Research Article

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Accelerated Aging of WPCs Based on Polypropylene and Plywood Production Residues

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Abstract: A lot of researchers are closely connected with natural, lignocellulose fibre containing bio-composites producing and studies. Various of polymer matrices, mainly polyolefins, combinations with natural fibres as a reinforcement are used. Our studies are focused on polypropylene based bio-composites containing birch plywood production by-product sanding dust (PSD) accelerated weathering processes. The nine groups of the samples with different composition were exposed in an accelerated weathering chamber for a total duration of the 1032 h. The surface colour, gloss, whiteness degree, microhardness and the tensile properties of the samples during the weathering were tested. In addition, the weathered surfaces were characterized by scanning electron microscopy (SEM) studies and by differential scanning calorimetry (DSC) investigations. The obtained results showed the following sight: after the weathering the surface of all samples is faded, also the changes of the gloss and of the whiteness degree occurs, but microhardness of the surface of specimens has decreased. The tensile strength of the samples changes a little, in the same time the tensile modulus increases significantly due to the decrease of the deformation ability of the polypropylene matrix and recrystallization processes in PP. The SEM images taken at the 100 and 500 times of the magnification revealed a lot of the different shape and sizes cracks on the surface of the weathered samples. DSC measurements showed the increase of the degree of crystallinity of the polypropylene after the weathering due to the recrystallization process in the polypropylene matrix.

Keywords: composites, polypropylene, birch plywood sanding dust, weathering, exploitation properties

1 Introduction

During the last 20-30 years, many researchers have paid attention to the studies of exploitation properties of wood polyolefin composites (WPCs) [1–8]. The most useful from the wide selection of polyolefins is polypropylene (PP) [2–8], but as a reinforcement of WPCs different waste materials comprising the lignocellulose fibres often are used. Such materials also are different wood residues which arise for example in plywood production industry [9–12]. A lot of researchers have cleared up the influence of the wood fibre on different exploitation properties of the WPCs such as physical mechanical indices, water resistance and technological properties [1–12]. All these properties considerably depend on the type of the fibre, fibre length (l), l/d ratio and interaction mechanism on the surface of the wood fibre and polypropylene matrix [1–12]. Our previous studies [9–12] showed that the plywood sanding dust (PSD) are promising reinforcement of the PP [9–11] and high-density polyethylene (HDPE) [12] matrices. The additives of the PSD up to 40-50 wt.% increase the tensile and the flexural modulus and the microhardness but decrease the deformation ability of the PP and the HDPE matrices and the impact strength, the water resistance as well as the fluidity of the composite melts. Modifying of the composites with the coupling agent maleated polypropylene (MAPP) or maleated polyethylene (MAPE) (up to 3-5 wt.%) significantly improve of all the above-mentioned properties: the tensile and the flexural strength and modulus, the microhardness, the impact strength and the water resistance increase to compare with the unmodified composites. The investigated WPCs practically do not swell in water and the total amount of the absorbed water after 600 h the water uptake is no more than 2.2% at the presence of the coupling agents. Nevertheless, all these excellent properties of WPCs can become worse during their exploitation in an open air under the influence of the environment circumstances. Therefore, many researchers in the world deal with the accelerated aging process investigations of WPCs

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comprising the WPCs based on the polypropylene [13–28]. Thus authors [13] have showed that the accelerated weathering of the samples during 400-2000 h is equivalent at least 2 years aging time under natural conditions. The main influence on WPCs aging process have UV radiance, air oxygen, surrounding humidity and temperature. Moreover, intensified weathering of WPCs materials occurs on the surface of the samples. During aging negative effects slowly can spread into material up to the 0.5 mm depth. The profound accelerated aging process of the WPCs based on the polypropylene have been studied in the works [13–28]. It is well known fact that polypropylene due to their macromolecules structure is very sensitive against UV radiance and at the presence of the oxygen begin to oxidize [18, 21]. As a result, in the polypropylene structure develop a lot of oxygen containing chemical groups which promote the absorption of the UV rays [14]. Besides the wood fibres works as UV ray absorption intensifier in the PP. That the extension of the wood fibre content in the WPCs from 25 up to 50 wt.% degradation degrees of the polypropylene grow up to 2 times [14]. For evaluation of the changes in WPCs which take place during aging process, researchers study the physical-mechanical properties (strength, hardness), the surface condition changes (colour, gloss, roughness degree, cracks and voids), estimate the changes in the volume of the polymer (molecules mass, degree of crystallinity, thermal destruction processes and so on) [19]. That authors [13, 18, 20–22] have shown that during the aging of the WPCs significantly change the colour of the specimen surface. The samples lose the colour and becomes grey. Alterations of the surface layers are possible to see in the SEM pictures of the replicas [18]. The burst of the polypropylene matrix, molecules mass and melting temperature decreases, but due to the recrystallization process the degree of crystallinity of the polypropylene increase [18, 21]. Furthermore, the additional =CO and –COOH groups are arisen. The coupling agents MAPP intensify UV ray's absorption. After 960 h of the weathering increase the roughness, diminish the gloss of the surface. The lignin which contain wood fibre stabilize WPCs materials because it absorbs up to 80% of the rays and this process take place during the first 240 h of the weathering [18]. Due to the bursts of the cellulose fibre mechanical properties of the WPCs decreases. Thus authors [19], studying PP composites with the pine wood fibre (10-30 wt.%), noted that the photo- degradation processes significantly accelerate at the presence of the water and in PP composites, occurs the all of previously mentioned phenomenon. The authors [15, 25] have cleared up that degrade also the layers of the surface border between the wood fibre and the polypropylene matrix. Due to these processes the wood fibres are able to pull out from the polymer matrix and the WPCs easy fracture. The presence of the water stimulates this breaking process. The loading of stabilizers in WPCs can significantly to prevent the weathering effects and to prolong the service time of materials [14, 15, 18, 22]. In details of the influence of the antioxidants on the weathering of the WPCs based on PP was investigated by authors [18]. The additives of the antioxidants (0.2-0.3%) diminish surface defects, the longer time (up to 480-720 h) maintain the colour and the gloss of the surface. The recrystallization process of the PP occurs during the 240-480 h of the weathering, but at the 720-980 h period of the UV exposure take place the fracture of the wood fibre and the naked fibres appears on the surface of specimens. The presented of all the previous study results shows that during the accelerated weathering processes occurs essential changes in all components of the WPCs which arise the significant decrease of the exploitation properties of materials. The goal of our work was to study how accelerated weathering process influence the WPCs based on the polypropylene and 40 wt.% of the birch plywood production by-product-sanding dust (PSD) with different composition structure and exploitation properties. To estimate the changes of the material surface condition (colour, gloss, whiteness degree, microhardness) and mechanical defects of the surface (cracks, voids) SEM studies were used, but for evaluation of the structural changes in the surface layers of the weathered specimens DSC investigations were done. The changes of mechanical properties of the weathered WPCs were noted by the tensile strength tests.

