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Waste Wood Biomass, Its Generation and Advanced Application

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Abstract

The waste wood biomass sludge (WB) was separated from the model wood processing wastewater by coagulation/flocculation process with two developed eco-friendly composite coagulants based on poly aluminum chloride. It was found that the separated WB could increase the sorption ability of clay. The sorption capacity of the modified clay sorbents essentially increased relative to heavy metals, rapeseed and silicone oil in comparison with the original clay. Since the surface of the WB contained both hydrophobic and partly hydrophilic regions, it was studied both as a potential structuring agent for sandy soil and the bio-additive for a wood-plastic composite based on recycled polymer. The results showed that the WB is capable of forming sandy soil aggregates and increasing the mechanical properties and decreasing the water uptake of the composite.

Keywords: wastewater treatment; wood biomass sludge; coagulants

Introduction

The principles of the Circular Economy are based on the sustainable and efficient management of wastes and by-products because their annual volume remarkably increases and negatively affects the environment. On other hand, waste recovery can provide a huge secondary resource for producing new materials and reducing their costs. Recently, much attention has been paid to wastewater treatment and rational utilization of waste wood biomass formed as sludge at woodworking enterprises as a result of wastewater treatment, keeping in mind that the qualitative and quantitative treatment of woodworking wastewater allows returning the purified water into the technological cycle, which is important from both economic and ecological viewpoints.

There are different treatment methods for removing organic substances from wastewater. They include chemical methods electrochemical methods combination of different methods biological treatment membrane technologies [1-4]. One of the most economic and effective methods for wastewater treatment is the coagulation/flocculation process, which allows maximally decreasing chemical oxygen demand (COD), total organic compounds content (TOC), and wastewater color. Polyaluminium chloride (PAC) is a more effective coagulant than other aluminum salts for paper and pulp mill wastewater treatment. At the same time, PAC is a more expensive coagulant in comparison with aluminum salts. To enhance the efficiency of wastewater treatment and decrease the required amount, PAC is used in compositions with other coagulants [5, 6]. The production of veneer in many countries of East Europe is accomplished by the hydrothermal treatment of birch wood in special open water basins for 18 h at a temperature of 60°C (Figure 1).

Figure 1: Hydrothermal treatment of birch roundwood in the water basin.

The formed wastewater contains high concentrations of hemicelluloses, lignin's compounds and extractives, which are responsible for the high values of TOC, COD and color. The aim of the work was to show the effectiveness of the developed composite coagulants based on PAC in removing the waste wood biomass (WB) from the wastewater and to present a perspective trend in the possible application of the obtained WB sludge.

Experimental

Materials

Reagents. Polyaluminium chloride Polypacs-30 was a cream colour powder with basicity ~ 80% and a mass fraction of Al2O3 ~35%. High-molecular polyethyleneimine (PEI) with Mw 750 KDa represented a viscous liquid. Model wastewater. The wastewater was presented by a model solution obtained by the hydrothermal treatment of the birch wood sawdust. The main parameters of the model solution were the followings: biomass - 1400 mg L-1, lignin and lignin-like substances - 280 mg L-1, COD – 1285 mgO2 L-1, total organic compounds (TOC) – 732 mg L-1, color - 746 mg L-1 Pt-1. WB contained hemicelluloses, lignin substances and water-soluble extractives with the following mass ratio: 1.2/6.7/1.0, respectively. Wastewater treatment. The coagulation jar test procedure was carried out according to [7]. The residual concentration of the biomass and lignin was defined using the previously obtained correlation curves.

Methods

Waste wood biomass characteristics. The elemental analyzer Vario MACRO CHNS (Elementar Analysensysteme) was used to determine the elemental composition of the biomass samples.The determination of the metal content in the waste wood biomass was performed in accordance with ISO 15586:2003. The chemical composition of the coagulate was studied with 13C-NMR (Bruker 300MHz). For analytical Py-GC/MS analysis, a Double-shot Pyrolyzer Py-2020iD (Frontier Lab) with a GC/MS-QP2010 gas chromatograph-mass spectrometer (Shimadzu) was used. The FT-IR study was performed using a Perkin Elmer Spectrum One apparatus. To determine the sizes of the air-dried WB, the Laser Particle Sizer ANALYSETTE 22 NanoTec (Fritsch and Leica MZ 16 A stereomicroscope (Leica Microsystems) were applied. Soil aggregates formation. For structuring soil, WB was centrifugated at 6000 rpm for 20 min for obtaining an 8-10% gel on dry matter. The WB water suspensions with different concentrations were used for structuring dusty sand/clay soil particles less than 0.25 mm. The fractional composition of the structured soil was determined using a set of sieves.

Modification of clay sorbents. The coagulated WB was used as an active additive for obtaining a clay-based sorbent. With this aim, clay particles were treated with the WB suspension with the followed drying. The WB content in the clay samples varied from 0.05 to 0.26 %. Additionally, the clay samples were thermally treated at 800°C. Improvement of wood-plastic composite properties. For fabricating the wood-plastic composite (WPC), a blend of recycled polypropylene (rPP) with the microparticles of activated birch sawdust and the coagulated WB was mixed with a vibratory micromill PULVERISETTE 0 (Frisch, Germany). The samples for tensile and bending tests were prepared by the extrusion and molding methods using HAAKE MiniLab II and MiniJet II (Thermo Fisher Scientific, Karlsruhe, Germany). The processing conditions were as follows: a chamber temperature of 175°C, screw rotation speed of 130 rpm, circulation time in the extruder of 5 min, injection pressure of 60 MPa and mold temperature of 120°C. The WPC samples were fabricated according to ASTM D638 (2007) and ISO 178 (2010), respectively. The filling degree in the WPC samples was 30%.

