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Research Article

THE ASSESSMENT OF REFUSE DERIVED FUEL (RDF) PRODUCTION FROM TEXTILE WASTE

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ABSTRACT
The increase in the world population and the improvement in living standards have led to a significant increase in textile consumption and thus textile production in recent years. Hence the amount of textile wastes generated has been increased. Some of these textile wastes are sold to scrap dealers for recycling, and some of them are thrown away or burned. 4.37% of the amount of industrial solid waste produced in Turkey are the wastes of the textile and cloth manufacturing. Recycling of textile materials can be applied only if the product consists of a single material. However, most of the products in the market are produced by mixing the fibers in order to provide different properties to the product. Hence textile wastes can be used to produce “Refuse Derived Fuel (RDF)”, which is developed for the purpose of using solid waste in the energy production plants and cement factories as fuel and/or co-fuel. Within the study, samples from a textile factory have been taken and the process of separation has been performed. The water content, calorific value, total chlorine analysis and heavy metal analysis of the 31 different samples of textile wastes have been analyzed, and the results have been evaluated according to The Statement on RDF, Additional Fuel and Alternative Raw Materials and the standards of European Union. Textile waste is one of the types of waste that can be used in the production of RDF provided that it meets the necessary conditions.

Keywords: *Refuse Derived Fuel (RDF), Solid Waste Management, Textile Wastes, Waste-to-Energy*

1. INTRODUCTION

The amount of waste has been gradually increasing due to reasons such as human activities, population growth, improvisations regarding to living standards, changes in consumption materials and urbanization. The ecosystem can only clean certain amounts of waste in a couple of years or longer, however, today the total amount of waste forces the capacity of ecosystem and exceeds its effects on top of the cleaning threshold of the ecosystem (Bölükbaş & Akıncı, 2018).

In order to prevent damage to environment and human health, types of solid wastes should be collected and removed from the environment with various methods and waste disposal technologies including recycling, reusing, incineration, landfilling and basic valorization. In this context, “Refuse Derived Fuel (RDF)” is a solid waste technology which is often used in waste disposal purposes. This method is developed for the purpose of using solid waste in the energy production plants and cement factories as fuel and/or co-fuel.

Processes such as yarn production and dyeing, sizing, fabric weaving and dyeing, printing, preparation of various textile products and embroidery are carried out in textile production units. The increase in the world population and the improvement in living standards have led to a significant increase in consumption of textile products and thus textile production in recent years. In these production units; industrial solid wastes such as parts of fabric, ilmar (yarn wastes), mattresses (cannabis used in cotton bales), fiber waste, cotton dust, topcoat and velvet powder are generated. Production units sell some of these solid wastes to scrap dealers for recycling, and some of them are thrown away or burned (Kozak, 2010). The same problem is valid for other countries. For example, 14.5 kg per capita textile waste was sent to landfill site in 2016 in China. Similarly, 29.3 and 9.6 kg per capita textile waste were sent to landfilling in the United States and European Union, respectively (Xu, Cheng, Liao, & Hu, 2019).

According to 2008 data, 4.37% of the amount of industrial solid waste produced in Turkey are the wastes of the textile and cloth manufacturing. Only 1% of the textile wastes were recycled, 26% of them were sold and remain part was disposed in 2008 (Kozak, 2010). The distribution of disposal methods can be seen in the Figure 1.

