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CHALLENGES AND OPPORTUNITIES OF REUSING NON-RECYCLABLE MATERIALS IN THE CONTEXT OF CLIMATE CHANGE MITIGATION

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Abstract:
This paper explores the potential application of innovative recycling technologies for non-recyclable composite and mixed plastics, offering a sustainable solution in the fight against climate change. An eco-column, made from recycled materials with both circular and square cross-sections, was developed, and its bending resistance was tested to evaluate its ability to replace traditional structures made from wood, concrete, metal, or other materials. By reducing waste, conserving natural resources, and lowering plastic production, this approach contributes to mitigating climate change.

Keywords: *Innovative recycling technology, Non-recyclable materials. Eco-column, Bending testing*

Introduction

Climate change represents one of the greatest global challenges of modern society. Changes in the atmosphere, including rising temperatures, extreme weather events, melting polar ice, and rising sea levels, are increasingly affecting ecosystems, human communities, and economies worldwide. Scientific research has clearly shown that human activities, primarily greenhouse gas emissions, are the main cause of these changes. According to data from the Intergovernmental Panel on Climate Change (IPCC), global temperatures have increased by approximately 1.1°C over the past 150 years, and this trend is expected to continue, with serious consequences for life on Earth [1].

In addition to the climate impacts, climate change also presents a serious challenge to sustainable development, resource efficiency, and

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environmental protection. In light of these issues, key questions include reducing CO_2 emissions, transitioning to renewable energy sources, and minimizing the negative impact of human activities on nature and ecosystems.

Climate change and its consequences also raise the question of how we can adapt and reduce their negative effects. Among the strategies being explored and implemented, recycling, waste management, and the reuse of materials play a crucial role in reducing greenhouse gas emissions and preserving resources. This paper will explore how the reuse of materials, particularly those that cannot be recycled, can contribute to mitigating the effects of climate change.

1. Climate change and plastic recycling

Climate change and plastic recycling are connected in several ways, even though they might not seem directly related at first view. However, there are key points where plastic recycling can help reduce the negative impact on the climate:

- CO_2 emissions reduction: Using recycled materials is more energy-efficient and has a lower climate impact.
- Waste reduction: Recycling plastic minimizes landfill waste and its environmental impact.
- Resource conservation: Recycling conserves resources like oil and natural gas, reducing the need for new fossil fuel extraction and lowering emissions.
- Circular economy: By reusing and recycling materials, the need for new production is reduced, benefiting CO_2 emissions.
- Plastic production reduction: More recycling reduces the need for new plastic, cutting fossil fuel use and emissions.

In summary, plastic recycling can play a key role in mitigating climate change by reducing greenhouse gas emissions, minimizing waste, conserving resources, and supporting sustainable practices.

2. The current situation in plastic production and recycling

Plastic production has steadily increased over the years, driven by its growing use across various industries, including the widespread application of plastic-based composites, which are not recyclable. The

worldwide production of plastics reached a staggering 390.7 million tons in 2021 [2]. Only 9% of the mentioned quantity of plastic produced after use is recycled, so it is clear that plastic waste represents a global problem [3]. It is expected that the amount of plastic waste will exceed one billion tons by 2050 [3], which necessitates a serious approach to recycling, as well as innovation in this field and the development of new types of materials.

Current plastic recycling processes require careful sorting by type, which is complex and requires expertise. Reports from recycling centers show that 5-10% of plastic waste can't be processed with current technology. Additionally, plastic items made from multiple materials are costly and difficult to separate, often requiring manual intervention, but even that doesn't guarantee full separation, leading to issues in further recycling [4, 5].

Currently, there is no known technology for recycling, processing, and reusing composite and mixed plastics with glass. Such waste materials are mostly incinerated or deposited in landfills. One of the recycling ideas for composite and mixed plastics is presented in this paper. The result is a new, innovative technology that successfully recycles 80% of previously non-recyclable, non-hazardous composite and mixed plastics and glass, with only 20% consisting of selected plastic materials. The resulting eco-material possesses good properties, as demonstrated in the following chapters of this paper. First, however, we will present the fundamentals of the innovative technology for recycling composite, mixed plastics, and glass.

3. The innovative recycling technology for recycling mixed and composite plastics

The innovative recycling technology allows for the processing and reuse of usually non-recyclable composite and mixed plastics, as well as glass, using a specialized preparation method. The key innovation lies in a distinctive homogenization process and adjustments to the recycling sequence.

When comparing conventional recycling with innovative recycling, the new technology provides the following solutions:

- Recycling and reusing a variety of waste mixtures, including plastic composites and glass.

- Sorting by type (such as polypropylene, polyethylene, polyvinyl chloride, etc.) is minimized or even eliminated, as our formulation uses only 20% of selected plastic. This results in significant savings in time, labor, and storage.
- The need for separate processing of sorted plastic (such as washing, drying, granulation) or waiting for one type to finish before processing the next is removed.
- Reducing the number of mechanical processing steps required before producing the final product.
- A specialized process and formulation for easily homogenizing mixed waste plastic.
- A new method for mixing waste plastic to create a versatile material suitable for a range of finished products.

Using injection molding and extrusion from regranulate, a new product is made, but the result depends on the type of initial plastic waste. The recycled product is of the same type, with specific characteristics and limited uses. In our case, the resulting eco-material has entirely new properties and a wide range of possibilities for a broad spectrum of finishing products.

