# Thermal pretreatment of sewage sludge to produce a solid fuel for potential use in thermochemical processes

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Highlights:

- Thermal pretreatment (torrefaction) of sewage sludge was evaluated as a sustainable alternative to produce energy dense solid fuel
- The HHV of sewage sludge increased from 24.9 to 31.5 MJ/kg on a ash dry free basis.
- H/C and O/C decreased with thermal pretreatment – moved it closer to lignite coal

Keywords: sewage sludge; torrefaction; biocoal

## INTRODUCTION

Sustainable management and practices to utilize sewage sludge are essential with increasing population and urbanization globally. Over 8 million metric tons (dry) are produced in the U.S. of which, 56% is land applied, 27% landfilled, and about 16% incinerated [1]. However, several challenges exist with land application, incineration, and landfilling, from environmental, socio-economic, as well as health perspective, prompting to seek alternative sustainable and environmentally benign practices. Sewage sludge typically is comprised of proteins, polysaccharides, and lipids [2]. Valorization of sewage sludge to produce chemicals and fuels has been considered as a viable option. Further, thermochemical conversion technologies, gasification and pyrolysis have been considered as promising routes for energy recovery [3]. Also, combustion is a mature thermal conversion technology, which typically uses fossil-based fuel sources such as coal. Renewable sources such as biomass is a very attractive and promising solid fuel alternative, however, biomass has some disadvantages such as lower heating value, low grindability index, are heterogeneous and hygroscopic, etc. Torrefaction is a thermal pretreatment process, wherein biomass is converted to a coal like product, typically in the temperature range of 200 -300ºC under inert or non-oxidizing environment [4]. Torrefied biomass thus produced possesses a higher energy density, is hydrophobic in nature, and are easier to grind compared to biomass. However, torrefaction of non-lignocellulosic materials, which are rich in energy, have not been investigated extensively. Sewage sludge is one such non-lignocellulosic biomass that has tremendous potential to be used as a solid fuel source for thermal energy applications. Hence, this study will evaluate thermal pretreatment (torrefaction) of sewage sludge to produce a fossil-based substitute.

## METHODOLOGY

Sewage sludge was obtained from a wastewater treatment plant in east Lafayette, LA and was dried in an oven to remove water, ground and sieved to particle sizes ranging between 60 and 150 mesh, which was used in this study. A bench scale fixed bed reactor was designed and set up to accommodate testing conditions for the study. Approximately 10 grams of sample was used for all tests and a nitrogen flowrate of 100 cc/min was purged through the reactor (stainless steel tube) to maintain an inert environment, which is located in a tube furnace to maintain the desired temperatures. Experiments were performed in the temperature range of 250 -350ºC and 10 to 30 minutes residence time. Solid and energy yields were calculated based on the mass loss and represents the amount of solid and energy retained, respectively, post torrefaction. The volatiles and gases released during the process were passed through a series of glass impingers with acetone, where the volatiles were condensed. Permanent gases were collected in tedlar sample bags, which were analyzed using gas chromatography (thermal conductivity detector). Proximate (moisture, fixed carbon, volatile matter, ash) and ultimate analysis (elemental composition and higher heating value (HHV)) was performed on untreated and torrefied samples according to ASTM standards.

## RESULTS AND CONCLUSIONS

The moisture content, ash, volatile matter, and fixed carbon were determined to be 0.45%, 37.8%, 56.5%, and 5.7%, respectively for the sewage sample tested. The HHV was determined to be 15.4 and 24.9 MJ/Kg on dry and dry ash free basis, respectively. Influence of temperature on solid, energy yield and higher heating value is presented in Figure 1. Mass and energy yields decreased with an increase in temperature, with energy yields being higher than mass yields at all temperatures, resulting in energy densification.

