Predicting Ash Behavior in Biomass Co-combustion – A Balance Between Chemistry and Mass Transport

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GTT-Technologies 9th Annual Workshop June 20-22, 2007

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Conclusion

- equilibrium calculations are very useful to **predict** ash reactions in combustion and gasification systems
- global equlilibrium analysis (GEA) can be used to predict over all **stabilities** and and **speciation**
- local equilibrium application (LEA) must be used when **mass transport** is limiting
- process **analysis** and **measurements** needed
- eq-**submodels** can be used in boiler modeling
- reliable **data** important – big systems

Topics

- **combustion modeling**
- **fuels are different**
- **combustion devices are different**
- **co-combustion effects**
- **examples**
  - burning particle
  - fluid bed agglomeration
  - deposits on heat transfer surfaces

Goal

to **predict** chemical reactions important for

- boiler design
- boiler operation

- thermal efficiency
- availability
- deposits
- corrosion
- emissions, etc.

Fuels are getting **worse** every day

Higher **performance** needed every day

Need to combine

mass balance models
process models
flow models
particle formation models
chemical equilibrium models
chemical kinetics models

macroscopic models (eg. turbulence)
microscopic models (eg. diffusion)

Fuel ash chemistry is complex

Fuel ash chemistry is complex

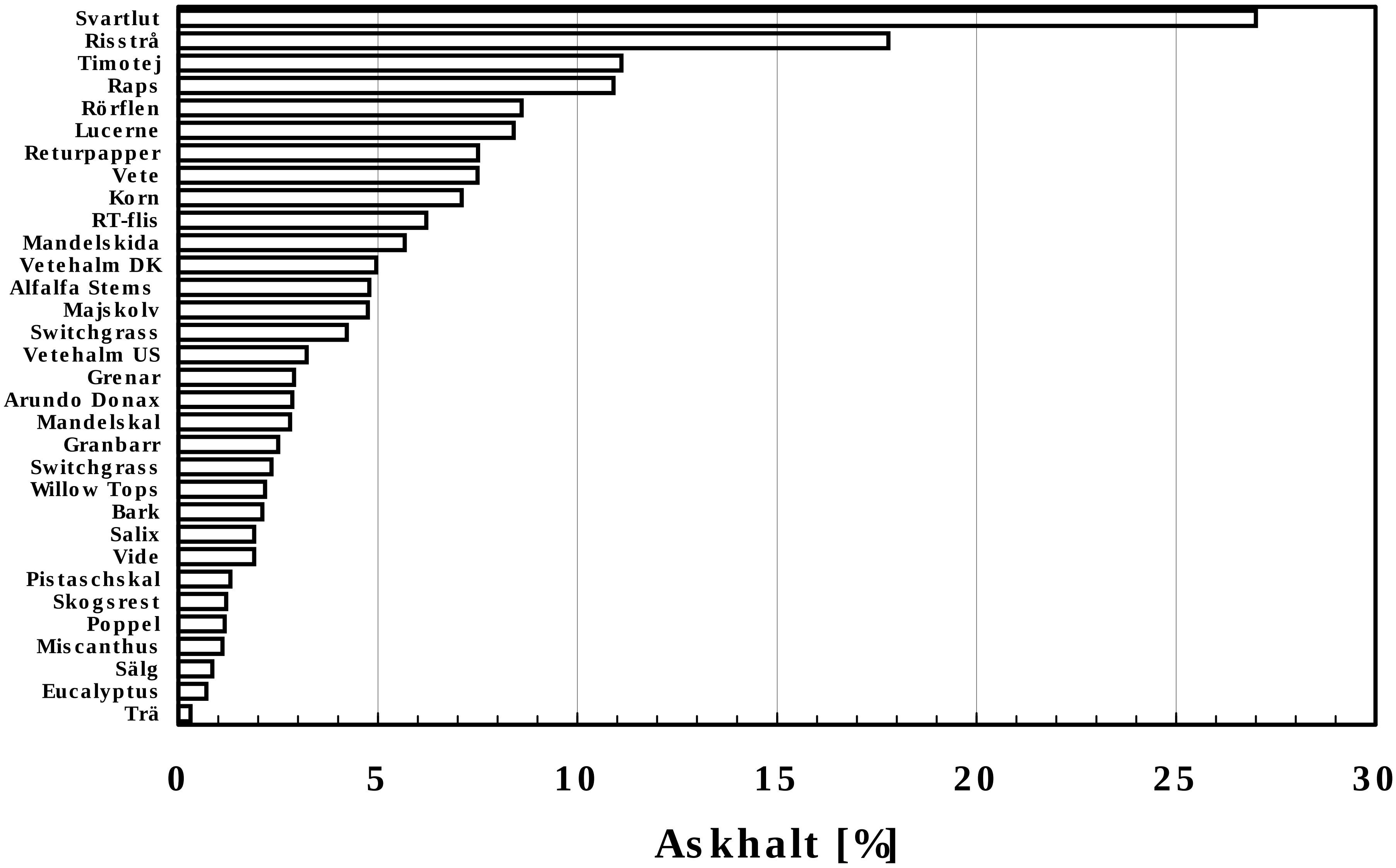
Organic part
C-H-O

Major ash components
Ca, K, Na, Mg, Si, Al Fe, S, Cl, P

Minor ash components
As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Tl, V, Zn

