

Mechanical Recycling of Plastic Solid Waste in an Urban District in Turkey

A. Genc, S. Sarac

Department of Environmental Engineering, Bulent Ecevit University, Zonguldak, 67100, Turkey

aytengenc@yahoo.com, Tel: +90 372 291 2627, Fax: +90 372 257 4023

Abstract

The usage of plastics has exponentially increased in our daily lives since the past 50 years because of its durability and potential for diverse applications, such as widespread use as disposable items. So, the recycling of plastic waste becomes one of the priority environmental problems due to its larger volume and easily recovered nature. In this study, the recycling cost of plastics has been estimated by analysing the amount of plastic waste collected at two recycling centers for a year in an urban area. The expenses in the collection and sorting of plastic wastes were taken into consideration in the economical assessment. The amount of plastic waste were also estimated depending on the characterization of municipality solid waste. The results show that the recovery of plastics was only 4%. Even with this low percentage, the use of recycled plastics as raw materials in the production of new plastics can be profitable. Therefore, mechanical recycling of plastics can be an economical and ecologically efficient option.

Keywords: Mechanical recycling, packaging waste, plastic solid waste, recycling cost

1. Purpose

Solid waste materials can cause serious damage on environment and population when they are disposed to water supply, sewage system, and landfill sites. In addition, the amount and the components of solid waste vary according to the seasons, geographic regions and economic and cultural level of inhabitants. Therefore, solid waste management is a major problem for many urban local bodies. As the implementation of waste management and the performance of separate collection systems vary in different regions and between countries, the composition of municipal solid waste (MSW) varies as well [1].

Plastics have become an integral part of our lives and their consumption is increasing without any limitations because of their low cost and easy disposal from households [2]. Hence, it is reasonable to find a considerable amount of PSW in MSW. Plastics are also used in in automotive and construction industries as a result of their low density, strength, robust, design and fabrication capabilities. According to Environmental Protection Agency (EPA), the percentage of plastic solid wastes (PSW) in MSW can reach up to 20%.

One of the effective ways of reducing plastic waste is recycling and reuse of consumed items. There are mainly four different approaches for recycling of PSW. Primary recycling involves the reintroduction of pre-consumer residues into the extrusion cycle to produce products of the same material [3]. Even though primary recycling appears environmentally friendly and economical, this approach usually is not suitable for recycling of plastics from MSW due to excess contamination. Secondary recycling or mechanical recycling refers to operations that recover PSW via mechanical processes. The mechanical methods usually involve cutting/shredding and granulation. On the other hand, tertiary recycling or chemical recycling involves pyrolysis, cracking and gasification. In another words, the recovery of monomers from PSW through de-polymerization process is called tertiary recycling. Finally, quaternary recycling or energy recovery consists of the incineration of PSW and the recovery of energy through the production of heat and/or electricity.

In this study, the recycling cost of PSW has been investigated by recording the amount of PSW for a year in the recycling centers in Zonguldak province of Turkey. The main components of collected plastics were polyethylene terephthalate (PET), polypropylene (PP), and polyethylene (PE).

2. Methods

a) Study Area

Zonguldak province which is located in western Black Sea region of Turkey (Fig. 1). It consists of 8 districts including the center, 25 municipalities, 176 neighbourhoods and 380 villages. The population living in the province was around 596892 inhabitants in an area of 3306 km². The generated MSW was around 119 thousand tonnes at 2016 and dumped on the landfill site located in the central district. According to the characterization of MSW, average organic and plastic waste percentages were around 34% and 15%, respectively [4].

b) The Recycling Centers

There are two recycling centers in the study area, one is located next to the landfill site. The second recycling center is placed in Devrek, which 50 km away from the center. There is only one licenced company in the study area that perform activities regarding the collection, transportation, separation, and recycling of packaging waste, and both recycling centers are operated by the same company. The recycling centers are operating in agreement with the provisions of the "Packages and Packaging Waste Control Regulation". The packaging wastes are transported to the recycling centers by two trucks having a volume of 16 m³. After the weight of these trucks are recorded, the packaging wastes are carried by a conveyor where plastic bags are opened. Then the packaging materials are separated manually into different groups by trained workers. They can easily separate milk bottles (high density polyethylene, HDPE) and drink bottles depending on color (green, blue, white PET). Sorting examples include garden furniture (PP), cable sleeves (HDPE), window profiles (polyvinyl chloride, PVC), etc. The sorted plastic materials are then ground into flakes and cleaned by washing to remove food residues, pulp fibers and adhesives. After drying, the flakes are compacted by means of pressure and are turned to granulate using extrusion machines.



Fig.1 Zonguldak Province in Turkey

3. Results

3.1 Solid Waste Management in Turkey

Municipalities are responsible for providing in all related services for the management of solid wastes by law in Turkey, i.e., collection, transportation, separation, recycling, disposal and storage of solid wastes. The municipalities can perform these facilities by themselves or appoint others to provide these services. Every 6 months, municipal authorities report to the Ministry the findings of their control and supervision activities, and the Ministry of Environment and Urbanism follows up the development of recovery activities via these reports.

