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Co-combustion in fluidised bed—influence of K, Cl and S

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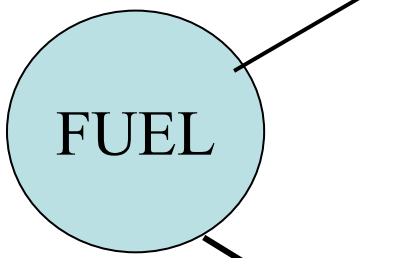
Some background facts

- Co-combustion is an advantageous way to utilise biofuels and wastes
- Fluidised bed is very suitable for co-combustion
- The fraction of fuels is determined by the heat balance of the combustor
- Potassium from biofuels may have a harmful effect on a boiler, especially together with chlorine

Release of ash components from fuel



Volatiles

$KX + HCl \rightarrow KCl$

$KX + SO_2 \rightarrow K_2SO_4$

$KX + CO_2 \rightarrow K_2CO_3$

$KX + Al,Si \rightarrow K,Al,Si$

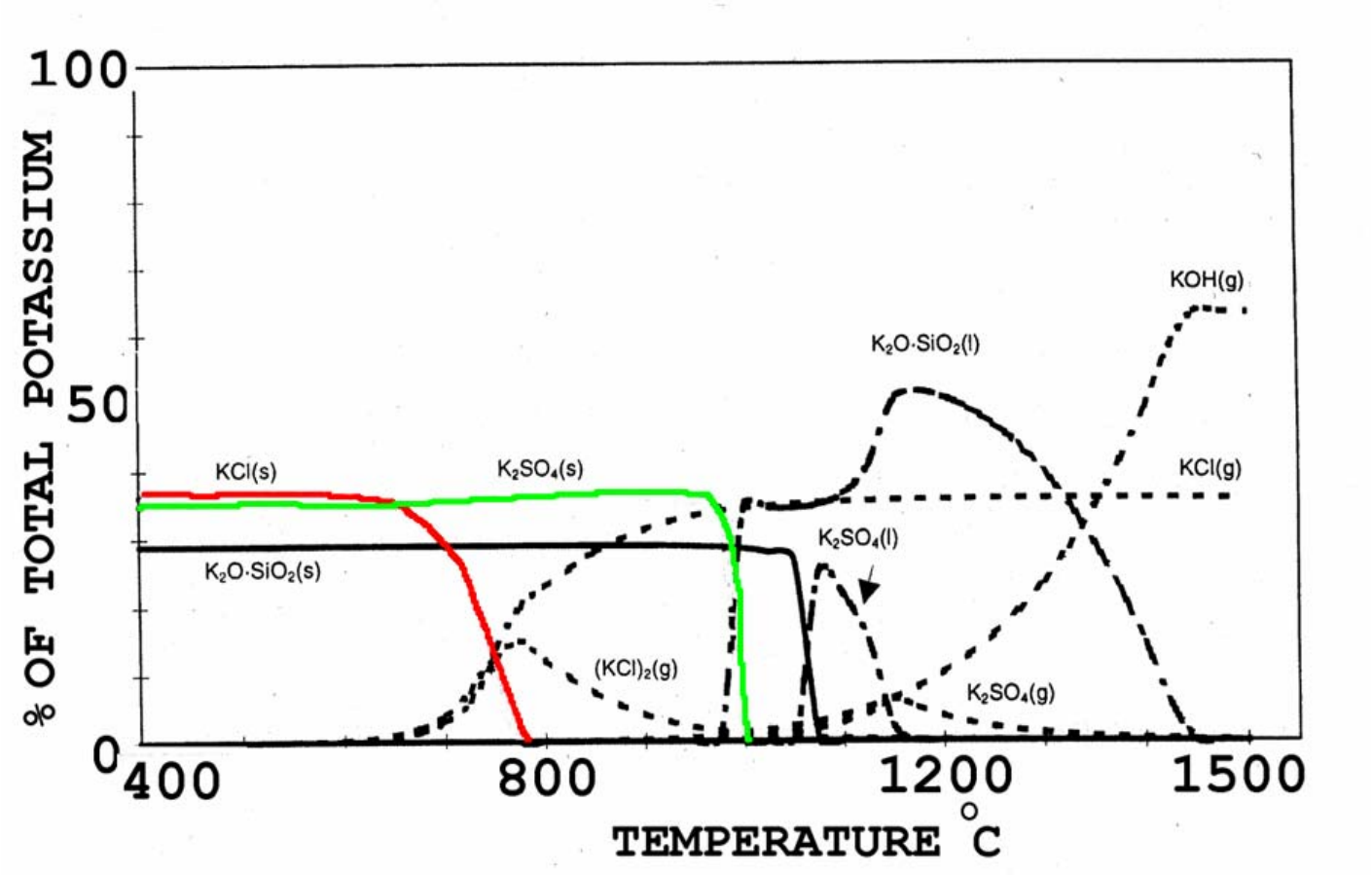
Bound ashes

(K,Na),Al,Si etc., for instance $K_2O \cdot Al_2O_3 \cdot 2SiO_2$

(Cl) predominantly formes HCl

Ash behaviour

Equilibrium calculations give an idea of the form of the ash components. The diagram shows only some potassiun compounds (for conditions of straw firing)

