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ORIGINAL RESEARCH ARTICLE

Study on the impact of water absorption processes on the application of wood waste in composite material production

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ABSTRACT

The issue of recycling and reusing waste from the wood processing industry has garnered significant attention from researchers, as effective solutions could yield economic benefits while mitigating environmental impacts. This article focuses on the development of artificial wood using unsaturated polyester resin combined with waste materials from carpentry workshops, specifically investigating its water absorption properties.

Research findings indicate that the water absorption coefficient of the samples increased with longer immersion times, higher organic filler content, and larger particle diameters. The calculated density reveals a broad spectrum of solid industrial boards that can be produced from these compositions, suggesting that consistent forming conditions enhance economic viability. Notably, optimal results were achieved with samples made from mixed wood powder without prior sorting, which contributes to reduced production costs, aligning with the study's objectives.

Furthermore, the investigation highlighted that the water absorption coefficient escalates with increased soaking time, organic filler content, and particle size, indicating that in humid environments, it is advisable to limit both filler content and particle size to maintain performance. Overall, the studies confirm the feasibility of utilizing wood powder as a filler, with varying particle diameters imparting distinct characteristics to the final product. These findings underscore the potential for innovative approaches to wood waste management in the industry.

Keywords: wood waste; water absorption; beech wood; composite material; Organic waste

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1. Introduction

The use of renewable organic materials is considered a sustainable and environmentally friendly alternative as it helps reduce harmful emissions and dependence on non-renewable resources. Additionally, waste materials for composites reduces the need for producing new materials, thereby reducing energy consumption and natural resource usage. It is important to work towards promoting these ideas and encouraging innovation in the use of sustainable materials and recycling for environmental preservation and achieving sustainable development.

Wood is one of the most commonly used materials in the production of new composite materials, as numerous studies have shown its effectiveness due to its stability, strength, and ability to withstand loads, which stem from its organized structure. However, a significant drawback of cellulose fillers, including wood, is their hydrophilic nature, limiting their application in outdoor environments. This necessitates modifications to improve their performance against climatic factors, particularly moisture[1]. Recent scientific research highlights the potential of incorporating thermoplastics or thermosetting plastics with innovative plastic materials within the industrial wood working sector [2-8].

A study conducted by Chiper et al.[1] demonstrates the possibility of preparing unsaturated polyester composites reinforced with hemp fibers by compression molding. The hemp fibers were treated with isocyanatoethyl methacrylate (IEM), and the study showed that the water absorption properties of the composite samples immersed in water at room temperature (≈ 25 °C) followed Fick's law of diffusion. However, at 100°C, there is a deviation from this behavior, and the treatment provides better resistance to absorption compared to untreated fibers.

A study developed by Lohw et al.[9] examines moisture diffusion in polymer materials, where deviations from Fick's law behavior occur when polymer relaxation affects the water absorption behavior. These influences are divided into two groups: traditional and anomalous. The first stage is diffusion according to Fick's law, which usually occurs when the relaxation rate is higher than the absorption rate. The second stage usually occurs when relaxation and diffusion have similar values, which are observed in many polymer materials that are the most common types for anomalous moisture absorption.

Bhaskar and Singh[10] prepared epoxy resin samples by adding coconut shell particles with diameters ranging from 200 to 800 μm in various weight ratios: 20, 25, 30, and 35 wt %. The samples were made by open molding due to its low cost and flowability. The results showed that water absorption increased with increasing coconut shell particle percentage.

Olszewski et al.[11] developed a new type of high-filled polyurethane wood composite (PU-WC) by utilizing a large amount of wood waste without the addition of a catalyst. The obtained results showed that composites with wood content up to 80% in terms of mechanical properties are inferior to commonly used medium density fiberboard MDF boards. This may be due to good adhesion between the polyurethane matrix and the wood filler, which was confirmed by scanning electron microscopy data. Thermogravimetric analysis showed that PU-WC decomposes in one step with T_{max} around 360 °C, and T2% decreases significantly with higher wood addition. Additionally, the studies showed that water absorption strongly depends on the wood content and ranges from 13 to 80%. Moreover, cyclic water absorption tests did not reveal significant differences in water absorption of samples after each cycle.

In the study developed by Najafia and Khademi[12] the possibility of using cellulose fillers to strengthen and reinforce recycled high-density polyethylene (RHDPE) was considered. Researchers used rice husk (RH), wood flour (WF), powder obtained from crushed medium-density fiberboard (MDF) waste, as well as large wood particles (Particleboard), denoted as (PB). They created four plates with different proportions of fillers and studied their water absorption. It was found that for short-term immersion of the plates in water (2-24 hours), the highest water absorption value was observed for RH, PB, WF, MDF fillers, respectively, and for long-term immersion of plates in water for more than 2016 hours, the highest water absorption value was observed for WF filler, followed by MDF, PB, and RH. Thus, the lowest water absorption value was observed for the RH filler.