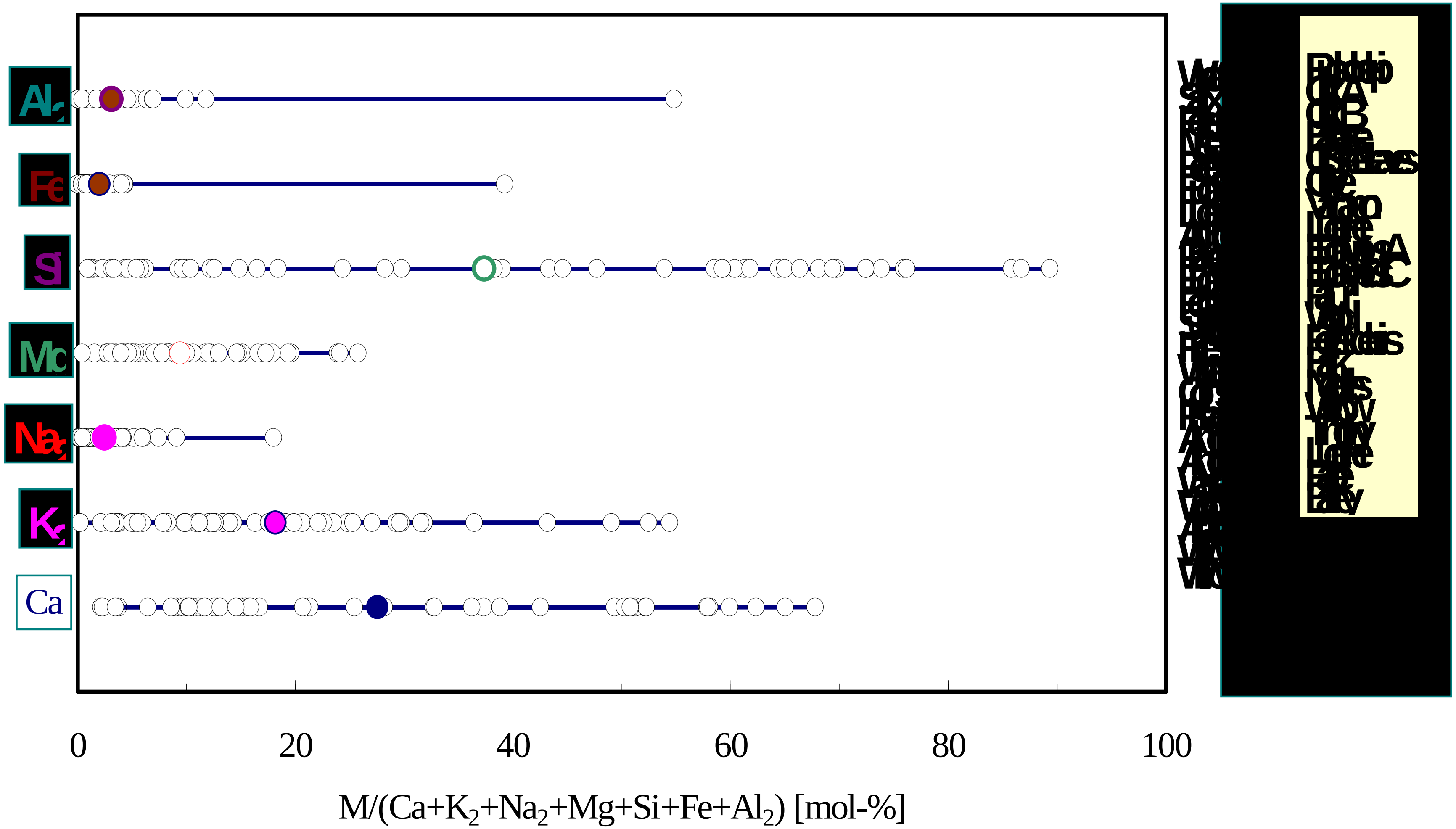
Fuel nitrogen, N

Ash content varies



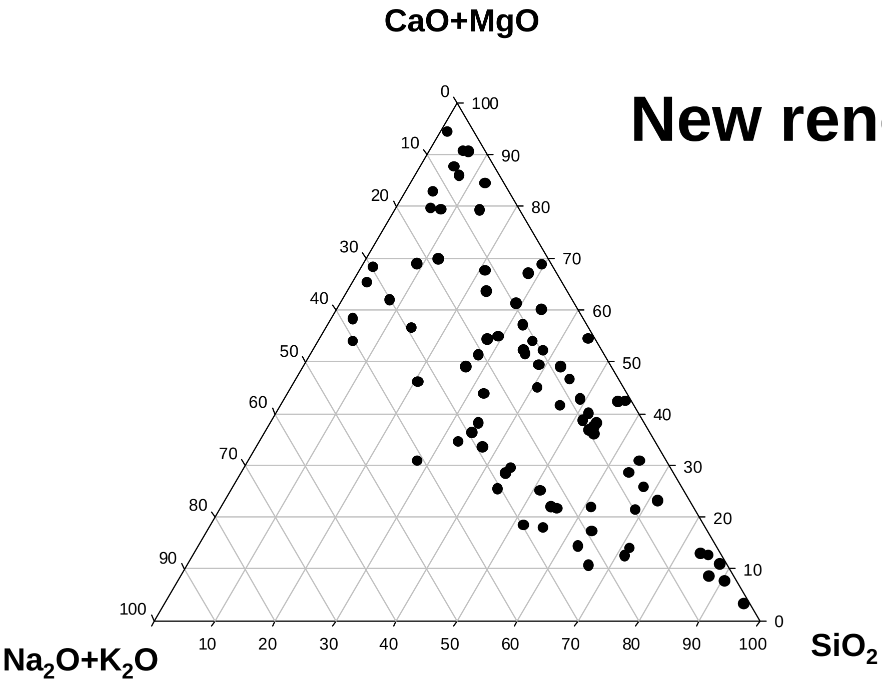
Main ash composition

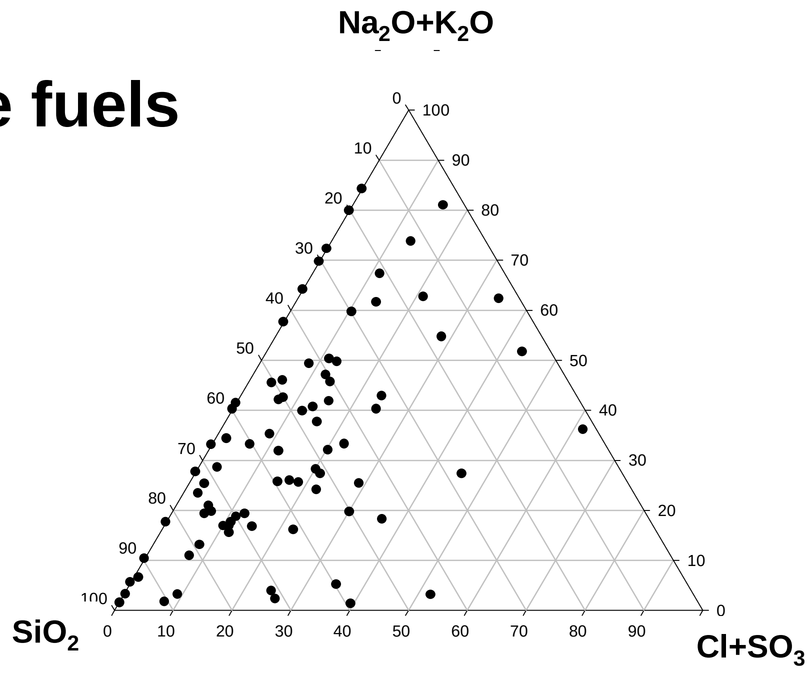
Relative metal concentration in various energy biofuels