Landfilling is a widespread method in waste management applications of Turkey. The rate of wastes disposed in sanitary landfill sites in Turkey was 34% in 2006 and increased to approximately 57% in 2016. According to the

Turkish Statistical Institute [5], the total amount of waste treated in 2016 was 77 million tonnes (Table 1) and the amount of waste disposed of in controlled landfill sites was 44 million tonnes. On the other hand, the amount of waste disposed of in incineration plants was only 310 thousand tonnes (0.4%). The amount of waste recovered in recovery facilities was 33 million tonnes (42.9%) and the highest recovery was at the recovery of metal, plastic, paper, mineral etc. waste being a total amount of 32 million tonnes. Since 2005, “Packages and Packaging Waste Control Regulation” has been established in order to reduce the amount of packaging waste going to landfill and includes all materials such as, plastics, metals, glass, paper/cardboard and composites. In accordance with this regulation, municipal authorities can either fulfil this obligation themselves or choose to work with a licensed company. The company that will perform collection within the municipal boundaries in accordance with the authority granted by the municipal authority through contract, needs to have a license or a temporary work permit for the collection and separation of packaging waste. There were 1516 licenced recovery facilities at 2016.

Table 1. Waste disposal and recovery facilities in 2016.

	Number of facilities	Total amount of waste treated (Tonnes)
Waste disposal and recovery facilities	1698	77208662
Waste disposal facilities	140	44125262
Controlled landfill sites	134	43815135
Incineration plants	6	310127
Waste recovery facilities	1558	33083400
Composting plants	7	140467
Co-incineration plants	35	738908
Other recovery facilities*	1516	32204025

* It includes the facilities which recover waste metal, plastic, paper, mineral etc.

3.2. Packaging waste in Zonguldak Province

According to the “Packages and Packaging Waste Control Regulation”, the recycled materials include all packages and packaging wastes independent of the materials used (plastics, metals, glasses, paper/cardboards, composites, etc.) and sources (households, industrial places, commercial places, business places, etc.). There were 94080 households, 10500 workplaces, 148 schools, 929 public institutions and organizations, 223 markets and sale points, and 8 bus stations in the study area. Even though big containers of about 30 m³ were used as the main collection system, small collection boxes were also placed in schools and public institutions to collect paper wastes separately. Two trucks with a volume of 16 m³ were available for carrying packaging materials to the recycling centers. The containers were transported to the recycling centers once a week. The mixed collection system has been implemented in the area since 2008.

3.3 The Evaluation of Plastic Recycling Cost

The amount of PE, PET and PP were recorded monthly at the recycling centers in 2016 and the results were shown in Table 2. January (I) was not included and months were indicated by Roman numbers. According to these results, the total amount of recycled plastics was around 695 tonnes. PET was collected at the highest percentage (58%). The corresponding percentages for PE and PP were 34% and 8%, respectively. In addition, the operating costs of collecting and separating of PSW were evaluated depending on labor and equipment expenses. There were 40 workers in total, and 10 of them were working in the collection of recycled materials while 30 of them were working in the sorting process. The workers' food, transport, insurance and salary fees were taken into account. The communication expenses among the workers were also included in the cost evaluation. In addition, the fuel required for the vehicles for the collection and the electricity and chemicals required in the sorting process were taken into consideration. The costs of each expense were shown in Table 3. According to these results, the cost of PSW recycling was found to be US\$ 0.32/kg when the fixed capital appreciation was not included. This amount shows that recycling of plastics can provide an environmentally friendly source of materials for the production of new products.

Table 2. The amount of collected PSW in Zonguldak Province at 2016 (kg/month)

	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PE	19378	22000	22000	15000	15271	28000	18500	21130	23508	26024	28595
PET	22120	71220	55357	56466	28440	14310	54919	28188	34120	17391	16677
PP	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	6150
TOTAL	46498	98220	82357	76466	48711	47310	78419	54318	62628	48415	51422

Table 3. The cost of PSW recycling process

	Collection Process (US\$)	Sorting Process (US\$)
Labor wages	27895	105263
Food	1316	7895
Fuel	1711	18947
Maintenance	1579	15789
Insurance + Electricity	658	10526
Communication + Transportation	526	23684
Chemicals	6579	3947

The total amount of MSW at 2016 was around 119000 tonnes in Zonguldak province [5]. When MSW was characterized by quaternary method, the plastic percentage in MSW was found to be around 15% [4]. According to these values, the total amount of plastic waste in the area can be estimated as 17850 tonnes. However, the amount of collected PSW was around 695 tonnes. Hence, these numbers shows that the recycling of plastics in the area is only around 4%.

4. Conclusions

The cost of plastic recycling was found to be around US\$ 0.32/kg. This price is comparable to the price of raw materials in the production of plastics. Therefore, the use of the recycled plastics granulates can be economical. In addition, if the recovery of plastic waste is improved recycling costs can be achieved at very low values. The recycling percentage of PSW was very low and around 4%. An improvement in communication and cooperation are required among the governmental local authorities and the public and private sectors in order to achieve higher recovery percentages.

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