Results and Discussion

Characteristic of waste wood biomass

The WB was separated from the model wastewater by the coagulation/flocculation process using two developed eco-friendly composite coagulants [8, 9]. The first coagulant (KHPAC) was a composite of PAC and aluminum chloride (AlCl3) obtained under defined circumstances. The increase in its coagulation ability was governed by the formation of various polynuclear high-molecular structures. The second coagulant (KHPAC/PEI) had a hybrid nature and represented the colloidal complex formed due to donor-acceptor interaction between the uncharged nitrogen atoms in imine groups of PEI and the aluminum ions in KHPAC.

Table 1 shows a comparison of the optimal parameters (dosage, pH) and efficiency (biomass yield, the color of treated MW, COD, etc.) of the coagulation-flocculation process using the KHPAC and the hybrid coagulant PEI- KHPAC. The coagulated WB sludge after centrifugation represented a pasty mass with a moisture content of about 90-92%, but after its drying at 60°C, it was a finely dispersed brown powder.

Table 1: Efficiency of the developed coagulants.

Parameters	KHPAC	PEI-KHPAC
Optimal dosage, mg/L	100	80
Optimal pH	6	6
Biomass removal, mg/L	1304	1358
Color removal, %	85.4	89.8
COD removal, %	46.7	49.7
Al ions residual, mg/L	0.063	0.032

The prevailing content of hemicelluloses in the waste wood biomass was testified by FT-IR and 13C-NMR spectroscopy. The analysis of 13C-NMR spectrum of the WB samples showed that the main component of the sample was hemicelluloses (75-80 %) in the form of O-acetyl-4-O-methyl-D-glucuronic-β-D-xylan. The granulometric analysis of the dried coagulated WB samples was characterized by the wide distribution of particle sizes varying from 2 to 246 µm and from 3 to 50 µm for the waste biomass isolated with KHPAC and KHPAC-PEI, respectively.

Possible application of the waste biomass sludge

Waste biomass sludge as a soil structuring agent

Due to hydrophobic regions, which are formed as a result of the interaction of the biomass components with the PEI-KHPAC hybrid coagulant, and free functional groups (carboxyl-, hydroxyl-, amino-), which were located in the coagulate segments (e.g., tails, loops), the WB revealed binding properties. Its ability to structure dusty soil particles for obtaining soil aggregates was studied [10]. The analysis of the fractional composition of the sandy soil treated with the WB suspensions showed that, with increasing the content of WB in the soil from 0.2% to 0.8%, the amount of the soil aggregates in the fractional composition increases from 10 % to 50 %. With increasing the clay content in the soil, the soil aggregate amount remarkably increases and shifts to a higher content of the large soil species. At a 70 % clay content, the amount of the aggregates achieves 98% of the soil mass using a 0.8 % WB suspension.

Waste biomass as a bio-additive to clay sorbent

It was found that the WB samples obtained as a result of the wastewater treatment with the composite coagulant KHPAC can increase the sorption ability of clay [11]. The optimal content of the WB in the clay sorbent varied from 0.05 to 0.26%. The sorption capacity of the modified sorbent samples for water, rapeseed and silicone oil increased by 35%, 31% and 21%, respectively, relative to the unmodified clay sorbent. The sorption efficiency of heavy metals (zinc and copper) from their water solutions was increased by 10–12%. The thermal treatment of the modified clay sorbent at 800o C led to an increase in its sorption capacity for oil products, but a decrease for heavy metals. These results testified that the WB sludge can be used to obtain environmentally friendly and inexpensive clay-based sorbents.

Waste biomass as a functional additive for wood-plastic composites

The air-dried WB sludge formed as a result of the model wastewater treatment with the KHPAC-PEI coagulant was used together with wood sanding dust to obtain the hybrid lignocellulosic filler in a quantity from 1% to 10% in terms of the rPP-based WPC mass (Figure 2).

Figure 2: WPC samples.

It was found that the presence of the WB in the hybrid filler led to an increase in the mechanical properties, a decrease in the water uptake and dimensional swelling, as well as a decrease in the polarity of the composite sample surface with its content in the WPC samples that did not exceed 5% [12]. Such a behavior indicated the WB ability to carry out the compatibilizer function. The coagulated WB was suggested to improve the interface adhesion in the composite system due to the presence of free functional groups located in the biomass coagulate segments (tails, loops) that can interact with the surfaces of both the lignocellulosic filler and the rPP matrix.

Conclusions

The performed investigations showed that the wood wastewater biomass sludge obtained as a result of the model wastewater treatment with the developed coagulants can be successfully used for structuring dusty soils, modification of clay-based coagulants as well as in the form of a functional bio-additive for improvement of the properties of wood-plastic composites based on recycled polymer.

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Conflict of interest

No conflict of interest.

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