Previous research indicates that the search for special compounds for the wood polymer composites is still ongoing. Types of artificial wood differ in their properties, which are determined by the organic waste used in them, process parameters, and the quality of the polymer binder material (thermosetting thermoplastic). Due to these combined reasons, a wide range of different types of artificial wood has been developed.

Based on this, the aim and objectives of the conducted research have been formulated.

Research goal: Wood polymer composites (WPCs) from unsaturated polyester using waste from carpentry workshops.

Research objectives:

1. Study water absorption properties, which play an important role in property changes.

2. Investigate water absorption behavior at room temperature.

3. Model water absorption behavior by determining parameters k, n, and D that reflect its properties.

4. Obtain changes in the structure of the final product.

Behavior of water diffusion in the polymer-wood complex follows one of three conditions:

1- Diffusion according to Fick's law, where the relaxation rate of the polymer is higher than the diffusion rate of water.

2- Controlled diffusion according to the second law of Fick.

3- Anomalous diffusion according to Fick's law.

The dominant state can be characterized theoretically by determining the constants n and k in the Equation (1) that describes the shape of the experimental water absorption curve.

$$\frac{M_t}{M_s} = k.t^n \tag{1}$$

where:

M_t - mass of moisture transported through unit surface area in time t; M_s - mass of absorbed water at saturation; n - exponent, dependent on the type of diffusion and determines how closely the diffusion behavior approximates or deviates from Fick's behavior; k - coefficient, dependent on the structural properties of the polymer and its interaction with water.

Water diffusion behavior follows Fick's law when n = 0.5, controlled diffusion when $n = 1$, and anomalous diffusion when $0.5 < n < 1$.

Similar to Fourier's theory of heat transfer, Fick's laws for molecular diffusion were formulated based on random mass transfer, where the mass transfer rate (*J*) is proportional to the concentration gradient (c) in the diffusion direction (x), expressed in Equation (2).

$$J =- D\frac{dc}{dx} , \quad \left[\frac{mg}{s.cm^2}\right] \tag{2}$$

where:

D-diffusion coefficient, with the sign (-) indicating movement of molecules from high to low concentration.

Equation (2) is known as Fick's first law of diffusion.

Taking into account mass conservation in the case of non-steady-state transport with the parameter *D*, the governing equation for mass transport in the direction of the x-axis in an isotropic medium can be expressed using Fick's second law of diffusion as described by Equation (3).

$$\frac{dc}{dt} =- D\frac{d^2c}{dx^2} \tag{3}$$

Under the assumption of a homogeneous material and diffusion occurring in a thin plate, as shown in **Figure 1**.

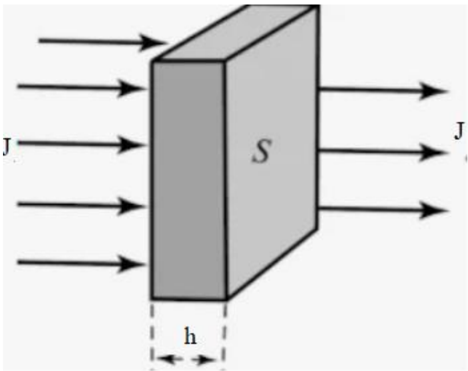


Figure 1. Diffusion through a thin plate.

Thus, the majority is transmitted through the surface boundaries, while a small portion is transmitted through the edges, which can be neglected, as the surrounding boundary conditions for humidity are constant.

The analytical solution of Equation (3) for a flat plate with thickness h can be expressed by the following relationship:

$$\frac{M_t}{M_s} = 1\frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n+1)}exp\left[-\frac{D(2n+1)^2\pi^2 t}{h^2}\right] \quad (4)$$

The diffusion coefficient *D*, according to Fick's law, is the most important parameter in this model. It determines the ability of solvent molecules to penetrate the composite material and can be calculated using the following Equations (5) and (6) (see **Figure 2**):

$$D_A = \frac{\pi\, h^2 \emptyset^2}{16 M_s^2} \quad (5)$$

$$\emptyset = \frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}} \quad (6)$$

where

D_A - apparent diffusion coefficient; $\emptyset$ - slope of the linear part of the absorption experimental curve.

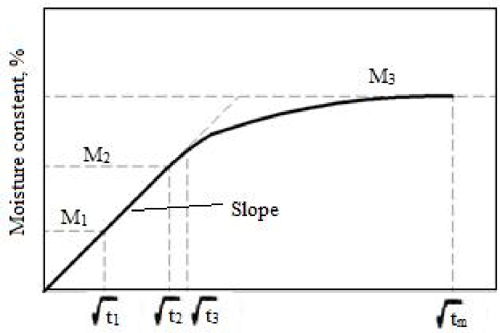


Figure 2. Experimental absorption curve.