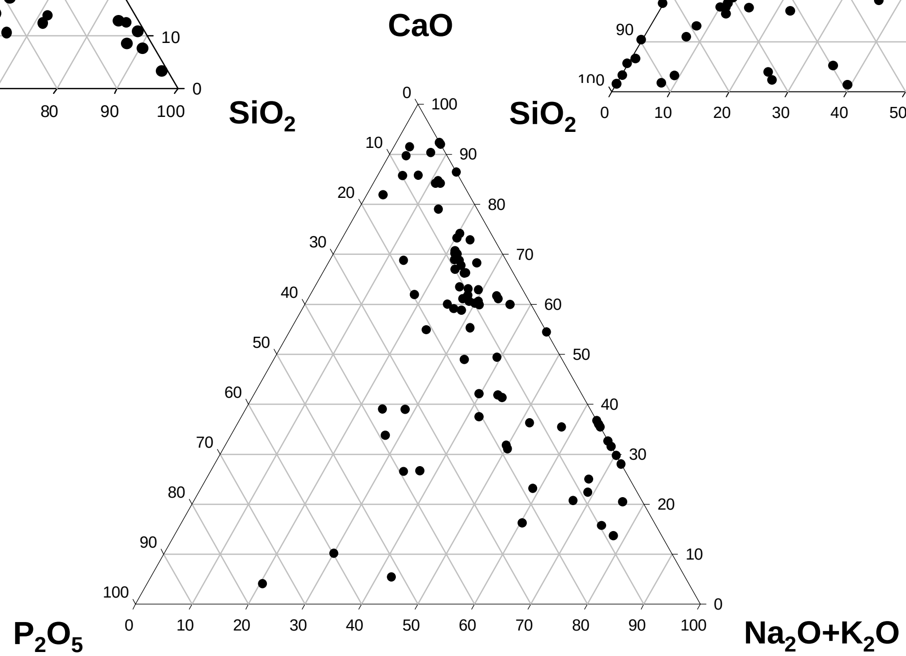


Main ash composition

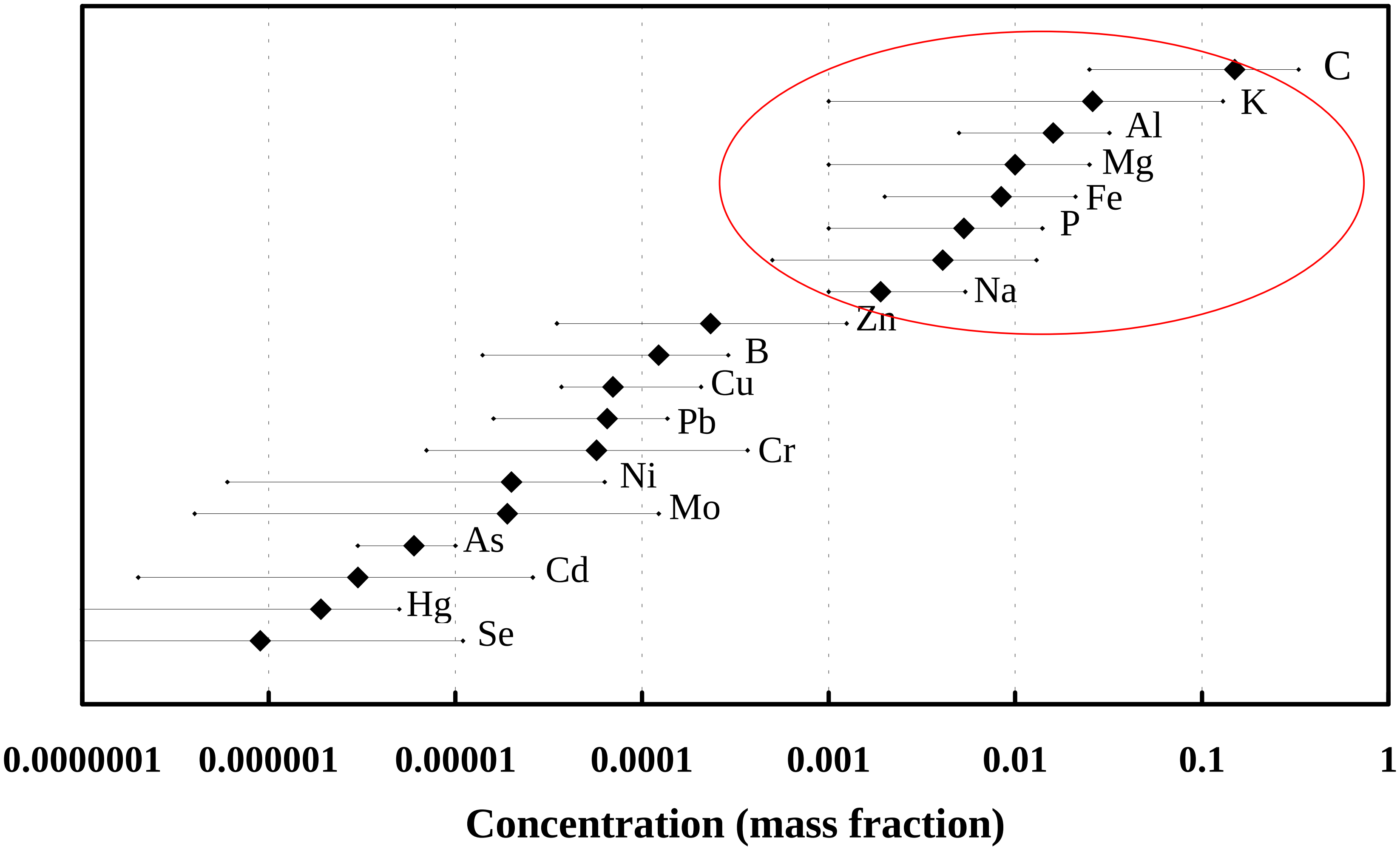
New renewable fuels



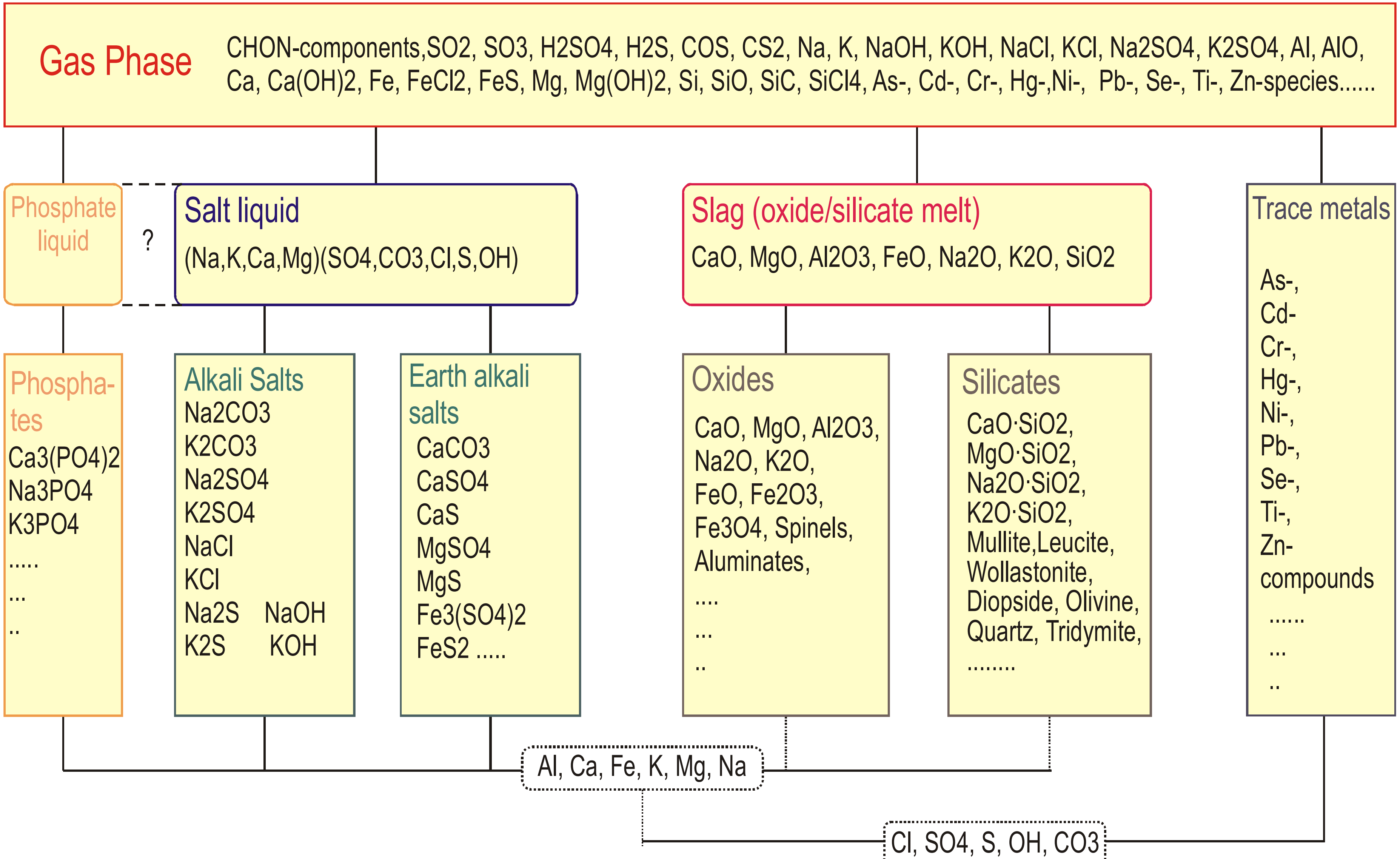




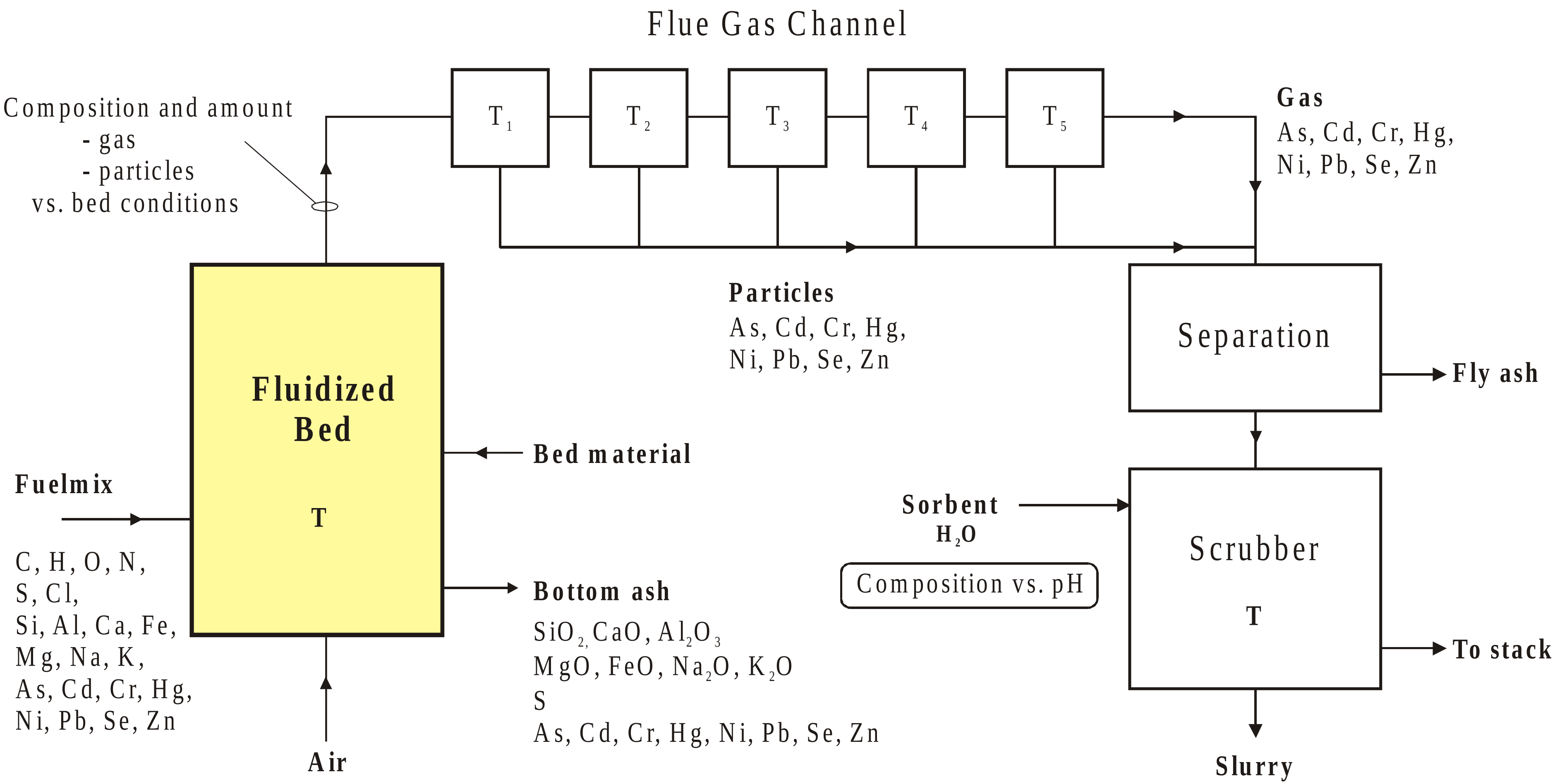
Metals in 37 wood species



Chemistry of ash forming elements



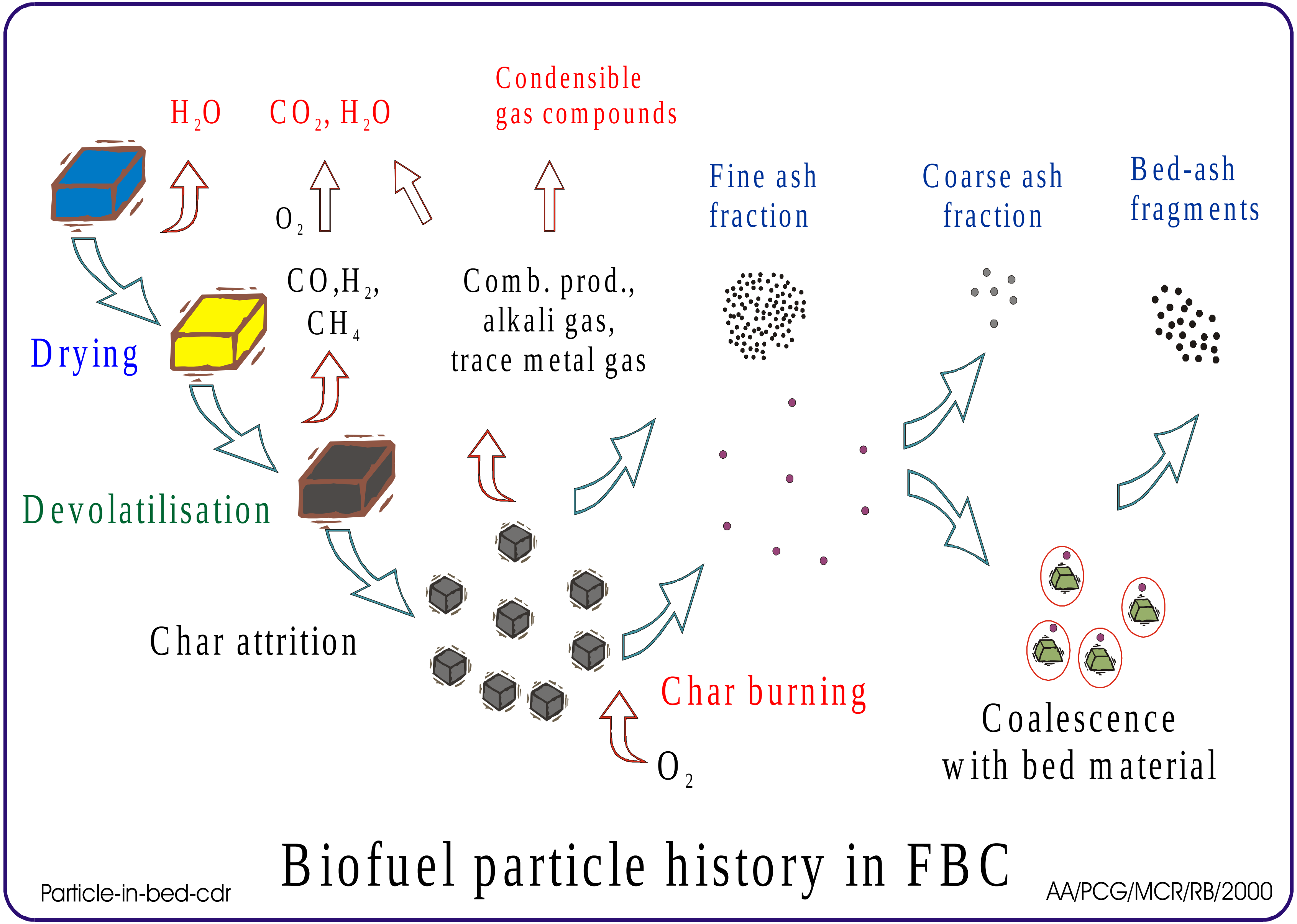
Advanced global equilibrium approach



