 1772 thousand USD, respectively. We also focused on SO_x emission as a regional pollution source because transportation and operation of the temporary storage sites generates air pollution. If the treatment of all waste were finished in 3 years, the environmental standard would be satisfied by setting work duration to 4.8 h/d.

1. Introduction

Although it is important that disaster waste be demolished and removed as soon as possible after a natural disaster, it is also important that its treatment be environmentally friendly and economical. To achieve these dual goals most effectively, pre-disaster waste management plans for treating and/or recycling the disaster waste are quite important. He and Zhuang (2016) indicate that disaster loss is determined not only by post-disaster relief but also by the pre-disaster mitigation plans and degree of preparedness. Disaster waste must be treated quickly and differently from conventional municipal solid waste. However, the extra environmental burden, along with excessive cost, is expected to be avoided even when disaster waste treatment is involved. This is because prevention of CO_2 emission was agreed at the COP21 in 2015, and because air pollutants such as SO_x, NO_x and PM cause damage to the health of disaster victims and workers in the affected area. Pre-disaster management is extremely important to promote treatment of waste after natural disasters. The US EPA (1998) created projections of the amount and kinds of disaster waste, grasp of treatment capacity in the region, instalment of temporary storage sites and investigation of methods for treating and/or recycling as an item of preliminary examination. In particular, investigation and double-checking of enough temporary storage sites before natural disasters should be conducted to avoid illegal dumping and inadequate segregation (Milke, 2011). In Japan, post-disaster waste management was investigated after the Great Hanshin earthquake in 1995. Japan Ministry of Environment (MOE) (2014b) also created guidelines for disaster waste management that contains

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methods for sorting, treating and/or recycling the disaster waste, in response to the Great east Japan earthquake in 2011. Japan Society of Material Cycles and Waste Management (JSMCWM) has also created a manual for treatment and recycling, taking into account the kinds of disaster waste (Asari et al., 2013). These have been provided to local municipalities and others.

The Japanese government remains concerned with the future occurrence of Tokyo inland earthquakes and Nankai mega-thrust earthquakes. The Nankai mega-thrust earthquakes are predicted to cause massive destruction in Japan, and will result in strong tremors over a sizeable area extending from Kanto to Kyushu. The probability of these earthquakes occurring as a class magnitude of 8–9 earthquake (stronger than the Great East Japan earthquake), from 1 January 2015, has been estimated to be 70% within 30 years and 90% within 50 years. The earthquake will cause an estimated maximum number of 323,000 deaths, and the quantity of disaster waste is estimated to be 250 million t (MOE, 2014a). Important preparations for this predicted earthquake include measures to prevent and mitigate potential damage, and to prepare resilience plans for damage prevention, mitigation, and reconstruction to allow for rapid recovery after the disaster.

The Japanese government created the basic disaster management plan for future natural disasters (Cabinet Office, Government of Japan, 2014). This plan contains strategies for treating and/or recycling disaster waste. Local municipalities have also created pre-disaster strategies for waste management. For example, Mie Prefecture (2015) has been investigating strategies for the disaster waste countermeasures.

Researchers have also conducted studies for pre-disaster management. Studies for estimating disaster waste are the ones most conducted in this field of study. For example, Chen et al. (2007) created an estimation model for flood damage. Xiao et al. (2012) and Yamanaka et al. (2014) also estimated disaster waste for earthquakes using information gained from previous earthquakes. Tabata et al. (2016) created a model to estimate the disaster waste derived from consumer durables, taking into account possessions and weight of consumer durables. The model created by Tabata et al. (2016) is effective for future natural disasters because this model can create estimates based on household characteristics at the area affected. In another study in this study field, Pramudita et al. (2014) discussed methods for construction of a transportation network for disaster debris if a Tokyo inland earthquake were to happen. Onan et al. (2015) created a decision-making tool to estimate disaster waste, and to investigate transportation networks and the location of temporary storage sites. Brown and Milke (2016) surveyed feasibility, methods and efficacy of recycling using information gained from previous major natural disasters around the world. Lorca et al. (2015) presented a decision-making tool that enables optimizing and balancing the financial and environmental costs, duration of removal operations, landfill usage, and amount of recycled materials generated.

