Environmental and Economic Benefits of Recycling PET Bottles

Havva ARABACI[1] **Nurcan ÖZKAN**[2]

[1]Instruc., University of Trakya, Edirne Vocational School of Social Sciences, Department of Accounting and Tax
arabacih@hotmail.com, ORCİD: 0000-0003-0212-6590

[2]Assoc. Prof. Dr., University of Trakya, Faculty of Education, Department of Mathematics and Science Education, nurcanozkan@hotmail.com, ORCID: 0000-0001-5045-6186

Abstract: Plastic is obtained from petroleum, the most important natural resource in the world. Most of the time it is used in the form of packaging, then it becomes garbage and remains as garbage forever. When plastics are treated with heat, they are considered in two groups as non-melting plastics (thermoset) and meltable plastics (thermoplastic). Thermoset plastics exist as solids at any temperature. Used thermoplastics are recycled under the influence of heat and pressure and used in the production phase. Increasing developments in the recycling technology of plastics have created a new raw material source for the textile industry due to price and ecological advantages. The most common types of plastic bottles used in daily life are Polyethylene Terephthalate (PET) and Polyvinyl Chloride (PVC). Polyethylene Terephthalate (PET) polymer is the most consumed polymer in the textile sector. PET bottles can find more usage areas after transformation. The most suitable material for recycling is PET polymers obtained from PET bottles. PET polymers; PET packaging, which is generally used in the marketing of liquid foods such as water, soft drinks, oil, can be converted into PET shavings (burr, flake) in recycling facilities. PET shavings were also mostly used for fiber production. Materials such as carpet floors, sleeping bags, pillows, duvets, insulators in clothing, auto parts, paint brushes, life-pads, bags, mailboxes, picnic tables, fences, hiking boots, double-compartment buckets, laser toner cartridges and belts are produced from the recycling of PETs. This provides environmental and economic benefits. In our country, solid wastes mainly constitute packaging wastes and it is observed that fiber production from PET shavings is increasing. This study was conducted to explain the environmental and economic benefits of recycling PET bottles.

Key Words: PET Bottle, Recycling, Economic Impact, Environmental Impact

PET Şişelerin Geri Dönüşümünün Çevresel ve Ekonomik Faydaları

Plastik, dünyadaki en önemli doğal kaynak olan petrolden elde edilmektedir. Çoğu zaman ambalaj şeklinde kullanılmakta, daha sonra ise çöp olmakta ve sonsuza kadar çöp olarak kalmaktadır. Plastikler ısı ile muamele edildiğinde erimeyen plastikler (termoset) ve eriyebilen plastikler (termoplastik) olarak iki grup olarak ele alınırlar. Termoset plastikler, her sıcaklıkta katı olarak bulunurlar. Kullanılmış termoplastikler ısı ve basıncın etkisiyle geri dönüştürülerek yeniden üretim aşamasında kullanılmaktadır. Plastiklerin geri dönüşüm teknolojisinde artan gelişmeler, fiyat ve ekolojik avantajlardan dolayı tekstil endüstrisi için yeni olan hammadde kaynağı oluşumunu sağlamıştır. Günlük hayat içinde kullanılmakta olunan plastik şişelerin en fazla olan çeşitleri Polietilen Teraftalat (PET) ve Polivinil Klorür (PVC)'dür. Tekstil sektöründe en çok tüketilen ise polimer olan Polietilen Tereftalat (PET) polimeridir. PET şişeler, dönüşümden sonra kendine daha fazla kullanım alanı bulabilmektedir. Geri dönüşüme en uygun malzeme PET şişelerden elde edilmekte olan PET polimerlerdir. PET polimerleri; genellikle su, meşrubat, sıvı yağ vb. sıvı gıdaların piyasaya sürülmesinde kullanılan PET ambalajlardan geri dönüşüm tesislerinde PET talaşlarına (çapak, flake) dönüştürülebilmektedir. PET talaşları da en çok lif üretimi için kullanılmıştır. Geri kazanılan PET'lerden ise halı tabanları, uyku tulumları, yastık, yorgan, giysilerdeki yalıtım maddesi, oto parçaları, boya fırçaları, cankurtaran yastıkları, torbalar, posta kutuları, piknik masaları, çitler, yürüyüş botları, çift bölmeli kovalar, lazer toner kartuşu ve kayışlar gibi malzemeler üretilmektedir. Bu ise çevresel ve ekonomik bakımdan fayda sağlamaktadır. Ülkemizde katı atıklar ağırlıkça, ambalaj atıklarını oluşturmakta ve PET talaşlarından lif üretiminin giderek artmakta olduğu gözlenmektedir. Bu çalışma, PET şişelerin geri dönüşümünün çevresel ve ekonomik faydalarını açıklamak amacıyla yapılmıştır.

