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THE INFLUENCE OF ULTRAVIOLET IRRADIATION ON THE PROPERTIES OF WOOD–POLYMER COMPOSITES

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The paper investigates the influence of ultraviolet irradiation on the properties of wood–polymer composites. The aim of the study was to evaluate the combined influence of light, predominantly in the ultraviolet region of the spectrum, oxygen, moisture, and various airborne pollutants on wood–polymer composites under simulated aging conditions. Wood–polymer composites were used as research objects, consisting of recycled polyethylene (15 wt.%), thermoplastic polyurethane (10 wt.%), petroleum polymer resin (8 wt.%), solvent (12 wt.%), polystyrene waste (7 wt.%), wood filler (sawdust) (45 wt.%), and microcalcite (3 wt.%). Particular attention was paid to assessing the impact of ultraviolet exposure on the physical and mechanical properties as well as the water absorption behavior of the composites. The results demonstrate that ultraviolet aging, especially under accelerated conditions, leads to pronounced morphological changes in the material. These changes include the formation of microcracks and microstructural defects, indicating a significant deterioration of the physical and mechanical performance of the composites. In addition, ultraviolet irradiation alters the chemical structure of wood–polymer composites, resulting in the formation of new functional groups and changes in the sorption characteristics of the material.

Keywords: composite, wood, recycled materials, polyethylene, polypropylene, ultraviolet irradiation, properties.

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Introduction

When exposed to outdoor atmospheric conditions, wood–polymer composite (WPC) products undergo gradual degradation as a result of the combined action of light (primarily in the ultraviolet region of the spectrum), oxygen, moisture and various airborne pollutants [1–3]. These factors have bad influence not only on the aesthetic appearance of the material but also its mechanical performance, increasing degradation rate as well as the intensity and duration of exposure grow [2,4]. Absorption of ultraviolet (UV) radiation leads to polymer chain scission and a loss of structural integrity at multiple points within the material [5–7]. Both the polymer matrix and the additives incorporated into the composite formulation are susceptible to photodegradation contributing to the overall deterioration of WPC properties.

To protect polymers from light-induced aging, various light stabilizers are commonly used [8,9]. Their action is based both on the absorption of solar radiation

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(UV absorbers) and on the inhibition of dark degradation reactions that are initiated by light exposure but continue in the absence of radiation. Such stabilizers are known as quenchers of excited states and inhibitors of radical chain photooxidation processes. UV-absorbing stabilizers prevent the penetration of ultraviolet light into the material. The effectiveness of their protective action is determined by their ability to absorb radiation in the same spectral region as the polymer while remaining resistant to side reactions that could lead to chemical transformation and rapid consumption of the stabilizer [10]. The molecular structure of UV absorbers must ensure reversible chemical transformations in the electronically excited state. Typical UV absorbers include derivatives of 2-hydroxybenzophenones, hydroxybenzotriazoles, esters of benzoic, salicylic and terephthalic acids with resorcinols and phenols, as well as cinnamic acid derivatives.

Light stabilizer quenchers deactivate the excited states of polymers through an intermolecular energy transfer mechanism, in which energy is transferred from the excited polymer molecule (donor) to the stabilizer molecule (acceptor). Such quenchers are usually complex compounds of transition metals, most commonly nickel. However, they tend to impart coloration to polymers and exhibit limited resistance to high processing temperatures and atmospheric gases.

Light stabilizer inhibitors operate via a chemical mechanism. This mechanism involves the suppression of dark (secondary) reactions that generate free radicals in polymers, as well as interactions with polymer hydroperoxides and functional groups of macromolecules that reduce resistance to aging. The greater the number of oxidation kinetic chains that an inhibitor molecule can terminate, the more effective it is as a light stabilizer. The practical value of a stabilizer depends on a combination of properties, including absorption capacity, ability to dissipate absorbed energy, photochemical and thermal stability, and intrinsic coloration. Compatibility with the polymer matrix, volatility, and odor are also important factors [9].

Materials and methods

The aim of this study is to investigate the physical and mechanical properties of wood–polymer composites (WPCs) after exposure to ultraviolet (UV) irradiation for durations of 24 and 72 hours.

To achieve this objective, the following tasks were addressed: selection of an appropriate methodology for accelerated aging of materials; determination of the radiation type and wavelength; and calculation of the corresponding photon frequency and energy.

UV irradiation tests were carried out on the developed WPC formulations. Previously studied WPCs [10–12] with an optimized composition were used as research objects, consisting of recycled polyethylene (15 wt.%), thermoplastic polyurethane (10 wt.%), petroleum polymer resin (8 wt.%), solvent (12 wt.%), polystyrene waste (7 wt.%), wood filler (sawdust) (45 wt.%) and microcalcite (3 wt.%).

