Impact of Inorganics in the Industrial Processing of Biomass

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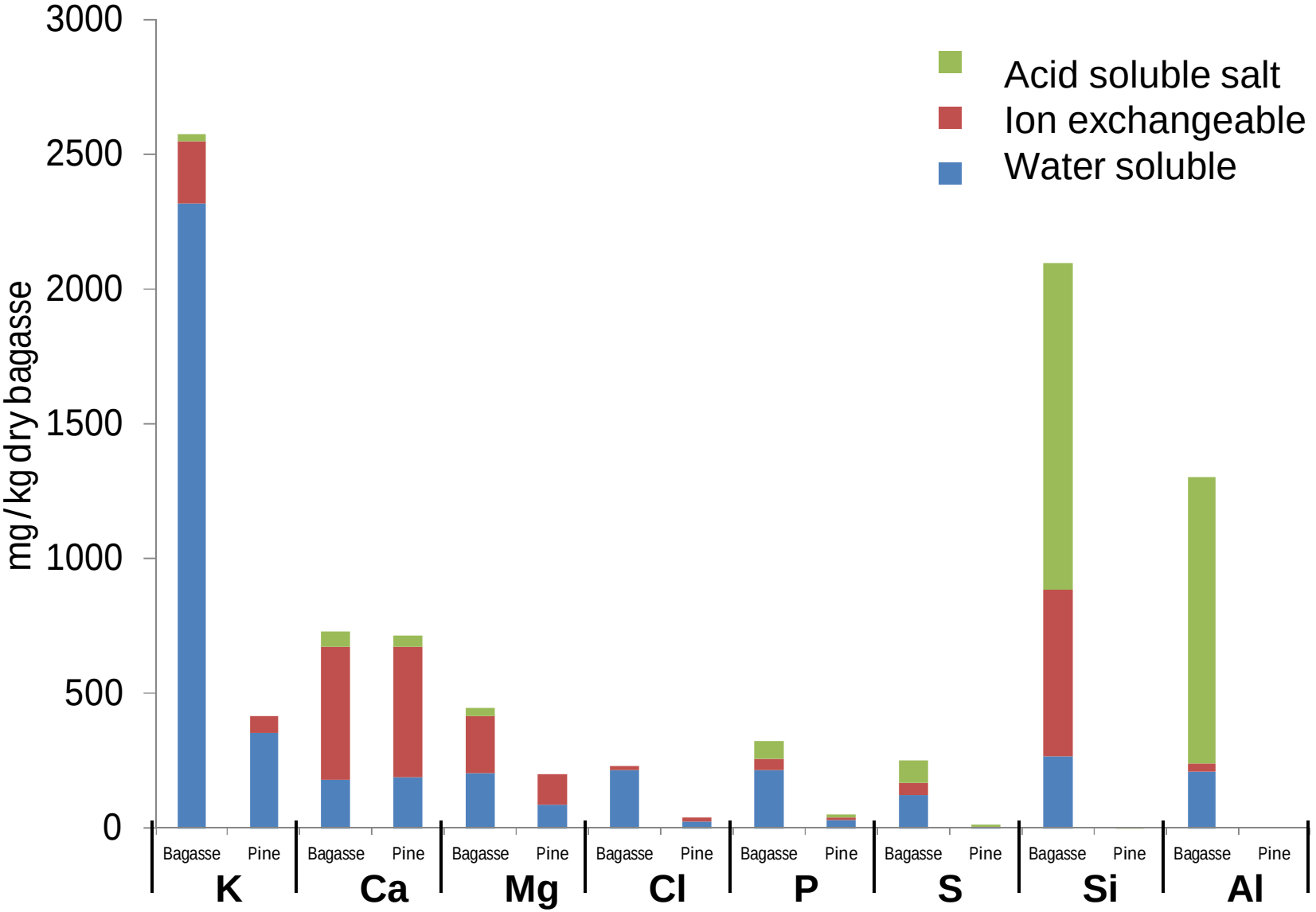
Bagasse & Pine



