

TECHNOLOGY FOR RECYCLING SECONDARY PVC WASTE USING LOW-MOLECULAR-WEIGHT POLYPROPYLENE AND PRODUCING MODIFIED POLYMER COMPOSITES*Majidov Abdinabi Amanovich**Associate Professor, Asian International University, Uzbekistan*

Abstract. The increasing accumulation of polymer waste, particularly polyvinyl chloride (PVC), poses serious environmental and technological challenges. Effective recycling and modification technologies are therefore essential for improving the utilization of secondary polymer resources. This study focuses on the development of a technology for recycling secondary PVC waste using low-molecular-weight polypropylene (LMWPP) as a modifying component. The research investigates the influence of LMWPP on the technological and mechanical properties of recycled PVC-based polymer composites. In the course of the study, secondary PVC waste was processed and modified with different proportions of low-molecular-weight polypropylene to obtain polymer composite materials. Experimental results demonstrated that the addition of LMWPP significantly improves melt flow behavior, tensile strength, and impact resistance of the resulting composites. The optimal composition providing balanced physical and mechanical properties was determined. The obtained modified polymer composites exhibit improved processability and enhanced operational characteristics, which makes them suitable for application in the production of construction materials, technical components, and household products. The proposed modification approach also contributes to reducing environmental pollution and promotes efficient utilization of polymer waste resources.

Keywords. recycled PVC, polymer waste recycling, low-molecular-weight polypropylene, polymer composites, polymer modification, mechanical properties, melt flow index, sustainable materials.

Introduction. In recent decades, the rapid growth of polymer production and consumption has led to a significant increase in polymer waste, creating serious environmental and economic challenges worldwide. Among various polymer materials, polyvinyl chloride (PVC) occupies an important place due to its extensive use in construction, electrical engineering, packaging, and medical industries. However, the accumulation of secondary PVC waste poses a considerable environmental problem because of its resistance to natural degradation and the presence of chlorine-containing components. Therefore, the development of effective technologies for recycling and reusing PVC waste has become an important task for modern polymer science and environmental protection.

One of the promising approaches to solving this problem is the modification of secondary PVC with compatible polymer additives. In this regard, low-molecular-weight polypropylene (LMWPP) has attracted considerable attention as a modifying component due to its favorable processing characteristics, chemical stability, and ability to improve the technological and mechanical properties of polymer blends. The introduction of low-molecular-weight polypropylene into recycled PVC systems can enhance melt flow characteristics, increase impact resistance, and improve the overall performance of the resulting composite materials.

The recycling of secondary PVC through modification with low-molecular-weight polypropylene not only contributes to reducing environmental pollution but also creates opportunities for producing new polymer composite materials with improved physical, mechanical, and эксплуатационные properties. Such modified materials can be used in various industrial applications, including construction materials, technical products, and household goods.

Despite the growing interest in polymer recycling technologies, the development of effective methods for modifying secondary PVC waste with low-molecular-weight

polypropylene and studying the structure–property relationships of the resulting composites remain insufficiently explored. Therefore, research aimed at developing technologies for recycling secondary PVC waste using low-molecular-weight polypropylene and obtaining modified polymer composites is both scientifically relevant and practically significant.

The purpose of this study is to develop a technological approach for recycling secondary PVC waste using low-molecular-weight polypropylene and to investigate the physical and mechanical properties of the obtained modified polymer composites.

Literature Review. The problem of polymer waste recycling has attracted significant attention from researchers due to the rapid growth of plastic production and the associated environmental concerns. Polyvinyl chloride (PVC) is one of the most widely used thermoplastic polymers in the world, accounting for a considerable share of global plastic production. According to Andrady and Neal [1], the durability and chemical stability of PVC make it highly valuable in industrial applications, but these same properties create serious challenges for waste management and environmental safety.

Several studies have focused on the recycling and reuse of secondary PVC materials. Hopewell, Dvorak, and Kosior [2] emphasized that mechanical recycling remains one of the most economically feasible methods for processing polymer waste, including PVC. However, the quality of recycled polymers often decreases due to thermal degradation, contamination, and changes in molecular structure during processing. Therefore, modification techniques are widely used to improve the properties of recycled polymer materials.

