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VALORIZATION OF PHYTOREMEDIATION BIOMASS FOR BIOGAS PRODUCTION: ADVANCING A CIRCULAR ECONOMY APPROACH TO MINE TAILINGS REHABILITATION IN SOUTH AFRICA

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Abstract – Since the inception of phytoremediation in South Africa, plant species selection has predominantly been guided by biodiversity conservation criteria, particularly the use of indigenous species capable of surviving on mine tailings while stabilizing or extracting contaminants. While this approach has supported ecological restoration objectives, it has largely overlooked the potential for integrating circular economy principles, such as reuse, recycling, and cradle-to-cradle material flows, into mine rehabilitation practices. Consequently, mine waste and associated phytoremediation biomass continue to be treated as residual waste streams, despite evolving sustainability perspectives. Regulatory frameworks have similarly remained largely stagnant in recognizing mine waste as a potential resource. This study explores a deliberate shift in phytoremediation strategy by assessing the use of bioenergy plants for mine tailings rehabilitation in South Africa, with the explicit aim of enabling post-harvest biomass valorization. Vetiver grass (*Chrysopogon zizanioides*), a high-biomass, stress-tolerant species, was cultivated on gold mine tailings located along the border of the North West and Gauteng provinces. Above-ground biomass was harvested and utilized as a feedstock for anaerobic digestion to evaluate its potential for renewable energy production. Biogas production experiments were conducted using the Automatic Methane Potential Test System (AMPTS II) under controlled laboratory conditions over a 50-day operational period. Continuous monitoring of biogas generation was performed to assess the biodegradability and energy recovery potential of vetiver grass biomass derived from contaminated substrates. The results indicate that vetiver grass grown on gold mine tailings is capable of producing biogas through anaerobic digestion, demonstrating successful conversion of phytoremediation biomass into renewable energy. Although detailed yield optimization and compositional analyses are ongoing, cumulative biogas production throughout the experimental period confirms the technical feasibility of this valorization pathway. The study provides evidence that incorporating bioenergy-oriented plant selection into phytoremediation frameworks can enhance the sustainability of mine rehabilitation by linking environmental remediation with resource recovery. This approach supports a transition from linear waste management toward circular economy practices and highlights the need for policy and regulatory reform to enable cradle-to-cradle implementation in mine tailings management.

Keywords – Anaerobic digestion; AMPTS II; bioenergy; biogas production; biomass valorization; circular economy; phytoremediation; sustainable mine rehabilitation; vetiver grass