Anahtar Kelimeler: PET Şişe, Geri Dönüşüm, Ekonomik Etki, Çevresel Etki

1. INTRODUCTION

Plastic; in the petrochemical industry, it is one of the important groups of substances that use petroleum-based products or products and natural gas as raw materials and are obtained by their chemical transformations. Plastics are divided into two groups as non-melting when heated (thermoset) and meltable plastics (thermoplastic). In thermoset plastics, the term thermoset means that it can become cross-linked at both room temperature and higher temperature. Due to the cross-links between polymer chains, these materials exist as solids at all temperatures (Kıralp et al., 2007). Thermoset plastics consist of phenolic resins, furan resins, amino acids, alkyds, unsaturated acid polyesters, epoxy resins, polyurethanes and silicones (Güler & Çobanoğlu, 1997).

Thermoplastics, another subgroup of plastics, are straight or branched polymers that can melt when heated. Due to the absence of cross-links, the

relatively weak forces between polymer chains disappear when heated, and the material becomes fluid as the chains slide easily over each other. Used thermoplastics can be recycled and reused by applying heat and pressure (Kıralp et al., 2007).

Packaging is any material that contains foodstuffs in order to protect the product from the moment it is manufactured until it reaches the consumer, to increase its performance and to provide information about the product (Işık et al., 2013: 27). The materials that can be used in packaging are different products such as plastic, metal, composite, paper-cardboard, glass and wood (Packaging Bulletin, 2016: 1). However, among so many different packaging options; Plastic packaging is widely used in commercial and social life due to its main features such as low transportation cost, being a durable and very safe container, being able to be given different shapes, being flexible or rigid, and being a good insulator. But the source of plastics is crude oil, gas and coal. Due to these features, the use of plastic packaging causes great controversy in every sense (Sevencan & Vaizoğlu, 2007). For example; Although plastic packaging materials are safe, economical and convenient to use, they create environmental problems (Ayana & Turhan, 2010: 152) because they do not biodegrade and it takes more than 500 years to mix with nature (Sayman & Akpulat, 2016: 13).

Plastic packaging is used in almost every sector. However, plastic products take up a lot of space, especially in the packaging used in the delivery and supply of liquid substances to the market. The product, which is used as polyethylene terephthalate in the plastics industry and is known as PET material among the people, started to be produced in the USA in the 1970s upon demand from consumers in order to reduce the risk of injury to children as a result of breaking glass bottles. Due to the different advantages it provides, it has become one of the most preferred packaging today (Arıkan, 2009: 34). Hundreds of different soft drinks and liquids are consumed in PET bottles and offered to consumers worldwide (Şimşek & Akdağ, 2017).

Plastic materials are very common materials with advantages such as cheapness, strength, easy processing, lightness and cleaning. Due to the short life span of plastics in packaging and packaging industry applications, they create a solid waste problem very soon after they are produced and have disadvantages such as not breaking down and remaining intact under natural conditions. Generally, plastic waste is generated after use by consumers or during production in industry. It is necessary and important to ensure the recycling of plastic materials both to protect the environment we live in, our world and our energy resources, and to continue to benefit from its superior properties (Kılıç & Yüce, 2014: 84-85).