If the sample dimensions correspond to the assumptions of a thin plate, where D_A is synonymous with the coefficient of unidirectional diffusion *D*, in order to find the correct diffusion coefficient for the used samples, it is necessary to introduce a correction factor to account for the diffusion occurring at their edges when $h \ll m$ as described by Equation (7).

$$D = D_A\left(1 + \frac{h}{l} + \frac{h}{m}\right)^{-2} \quad (7)$$

2. Methods and Materials

An unsaturated polyester resin produced in Saudi Arabia was used as the binder (TOPAZ-1600 AT (H.G.T) (MARBLE GRADE (LOW EXOTHERM) PREACCELERATED), with the following characteristics (**Table 1**).

This resin is medium reactive, diluted in Styrene monomer, inhibited sufficiently for long shelf life. The resin is flexible and possess good impact and is resistant to sanitary chemicals.

Table 1. Characteristics unsaturated polyester resin.

Physical Property	**Transparent liquid**
Color	Yellow
Odor	Pungent
Density	at 30°C: 450-650 kg/cm^3
Flash Point	340°C
Gelation Point	15-20 minutes

Organic waste from carpentry workshops, obtained during the formation of wooden products, was used as the organic filler. Powders of wood of different species and diameters were used. Three groups of prepared samples were formed, in which the main binder was unsaturated polyester resin (UPR), and the samples differed in particle diameter and type of organic filler. Accordingly, the laboratory samples were classified as follows:

Group 1: Using beech wood powder with particles of small diameter, 0.2 > *D* > 0.125 mm (**Figure 3**a); Group 2: Using beech wood powder with particles of medium diameter, 0.3 > *D* > 0.2 mm (Figure 3b); Group 3: Using mixed wood powder with different particle diameters.

a) b)

Figure 3. Beech wood powder: a) small diameter and b) medium diameter.

Each of these groups included 3 samples according to the following proportions:

- UPR + 150% organic filler; UPR + 200% organic filler; UPR + 250% organic filler.

These samples were obtained using a semi-hydraulic press, shown in **Figure 4**, according to the following system:

- Press mold temperature T = 100 °C;
- Initial molding pressure P = 10 kg/cm^2;
- Time of applying initial molding pressure 3-4 min;
- Final molding pressure P = 85 kg/cm^2;
- Time of applying final molding pressure 6-7 min.

a) b)

Figure 4. a) Semi-hydraulic press and b) samples UPR + organic filler.

After the forming cycle was completed, the mold was cooled down while maintaining the final molding pressure until reaching a temperature at which the final product could be removed without deformation.

2.1. Experimental Procedure

2.1.1. Density Calculation

To determine whether the boards were lightweight or heavy and to approximate their density to that of natural wood, samples were made in the laboratory by cutting them out from large boards. The density was calculated using Equation (8):

$$\rho = \frac{m}{V}, \quad g/cm^3 \tag{8}$$

where:

m - mass of the cut-out sample (g); *V* - volume of the cut-out sample (cm^3), which was determined after precise measurement of its dimensions using a digital caliper with an accuracy of 0.01 mm.

Short-term water absorption tests were conducted on the prepared samples for 24 and 48 hours. The test samples were plates with dimensions of 2 x 2 x 0.5 cm **Figure 5**, and their weight was measured before and after immersion in water to determine the water absorption over the specified period of time. The percentage water absorption was calculated using Equation (9):

$$W = \frac{W_2 - W_1}{W_1}.100, \quad \% \tag{9}$$

where:

W_1 - weight of the sample before immersion (g); W_2 - weight of the sample after immersion (g); W - water absorption (%).

a) b) c)

Figure 5. Test samples: a) UPR + 150% organic filler, b) UPR + 200% organic filler; and c) UPR + 250% organic filler.

A long-term water absorption test was conducted in which samples were immersed in regular freshwater and maintained in this environment for a duration of three months.

3. Results and Discussion:

3.1. Density Variation Curves:

The results of measuring the density of the studied samples showed different values, which can be explained by significant differences in the densities of the fillers used.

As cited by Kiaeifar et al.[2], the density of wood powder is about 1.5 g/cm^3, while the densities of other types of fillers with different particle sizes (short-medium-long-random), obtained from wood, are usually in the range of 0.4 to 0.8 g/cm^3. Therefore, considering that the density of samples made only from unsaturated polyester is 1.2 g/cm^3, the significant difference in the density values of the binder material and the fillers used led to different behavior of the density variation curves.

Figure 6a shows that with increasing organic filler content, the density slightly decreased from 1.2 g/cm^3 at 0% to 1.02 g/cm^3 at 150%. Then, the density increased again to 1.25 g/cm^3 at 250% filler content. This result can be explained by the fact that the organic filler and the main material have different densities, and with increasing organic filler content, the structure and bond between the components change, leading to a change in density. Increasing the filler content can be one of the factors contributing to an increase in density, as materials used as fillers usually have high density.

Based on these results, it can be said that all samples, according to the results presented in **Figure 6a**, belong to solid rocks with high density, according to the classification mentioned by Suchsland and Woodson[13].