UV-A radiation with a wavelength of 340 nm was applied, corresponding to a frequency of $f=8.8210^{14}$ Hz and a photon energy of $E=5.83\cdot10^{-19}$ J. This energy is sufficient to initiate photodegradation of polyethylene, cleavage of urethane bonds and oxidation of the wood filler surface.

Accelerated aging tests were conducted in accordance with QUV ASTM G154 and ISO 4892-3 standards. The following materials were investigated: polyethylene (PE), polyurethane (PU), and wood–polymer composites (WPCs) under UV-A irradiation at a wavelength of 340 nm.

The applied methodology involves exposure to ultraviolet radiation at 340 nm to simulate photodegradation processes and to assess the resistance of materials to external climatic factors.

Tubular UV-A 340 lamps (manufacturer Q-Lab; models QUV/se and QUV/spray) were used. According to the standard procedure, the lamps were positioned directly above the specimens, with a distance of approximately 50 mm between the lamp surface and the sample surface. This configuration ensures stable UV radiation intensity, uniform exposure and compliance with the requirements of ASTM G154 and ISO 4892-3.

Results and discussion

A series of experimental results was obtained to evaluate the effect of UV irradiation on the physical, mechanical and service properties over exposure periods of 24 and 72 hours, and to compare the proposed WPC samples with an optimized composition to commercial analogues. After 24 hours of UV exposure, the WPC samples with the optimized composition exhibited the IR spectrum shown in Fig. 1.

Noticeable changes are observed in the absorption area of 3330–3350 cm^{-1} (O–H, hydroxyl groups). They are associated with the formation of hydroxyl and carboxyl groups as a result of oxidative processes. After UV exposure, the peak intensity increases and shifts toward the area of 3340–3380 cm^{-1}, indicating intensified oxidation of cellulose and an increased concentration of –OH groups [13].

A slight enhancement of the absorption band near 3400 cm^{-1} is also detected. The relatively narrow peak shape suggests that oxidative processes are limited due to the presence of petroleum polymer resins, which exhibit a stabilizing effect, as well as a protective polymer layer. Overall, the observed changes are minimal. The peak does not increase significantly because the PE/TPU matrix effectively absorbs UV radiation and shields the wood domains. Photolysis is restricted. Analysis of the absorption bands in the area of 2918–2850 cm^{-1} (C–H of alkanes, PE, TPU) indicates that this region is sensitive to degradation of alkane chains in the polyethylene and polyurethane phases. No significant changes are observed, as the contribution of wood components is minor. The intensity of these bands decreases by approximately 3–7%, which corresponds to the initial stage of photodegradation of polyethylene-containing domains and the formation of oxygen-containing products. Overall, the reduction in intensity reaches 5–10%, indicating the onset of chain scission in the polymer matrix accompanied by a decrease in the concentration of saturated C–H bonds.

The absorption area of 1600–1500 cm^{-1} (C=O, aromatic rings of resins and polystyrene) proves to be one of the most UV-sensitive areas of the spectrum. An increase in the band at 1630–1650 cm^{-1} is associated with the formation of aldehyde and ketone groups resulting from lignin degradation. A distinct “shoulder” appears in the area of 1600–1700 cm^{-1}, corresponding to an increased content of carbonyl compounds formed during photodegradation of the PE/TPU matrix [14]. In addition, an intense band emerges at 1710–1730 cm^{-1}, which is characteristic of carbonates, peroxides and carboxylic acids, typical products of polyethylene photooxidation.

In the area of 1020–1240 cm^{-1} (C–O, polyester structures, TPU, wood components) [15], an increase in peak width and intensity is observed, indicating partial cleavage of cellulose and the formation of new C–O bonds. The peak intensity increases by 5–12%, reflecting the formation of esters and peroxides as products of photooxidation of polyethylene and polyurethane [15]. Broadening of the band and a shift of 3–6 cm^{-1} are detected, which is characteristic of TPU degradation and accumulation of oxygen-containing functional groups. In the area of 873–697 cm^{-1} (aromatic vibrations of polystyrene and $CaCO_3$), no significant changes are observed due to the limited contribution of aromatic and carbonate phases. However, in the case of the modified filler, these bands become more pronounced, which can be attributed to increased brittleness of the resinous and polystyrene phases after UV exposure. The intensification of the bands at 873, 719, and 697 cm^{-1} by 5–8% is associated with a reduction in the masking effect of the organic matrix that has undergone partial degradation.

In the low-frequency area below 650 cm^{-1} ($CaCO_3$ and other inorganic components), no new peaks appear. The bands in the 463–555 cm^{-1} range retain their shape and intensity, confirming the photostability of the carbonate phase. A slight increase in spectral contrast is observed, resulting from the reduced fraction of the organic phase and the more distinct manifestation of $CaCO_3$ vibrational modes.