There are also only a few studies about conducting environmental and economic evaluations of disaster waste treatment scenarios for future natural disasters. Joana and Lisa (2016) conducted environmental and economic evaluations by focusing on energy recovery from the disaster waste in the case of the Great East Japan earthquake, but they used information gained post-natural disaster, and they focused on the energy utilization of biomass. In Japan, many local municipalities, including that containing Mie Prefecture (2015), have created scenarios for treating disaster waste. However, they cannot confirm the feasibility and effectiveness of their scenarios. One of the reasons that they cannot conduct feasibility studies is that the evaluation methods and inventory data required for the evaluation do not exist. Lorca et al. (2015) indicates that each local municipality is required to determine a number of potential disaster scenarios. If the method and the inventory data existed, this would be a feasible and effective tool for selecting environmentally friendly and economic scenarios. Then, they could use this tool for decision-making when they meet with stakeholders (businesses and members of the community) to select the scenarios.

The aim of this study was to create a method and to inventory data that would make it possible to evaluate waste treatment scenarios environmentally and economically, for pre-disaster planning of disaster waste management. This study evaluates the environmental burden and cost of such preparation in Minami-Ise, a Japanese town chosen for a case study. For the case study, we estimated the potential amount of disaster waste generated, derived from existing dwellings, if a Nankai mega-thrust earthquake were to happen. We also conducted environmental and economic evaluations of disaster waste recycling scenarios using life cycle assessment (LCA) and life cycle cost (LCC) methodologies.

2. Materials and methods

2.1. Case study area

Fig. 1 shows the geographical location of Minami-Ise town. The population and the number of households in January 2016, was 13,891 and 6159, respectively. The land area was 241.89 km^2 (24,189 ha). However, because most of the area near the town is mountainous (Fig. 2), most of the dwellings in the town are located in a maritime area (near coastal).

This town is an area predicted to be affected if a Nankai mega-thrust earthquake were to happen. The Japan Meteorological Agency (JMA) has predicted the seismic intensity and inundation depth for this town would be 5.4–6.6 and 0.1–7.4 m, respectively. The predicted JMA seismic intensity and inundation depth are different for each district in this town. Severe coastal damage is predicted from seismic, tsunami and liquefaction effects caused by such an earthquake. The JMA seismic intensity scale is a seismic intensity index determined using seismic intensity meters installed in the ground or on the first floor of low-rise buildings (JMA, 2014). The reason we chose this town as the case study area is that, if the Nankai Mega-thrust earthquakes were to happen, many small cities and towns are predicted to get severe damage.

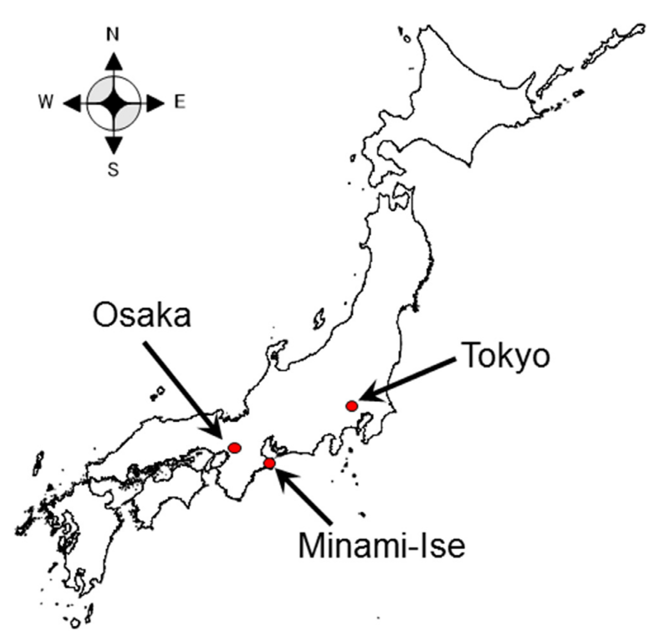

Fig. 1. Location of case study area.