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Valorization of textile waste through the production of new products

Valorificarea deșeurilor textile cu obținerea produselor noi

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Abstract. *The present study investigates the valorization of textile and cellulose-based waste through the production of sustainable composite materials. Post-consumer textile waste (cotton, polyester, and blends) was combined with paper and cardboard residues to produce decorative panels, bricks, composite boards, handmade paper, compost, and industrial absorbents. The manufacturing processes involved pressing, molding, extrusion, and maceration with eco-friendly binders and mineral additives to enhance mechanical, thermal, and fire-resistant properties. Characterization included thermal conductivity, compressive strength, morphological analysis, and aesthetic evaluation. Results indicate that the recycled products exhibit comparable performance to conventional materials, offering good thermal and acoustic insulation, fire resistance, and low emissions. The approach provides a viable circular economy solution, reducing landfill waste and conserving natural resources.*

Key words: *textile, waste, cellulose, recycled, product*

Rezumat. *Studiul de față investighează valorificarea deșeurilor textile și a celor pe bază de celuloză prin obținerea unor materiale compozite sustenabile. Deșeurile textile post-consum (bumbac, poliester și amestecuri) au fost combinate cu reziduuri de hârtie și carton pentru a produce panouri decorative, cărămizi, plăci compozite, hârtie manuală, compost, etc. Procesele de fabricare au inclus presarea, turnarea, extrudarea și macerarea, utilizând lianți ecologici și aditivi minerali pentru îmbunătățirea proprietăților mecanice, termice și de rezistență la foc. Caracterizarea materialelor a cuprins determinarea conductivității termice, a rezistenței la compresiune, analiza morfologică și evaluarea estetică. Rezultatele indică faptul că produsele reciclate prezintă performanțe comparabile cu cele ale materialelor convenționale, oferind o bună izolație termică și acustică, rezistență la foc și emisii reduse. Abordarea propusă reprezintă o soluție viabilă de economie circulară, contribuind la reducerea cantității de deșeuri depozitate și la conservarea resurselor naturale*

Cuvinte cheie: *textile, deșeuri, celuloză, reciclat, produs*

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1. Introduction

The textile industry is one of the largest consumers of natural resources and a major source of solid waste globally. According to data from the literature [1], the equivalent of one garbage truck full of textiles is either incinerated or landfilled every second. At the same time, the paper and cardboard industry generates large amounts of waste, especially from packaging, used paper, and post-industrial residues. These two waste streams – textile and cellulose-based – can represent a valuable resource if intelligently combined and processed through innovative material recovery solutions.

Textile waste processing increasingly involves combining it with cardboard waste or other cellulose sources to obtain new products such as thermal insulation panels, composite materials, particle boards, or textile paper. This approach relies on the synergy between textile fibers (natural or synthetic) and the cellulose matrix, which helps improve the mechanical, thermal, or aesthetic properties of the final product [2,3].

From a technical perspective, textile fibers – especially cotton and cellulose blends – show high compatibility with paper and cardboard fibers, allowing the formation of composite structures with increased strength and reduced environmental impact. Recent studies indicate that mixing textiles with paper waste can result in products with good thermal insulation properties and potential applications in construction, eco-friendly packaging, or urban furniture [4,5].

This recovery method has multiple advantages: it reduces the volume of waste sent to landfills; it replaces virgin resources with secondary materials; it contributes to circular economy objectives and reduces the carbon footprint.

Moreover, this approach aligns with recent European directives regarding Extended Producer Responsibility (EPR) and the EU Strategy for Sustainable and Circular Textiles [6], which require the separate collection of textiles by 2025 and encourage innovation in the recycling of mixed textile materials.

Therefore, research and development of new products made from textile–cellulose blends represent not only an ecological necessity but also an industrial opportunity. This paper proposes an evaluation of the potential for valorizing textile waste by combining it with cardboard and paper waste to obtain composite materials with practical applications in various fields.

