**Study of Chemical Resistance of Polyhydroxybutyrate-Based Composites and the Influence of Filler Components**

Olimjon Muratkulov1, a), Lola Boltaeva1, b), Guzal Akmalova1, c),  
Sherzod Mengliev2, d), Elmurod Egamberdiev1, e) and Nargiza Yuldasheva3, f)

1*Tashkent State Technical University, 2 University Street, 100095 Tashkent, Uzbekistan*2*Tashkent Institute of Chemical Technology, 32 Navoi Street, Tashkent 100011, Uzbekistan*3*Tashkent State Transport University, 1 Temiryulchilar St., Tashkent 100167, Uzbekistan*

*a) Corresponding author:* [*olimjonmuratkulov9@gmail.com*](mailto:olimjonmuratkulov9@gmail.com)*b)* [*maxmudovalola3412@gmail.com*](mailto:maxmudovalola3412@gmail.com) *c)* [*Guzal70@yandex.com*](mailto:Guzal70@yandex.com) *d)* [*Sh.shoimovich@gmail.com*](mailto:Sh.shoimovich@gmail.com) *e)* [*el.1909@mail.ru*](mailto:el.1909@mail.ru) *f) nargiza\_p@tstu.uz*

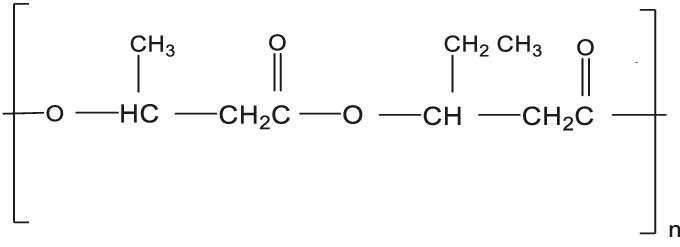
**Abstract**. This paper presents an experimental investigation into the resistance of polyhydroxybutyrate (PGB)-based composite materials to alkaline and acidic chemical environments, conducted by GOST 12020-2018. The composites tested used wood flour and cellolignin which was produced by a two-stage hydrolysis of pine, and their mixture as filler. The results showed that strong alkaline solutions (1, 3, 5% LiOH, NaOH and KOH) caused the breakdown of the composites, while stability was maintained in mild acids (H₃PO₄, and CH₃COOH). Studies were conducted with 1, 3, and 5 percent concentrations of chemical reagents, but this article only analyzed the results of the 5 percent concentration. In addition, the tensile strength under ultraviolet radiation varied due to the filler composition. Notably, the samples with wood flour and cellolignin showed increased strength. The study found that a filler content of 20–50% by mass is best. The results of the research may expand the use of composite materials in industry.

**Keywords:** composite materials, polyhydroxybutyrate (PGB), cellolignin, wood filler, chemical environment, alkaline solution, acidic solution, resistance

**INTRODUCTION**

In recent years, demand has greatly increased for polymer composite materials based on raw materials that are eco-safe, biodegradable, and renewable. Notably, composites made from biodegradable thermoplastics, like polyhydroxybutyrate (PGB), are viewed as an alternative material that does not harm the environment (figure 1.). PGB stands out because it is biologically inert, thermoplastic, and compostable. To improve its mechanical properties, lower its price, and raise its stability, different natural fillers must be added. Using lignocellulosic waste, in particular wood flour as filler, is common. But wood fillers have low chemical resistance and stability to ultraviolet radiation, which limits how they can be used. Therefore, using modified natural fillers like cellolignin from hydrolyzed wood waste is a hopeful method. This paper studies how PHB-based composites resist strong alkaline and acidic environments and how mechanical properties change under ultraviolet radiation. The effect of varying the ratio of different fillers in the composite was analyzed, and the possibility of use in industry was assessed.

Research in biodegradable composite materials shows that polyhydroxybutyrate (PGB) polymer is considered a material that does not harm the surrounding area, but has strength and thermal stability limits (figure 1.) [1, 2].



