OVERVIEW OF THE WASTE PLASTIC RECYCLING SYSTEM IN JAPAN AND FUTURE TASKS

Tohru Kamo[1]

[1]National Institute of Advanced Industrial Science and Technology (AIST), 16-1 Onogawa, Tsukuba 305-8569, Japan
e-mail: tohru-kamo@aist.go.jp

Abstract

Development of the recycling technology and social system is important to construction of sustainable society. The Containers and Packaging Recycling Law came into force completely in 2000. Approximately 0.4 million tons of waste plastic have been recycled by the recycling law. They were treated by feedstock recycle; for instance coke oven, gasification, blast furnace, or by mechanical recycle. Life cycle assessment (LCA) indicated that recycling of waste plastic or used PET bottle contributes to reduction of environmental load. Gasification of waste plastic to synthesize ammonia or thermal decomposition of waste plastic in a coke oven was much more effective than others. Recycling of PET bottle was also effective for reduction of environmental load, and the mechanical recycling in China of PET bottle used in Japan was better than recycling within Japan. Japanese recycling system has been run well and we are expecting that the recycling system is improved to have further higher economical efficiency.

Keywords: *Recycle, Waste plastic, LCA, Feedstock recycling, Mechanical recycling*

1. Introduction

Municipal waste had been landfilled in Japan until a half century ago. However, after the high economical growth in 1960's, most of them were incinerated due to serious shortage of landfill site caused on large scale production and consumption. Some municipalities began to separate plastics from the municipal waste after 1970's, because content percentage of plastics in the municipal waste increased, and high incineration temperature due to high calorific value of the plastics gave serious damage to waste incinerator. Particularly, after toxic materials such as dioxins was discovered in incineration residue or emission gas, plastics containing chlorine were separated from the municipal waste and they were landfilled again. The dioxin problem was almost cleared by improving of incineration furnace. However, recycling of waste plastic separated from the municipal waste was promoted to create circulation type society aiming for the sustainable development since the Earth Summit held in Rio de Janeiro in 1992 as well as recycling of vehicle or home electric appliances.

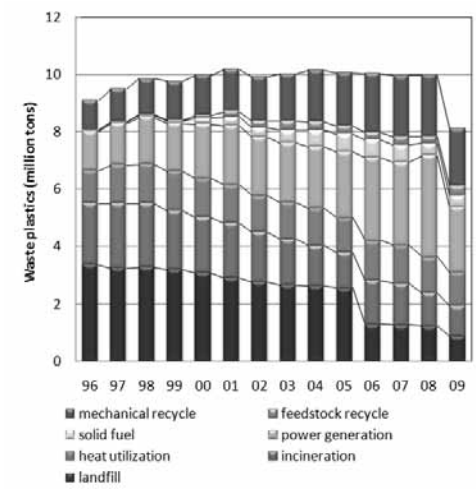

Fig. 1. Recycled waste plastic since 1996 in Japan.

Approximately 11.9 million tons of plastics were produced and 8.1 million tons of waste plastic was discarded in 2009[1] as shown in Fig.1. Total rate of simple incineration and landfill have decreased gradually since the Containers and Packaging Recycling Law came into force. However, more than 25 % of waste plastic have been still discarded without using effectively.

In my presentation, I will introduce overview of waste plastic recycling in Japan with a central focus on the Containers and Packaging Recycling Law, and I would like to point out some problems and future tasks.

2. Present situation of recycling in Japan

The Containers and Packaging Recycling Law was promulgated in 1995 to promote recycling of waste plastic, glass bottle, metal can, and paper, and it came into force completely in 2000. Conceptual diagram of the recycling system designed by the law was shown in Fig.2. This recycling system have been supported financially by commission donated from the two kinds of facilitating business; manufacturer and distributor. Containers or packages which was used by consumer were collected by municipalities, and it was packaged by veil after removing unrecyclable materials. The Japan Containers

Fig. 2. Conceptual diagram of the system designed by the Containers and Packaging Recycling Law.

and Packaging Recycling Association make bidding every year, and recycle company who offer lowest price can use the waste materials. To give priority to the materials recycle, only material recycling companies can participate in the first bidding.