2. Materials and Methods

Pressed Agglomeration Process (Manufacturing of Thermal Insulation Panels). Textile waste is shredded and combined with rehydrated cardboard slurry (or recyclable paper). An eco-friendly binder (starch, natural latex, vegetable resin) is added. The mixture is placed into molds, pressed, and dried at temperatures of 80–120°C [7]. Thermal insulation panels for construction (interior walls, attics) and sound-absorbing boards are obtained (Composite panels made of 70% used cotton + 30% ground cardboard, bound with modified starch → thermal conductivity of 0.045 W/mK, comparable to expanded polystyrene).

For the manufacturing of decorative panels, recycled textile waste (cotton, polyester, blends) and cellulosic waste (paper, recycled cardboard) were used. These materials were selected due to their high availability and renewable nature, contributing to the reduction of environmental impact [8].

As a binder, eco-friendly gypsum-based compounds (universal PVA glue, wallpaper adhesive) were employed, ensuring the structural cohesion of the composite. In addition, mineral additives such as borax, liquid glass, kieselguhr, bio-adhesives, and modified starch were incorporated to enhance mechanical strength, improve fire resistance, and ensure dimensional stability. To achieve a uniform visual appearance, dyes were added, while tap/drinking water was used as a solvent and dispersion medium (Table 1).

Table 1

Raw materials and additives used for the manufacturing of panels, bricks, and other decorative objects from recycled materials

Component	*Exemple / Type*	*Main role*
Textile waste	Cotton, polyester, blends	Recyclable raw material, providing bulk and strength
Cellulosic waste	Paper, recycled cardboard	Filler and reinforcement, utilization of wastepaper
Eco-friendly binders	PVA glue, wallpaper adhesive, gypsum	Structural cohesion
Mineral additives	Borax, liquid glass, kieselguhr, bio-adhesives, modified starch	Mechanical strength, fire resistance, dimensional stability
Colorants	Eco-friendly pigments	Visual uniformity
Potable water	-	Solvent and dispersion medium

Molding Process (Manufacturing of Eco-friendly Bricks). Textile fibers, paper/cardboard pulp, and a binder such as cement or clay are combined. Water is added until a homogeneous mixture is formed. The mixture is poured into brick or block molds and left to harden [9,10]. Eco-friendly bricks for non-load-bearing construction, decorative masonry, or gardening can be obtained (Bricks made from a mix of used jeans + recycled newspaper + cement → reduced weight and improved insulation).

Extrusion Process (Manufacturing of Composite Boards). Textile fibers and cardboard waste are mixed with a thermoplastic matrix (e.g., PLA, polypropylene). The mixture is introduced into an extruder (160–200°C) and homogenized. It is formed by molding or laminating [11,12]. Rigid composite boards can be obtained, used for furniture, flooring, or partitions (Boards made from 40% textile fibers + 20% cardboard + 40% PLA → reduced density, good resistance to mechanical shocks).

Handmade Paper Manufacturing Process with Textile Inserts. Paper/cardboard waste is macerated in water to obtain pulp. Very finely cut textile fibers are added (e.g., white cotton). Sheets are formed by screening and pressing, then naturally dried [13,14]. Textured handmade paper can be obtained, used for invitations, luxury packaging, and artistic stationery (Handmade paper made from 60% recycled newspaper + 30% white linen scraps + 10% plant fibers → natural appearance, increased durability).

Co-composting Process (Biological Valorization). Natural textile waste (cotton, flax, wool) and paper/cardboard scraps are shredded. They are introduced into compost along with organic waste (leaves, plant residues). Moisture and aeration are controlled for 30–60 days [15,16]. A natural fertilizing compost is obtained, used in agriculture or gardening (Compost made from a mix of paper napkins + cotton clothes + leaves → neutral pH, rich in nitrogen).

Manufacturing Process of Industrial Absorbent Materials. Textile waste (including synthetic fibers) and cardboard are shredded, then impregnated with hydrophilic agents. Absorbent materials are formed into rolls or mats [17,18]. Industrial absorbents for oils, toxic substances, or automotive maintenance are obtained (Mats made from polyester + shredded cardboard → oil absorption capacity >8x its own weight).

The technological process included the following stages (Table 2): *preparation of raw materials* – sorting, shredding, and homogenization of textile and cellulosic waste; *mixture preparation* – combining the recycled materials with the gypsum-based binder and mineral additives in optimal proportions; *molding* – producing panels and bricks with standard dimensions (200 × 100 × 60 mm), in both solid and hollow variants; *drying and curing* – carried out under controlled conditions to prevent cracking and to achieve the desired density (0.87 g/cm³); *finishing and packaging* – ensuring mechanical protection and resistance against moisture absorption during transport and storage.