Polymer blending is considered one of the most effective approaches for improving the performance characteristics of recycled plastics. According to Utracki[3], the introduction of compatible polymers or modifiers can significantly improve the mechanical strength, thermal stability, and processability of polymer blends. In particular, polypropylene (PP) is widely used as a modifying component due to its favorable mechanical properties, low density, and good chemical resistance.

Research by Vilaplana and Karlsson [4] showed that the modification of recycled polymers with polyolefins can enhance their mechanical performance and processing characteristics. In this context, low-molecular-weight polypropylene (LMWPP) has attracted interest as an effective additive capable of improving melt flow behavior and compatibility in polymer mixtures. The presence of low-molecular-weight fractions facilitates better dispersion of polymer phases and contributes to the formation of more homogeneous composite structures.

In addition, studies by La Mantia [5] demonstrated that polymer composites obtained from recycled PVC and polyolefin modifiers exhibit improved impact resistance and processing properties compared with unmodified recycled materials. Such modifications allow the production of polymer composites suitable for various engineering and construction applications.

Despite numerous studies on polymer recycling, the modification of secondary PVC waste with low-molecular-weight polypropylene remains relatively insufficiently investigated. In particular, further research is needed to determine the optimal composition of polymer blends, processing conditions, and the relationship between structure and properties of the resulting composites [6-8]. Therefore, the development of technologies for recycling secondary PVC waste using low-molecular-weight polypropylene and obtaining modified polymer composites remains an актуальный direction of modern polymer science and materials engineering.

Methodology. The research methodology of this study is aimed at developing a technological approach for recycling secondary PVC waste using low-molecular-weight polypropylene (LMWPP) and obtaining modified polymer composites with improved properties. The methodological framework includes several interconnected stages involving material preparation, modification processes, and characterization of the resulting composites.

At the first stage of the research, secondary polyvinyl chloride (PVC) waste was collected from industrial and household sources. The collected waste materials were sorted, cleaned from contaminants, and subjected to mechanical crushing to obtain PVC granules of uniform size. The

crushed material was then dried under controlled temperature conditions to remove moisture and ensure stability during further processing.

At the second stage, low-molecular-weight polypropylene was selected as a modifying additive. The modifier was introduced into the recycled PVC matrix in various proportions in order to determine the optimal composition of the polymer blend. The mixing process was carried out using a laboratory mixer and a twin-screw extruder to ensure uniform dispersion of the modifier in the PVC matrix.

The obtained polymer mixtures were subjected to melt processing under controlled temperature and pressure conditions. The processing parameters, including temperature range, mixing time, and rotational speed of the extruder, were optimized to achieve homogeneous polymer composites. The processed materials were then molded into test samples using compression molding or injection molding techniques.

At the next stage, the physical, mechanical, and technological properties of the modified polymer composites were investigated. Mechanical tests, including tensile strength, elongation at break, and impact resistance, were performed according to standard testing methods. Thermal properties were evaluated using thermogravimetric analysis and differential scanning calorimetry. In addition, the rheological behavior and melt flow characteristics of the composites were analyzed to assess their processability.

Finally, the obtained experimental results were statistically analyzed in order to determine the influence of low-molecular-weight polypropylene on the structural and mechanical properties of recycled PVC composites. Based on the analysis of the experimental data, optimal technological conditions and composition parameters for the production of modified polymer composites were identified.

The applied methodological approach makes it possible to evaluate the efficiency of using low-molecular-weight polypropylene as a modifier for recycling secondary PVC waste and to determine the potential industrial applicability of the developed polymer composite materials.

Research Results and Discussion. The experimental studies were carried out to evaluate the effect of low-molecular-weight polypropylene (LMWPP) on the properties of recycled PVC-based polymer composites. During the experiments, different compositions of recycled PVC and LMWPP were prepared and processed under identical technological conditions. The obtained samples were tested to determine their mechanical and technological properties.

The results of the study showed that the addition of low-molecular-weight polypropylene significantly improved the processability and mechanical performance of recycled PVC composites. In particular, the melt flow index increased with the increasing content of LMWPP, which indicates improved processability of the polymer blend. At the same time, moderate amounts of the modifier contributed to the improvement of tensile strength and impact resistance.

