Assessment of the environmental impacts of wood plastic composites

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Summary

The best ways to limit the release of plastics, and consequently nanoplastics, into the environment are their reduction, reuse, and primarily recycling. Due to the wide usage of chipboards in both indoors and outdoors, recycling plastic waste from the automotive industry as a substitute for wood in chipboards is one of the current methods of their utilization. This article addresses the assessment of the impacts of wood-plastic composites on aquatic and terrestrial environments. Nine chipboard samples were tested, manufactured with 10 %, 15 % and 20 % proportion of ground granulate from painted and unpainted bumpers and fuel tanks, from which the aqueous leachates were prepared. The pH and COD were determined in the aquatic leachates. The effect of the aqueous leachates from the wood-plastic composites samples was monitored by ecotoxicological tests with the test organisms Lemna minor and Daphnia magna. The results confirmed that an increased content of plastic waste in chipboard leads to a decrease in the content of organic matter in the aqueous leachates in comparison to chipboard without wood replacement.

Key words: *automotive industry, plastic composites, chipboard, ecotoxicological tests, environment*

Introduction

Human activities, including the automotive industry, generate significant waste that harms the environment. Recycling automotive waste materials, such as metals, plastics, and rubber, can help address resource depletion and environmental issues. In Slovakia, there are sufficient facilities to process old vehicles, but finding suitable waste processors remains a challenge. The increasing use of plastics in car production contributes to plastic waste, with plastics primarily used in bumpers, dashboards, seats, fuel tanks, and batteries. Recycling these plastics is vital for sustainability [1, 2]. Recycling leads to reduced extraction of materials and less landfill deposition, benefiting the environment. Annually, 4.4 million tons of plastics are used in automotive equipment production. Recycled materials from old cars have various applications, such as using rubber granulate from tires in new tire production and producing sound-absorbing materials from recycled car seats, carpets, and airbags. Plastics, being durable and slow to biodegrade, pose environmental risks, including entering the food chain [3, 4]. Ecotoxicological bioassays assess waste's potential toxic effects at molecular to ecosystem levels. Ecotoxicity, a dangerous waste property, results from its toxic impact on the environment. This article focuses on repurposing plastic waste as a wood substitute in chipboards and uses ecotoxicological tests to evaluate its environmental impact [5,6].

Experimental part

Production of wood-plastic boards

The tested single-layer chipboards with the addition of crushed waste plastics were prepared in the laboratories of the Woodworking Faculty of the Technical University in Zvolen, the Department of Chemistry and Chemical Technology and the Department of Wood Technology. The basic material was supplemented with a bumper - unpainted, polypropylene, bumper - painted, polypropylene and fuel tank, polyethylene. Chipboard samples with dimensions of 360 mm x 280 mm x 15 mm were tested. The percentage of plastics in the samples was 10, 15 and 20 % waste plastics. In the article, we use abbreviations: P for painted bumpers, UP for unpainted bumpers and FT for fuel tanks. The numerical value for the index represents the percentage of the component.

Production process

Chipboards were prepared by cold pre-pressing particle mats under a pressure of 1 MPa and then hot pressing under pressure on a laboratory press CBJ 100–11, TOS (manufacturer Rakovník, former Czechoslovakia). The wood particles crushed granulate and resin mixture were mixed in a laboratory application drum. One wooden composite weighed 971 grams after mixing into the mold. The mold was placed in a hydraulic prepress machine for about 2 minutes. Pre-pressing was followed by hot pressing under pressing pressures of 30, 15 and 7.5 MPa at different time intervals. The total pressing time was 6 minutes at a temperature of 240 °C. Due to the higher content of recycled plastics in chipboards compared to the conditions a higher temperature could have been used during their pressing [7].

Preparation of water extracts

Demineralized water adjusted to pH 3 was used to prepare the extracts. The volume of water in which the samples were leached was calculated according to the procedure resulting from [8, 9]. The samples were infused in glass containers for 24 hours. The chipboards were removed and the leachate was used for testing.

Determination of pH and chemical oxygen consumption

An instrument with a combined electrode was used to determine pH. pHmeter, type InoLab Level 1, WTW Germany [10]. The determination method for chemical oxygen consumption is based on STN [11].