Recycle; It is expressed as the recycling of recyclable waste materials that are out of use as raw materials through various methods (URL, 1). Recycling materials; plastic bottles, car tires, broken glass pieces, unusable metal parts, all items that have lost their use potential. These materials are separated to their raw materials by recycling. Then, a new product is created with these materials, which become raw materials. This whole process is called the "Recycling Process". This event is called the “Recycling Process”. These:

a. Economic contributions of recycling (URL, 2);

• For the economy, recycling means avoiding waste. By preventing the waste of waste materials that can provide benefits, benefits are provided for the society.

• Some problems such as transporting or stacking waste materials and garbage are eliminated.

• Unnecessary consumption in terms of raw materials is reduced.

• Unnecessary energy consumption is prevented.

• It ensures that unusable, waste materials are offered to consumers as a brand new product.

• It prevents waste materials from being a problem in crowded populated areas.

• It increases employment and reduces unemployment by creating a new business line.

• It reduces the amount of raw material that needs to be imported from other countries by making waste materials into raw materials and ensuring their re-production. Thus, it greatly reduces import costs.

b. Environmental contributions of recycling (URL, 2);

• Recycling contributes to the protection of trees, minerals and water resources.

• It greatly reduces the search for new raw materials for the production of consumables. Thus, it prevents both air and environmental pollution.

• Contributes to the reduction of greenhouse gas emissions.

• Finally, soil fertility increases thanks to compost materials and fertilizers from household waste. As a result, organic and nutritionally rich products are provided.

The reasons such as the increase in production and consumption with the increase in the world population, the protection of limited resources and the provision of energy savings have made the concept of recycling very important. Recycling ensures that wastes from various sources are included in production by passing through different process steps so that they can be re-evaluated. Waste disposal has become mandatory for producers and consumers due to reasons such as the decrease in the areas required for the storage of wastes and the increase in logistics costs. However, only recycling practices made with environmentally friendly approaches are fully beneficial (Macit et al., 2019).

The packaging and construction industry is one of the leading sectors in the world's plastic consumption. Advances in recycling technology of plastics have provided a brand new source of raw materials to the textile industry, considering the price and ecological benefits. This is the PET polymers obtained from PET bottles, which are considered the most useful material in terms of recycling in the activities of the Plastics Council of America. Because, when life cycle analyzes are examined, PET bottles, which make up 30% of PET-based materials with the highest consumption among plastics; less amount of composite is used, it can be recycled more easily. For this reason, it loses its feature less and can find more usage areas after transformation (Sevencan & Vaizoğlu, 2007).

The first PET recycling project was started in 1976 in St. It was started by a company called Jude Polymers. Empty PET packaging that is used and thrown away by the user becomes PET waste. In the recycling industry, this is called post consumer PET. The first recycling process of POSTC-PET (Post consumer PET) or r-PET (recycled PET) was made in 1977. Since 1995, polyester has been widely used in the felt industry (Tayyar & Üstün, 2010).

It is estimated that 80-85% of recycled PET is used in polyester fiber production in the world. Since polyester fiber is an alternative to cotton; it is an item that is in high demand and its price rises in years when the annual product amount of cotton is very low. Since Turkey is a textile country, serious facilities that can produce fiber from recycled PET burrs continue their activities in cities such as Adana, Gaziantep, Bursa and Uşak. The polyester production center in the world is China. As a matter of fact, most of the recycling facilities in Turkey export PET burrs to facilities located in China (Anabal, 2007; Tayyar & Üstün, 2010).

Increasingly developing industrialization, urbanization and technological advances have led to an increase in the problems of depletion of natural resources and environmental pollution. It provides a great advantage especially for countries that do not have enough space to dispose of wastes on a regular basis, in terms of evaluating waste or reducing the amount and volume of disposal waste. In line with these purposes, many studies are carried out and projects are developed in order to protect resources and prevent environmental pollution. PET bottles are widely used, especially in the soft drinks industry, and can be reused after physical or chemical recovery. The usage areas of recycled PET bottles are developing rapidly. As the recycled PET is used in the plastic industry, the composite industry also offers alternatives in the use of this material. The textile sector is also a suitable sector for the recycling of some plastics whose raw material is polymer.