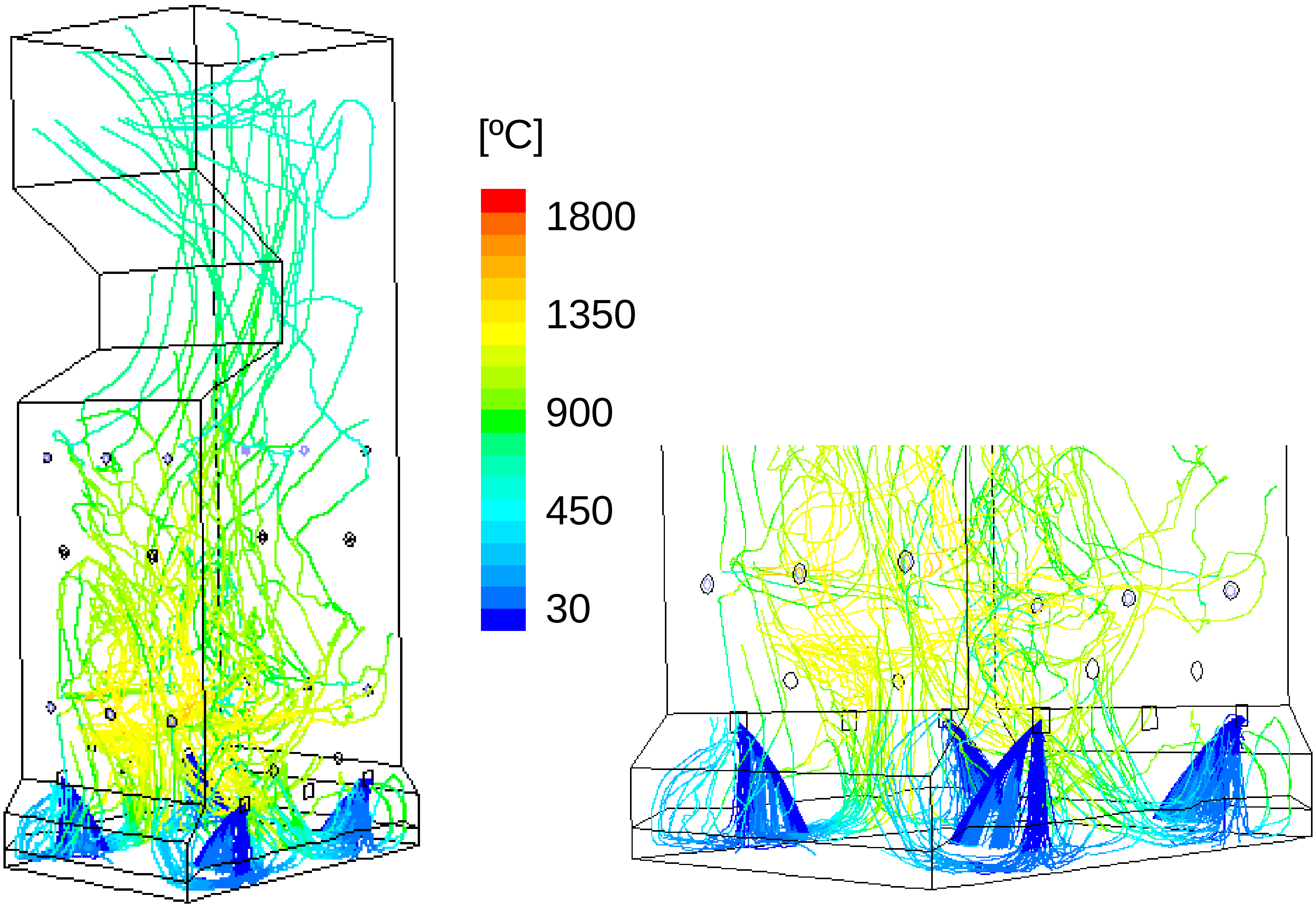
Toxic metal predictor

Particles and devices

ETPC omplicated particle time-temperature history



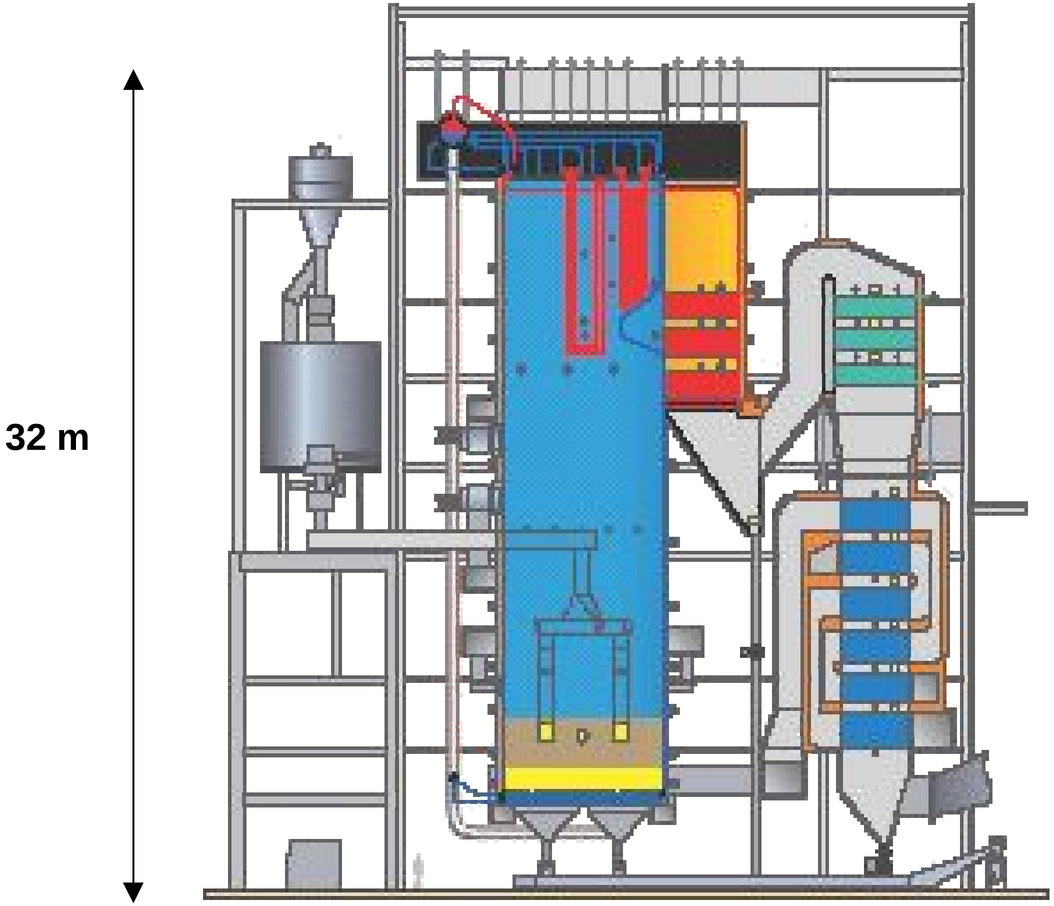
Peat/Ash Particle Movement – f(T)



Multifuel bubbling bed (BFBC)

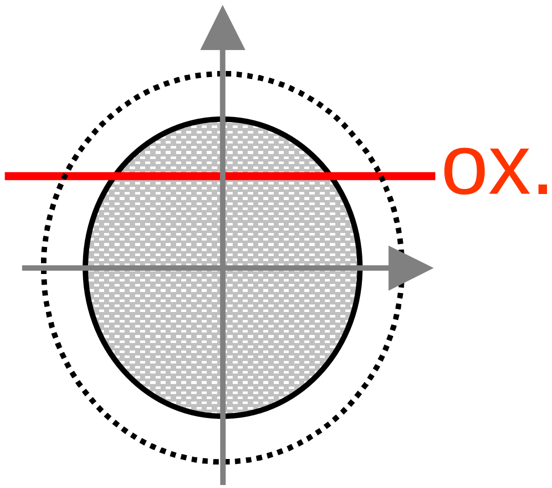
132 MW_{th}, 12.0 MPa/520℃
bark, sawdust, forest residue, peat

