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Municipal waste leachate conversion via catalytic supercritical water gasification process

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ABSTRACT

The aim of the paper is to investigate the thermal conversion of Municipal Waste Leachate (MWL) to Synthetic Natural Gas (SNG), based on two step process: gasification with water in supercritical conditions (SCWG) followed by a catalytic upgrading of the resulting gas phase. The proposed combination showed advantages in terms of biomass conversion efficiency with respect to the conventional approaches. As the initial biomass liquid phase includes some carboxylic acids, which are the usual intermediate of biomass decomposition process in SCWG, it is expected that the combined effect of catalysis and SCW leads to an increase of syngas yield, together with an enrichment in hydrogen. Experimental tests, carried out by varying MWL flow rate, showed that SCWG technology allows to produce a syngas with a Higher Heating Value (HHV) of about 15–17 MJ/kg. Hydrogen and methane compositions of the produced syngas varied in the range 25–47%v/v and 11–18%v/v, respectively. Syngas upgrading experimental tests were carried out by using a Nickel based catalyst increasing methane SNG fraction up to 50%v/v.

1. Introduction

Municipal Waste Leachate (MWL) treatment represents one of the most relevant problem in the field of waste treatment as this liquid watery fraction -diluted an rich of organic content- comes-up from any of the waste treatment processes: from sanitary landfilling to any of the energy valorisation techniques (anaerobic digestion, composting etc.) [1]. Leachate contains inorganic and organic elements, xenobiotic organic compounds and heavy metals, generally classified as hazardous substances occurring in leachate. In fact, MWL exhibits acute and chronic toxicity and if not appropriately treated, it can permeate ground water increasing the pollution of soil, ground and surface water [2]. Moreover, leachate is a product of landfills, wherein excess water percolates through landfill waste layers, freeing organic compounds from the waste and carrying them away concentrated in leachate. Furthermore, the presence of leachate may cause malodorous and aerosols [3,4], increasing distrust of the people toward this liquid fraction.

Biological and chemical treatment have been proposed to overcome leachate processing problem [5,6]: flocculation/precipitation techniques have been studied by Amokrane et al. and Tatsi et al. [7,8], whilst Copa and Medil proposed activated carbon adsorption of organic fraction to treat this leachate flows [9]. Recently, chemical oxidation method [10,11] and membrane processes such as reverse osmosis [12] and nanofiltration [13] have been also investigated.

In addition, due to the high available volume, a more effective energy valorisation of this substrate would be a profitable way to recover the organic fraction of MWL, even though the high water dilution represents a difficult task to be overcome. On the other hand, gasification in supercritical water condition (SCWG) is a promising technology to more profitably treat and promote wet biomass and organic wet substances [14] such as digestate, municipal solid organic wastes etc., compared to the traditional methods used to produce synthetic natural gas or liquid biofuels [15–21]. In fact, the SCWG technology is suitable for treatment of biomasses containing large amount of water (up to 90%) and this is due to

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the possibility to recover the energy contents from the outstream thanks to the vaporization of feed stream. This configuration is similar to a steam cycle but with the advantage that it is possible to recover the organics from the gasification reactions taking place at the SCWG operative conditions [22]. Another advantage of this process is related to the high vapour content in the gas phase that promotes the water gas shift reaction, in order to increase the hydrogen content in the syngas and helps the methanation stoichiometry reaction [23,24]. At last but not least, is the overcoming of the Achille's heel of the gasification processes, that is the tar formation [25–27]. Water in supercritical conditions changes its polarity and more tars can be solubilized in the liquid phase with the main effect to obtain a tar-free syngas.

The Renewable Energy Directive (2009/28/EC) establishes an overall policy for the production and promotion of energy from renewable sources in the EU. In this direction, in the biofuel sector, it is provided that all EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020. Furthermore, on 30 November 2016, the Commission

Table 1
Waste Leachate composition.