Overall, after 24 hours of UV exposure, a significant enhancement of carbonyl (C=O) bands is observed, which represents a primary indicator of photooxidation in the PE/TPU matrix, most pronounced in thin-film regions. Broadening of the O–H absorption area indicates increased hydrophilicity of the materials, with the effect being strongest for wood and weakest for the composites. A decrease in the intensity of C–H bands at 2920–2850 cm^{-1} reflects degradation of polyethylene alkane chains. Enhanced C–O bands indicate the formation of esters, peroxides and other oxygen-containing products. In contrast,

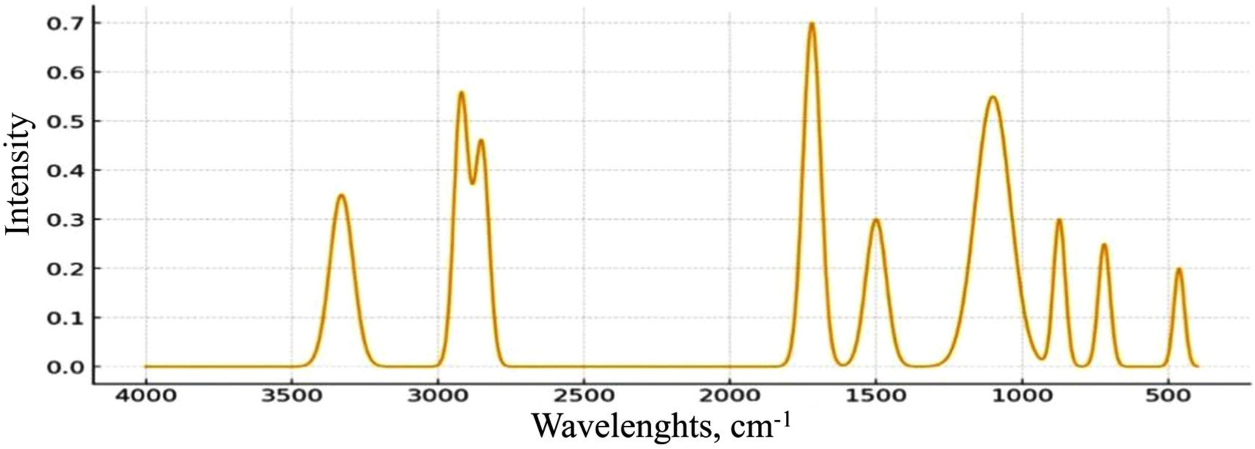

Fig. 1. IR spectrum of WPC samples after 24 hours of UV irradiation

inorganic bands related to $CaCO_3$ remain stable, confirming their inertness toward photodegradation.

After 72 hours of UV irradiation, the WPC samples with the optimized composition exhibited the IR spectrum shown in Fig. 2.

A moderate increase in the carbonyl absorption band (C=O at 1735 cm^{-1}: 0.05→0.12) is observed, indicating oxidative processes associated with the formation of carbonyl-containing products, which is characteristic of mild photoaging [14,15]. In addition, an increase in the O–H band intensity at 3332 cm^{-1} is detected, reflecting a higher concentration of hydroxyl groups and, consequently, enhanced water adsorption. A decrease in the intensity of aliphatic C–H bands in the area of 2850–2918 cm^{-1} is also observed, suggesting partial fragmentation of polymer chains. An increase in the intensity of C–O bands around 1100 cm^{-1}, together with a moderate enhancement of the band at 1630 cm^{-1}, indicates the formation of ester groups and alcohol or conjugated oxidative fragments. The spectral area around approximately 800 cm^{-1} shows the appearance of additional features, manifested as increased noise and changes related to the filler or secondary degradation products. Based on the IR spectral analysis, a moderate deterioration of mechanical properties and an increase in water absorption can be expected after prolonged UV exposure. The physical and mechanical properties of the WPC samples after 24 and 72 hours of UV irradiation are summarized in Table 1 and 2, respectively.

The investigation and analysis of the IR spectra demonstrated that UV exposure initiates photooxidation of polyethylene, leading to the formation of microcracks, a reduction in interfacial adhesion between the polymer matrix and wood filler, and the onset of oxidative processes on the surface of the modified filler [14,15].