Table 2

Technological process for the production of panels, bricks, and other decorative objects from textile and cellulosic waste

Stage	*Description*
Preparation of raw materials	Sorting, shredding, homogenization
Mixture preparation	Combining recycled materials with binders and additives in optimal proportions
Molding	Production of standard panels/bricks (200 × 100 × 60 mm)
Drying and curing	Controlled process to prevent cracking and achieve target density
Finishing and packaging	Mechanical protection and moisture resistance

The products were labeled in accordance with Government Decision no. 913/2016 and the harmonized standards *SM EN 14322:2022* [19]. The label provides information on composition, qualitative characteristics, intended use, shelf life, and environmental benefits (≥30% recycled materials), and is accompanied by the environmental declaration according to *SM EN ISO 14021:2016* (Table 3) [20].

Table 3

Labeling and applicable regulations for recycled construction products

Regulation / Standard	*Content / Relevance*
Government Decision no 913/2016	Minimum requirements for the marketing of construction products
SM EN 14322:2022	Technical requirements for wood-based panels with melamine-faced surfaces
ISO 14021:2016	Environmental declaration (≥30% recycled materials)
Product label	Includes: composition, characteristics, intended use, shelf life, marking

The products were intended exclusively for interior use (wall decoration, panels, non-load-bearing partitions), with structural applications, high-humidity areas, and horizontal surfaces subjected to traffic being excluded. Performance testing focused on mechanical strength, acoustic and thermal insulation, fire resistance, and the determination of volatile emissions and toxic element migration (Table 4).

Table 4

Instructions for use and recommended applications for recycled decorative panels

Application area	*Example / Limitations*
Recommended	Wall decoration, panels, lightweight partitions
Not recommended	Horizontal surfaces, high-humidity areas, structural applications
Tests performed	Mechanical strength, acoustic and thermal insulation, fire resistance, volatile emissions, and element migration

The obtained samples were characterized using thermal conductivity, mechanical resistance, morphological analysis, and aesthetic and practical evaluation.

Thermal Conductivity determined using a Hot Disk device. The Hot Disk method is a transient thermal conductivity measurement technique using a dual-purpose sensor: a heat source and a thermometer. The sensor is placed between two material samples, and the temperature variation is analyzed to determine the thermal conductivity. It is applied to insulating, porous, composite materials. The measurement is conducted according to the ISO 22007-2 standard [21,22].

Compression Test (Evaluation of Mechanical Strength). Conducted according to the ISO 844 standard. The compression test determines the resistance to forces applied perpendicular to the material's surface. It is essential for evaluating construction materials, insulating panels, or rigid composites. The test is performed according to the ISO 844:2014 standard – "Rigid cellular plastics — Determination of compression properties" [23]. Obtained parameters: elastic modulus, compressive strength at 10% strain [24].

Morphological Analysis. Optical microscopy for fiber distribution analysis. Optical microscopy is used to investigate the internal structure of composites and the distribution of textile and cellulose fibers. Agglomerations, fiber orientation, and material porosity can be observed [25]. Sample preparation involves cutting a cross-sectional slice and observing it with a binocular microscope or digital camera. It can be complemented with image analysis (ImageJ) [26].

Aesthetic and Practical Evaluation. Aesthetic and functional evaluation is carried out by applying a standardized questionnaire to a group of users (e.g., 20 people) [27]. This method is commonly used in product design studies, innovative materials, or eco-design. The questionnaire may include Likert scale items (1–5) regarding: visual appearance, touch sensation, perception of durability, and utility. The responses are analyzed statistically (mean, standard deviation, relative scores) [28,29].

3. Results and discussion

The experimental results highlight that decorative panels produced from textile and cellulosic waste represent a viable alternative to conventional materials used in interior finishes. They combine the necessary technical performance with significant environmental benefits, positioning them as a competitive option in the sustainable construction materials market (Table 5) [30,31].