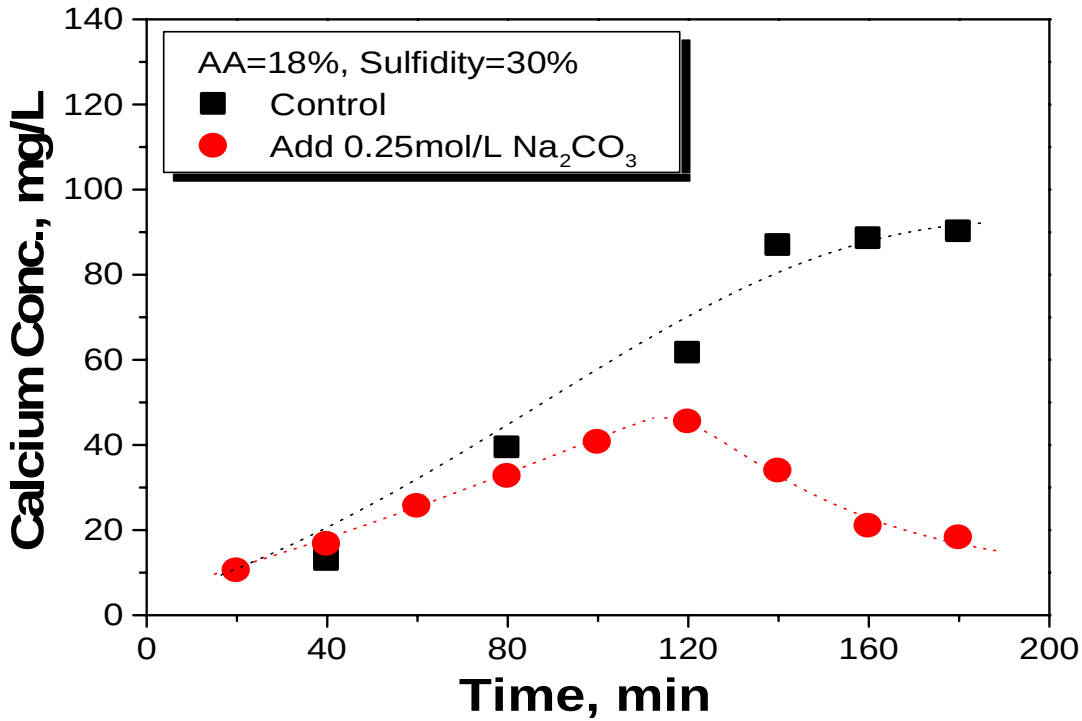
Zevenhoven et al. Energy and Fuels, In press http://dx.doi.org/10.1021/ef300621j
Werkelin et al. Fuel 2010

Examples

- Ca in pulping
- Role of alkali in thermal conversion:
  - Torrefaction
  - Pyrolysis
  - Low Temperature Corrosion in Biomass Boilers

Fate of Ca during alkaline pulping

- During pulping, Ca released from wood and binds to organic anions
- Eventually, these org-Ca bonds break and $CaCO_3$ precipitates on fibers and heat transfer surfaces



Implications

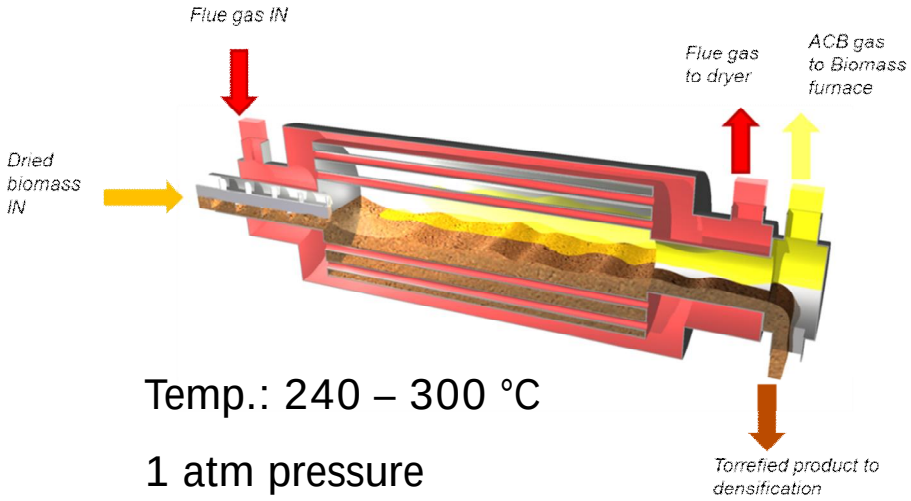
- In alkaline pulping - $CaCO_3$ scales heat transfer surfaces
- In new fractionation concepts Ca and other metals in wood bind to organics, affecting material applications

Examples

- Ca in pulping
- Role of alkali in thermal conversion:
  - Torrefaction
  - Pyrolysis
  - Gasification
  - Low Temperature Corrosion in Biomass Boilers

Torrefaction of biomass

Andritz ACB Process, Austria (1 t/h)



Temp.: 240 – 300 °C

1 atm pressure

~15-45 min

(Andritz)

Benefits

- Improved storage properties
  - Higher energy density possible
  - Reduced water uptake
  - Reduced biological decay
- Improved grindability
  - Can use same grinders as for coal
  - Better grindability
    - Lower energy consumption
    - Smaller particles