It can be concluded that impact strength is the

Table 1

Physical and mechanical properties of WPCs after 24 hours of UV irradiation

Sample	Water absorption W, %	Flexural strength, MPa	Impact strength, kJ/m^2
Prepared by simultaneous modification method	1.13	15.5	12.6

Table 2

Physical and mechanical properties of WPC samples after 72 hours of UV irradiation

Sample	Water absorption W, %	Flexural strength, MPa	Impact strength, kJ/m^2
Prepared by simultaneous modification method	1.22	13.4	11.2

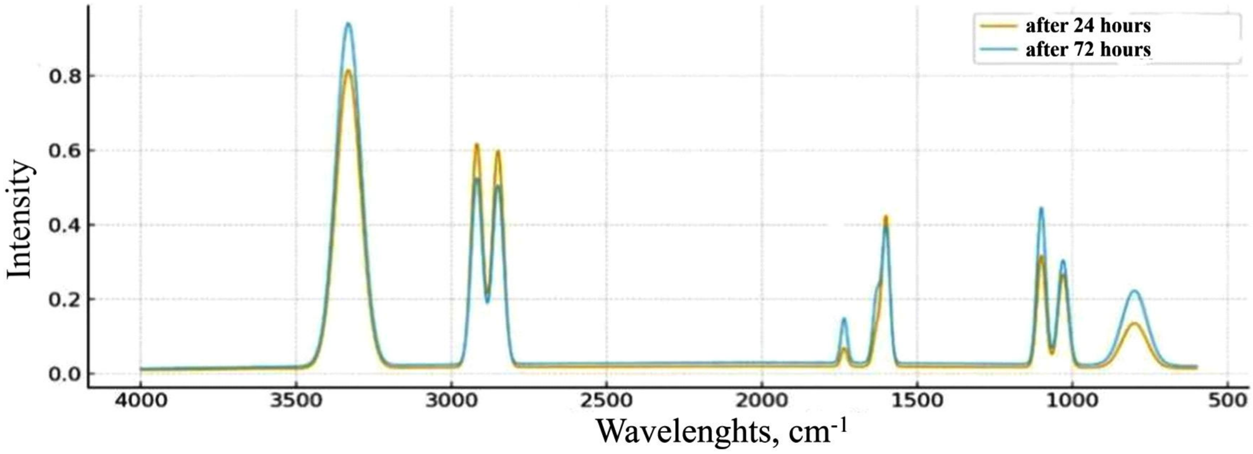

Fig. 2. Comparative IR spectra of samples after 72 hours of UV exposure

mechanical property most sensitive to photooxidation of polyethylene. After water absorption following 72 hours of UV exposure, microcracks appear on the surface, accompanied by oxidation, an increase in surface polarity and enhanced wettability.

Based on the experimental results, the evolution of material properties under prolonged UV exposure ranging from 250 to 2000 hours was modeled. The modeling was carried out using the following assumptions: the energy of a single photon in each spectral range was calculated using the expression $E_{ph}=h \cdot f$; the spectral power distribution was assumed to be uniform across the wavelength ranges. The photochemical efficiency (per unit of absorbed energy) was assumed to be proportional to the photon energy, meaning that higher-energy quanta induce more effective degradation per unit of absorbed energy.

The assumptions of uniform spectral power distribution and linear dependence of degradation efficiency on photon energy represent is a simplification. The overall parameters of the model were as follows: irradiation intensity $E=500$ W/m^2, exposure time $t=2000$ h, and total energy dose across the spectral ranges $D=3.6 \cdot 10^9$ J/m^2. To predict the composite properties after UV exposure from 250 to 2000 hours, the Bolland–Gee autooxidative photodegradation model, adapted for aromatic polymers, was applied. The degradation process includes the following stages:

1) initiation (photoexcitation of aromatic rings);
2) radical formation;
3) peroxide formation;
4) decomposition of ROOH→C=O, –CHO, –COOH;
5) secondary oxidation.

The temporal evolution of each functional group was assumed to follow pseudo-first-order kinetics with respect to irradiation time and can be expressed as:

$$\frac{dA_i}{dt} = k_i \cdot f(I, \lambda, T, O_2),$$

where A_i is the integrated intensity of the corresponding FTIR band; k_i is the effective photodegradation rate constant; I is the UV intensity; λ is the wavelength (340 nm); T is the temperature; and O_2 is the oxygen availability.

For aromatic bands, $k_i<0$, whereas for carbonyl bands, $k_i>0$.

The growth of the carbonyl index (CI) was modeled for the band at approximately 1710 cm^{-1} using a logistic-exponential function.

At the early stage (0–24 h), the carbonyl index follows a linear relationship $CI(t) = CI_0 + k_1 t$, while at the intermediate stage (24–72 h), it follows $CI(t) = CI_{max}\left(1 - e^{-k_2 t}\right)$, corresponding to the transition from the initiation stage to the autooxidative regime.

