On the gasification of end-of-life plastic waste in an air/oxygen/steam atmosphere

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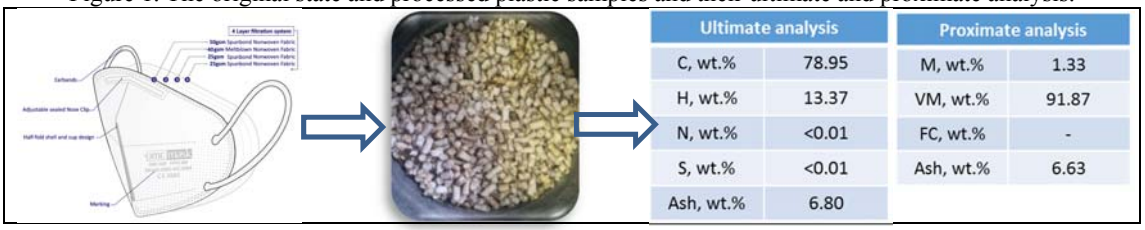
Currently, more than 129 million surgical masks are wasted every month due to their short lifespan and single use. This type of waste constitutes the majority of medical waste and contains a large amount of plastic material in the form of fibers. These masks are typically composed of three layers: the traditional two non-woven fabrics (top and bottom layers) and a middle layer (melt blown filter) made of polypropylene as the main polymeric material, mixed with other polymeric fillers (e.g. PET, PA, PE, PUR etc.). All these layers are connected by a mechanical bond resulting from friction between the polymer fibers. In addition, these wastes are classified as non-biodegradable waste and have negative impacts on the environment and human health. They are considered as a new source of micro plastic production with several serious consequences for living organisms and marine life. Despite all these scourges, these masks, when exposed to thermal treatments (e.g. gasification), can decompose into so-called syngas with high heating value and economic benefits. This paper presents results of the syngas production from gasification of pelletized end of life facemasks as a source of waste plastics.

The gasification tests of the plastic pellets (Figure 1) were performed in an experimental rig (Figure 2) with a small gasification reactor to determine gas composition, tar content and solid by-product production. The rig consists of stationary bed reactor, tar condensation and gas sampling system. The experiments were performed at 700, 800 and 900 °C temperature. The temperature was controlled by K-type thermocouple mounted inside electrically heated vertical furnace. A reactor is made from stainless steel tube with diameter of 16 cm and length of 80 cm. The feedstock is continuously feed with rate of 1 kg/h. In addition, to create appropriate oxidative atmosphere the flow of air/oxygen/steam in the mixture with nitrogen was continuously supplied. Generated raw hot gas is then forwarded to the high temperature filter with ceramic element for carbonaceous solid particle removal. The gas and tar samples are taken before and after, while solid residues from the bottom of the filter.

Figure 1. The original state and processed plastic samples and their ultimate and proximate analysis.



Ultimate analysis		Proximate analysis	
C, wt.%	78.95	M, wt.%	1.33
H, wt.%	13.37	VM, wt.%	91.87
N, wt.%	<0.01	FC, wt.%	-
S, wt.%	<0.01	Ash, wt.%	6.63
Ash, wt.%	6.80		

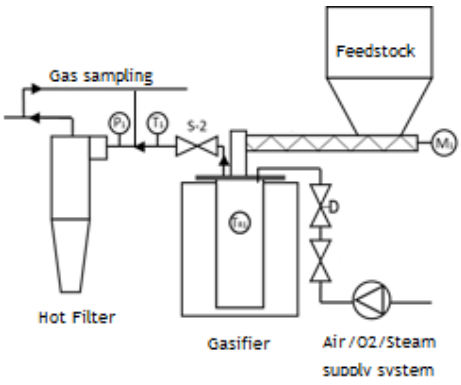


Figure 2. Scheme of experimental rig for plastic pellet gasification

The composition of syngas was determined by two methods: firstly, in order to see online variation of light gas (CO_2, H_2, CO, O_2) composition a portable gas analyser VISIT 03H was used; secondly, a gas samples were taken and analysed using the Agilent 7890A gas chromatograph with a two-channel thermal conductivity detectors (TCD). Tar concentrations are determined using the CEN BT/TF 14385 method. The taken samples of condensed tars are weighted and analysed using the Varian GC-3800 gas chromatograph with the flame ionisation detector. For

chromatographic separation of species, a universal Restek RXI-5ms capillary column of 60 m length and 0.25 mm inner diameter lined with a 0.25 μm thick (5%-phenol) layer of methylpolysiloxane was used. A sufficient repeatability of results was obtained in each series of the samples. The species produced during the experiment were identified based on the characteristic exit times determined by analysis of the calibration mixture. The chemical structure and crystal structure of the obtained char were examined using STA-FTIR. Besides, the morphology and chemical composition of char fraction were observed using SEM-EDX.

Figure 3 presents some of the results associated with the concentration of main gases obtained during the gasification of prepared plastic pellets. There can be established that at higher temperatures and at certain air equivalent ratio (ER), the concentration of hydrogen as the main compound of syngas was the highest. Also as expected the high concentration of light hydrocarbons were detected especially CH_4. Further catalytic reforming should be applied in order to get pure syngas containing H_2 and CO.

The tar concentration during gasification also varied according to the gasification temperature. The highest was detected to be at the lowest applied gasification temperature, while lowest in opposite and was about 30 g/m^3. The main constituent of tar were aromatic hydrocarbons.

Finally the formation of carbonaceous products were obtained, which were collected in the filter. The yield and the structure of the carbonaceous residues varied according to the gasification conditions. The highest amount of carbon particles were detected at the highest temperature leading to the formation of the very specific shaped nano-particles, which characterization was performed during this study.

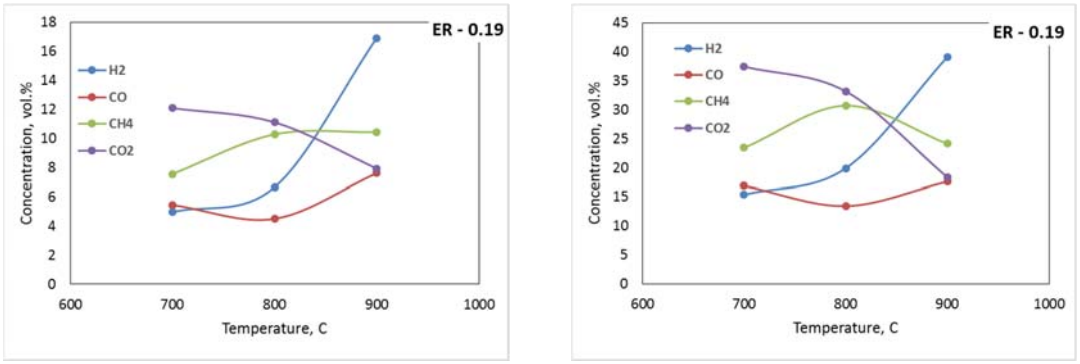


Figure 3. The concentration of main gaseous products during gasification of plastic pellets in an air and oxygen atmosphere at different temperatures

Conclusions

Studies on the gasification of plastic waste revealed that this type of plastic waste is a potential feedstock for the production of hydrogen-enriched synthetic gases. The study has shown that large quantities of light and condensable (tar) hydrocarbons are produced, the removal of which must be achieved by applying a catalytic reforming. The study also reveals that the gasification process can be adopted to generate carbon nanostructures with a specific shape.

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