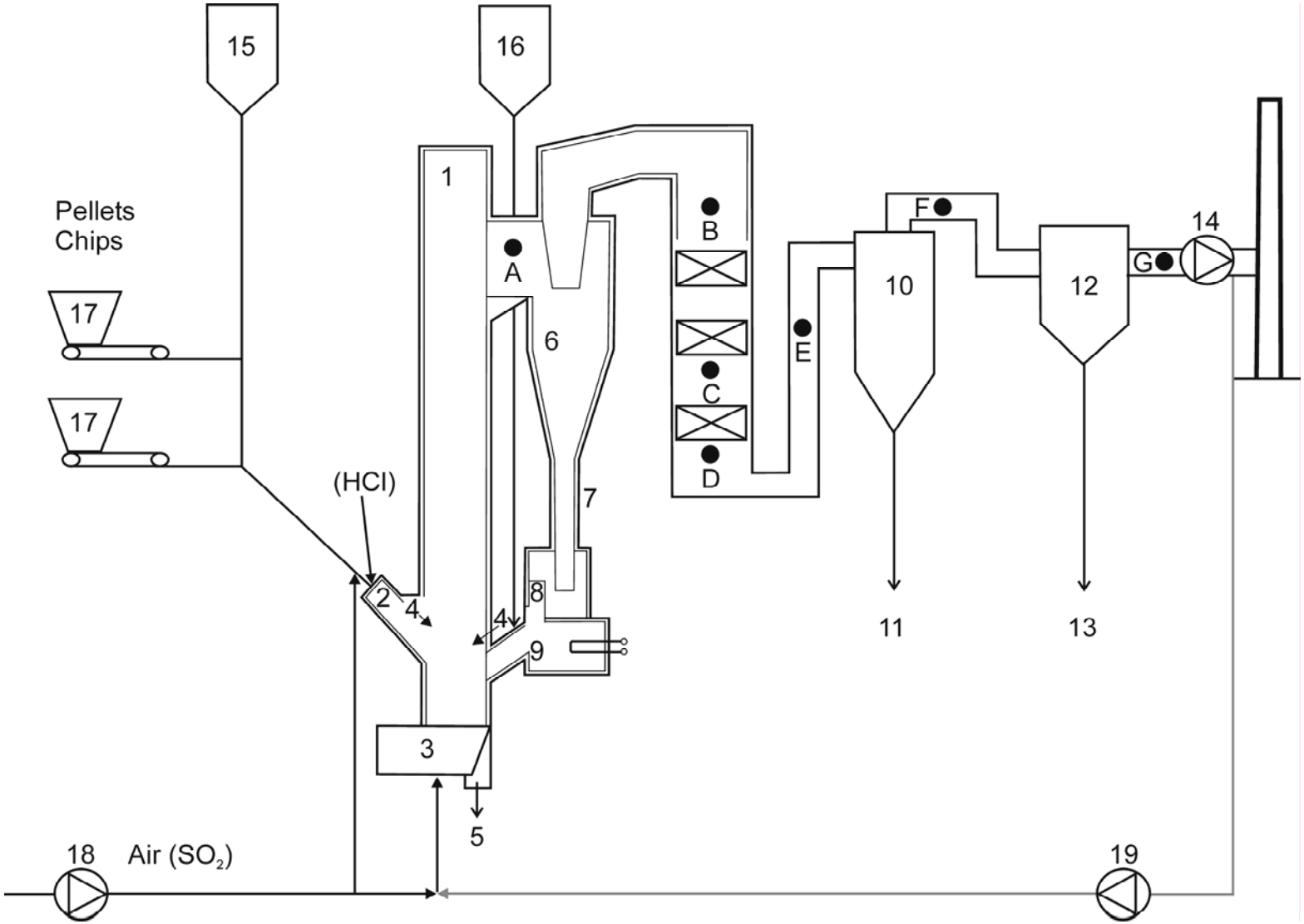


The purpose

- To study deposits on heat transfer tubes caused by potassium, chlorine and sulphur

- Two cases will be treated: wood-coal and wood-sewage sludge.

Equipment


15
16
1
Pellets
Chips
17
17
A
B
C
D
E
F
G
6
7
8
9
10
11
12
13
14
(HCl)
2
4
4
3
5
18
Air (SO_2)
19

Combustibles

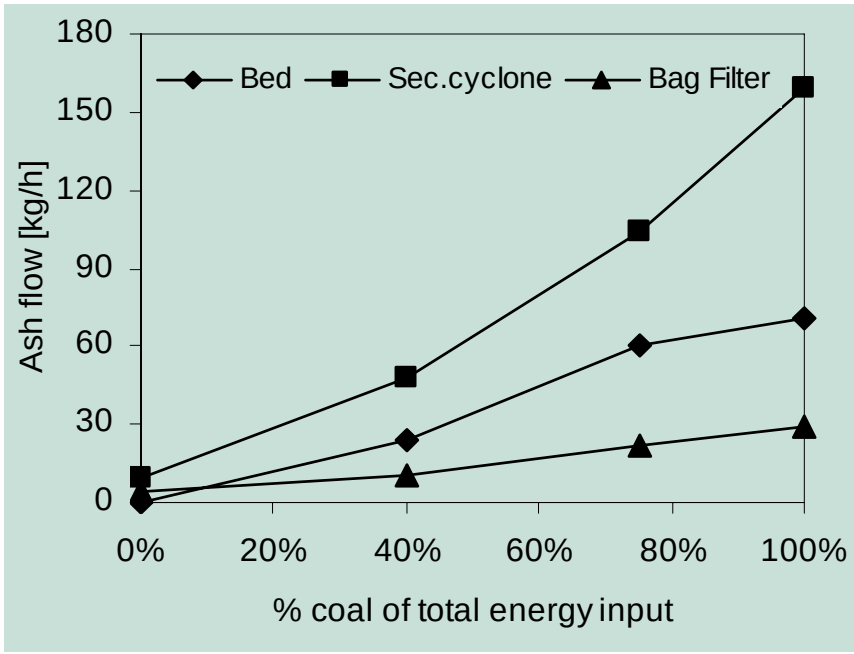
Elemental analysis[kg/kg comb.]	*Wood chips*	*Wood pellets*	*Coal*	*Sludge*
C	49.8	49.7	68.2	51.7
H	6.2	6.4	4.2	7.2
O	43.8	43.8	25.8	32.9
S	0.014	0.018	0.57	1.8
N	0.14	0.11	1.15	6.2
Cl	0.019	0.022	0.046	0.12
Ash analysis [mg/kg dry fuel]				
K	1142	407	1184	6100
Na	32	24	231	3700
Al	67	27	10062	34200
Si	380	406	52886	61000
Ca	1342	1149	4859	19700
P	73	77	259	31000