Fig.3 shows annual variation of the recycled waste plastic by the Containers and Packaging Recycling Law[2]. In the first year when the recycling law was enforced, only 44,000 tons of waste plastic was recycled in all, blast furnace was a major recycling method. The recycled waste plastic have increased year by year, and 393,000 tons of waste plastic was treated by the recycle law in 2009. Major method was mechanical recycling or coke oven chemical feedstock recycling, more than 80 % of the waste plastic were treated by the two methods. In the coke oven recycling, waste plastic was mixed with coal at weight ratio of 1%, and was decomposed to gas (36%), liquid (36%), and solid carbon (18%) at temperature above 1000 °C. The gas or liquid products have been used as feedstock or energy source, the solid carbon was used as blast furnace coke The coke oven has treated the maximum amount of waste plastic as a feedstock recycling method, because it has a significant economical advantage point due to use of existing large facilities. In the mechanical recycling, approximately 50 wt% of the waste plastic was used as raw material, and other residual waste plastic was used as solid fuel.

PET bottle is one of the plastics which can be recovered from consumer as the most pure material due to its characteristic appearance as a material. Used PET bottle have been converted to fiber or sheet mechanically, and they are used for working clothes or egg box. Complete recycle process from the used PET bottle to PET bottle were put to practical use by two Japanese companies independently, and one company has been operating still now. Amount of recycled PET bottle in Japan was very sensitive to the world or Chinese economic trend, because a lot of used PET bottle was exported to China from Japan (Fig.4). For instance, the amount of recycled PET bottle in Japan began to decrease from 2004 when Chinese economical growth was accelerated, and domestically recycled PET bottle increased rapidly just

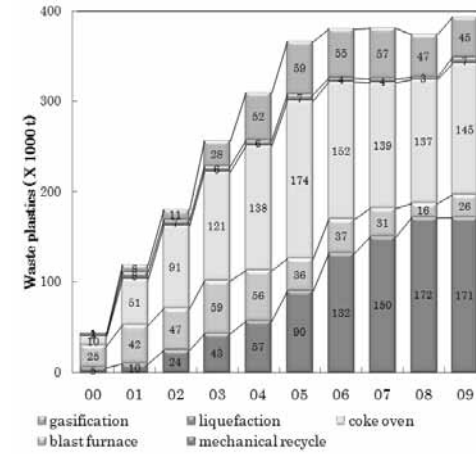

Fig. 3. Recycled waste plastic by the law of containers and packaging recycling.

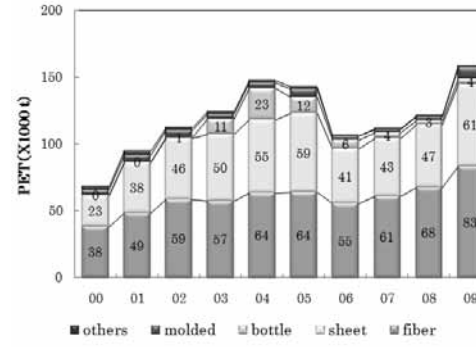

Fig. 4. Recycled PET bottle by the law of containers and packaging recycling.

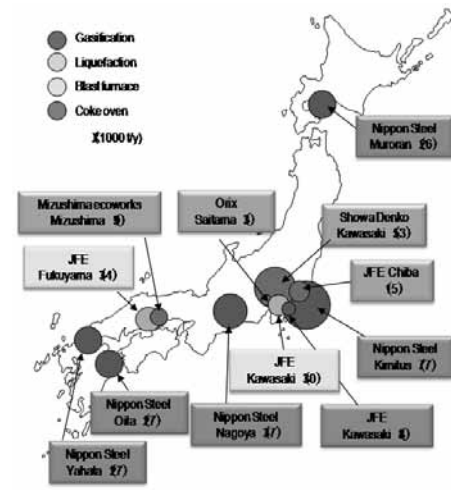

Fig.5. Major feedstock recycling facilities in Japan.

after Lehman's fall in 2008 when demand for used PET bottle in China reduced.

Fig.5 shows major feedstock recycling facilities in Japan. Six coke oven facilities, four gasification facilities, and two blast furnace facilities could be awarded a contract in 2011. Two major steel companies, Nippon Steel and JFE, have occupied more than 60% market share of the waste plastic recycle, because feedstock recycling have a tendency toward apparatus industry. On the other hand, many small companies have participated to mechanical recycle of waste plastic or the used PET bottle, because large equipment is not required.