Approximately 1.2 kg of crude oil is used in the production of one PET bottle. The water consumption required for the extraction of this oil depends on the well, and since the exact amount cannot be determined, it is thought that at least 65 liters of water is used. In addition, although the amount of electricity consumed in crude oil exploration and extraction processes is not known, it is seen that at least 200W/h of electricity is consumed. A plastic bottle does not disappear in nature for 3 thousand years, and when one ton of plastic is recycled, 14 thousand kW/h of energy is saved (Anonymous, 2009).

165 thousand tons of plastic bottles are produced annually in Turkey. However, only 40 thousand tons of it can be recycled. The material value of 125 thousand tons of plastic bottles that are mixed with nature every year is 70 million dollars, and Turkey pays 1.7 billion dollars per year for synthetic fiber. Since 1 billion dollars of this goes to the import of polyester fiber obtained from recycling, 1 billion dollars will be able to stay in Turkey if enough attention is paid to recycling (Anonymous, 2007).

Most of the plastic bottles used in daily life are Polyethylene Terephthalate (PET) and Polyvinyl Chloride (PVC). In the textile sector, the most widely consumed polymer is Polyethylene terephthalate (PET) and it is mostly preferred in liquid foods such as water, soft drinks and oil. It can then be converted from PET packaging to PET shavings (burr, flake) in recycling facilities.

PET shavings are obtained after a series of process steps such as crushing, washing and drying by separating PET bottle wastes from other wastes. PET shavings are mostly used in fiber production (Telli et al., 2012: 50). This provides environmental and economic benefits.

Materials such as carpet floors, sleeping bags, pillows, duvets, insulators in clothing, auto parts, paint brushes, life-pads, bags, mailboxes, picnic tables, fences, hiking boots, double-compartment buckets, laser toner cartridge and belts are produced from recycled PET. The usage area of refillable containers made of PET has gradually expanded (Sevencan & Vaizoğlu, 2007).

1.1. Benefits of Recycling Pet Bottles

The benefits of recycling have the potential to affect the whole world, both socially and economically. Importance of recycling in terms of environment; natural resources are protected and the amount of waste is reduced. In terms of economy, energy saving is provided, contribution to the economy is provided, it is an investment for the future.

It is possible to use natural resources in the most effective way by minimizing the consumption of materials and recycling wastes that can be evaluated. Glass, metal, plastic and paper/cardboard packages are provided by the use of natural resources such as forests, water and oil in the production process. When the packages put on the market turn into waste, they are separated into types and sent to the industry for recycling. The materials recycled here serve as secondary raw materials in the production of many products. As a result, natural resources are used at a minimum level and in this way a contribution is made to nature. There is a decrease in the amount of waste that is garbage through recycling, and less space and energy is used in the transportation and storage of waste (URL, 1).

Recycling is an efficient economic investment in the long run. Economic problems can be experienced due to the decrease in the raw material to be used and the excessive reduction of natural resources. Recycling can provide positive effects for the economy here. Reducing the use of energy and natural resources greatly benefits the country's economy. In addition, as a result of the decrease in the consumption of raw materials such as oil, which is dependent on abroad, the economy is getting better as the money stays in the country. Products such as synthetic fiber formed as a result of recycling are also sold abroad, providing foreign currency inflow to the country (URL, 1).

Solid waste in Turkey is mostly packaging waste. The recycling of packaging waste started to gain momentum after the “Packaging Waste Control Regulation” published in the Official Gazette on 1991, 2004, 2007 and lastly on 24 August 2011.

