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Research Article

Rubber Waste Management and Waste Management Practices in Rubber Production Facilities

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Abstract – It is noted that in countries that have completed the industrial revolution, the cost of repairing environmental damage far outweighs the cost of protecting the environment. Within the framework of sustainable use of natural resources and effective waste management, recycling and utilising rubber waste for energy generation is of paramount importance. The significant increase in the number of vehicles worldwide and the lack of technical and economic mechanisms for processing end-of-life automobile tires have led to the accumulation of waste tires in landfills, creating a serious environmental problem. It is estimated that approximately 80% of waste tires globally remain unused, and the amount of waste tires in Turkey is doubling annually. This situation highlights the need for urgent action plans for waste tire management. Rubber waste can be used both in businesses by converting it into more durable materials (vulcanisation) and in energy production in power plants.
In this study, the use of rubber in the automotive sector and recycling alternatives of waste tires were evaluated and the methods of reusing waste rubber were examined through a sample enterprise.

Key words– Automobile sector, end-of-life automobile tires, rubber, vulcanisation, waste management

I. INTRODUCTION

Rubbers are cross-linkable and vulcanisable polymers. Unvulcanised rubber has poor mechanical properties, is adhesive, and is resistant to chemical influences. However, after vulcanisation, it loses its adhesiveness, and its physical properties and chemical resistance improve [1]. Rubber is the raw material for many materials used in daily life. More than 60% of rubber is used in the automotive sector [2]. Rubber products are widely used in the white goods sector, medicine and surgery, park and garden flooring, escalator conveyor belts, sports balls, and shoe manufacturing.

Because rubber and tire production is used as a primary or by-product in many different sectors, its production continues to increase. However, waste from rubber and plastic production, as well as waste rubber and waste plastic, poses a risk to environmental health. The Association of Tire Industrialists has reported that 300,000 tonnes of waste tires are generated annually in Turkey [3]. Waste tires are known to be a waste that local governments struggle to manage. Storing these wastes harms human health and negatively impacts the aesthetic appearance of the areas where they are stored [4]. To prevent the risk of fire from end-of-life tires, factors such as the high heat generated by their structure, the smoke generated, and the number of tires in storage areas should be taken into consideration. Uncontrolled tire burning, intended to sell the steel fibres in waste tires, causes air, soil, and groundwater pollution.

Recycling waste tires and rubber is crucial for their use as raw materials and energy sources. Recycling projects enable the reintegration of materials used in these areas into production and support sustainable production [5]. Recycling tires reduces production costs and prevents degradation of the natural environment and soil structure. At the same time, this recycling prevents environmental pollution caused by tire and rubber waste and reduces the need for raw materials required for green-field production. This not only contributes to the creation of new job opportunities, reducing unemployment, but also enables the establishment of new work areas [6, 7].

II. WASTE RUBBER RECYCLING METHODS

As is well known, the waste management hierarchy is structured as follows: preventing and reducing waste generation to minimise environmental damage, reusing and recycling waste, recovering energy from waste, and storing it. Waste tire management generally involves recycling, reuse, storage, and recovery methods.

It's known that tires take a long time to decompose in the natural environment. This also degrades soil quality. Recycling these tires and using them in various sectors offers significant benefits. Literature indicates that tires are generally recycled using four different methods [8]. These methods are:

A. Re-Coating Method

In this method, tires that have become waste due to worn-out grooves and treads on the top and sides of the tires are re-retreaded and replaced. The tire is not shredded or ground; only the existing tire is recycled. While retreading is used to recycle car tires, it is more commonly used for truck tires [9].

B. Energy Recovery Method

This method utilises tires, which cannot be recycled, as energy. Burning tires releases a significant amount of energy, which can be used when heat is needed in factories. Burning tires is particularly preferred in the cement industry because it provides a practical and inexpensive fuel. While the environmental impact of burning tires is a matter of debate, a World Business Council report indicates that this process is suitable in terms of emissions. While CO_2 emissions from tires used as fuel are lower than those of diesel fuels, they are higher than those of wood and natural gas [8, 10, 11].

C. Pyrolysis Method

The purpose of this technique is to convert vehicle tires into various components. The tires are subjected to a thermal treatment in a reactor, and oxygen is removed. This process decomposes the tires into hydrocarbon gas, pyrolysis oil, and carbon black. The hydrocarbons can be filtered from the resulting components and used as heating oil. The products obtained after the pyrolysis reaction include small amounts of steel, oil, carbon black, and high-calorie combustible gas. Pyrolysis is preferred over other methods because it does not harm the environment or cause pollution during the tire processing process. This method can yield components such as 73% granular rubber material, 19% steel fibre, and 8% textile [12].

D. Product and Material Recycling Method

This method involves transferring waste tires to industries where they can be used as derivative products or filler materials. Many businesses in the US and Europe recycle their waste tires for use in various sectors. Vehicle tires are used in traffic-related products, sidewalks, playground coatings, artificial turf, animal care products, and exterior cladding materials. Additionally, shredded tires are used in the construction industry in the production of ready-mixed concrete and asphalt. One of the primary uses of tire crumb is for flooring in sports fields [10].