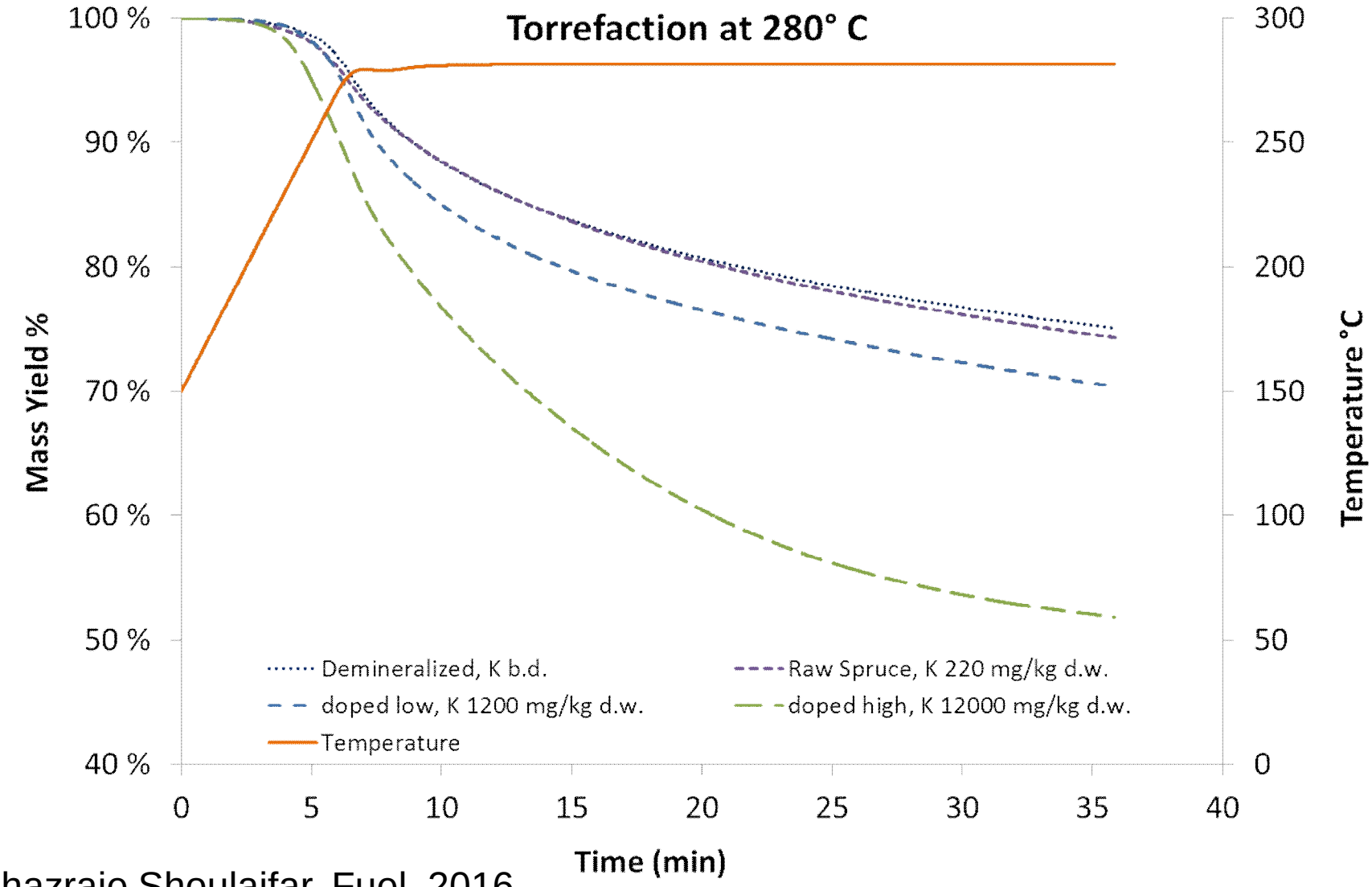
Demineralization & Doping of Biomass

- Method to study the influence of individual metals
- Biomass demineralized with 0.01M EDTA solution, then 0.01M HCl, both steps 2h at room temperature
- Doping 0.05M metal nitrate solution, solution pH adjusted with metal hydroxide to change level of loading