Smurfit-Kappa, Piteå, Sweden

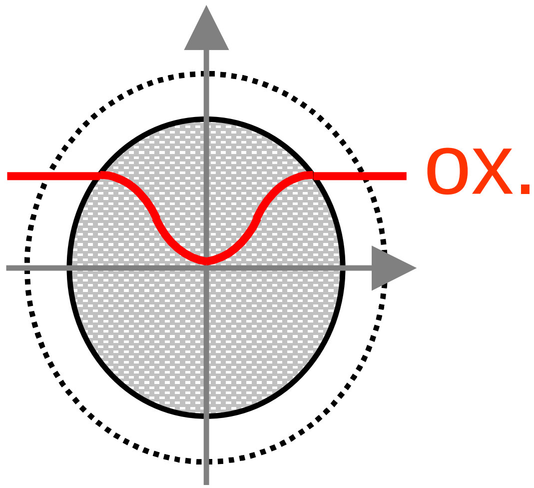


Chemistry

slow chemistry, low T

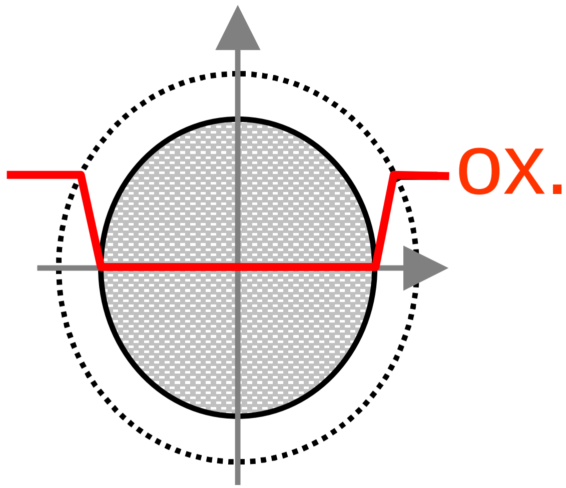


Pore diffusion

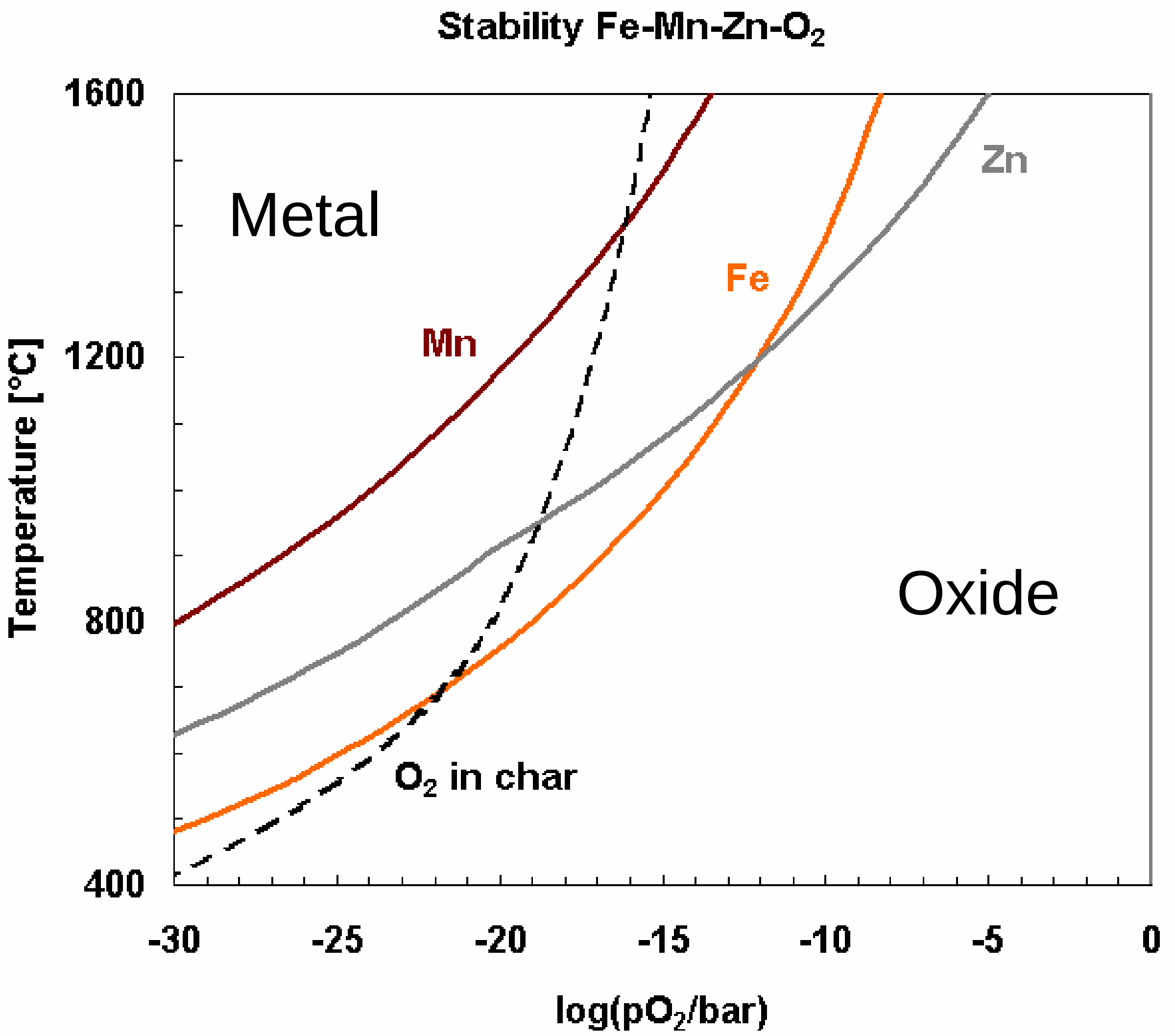


External mass transfer

fast chemistry, high T



Redox processes in char particle



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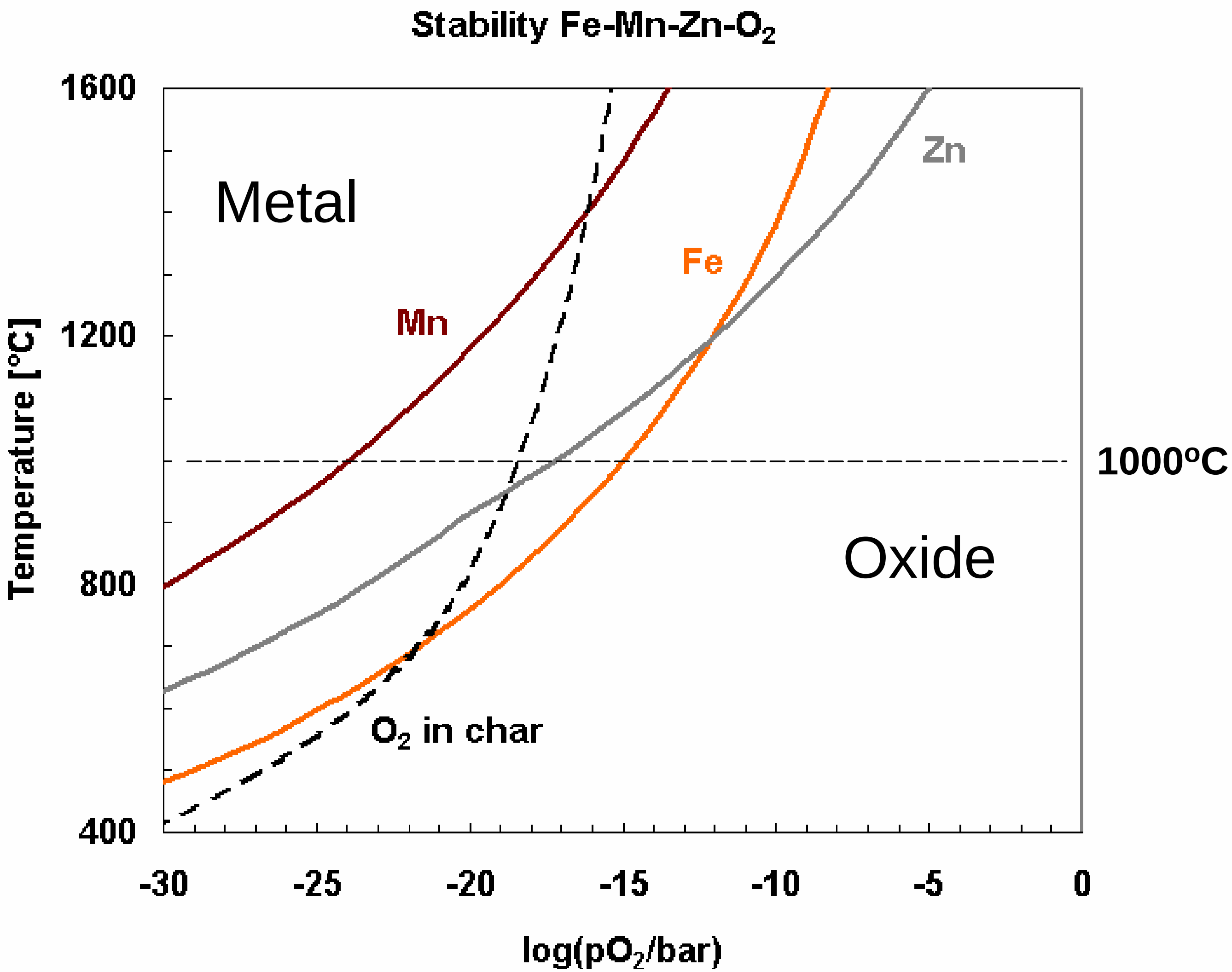

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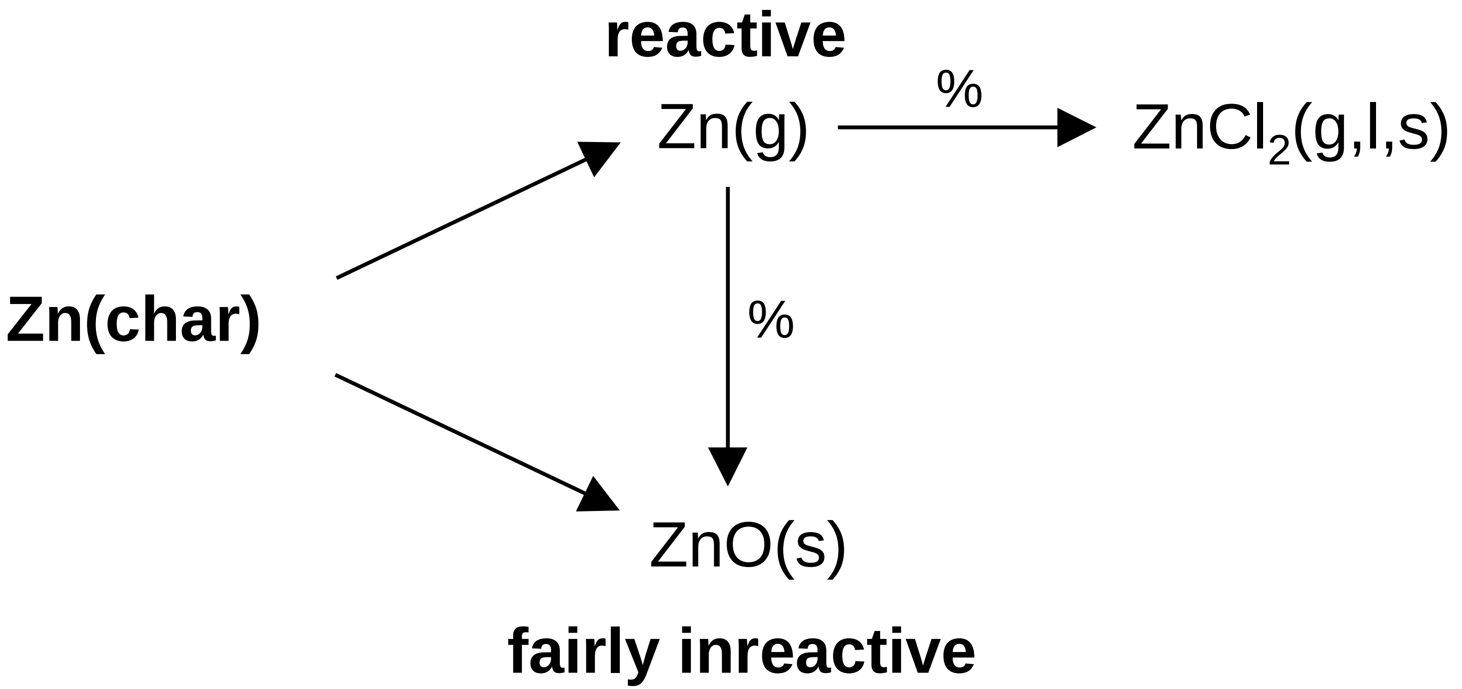

Bed agglomeration

Multifuel bubbling bed (BFBC)

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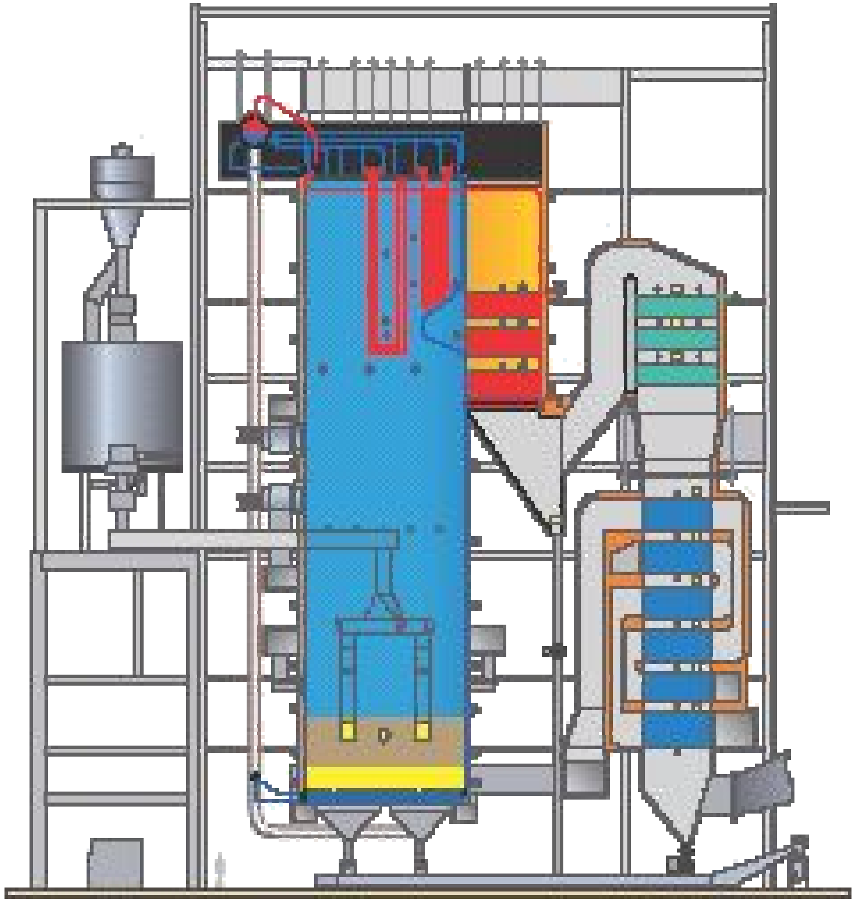
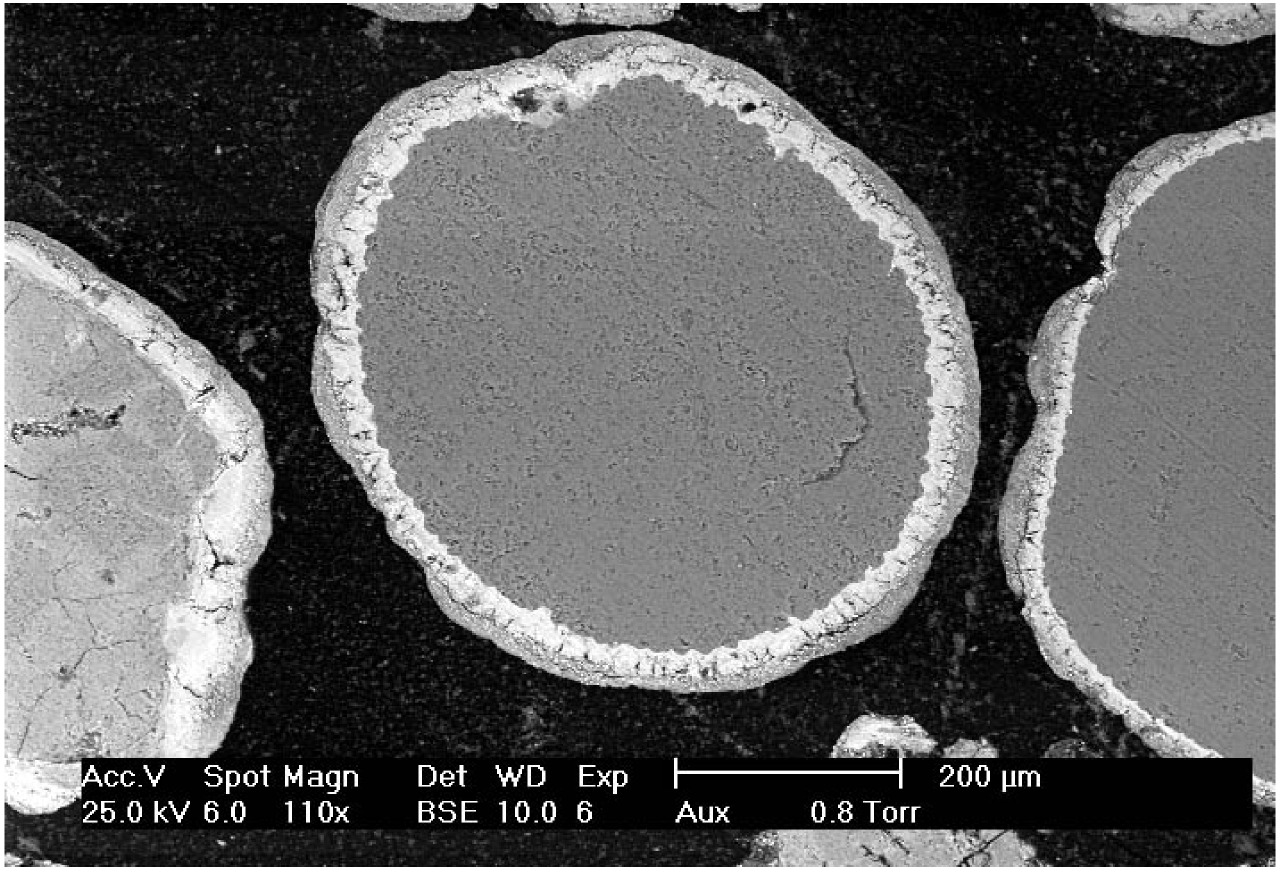
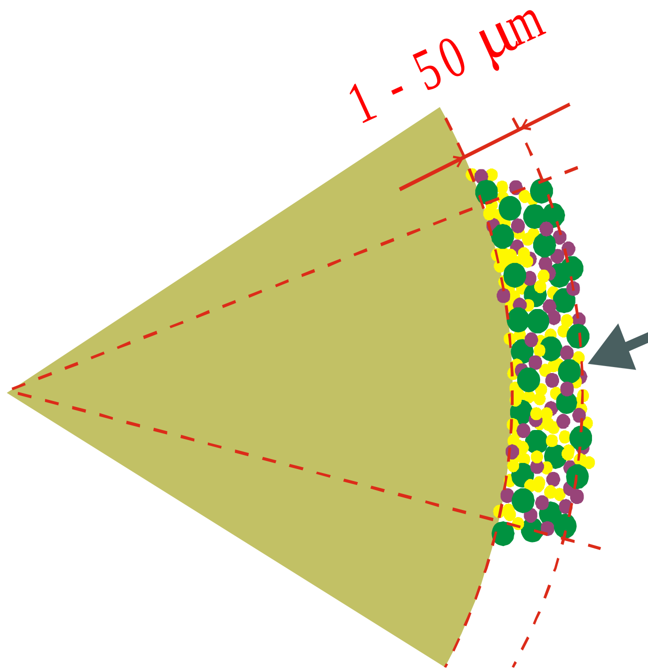
Smurfit-Kappa, Piteå, Sweden