**FIGURE 1.** Chemical formula of polyhydroxybutyrate (PGB)

Many studies have been done on making composites with natural fillers to fix these issues [3, 4]. Wood flour is often used as a filler because it is cheap and easy to get [5]. But wood fillers are strongly hydrophilic, meaning they absorb moisture easily, and do not resist chemical environments well, which negatively impacts how long they last in composites [6, 7]. Cellolignin is a wood-based hydrolysis product that keeps the complex structure of lignin and cellulose. This gives it more resistance to chemicals and ultraviolet radiation [8]. Many studies have pointed out that composites enhanced with cellolignin fillers have better physical and mechanical qualities and are more resistant to breakdown [9, 10]. Also, to assess the chemical stability of composite materials, keeping them in certain solutions (LiOH, KOH, NaOH, H₃PO₄, H3SO3 CH₃COOH) based on GOST 12020-2018 and watching for changes after is widely used [11]. This method helps predict how well materials will hold up under different industrial conditions.

**MATERIALS AND METHODS**

The effect of chemical exposure to the undergone composite materials was studied, given those composite materials are meant to be used in several conditions, its chemical resistance is one of the top qualities, the effect of chemical and alkaline mediums on composite materials studied by GOST 12020-2018 standards. At first, composites were dehydrated (lost moisture) at 20 °C using 5% solutions of LiOH, KOH, NaOH, H₃PO₄, H3SO3 and CH₃COOH. The list of acids and alkaline are very demanded; this made our choice towards the reagents. The alkali that makes strong reactions and weak acids were both used.

**RESULTS AND DISCUSSION**

The square shaped patterns were dried first, immersed into the test cup. After the materials remained in solutions for 24 hours, temperatures were kept at the degree of 50±5°C, with vacuumed drying, until they are weight stable.

|  |  |
| --- | --- |
| C:\Users\User\Desktop\IMG_1461-1024x768.jfif | C:\Users\User\Desktop\IMG_8646-1024x768.jfif |

*(a)*  ***(****b)*

**FIGURE 2.** Shows composite material samples during a study of chemical stability:   
*(a) the mass of composite materials as they are submerged in a NaOH solution; b) samples after being held in NaOH solution for 24 hours*

The results of a study on how wood filler concentration affects a composite material’s resistance to alkaline and acidic environments are in Figure 2. Composites made of PGB/poplar wood flour, PGB/cellolignin and PGB/poplar wood flour+cellolignin at ratios of 60/40, 50/50, and 40/60 % broke down after being kept in 5% LiOH, KOH and NaOH solutions for 24 hours, leaving only a cellolignin deposit. Composites kept in H₃PO₄, H3SO3 and CH₃COOH solutions were barely changed by the acidic environment.

*(a)*

*(b) (c)*

**FIGURE 3.** Shows the mass loss of samples in alkaline and acidic environments over 24 hours for:   
*(a) PGB/wood flour; (b) PGB/cellolignin; (c) PGB/wood flour + cellolignin*

To check how well the composite material resists UV light, specimens were tested in a QUV climate test chamber with UV lamps. Samples shaped like thin bars (10 mm × 1.2 mm, 1 mm thick) were firmly attached to a test panel so all samples were exposed to radiation. The test panels were placed in the chamber for 96 hours. Inside the device, the UV light strength was 1.38 W/sm2, the wavelength was 340 nm, and the temperature reached 60 °C. After this time, the samples were taken out and compared to reference samples.

After keeping the samples in the chamber, they were compared to the reference samples using a Gotech AI-7000M universal testing machine. The test used a deformation rate of 10 mm/min and a distance of 40 mm between clamps.

*(a)*

*(b)*

*(c)*

**FIGURE 4.** Shows the change in density of composite material samples before and after UV exposure:   
*(a) PGB/wood flour; (b) PGB/cellolignin; and (c) PGB/wood flour + cellolignin*

Based on the analysis of Figure 3, the tensile strength of composite materials with wood flour and cellolignin decreased after exposure to UV light. The samples with wood flour showed a clear drop in strength, but the cellolignin samples were fairly stable.

Samples containing a mix of wood flour and cellolignin behaved differently. With filler content from 20 to 60% by mass, UV exposure increased their tensile strength. This may be because the UV light caused the wood flour and cellolignin to interact, strengthening their structures. Polymerization could be happening between the two different filler components, and the polyhydroxybutyrate may have entered cell spaces when heated, which increased the strength of the composite materials.

