Environment impact and bioenergy analysis on the microwave pyrolysis of WAS from food industry: Comparison of CO_2 and N_2 atmosphere

ABSTRACT

The alarming output of waste activated sludge (WAS) from industries requires proper management routes to minimize its impact on the environment during disposal. Pyrolysis is a feasible way of processing and valorizing WAS into higher-value products of alternate use. Despite extensive research into the potential of WAS through pyrolysis, the technology's long-term viability and environmental impact have yet to be fully revealed. In addition, the environmental effects of utilizing different pyrolysis atmosphere (N_2 or CO_2) has not been studied before, although benefits of CO_2 reactivity during pyrolysis have been discovered. This study evaluates the process's environmental impact, carbon footprint, and bioenergy yield when different pyrolysis atmospheres are used. The global warming potential (GWP) for a functional unit of 1 t of dried WAS is 203.81 kg CO_2 eq. The heat required during pyrolysis contributes the most (63.7%) towards GWP due to high energy usage, followed by the drying process (23.6%). Transportation contributes the most towards toxicity impact (59.3%) through dust, NO_x, NH_3 and SO_2 emissions. The initial moisture content of raw WAS (65%) greatly impacts overall energy consumption and environmental impact. Pyrolysis in an N_2 atmosphere will result in a higher overall bioenergy yield (833 kWh/tonne) and a lower carbon footprint (−1.09 kg CO_2/tonne). However, when CO_2 was used, the specific energy value within the biochar is higher (22.26 MJ/kg) due to enhanced carbonization. The carbon content of gas derived increased due to higher CO yield. From an energy perspective, the current setup will achieve a net positive bioenergy yield of 561 kW (CO_2) and 833 kW (N_2), where end products like biochar, bio-oil and gas can be used for power production. Despite the energy-intensive process, microwave pyrolysis has excellent potential to achieve a negative carbon footprint. The biochar used for soil amendment served as a good carbon sink. The utilization of CO_2 as carrier gases provides a pathway to utilize anthropogenic CO_2, which helps reduce global warming. This work demonstrates microwave pyrolysis as a negative emission, bioenergy-producing approach for WAS disposal and valorization.