Sand bed particle after 33 days - Biomass in BFBC



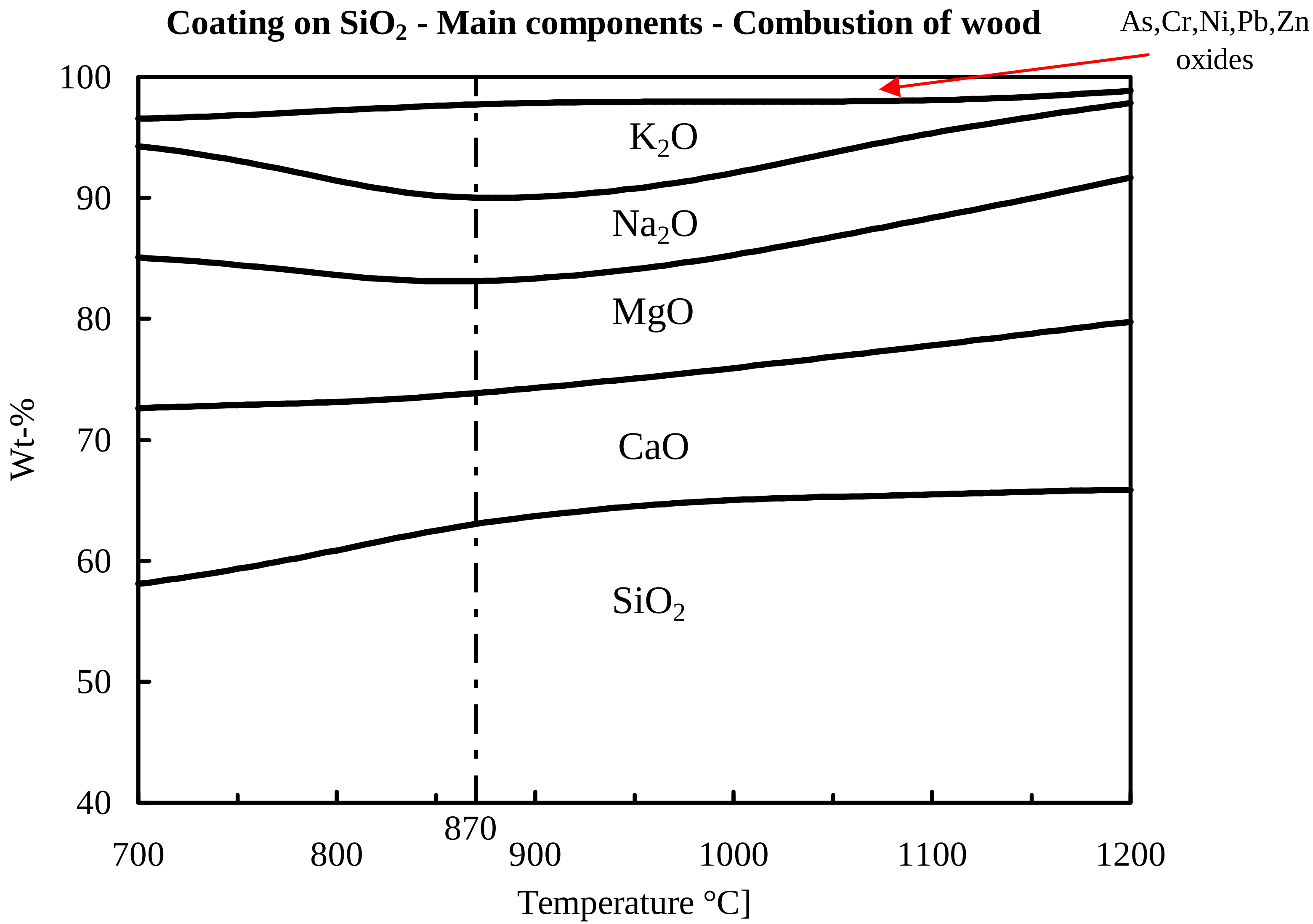
Coating composition



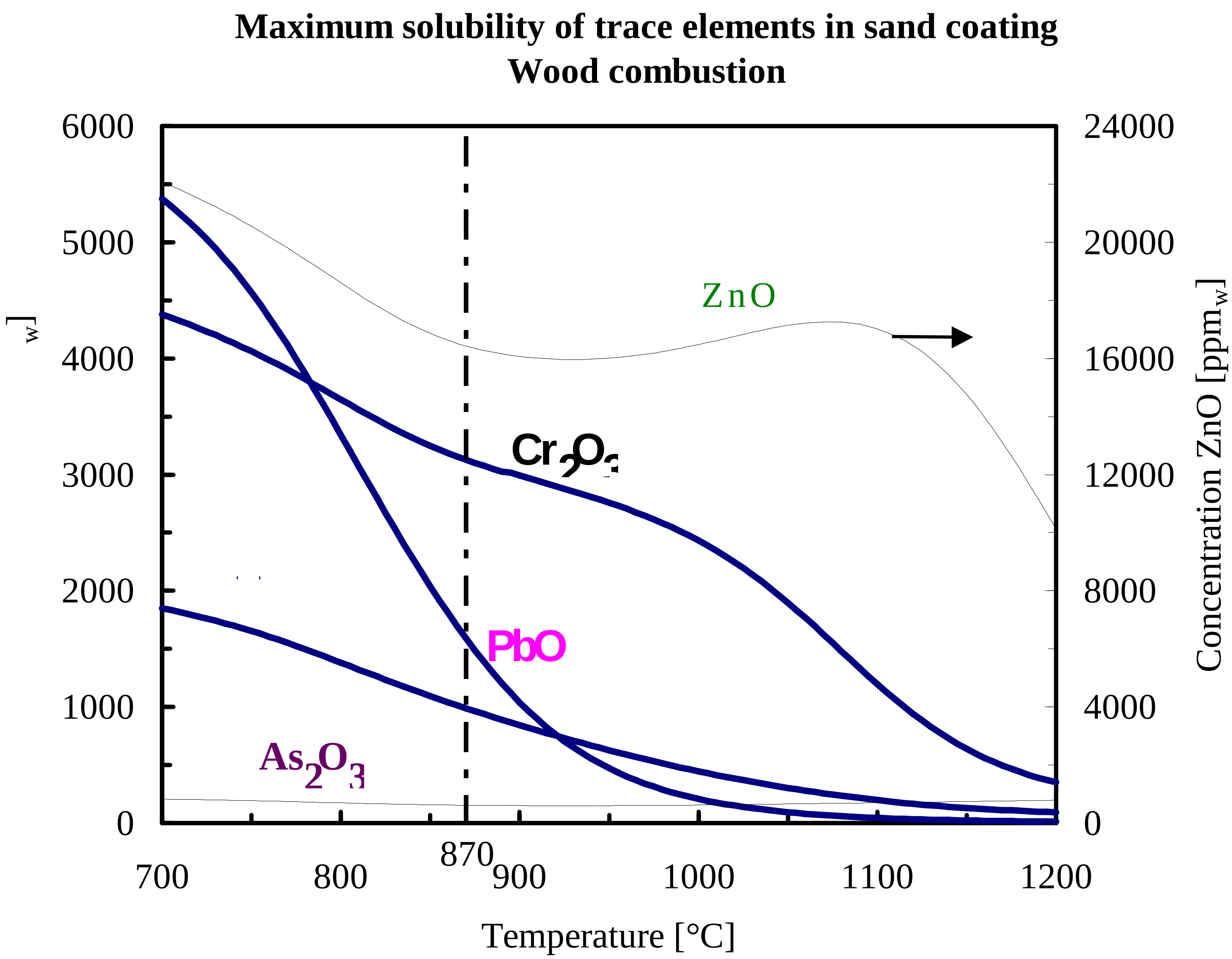
	wt-%
SiO_2	63
CaO	15
K_2O	10
P_2O_5	4
MgO	3
Al_2O_3	3
Na_2O	1

- transport to the surface
- gas diffusion in cracks
- solid and liquid diffusion
- mechanical attrition