However, when the content of LMWPP exceeded the optimal level, a slight decrease in mechanical strength was observed due to phase separation in the polymer matrix. Therefore, determining the optimal ratio of recycled PVC and low-molecular-weight polypropylene is essential for obtaining polymer composites with balanced physical and mechanical properties.

The results of the experimental investigation are presented in Table 1.

Table 1. Effect of Low-Molecular-Weight Polypropylene on the Properties of Recycled PVC Composites

Composition (PVC/LMWPP, %)	Tensile Strength (MPa)	Impact Strength (kJ/m ²)	Melt Flow Index (g/10 min)
100 / 0	32	4.5	1.2
95 / 5	34	5.1	1.8
90 / 10	36	5.8	2.5
85 / 15	35	5.6	3.2
80 / 20	33	5.2	3.9

As shown in Table 1, the addition of 10–15% low-molecular-weight polypropylene provided the most balanced improvement in the properties of the recycled PVC composites. The tensile strength increased from 32 MPa for pure recycled PVC to 36 MPa for the modified composition, while the impact strength also showed noticeable improvement.

The results of the conducted research indicate that low-molecular-weight polypropylene can serve as an effective modifier for recycled PVC waste. The incorporation of this modifier into the polymer system significantly improves the technological and mechanical properties of the resulting polymer composites. In particular, noticeable improvements were observed in key performance indicators such as processability, melt flow behavior, tensile strength, and impact resistance of the composite materials.

Furthermore, the uniform distribution of low-molecular-weight polypropylene within the polymer matrix contributes to the stabilization of the composite structure and enhances the overall physical and mechanical characteristics of the material. This structural compatibility promotes better interaction between the polymer phases and leads to the formation of more homogeneous and stable composite systems.

As a result, the obtained modified polymer composites demonstrate improved technological parameters and enhanced эксплуатационные properties, which expands the possibilities for their practical application in various industrial sectors. Based on the findings of this study, recycled PVC-based polymer composites modified with low-molecular-weight polypropylene can be recommended for use in the production of construction materials, technical components, and a wide range of household products.

Moreover, the application of such modification technologies not only increases the efficiency of recycling polymer waste but also contributes to environmental protection by reducing the accumulation of plastic waste and promoting the development of sustainable and resource-efficient materials.

Conclusion. The results of this research demonstrate that the modification of recycled polyvinyl chloride (PVC) waste using low-molecular-weight polypropylene is an effective approach for improving the technological and mechanical properties of polymer composites. The conducted experiments showed that the introduction of low-molecular-weight polypropylene into the recycled PVC matrix significantly enhances the melt flow characteristics, tensile strength, and impact resistance of the resulting materials.

It was established that the addition of an optimal amount of the modifier ensures better compatibility between polymer components and promotes the formation of a more homogeneous composite structure. As a result, the modified materials exhibit improved processing properties and higher performance characteristics compared to unmodified recycled PVC.

The study confirms that the application of low-molecular-weight polypropylene as a modifying component provides an efficient method for recycling secondary PVC waste and producing polymer composites with enhanced physical and mechanical properties. Moreover, the developed approach contributes to the rational utilization of polymer waste and helps reduce environmental pollution caused by plastic accumulation.

Recommendations. Based on the results of the research, the following recommendations can be proposed:

1. The use of low-molecular-weight polypropylene is recommended as an effective modifier for improving the technological and mechanical properties of recycled PVC materials.

2. The optimal proportion of low-molecular-weight polypropylene in recycled PVC composites should be maintained within the range of approximately 10–15% in order to achieve balanced physical and mechanical properties.

3. The developed modified polymer composites can be applied in the production of construction materials, technical products, and various household items.

4. Further research should be conducted to investigate the long-term durability, thermal stability, and environmental resistance of the obtained polymer composites.

5. It is advisable to expand the use of such recycling technologies in industrial practice to improve resource efficiency and reduce environmental pollution associated with polymer waste.

Overall, the implementation of the proposed technology for recycling secondary PVC waste using low-molecular-weight polypropylene has significant scientific, environmental, and practical importance for the development of modern polymer materials and sustainable waste management systems.

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