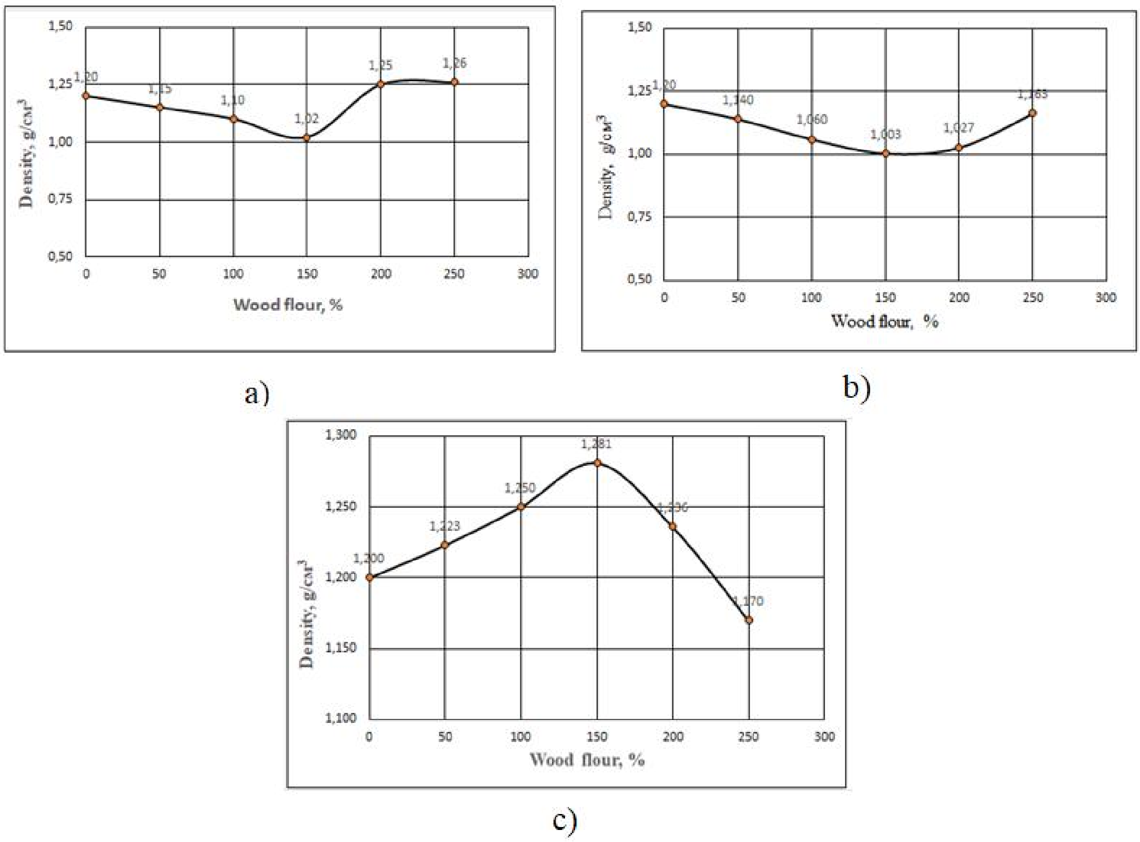


Figure 6. Variation in density of unsaturated polyester samples with different content of beech wood powder: a) mixed, b) with particle diameter of 0.3 mm, and c) with particle diameter of 0.125 mm.

Density measurements of samples composed of unsaturated polyester and beech wood powder particles with a diameter of 0.3 mm showed slight differences in density values compared to the density of the main binder material, as shown in **Figure 6b**, where a slight decrease is observed. The density of samples with 0% wood powder content was 1.2 g/cm3, then at 150% content, it slightly decreased to 1.003 g/cm3, and then started to increase again, approaching the density of the main material at 1.163 g/cm3 with 250% content.

The result presented in **Figure 6b** indicates that, according to Suchsland and Woodson[13], the density values classify these composites as solid artificial wood, and the addition of beech wood powder particles with a diameter of 0.3 mm up to 150% content leads to a slight decrease in overall density values. The results also demonstrate the possibility of producing a wide range of composites with densities approximately equal to the density of the main material.

Figure 6c shows the density change curve of samples consisting of unsaturated polyester as the base material with varying content of beech wood powder filler with a particle diameter of 0.125 mm. As seen from the graph, there is a slight increase in density at a 150% content before a sharp decrease occurs at a 250% content. At a 250% content, the density becomes low and amounts to 1.17 g/cm^3. This indicates that using a filler content exceeding 250% leads to an increase in the overall volume of the composition and a decrease in its density.

The results presented in **Figure 5c** indicate the possibility of producing boards with different densities. Specifically, at 150% content of beech wood powder, high-density boards can be obtained, while at 250% content, low-density boards can be produced. Therefore, all these boards can be classified as solid artificial wood boards according to Suchsland and Woodson[13].