Oxide layer composition



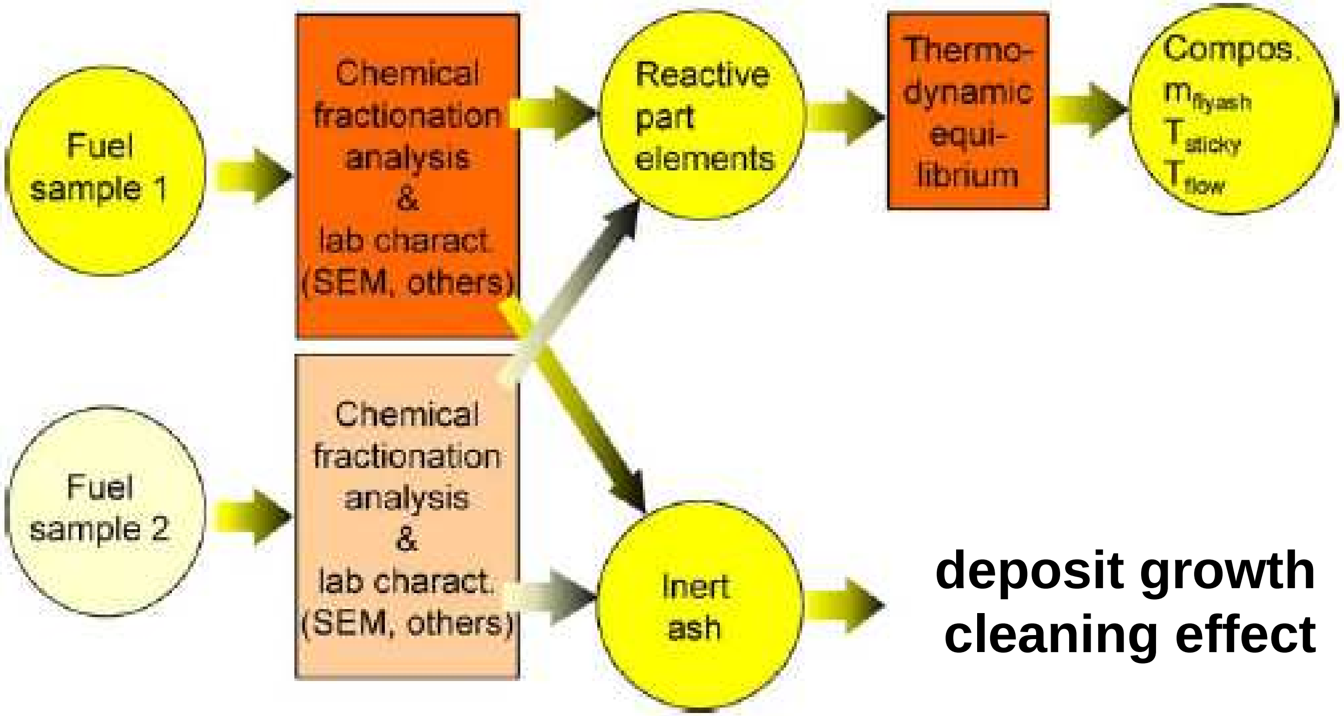
Trace metal solubilities



Co-combustion and deposits

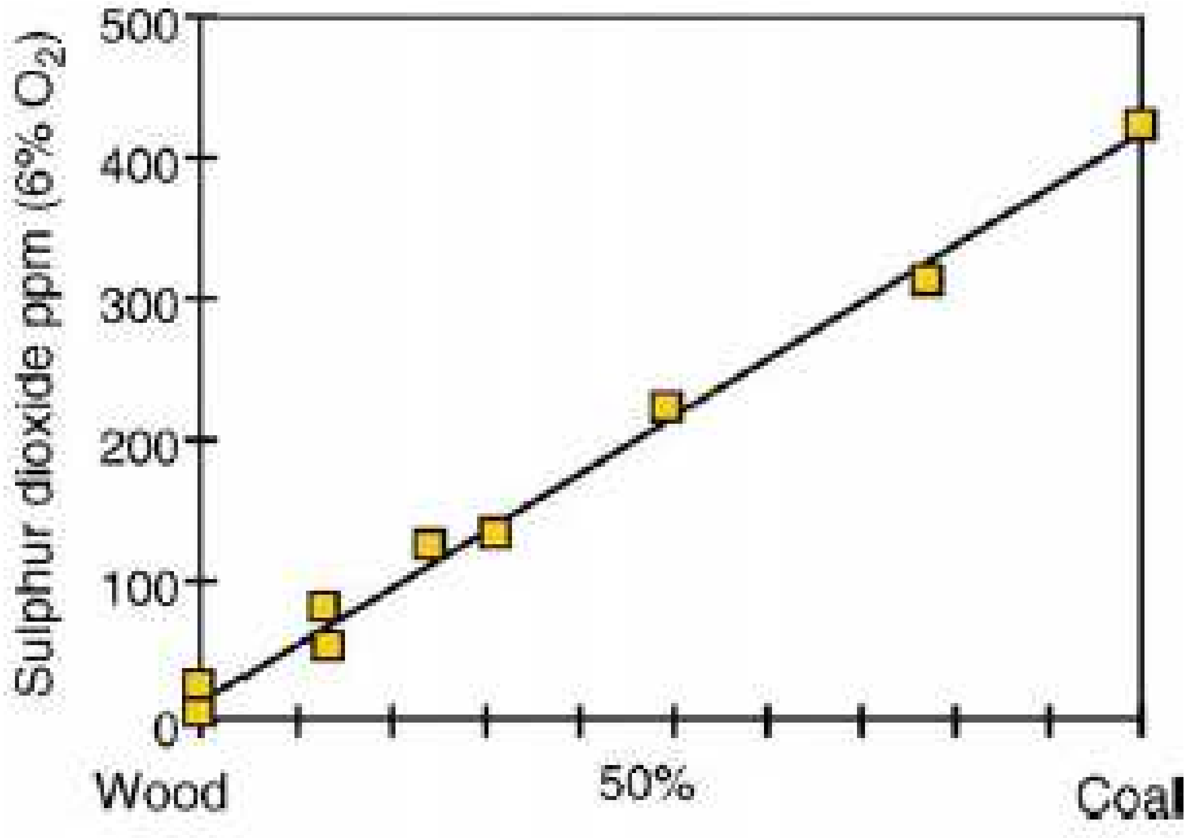
Ash predictor for co-combustion

initial deposition



deposit growth
cleaning effect

SO_2 emissions 12 MW CFBC

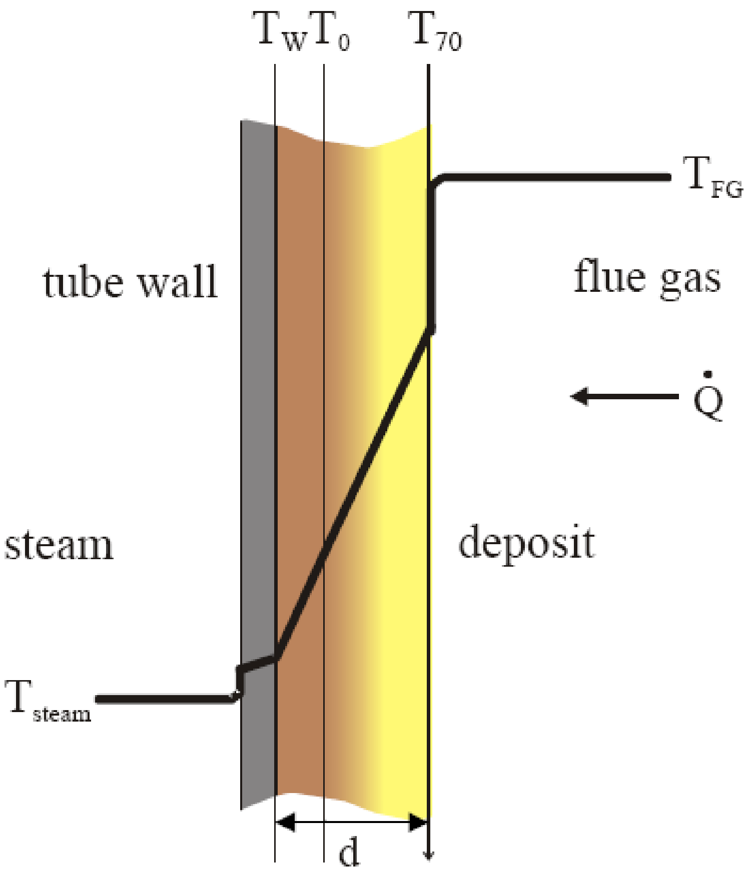


Deposition - corrosion

Superheater deposit

Tube corrosion

Deposit steady state thickness



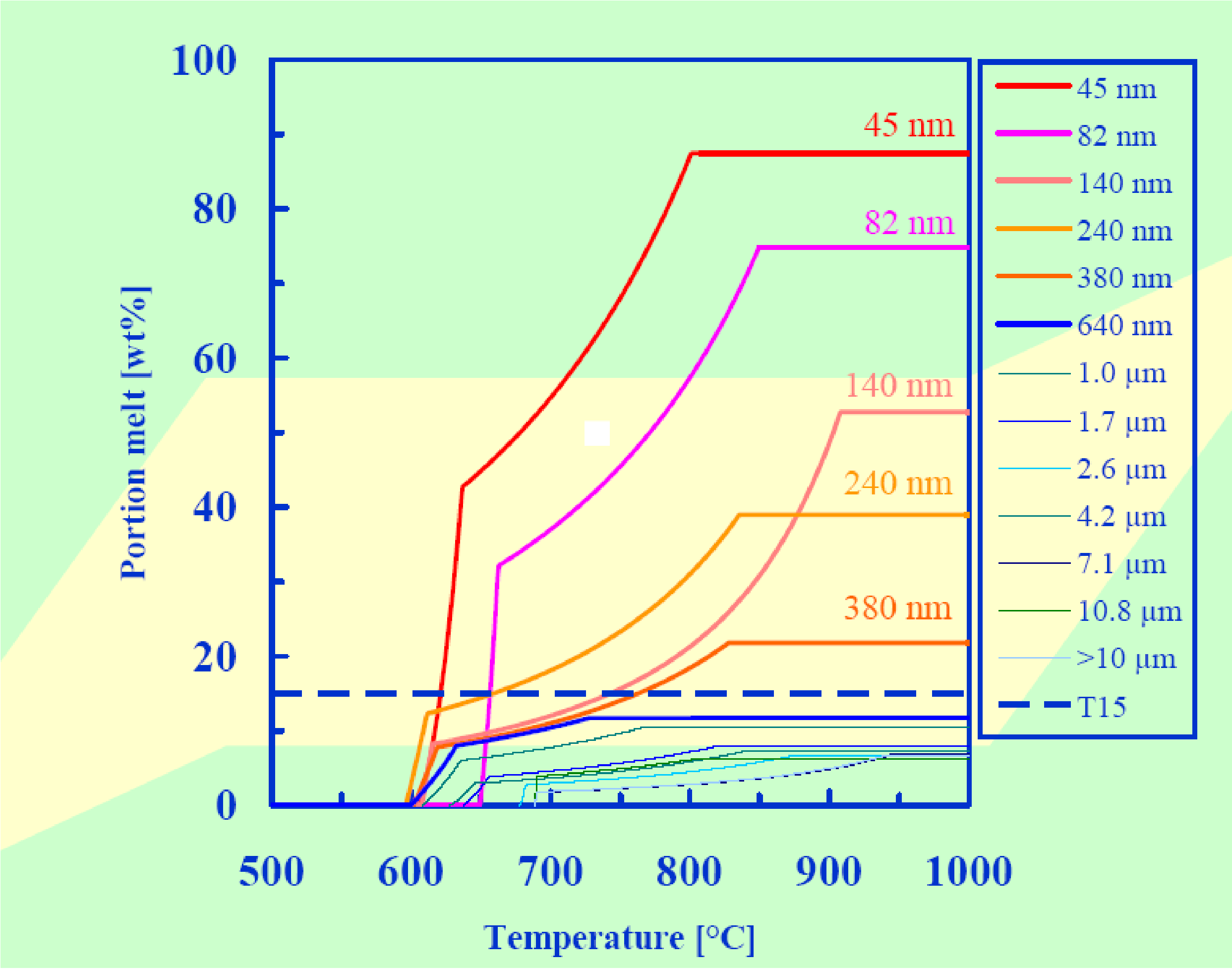
Steady-state smelt layer thickness [mm]

