Utilizing Gasification for Thermal Energy Production from Menstrual Waste: A Waste-to Energy Approach

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Abstract:

This study explores co-gasification as an efficient method for treating menstrual waste or specifically personal hygiene waste (sanitary pads), in conjunction with garden waste biomass. Menstrual waste are the main product used by women during their menstrual cycle (Wagh et al., 2018). In India, studies have shown that about 0.12 billion women and teenage girls use an average of 8 pads per month, making up 36% of the menstruating population (Bhor & Ponkshe, 2018). This leads to an annual consumption of 12.3 billion pads, which produces roughly 102511.8 metric tonnes of menstrual waste. Each woman contributes 0.045m^3 of disposable sanitary napkin waste every year (Ministry of India science, 2021). The disposal of such a large amount of waste presents significant challenges for waste management sectors. A variety of methods, such as incineration, chemical treatment, mechanical disintegration, UV sanitization, open burning, and deep burial, are used to dispose of sanitary napkins (Sasidaran et al., 2021). This study explores an efficient thermochemical conversion method (co-gasification) to treat menstrual waste, including menstrual fluid, aiming for both waste treatment and thermal energy recovery. The elemental analysis or CHNS for both the menstrual waste and garden waste pellets was determined using elemental analyser.

Experimental studies conducted on a 15kg/hr capacity downdraft gasifier, to utilise producer gas obtained from menstrual waste gasification for thermal applications. Blending of menstrual waste and garden waste pellets at different wt% ranging from 1wt.% to 8wt.% of menstrual waste in continuous type downdraft gasifier was studied. The feed loading pattern inside the reactor was followed as per methodology given by (Deore et al., 2023). The study uses case 1 type of feed loading pattern. Reactor operation parameters like equivalence ratio, tar content, gas composition, obtained gas thermal output and emissions were measured. The output producer gas was tested via water boiling test to test thermal feasibility. Effect on lower heating value, clinker formation and cold gas efficiency obtained were above 4.5MJ/Nm^3, <0.5% of total feedstock and 59%, respectively. The experiment revealed that the obtained producer gas from co-gasification experiment generated flame temperatures above 1050°C and operated up to turndown ratio of 3. The temperatures are measured at both axial and radial distances of the combustor to determine the thermal stability for gas combustion. Emission such as CO, SO_x, NO_x and UHC were determined using flue gas analyser at iso-kinetic conditions. The obtained emissions were below <30ppm and as per limits prescribed by central pollution control boards norms of India. Similarly, the particulate matter

emission ($PM_{2.5}$ and PM_{10}) were 8 times lower the standard limits. Tar analysis performed using tar impinger bottle setup revels decrease in tar content with increase in menstrual waste loading inside the reactor. Higher menstrual waste content (wt.%) in the garden waste pellets blend mixture extends volatile residence time, facilitating tar elimination during volatile breakdown in combustion zone of the reactor. This research addresses hygiene concerns associated with menstrual waste by eliminating the need for pre-treatment before the gasification process.

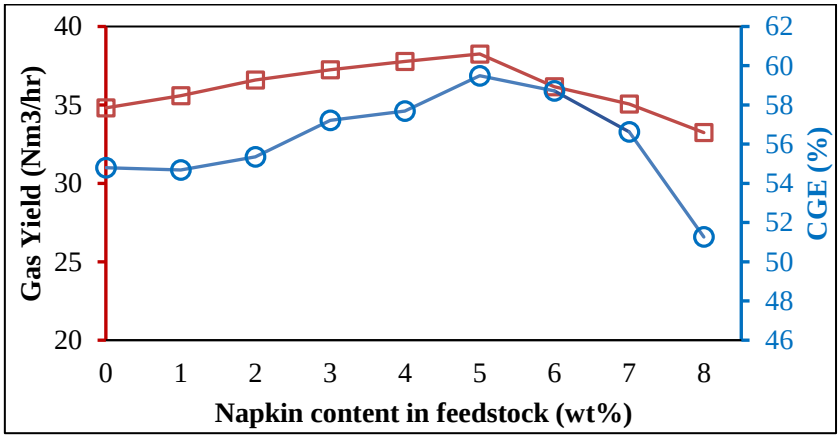

Fig.1. Effect of napkin content (wt.%) on gas yield (Nm^3/hr) and cold gas efficiency (CGE) of gasifier

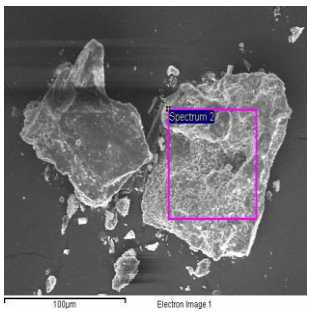

Fig.2. Surface of ash particle after gasification of menstrual waste for elemental composition

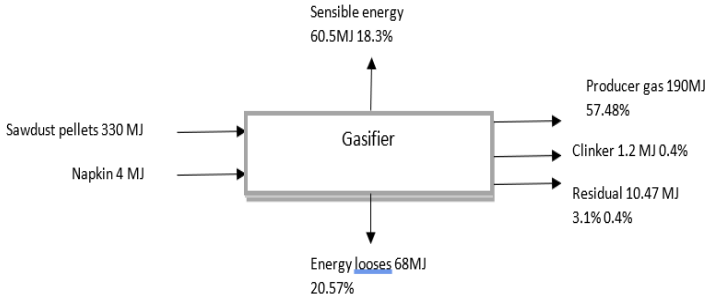

Fig.3. Energy balance for menstrual waste loading of 2% at equivalence ration of 0.34.

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