2 Materials and methods

For the UV accelerated aging investigations nine types of the industrially prepared by extrusion process (temperature 215°C) composites based on polypropylene (PP) with 40wt.% of the birch plywood sanding dust (PSD) were used. The UV accelerated weathering was realized in the UV chamber (Q-UV Spray with Solar Eye Irradiance control) corresponding with ASTM G154 (2004) standard during 1032 h (80 cycles, each cycle 12 h: 8 h exposure to UV rays, temperature 60°C, 4 h in water steam, temperature 50°C, irradiation power 0.89 w/m^2). As a polymer matrix serve polypropylene type PPC 3650 with melt flow index MFI= 3.4 g/10min. As a reinforcement the birch plywood production by-product-sanding dust (PSD) with following sizes of the fibres: fractions with size (length) more than 500 microns (1.04%), between 250-500 microns (32.16%) and smaller than 250 microns (66.8%) was used. The com-

Table 1: WPCs based on polypropylene + 40 wt.% birch plywood sanding dust (PSD) composition.

Comp. No.	PSD, cont wt.%	Struktol TWP, wt.%	1010 antiox.%	168 thermal stab.%	770 UV stabilizer,%	Pigm. conc.%
1-A	40	3	0.33	0.33	0.5	2
2-A	40	3	0.33	0.33	0.5	1
3-A	40	3	0.33	0.33	0.2	0
4-A	40	1.8	0.00	0.00	0.0	0
5-A	40	0	0.00	0.00	0.0	0
6-A	40	3	0.33	0.33	1.0	0
7-A	40	3	0.33	0.33	0.5	0
8-A	40	3	0.33	0.00	0.0	0
9-A	40	3	0.33	0.33	0.0	0

posites also contain different additives like lubricant Struktol TWP, antioxidant, thermal and UV stabilizers, pigment concentrate based on the low-density polyethylene and carbon black. The composition of the tested composites is given in the Table 1.

For comparison once more, type (A) of industrially produced WPCs based on PP+40 wt.% of wood fibres (other components of material producers do not reveal) was used. During the accelerated weathering of the samples (T=60 and 50°C, UV light intensity 0.89 w/m^2 at wave length 340 nm) after every exposure cycle 240, 528, 816 and 1032 h for all specimens the whiteness degree (extent), the surface gloss, the changes of the surface colour and microhardness were noted. The colour changes were evaluated by Colour colorimeter analyser (Easy Colour QA+Software CQA Easy Colour V3.0 light origin D_{65} angle of observation 10° 1964). The whiteness degree of specimens was observed with equipment NOVO-SHADE DUO^{TM} 45^0/0 opacity/shade Meter). The gloss of the surface was measured with NOVO-GLOSS LITE^{TM} Statistical Glossmeter at standard parameter 60°. The tensile strength experiments of the composites according to the standard ASTM 638 M (EN ISO 527-2:2012) were made. Microhardness measurements by Vickers M-41 at the load 200 g were done. For visual checking of the surface of the accelerated weathered specimens a scanning electronic microscope TESCAN TS 5136 MM supplied with VEGA TC computer software and Sputter coater EMITECH K 550X for applying an Au layer on the analysed surface were used. The evaluation of the structural changes of material in the surface layers was made by Differential Scanning Calorimeter (DSC) measurements on Mettler Toledo DSC-1 apparatus at the heating rate 10°C/min. by 220°C. Degree of the crystallinity was calculated similar as in [18].

3 Results and discussion

3.1 Colour analysis during weathering

Quantified colour changes in lightness (Δ L*) and a total colour changes (ΔE) of the WPCs with different composition during weathering are listed in the Table 2. Throughout the development of the weathering process the values of Δ L* and ΔE in all composites have increased to compare with initial, un-weathered samples. The increase of the lightness with exposure time can be attributed to lignin colour changes because in wood lignin is more vulnerable to UV light compared to the other components of the wood fibre [16]. Due to photochemical reactions lignin can be degraded into water soluble fractions which are able to remove from the surface of the samples when they are besprinkled (sprayed) with water. Water soluble products of the lignin and hemicellulose are able to develop erosion of the surface (see SEM images, Table 9) of the samples. The products of destruction of the lignin are washed away during the spraying of the samples with water [18]. The cellulose fibres are stronger against UV radiation influence and therefore the concentration of the cellulose fibres on the surface of the samples become greater [18]. Due to the white colour of the cellulose the values of the lightness of the weathered surface increase. The best results show system A which precise composition is unknown (producers do not reveal all components of material), but from our another investigated composites more perspective are systems 1-A and 2-A. For these materials the gained numerical values of the lightness Δ L* and a common colour changes ΔE are the smallest and the nearest to the system A which serve as prototype. May be in the case of the composites 1-A and 2-A as additional stabilizer against UV light work the pigment concentrate which contain both composites (2 and 1 wt.% respectively). Necessary to note that the great-

Table 2: Colour parameters of all WPCs composites at the different weathering time.

Comp.	Δ L*				ΔE			
No.	240 h	528 h	816 h	1032 h	240 h	528 h	816 h	1032 h
1-A	22.03	24.31	25.27	25.08	22.42	24.98	25.98	25.87
2-A	25.76	28.92	29.70	29.62	26.28	30.02	30.92	30.94
3-A	36.59	43.22	47.53	47.78	37.75	45.90	49.78	50.15
4-A	31.26	38.99	42.14	41.37	33.30	41.96	44.97	44.60
5-A	35.97	43.17	44.58	45.47	37.28	45.04	46.71	47.72
6-A	29.87	34.30	35.68	35.83	31.05	36.29	37.91	38.17
7-A	35.20	42.85	45.25	46.27	36.29	45.19	48.09	49.24
8-A	34.22	42.26	44.36	45.07	35.76	45.31	47.64	48.58
9-A	36.25	43.81	45.21	46.15	38.52	47.00	48.70	49.90
A	9.34	16.54	18.15	18.40	9.36	16.55	18.15	18.42

Table 3: Changes of the surface gloss of all composites as a function of the weathering time[1]

Comp.	Weathering time, h.				
No.	0	240	528	816	1032
1-A	1.7	2.6	2.6	2.6	2.5
2-A	2.0	3.1	3.1	3.2	3.2
3-A	2.2	3.7	3.9	3.8	3.8
4-A	18.7	14.9	9.6	6.9	5.1
5-A	18.7	7.6	4.4	3.4	3.0
6-A	1.9	3.5	3.3	3.4	3.4
7-A	2.7	4.6	4.4	4.3	4.2
8-A	2.9	4.8	4.3	4.0	3.8
9-A	2.2	3.8	3.5	3,5	3.0
A	6.4	5.0	3.9	3.2	2.2