Spectral normalization was performed using an inert reference band (approximately 1450 cm^{-1} or 1600 cm^{-1}), and the analysis was based on relative rather than absolute integrated intensities. Accordingly, the changes in band intensities were evaluated using the relation $\Delta A_i(t) = A_i(t)/A_{ref}(t)$.

The results of modeling UV irradiation up to 2000 hours are summarized in Table 3.

The analysis of changes in the intensities of key FTIR peaks after UV exposure confirms the development of photooxidative processes in the WPC samples. The intensity of the O–H band at 3332 cm^{-1} decreases by 27.2%, indicating a significant reduction in hydroxyl groups, which reflects surface dehydration, disruption of hydrogen bonding and partial degradation of polar structures in the wood or polymer components. This behavior is typical of photodegradation and drying effects in polymeric materials. A decrease of 16.4% in the intensity of the C–H band at 2920 cm^{-1} is also observed, indicating weakening of aliphatic C–H bonds due to chain scission in polyethylene or polyurethane, a reduction in the organic matrix content and the onset of hydrocarbon fragment degradation. Such changes are characteristic of early-stage photooxidative degradation of polymers. In contrast, a pronounced increase of 22.3% in the carbonyl band at 1735 cm^{-1} is detected, reflecting the intensive formation of oxygen-containing

Table 3

Results of modeling UV irradiation for 2000 hours

Peak, cm^{-1}	Type	Intensity after irradiation	Change
OH 3332	decrease	0.221	–27.2%
CH 2920	decrease	0.665	–16.4%
C=O 1735	increase	1.543	+22.3%
Aromatic 1600	decrease	0.84	–13.1%
C–O 1100	increase	1.057	+10.2%

functional groups such as aldehydes, ketones and esters. This increase represents a key marker of polymer aging under UV irradiation [15]. A reduction of 13.1% in the aromatic C=C band at 1600 cm^{-1} indicates degradation of aromatic structures within the filler or resin components and a decrease in conjugated systems that contribute to material stabilization. Additionally, an increase of 10.2% in the C—O band at 1100 cm^{-1} confirms oxidation processes accompanied by the formation of ester and alcohol groups and the transformation of polar functionalities into more stable structures [15].

Based on the conducted studies, it can be stated that the material undergoes photooxidative aging [5,6], which is expected to result in a reduction in strength, impact resistance and an increase in brittleness. With continued UV exposure, oxidative processes are likely to accelerate and become irreversible [15].

The experimentally measured and predicted physical and mechanical properties of WPC samples after 2000 hours of UV irradiation are presented in Table 4.

The presented data can be explained as follows. Impact strength decreases most rapidly because microcracks and structural defects significantly reduce the material's resistance to dynamic loading. Static bending strength decreases more gradually; however, under prolonged exposure, polymer chain scission becomes the dominant degradation mechanism. Water absorption increases due to the formation of surface microcracks, oxidation processes and an increase in surface polarity.

Based on the obtained results, several key degradation trends can be identified:

– water absorption increases almost linearly (approximately +0.0006% per hour);

– static strength decreases slowly, with a total loss of approximately 25% after 2000 hours of UV exposure;

– impact strength degrades most rapidly, showing a reduction of approximately 40% over the same period, making it the primary limiting parameter.

Complete and irreversible material degradation is assumed to occur when the residual mechanical properties decrease to 30% of their initial values. Based on this criterion, the critical performance indicators are static bending strength and impact strength. The initial values were as follows: impact strength of 13.3 kJ/m^2, with a 50% reduction corresponding to 6.65 kJ/m^2, and static bending strength of 16.1 MPa, with a 75% reduction corresponding to 12.1 MPa.

The calculated degradation rates indicate that the rate of impact strength degradation is approximately 0.00266 kJ/m^2 per hour, while the degradation rate of static bending strength is approximately 0.0006 MPa per hour.

The predicted service life of WPC under extreme conditions suggests that the key mechanical parameters approach critical values after approximately 2800—3000 hours of UV exposure. This corresponds to about 125 days of continuous UV irradiation or approximately 8—9 years of operation under severe environmental conditions.

After exposure of commercial WPC samples to intensive UV irradiation at a wavelength of 340 nm for 24 hours, the IR spectrum shown in Fig. 3 was obtained.

The FTIR analysis of commercial WPC samples after 24 hours of UV irradiation showed a strong and broad absorption band in the range of 3600—3200 cm^{-1} (O—H stretching). This indicates lignin photolysis, evidenced by the formation of phenolic —OH groups, as well as the presence of carboxylic acids and hydroperoxides.