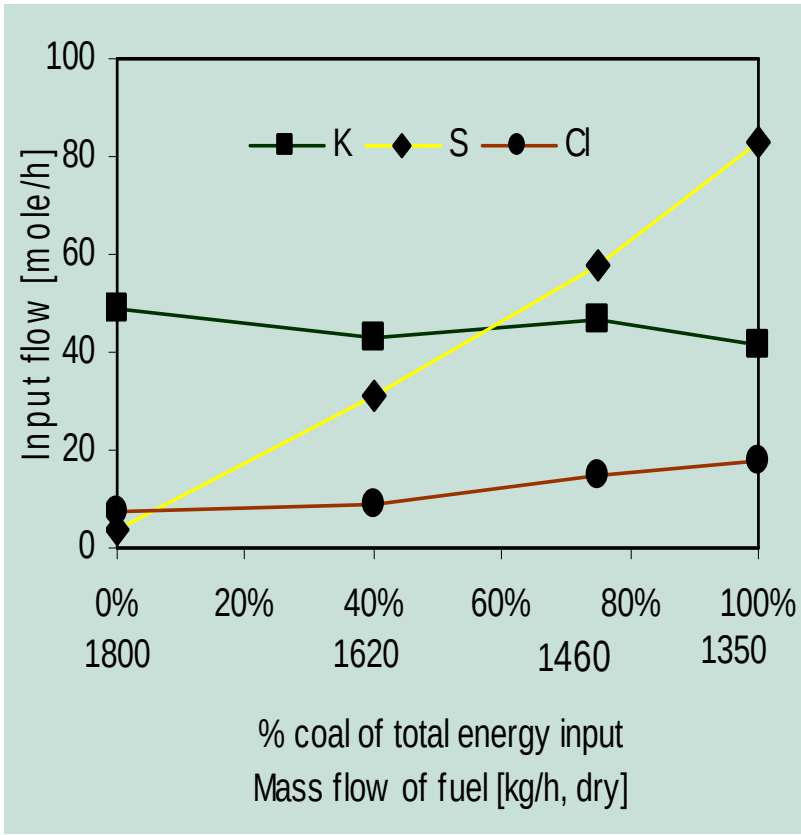
The contents of K are the same for wood and coal but the forms, and hence the behaviour, is different. The form of K in sludge has not been investigated.

Operation

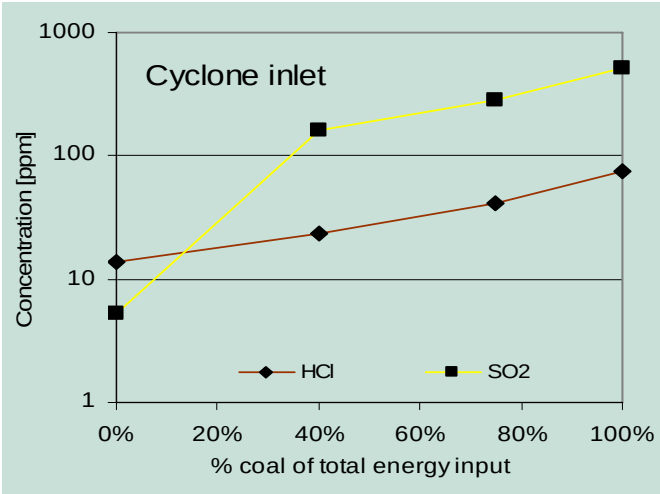
- The boiler was always operated under the same standard conditions, irrespective of the fuel mix

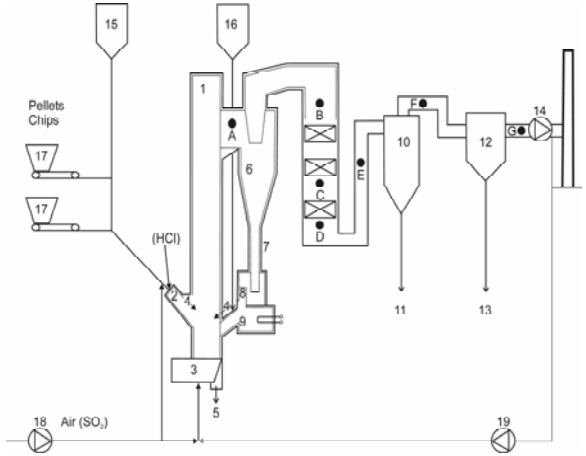
I. Wood—coal
Input and distribution of ashes