Kinetics of Torrefaction

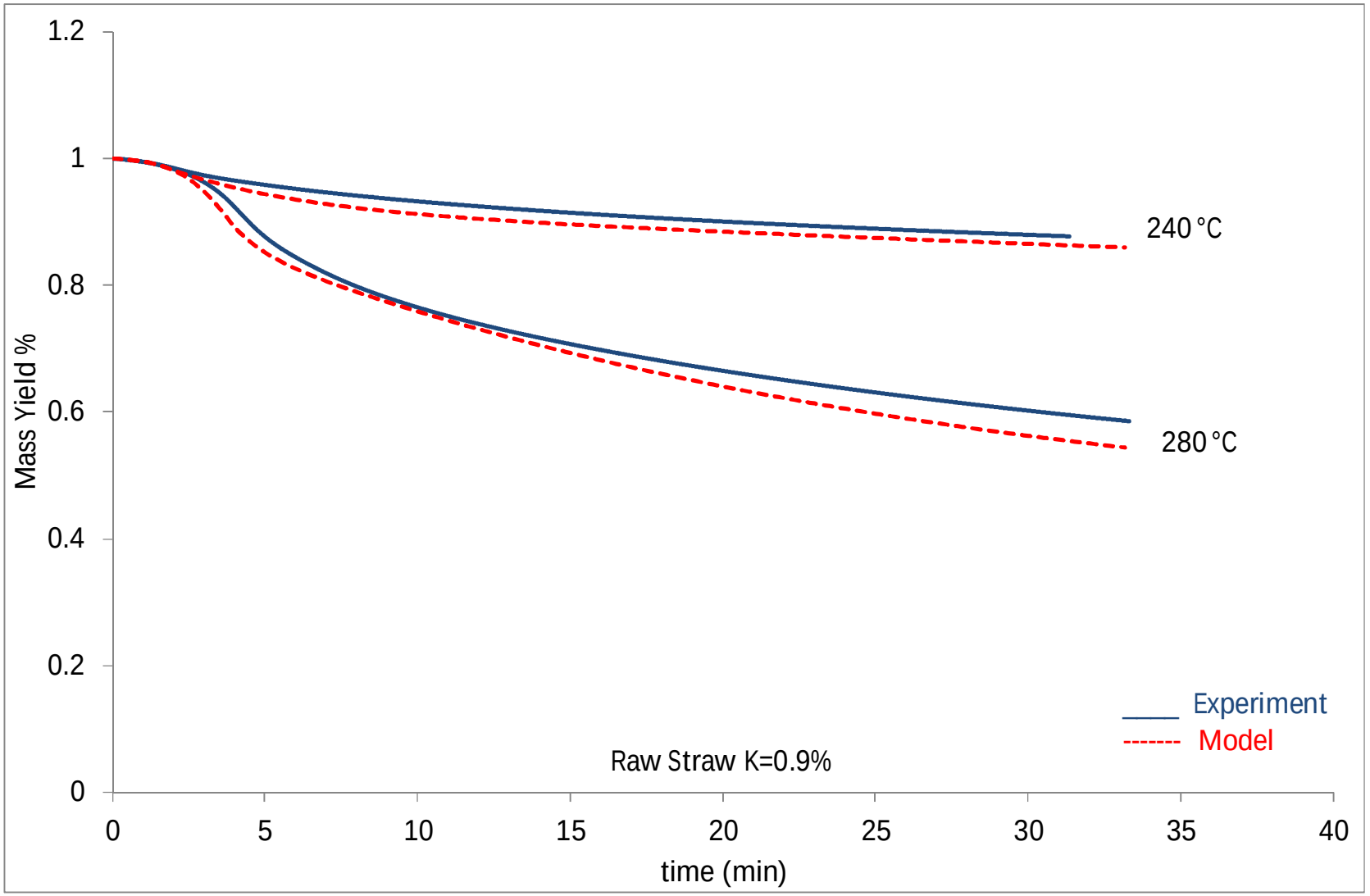
- Spruce wood with different levels of doping torrefied at 5 temperatures
- Rate constants determined for a 2 step kinetic model
- Pre-exponential factors found to be a linear function of K
- Kinetic model found to describe kinetics torrefaction of other fuels tested: aspen, straw and miscanthus