The results of the market research show that fiber production from PET shavings is increased in Turkey. As of 2012, it has been determined that eight fiber producers are operating in Uşak, Bursa, Adana, Gaziantep, Tekirdağ and Afyonkarahisar. Only 3 companies are working with suitable fiber fineness (1.3 dtex) for yarn production. They are generally produced in ecru, white and black color tones. r-PET fiber customers are particularly active in areas such as insulation, pillow filling material, reinforcement material, socks, blankets and carpet sectors (Telli et al., 2012).

1.2. Researchs on PET Recycling

Inoue and Yamamoto (2004) investigated the use and durability properties of polyester-containing woven fabrics, which were thermomechanically recycled from PET bottles. According to the study, as the recycled fiber ratio increases in fabrics containing recycled polyester, the fabrics tend to show a tighter structure. They stated that this situation also affects the bending and shear strength properties positively.

Üstün Çetin (2010) produced a nonwoven fabric using original polyester and rPET (thermomechanically recycled polyester from a PET bottle) by needle punching at different mixing ratios and different cheesecloth coefficients. Stating that the fabrics are aimed to be used for insulation purposes, the researcher examined the mechanical strength properties and permeability properties of the fabrics. It has been stated that the effect of using recycled fiber on properties such as drape and air permeability is insignificant. The researcher reported that the values of the product with 100% rPET raw material in relative water vapor permeability were statistically different from the products with other blending ratios.

Tayyar and Üstün (2010) gave information about recycled polyester fibers from PET bottles in their study. In addition to the sections containing detailed literature data on the identification and classification of plastics, the researchers explained the recycling of PET bottles and the possibilities of using recycled PET fibers in textiles. Researchers talking about the use of rPET fibers in the non-textile and textile sector emphasized the importance of using recycled fibers in terms of sustainability.

Rajamanickam and Vasudevan (2014) obtained yarn by using thermomechanically recycled fiber from Lyocell and PET bottles at different mixing ratios in their study. Ring yarns produced with lyocell and recycled polyester blends were found to be satisfactory in terms of strength and elongation values. All blended yarn samples treated with chitosan had better antibacterial properties than

the control groups (Rajamanickam & Vasudevan, 2014).

In her study, Telli (2016) produced yarns and denim fabrics from these yarns by using recycled cotton and recycled PET (r-PET) that occur in the cotton spinning process. The researcher stated that in the mechanical strength test results made to determine the usage performance of the yarns produced, there was an increase in the breaking strength and elongation at break, and a decrease in the unevenness, yarn defects and hairiness values with the increase in the amount of r-PET in the blends. The use of recycled cotton in denim fabrics, which are in the form of the final product, caused a decrease in breaking and tear strength. With a similar view; while r-PET fiber contributes to breaking strength, elongation at break and tear strength, it has been observed that it adversely affects softness.

Chauhan et al. (2019) produced nonwoven fabrics in different production parameters by needling using original and rPET. When the breaking properties of the products were examined, the breaking strength of the product obtained from recycled fibers was found to be only 8-10% lower than the original.

Atakan et al. (2018) used original and recycled rPET from PET bottles in their studies. Fabrics with predetermined production and molding parameters were produced from blends of rPET and original PET fibers for use as automotive upholstery.

When the developed upholstery is compared in terms of abrasion resistance, it has been observed that the upholstery containing rPET has almost the same performance characteristics in terms of fiber loss and appearance as those without (Atakan et al., 2018).

In the study of Uyanık (2019), virgin polyester (PET), recycled polyester (rPET) and viscose (CV) fibers were used in 4 different yarn counts as Ne 10, Ne 20, Ne 30, Ne 40 and 100%- 65-35%, He obtained yarns at 50-50%, 35-65% blend ratios and investigated which yarn count and blend ratio rPET fiber is more suitable for. As a result of the tests applied to the yarns and the statistical analysis, the researcher determined that the rPET fiber generally has negative effects on the yarn properties, especially in fine yarns, due to the physical and chemical degradation that occurs during its recovery. As a result, she stated that rPET fiber is suitable for use in thick numbered yarns such as Ne 10 and Ne 20 in 100% state and in all mixing ratios. When the thread number is thin; it has been reported that it is appropriate to use less than 65% for Ne 30 and less than 35% for Ne 40.