Ecotoxicological testing

To assess the effects of substances dissolved in water extracts from chipboard samples, we performed preliminary tests: growth inhibition (stimulation) test on *Lemna minor* and acute toxicity test on *Daphnia magna.*

Growth inhibition (stimulation) test on Lemna minor:

This test evaluates the toxic effects of substances on freshwater plants. It is a standardized test [12] with the test organism *Lemna minor* [13].

Acute toxicity test on Daphnia magna

Test is most often used to assess the toxic effect of substances in the aquatic environment. Immobilization of the organism is evaluated. The organisms used cannot be older than 24 hours [14, 15.]

Results and discussion

Determination of pH and COD

COD (Chemical Oxygen Demand) serves as an indicator for organic water pollution. In our study, water leachates from chipboard samples used in various environments were simulated to assess their impact on surface water. The COD values in control samples, representing clean chipboards, exceeded the legal limit by 50 times by Regulation of the Government of the Slovak Republic amending Regulation of the Government of the Slovak Republic No. 269/2010 Coll., which establishes requirements for achieving good water status. Interestingly, as the proportion of waste replacing wood increased, the organic substance content extracted into the water decreased, possibly due to the poor solubility of plastics used in chipboards. The pH levels also varied, with the addition of waste plastic resulting in higher pH values. Specifically, the sample containing 20% granulate from painted bumpers had the lowest COD values. This trend was consistent in leachates from boards containing waste rubber from the automotive industry [16].

Table 1: Labeling of samples and their composition

	UP 10	**UP 15**	**UP 20**	**P 10**	**P 15**	**P 20**	**FT 10**	**FT 15**	**FT20**	**C**
COD mg/l	1 305	1209	1 112	1 499	1 209	919	1450	1401	1450	1655
pH	5.16	5.02	5.02	5.09	5.05	4.96	4.85	5.02	5.01	3.66

Lemna minor growth inhibition test

The preliminary test with test organisms *Lemna minor* is negative if the growth inhibition is < 30% compared to the control and positive if the growth inhibition is ≥ 30% [12, 13].

Table 2: Representation of Lemna minor growth inhibition

Sample	**Iμ, %**				**Number of repetitions**
	Average	**SD**	**-95.00%**	**95.00%**	
P	81.56	3.10	73.60	89.52	6
P	78.57	1.88	73.74	83.40	6
P	74.06	4.61	62.22	85.90	6
UP	70.08	2.77	62.96	77.20	6
UP	68.87	2.67	61.99	75.74	6
UP	64.54	4.72	52.41	76.68	6
FT	83.40	4.09	72.88	93.92	6
FT	73.09	2.96	65.47	80.70	6
FT	64.05	2.98	56.40	71.71	6

By using plastic waste in the board, growth rate inhibition is reduced. In the pure board sample, the inhibition was 79.18%. Between the tested samples with painted and unpainted bumpers, the difference in inhibition is approximately 10%. The sample with 10% content of fuel tank waste had the highest growth inhibition. *Lemna minor* has been successfully used as a test organism to evaluate the toxic effects of chemicals for several years, which is also confirmed by a study by Hybská et al. [16], where the use of *Lemna minor* to evaluate the toxicity of leachates from waste tires was confirmed.

Acute toxicity test Daphnia magna

The *Daphnia magna* preliminary test result is negative if < 50% death or immobilization occurred during the test. The test is positive if death or immobilization is ≥ 50% compared to the control [14, 15]. The number of immobilized individuals was evaluated after 24 hours and 48 hours. % immobilization after 48 hours is recorded in Table 3.

Table 3: Immobilization (I in %) of Daphnia magna after 48 hours

	P 10	P 15	P 20	UP 10	UP 15	UP 20	FT 10	FT 15	FT 20
	70	60	65	60	80	70	55	70	55
	60	75	75	55	65	55	50	65	65
	70	50	75	70	75	65	35	65	65
	52	80	72	75	70	55	25	80	80
Average	**63**	**66**	**72**	**65**	**73**	**61**	**41**	**70**	**66**

The data (Table 3) show that the % of immobilization increases with the increasing proportion of waste plastics in the board. The test result was positive (immobilization ≥ 50%), except for the plate leachate with 10% fuel tank content (41.25%). With a higher proportion of waste in the board, there was an increase in immobilization in the leachate. In a study Hybská et al. 2023 [16] the toxicity of a board with rubber waste substitute was tested, where all the determined immobilizations were also positive.