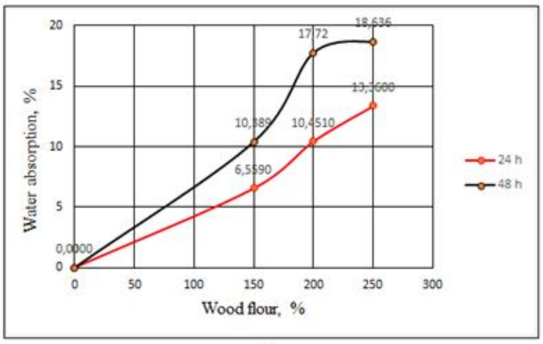
To utilize various waste materials of random diameters, a simple sorting process was employed using manual sieves instead of a precise sorting process and determining specific particle sizes. This reduced production costs and simplified the process of transforming waste into valuable products.

Dildare Basalp et al. and Storodubtseva et al.[14,15] It has been demonstrated that the use of organic waste leads to good results in the production of wood-based composite materials. The experimental studies showed the potential for using such organic waste and obtaining products with good properties, as the test samples maintained their integrity after being immersed in water for more than 150 days.The research also revealed that the maximum amount of organic filler that can be used according to the methodology described in the practical section is 350% for certain types of organic fillers.

Density measurements indicate that by using the component contents mentioned in **Figure 6** under constant forming conditions, solid artificial wood boards with densities ranging from 1.003 to 1.281 g/cm^3 can be produced. This means that this method can be used to manufacture wood boards with different densities within this range.

Short-term water absorption

The water absorption test was conducted by immersing the samples in water for a specific period of time. This test is an important part of evaluating industrial wood and ensuring its quality and resistance to water. It is also used as a physical test for industrial wood within international standards Suchsland and Woodson[13].



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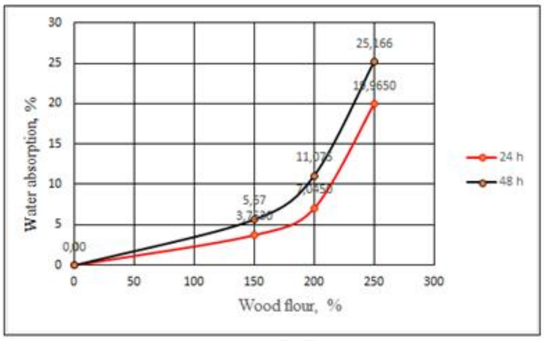

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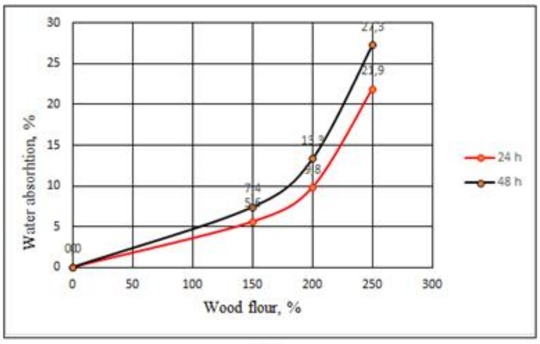


c)

Figure 7. Water absorption of polyester samples depending on the percentage content of wood powder: a) mixed, b) with particle diameter of 0.125 mm, and c) with particle diameter of 0.3 mm.

From **Figures 7a, 7b, and 7c**, the following observations can be made: the increase in water absorption with longer immersion times and higher filler content indicates that chemical reactions are occurring between water and both organic and inorganic substances in cellulose compounds. Additionally, the decrease in density and water absorption capacity of the main material with increasing filler content explains the rise in water absorption associated with higher levels of organic filler content.

The results showed clear differences in water absorption values depending on the type and particle size of the organic filler. The results in **Figure 7c** show that samples with beech wood powder filler with a particle diameter of 0.3 mm exhibit rapid water absorption. It should be noted that the water absorption reached high levels at 250% filler content, especially after 48 hours of immersion, where it exceeded 27%. This result indicates the low density of the main material and its inability to achieve the necessary cohesion between all particles of the organic filler, which is related to the presence of compounds containing high concentrations of organic filler.

Similar measurements were conducted on samples containing mixed wood powder. As seen in **Figure 6a**, the average water absorption after 48 hours of immersion was approximately 18.63% at 250% filler content. **Figure 7b** shows that the water absorption value varied depending on the content of the organic filler, represented by beech wood powder with a particle diameter of 0.125 mm. As seen in the **Figure 7b**, the highest water absorption value was achieved at 250% filler content, with an average value of 25% after 48 hours of sample immersion in water.

Short-time thickness yield curves:

The process of capillary absorption usually occurs when a dry sample is placed in a humid environment or immersed in water, where the liquid begins to spread and migrate gradually from the moist surface to the dry areas inside the sample. Stress at the boundaries between moist and dry layers arises due to the flow of moist areas. Internal forces formed within the tested sample cause internal stresses. The combination of internal forces that occur during absorption contributes to the gradual occurrence of volumetric shrinkage until saturation is reached.

