



# Pyrolysis of pine and gasification of pine chars – Influence of organically bound metals

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## HIGHLIGHTS

- ▶ Selective leaching of ash-forming elements from biomass.
- ▶ Adsorption of alkali and alkaline earth metals to the leached biomass sample.
- ▶ Pyrolysis of the leached and metal modified sample.
- ▶ Gasification of the pyrolysis chars.
- ▶ Strong influence on the pyrolysis and gasification by the metals.

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## ABSTRACT

Pyrolysis of pine and gasification of pine chars was studied in this work, focusing on the influence of organically bound metals. Selective leaching of the major ash-forming elements in pine wood was performed with different acids, namely, nitric, sulfuric, hydrochloric and oxalic acids. No other major changes in the chemical composition of the biomass were observed except the removal of the metals. The effect of organically bound sodium, potassium, magnesium and calcium was studied in both pyrolysis and gasification. Removal of the metals had a positive effect on the pyrolysis, resulting in higher bio-oil, lower char and gas yields.

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## 1. Introduction

Woody biomass can be transformed into liquid, solid and gaseous bio-products through pyrolysis and/or gasification. In pyrolysis the woody biomass is degraded into the above mentioned products in an atmosphere free of oxygen at 400–500 °C (Bridgwater, 2002). These conditions are chosen to maximize the production of liquid products. Gasification involves the oxidation of the char with a sub-stoichiometric amount of oxygen in a reactive atmosphere containing oxygen, steam or carbon dioxide as the reactive phase (Suzuki et al., 2011).

Biomass contains various amounts of cellulose, hemicellulose and lignin as well as inorganic ash-forming elements (Fengel and Wegener, 1984). The latter ones are bound to the biomass at carboxylic and/or phenolic groups (Wilson, 1966). The chemical

composition of the biomass affects the distribution and composition of the pyrolysis products. Typical yields of woody biomass pyrolysis are 60–75% bio-oil, 10–20% gases, and 15–25% solid char (Mohan et al., 2006). Pyrolysis of biomass with a higher lignin content than woody biomass tends to yield less bio-oil (Mohan et al., 2006). The ash-forming metals in the biomass affect the composition of the bio-oil (Huber et al., 2006). Pyrolysis of cellulose can produce bio-oil with up to 66% of levoglucosan (Essig et al., 1988). However, small amounts of inorganic salts change the composition of the bio-oil in a way that the levoglucosan concentration is significantly lower and higher concentrations of formic acid, glycolaldehyde and acetol are formed (Evans and Milne, 1987; Patwardhan et al., 2010; Ronsse et al., 2012).

The ash-forming elements can be removed to some extent from the biomass by using water (Davidsson et al., 2002; Eom et al., 2011; Stephanidis et al., 2011). More extensive removal of the metals can be performed in acidic medium (Davidsson et al., 2002; Granholm et al., 2009; Eom et al., 2011; Su et al., 2010, 2012).

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