In the absorption bands at 2916 and 2848 cm^{-1} (C—H stretching of polyethylene), a noticeable decrease in intensity and band broadening was observed, indicating the onset of polymer chain scission and a reduction in polyethylene crystallinity. This confirms that degradation processes, rather than simple thermal

Table 4

Experimental and predicted physical and mechanical properties of WPC after UV exposure for up to 2000 hours

Exposure time, h	Exposure time, h	Static bending strength, MPa	Static bending strength, MPa
Impact strength, kJ/m^2			
0	1.0	16.1	13.3
24	1.13	15.5	12.6
72	1.22	14.91	11.2
Predicted WPC samples			
250	1.51	14.23	10.84
500	1.63	13.96	10.32
1000	1.92	12.88	9.31
2000	2.2	12.07	7.98

effects, are present.

The absorption band at 1735 cm^{-1} (C=O stretching) appears as a very strong dominant peak in the spectrum, corresponding to the formation of ketones, aldehydes, and carboxylic acids in polyethylene, oxidized hemicellulose, lignin photolysis products and a sharp increase in the carbonyl index. This band is a key indicator of QUV aging.

The absorption band at 1635 cm^{-1} indicates the presence of lignin and conjugated C=O groups. Its higher intensity compared to the initial FTIR spectrum suggests the degradation of the aromatic lignin network. The band at 1465 cm^{-1} (δ(CH)) is weakened, confirming the loss of crystallinity and the occurrence of surface chalking. The band at 1170 cm^{-1} (C–O/ester groups), newly formed, is characteristic of UV-induced secondary oxidation products. The absorption band at 1030 cm^{-1} (C–O stretching of cellulose) is reduced but still present, indicating partial degradation without destruction of the structural framework.

Overall, it can be concluded that 24 hours of intensive UV irradiation at 340 nm causes significant photo-oxidative degradation in standard WPC materials. UV exposure initiates photo-oxidative processes, leading to the formation of a brittle and polar surface, significantly increases the concentration of C=O and –OH functional groups, reduces impact resistance, and creates conditions for surface chalking. This level of degradation is equivalent to several months of real outdoor exposure under sunlight.

FTIR spectrum of commercial samples after 72 hours of UV exposure is shown in Fig. 4.

After 72 hours of intensive UV irradiation at 340 nm, profound photo-oxidative degradation of the surface layer of the wood–plastic composite (WPC) is observed. This degradation significantly exceeds the initial aging stage (24 h) and develops into advanced destruction of the polymer–wood matrix. At this stage, the process becomes irreversible and clearly dominates over thermal effects. A very strong and broad absorption band in the range of 3600–3200 cm^{-1} (O–H stretching) is observed, reaching maximum intensity and width. This indicates extensive lignin photolysis accompanied by the formation of phenolic and alcoholic –OH groups, accumulation of carboxylic acids and a high concentration of hydroperoxides. These changes reflect strong surface polarization and a pronounced loss of hydrophobicity.

The advanced stage of UV aging of WPC is clearly visible in the absorption bands at 2916/2848 cm^{-1} (ν(CH)), where a sharp decrease in intensity is detected. This corresponds to active polymer chain scission, a significant reduction in polyethylene crystallinity and the onset of macromolecular fragmentation. At this stage, polyethylene loses its function as an effective binding phase. The absorption band at 1735 cm^{-1} (C=O) becomes the most intense and dominant peak in the spectrum. It corresponds to the formation of ketones, aldehydes and carboxylic acids in polyethylene, oxidized hemicellulose and products of deep lignin photolysis. This band represents an unambiguous marker of critical UV aging under QUV-340 conditions. High intensity, broadening and shifting of the absorption band at 1635 cm^{-1} (lignin/conjugated C=O groups) indicate severe degradation of the aromatic lignin network and the loss of the UV-shielding function of the wood phase. The absorption band at 1465 cm^{-1} (δ(CH_2)) is significantly weakened, confirming the loss of polyethylene structural order, the development of surface chalking, and a reduction in mechanical integrity. A clearly formed absorption peak at 1170 cm^{-1} (C–O/ester groups) reflects the accumulation of secondary photo-oxidation products and continued polymer chain cleavage. The absorption band at 1030 cm^{-1} (C–O stretching of cellulose) shows a noticeable decrease in intensity; although the

