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DEVELOPMENT OF A TECHNOLOGY FOR THE DISPOSAL OF RESIDUE DERIVED FROM USED TIRES

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Abstract: The increasing accumulation of end-of-life tires has become a significant environmental and technological challenge due to their complex composition, high resistance to natural degradation, and potential release of hazardous substances during uncontrolled disposal. This study focuses on the development of a technological approach for the utilization and disposal of solid residue generated during the processing of used tires. The proposed technology combines mechanical preparation, thermal treatment, separation, stabilization, and subsequent utilization of the resulting residue. Particular attention is given to reducing the environmental impact of tire-derived waste and increasing the potential for secondary resource recovery. The technological parameters considered include particle size, temperature, residence time, moisture content, and the proportion of mineral and carbonaceous components. The proposed approach can contribute to the development of a circular economy by transforming problematic tire waste into useful secondary materials and reducing the amount of waste sent to landfills.

Keywords: used tires, tire waste, recycling, residue, thermal treatment, pyrolysis, waste disposal, secondary raw materials.

Introduction. The rapid growth of the global vehicle fleet has resulted in a continuous increase in the generation of waste tires. End-of-life tires represent a specific category of solid waste because they contain rubber, carbon black, steel, textile fibers, additives, and other chemical components. Their high durability, elasticity, and resistance to biological degradation make conventional landfill disposal environmentally undesirable. Improperly stored or illegally dumped tires occupy considerable land areas and may accumulate water, creating favorable conditions for insects and microorganisms. Tire fires can also produce smoke and potentially hazardous combustion products. Therefore, the development of environmentally safe technologies for the processing and utilization of used tires has become an important direction of modern waste-management research. Used tires should not be regarded solely as waste. Their composition contains significant quantities of carbonaceous and mineral materials that can potentially be recovered and reused. Mechanical recycling, devulcanization,

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pyrolysis, gasification, co-processing, and incorporation of tire-derived materials into construction products are among the approaches investigated for this purpose. However, most tire-processing technologies generate secondary residues. If these residues are not properly managed, the environmental benefits of recycling may be reduced. Therefore, the development of a technological system specifically designed for the treatment and utilization of tire-derived residue is an important scientific and practical task. The purpose of this study is to develop a technological scheme for the environmentally safe disposal and potential utilization of residue obtained from used-tire processing.

technology.

Literature review. The problem of end-of-life tire management has been investigated by numerous researchers. According to Adhikari, Maiti and Ghosh, waste tires possess considerable potential as secondary raw materials because of their high organic and carbon content. Mechanical processing allows rubber granules and steel components to be separated, while thermal processes can produce oil, gas, and carbonaceous solid products. Williams investigated the pyrolysis of waste tires and demonstrated that thermal decomposition can produce several valuable fractions, including gaseous products, liquid hydrocarbons, and solid char. The properties and yields of these products depend significantly on temperature, heating rate, residence time, and reactor configuration. Martínez et al. emphasized that tire pyrolysis can contribute to resource recovery; however, the quality of pyrolysis products and the treatment of residual solids must be considered when evaluating the overall environmental performance of the process. Research on the use of crumb rubber has demonstrated that mechanically processed tire materials can be incorporated into asphalt mixtures, concrete, rubber-modified products, and other construction materials. Nevertheless, contamination, particle size distribution, surface properties, and the presence of additives may influence their suitability for particular applications. From an environmental perspective, the treatment of tire-derived residues should prevent the uncontrolled release of volatile organic compounds, sulfur-containing substances, heavy metals, and other potentially hazardous components. Stabilization and controlled thermal processing can therefore be considered important stages of an integrated waste-management system. The analysis of existing studies indicates that many technologies concentrate primarily on the recovery of rubber, steel, pyrolysis oil, and gas, while comparatively less attention is given to the final stabilization and utilization of the solid residue. This creates a research gap that can be addressed through an integrated technological approach.

Materials and methods. The proposed technology uses residue generated during the processing of end-of-life automobile and truck tires. The residue may contain carbonaceous material, mineral fillers, residual rubber, textile fibers, and fine particles of steel.

Before treatment, the material should be characterized according to: particle-size distribution, moisture content, ash content, volatile matter, fixed carbon, sulfur content, elemental composition, calorific value, concentration of potentially hazardous elements.