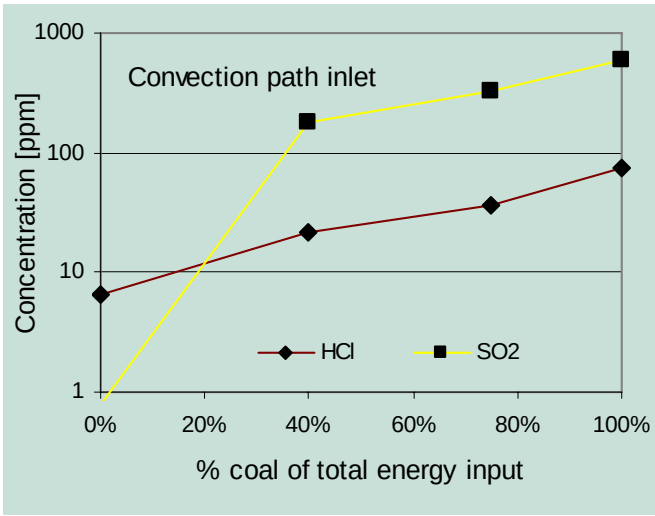


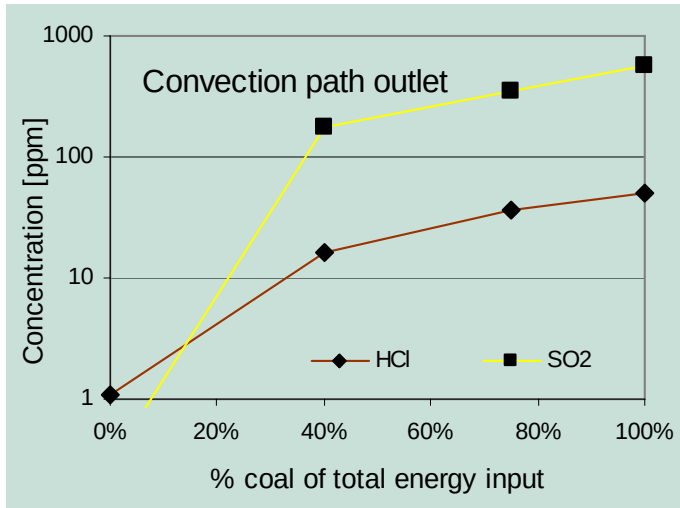


Concentrations of gaseous SO_2 and HCl in cyclone and convection pass

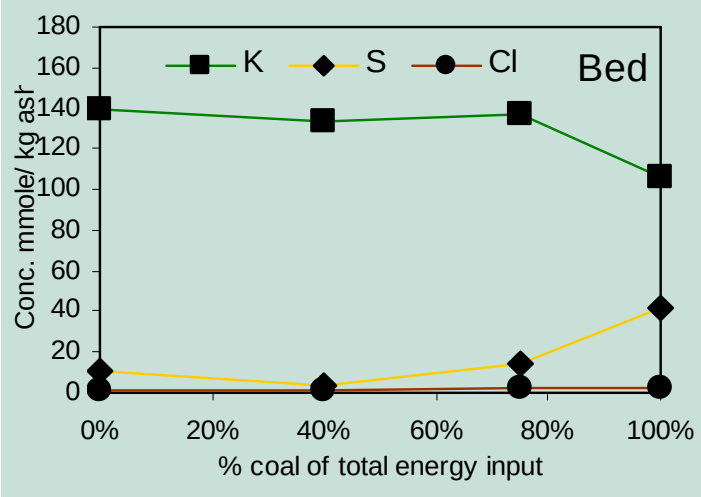


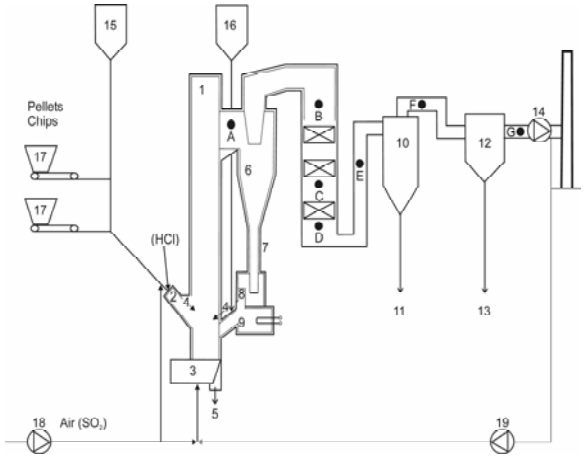