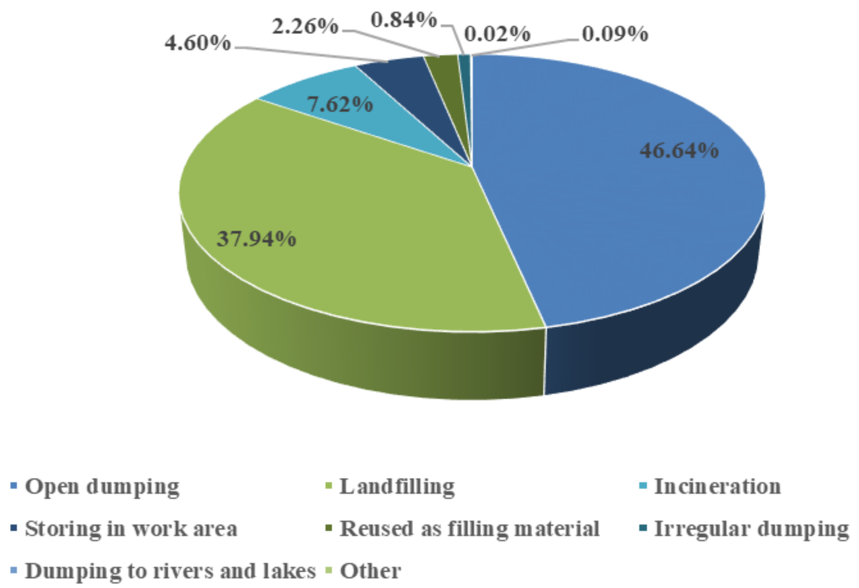

Fig 1. The disposal methods of textile wastes in 2008 in Turkey

Textile wastes which are not reused or cannot be recycled are usually burned. The energy released after this process is recovered. The main advantage of the combustion process in the waste management of textiles is that they can be used for all types of waste. Thus, there is no need to separate the textiles from waste masses. Waste incineration has a negative environmental impact due to CO_2 emissions. On the other hand, thanks to the energy recovered, the consumption of fossil fuels is avoided, and the effects of CO_2 emissions can be compensated (Eser, Celik, Cay, & Akgumus, 2016).

Recycling of textile materials can be applied only if the product consists of a single material. However, most of the products in the market are produced by mixing the fibers in order to provide different properties to the product. In today's markets, the current clothing varies widely in terms of both design and fiber content (Eser et al., 2016). The recycling of clothes are difficult in terms of expensive sorting procedures due to the usage of different fiber blends (Xu et al., 2019).

After the introduction of synthetic fibers in the 20th century, the recycling of textiles has become quite complicated for two reasons: the first is the increased strength of the fibers and the disintegration and opening of the waste has become difficult; secondly, the mixing of the fibers made the separation difficult (Eser et al., 2016; Dahlbo, Aalto, Eskelinen, & Salmenperä, 2017). These reasons make the incineration of the textile wastes as RDF more important.

The second important source of textile wastes is the wastes produced after usage. Waste amount per capita in Turkey is 1.77 kg / day (2012). The ratio of textile wastes in the total MSW is 1.14%. When considered together with household waste and industrial waste each year in Turkey, approximately around 1.155 million tons of textile waste seems to occur (Altun, 2014).

The study includes characterizations of RDF, which was produced by the textile waste emerged from weaving industry, applicability of production and fields of application of RDF. It is important to observe the availability of the RDF production from textile waste. It seems beneficial to send textile waste to waste-to-energy processes instead of landfilling. There are no previous studies about the suitability of RDF production from textile waste. Therefore, the study focuses on characterization of the textile waste regarding requirements of RDF production.

2. MATERIAL AND METHODS

Within the study, samples from a textile factory have been taken and the process of separation has been performed. As a result of the process from the factory; the water content, calorific value, total chlorine analysis and heavy metal analysis of the 31 different samples that were produced as a result of the production of suits, women's clothing and shirts have been analyzed, and the results have been evaluated according to The Statement on Refuse Derived Fuel, Additional Fuel and Alternative Raw Materials and the standards of European Union (Official Journal (o.j), 2017).

3. RESULTS AND DISCUSSION

The results of textile wastes are given below. The water content of the textile wastes can be seen in the Table 1. The average water content of the textile wastes has been calculated as 4.14% which is below the limit value in The Statement (35%).

It has been seen that the organic matter values of the samples were over 99% for 31 samples. A literature comparison was made, and the values were found to be appropriate.

Table 1. The water content of the textile wastes

Sample	Water Content, %	Sample	Water Content, %	Sample	Water Content, %
T1	4.57	G3	3.34	B6	7.07
T2	5.00	G4	4.91	B7	4.17
T3	3.22	G5	0.39	B8	7.98
T4	6.57	G6	2.63	B9	4.08
T5	5.99	G7	2.11	B10	0.16
T6	4.78	G8	5.07	B11	1.04
T7	4.16	B1	2.51	B12	5.62
T8	6.32	B2	4.48	B13	6.88
G1	1.67	B3	5.73	B14	6.10
G2	4.38	B4	0.20	B15	7.11
		B5	0.00	Ave.	4.14

According to the statement, the required calorific value should be minimum 2500 kcal / kg. As can be seen from the results in the Table 2, all samples were over 2500 kcal / kg, which is very suitable for RDF.

