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Research on the impact of pyrolysis technological parameters and substrate properties on the release of volatile organic compounds from biochar

This dissertation, entitled *" Research on the impact of pyrolysis technological parameters and substrate properties on the release of volatile organic compounds from biochar"* by Ewa Syguła, presents an analysis of the influence of technological parameters of lignocellulosic biomass pyrolysis on the release of volatile organic compounds (VOCs) from biochar. Researchers' studies to date have focused on the positive effects of biochar, ignoring the environmental impact of this material. Recently, there have been reports of negative effects regarding biochar, which can contain potentially hazardous and toxic substances. The release of VOCs during the production of biochar exposes workers, production line operators to inhalation of these substances and their release into the environment. Limited information exists on the effects of different pyrolysis process conditions and substrate properties on the release of VOCs from biochar.

The subjects of the study were chemically produced mixtures consisting of different contents of structural components (lignin, cellulose and hemicellulose). The choice of such a substrate allowed the analysis of a wide range of biomass in terms of the influence of technological parameters of torrefaction/pyrolysis on the release of VOCs. To verify the data, validation was performed using real biomass (apple, pine and hemp straw). The aim of the study was to evaluate the influence of the structural components of cellulose (C), hemicellulose (H) and lignin (L), biomass and the thermal conditions of the pyrolysis process on the occurrence of VOC release. The released substances were qualitatively assessed to determine the potential risk. Based on the EU regulation (OJ L 353/1 EC NR 1272/2008) on classification and labeling of substances, the occurrence of hazardous VOCs in biochar was determined. This classification determines the hazard associated with contact with the volatile substance in question. The biochar for which the release of VOCs was determined was analyzed using a nonlinear regression function based on a polynomial equation (with an assumed significance level of $p<0.05$) for parameters determining the physical-chemical properties dependent on the temperature of the pyrolysis process and the ash-free molar mass. The results of the analysis are presented in the form of equations describing the given relationship and the coefficient of determination (R2) describing the model's fit to the empirical data. Against this equation, backward stepwise regression was applied to eliminate non-significant parameters. In addition, a balance of net VOC release from biochar was performed for each test sample to observe VOC release. With this approach, the direct effect of the torrefaction/pyrolysis process on VOC release from biochar was determined. A net release balance of hazardous VOCs was also performed to observe the presence of hazardous substances.

Studies have confirmed that biochar can be a hazard to handling and a source of environmentally hazardous VOCs, requiring the process to be run at optimal conditions. The general trend shows that the release of VOCs from biochar decreases as the process temperature increases, which is key to minimizing negative environmental effects. Lignin biochar was the source of the lowest number of VOCs compared to the baseline sample, indicating its lower capacity to release hazardous substances.

Hemicellulose showed no negative net release for all biochar over the temperature range, indicating that it releases more VOCs than the untreated substrate.

The conducted research can lay the foundation for future work on optimizing biochar production and minimizing VOC release. It is crucial to understand the impact of process parameters and the chemical composition of biomass on VOC release, which is essential for the development of safe biochar production technologies. Further research can increase the application of biochar in various economic sectors, minimizing its negative impact on human health and the environment.

Further optimization of pyrolysis conditions is recommended, and process control using ash-free molar mass can be an effective parameter in determining biomass volatility. Studies on the balance of VOC release and sorption in different types of biochar can provide valuable information on optimizing production and minimizing VOC release. Understanding the mechanism of uptake and release of VOCs is key to improving the safety of this material for human and environmental use.

Research on the impact of VOC release on human and environmental health is also recommended, especially in the context of long-term exposure. Continued research on the use of biochar as a soil additive and its effects on the health of plants and soil microorganisms is necessary. Cooperation with regulatory institutions to develop standards for the production and release of VOCs from biochar is also advisable.