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HYDROTHERMAL HUMIFICATION OF SPRUCE GREENERY AS AN ENVIRONMENTALLY FRIENDLY TOOL FOR PRODUCTION OF SYNTHETIC HUMIC SUBSTANCES AND EVALUATION OF REACTION DYNAMICS

Lauris ARBIDANS^{1*}, Marcis MEZULIS², Uldis GRINFELDS³, Maris KLAVINS⁴

^{1,2,4} Department of Environmental Science, University of Latvia, Jelgavas iela 1, Rīga, LV 1004, Latvia

³ Latvian State Forest Research Institute Silava, Rīgas iela 111, Salaspils, LV 2169, Latvia

* **Corresponding author.** Email address: lauris.arbidans@lu.lv

Abstract – Peat is the main raw material for soil enhancers, but it is a slowly renewable fossil resource, and its extraction leads to significant greenhouse gas emissions, primarily in form of CO₂ and CH₄ with minimal NO_x discharge. According to the Latvian State Forest Research Institute ‘Silava’, 70 % of these emissions come from peat used in agriculture, contributing to a total of 1 709 kt CO₂ equivalent. A sustainable alternative is spruce (*Picea abies* L.) greenery, a forestry by-product left behind after log extraction. This underutilized biomass, which can account for up to 50 % of a spruce tree’s dry mass, contains valuable compounds that can be extracted. The remaining material, rich in lignin, cellulose, and hemicellulose, can then be converted into synthetic humic substances through a hydrothermal humification process. This study promotes an end-of-waste approach by applying an innovative hydrothermal humification method to transform low-value forestry residues into synthetic humic substances that replicate the properties of natural peat humic substances for agricultural use. This conversion process generates significantly fewer greenhouse gas emissions than peat extraction and has the advantage of not requiring energy-intensive drying of biomass before synthesis. The findings of this research contribute to the development of high-value bioproducts from forestry residues, supporting circular economy principles within Latvia’s bioeconomy. Results demonstrate that spruce greenery biomass can be effectively converted into synthetic humic substances. The study examines the optimal conditions for hydrothermal humification, synthesis duration, and process temperature, to maximize the yield of synthetic humic acids, fulvic acids, and their low-molecular byproducts. The structural formation dynamics of synthetic humic substances were analyzed using advanced analytical techniques such as FTIR, ¹³C-CPMAS-NMR, and EPR spectroscopy, while the formation of fulvic acids and by-products were assessed using spectrophotometric methods such as total carbohydrates, total polyphenols, and their corresponding biological activities. This research provides essential insights into hydrothermal humification dynamics for the production of synthetic humic substances, their properties and future synthesis designs.

Keywords – *Circular bioeconomy; forestry by-products; greenhouse gases; humic acids; hydrothermal humification; peat; sustainable chemistry*

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