$$d = \frac{\lambda \cdot (T_{70} - T_{Wall})}{\alpha \cdot (T_{SG} - T_{70}) + \sigma \cdot \varepsilon \cdot (T_{SG}^4 - T_{70}^4)} \cdot 1000$$

d = steady state thickness [mm]
λ = heat conductivity of deposit [W/mK]
α = heat transfer coefficient [W/m^{2}K]
σ = Stefan-Boltzmann constant [W/m^{2}K^4]
ε = emissivity [-]
T_W = wall temperature [K]
T_{SG} = fluegas temperature [K]
T_{70} = deposit flow temperature [K]

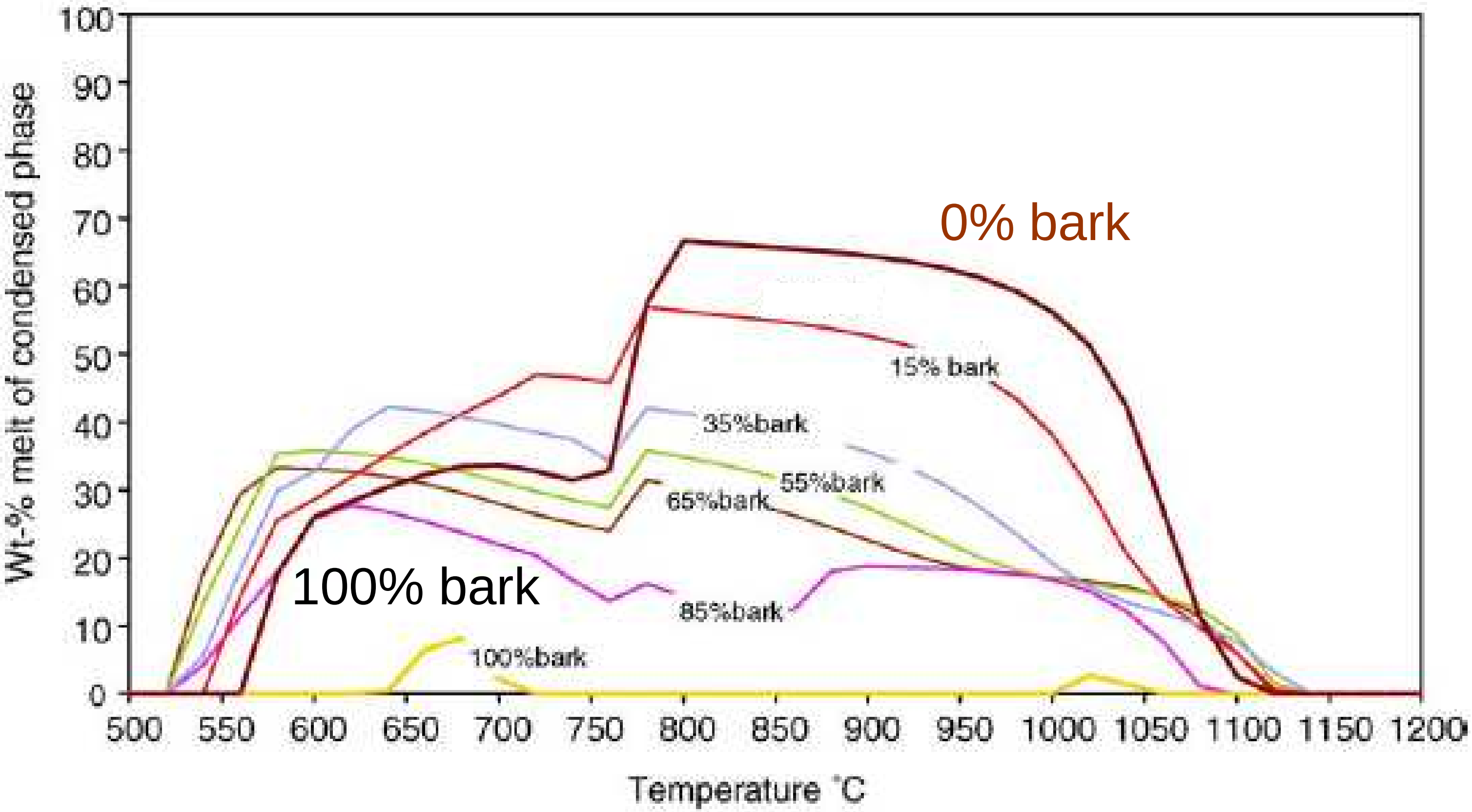
Calculated portion of melt

BFBC – biomass flyash particles



Non-linear mixing behavior

Calculated amount of molten phase bark – rice husk



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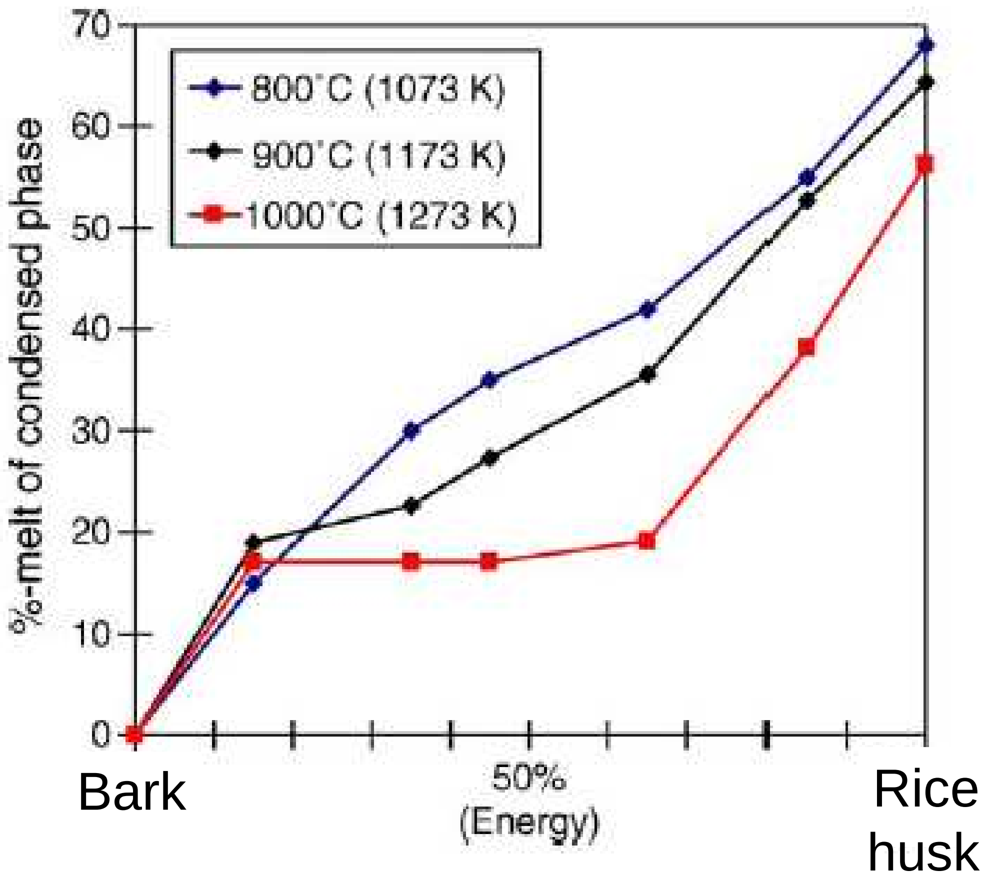
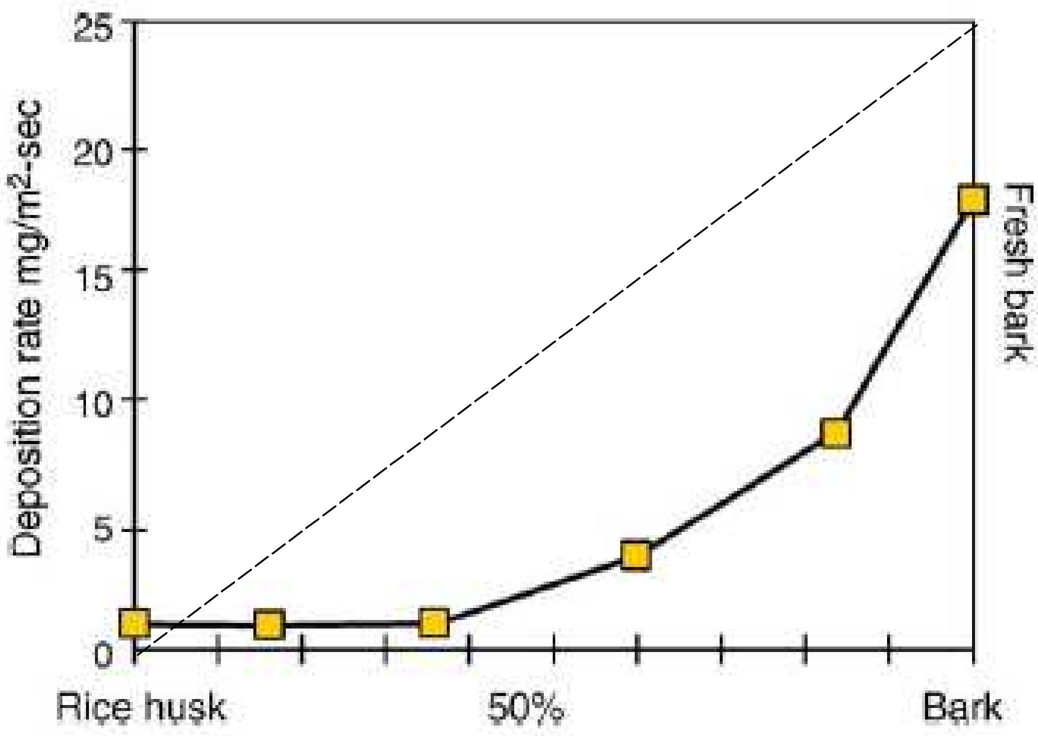


Deposition rate, test rig



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