

## **IMPLEMENTASI *LIFE CYCLE ASSESSMENT* (LCA) UNTUK PENGEMBANGAN PRODUK BIOCHAR SEKAM PADI DAN APLIKASINYA PADA BUDIDAYA SAWI HIJAU (*Brassica Juncea L.*) DI TANAH TAILING PASCA TAMBANG TIMAH**

### **INTISARI**

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Sektor pertanian merupakan kontributor signifikan terhadap emisi gas rumah kaca (GRK), terutama melalui pengelolaan tanah dan penggunaan input yang kurang ramah lingkungan. Biochar dari sekam padi berpotensi menjadi solusi strategis karena berfungsi ganda sebagai pembenah tanah dan penyerap karbon, meskipun proses produksinya juga berpotensi melepaskan emisi. Penelitian ini bertujuan untuk membandingkan variasi emisi karbon (CO<sub>2</sub> dan N<sub>2</sub>O) dari proses pirolisis biochar sekam padi pada berbagai kombinasi suhu (300–550 °C) dan durasi (30–90 menit), mengevaluasi efektivitas biochar rendah emisi dalam remediasi tanah tailing pasca tambang, serta menilai dampak lingkungannya melalui pendekatan *Life Cycle Assessment* (LCA). Metode penelitian dilakukan melalui eksperimen laboratorium dan rumah kaca dengan Rancangan Acak Lengkap (RAL). Fase pertama mencakup produksi biochar pada 30 kombinasi suhu dan durasi pirolisis. Hasil biochar diukur emisinya menggunakan kromatografi gas. Fase kedua menguji aplikasi biochar terbaik (emisi rendah) untuk budidaya sawi hijau (*Brassica juncea L.*). Emisi CO<sub>2</sub> dan N<sub>2</sub>O tanah diukur secara berkala dengan metode *closed chamber*. Analisis LCA dilakukan menggunakan perangkat lunak OpenLCA dengan batas sistem *cradle-to-gate*. Hasil penelitian menunjukkan bahwa kombinasi suhu menengah (400 - 450 °C) dengan durasi 60–75 menit menghasilkan biochar berkualitas dengan emisi relatif rendah. Aplikasi biochar terbukti mampu memperbaiki sifat kimia tanah, meningkatkan produktivitas sawi, serta menekan emisi N<sub>2</sub>O dari tanah dibanding kontrol. Evaluasi LCA mengidentifikasi tahap pirolisis sebagai kontributor utama emisi, namun secara keseluruhan biochar sekam padi tetap memberikan keuntungan mitigasi karbon pada sistem pertanian. Penelitian ini menyimpulkan bahwa biochar rendah emisi dari sekam padi berpotensi sebagai inovasi ramah lingkungan untuk remediasi tanah terdegradasi dan mendukung pertanian rendah emisi. Hasil ini diharapkan dapat menjadi dasar rekomendasi bagi pengembangan biochar berbasis biomassa lokal dalam kerangka bioekonomi sirkular dan mitigasi perubahan iklim.

**Kata Kunci :** biochar sekam padi, pirolisis, emisi gas rumah kaca, *Life Cycle Assessment* (LCA), remediasi tanah; pertanian rendah emisi.

## **IMPLEMENTATION OF LIFE CYCLE ASSESSMENT (LCA) FOR THE DEVELOPMENT OF RICE HUSK BIOCHAR AND ITS APPLICATION IN GREEN MUSTARD (*Brassica juncea L.*) CULTIVATION ON POST-TIN MINING TAILING SOIL**

### **ABSTRACT**

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The agricultural sector is a significant contributor to greenhouse gas (GHG) emissions, primarily through soil management practices and the use of environmentally unfriendly inputs. Rice husk biochar has the potential to serve as a strategic solution, functioning both as a soil amendment and a carbon sink, although its production process may also release emissions. This study aims to compare variations in carbon emissions (CO<sub>2</sub> and N<sub>2</sub>O) from the pyrolysis of rice husk biochar under different temperature (300–550 °C) and duration (30–90 minutes) combinations, to evaluate the effectiveness of low-emission biochar in remediating post-mining tailing soils, and to assess its environmental impact using a Life Cycle Assessment (LCA) approach. The research was conducted through laboratory and greenhouse experiments based on a Completely Randomized Design (CRD). The first phase involved the production of biochar across 30 pyrolysis temperature–time combinations, with carbon emissions measured using gas chromatography. The second phase tested the application of the most effective low-emission biochar for cultivating mustard greens (*Brassica juncea L.*). Soil CO<sub>2</sub> and N<sub>2</sub>O emissions were periodically monitored using the closed-chamber method. LCA analysis was performed using OpenLCA software with cradle-to-gate system boundaries. The results indicate that medium temperature ranges (400–450 °C) combined with 60–75 minutes of pyrolysis produce high-quality biochar with relatively low emissions. Biochar application improved soil chemical properties, enhanced mustard crop productivity, and reduced N<sub>2</sub>O emissions compared with the control. LCA evaluation identified the pyrolysis stage as the primary contributor to emissions; however, overall, rice husk biochar still provided net carbon mitigation benefits in agricultural systems. The study concludes that low-emission rice husk biochar has strong potential as an environmentally friendly innovation for remediating degraded soils and supporting low-emission agriculture. These findings are expected to inform recommendations for the development of locally sourced biomass-based biochar within the framework of a circular bioeconomy and climate change mitigation.

**Keyword :** Rice husk biochar, pyrolysis, greenhouse gas emissions, Life Cycle Assessment (LCA), soil remediation, low-emission agriculture.