The aforementioned observations lead to the conclusion that this innovative technology presents a solution for the reutilization of a significant quantity of mixed waste plastics, composites, and glass. It demonstrates energy efficiency and yields a product with a broad spectrum of applications. It serves as a noteworthy illustration of sustainable development and the circular economy, both of which are global aspirations.

While similar concepts exist for recycling composite and mixed plastic waste, they are usually limited to specific plastic mixtures and involve more complex mechanical treatments. Unlike our solution, they lack a homogenization process, relying on high temperatures that lead to higher energy consumption and increased recycling costs.

The formulation of innovative technology involves the following types of waste materials:

- Soft PVC (Waste index number 150201, [6]) is rarely recycled, despite being recyclable. After grinding, it is homogenized with

glass and non-recyclable plastics and used as a filler for profiles, often incinerated instead.

- Rigid PVC - Waste index number: 15 01 02 [6]. It is used as a filler in a certain percentage or for manufacturing profiles.
- Multi-layer HDPE plastic bags with an addition of 10-15% PA or PET are used as a component for filling material. Waste index number: 150102 [6].
- Ground packaging glass, waste index number 150107 [6]. The potential for recycling is significant, but it has almost become inactive in our region.

4. The eco-column as one of the application possibilities of recycled materials

From materials obtained in this way, various products can be made, and the paper examines filled or hollow plastic profiles, which can serve as a replacement for traditional columns made of wood, concrete, metal, etc. For this patent, an intellectual property protection certificate number 57664 was obtained in Serbia. Until now, there hasn't been a cost-effective and beneficial solution for waste materials such as composite plastics, various plastic mixtures combined with waste glass, etc., the market for this innovative technology, eco-material, and its related products is substantial.

Manufacturing products from non-hazardous waste plastics that have not been suitable for recycling until now, occurs in several stages.

- The extrusion process for creating hollow profiles from recycled plastic,
- Filling hollow profiles with a composite filler made from non-recyclable plastic-based materials, with the addition of ground glass or fabric.

The filled profiles are called eco-columns.

5. Laboratory bending testing of circular and square cross-section columns until failure

In order to obtain certain mechanical properties of the eco-columns, tests were conducted on hollow and filled plastic profiles. The tests were conducted in laboratory at the Faculty of Civil Engineering in

Subotica. The columns with circular and square cross-sections have been made. The cross-sections are shown in Picture 1, [7]..

Picture 1. *The column samples during testing: circular and square cross-sections (hollow and filled) [7]*

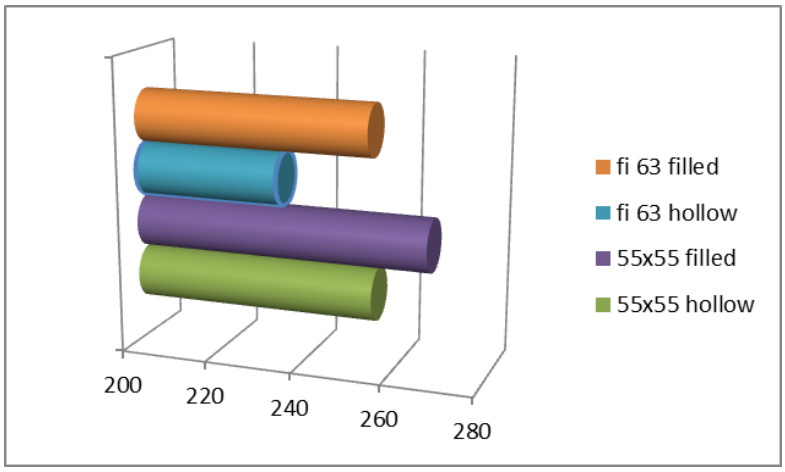
The samples during testing are presented on Picture 2. The dimensions of the cross-section and other important characteristics, as well as the results obtained from bending tests, are presented in Table 1.

Picture 2. *Bending testing of circular cross-section columns until failure and reversible deformations on the sample after testing [7]*

Picture 3 shows a graphical representation comparing the bending moment values for different samples. The data shown in Table 1 and in Picture 3 indicate that the filled column with a square cross-section demonstrated better bending resistance than the circular column, while also having a lower mass, which would be a better practical solution.

Table 1: *The dimensions of the cross-section and other important characteristics, as well as the results obtained from bending tests*

Cross-section dimensions [mm]	***Column weight m [kg]***	***Profile wall thickness [mm]***	***Bending moment at fracture M [Nm]***	***Deflection at fracture u [cm]***
55×55 (*hollow*)	2,00	6,3	255	22.5
55×55 (*filled*)	7,98	6,2	267.1	23.8
Ø63 (*hollow*)	2,05	8,1	233.3	24.8
Ø63 (*filled*)	8,12	8,1	253.9	22.8



Picture 3. *Comparative values of the bending moment M [Nm] for different samples*

Conclusion

In this paper, we explore the potential of materials developed through research in innovative technology for recycling composite plastics. These eco-materials provide several key benefits, especially in the fight against climate change, including:

- Contributes to environmental protection by reducing pollution and resource depletion.
- Saves and conserves natural resources by repurposing waste materials instead of incinerating or landfilling them.

- Replaces traditional materials (metal, concrete, wood) in various sectors like construction, agriculture, and transportation.
- Products are recyclable and can be reused with the same technology.

The points highlighted in this paper undeniably lead to the conclusion that this innovative technology provides an energy-efficient solution for recycling a wide range of waste plastic mixtures, composites, and glass. This process not only reduces environmental impact but also promotes sustainable development and the circular economy-principles that are increasingly vital in the fight against climate change and the global drive for more sustainable practices.

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