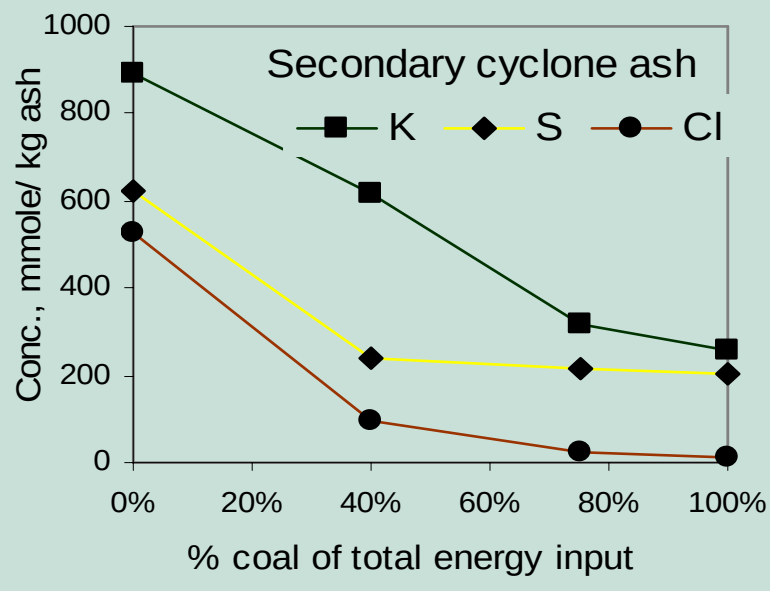


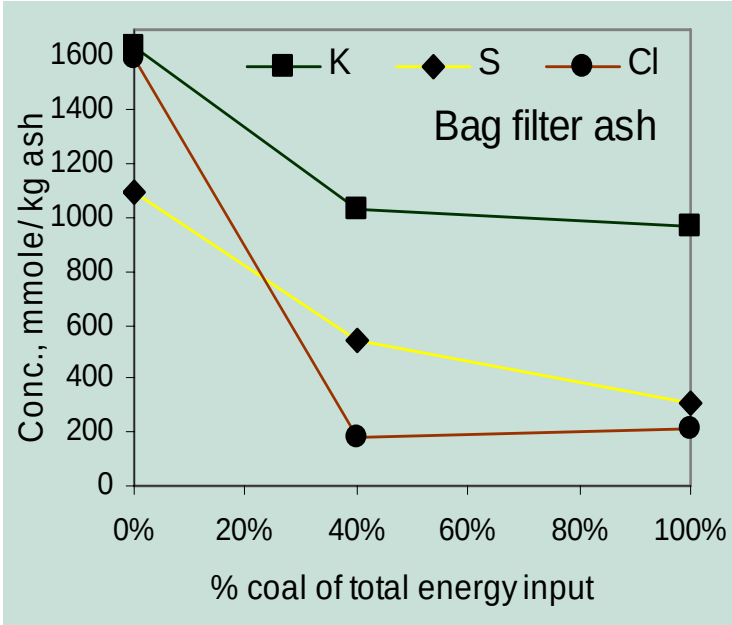


Ash concentrations in bed, secondary cyclone and bag filter









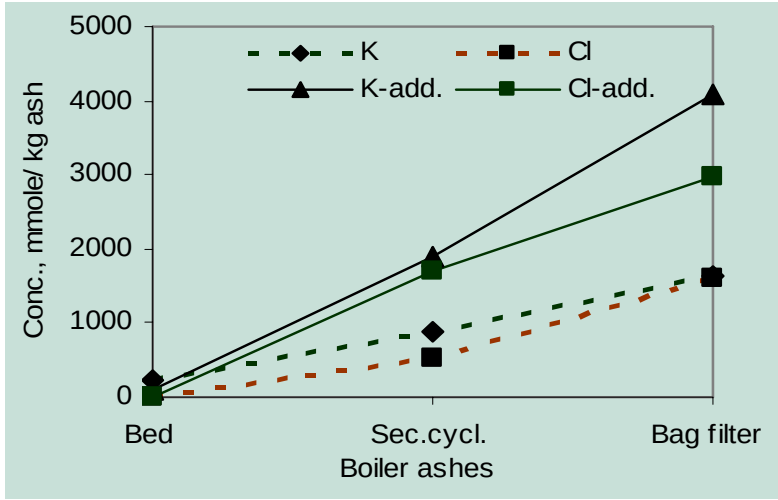
Crystalline compounds identified in fly ashes, in order of importance