Sarıoğlu (2019) obtained single jersey fabrics from recycled polyester and original polyester fibers from a PET bottle by thermomechanical means. The researcher studied the bursting, air permeability and wetting properties of fabrics. Optimization analysis was also carried out in order to produce single jersey fabric from yarn with optimum fiber blend ratio. As a result, it was observed that the blend type, blend ratio and yarn production technology had a statistically significant effect on burst strength and air permeability. Researcher stated that it is recommended to turn recycled polyester into yarn and use it in knitted fabrics.

Ahrabi et al. (2012) mentioned the importance of reuse of plastic materials in their study. The particles obtained from waste PET (Polyethylene terephthalate) bottles were mixed with marble dust and used in the production of composite materials, which can be evaluated as sheets. In the test results of the products, the lowest hardness value was found in the pure PET sample, while this value increased approximately twice in the sample where the marble ratio was 30% by weight.

2. RESULT

Industrialization, urbanization, technological advances and depletion of natural resources, which are gaining momentum, increase environmental pollution problems. Industrialization has become the most important responsible of environmental pollution by creating mass production and consumption society. Waste and mostly plastic packaging are left to the environment without being recycled as desired. This not only endangers the natural life for sea creatures, but also causes many problems by polluting the soil, causing deterioration in the ecological balance and decreasing the fertility of the soil (Şimşek & Akdağ, 2017).

In the century we live in, the dimensions of environmental pollution are increasing day by day and environmental problems threaten human beings at a level that can cause global warming (Sevencan & Vaizoğlu, 2007: 309). Environmental pollution, especially caused by plastic packaging, harms nature and people in every field. The fact that plastic packaging is disposable, cheap, light, and the production process is easy has increased the rate of plastic use by people, so the variety and number of plastic materials used has increased every year. However, the negative effects of the raw materials used in the plastic product production process on human health cause the need for nature-friendly, new and sustainable alternatives in individuals. It is certain that plastic wastes and other industrial wastes should be used in the best way in our age

where environmental protection awareness is rapidly advancing and the materials obtained should be used more economically and ecologically.

Today, scientific progress as a result of developments in industry and technology makes it possible to launch new products in different fields. In particular, the emergence of alternative food and beverage and the taking place of these products in social life; It helps today's resources to be used in a balanced way without destroying the natural resources that will enable future generations to continue their lives. This process, called sustainability, means protecting the world of the future as well as the present and shaping the future from today. One of the new concepts that have emerged in recent years related to sustainability is edible water bottles. In particular, the balance of nature protection and use; Edible water bottles, which emerged as an alternative to PET bottles that take years to dissolve in the soil, have begun to be accepted as a much cleaner and healthier alternative to existing bottles that cause environmental pollution. From this point of view, it is possible to say that making edible water bottles usable in daily life will make significant contributions to both nature and humanity. Considering the production and stocking issues in large quantities, it is necessary to carry out different studies in order to reach the final consumers of edible water bottles (Şimşek & Akdağ, 2017).

The amount of waste that creates environmental pollution caused by industry can be minimized by creating financial resources for education, planning, good management, state control and environmental protection, but it cannot be completely eliminated. However, while both waste of natural resources and waste problems are reduced, economic inputs can be increased (Tayyar & Üstün, 2010).

It is aimed to prevent the rapid consumption of natural resources and to transform the wastes produced into an input for the economy by not being a threat to the environment and human health. These waste management strategies form the basis of the "sustainable development" approach, which is increasingly being adopted as a priority policy target all over the world. As can be understood from the researches, the areas where PET recovery is used the most are composite material production and plastic industry. The developments in the recycling technologies of plastics have created a new raw material source for the textile industry due to price and ecological advantages. This provides environmental and economic benefits. Wastes can be separated from each other by various chemical and technological studies, but this must be done in the most economical way without harming the environment.

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