From the test results, it can be seen that water absorption values increase with increasing organic filler content. It should be noted that the highest values are present at higher ratios, while the lowest values are observed in materials with minimal organic filler content. **Figures 8a, 8b, and 8c** show that water absorption values after 48 hours of immersion of all samples in water are acceptable compared to absorption values of industrial wood materials according to the mentioned classification Suchsland and Woodson[13]. Water absorption values are higher at high ratios, reaching 15% for materials containing 250% beech wood powder with a particle diameter of 0.3 mm when samples are immersed in fresh water.

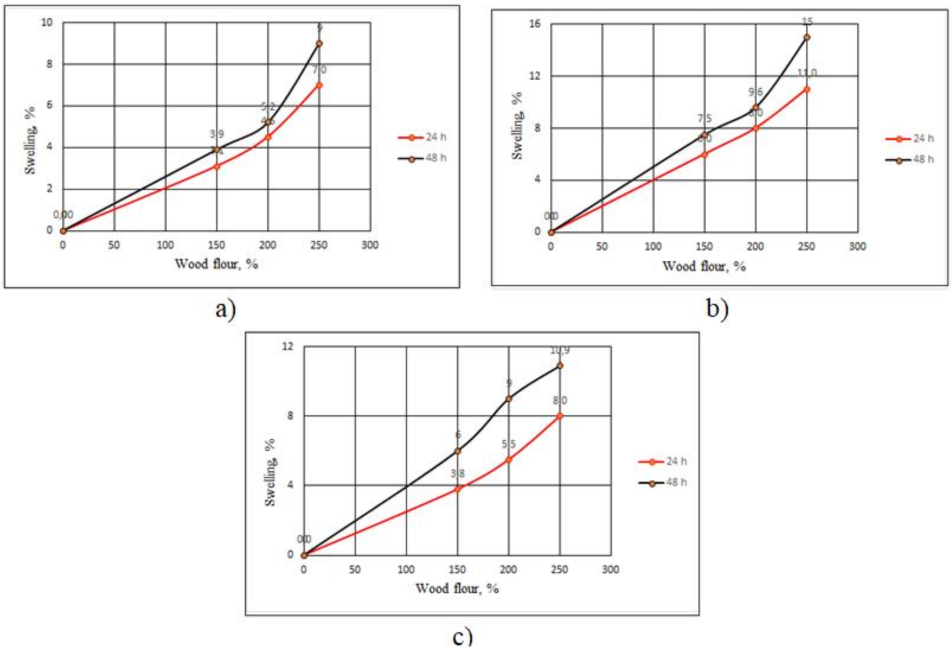


Figure 8. Swelling degree of samples in fresh water over a short period with beech wood powder filler of particle diameter: a) 0.125 mm, b) 0.3 mm, and c) mixed.

The results show that swelling values increase with increasing organic filler content. Obviously, the highest swelling values are registered in samples with high organic filler content, where its value reaches 9% when samples containing beech wood powder with a particle diameter of 0.125 mm are immersed in fresh water, and 10.9% in samples containing mixed wood powder (**Figure 8a and 8c**). Compared to the results obtained in samples with wood powder, it becomes clear that an increase in the volume of organic filler leads to an increase in swelling values in fresh water.

It can also be seen from **Figure 8b** that samples with filler made of beech wood powder with a particle diameter of 0.3 mm have the highest swelling value, with this value reaching 11% after 24 hours of immersion and 15% after 48 hours, at a content of 250%, which is higher than in similar samples made of beech wood powder with a particle diameter of 0.125 mm. In the case of using mixed wood powder, the swelling value was 8% after 24 hours and 10.9% after 48 hours of water immersion at the same ratio, as seen in **Figure 8c**.

Long-term water absorption curves

Figures 9a, 9b, and 9c show the water absorption curves of samples prepared with different organic fillers, reaching a value of 250%.

