Waste to chemicals: technical-economic analysis of an hydrothermal liquefaction process

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Recent problems related to climate change combined with the exhaustion of fossil fuel deposits, have sparked interest in renewable sources. Furthermore, rapid urbanization and rising living standards in developing countries have significantly accelerated the rate of municipal solid waste generation.
Research and Development Institutes are developing second generation biofuels to further reduce the impact on the environment and on the prices of the agri-food market. One of the most promising technological innovations concerns the production of biofuel from organic waste.
In recent years, research has focused on innovative treatments, such as the hydrothermal liquefaction process (HTL), which is a promising technology, as it is able to treat biomass even with a high degree of humidity, with high efficiency and short residence time.
The purposes of this study were the design, development, and optimization of a process for converting the organic fraction of municipal solid waste (OFMSW) through a process of hydrothermal liquefaction and subsequent upgrading. The final aim is the recovery of material and energy from OFMSW, obtaining a marketable biofuel and good quality.
The project stems from the need to develop an integrated process that would allow both the production of a biofuel, a renewable resource with lower emissions than conventional fuels, and the recycling of the OFMSW, avoiding its disposal in landfills.
The work was carried out in two phases. Starting from the analysis of a typical organic fraction of municipal solid waste, the complete steady-state process was developed, using the Aspen Plus software. It is generally recognized that the hydrothermal decomposition of biomass is a complicated process involving many types of chemical reactions. A general reaction network and a quantitative kinetic model were proposed for HTL of municipal solid waste, which showed good results based on validation with experimental data.
The sequence of operations was finalized and the operating conditions for the various equipment were established. A process scheme was built, divided into blocks, which made it possible to analyse the phases leaving the hydrothermal liquefaction reactor, with the aim of recovering as much as possible the energy value of the biomass and obtaining products with high added value.
A sensitivity analysis of the reaction temperature and of the residence time was carried out, aimed at finding an excellent operating solution capable of maximizing the yield of biocrude while ensuring a good quality of the product obtained.
The bio-oil obtained from the liquefaction and upgrading of biomass has an energy value and chemical composition similar to petroleum-based diesel. The upgraded biocrude shows a significant change in composition. In particular, the removal of oxygen is evident, the content of which is reduced by 88%. After hydrotreating, a shift towards lower boiling points occurred. These results showed that a high-quality fuel can be produced by upgrading HTL bio-crude, with yields of up to 33% of gasoline and diesel fractions on a dry basis of MSW.
With a view to a future implementation of the process, the second part of the study focused on the energy, environmental and economic analysis of the plant. The objective was to evaluate the overall efficiency of the process, in order to then be able to make a comparison between the various proposed configurations, and to draw conclusions on the feasibility of the process.
From the evaluation of the data obtained from the simulation, an average value of CO_2 emissions of approximately 12.41 g CO_2 eq/MJ is obtained. This is significantly lower than the release rate of fossil fuel technologies, where the amount of CO_2 emitted is approximately 40g.
From the economic analysis of the process, it has been seen that the capital costs associated with the HTL area and upgrading are the most significant. The main reason is the very high operating pressure and the more expensive shell and tube design for HTL reactors compared to a classic PFR reactor.