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# Evaluation of environmental burdens caused by changes of food waste management systems in Seoul, Korea

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**Abstract**

During the last decade, there have been remarkable changes in food waste management in Korea following a ban on direct landfilling. To evaluate the environmental impacts of food waste management systems, we examined individual treatment systems with the LCA approach – landfill, incineration, composting, and feed manufacturing – and estimated the change from 1997 to 2005. The efficient system was different in each impact category, but it was evaluated that landfill is the main contributor to human toxicity and global warming (based on fossil $CO_2$). In contrast, due to the increase of food waste recycling, acidification, eutrophication, and fresh water aquatic ecotoxicity impact was increased. Especially, the high energy consumption and generated residue in recycling systems caused the large burdens in toxicity categories.


*Keywords:* Food waste; Landfill; Incineration; Composting; Feed manufacturing; Environmental burden; Life cycle assessment

## 1. Introduction

Food waste is a main component of municipal solid waste (MSW), which is known to induce putrefaction in waste collection and transportation; lower the efficiency of storing, conveying, shredding and separating; introduce moisture and Cl in the incineration process; lead to the emission of odorous compounds; adversely affect the quality of leachate from landfill, and so on (Durlak et al., 1997; Wang et al., 1999). In Korea, food waste accounts for about 30% of total MSW generation, and its proper management has become one of the most actively debated issues in the last decade. Most discharged food waste used to be directly dumped with MSW, but it continuously provoked complaints from those living near landfills. Therefore, not only to utilize available resources but also to reduce the environmental impact of landfills, in 1997 the Korean government announced several policies for effective food waste management. These included food waste reduction and separate collection from sources, the enlargement of recycling, and especially the prohibition of direct disposal in landfills from 2005. Pursuant to these policies, food waste management has attracted growing attention in recent years, and it has greatly changed in a short period of time, with a rapid increase of recycling and an abrupt decrease of landfilling.

Despite increasing interest in studying individual technologies, however, there has been little research on the comprehensive evaluation of the Korean food waste

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management system in the environmental view so far. In this study, based on operating parameters of actual facilities, we evaluated each fundamental food waste management technology, considering the treatment of one ton of food waste in systems as a unit. Based on the calculated results as well as statistical data, we estimated the change of environmental impacts of the food waste management system in Seoul from 1997 to 2005 using the LCA (life cycle assessment) method.

LCA is an objective and systematic tool for evaluating environmental aspects throughout the life cycle of a product or service. Though LCA aims to be science-based, it involves a number of technical assumptions and value choices. In addition, the environmental impacts obtained from LCA are often described as potential impacts, because they are not specified in time and space (Guinée, 2002). In spite of its limitations, the growing importance of applying LCA to waste management systems has been shown by many studies. Already there have been some studies to compare a few biowaste treatment systems (Hirai et al., 2000; Lundie and Peters, 2005; Güereca et al., 2006) as well as on the biological treatments of organic material as a part of integrated MSW management (Mendes et al., 2004; Eriksson et al., 2005; Bovea and Powell, 2006; Özeler et al., 2006; Hong et al., 2006) investigated by the LCA approach, to the best of our knowledge Korea is the only country that has implemented a series of strict food waste management policies. Accordingly this study may help clarify the substantial effect of separation and recycling of food waste.

## 2. Current situation of food waste management in Seoul

Seoul is the capital city of Korea, with a population of approximately 10 million. Table 1 shows the state of food waste generation and treatment in Seoul. Due to a series of strict policies, e.g., separate food waste collection and volume-based charge system, generation gradually decreased from 1998, but in contrast to the government's expectations, it has been steadily increasing since 2003. Several reasons for its rebound have been suggested, e.g., discrepancies of statistical definitions in waste censuses, underestimation of the moisture content of food waste with MSW, increasing nonrecyclables in collected food waste, and so on. Especially, one interesting feature is that the proportion of sorting residues in collected food waste destined for recycling, e.g., plastic chips, toothpicks, caps, and other miscellaneous items, has increased since direct landfilling was banned in 2005.

Landfill accounted for more than 90% of generated food waste just a few years ago, but the same proportion is now recycled. Officially, it was stated that all food waste was completely recycled in 2005, but some reports show that some food waste still flowed into incinerators or landfill with MSW. Based on the treated amount of MSW and its composition in each facility, it was estimated that food waste in landfill and incinerators totaled 0.11 and 0.03 million tons in 2005, respectively, as shown in Table 1. The collected food waste is transported to recycling facilities in and around Seoul, but recycling facilities in Seoul can handle less than 20% of the amount generated, because most of them are located in suburbs or rural areas largely as a result of the "not in my back yard" (NIMBY) syndrome. Though the Korean government has strived to diversify recycling technologies, e.g., anaerobic digestion, carbonization, co-treatment with sludge or sewage, the main technologies are feed manufacturing and composting, which account for 58% and 39% of the total recycled amount, respectively, due to their attractive advantages of lower initial investment cost and higher source accessibility. The produced feed and compost are supplied to farmlands, stock farms or commercial feed makers at a low price or for free.

## 3. Materials and methods

### 3.1. Processes descriptions and assumptions

To estimate the environmental burdens from food waste management in Seoul, we compared two systems: the landfill-based waste management system for 1997,

Table 1
Food waste generation and its treatment in Seoul (million tons $yr^{-1}$)

| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 [a] |
|---|---|---|---|---|---|---|---|---|---|
| Generation | 1.01 | 1.08 | 1.06 | 0.93 | 0.93 | 0.92 | 0.95 | 0.97 | 1.30 |
| Landfill | 0.88 | 0.82 | 0.70 | 0.41 | 0.27 | 0.26 | 0.20 | 0.09 | 0.11 |
| Incineration | 0.07 | 0.07 | 0.04 | 0.05 | 0.03 | 0.02 | 0.00 | 0.00 | 0.03 |
| Recycling | 0.06 | 0.19 | 0.32 | 0.47 | 0.63 | 0.64 | 0.75 | 0.88 | 1.16 |

[a] Amounts estimated from data of waste treatment facilities in Seoul.