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ScienceDirect

Energy Procedia 136 (2017) 463–467

Energy Procedia

www.elsevier.com/locate/procedia

4th International Conference on Energy and Environment Research, ICEER 2017, 17-20 July 2017, Porto, Portugal

Green bio-oil obtained from digested sewage sludge: new substitute bio-fuel to diesel oil in thermoelectric plants

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Abstract

This study aims to take advantage of the residual sludge generated in sewage treatment plants (STP) for production of bio-oil fuel in order to apply it in thermoelectric plants by reducing the impacts on power generation. The sewage sludge was subjected to the process of pyrolysis in a fixed-bed reactor for the production of bio-oil. The average of yield of bio-oil was 10.52-18.38% (m/m). The analysis of bio-oil showed pH 8.35, density 0.97 g cm^{-3} and higher calorific value 32.36 MJ kg^{-1}, the mixture 1:1 bio-oil/diesel presented calorific value 41.41 MJ kg^{-1} and density 0.94 g cm^{-3}.

Peer-review under responsibility of the scientific committee of the 4th International Conference on Energy and Environment Research.

Keywords: Bio-oil; pyrolysis; renewable energy; sewage sludge

1. Introduction

Fossil fuels are potentially polluting and finite; studies with biomass as renewable resource for energy production are of the utmost relevance. In this context, municipal solid waste, especially sewage sludge generated by sewage treatment plants (STP), has shown considerable potential as feedstock to be applied in thermochemical processes such as pyrolysis for the production of biofuels [1,2].

The production of sewage sludge, coupled with the population growth, industrialization, and the trend of

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1876-6102
Peer-review under responsibility of the scientific committee of the 4th International Conference on Energy and Environment Research.
10.1016/j.egypro.2017.10.304

universalization of basic sanitation services worldwide, tends to increase in such a way that the traditional applications of final management for this residue will be unviable economically and environmentally [3].

Different destinations are used for the sludge generated in sewage treatment plants, between these processes are included: landfill, agricultural use, aerobic digestion, incineration and composting. However, the thermochemical processes are considered one of the most promising ways in order to recover the potential energy through the products obtained from the sewage sludge. Among the thermochemical processes, pyrolysis is the thermal decomposition carried out in the absence of oxygen, producing four fractions: aqueous liquid, organic liquid (bio-oil), solid and gaseous [4].

Bio-oil production in this process has aroused significant interest due to its high potential for obtaining chemicals products and use as biofuel for energy production [5-7]. According to [8], the fact that the sewage sludge is abundant throughout the world makes the development of pyrolysis of this residue successful and of great interest.

Therefore, this study aims to characterize and assess the potential use of thedigested sludge as an alternative source of fuel in power generation through the pyrolysis process, integrating the sustainable use of renewable resources with the rational and efficient use of energy as well, producing a biofuel, called bio-oil green, which features chemical and physico-chemical characteristics similar to petroleum products (diesel) and performstudies of blends with diesel fuel for future replacement in thermoelectric plants.

2. Material and methods

2.1. Collection of sewage sludge

The digested sewage sludge used in this work, was ceded by a sewage treatment plant located in the city of Rio de Janeiro-RJ, Brazil, as shown in Fig. 1, showing a moisture content of 7.45% (m/m).

Fig. 1. Sewage sludge (Source: LEDBIO).

2.2. Characterization of sewage sludge

The sewage sludge extracts, obtained from the extraction with Sohxlet using the solvents ethanol and hexane, were characterized by the gas chromatography coupled to mass spectrometry (GC/MS) using helium with purity of 99.999% as a carrier gas, with flow in the column of 1 mL min^{-1}, injector temperature 300 ºC, split injection, ratio 1:20, capillary column VF-5ms (30 m x 0.25 mm x 0.25 µm) and VF1-ms (15 m x 0.25 mm x 0.25 µm). The temperature program was: initial temperature of 40 °C, isotherm for 5 min, increased from 40 °C to 300 °C in 10 °C min^{-1} and isotherm for 30 min.