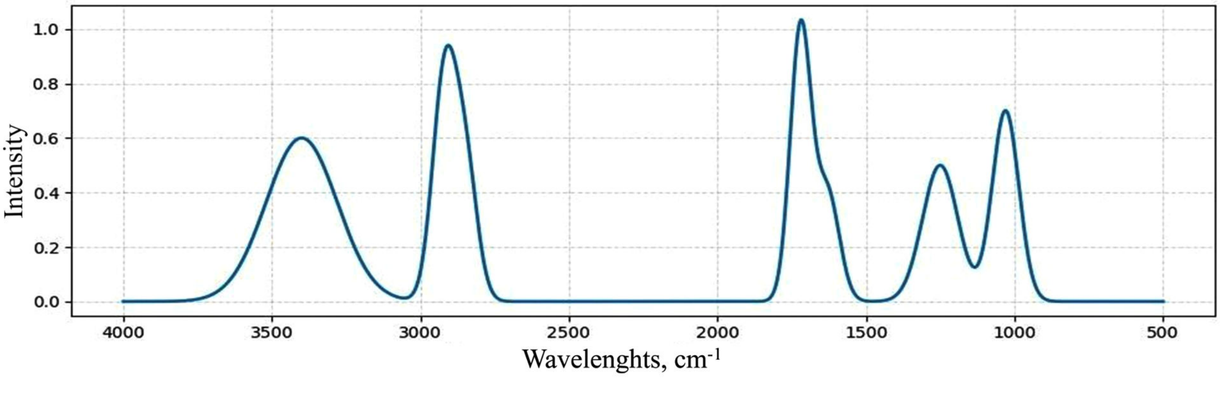

Fig. 3. FTIR spectrum of a commercial sample after 24 hours of exposure

structure is still present, it is significantly degraded, indicating partial destruction of the cellulose framework and reduced wood–polymer interfacial adhesion.

In general, 72 hours of intensive UV irradiation at 340 nm induces advanced photo-oxidative degradation in standard WPCs, leading to the formation of a brittle, highly polar and oxidized surface layer with a sharply increased concentration of C=O and –OH functional groups. These changes result in a substantial loss of impact strength, deterioration of interfacial adhesion, and intensive surface chalking. This level of degradation is equivalent to approximately 6–12 months of real outdoor exposure without UV protection, depending on climatic conditions.

After 72 hours of UV exposure at 340 nm, standard WPCs without stabilizers can be considered functionally degraded at the surface. The material loses long-term service reliability and requires mandatory UV protection for outdoor applications.

An analysis of the effects of QUV-340 UV irradiation (ASTM G154/ISO 4892-3) for 72 hours and 2000 hours was performed on standard WPCs with initial properties (Table 5): water absorption 10.8%; impact strength 2.74 kJ/m^2; static bending strength 18.2 MPa.

Considering that QUV-340 exposure induces photochemical degradation, which is significantly more aggressive than infrared effects and is accompanied by polyethylene chain scission, lignin photolysis and surface chalking, it leads to severe deterioration of impact strength, static bending strength and water resistance of standard WPCs.

Conclusions

The conducted studies demonstrated that UV irradiation activates photo-oxidative processes in the PE/TPU polymer matrix, which is evidenced by a pronounced increase in carbonyl absorption bands in the range of 1710–1730 cm^{-1}. Modifying additives and resins partially protect wood particles by reducing the intensity of oxidative reactions and suppressing the growth of the O–H absorption band. The highest photostability was observed for the composite film in which mineral ($CaCO_3$) and aromatic (PS) components act as UV-shielding phases. The main structural changes are localized within the organic polymer matrix, while inorganic fillers remain inert to UV exposure. UV irradiation for 24 hours initiates an early surface stage of photodegradation without causing deep structural damage to the material. The presence of $CaCO_3$ and aromatic domains significantly slows down degradation processes, as confirmed by the stability of low-frequency absorption bands. In

Table 5

Effects of QUV-340 UV irradiation (ASTM G154/ISO 4892-3) for 72 and 2000 hours on standard WPCs

Parameter	Value		
	Initial	72 h	2000 h
Water absorption, %	10.8	14.5–16.0	22–26
Impact strength, kJ/m^2	2.74	1.95–2.15	0.85–1.20
Static bending strength, MPa	18.2	15.5–16.8	9.5–11.5