Fig.6 shows average bidding price of each waste plastic recycling method. The bidding price of the mechanical recycle decreased slightly each year. However, reduction rate of the bidding price was not enough in comparison to other methods, and abolishment of priority right in the bidding have sometimes discussed. Bidding price of the three feedstock recycling methods; coke oven, gasification, and blast furnace; decreased in the same way. Once, three large liquefaction plants of waste plastic had operated simultaneously. However, all of the three plants were finally closed, because they could not withstand decrease of bidding price competition. Although the bidding price of the used PET bottle was extremely high, it decreased dramatically in a short period, and recently it has exported as valuable resources to China.

Ten years have passed since enforcement of the Containers and Packaging Recycling Law, however, the sum amount of recycled waste plastic and used PET bottle was still less than 0.6 million tons, and increasing rate of recycled waste plastic is almost saturated recently. A lot of waste plastic commingled with municipal waste have been incinerated. Most of incineration plants of municipal waste in Japan are smaller than 200 t/day and power generation efficiency is around only 10%, because it was very difficult to transport the waste beyond the border of each administrative area. Power generation efficiency of incineration plant increased by development of technologies decade after decade as shown in Fig.7[3]. The Japanese recycling law have not recognized incineration as an effective use way. Incineration is not ideal way, but it has begun to be reconsidered as one of realistic and effective usage of low quality waste plastic.

3. Life cycle assessment (LCA) assessment of waste plastic recycling

LCA is effective to compare the environmental load of each recycling method. Recently, various recycling methods of waste plastic were evaluated by basket method of LCA[2]. In this method, difference of the total energy consumption between the recycle system and the original system was evaluated as effect of recycling.

Figure 8 shows detail of LCA calculation of a shipping pallet manufactured from waste plastic by material recycle. Total energy of the recycle system was consisting of the energy required to manufacture a pallet from waste plastic (1kg) and to incinerate the pallet used once. Total energy of the original system was calculated from energy consumed to produce a equivalent pallet from crude oil and to incinerate of the waste plastic (1kg). Although the weight of the pallet made from virgin

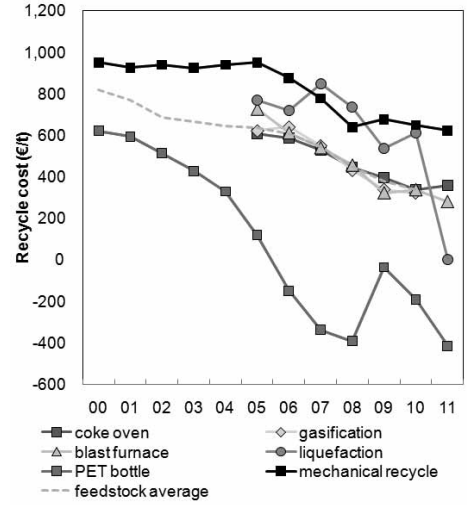

Fig. 6. Average bidding price of each waste plastic recycling.

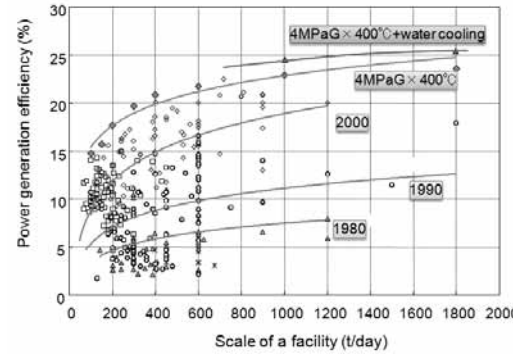

Fig.7. Development of power generation efficiency of municipal waste incinerator.

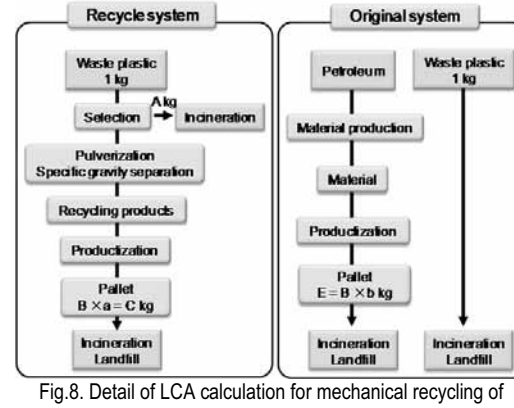

Fig.8. Detail of LCA calculation for mechanical recycling of waste plastic.

material and waste plastic differs, they have the equivalent function.