Spruce Torrefaction – Effect of K



Khazraie Shoulaifar, Fuel, 2016

Effect of K on Torrefaction - Modeling



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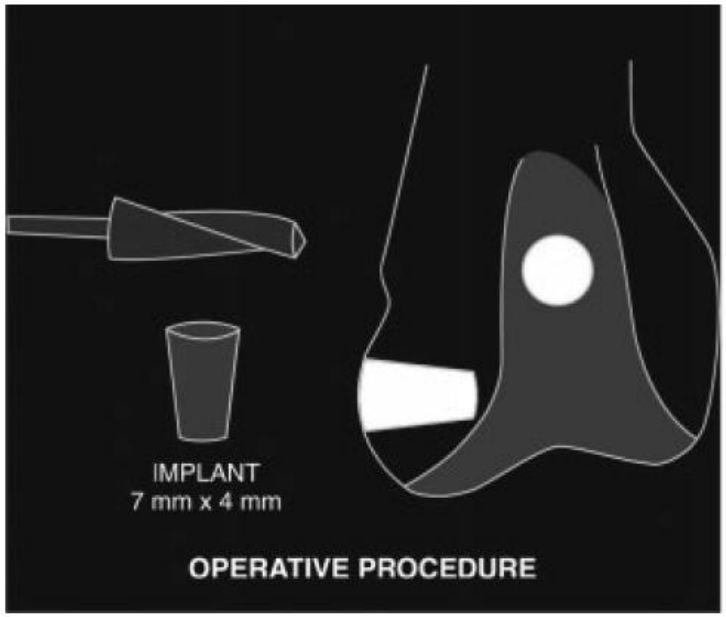
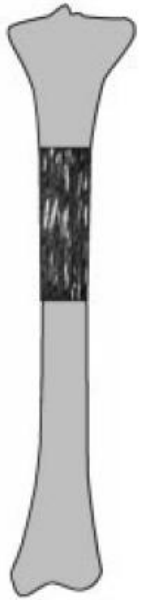
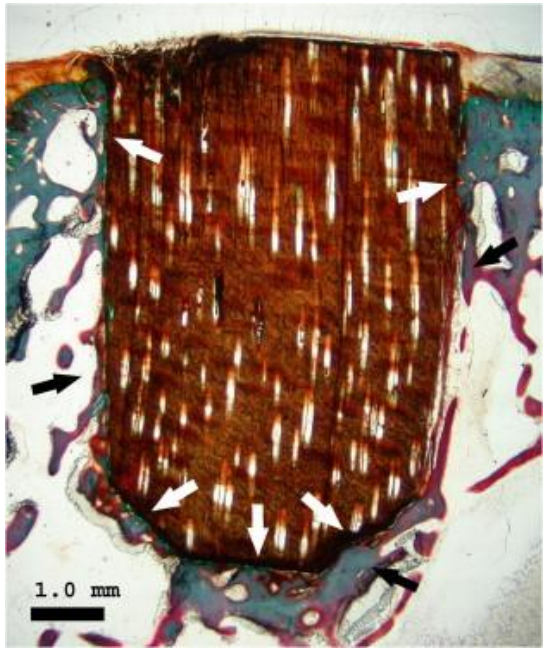
Possible Material Applications of Heat Treating Doped Wood

- In vivo studies in rabbit femurs have shown that heat treated wood is osteoconductive, whereas untreated wood was not [Rekola et al.]
- The heat treated wood was not well characterized

Implanting heat treated-wood in rabbit's bone







Rekola, J. et al. The effect of heat treatment of wood on osteoconductivity. Acta Biomaterialia 5 (2009) 1596–1604