III. WASTE MANAGEMENT IN A PLASTIC RUBBER INDUSTRY FACILITY: A BUSINESS EXAMPLE

This section examines the waste management processes at a company that produces plastic construction materials. Founded in 1972, it boasts one of Europe's three largest plastics production complexes. The company produces plastic-based products for various sectors, including construction, agriculture, automotive, medical, and white goods.

A. Rubber Wick Unit and Production Process

The rubber wick unit at the facility under investigation covers an area of 4,480 square meters and houses two primary machines: a Banbury mixer and a microwave vulcaniser. These machines transform rubber into a more durable material and have a total processing capacity of over 2,000 tonnes. Raw materials such as rubber, calcite, and paraffin oil are used in production. This unit primarily produces hoses used in washing machines and other electronic devices.

The rubber production process consists of a Banbury mixer and a vulcanisation line. Raw materials arrive at the Banbury mixer at the desired temperature, are partially ground into dough, lowered into a cylinder, sliced, and cooled. The doughy rubber travels through a screw system (salt bath or microwave) in the vulcanisation line, where it melts and is then forced through molds to shape. Shaped objects (such as gaskets) are then baked in microwave ovens, hardened, and then transferred to a cooling pool.

B. Planning Regarding Waste Generation

The rubber production process generates hazardous and non-hazardous wastes (Figure 1 and Figure 2). Hazardous waste includes contaminated waste, contaminated packaging, waste fluorescent, waste cartridges or toner, waste electronic equipment, and unused chemicals, while non-hazardous waste includes waste plastic, ferrous metal shavings and chips, non-ferrous metal dust and particles, grinding parts and materials, paper and cardboard packaging, plastic packaging, wood packaging, copper, bronze, brass, aluminium, cables, paper and cardboard, and metals.