At the first stage, foreign materials and unsuitable objects are removed from the collected tire-processing residue. Magnetic separation is then applied to remove remaining steel particles. The material is subsequently subjected to size reduction. The objective of this stage is to obtain a relatively homogeneous particle size, which improves heat transfer and treatment efficiency.

Thermal treatment. Thermal treatment can be carried out under oxygen-limited conditions. The temperature should be selected according to the composition of the residue and the intended final product.

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A general mass balance of the thermal process can be expressed as:

$$M_0=M_g+M_l+M_s+M_f$$

where:

M_0– initial mass of residue, kg;

M_g– mass of gaseous products, kg;

M_l– mass of liquid products, kg;

M_s– mass of solid carbonaceous residue, kg;

M_f– mass of other separated fractions, kg.

The solid fraction remaining after thermal treatment requires additional stabilization before final utilization.

Stabilization. The stabilization stage is designed to reduce the mobility of potentially hazardous components. Depending on the chemical characteristics of the residue, stabilization can involve: controlled cooling, mineral blending, binder addition, encapsulation, alkaline stabilization, incorporation into construction materials. The selection of the stabilization method should be based on laboratory testing.

Evaluation of treatment efficiency. The overall treatment efficiency can be estimated using the following expression:

$$\eta=\frac{M_0-M_r}{M_0}\times 100\%$$

where:

η– treatment efficiency, %;

M_0– initial mass of waste, kg;

M_r– mass of final residue requiring disposal, kg.

The reduction in waste requiring final disposal is one of the principal indicators of technological effectiveness.

Results and discussion. Proposed technological scheme. The developed technological concept provides sequential processing of tire-derived residue and separates the process into mechanical, thermal, stabilization, and utilization stages.

Table 1. Main stages of the proposed technology

Main operation	**Purpose**	**Expected result**
Preliminary sorting	Removal of foreign materials	Homogeneous feedstock
Magnetic separation	Removal of steel	Reduced metal content
Size reduction	Particle-size homogenization	Improved heat transfer
Thermal treatment	Decomposition of residual organic components	Gas, liquid and solid fractions
Cooling	Controlled temperature reduction	Stable solid product
Secondary separation	Removal of remaining impurities	Improved product quality
Stabilization	Reduction of contaminant mobility	Environmentally safer residue
Quality control	Laboratory analysis	Compliance assessment
Utilization	Secondary use of processed material	Reduced disposal volume

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The main advantage of the proposed scheme is that residue treatment is considered an integral component of the entire tire-recycling process rather than as a separate final disposal operation.

Influence of particle size. Particle size has an important effect on thermal processing. Smaller particles generally provide a greater specific surface area and improve heat transfer. However, excessive grinding increases electricity consumption and may reduce the economic efficiency of the process. Therefore, an optimum particle-size range should be established experimentally based on the reactor characteristics and desired product quality.

Influence of temperature. Temperature is one of the principal parameters controlling the decomposition of rubber and other organic compounds. Increasing the treatment temperature generally accelerates thermal decomposition. However, excessive temperature may increase energy consumption and influence the composition of gaseous and liquid products. Consequently, temperature optimization should consider not only the degree of decomposition but also energy consumption, product quality, and environmental safety.

Residual carbonaceous material. The solid fraction obtained after thermal treatment generally contains carbonaceous material, mineral components, and ash. Depending on its physicochemical characteristics, this material may have potential applications as a secondary carbonaceous or mineral resource.

Possible utilization pathways include: production of composite materials, incorporation into selected construction materials, use as a filler after appropriate treatment, production of adsorbent materials after activation, controlled industrial energy recovery. Before any application, the residue must undergo chemical and environmental characterization.

Table 2. Potential directions for utilization of processed residue

Residue fraction	Potential application	Required treatment
Carbon-rich fraction	Composite materials	Purification and particle-size control
Mineral fraction	Construction materials	Stabilization and quality testing
Fine fraction	Filler material	Chemical characterization
Residual textile fraction	Composite products	Separation and thermal treatment
Metal fraction	Metallurgical recycling	Magnetic separation

Environmental efficiency. The proposed technology can reduce the volume of tire-derived waste requiring landfill disposal. It also creates conditions for recovering useful components from a complex waste stream. An important environmental indicator is the reduction of uncontrolled waste accumulation. Additional benefits include the recovery of secondary materials and the possibility of reducing the consumption of primary resources. However, environmental performance depends strongly on the operating conditions of the thermal treatment unit and the effectiveness of gas-cleaning systems. Therefore, the process should include appropriate filtration, condensation, and emission-control equipment.