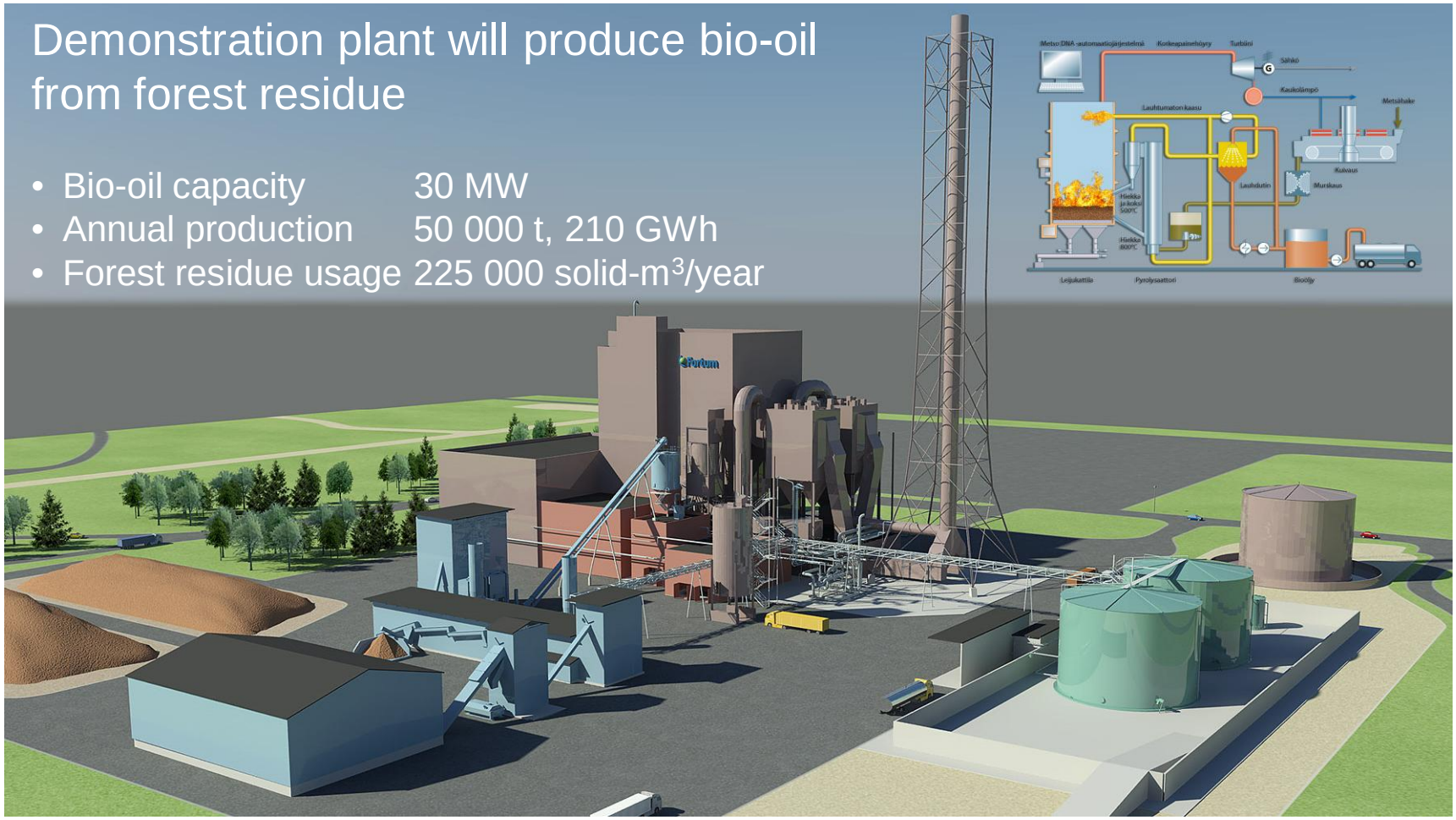
Possible Use of Alkali

- One torrefaction study found an increase in carboxyllic acid sites after torrefaction of K_2CO_3 doped biomass
- Is it possible to increase the number of anionic sites by torrefying doped wood?
- These sites could be used to bind cations such as Ca for biomaterial applications...
- we start analyzing samples this week...