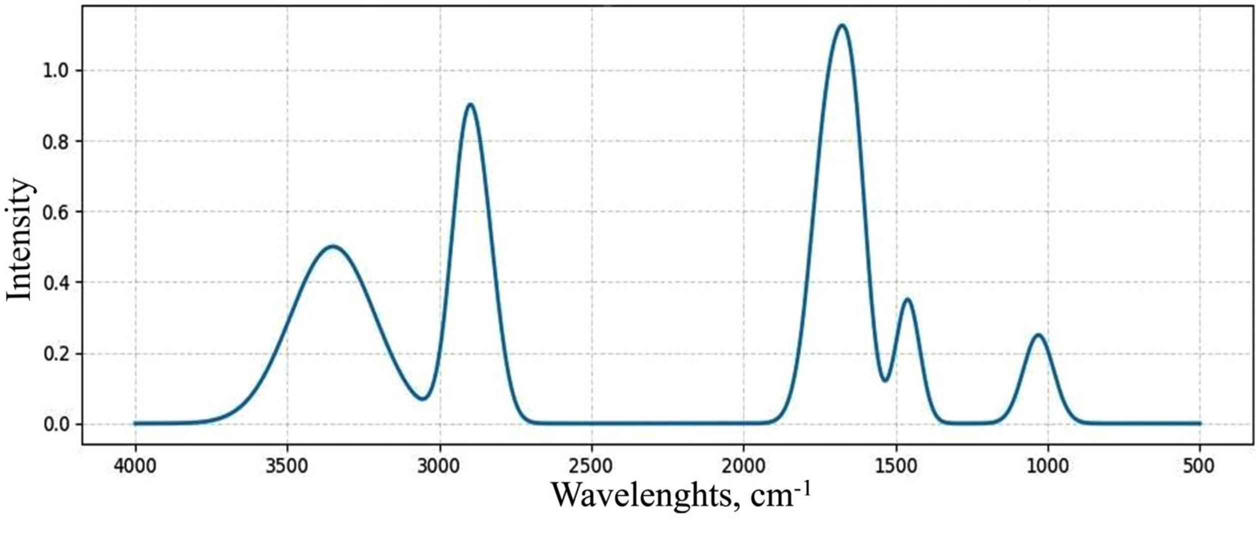

Fig. 4. FTIR spectrum of a commercial sample after 72 hours of exposure

the absence of UV stabilization, standard WPCs do not withstand prolonged QUV-340 aging. After 2000 hours of exposure, impact strength and water resistance reach unacceptable levels, static bending strength remains at the threshold of standard requirements and outdoor application of the material becomes impossible.

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ВПЛИВ УЛЬТРАФІОЛЕТОВОГО ОПРОМІНЕННЯ НА ВЛАСТИВОСТІ ДЕРЕВНО-ПОЛІМЕРНИХ КОМПОЗИТІВ

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У статті досліджується вплив ультрафіолетового опромінення на властивості деревно-полімерних композитів. Метою дослідження була оцінка комбінованого впливу світла, переважно в ультрафіолетовій ділянці спектра, а також кисню, вологи та різних забруднювачів повітря на деревно-полімерні композити в умовах моделювання старіння. Як об'єкти дослідження використовувалися деревно-полімерні композити, що складаються з переробленого поліетилену (15 мас.%), термопластичного поліуретану (10 мас.%), нафтополімерної смоли (8 мас.%), розчинника (12 мас.%), відходів полістиролу (7 мас.%), деревного наповнювача (тирса) (45 мас.%) та мікрокальциту (3 мас.%). Особливу увагу було приділено оцінці впливу ультрафіолетового опромінення на фізико-механічні властивості, а також водопоглинальну поведінку композитів. Результати показують, що ультрафіолетове старіння, особливо в прискорених умовах, приводить до виражених морфологічних змін у матеріалі. Ці зміни включають утворення мікротріщин та мікроструктурних дефектів, що свідчить про значне погіршення фізико-механічних характеристик композитів. Крім того, ультрафіолетове опромінення змінює хімічну структуру деревно-полімерних композитів, що призводить до утворення нових функціональних груп та змін сорбційних характеристик матеріалу.

Ключові слова: композит, деревина, перероблені матеріали, поліетилен, поліпропілен, ультрафіолетове опромінення, властивості.

THE INFLUENCE OF ULTRAVIOLET IRRADIATION ON THE PROPERTIES OF WOOD–POLYMER COMPOSITES

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The paper investigates the influence of ultraviolet irradiation on the properties of wood–polymer composites. The aim of the study was to evaluate the combined influence of light, predominantly in the ultraviolet region of the spectrum, oxygen, moisture, and various airborne pollutants on wood–polymer composites under simulated aging conditions. Wood–polymer composites were used as research objects, consisting of recycled polyethylene (15 wt.%), thermoplastic polyurethane (10 wt.%), petroleum polymer resin (8 wt.%), solvent (12 wt.%), polystyrene waste (7 wt.%), wood filler (sawdust) (45 wt.%), and microcalcite (3 wt.%). Particular attention was paid to assessing the impact of ultraviolet exposure on the physical and mechanical properties as well as the water absorption behavior of the composites. The results demonstrate that ultraviolet aging, especially under accelerated conditions, leads to pronounced morphological changes in the material. These changes include the formation of microcracks and microstructural defects, indicating a significant deterioration of the physical and mechanical performance of the composites. In addition, ultraviolet irradiation alters the chemical structure of wood–polymer composites, resulting in the formation of new functional groups and changes in the sorption characteristics of the material.

Keywords: composite; wood; recycled materials; polyethylene; polypropylene; ultraviolet irradiation; properties.

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