Linthner et al. [17] monitored the toxicity of 26 plastic products, made from 5 types of plastics, which were leached in deionized water and tested for acute toxicity to *Daphnia magna*. All leachates from softened PVC and epoxy products were shown to be toxic, and none of the leachates from polypropylene, ABS (acrylonitrile-butadiene-styrene) and rigid PVC products showed toxicity. Toxicity is mainly caused by hydrophobic organic substances and metals were the main cause of toxicity in one leachate (release of metals was also confirmed by chemical analysis).

The study by Hybská et al. [8] was aimed at evaluating the ecotoxicological impact of waste tires on the environment. They found that the most sensitive test organism was *Daphnia magna*. Furthermore, the influence of the particle size of the waste material, which has a significant impact on ecotoxicity, was found. Samples that contained tire parts < 1 mm in size showed higher toxicity than samples with particle size > 3 mm.

In studies by Wik et al. [18] recommend using the toxicity test method with the test organisms *Daphnia magna* as a basis for environmental labeling of automotive tires.

It follows from the above that *Daphnia magna* are among the frequently used test organisms for their sensitivity. *Lemna minor* is also a sensitive test organism for the aquatic environment. *Lemna minor* is a more accessible aquatic plant and its care is also easier in the laboratory than ensuring the laboratory breeding of *Daphnia magna*.

Conclusion

The article focuses on assessing the impact of chipboards on aquatic environments. Several ekotoxicology biotests were employed for testing. Testing the water leachates from the experimental samples revealed the most significant impact on the growth rate of *Lemna minor* and the immobilization of *Daphnia magna*. The results suggest that bioassays are a suitable tool for assessing environmental impacts compared to results obtained from testing chipboard leachates without wood replacement with plastic. The best methods to limit plastic release into the environment are reduction, reuse, and primarily recycling. Given the widespread use of particleboards indoors and outdoors, recycling automotive plastic waste as a wood substitute in chipboards is a current method of utilization. Utilizing plastic waste as a partial replacement in chipboards is a suitable approach. Experimental studies shown the safe use of chipboards manufactured with wood replaced by automotive plastic waste, compared to pure chipboards.

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Hodnotenie vplyvov drevoplastových kompozitov na životné prostredie

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Súhrn

Najlepšie spôsoby, ako obmedziť uvoľňovanie plastov, a teda aj nanoplastov do životného prostredia, sú ich znižovanie, opätovné používanie a predovšetkým recyklácia. Vzhľadom na široké využitie drevotrieskových dosiek v interiéri aj exteriéri je recyklácia plastového odpadu z automobilového priemyslu ako náhrada dreva v drevotrieskových doskách jednou zo súčasných možností ich využitia. Tento článok sa zaoberá posudzovaním vplyvu drevoplastových kompozitov na vodné a terestrické prostredie. Testovalo sa deväť vzoriek drevotrieskových dosiek vyrobených s 10 %, 15 % a 20 % podielom mletého granulátu z lakovaných a nelakovaných nárazníkov a palivových nádrží, z ktorých sa pripravili vodné výluhy. Vo vodných výluhoch sa stanovilo pH a CHSK. Vplyv vodných výluhov zo vzoriek drevoplastových kompozitov sa monitoroval ekotoxikologickými testami s testovacími organizmami *Lemna minor* a *Daphnia magna*. Výsledky potvrdili, že zvýšený obsah plastového odpadu v drevotrieskových doskách vedie k zníženiu obsahu organických látok vo vodných výluhoch v porovnaní s drevotrieskovými doskami bez náhrady dreva.

Klíčová slova: *plastové kompozity, drevotriesková doska, ekotoxikologické testy, životné prostredie, automobilový priemysel*