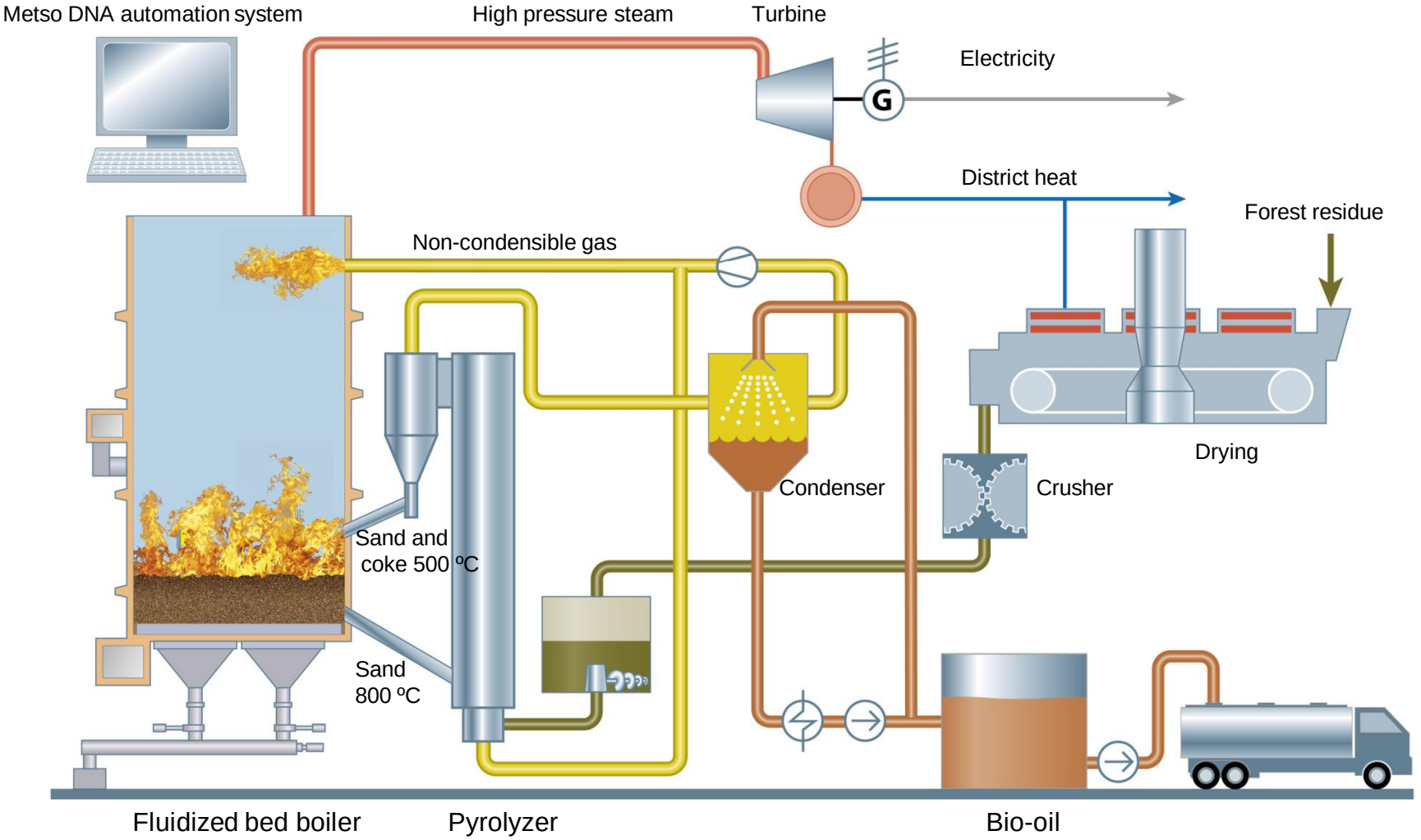
Examples

- Ca in pulping
- Role of alkali in thermal conversion:
  - Torrefaction
  - Pyrolysis
  - Low Temperature Corrosion in Biomass Boilers

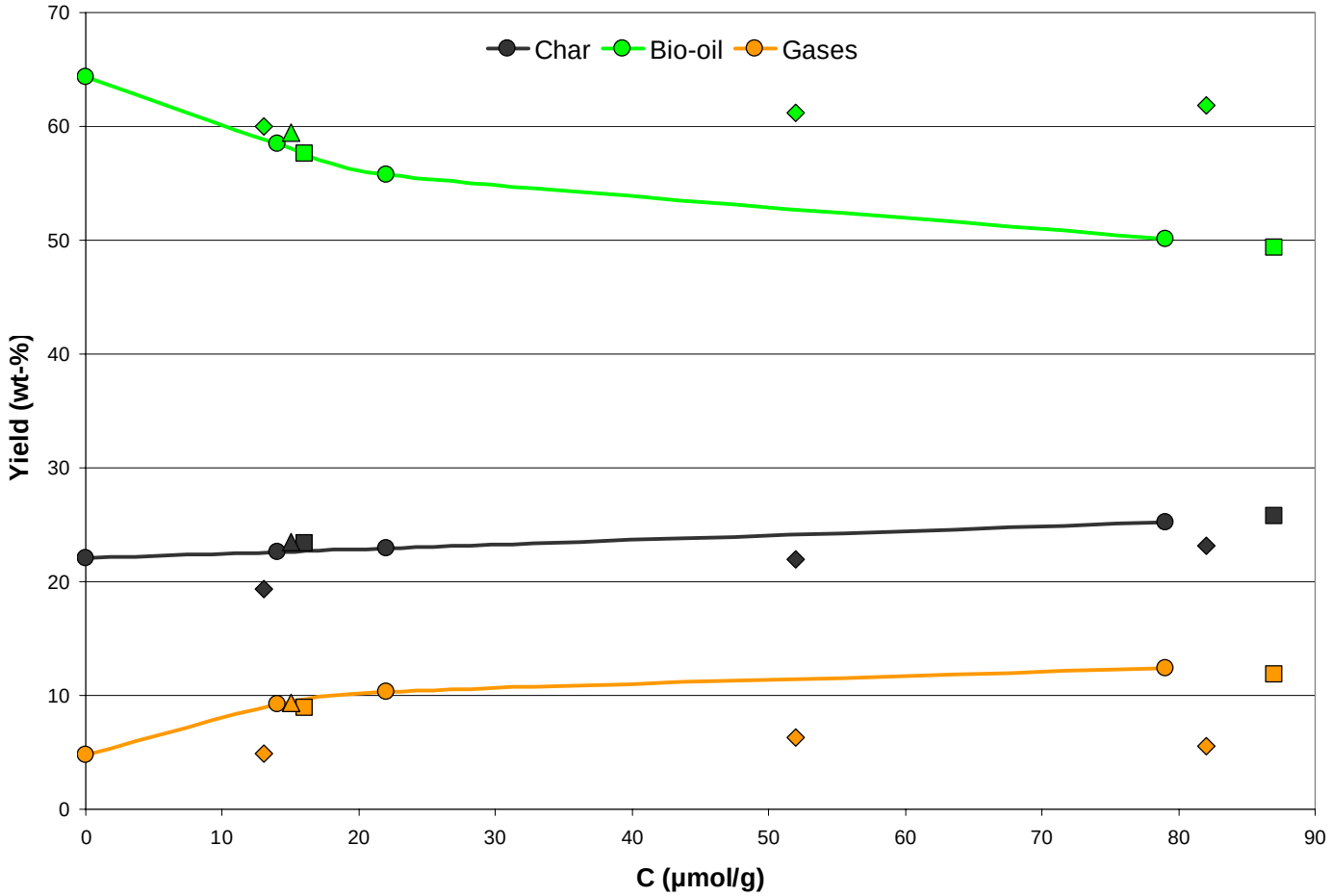
Metso supplies a bio-oil production plant to Fortum Joensuu power plant in Finland