Returnable pallet was more environmentally friendly than one way pallet. Effect of mechanical recycling was smaller than other recycle methods, because only 50% of waste plastic have used for production of the pallet (Fig.9). Effect of mechanical recycling would be improved by 60 %, if the removed waste plastic was used as a solid fuel[4]. Synthesis of ammonia using hydrogen derived from waste plastic was the most effective method to reduce environmental load than any other recycles, because energy to produce hydrogen can be saved. Effect of liquefaction of waste plastic was not high due to low conversion rate from waste plastic to liquid product. On the other hand, effect of the coke oven was the second highest in other recycling methods, because not only gaseous or liquid product but also residual carbon can be used as an alternative of coke. Effect of the waste power generation based on the power generation efficiency of 10% was not high. However, waste power generation would be estimated to show equivalent effect to other recycle methods, if the power generation efficiency was more than 20-30%.

Recycling of the used PET bottles contribute to reduction of the environmental load compared to incineration or landfill, regardless of mechanical recycling and feedstock recycling (Fig.10)[5]. Production of long fiber or short fiber from mechanical recycle of used PET bottle was better than chemical recycle of used PET bottle. Even if energy was consumed in transportation, production of short fiber or clothes in China from the PET bottle used in Japan would be evaluated better than others. This result was mainly due to the power generation efficiency difference of two countries.

4. Future tasks

The Containers and Packaging Recycling Law was effective to reduce energy consumption or carbon dioxide emission. However, percentage of recycled waste plastic by this system was only 5% of whole discarded waste plastic in Japan annually. And participation rate of municipality was around 60%, because this system was expensive not only for the facilitating business but also for municipalities. The facilitating businesses have donated 455 million Euro in 2009, and additionally municipalities have paid 354 €/kg for collecting or storing waste plastic. In this recycling system, the cost to reduce emission of carbon dioxide was approximately 0.27 €/kg, it is 20 times more expensive compared to price in the international emission trading market. To reduce the supporting cost of this system, it is necessary to abolish preferential treatment of mechanical recycling in bidding, and to recognize high efficiency power generation as a valid method only in low quality waste plastic. It is very important to construct economically feasible recycling system and less sensitive to international economy for using effectively waste plastic as valuable domestic resources.

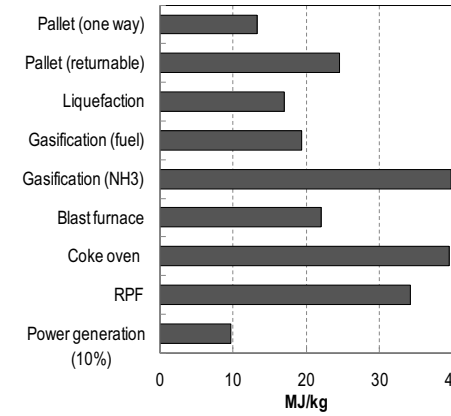

Fig. 9. Effect of various waste plastic recycling methods to reduction of environmental load.

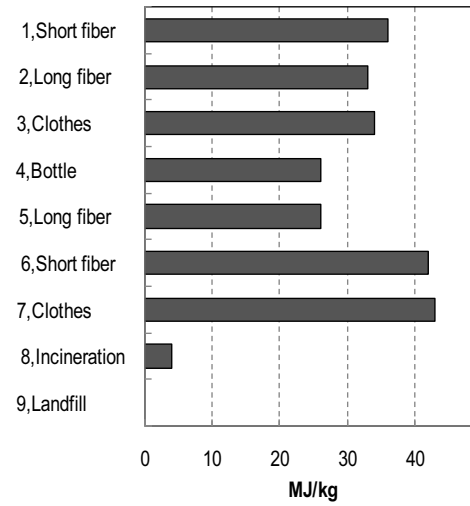

Fig.10. Effect of various PET bottle recycling methods to reduction of environmental load.

1. Short fiber (mechanical recycle in Japan), 2.Long fiber (mechanical recycle in Japan), 3.Clothes (mechanical recycle in Japan), 4.Bottle (chemical recycle in Japan), 5.Long fiber (chemical recycle in Japan), 6.Short fiber (mechanical recycle in China), 7.Clothes(mechanical recycle in China), 8.Incineration, 9.Landfill

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