[1] Standard parameters 60°

Table 4: Changes of the whiteness degree. of all composites as a function of weathering time

Comp.	Weathering time, h.				
No.	0	240	528	816	1032
1-A	11.5	31.8	33.5	34.2	34.7
2-A	12.7	38.7	41.6	42.5	42.9
3-A	14.8	57.8	69.3	74.6	76.8
4-A	19.5	59.8	72.4	76.8	79.0
5-A	13.2	59.6	73.5	78.4	80.0
6-A	12.7	46.1	49.6	53.0	53.8
7-A	15.9	57.4	71.2	75.3	78.0
8-A	16.0	58.5	73.4	76.2	80.0
9-A	16.9	60.3	72.5	75.5	77.7
A	9.5	17.0	24.9	27.3	28.6

est changes of ΔL* and ΔE occur in the first 240 h of the UV irradiation time when the great part of the lignin has degraded. The promising results show also composite 6-A. which contain 1 wt.% of UV stabilizer. Similar results were gained by authors [18].

3.2 Surface gloss analyses

The gloss of the surface was determined by the surface reflectivity of a substance. The gloss also is highly related with the surface smoothness (see Table 9). Our SEM investigations showed that the weathering damage the samples and the surface of the samples has become rough. Results of the gloss measurements are presented in the Table 3. Before the weathering only systems 4-A and 5-A shows high gloss values. Small values of the gloss of initial samples 1-A, 2-A, 3-A, 6-A, 7-A, 9-A and 9-A indicating on the rougher surface than of the samples 4-A and 5-A. Relatively high roughness of the surface of initial samples (gloss values are very small) may be form during preparing of the sheets by extrusion process and therefore we are not able to observe the influence of the weathering time on the gloss of the surface. Only for the systems 4-A, 5-A and A we managed to fix the significant decrease of the numerical values of the gloss with the increase of the weathering time. The similar results were observed by authors [18] during the study of accelerated weathering of the WPCs based on polypropylene. Necessary to note that the faster diminish of the gloss observe for the composites 4-A and 5-A during the first 240 h of the weathering to compare with prototype A. It could be explained with different composition of the 4-A and 5-A composites which no contain any stabilizers. The results of the gloss of the surface measurements also conforms with the SEM studies (see Table 9).

Table 5: Results of differential scanning calorimetry (DSC) measurements of the un-weathered composites

Comp.	W_{PP},	1^{st}.heating			Cooling		2^{nd} heating		
No.	mas. p.	T_m°C	Δ H_m J/g	X_c,%	$T_{cr.}$,°C	Δ $H_{m.}$ J/g	$T_{m,}$°C	ΔH_m J/g	X_c,%
A	0.60	165.36	52.08	41.53	120.41	55.43	165.14	54.40	43.38
1-A	0.54	163.92	49.10	43.56	114.98	56.15	161.41	51.35	45.50
3-A	0.56	164.12	46.94	41.05	114.47	55.72	161.44	50.17	42.86.
5-A	0.60	164.27	50.34	40.14	118.74	58.06	162.73	53.80	42.90
7-A	0.56	164.26	40.62	41.54	114.64	56.36	161.41	51.10	43.66.

Table 6: Results of differential scanning calorimetry (DSC) measurements of the weathered (1032h) composites

Comp.	W_{PP},	1^{st} heating			Cooling		2^{nd} heating		
No.	mas. p.	T_m°C	Δ H_m J/g	X_c,%	$T_{cr.}$,°C	Δ $H_{m.}$ J/g	$T_{m,}$°C	ΔH_m J/g	X_c,%
A	0.60	164.78	44.54	35.51	118.13	53.45	162.93	52.44	41.84
1-A	0.54	162.29	51.05	45.23	116.14	59.54	160.77	52.17	46.22
3-A	0.56	163.44	53.59	45.78	114.84	62.21	160.10	57.48	49.11
5-A	0.60	164.69	45.52	36.29	116.77	57.11	160.98	57.48	45.83
7-A	0.56	163.19	50.89	43.48	115.05	56.33	160.03	50.80	43.40

During the weathering after each aging cycle also the whiteness degree of the surface of the samples was evaluated (see the Table 4). Generally necessary to note that these results very well correlate with our previous measurements of the changes of the lightness (ΔL^*) and the common colour changes (ΔE) (see Table 1).

For all investigated system the significant increase of the whiteness degree is observed. It means that surface of the all samples is faded. The best stability against UV light influence shows systems 1-A, 2-A and A. After 1032 h of the weathering time the values of the whiteness degree are 34.7, 42.9 and 28.6 (respectively). For these systems also have the smallest changes in lightness and in a common colour changes. Researches of the whiteness degree, the changes of the lightness and colour also confirms that the presence of the pigment concentrate in the composites 1-A, 2-A retard UV weathering process. The smaller loses of the surface colour and whiteness degree of specimens partially can to explain like in [29] by the additional presence of the pigments in the systems 1-A and 2-A. The UV aging characteristics of the composites 1-A and 2-A are the nearest of the aging parameters which were observed for prototype A and it was one of the goal which we needed to achieve during this researches.

3.3 Differential scanning calorimetry investigations

Based on the previous data presented in the Tables 2-4, for DSC investigations five systems were chosen: two the most promising (A and 1-A) based on UV aging results and three the worse (a high numerical values of the whiteness degree 76.8 (3-A), 80 (5-A) and 78 (7-A) and bad other aging parameters) composites which have also different composition: 5-A without any stabilizers and 3-A, 7-A with different content of UV stabilizers. The material for DSC measurements were prepared by the scraping off along the surface of the un-weathered and the weathered specimens. The depth of the scrape probably was approximately 30-50 microns. The DSC studies give possibility to evaluate the influence of the UV weathering on the changes of the polymer structure and the thermal oxidation and degradation processes of the WF/PP composites which develop in surface layers of the samples. The melting temperature (Tm), enthalpy of the melting (Δ H_m) and degree of the crystallinity (Xc) of the composites before and after the weathering (1032 h) are presented in the Table 5 and the Table 6 respectively.

For calculations of the degree of crystallinity (X_c), enthalpy ($\Delta H^0{}_m$) values 209 J/g of 100% crystallized PP was utilized [18].