The study found that a filler amount between 20 and 50% by mass is best. Also, using cellolignin from the two-stage hydrolysis of pine wood seems like a good idea, since composite materials made from it have physical and mechanical properties close to those of composites made from wood flour. So, it is worth thinking about using these mixes in industry.

**CONCLUSION**

Tests checked the chemical resistance and mechanical stability of composite materials made from polyhydroxybutyrate (PGB) with wood flour and cellolignin. The tests followed GOST 12020-2018 standards using 5% solutions of alkaline (LiOH, NaOH, KOH) and acidic (H₃PO₄, H3SO3 CH₃COOH) substances. The composites with wood flour fell apart fast in strong alkaline solutions, leaving only cellolignin. But the composites stayed stable in weak acidic environments. UV light made the wood flour samples much weaker, while the cellolignin composites stayed pretty stable. Interestingly, the composites mixed with wood flour and cellolignin increased in tensile strength after UV exposure, likely because of a combined effect between the two components. Research suggests that mixes with 20-50% filler have the best mechanical and chemical properties. Cellolignin from hydrolyzed wood waste is a good filler for boosting the physical and chemical stability of PGB composites. Therefore, cellolignin composites are suggested as a possible material for different industries, especially for making bio-composites that are safe for the environment and stable against chemicals.

**REFERENCES**

1. V. K. Haugaard, B. Danielsen, and G. Bertelsen, “Impact of polylactate and poly(hydroxybutyrate) on food quality,” Eur. Food Res. Technol. **216**, 233–240 (2003).
2. B. S. Kim, S. C. Lee, S. Y. Lee, H. N. Chang, Y. K. Chang, and S. I. Woo, “Production of poly(3-hydroxybutyric acid) by fed-batch culture of Alcaligenes eutrophus with glucose concentration control,” Biotechnol. Bioeng. **43**, 892–898 (1994).
3. Y. Lv, Y. Zhang, and Y. Xu, “Understanding and technological approach of acid hydrolysis processing for lignocellulose biorefinery: Panorama and perspectives,” Biomass Bioenergy **183**, 107133 (2024).
4. S. Modi, K. Koelling, and Y. Vodovotz, “Assessing the mechanical, phase inversion, and rheological properties of poly-[(R)-3-hydroxybutyrate-co-(R)-3-hydroxyvalerate] (PHBV) blended with poly-(L-lactic acid) (PLA),” Eur. Polym. J. **49**, 3681–3690 (2013).
5. H. Cheng and L. Wang, “Lignocelluloses feedstock biorefinery as petrorefinery substitutes,” in Biomass Now – Sustainable Growth and Use, 347–388 (2013).
6. P. Ghosh and A. Singh, “Physiochemical and biological treatments for enzymatic/microbial conversion of lignocellulosic biomass,” Adv. Appl. Microbiol. **39**, 295–333 (1993).
7. E. Egamberdiev, K. Khaydullaev, S. Abdurazakova, Q. Khoshimov, O. Muratkulov, K. Tilovov,   
   B. Rakhimjonov, and M. Alieva, “Composite papers based on natural polymers,” E3S Web Conf. **497**, 03031 (2024).
8. E. Egamberdiev, Y. Ergashev, K. Khaydullaev, D. Shomurodov, A. Atakhodjaev, S. Mengliev,   
   N. Igamkulova, M. Mukhamedjanov, and S. Turabdjanov, “Application of waste paper in composite materials based on mineral fibers,” E3S Web Conf. **497**, 02026 (2024).
9. A. Turgunov, A. Turgunov, O. Turgunova, R. Rashidov, O. Muratkulov, O. Sobitov, N. Igamkulova,   
   Y. Ergashev, and S. Turabdjanov, “Quantitative and qualitative composition of solid particles released into the atmosphere when burning coal (a case study from a brick factory of Uzbekistan),” E3S Web Conf. **497**, 02036 (2024).
10. Y. Ergashev, E. Egamberdiev, and G. Akmalova, “Effects and analysis of chytazone in the process of processing paper from natural polymers,” E3S Web Conf. **477**, 00053 (2024).
11. F. Yin, D. Li, X. Ma, J. Li, and Y. Qiu, “Poly(3-hydroxybutyrate-3-hydroxyvalerate) production from pretreated waste lignocellulosic hydrolysates and acetate co-substrate,” Bioresour. Technol. **316**, 123911 (2020).