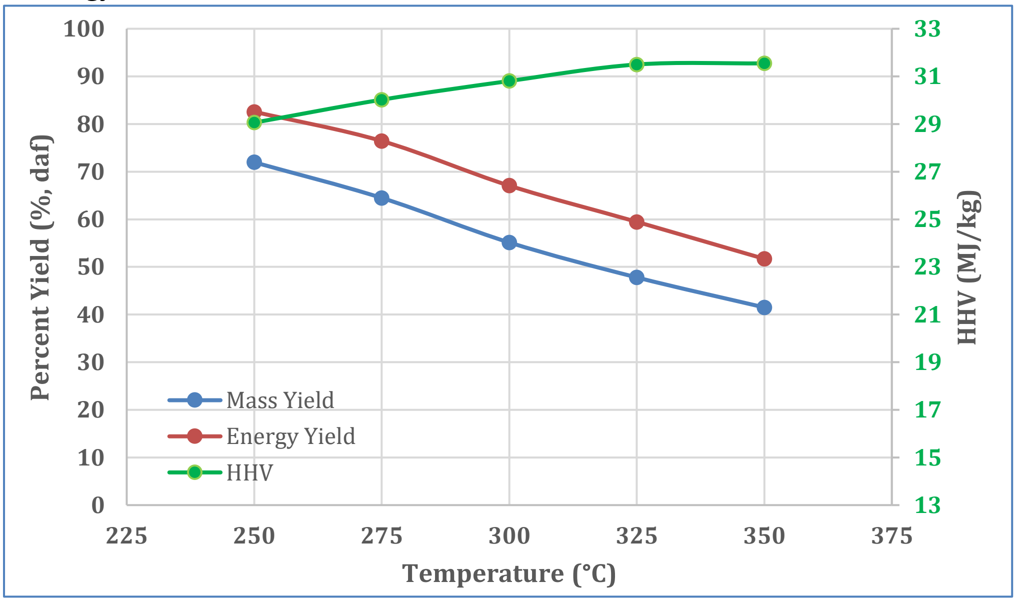


Figure 1: Influence of temperature on solid yield, energy yield, and higher heating value (dry ash free basis). [Untreated sewage sludge HHV: 24.9 MJ/Kg]

As seen in Figure 1, the HHV increased from 24.9 MJ/Kg (raw) to 31.5 MJ/Kg (350ºC) on a dry ash free basis. Degradation/devolatilization of carbohydrates, lipids, and proteins takes place with increasing temperatures releasing compounds with lower heating values and removal of oxygen in the form of water and volatiles, contributing to an increase in energy density [5]. This was also evident from the elemental composition data. It was also observed that temperature had a higher influence than residence time during the process. An increase in residence time from 10 to 30 minutes resulted in less than 2% increase in HHV.

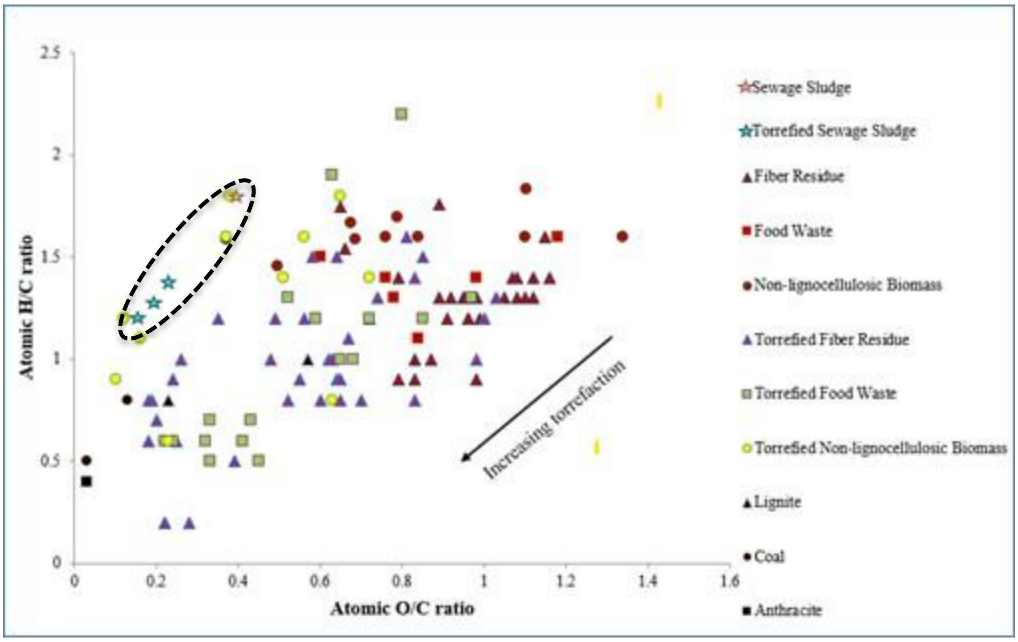


Figure 2: Van krevelen diagram – Sewage sludge and torrefied sewage sludge highlighted in oval region {Adapted from [6]}

Figure 2 presents an overlay of sewage sludge and torrefied sewage sludge on the modified Van krevelen diagram. As seen on the diagram, hydrogen to carbon (H/C) as well as oxygen to carbon (O/C) decreased with an increase in torrefaction severity (dotted back oval section), which moves torrefied sewage sludge into the vicinity of lignite coals. Thus, it can be concluded that torrefaction increased the energy density and HHV of sewage sludge, thereby enhancing the fuel properties of sewage sludge on an ash free basis. However, the high ash content of sewage sludge, which varies widely (10 - 40%) depending on the source of sewage sludge and treatment type, could be detrimental to be used as a solid fuel in thermochemical applications. However, co-processing (blending) other lignocellulosic waste available at the treatment facilities with sewage sludge will address the issue of high ash content and make the technology viable. Also, combustion behavior of torrefied sewage sludge in comparison with lignite coal will provide insights into the potential for cofiring torrefied sewage sludge with coal at existing coal plants. Further, torrefied sewage sludge has a promising potential to be used as a soil amendment and/or carbon capture and storage, however further investigation is warranted to evaluate the leaching potential of organics and metals from torrefied sewage sludge. Various scenarios that address the thermal energy requirement for the torrefaction process was evaluated and will be presented.

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