The differences in degree of crystallinity of the composites before weathering could be explained by the additions of the UV stabilizers (1-A, 3-A and 7-A) which can develop nucleation effects and promote the crystallization process during preparing of the samples (extrusion process) [18]. The melting temperatures differs small and are the similar for the all composites. After the first heating all samples are cooled and during cooling crystallization temperature T_{cr}.is about 114.5-118.7°C. The enthalpy of crystallization (melting) of the all systems has increased (about 7-16 J/g). The second heating decrease the temperature of the melting T_m about 1.5-2.6°C but significantly increase the values of Δ H_m up to 1.1.-10.6 J/g to compare with the first cycle of the heating. The degree of crystallization has increased up to 2.12% (sample 7-A). The increase of Δ H_m and X_c can explain by recrystallization processes which occurs in PP matrix. Similar results were gained by authors [18, 21].

After 1032 h of the weathering rather significant changes in the structure of polypropylene and the thermal properties of the composites are observed (see Table 6).

The changes of the melting temperature of the systems to compare with un-weathered materials are negligible, but the tendency of the increase of the enthalpy of melting (1-A, 3-A) and the degree of crystallinity (1-A, 3-A, 7-A) is clearly seen (see Table 6). Exception is the system 5-A which do not contain any stabilizers and therefore the noted X_c values are smaller (40.14% for un-weathered and 36.29% for weathered materials). Due to the recrystallization processes in polypropylene matrix the degree of crystallinity and Δ H_m numerical values continues to increase after second heating cycle for all weathered composites. Similar, corresponding results are gained also by authors [18, 21].

3.4 Microhardness (MH) and tensile test results

During aging process we fixed changes of the microhardness (MH) of the surface of the samples (see Table 7). It was rather difficult to do, because during weathering surface of the samples faded and became rougher therefore to distinguish the impress of diamond prism on the surface was difficult. Looking over the results of the MH measurements we can conclude that in the aggregate the tendency of the significant (approximately up to 2.0-2.5 times) decrease of the microhardness is observed. The highest values of MH maintain systems A, 1-A which shows smaller UV weathering degree (microhadeness diminish only up to 1.7 times, system 1-A) and for system 5-A (diminishing is 2 times). Necessary to note that the composite 5-A has the highest initial values of the MH and this material no contain functional lubricant Struktol TWP which is able to serve also as plasticizer of the composite and therefore to decrease the numerical values of the MH. The measurement results of the MH of the surface could be influenced also by the cracks and voids which forms on the surface of the samples during weathering process (see the Table 9).

Table 7: Results of the surface microhardness (MPa) measurements after different time of the weathering.

Comp.	Weathering time, h.				
No.	0	240	528	816	1032
A	92.52	-	-	-	88.53
1-A	105.90	62.26	49.58	66.55	60.09
2-A	113.20	60.49	51.43	60.18	56.66
3-A	99.26	53.90	41.93	42.89	37.72
4-A	120.10	60.03	39.10	42.91	50.65
5-A	129.17	56.71	41.29	55.14	65.98
6-A	109.33	58.92	55.16	51.50	46.49
7-A	91.47	54.65	50.70	52.07	52.20
8-A	90.11	55.95	50.17	46.51	44.06
9-A	77.94	42.75	46.14	38.72	35.55

We examined also mechanical properties of materials after aging process. The tensile strength test results are presented in the Table 8. From presented results we are able to conclude that the tensile modulus of the all investigated systems significantly (up to 4 times) has increased after the 1032 h of the UV weathering. The various values show tensile strength parameter. The tensile strength (σ_t) of some composites (1-A, 2-A, 3-A, 9-A) decrease, but for another composites (4-A, 5-A, 6-A, 7-A, 8-A) have increased. The similar sight for the elongation at break (ϵ_t) is observed. Such increase of the tensile properties could be explained by crosslinking processes in polymer (PP) matrix which can strengthen the structure of the composites and recrystallization processes of PP [18, 21, 24]. Due to very different composition of the investigated composites the strengthening mechanisms of WF containing systems could be rather complicated. Authors [18, 21] indicate that exist four different mechanisms which can be responsible for changes which occurs in WPCs during different periods of UV weathering. The first mechanism is PP degradation through the chain scission and forming the short PP chains. This process can result as decrease of mechanical properties of material. The second mechanism is PP matrix recrystallization. The short PP chains accumulate and forms additional crystalline regions which could promote the increase of the strength of the system. The both previously mentioned reasons are closely related with the state of wood fibres on the composite surface. Protrusion of wood fibres on the surface could inhibit the recrystallization process of polypropylene. The third surface cracks

Table 8: Tensile test results before and after 1032 h of the weathering

Comp No.	Tensile test					
	Non-weathered, 0 h.			Weathered, 1032 h.		
	E_t, MPa	σ_t, MPa	ϵ_t.,%	E_t, MPa	σ_t, MPa	$\epsilon_{t.}$,%
1-A	671.33	18.64	6.06	2090.05	16.54	6.90
2-A	614.98	19.19	6.11	2310.62	16.78	7.01
3-A	647.44	17.22	7.99	1879.53	13.99	7.95
4-A	896.98	17.62	4.60	1860.64	18.50	7.24
5-A	689.69	21.02	6.15	2.846.70	23.30	3.62
6-A	774.12	17.10	7.88	2.616.16	22.01	4.25
7-A	760.78	17.12	8.12	2951.24	22.57	4.26
8-A	855.82	17.84	7.03	2527.94	22.51	3.07
9-A	710.91	15.35	7.19	1619.77	15.02	3.36

which resulted in the poor interfacial interaction which might be the main factor for the decrease of mechanical properties. The fourth reason is WF degradation and leaching. During UV irradiation and the following condensation of the water, degradation products which have concentrated on the surface can leach out and benefit the recrystallization of PP. Which mechanism prevail during aging processes of our investigated systems is difficult to say. Sooner that all mentioned above mechanisms can occurs also in presented composites and profound recrystallization processes occurs not only on the surface but also in the depth of the samples. Seems that in our case cracks and voids forms only on the surface and have not spread so deep to diminish significantly the tensile properties of WPCs. Authors [13] have showed that sometimes the depth of the cracks in weathered natural fibre containing polymer composites can reach 0.5 mm.