Table 2. Calorific values of the textile wastes

Sample	Calorific Value, kcal/kg	Sample	Calorific Value, kcal/kg
T1	4891	B1	7207
T2	4249	B2	3983
T3	5879	B3	4973
T4	3643	B4	5340
T5	4960	B5	5378
T6	4879	B6	5351
T7	4939	B7	4158
T8	4945	B8	4981
G1	3845	B9	4155
G2	5110	B10	5325
G3	5139	B11	5968
G4	4910	B12	5093
G5	5160	B13	3653
G6	3949	B14	3640
G7	3975	B15	4565
G8	5282	Ave.	4822

According to the statement, the required chlorine value should be maximum 1%. As shown in the results the Table 3, all samples were below 1% and the average chlorine content was calculated as 0.2%.

Table 3. Chlorine content of the textile wastes

Sample	Total Chlorine, %	Sample	Total Chlorine, %	Sample	Total Chlorine, %
T1	0.26	G3	0.14	B6	0.16
T2	0.10	G4	0.08	B7	0.10
T3	0.08	G5	0.18	B8	0.20
T4	0.14	G6	0.12	B9	0.12
T5	1.00	G7	0.04	B10	0.06
T6	0.06	G8	0.12	B11	0.12
T7	0.18	B1	0.10	B12	0.18
T8	0.80	B2	0.40	B13	0.18
G1	0.10	B3	0.18	B14	0.14
G2	0.04	B4	0.10	B15	0.78
		B5	0.08	Ave.	0.20

Some samples having high calorific value and low chorine content have been sent to heavy metal analysis. After acid digestion, the analyzes have been carried out in ICP-OES. The results can be seen in the Table 4 and all values are under limit values.

Table 4. Heavy metal contents of the textile waste

Sample	Al, ppm	Ca, ppm	Cd, ppm	Cr, ppm	Cu, ppm	K, ppm
B1	0.3361	12.59	0.009	0.0233	0.0365	0.5134
B5	0.3445	11.3	0.0107	0.1659	0.0331	0.5361
G5	1.058	17.5	0.0096	0.0372	0.1484	0.8844
G8	0.4207	13.34	0.0107	0.0131	0.0471	0.6427
T3	0.2469	23.81	0.0092	0.0214	0.0551	0.5672
T7	0.2977	10.85	0.0073	0.0184	0.0429	0.4245

Sample	Mg, ppm	Mn, ppm	Na, ppm	Ni, ppm	Pb, ppm	Zn, ppm
B1	2.474	0.0376	6.398	0.0131	0.0236	0.169
B5	2.421	0.0488	5.649	0.0711	0.0591	0.1907
G5	2.85	0.0823	9.372	0.5504	0.0575	0.7248
G8	2.612	0.0396	11.33	0.0041	--	0.882
T3	3.483	0.1052	5.694	0.2135	0.0135	0.7169
T7	2.372	0.0321	4.466	0.1985	0.0427	0.3972

If textile wastes are used in the production of electricity, 4822 kcal of energy will be obtained from one kilogram of textile waste. The electrical energy of this is 5.6 kwh. The price of electricity sold in Turkey as a result of unlicensed electricity production 0.8 TL / 1 kWh. The gain from one kilogram of waste is 4.5 TL. Therefore, a gain of 4500 TL is obtained from 1 ton of waste.

In another view, hybrid primary energy index (HPE) calculation could be applied to observe the inputs and outputs (Di Maria et al., 2018). If the total amount of textile wastes generated per year is assumed as one million, the HPE is calculated as follow by Eq. (1):

$$HPE = (Mwaste\ (Mg)\ x\ LVHwaste\ (MJ/Mg) + \sum CEDin\ (MJ) - \sum CEDout\ (MJ) \qquad (1)$$

HPE = (1,000,000 Mg x 20 MJ/kg x 103 kg/Mg) + 1900 MJ/Mg x 106 Mg – 13,000 MJ/Mg x 106 Mg

HPE = 2 x 1010 + 1.9 x 109- 1.3 x 1010

HPE = 8.9 x 109 MJ = 2.5 x 109 kWh

(CEDin & CEDout are assumed as 1,900 MJ/Mg and 13,000 MJ/Mg, respectively.)