Table 5

Physico-mechanical properties of recycled panels

Tested parameter	*Obtained result*	*Advantage*
Acoustic insulation	Confirmed by laboratory tests	Acoustic comfort
Thermal insulation	Confirmed by laboratory tests	Energy efficiency
Fire resistance	Enhanced by mineral additives	Fire safety
Emissions / migration	Within acceptable limits	Sanitary safety for interior use

From a physico-mechanical perspective, the standardized dimensions (200 × 100 × 60 mm) and an average density of 0.87 g/cm³ indicate a lightweight structure, which facilitates transport and installation while simultaneously reducing the static load on structural elements. The absence of cracks and deformations during internal inspections confirms dimensional stability, an essential criterion for long-term use under varying interior microclimate conditions.

Laboratory tests confirmed the acoustic and thermal insulation capabilities, properties that enhance the comfort of interior spaces and reduce energy costs. These characteristics make the product particularly suitable for educational, cultural, and commercial spaces, where acoustic comfort and energy efficiency are priorities. Fire resistance, improved through the use of mineral additives such as borax and liquid glass, provides an additional safety advantage, increasing the material's acceptability in construction and renovation projects, especially in areas with stringent fire protection requirements (Table 6).

Regarding user health safety, analyses of volatile emissions and element migration demonstrated compliance with the permissible limits. This aspect is crucial, as it ensures that the panels can be used in residential, office, and public spaces without health risks, thereby confirming the product's conformity with current quality and safety requirements.

Table 6

Functional performance of recycled panels

Tested parameter	*Obtained result*	*Advantage*
Acoustic insulation	Confirmed by laboratory tests	Acoustic comfort
Thermal insulation	Confirmed by laboratory tests	Energy efficiency
Fire resistance	Enhanced by mineral additives	Fire safety
Emissions / migration	Within permissible limits	Sanitary safety for interior use

A major differentiating factor is the environmental and economic component. The use of at least 30% post-consumer textile and cellulosic waste contributes to reducing the volume of waste sent to landfills, supporting the principles of a circular economy (Table 7). Furthermore, the choice of recyclable and biodegradable packaging reduces environmental impact and increases the product's appeal to consumers who are conscious of the importance of sustainability [32].

Table 7

Environmental and economic advantages of decorative panels made from recycled materials

Characteristic	Obtained result	Ecological / Economic benefit
Recycled material	≥30% post-consumer textile and cellulosic waste	Reduction of waste volume
Packaging	Recyclable cardboard, biodegradable film	Reduced environmental impact
Environmental declaration	In accordance with ISO 14021:2016	Official recognition of sustainability

Practical aspects also confirm the feasibility of the product: rapid installation (performed using polymer adhesives and simple tools such as a cutter or scissors) and easy maintenance (periodic cleaning and application of an eco-friendly protective lacquer) make the panels accessible even to non-specialist users. This characteristic renders them a material that is not only environmentally friendly but also user-friendly (Table 8).

Table 8

Practicality and maintenance of recycled panels

Aspect	*Obtained result*	*Practical advantage*
Installation	Easy (polymer adhesives, simple cutting)	Accessible and quick to install
Maintenance	Periodic cleaning, eco-friendly protective lacquer	Extended service life and preserved appearance

A comprehensive analysis of the results indicates that decorative panels based on textile and cellulosic waste meet the technical and environmental requirements of modern finishing materials, offering an optimal combination of performance, safety, and sustainability. They can be regarded as an innovative solution for green construction, with a high potential for integration into the interior design materials market.

6. Conclusions

The study demonstrates that combining textile and cellulose-based waste enables the production of functional and sustainable materials suitable for interior construction and decorative applications. The manufactured panels and bricks, composed of ≥30% post-consumer waste, achieve standardized dimensions, adequate density, and improved mechanical, thermal, and fire-resistance properties, making them suitable for wall cladding, partitions, and sound-absorbing applications. Aesthetic and practical evaluations confirmed user acceptability and ease of installation. Environmental assessment highlighted the significant ecological benefits, including reduced landfill deposition, lower resource consumption, and alignment with international sustainability standards such as ISO 14021:2016. Overall, the proposed valorization strategy not only provides high-performance alternative materials but also contributes to the circular economy, promoting innovation in sustainable construction and interior design.

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