3.5 Scanning electron microscopy

Visual control of the surface condition before and after the weathering at 100 and 500 times of magnification was done by taken SEM images of the surface of the samples of all investigated systems. To economize the volume of the article we chose to present only some more typical samples (A, 1-A, 2-A, 5-A and 9-A, see the Table 9). The similar weathering character was observed for all another system: 3-A, 4-A, 6-A, 7-A and 8-A. The Table 9 shows that SEM images of the surfaces of all composites before weathering are not very smooth. Really it relates to the samples preparing parameters by extrusion process. On the lack of the insufficient smoothness of the surface of the samples indicate also the gloss measurement results (see the Table 3). The SEM images shows that exist also some hollows and platforms on the surface of the initial samples which better are able to see at the 500 times of the magnification (see A, 1-A, 2-A, 5-A, 9-A). The uneven surface of the samples is formed during industrially production of the sheets. After the 1032 h of exposure the degradation of the surface layers of all samples particularly 5-A which no contain stabilizers is very serious. The smaller changes UV weathering process induces in the surface of the samples (A, 1-A, 2-A). This fact could be explained by the presence of stabilizers and pigments in composition of these composites which prevent the UV aging process [18, 21, 29]. Seems that as in the works [18, 21] the efficiency of antioxidants has vanished after 1032 h of the weathering. Due to the long weathering time and insufficient amount of stabilizers a lot of defects: numerous cracks in the polymer matrix and another voids on the surface of the weathered samples we can find. Moreover, wood components can swell and shrink after absorbing and desorbing moisture during weathering cycle [29]. Under UV-irradiation influence the surface layers between PP matrix and wood fibres (WF) became more brittle [18]. Due to these factors create additional stresses at the interface of the components, causing development of the cracks on the weathered surface of the samples. During the aging experiment on the surface of the specimens forms a lot of water droplets which can leach from the weathered surface of the PP the soluble UV degradation products and lead to the protrusion of the WF on the surface of the samples [30]. Practically similar SEM investigation results were gained by authors [18, 21, 23, 25].

Table 9: SEM images of the surface of all groups of WF/PP (non-weathered and weathered at 1032 h) composites taken at 100 and 500 times of magnification

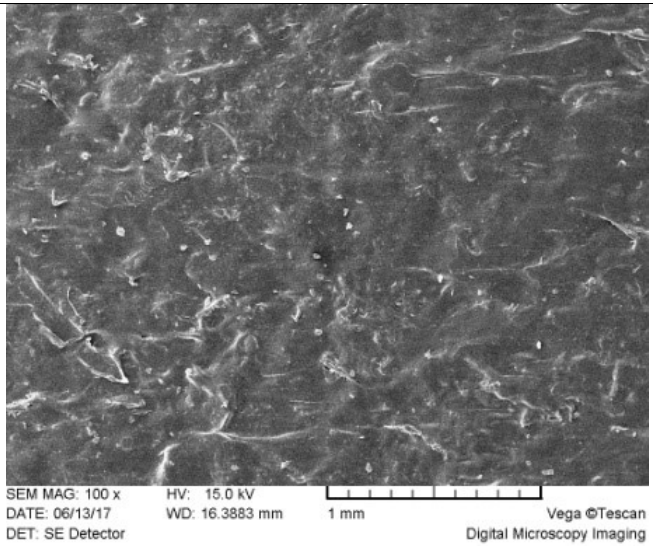
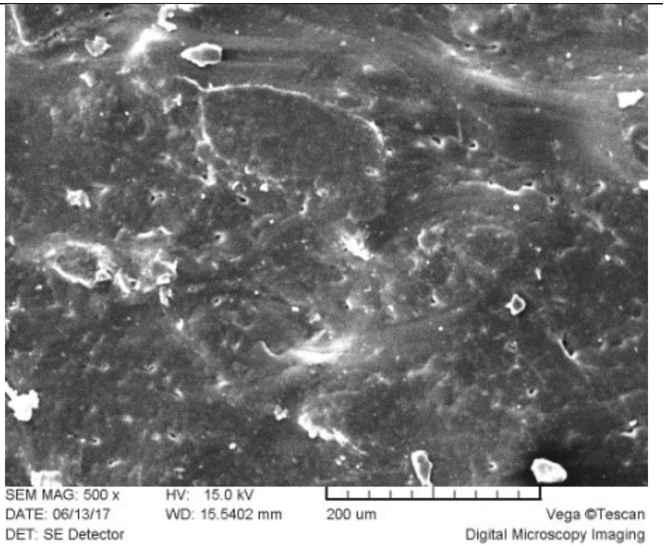
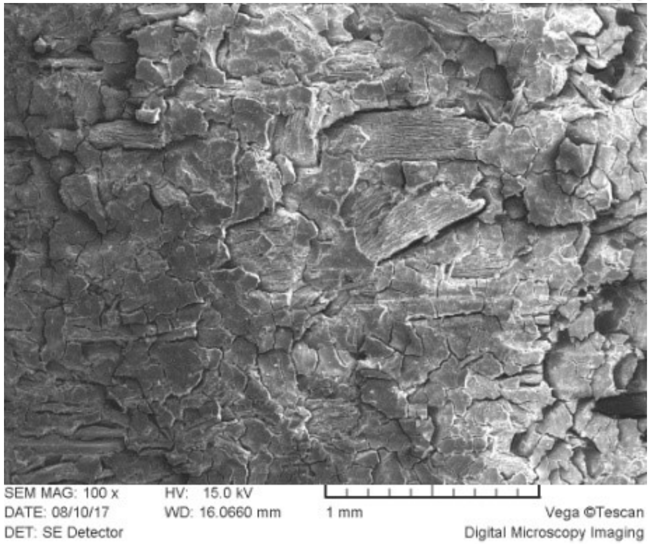
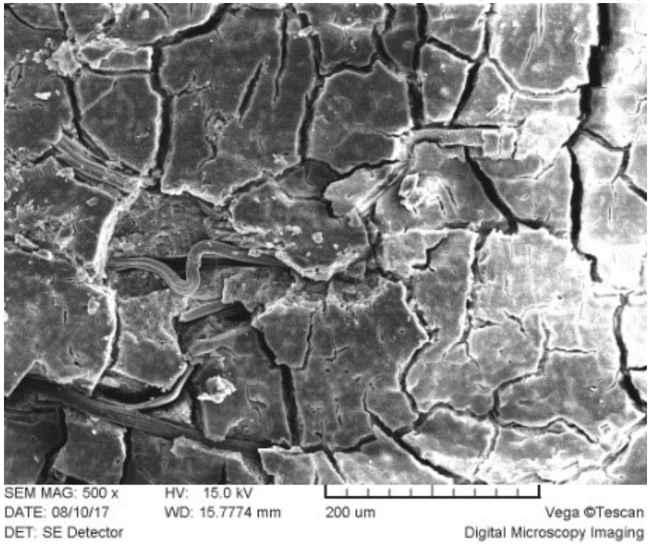
Comp. No.		100 X	500X
A	Non-W.		
	W.		