Furthermore, Tanner diagram could be used to evaluate the incinerability of the wastes. Incinerability means that the suitability of MSW to be burned to sterile ash with minimum environmental impact, optimum energy recovery and economic sustainability. The Tanner diagram depends on the proximate analysis of the MSW feed to define a zone of combustibility (Tanner, 1965). The proximity to the point of maximum combustibility defined by 100% volatile fraction, 0% inert content and 0% moisture content was taken as the measure of incinerability (Sebastian et al., 2019). The application of the Tanner diagram for the textile wastes in this study can be seen in the Figure 2.

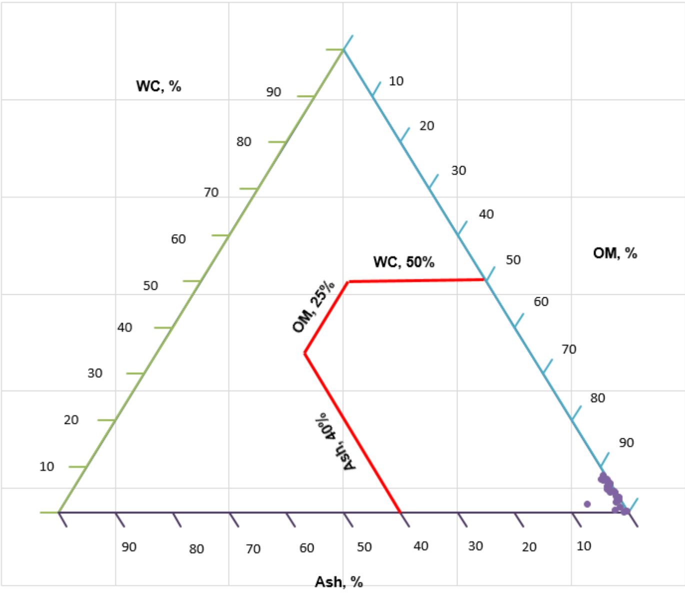

Fig. 2. The Tanner diagram for the textile wastes

All the waste samples are in the range of incinerability. As it can be understood from the figure, the textile wastes are very proper for incineration.

4. CONCLUSION

When the above results are evaluated according to the Statement on Refuse Derived Fuel, Additional Fuel and Alternative Raw Materials and European Union standards, the following conclusions have been obtained:

• Textile waste is one of the types of waste that can be used in the production of Refuse Derived Fuel provided that it meets the necessary conditions as stated in the Statement.

• It has a significant amount of resources for the production of RDF to which Turkey is advanced in terms of textile industry.

• Water content is required to be less than 35% in the Statement and less than 20% in European Union standards (Alp, 2011). According to the results, the water content of the textile wastes used in the study was found as 4.14% on average. Accordingly, the wastes in terms of water content meet the given limits.

• Calorific value is higher than 2500 kcal / kg. The average calorific value of textile wastes was found as 4822 kcal / kg. It is well above the desired value. In other words, when the textile wastes are burned, the energy to be released is significant. In the European Union standards, the calorific value is more than 3500 kcal / kg (Alp, 2011). Waste according to this standard is also suitable.

• Total chlorine content is less than 1% in the Statement and less than 0.5% in European Union standards. The total chlorine content of the wastes was found as 0.2% on average. The wastes are also suitable for the total chlorine content.

• Heavy metal concentrations of textile wastes were far below the limit values in both the Communiqué and European Union standards. In other words, textile wastes in terms of heavy metal contents are suitable for RDF production.

• Consequently, textile wastes are suitable for production of RDF according to the results of these analyzes. After necessary pretreatments, textile wastes can be used in the production of RDF.

Turkey is quite advanced in the production of textiles. It has an important share in both domestic and foreign markets. Therefore, the amount of textile wastes released is also high. Not all these wastes are suitable for recycling. Therefore, another evaluation method is needed. Refuse Derived Fuel production is a suitable method for the evaluation of textile waste. According to the results of this study, textile wastes provided the necessary conditions for RDF production.

According to the results of the study by Sarc and Lorber, the textile wastes used in the study were found suitable for use in the secondary furnace of the clinker (Sarc & Lorber, 2013). The wastes have an average calorific value of 20 MJ/kg and the particle size can be adjusted to the desired value. In addition, its low water content makes textile wastes more valuable.

As a result, when all these results are evaluated, the textile wastes are found suitable for the production of Waste Derived Fuel and the energy obtained will provide a significant gain.

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