Raw leachate sample [%w/w]		Dry basis composition [%w/w]	
Water	86 ± 3	Volatiles	80 ± 2
Total solid content	9.5 ± 0.8	*Ashes*	20 ± 2
Lactic acid	8.8 ± 0.07	*HHV / LHV [MJ/kg]*	20 ± 2/ 11.8 ± 1
Acetic Acid	0.9 ± 0.007	*C*	33 ± 1
Ethanol	0.2 ± 0.002	*H*	3.5 ± 0.4
		N	2.1 ± 0.1

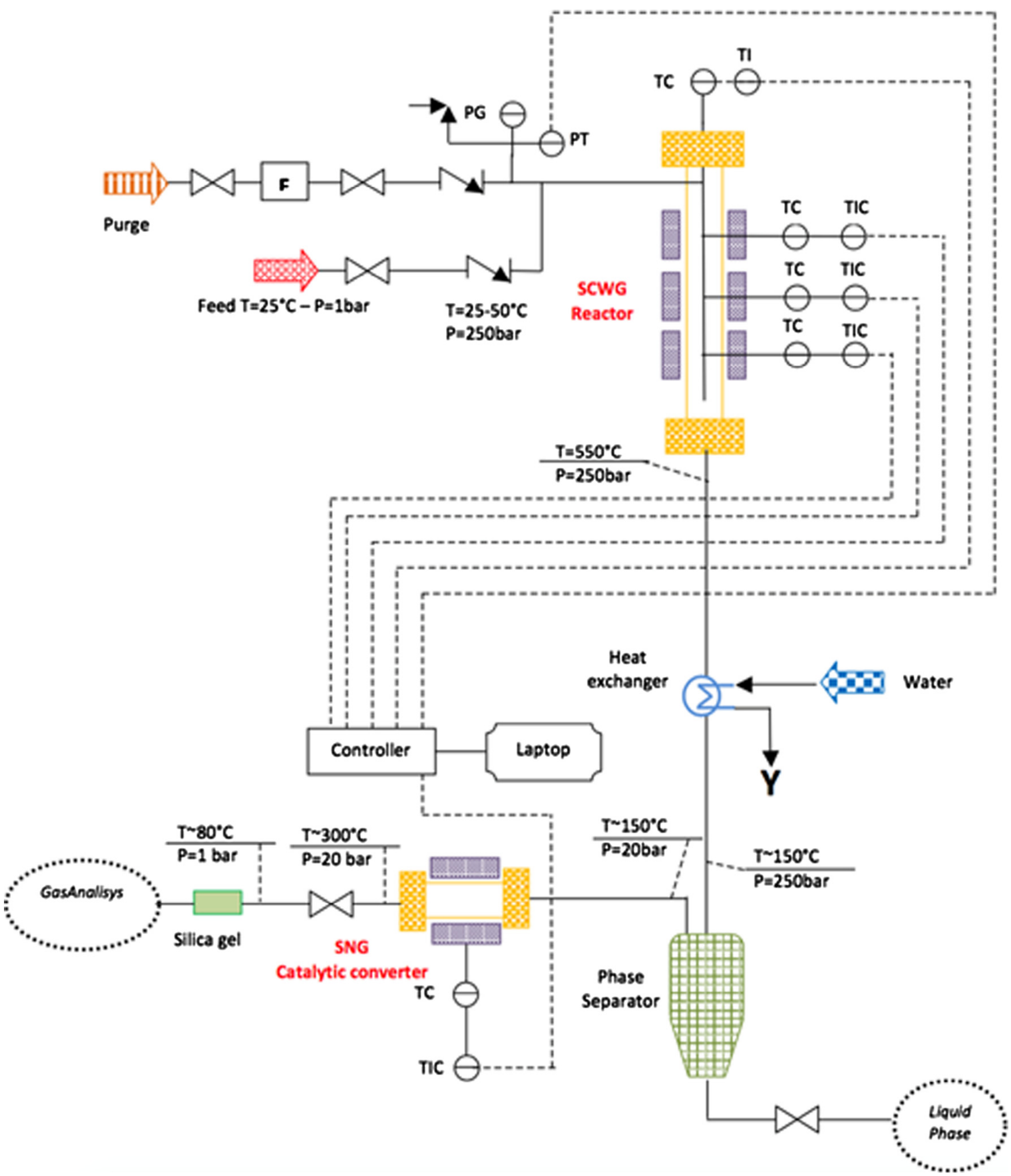

Fig. 1. Combined SCGW + Catalytic SNG converter experimental apparatus.