Table 9: …continued

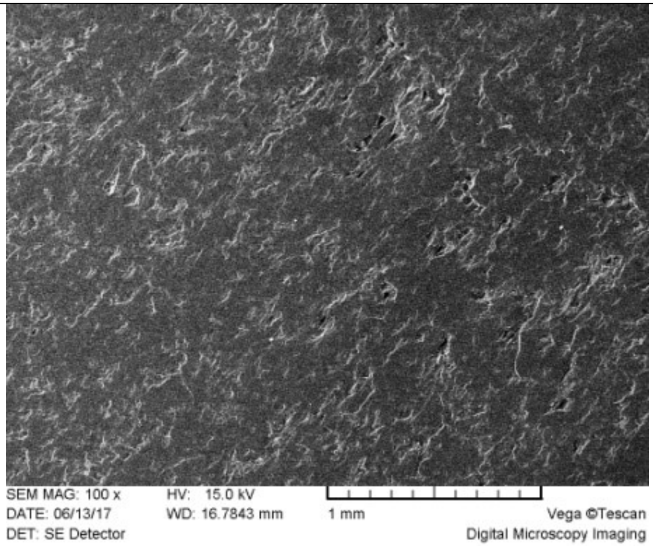
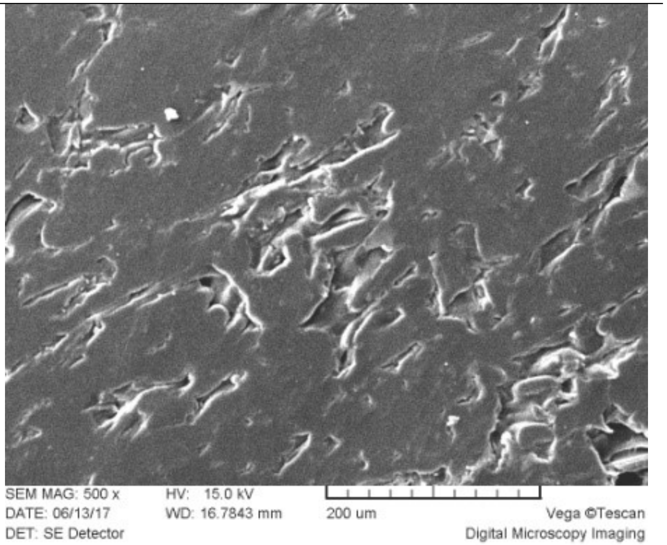
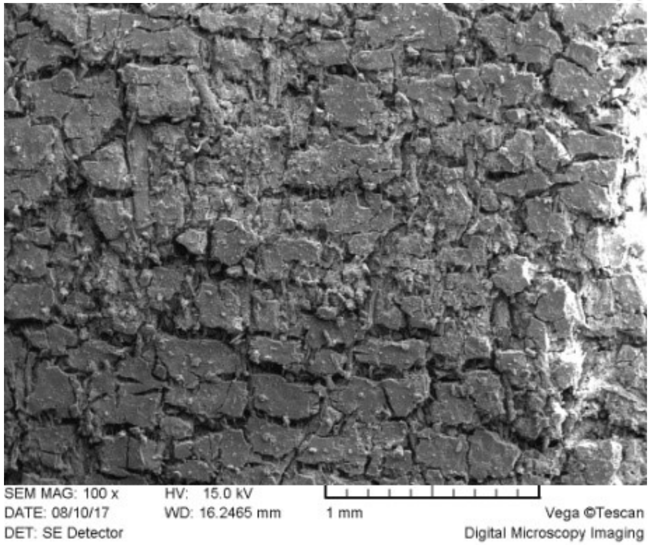
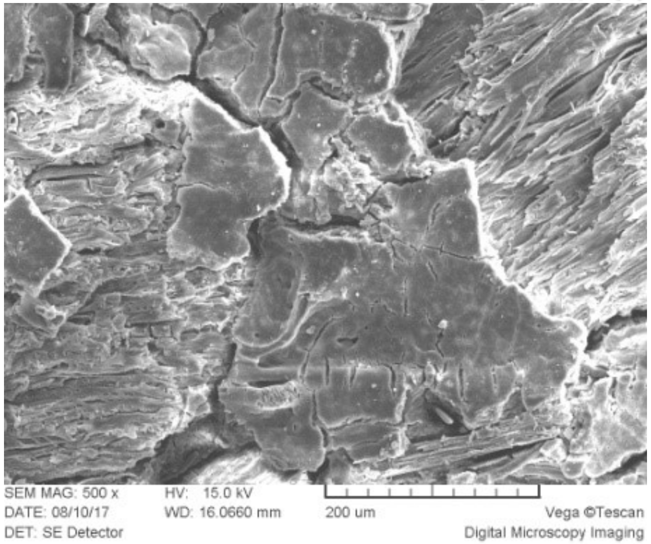
Comp. No.		100 X	500X
1A	Non-W.		
	W		

Table 9: …continued

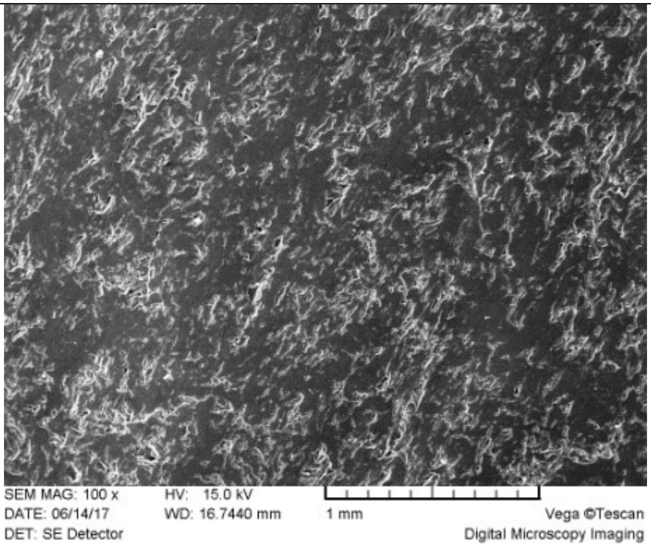
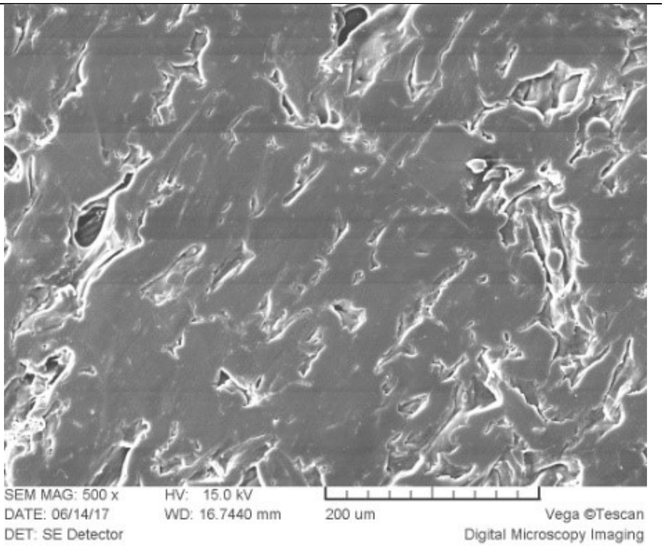
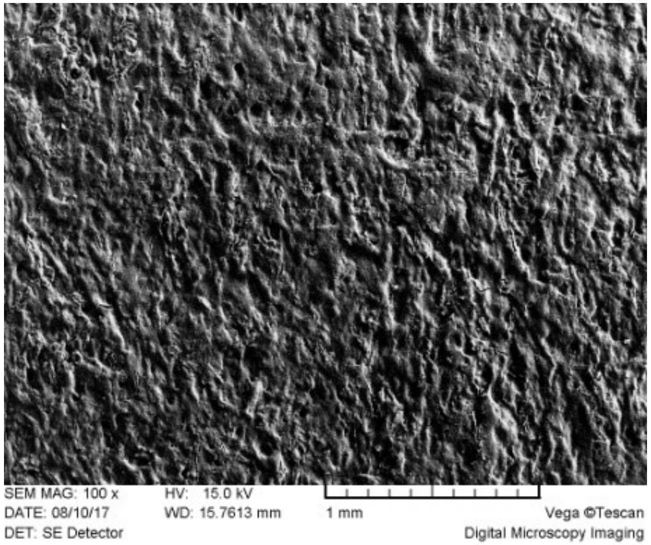
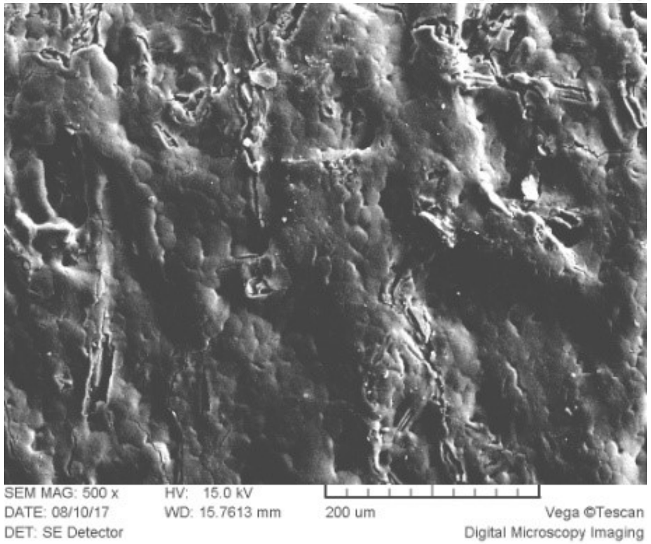
Comp. No.		100 X	500X
2A	Non-W.		
	W		