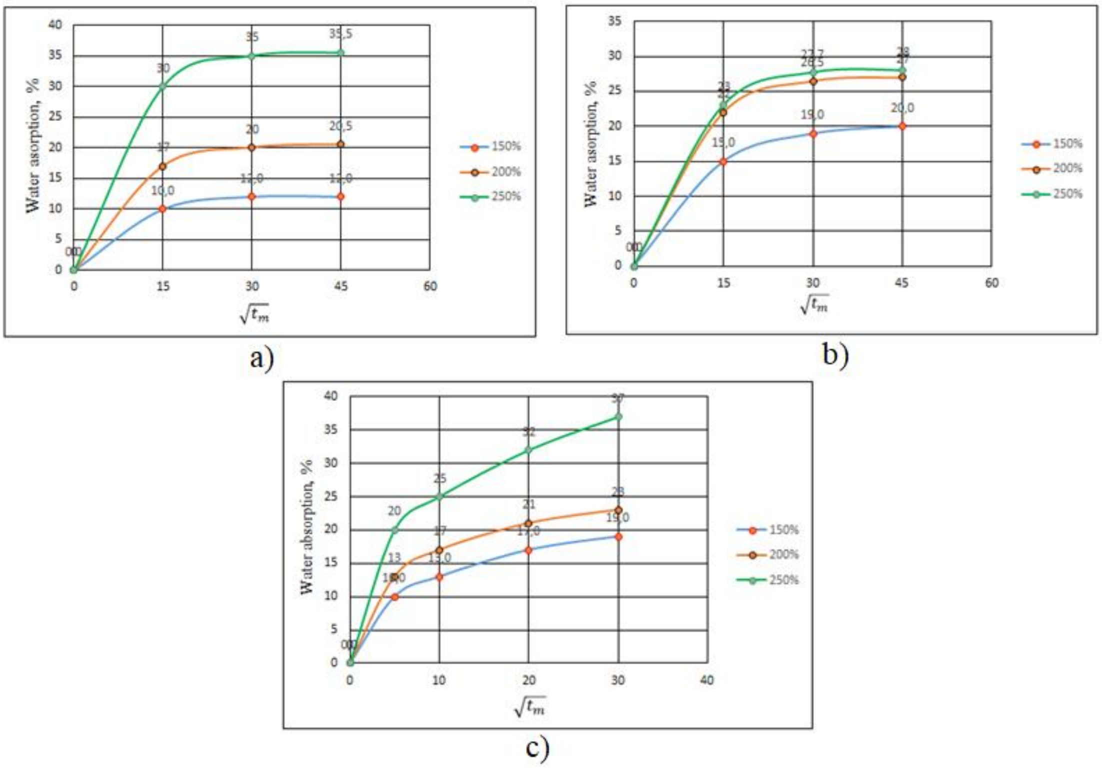


Figure 9. Changes in water absorption over time for beech wood powder samples: a) with particle diameter of 0.125 mm, b) mixed, and c) with particle diameter of 0.3 mm.

It is evident that the overall behavior of the water absorption curves is similar, despite the difference in filler content, with almost all samples reaching saturation after approximately 150 days of immersion. Additionally, from **Figures 9a and 9b**, we can observe that the water absorption curves can be divided into the following stages:

Stage 1 - linear, observed in the first few days of immersion, which occurs at high filler concentrations; Stage 2 - nonlinear, following the first stage, with an inverse relationship; Stage 3 - the water absorption coefficient values tend to increase linearly, but very slowly.

When comparing the water absorption values of different samples, it can be seen that, overall, the values are acceptable. However, it should be noted that particles of beech wood powder with a diameter of 0.3 mm have significantly higher water absorption values compared to other samples. Interestingly, all samples remain intact and retain this property even after prolonged exposure to water.

By comparing the long-term absorption curves, a diffusion mechanism was modeled. **Figure 9** show the water absorption curves of samples with beech wood powder filler with particle diameters of 0.125 mm, 0.3 mm, and mixed at room temperature. Each point on the curves represents the average values obtained from testing three samples, with an immersion time of approximately 4 months. The experiments were terminated when the samples reached a nearly equilibrium state. Water absorption did not result in visible damage to the material, except for color changes in the samples and observation of water cloudiness after 1.5 months.

From **Figure 9** it is clear that the diffusion behavior follows Fick's law or deviates slightly from it in samples with beech wood powder filler with particle diameters of 0.125 mm within the range of 150% - 200% and in samples with particle diameters of 0.3 mm within the range of 150% - 250%, as well as in samples with mixed wood powder within the range of 150% - 250%.

To determine whether the absorption behavior of these samples follows Fick's law, the values of k and n were calculated from the curves that represent the relationship between log (M_t/M_S) and *log (t)*. **Figure 10** shows the graph of the dependence of log (M_t/M_S) on *log (t)* for samples with mixed wood powder filler with a content of 200%.

It should be noted that the value of n, in terms of compliance with Fick's law, ranges from 0.38 to 0.5. Values of n less than 0.5 and even 0.38 suggest that moisture diffusion slightly deviates from Fickian behavior, which can be considered anomalous.

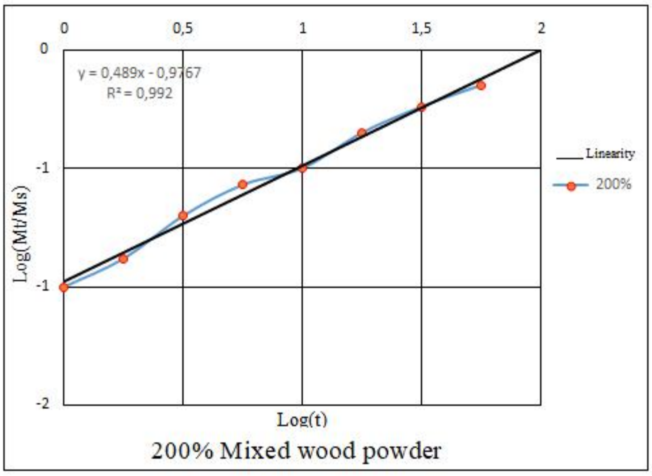
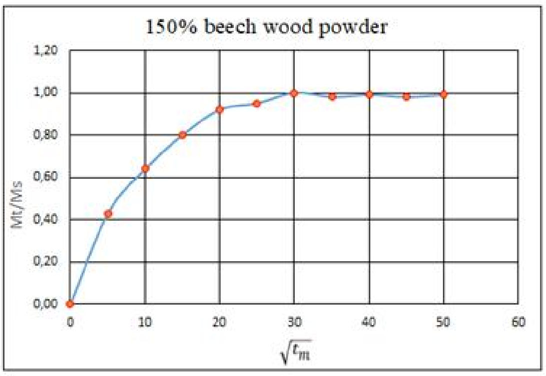


Figure 10. Dependency describing the diffusion behavior of samples made from 200% mixed wood powder.