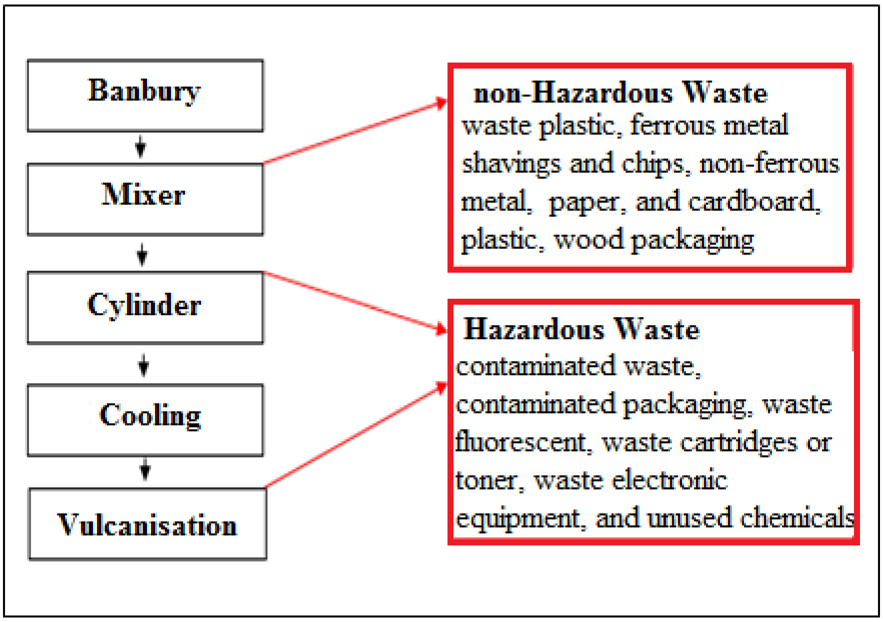

Figure 1. Work flow diagram of Banbury mixer and generated waste

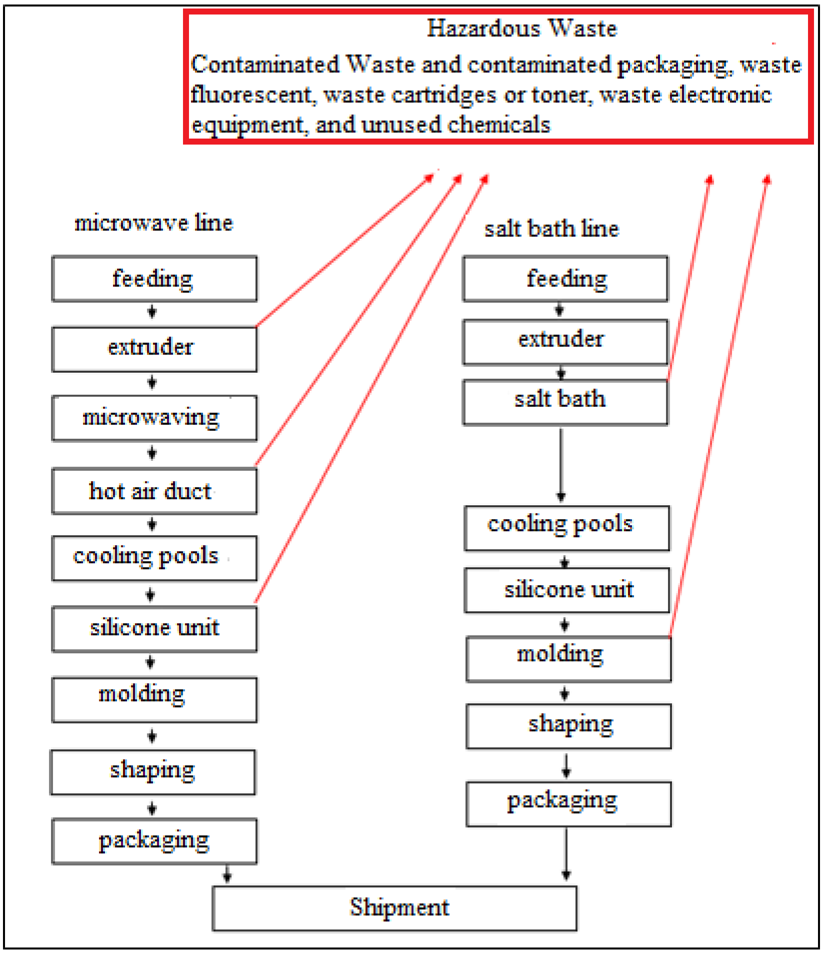

Figure 2. Flow chart of the vulcanisation and salt line and the resulting wastes

Waste management plans at the facility are based on waste codes determined according to the European Waste Codes (EWC). Waste codes and recovery methods (R codes) are determined according to the Waste Management Directive [13]. Here, for example, R4 represents the reclamation or recycling of metals and metal components; R9 represents the re-refining or other reuse of oils; R12 represents the exchange of waste for any of the processes listed in R1 to R11 (including pre-treatment activities); and R13 represents the temporary storage of waste within the waste-generating area, excluding collection, until it undergoes any of the processes listed in R1 to R12. According to the facility's waste volume planning management, the waste volumes generated for 2021 and the recovery methods are detailed. Accordingly, 2,326,562 kg of waste was released from the facility under the R4 method, 55,840 kg under the R9 method, 1,484,061 kg under the R12 method and 2,476 kg under the R13 method.

Accordingly, it can be stated that R4 (reclamation and recycling of metals and metal components) and R12 (recycling by combining other waste codes) methods are prominent in rubber and plastic industry facilities according to the relevant articles of the Waste Management Regulation.

C. In-Plant Recycling

Within the facility, packaging for purchased raw materials is crushed and granulated in crushing machines, before being re-produced as packaging bags (film bags) in extrusion lines. This ensures the recycling of raw material bags. This process is monitored through the Mobile Waste Tracking System (MOTAT). Suggestions for reducing waste at the facility include:

•For wastes categorised as 08 03 17 (waste printing toner containing hazardous substances): Use refillable cartridges and toners.

• For wastes categorised as 13 01 13 (hydraulic and press oils): Continue regular maintenance of injection molding machines, reducing oil leaks.

• For wastes categorised as 15 02 02 (absorbents, filter materials, cleaning cloths, protective clothing contaminated with hazardous substances): Continue regular maintenance of machines throughout production, reducing oil leaks, thereby reducing contaminated waste.

IV. RESULTS AND RECOMMENDATIONS

The widespread use of polymeric materials produced from petroleum and petroleum products, particularly rubber, have made their recycling critical. Rubber has a wide range of uses, including conveyor belts, the footwear industry, pipes, and sealants. The automotive industry is a significant area of use for rubber and plastic products. Every vehicle has at least four tires, and these tires are replaced at regular intervals.

Globally, 1.5 billion tonnes of waste tires are generated annually, with 3.6 million tonnes in Europe and 4.5 million tonnes in the US. 75-80% of waste tires generated globally are disposed of in the environment. In Turkey, not all waste tires are recycled, so the amount of waste tires doubles each year. This demonstrates the growing need for tires and the need to recycle all waste tires to prevent environmental problems.

Recycling waste tires offers significant economic benefits. Methods such as retreading, energy recovery, pyrolysis, and product and material recycling are prominent in the utilisation of waste tires. These methods vary in how the tires are utilised, and since not every method is applicable to every facility, facilities should be built around these methods. The proximity of recycling facilities to tire factories is also important for cost.

Disposing of waste tires in landfills is prohibited in Turkey. Instead, energy is generated through the environmentally friendly and non-polluting pyrolysis method, yielding components such as 73% granular rubber, 19% steel fibre, and 8% textile. Therefore, efforts to develop new environmentally friendly and non-polluting recycling methods, such as pyrolysis, should be supported.

Ensuring the recycling of waste in plastic and rubber industry facilities and reducing the amount of waste generated is vital for waste management, environmental efficiency, and sustainability. Therefore, the establishment of recycling facilities within production facilities should be encouraged in Turkey through public and private sector collaboration to recover rubber waste generated by plastic and rubber industry facilities. If establishing a recycling facility within production facilities is not feasible, rubber waste must be delivered to authorised off-site recycling facilities.

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