Table 9: …continued

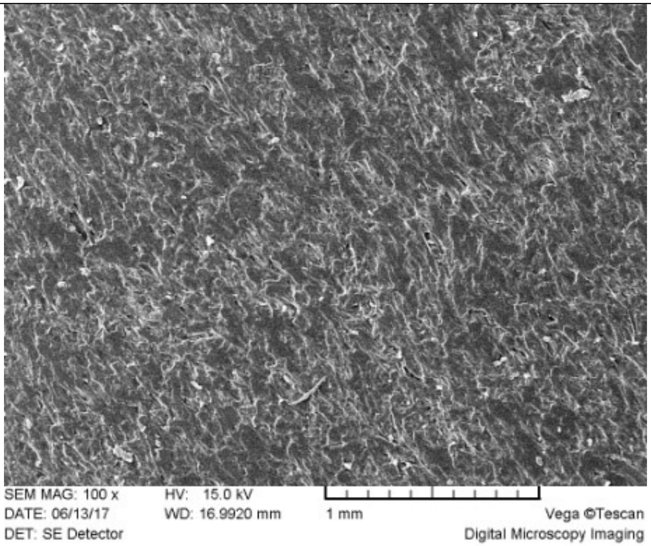
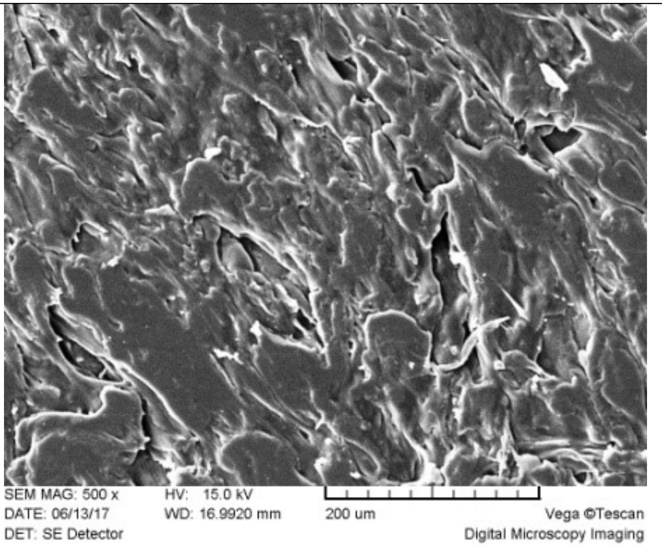
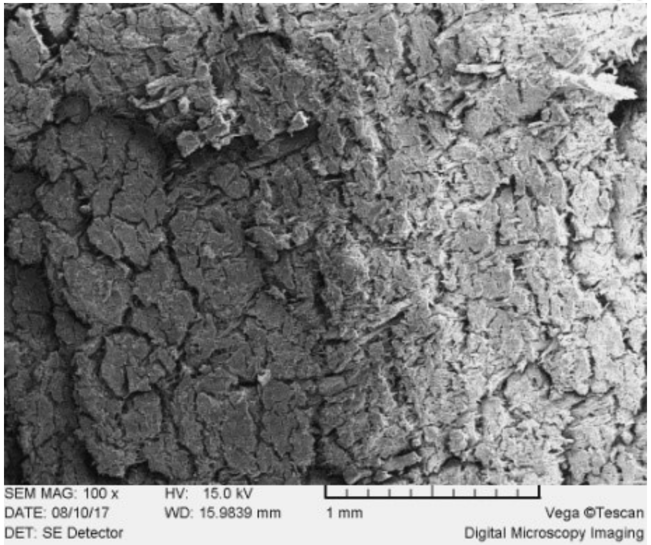
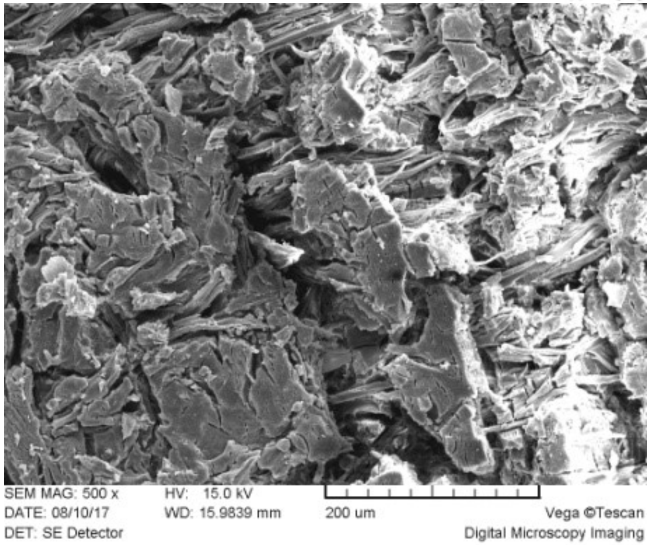
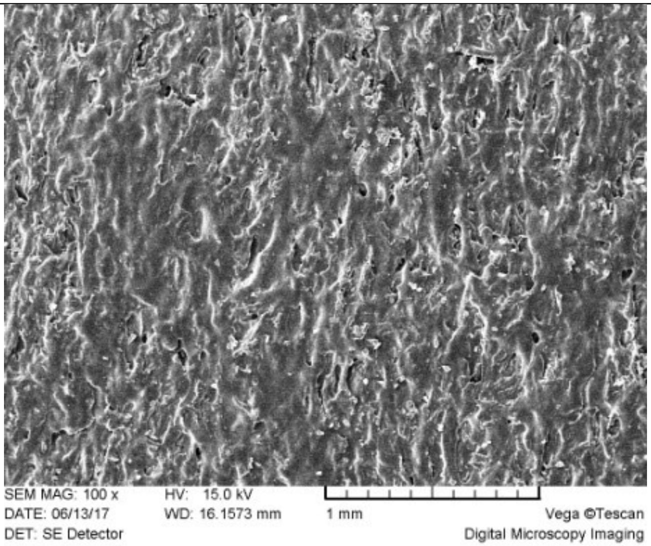
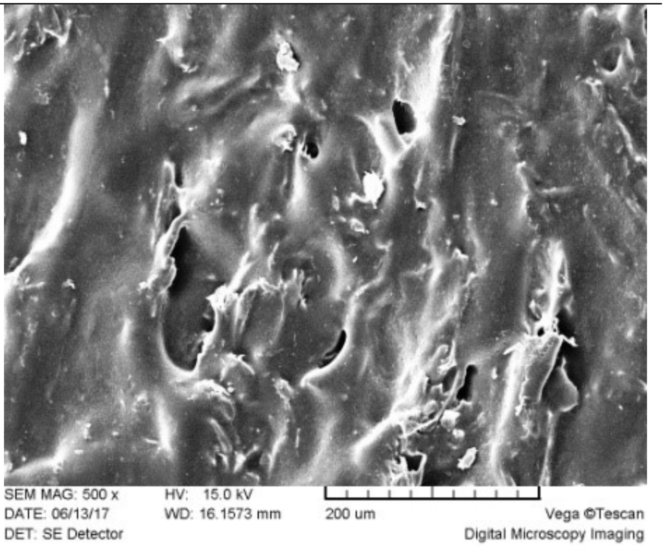
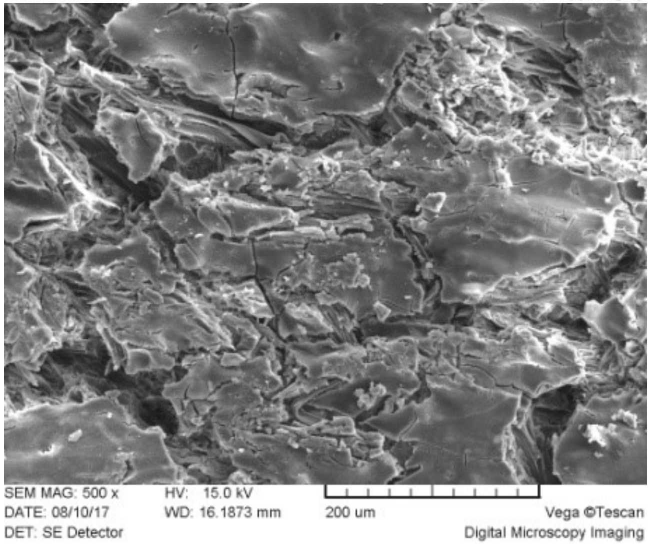
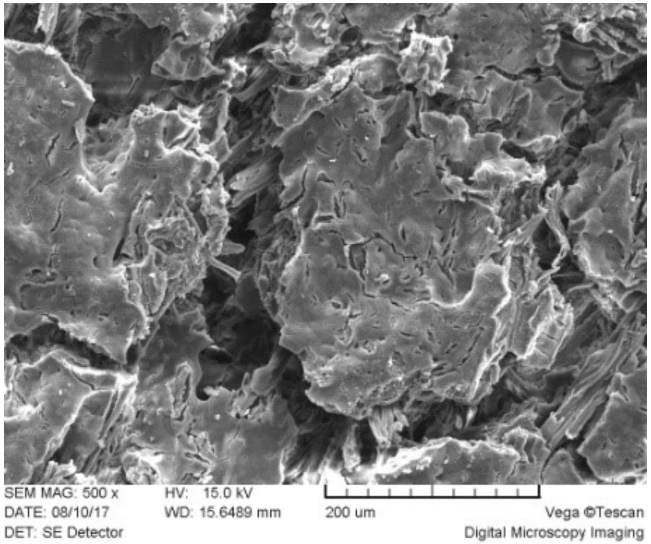
Comp. No.		100 X	500X
5A	Non-W.		
	W		

Table 9: …continued

Comp. No.		100 X	500X
9A	Non-W.		
	W.		

4 Conclusions

The accelerated UV weathering studies of the WPCs based on virgin polypropylene and birch plywood production sanding dust (PSD) showed that the surface of all investigated samples significantly age during artificial weathering. The degree of aging considerably depends on composition of the composites. The colorimetric analyses measurements of the changes in lightness and a common changes of the colour revealed that the best of UV stability shows composites with UV stabilizers and pigments (A, 1-A, 2-A and 6-A). These systems have the smallest changes of the whiteness degree, of the light and a common changes of the colour.

After 1032 h of the weathering the DSC analyses results showed the increase of the degree of crystallinity of the PP in the surface layers of the samples. Due to the recrystallization processes which occurs in PP matrix can improve mechanical properties of the composites. The tensile strength has no significant changes after the weathering. The serious changes during accelerated weathering occurs only on the surface and in the surface layers of the samples what confirm selective increase of the tensile strength and significant increase of the tensile modulus of all composites.

Looking over the SEM images of the surface of the samples before and after the weathering we can conclude that the surface of initial samples is not sufficiently smooth and there are no cracks and serious voids but after the 1032 h of the artificial weathering the condition of the surface considerably become worse. After the weathering the surface of the samples has become rougher (also decreases of the gloss) and a lot of different shapes and sizes cracks and another voids in polymer matrix are observed.

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