Table 2 presents the values of each parameter *n, k, R^2*, Ms and explains the behavior of Fick's distribution based on the values of n and Mt/Ms ratios. The values of *k* and n were calculated using Equation (1). 200% Mixed wood powder.

Figure 11a presents examples of Mt/Ms graph values relative to √t, used to test the linearity of curves when Mt/Ms ≤ 0.6.

Figure 11a presents examples of Mt/Ms graph values relative to √t, which are used to test the linearity of curves when Mt/Ms ≤ 0.6. The graph illustrates the dependence of Mt/Ms on √t, demonstrating a deviation from Fick's distribution behavior. It is evident from **Figure 11a** that the graph remains linear up to the value of Mt = 0.6Ms. Similarly, **Figure 11b** shows a linear relationship for values of Mt less than 0.6Ms. Based on these observations, it can be concluded that the water absorption of samples with beech wood powder filler adheres to the diffusion model of Fick's law at an organic filler content of 250%, while it deviates from this model at values between 150% and 200%



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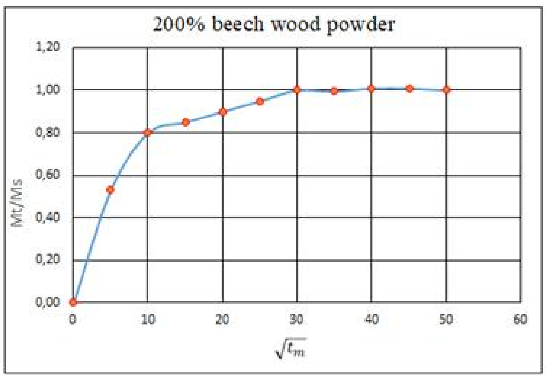

b)

Figure 11. Graphs of Mt/Ms dependence on √t used for: a) checking the linearity of curves when Mt/Ms ≤ 0.6, and b) deviation from Fickian behavior.

The same method was employed to determine the diffusion behavior in the remaining samples, with the results presented in **Table 2**. Additionally, the water absorption behavior in the samples was evaluated using the diffusion coefficient D, which quantifies the ability of water molecules to move and penetrate through the surface of the samples. For one-dimensional diffusion in a flat plate with thickness h, the second law of Fick is represented by equation (5).

The values of D for all the investigated samples in this article are given in **Table 2**. It should be noted that with an increase in the content of organic filler - wood powder, the diffusion coefficient increased.

After 2016 hours, the amount of moisture continued to increase but remained close to saturation. It should be noted that *Ms* increases with an increase in the percentage content of organic fillers and the particle size of wood powder, which can be observed from the results of previous experiments on water absorption of samples with beech wood powder filler.

Table 2. Values of diffusion parameters (type and diffusion coefficient).

Contents of component		$M_t / M_s = k_t^n$			$M_t / M_s = 0.6$	D ×10^{-12} m^2/s	Fickian or not-fickian
		n	k	R^2			
Mixed Powder	150%	0.528	-1.3	0.943	no	6.8185	Fickian
	200%	0.488	-0.932	0.953	yes	7.5736	Fickian
	250%	0.722	-1.412	0.931	no	11.039	Non-fick
Beech powder 0.3 mm	150%	0.383	-1.115	0.951	yes	2.932	Fickian
	200%	0.428	-0.802	0.988	yes	3.2699	Fickian
	250%	0.335	-1.033	0.921	no	5.1539	Non-fick
Beech powder 0.125mm	150%	0.546	-1.335	0.993	no	2.1226	Non-fick
	200%	0.517	-1.23	0.985	yes	2.776	Fickian
	250%	0.418	-0.846	0.988	yes	5.994	Fickian

4. Conclusions

1. The calculated density shows a wide range of solid industrial boards that can be obtained from these compositions. If it is known that the samples were prepared under constant forming conditions, their production becomes economically advantageous.

2. The best results were obtained when studying samples using mixed wood powder that did not undergo sorting process, which allows reducing production costs and is one of the goals.

3. The water absorption coefficient of the samples increased with increasing water soaking time, organic filler content, and particle diameters. This means that when using such boards in a humid environment, large values of organic filler content and particle sizes should be avoided.

4. The studies demonstrated the possibility of using wood powder as a filler with particles of different diameters, each of which imparts its unique characteristics to the final product.

Conflict of interest

The authors declare no conflict of interest

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