Economic considerations. The economic feasibility of the proposed technology depends on several factors: quantity of available tire waste, energy consumption, equipment capacity, labor and maintenance costs, market value of recovered products, transportation costs, environmental compliance requirements.

The economic efficiency can be estimated by:

$$E_c = R - (C_e + C_m + C_t + C_d)$$

where:

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E_c– economic effect;
R– revenue from recovered products;
C_e– energy costs;
C_m– maintenance and operational costs;
C_t– transportation costs;
C_d– costs associated with final disposal.

A positive economic effect can be achieved when the value of recovered materials and avoided disposal costs exceeds the operational costs of the technology.

Discussion. The proposed technological approach demonstrates that the residue produced during used-tire processing should be considered a potentially recoverable secondary resource rather than simply an unavoidable waste product. Mechanical preparation improves the uniformity of the feedstock, while thermal treatment facilitates the decomposition of residual rubber and other organic compounds. Subsequent stabilization is essential because the solid residue may contain concentrated mineral components and potentially hazardous substances. The technology also corresponds to the principles of circular economy because it aims to minimize final disposal and maximize the recovery of useful materials. Nevertheless, several limitations should be considered. First, the exact composition of tire-derived residue varies depending on tire type, manufacturer, age, and previous processing conditions. Second, the optimal thermal-treatment parameters cannot be universally established without experimental investigation. Third, potential utilization of the final solid fraction requires compliance with environmental and technical standards. Therefore, further experimental studies should investigate the relationship between treatment temperature, residence time, particle size, mass yield, chemical composition, and environmental safety indicators.

Conclusion. A technological approach for the treatment and disposal of residue derived from used tires has been developed. The proposed system includes preliminary sorting, mechanical separation, size reduction, controlled thermal treatment, cooling, secondary separation, stabilization, quality control, and subsequent utilization or safe disposal. The analysis demonstrates that integrated processing can reduce the quantity of residue requiring final disposal while creating opportunities for the recovery of carbonaceous, mineral, and metallic components. The effectiveness of the technology depends on the optimization of particle size, thermal-treatment temperature, residence time, and stabilization conditions.

References

1. Adhikari, B., De, D., & Maiti, S. (2000). Reclamation and recycling of waste rubber. *Progress in Polymer Science*, 25(7), 909–948.
2. Williams, P.T. (2013). Pyrolysis of waste tyres: A review. *Waste Management*, 33(8), 1714–1728.
3. Martínez, J.D., Puy, N., Murillo, R., García, T., Navarro, M.V., & Mastral, A.M. (2013). Waste tyre pyrolysis – A review. *Renewable and Sustainable Energy Reviews*, 23, 179–213.
4. Ramarad, S., Khalid, M., Ratnam, C.T., Chuah, A.L., & Rashmi, W. (2015). Waste tire rubber in polymer blends: A review on the evolution, properties and future. *Progress in Materials Science*, 72, 100–140.
5. Thomas, B.S., & Gupta, R.C. (2016). A comprehensive review on the applications of waste tire rubber in cement concrete. *Renewable and Sustainable Energy Reviews*, 54, 1323–1333.

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HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

6. Reschner, K. (2008). *Scrap Tire Recycling: A Summary of Prevalent Disposal and Recycling Methods*. Waste Reduction and Recycling.
7. Rowhani, A., & Rainey, T.J. (2016). Scrap tyre management pathways and their use as a fuel—A review. *Energies*, 9(11), 888.
8. Williams, P.T. (2013). *Waste Treatment and Disposal*. Wiley.
9. European Tyre and Rubber Manufacturers' Association (ETRMA). (2023). *End-of-Life Tyres Management and Resource Recovery*. Brussels.
10. United Nations Environment Programme (UNEP). (2023). *Global Waste Management Outlook*. Nairobi: United Nations Environment Programme.