Bio-oil production technology



Influence of Metal Concentration in Wood on Distribution of Pyrolysis Products



K as circles (●) Na as squares (□), Ca, Mg, Mn as diamonds (◊)

Aho, A., Bioresource Technol. 2013

Examples

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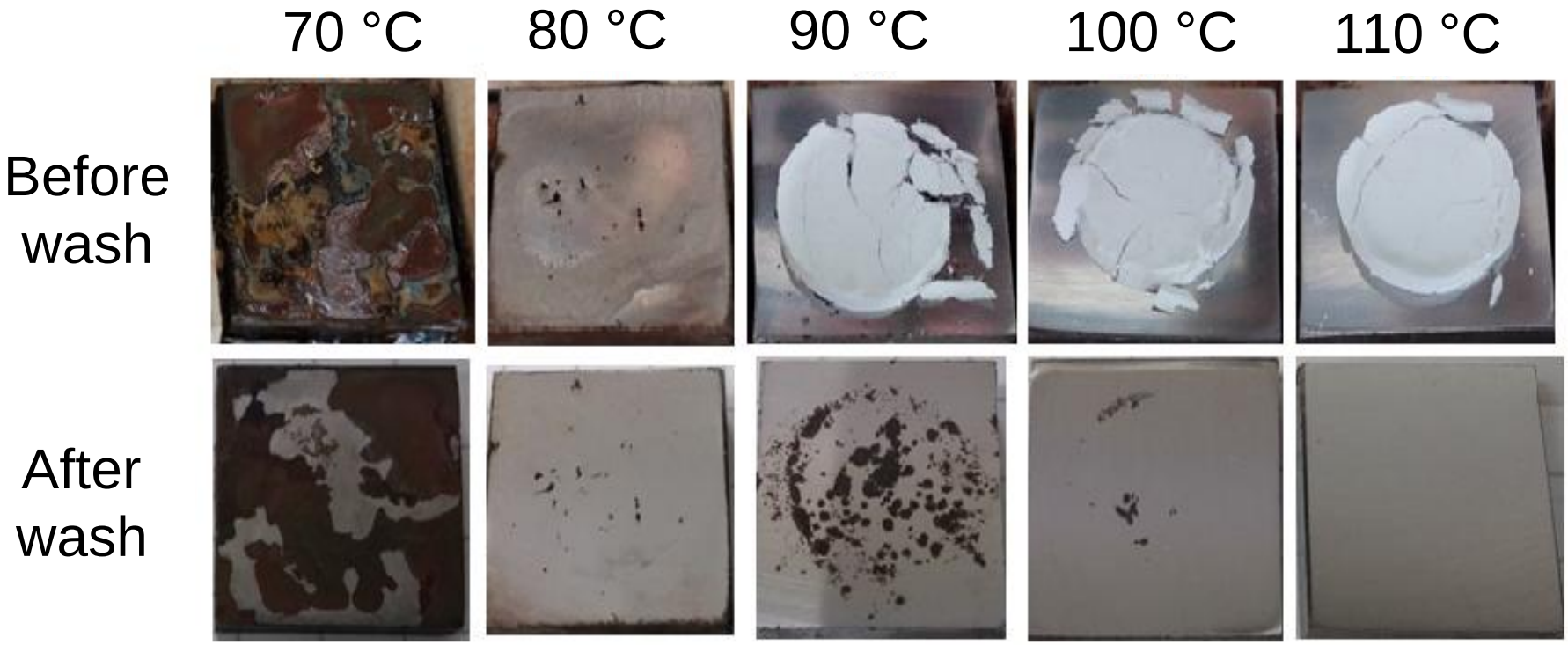
Ash Forming Elements – Low Temperature Corrosion

- New research indicates that the lowest acceptable temperature of flue gas determined by hygroscopic nature of salts
- Every 10 °C of heat recovered from flue gas ≈0.5% improvement in thermal efficiency
- Industry will be able to improve biomass boiler effeciency by 2-3%

Salt: Precipitator Ash 1

H_2O: 27 vol-%

Exposure: 24h



Summary

- Inorganic chemistry plays a role in most industrial processes for biomass and waste
- New interesting questions continuously arising from industry as technology advances

Thank you!
Questions?