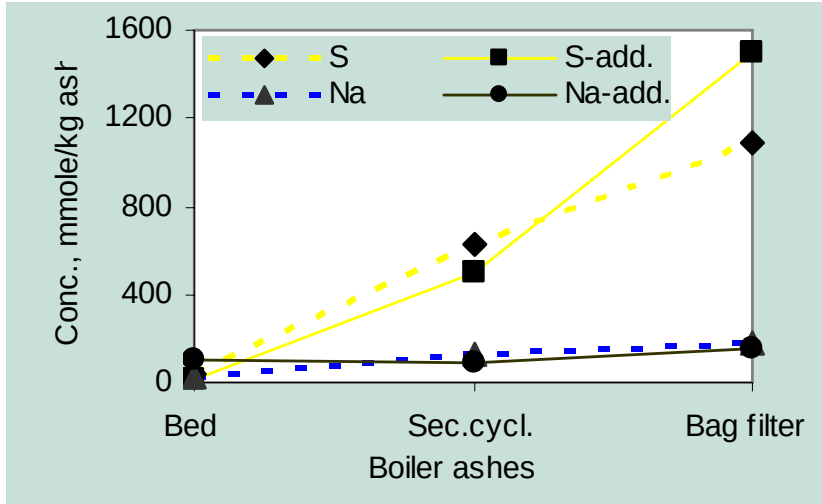
Case	Secondary cyclone ash	Bag filter ash
Wood	SiO_2, $CaCO_3$, KCl, MgO	KCl, $CaCO_3$, Ca-silicate
HCl-add	KCl, $CaCO_3$, SiO_2, MgO	KCl, $CaCO_3$,MgO,$CaSO_4$
Coal	SiO_2, $CaCO_3$, silicates, MgO	SiO_2, KCl, Fe_2O_3, MgO

Result of Cl addition on the pure wood case

Input component [moles/h]	*Wood*	*HCl addition*
Potassium	53	55
Chlorine	13	77
Gas concentration at cyclone inlet		
HCl [ppm]	14	22
SO_2 [ppm]	5	20
CO [ppm]	2092	4352
H_2O [%]	20	20

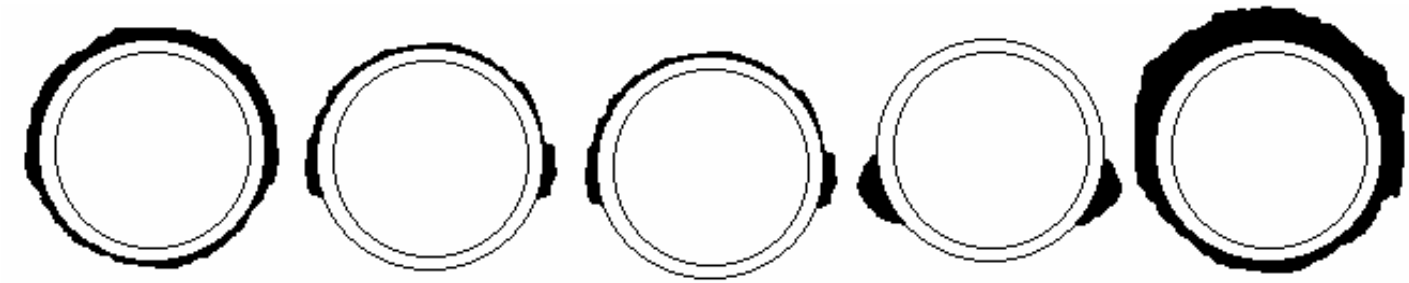
The addition of chlorine to the wood was the same as the amount of chlorine in coal





Five cases of tube exposure

Flue gas flow



Leeward side of deposition ring

100% wood	40% coal+ 60% wood	75% coal+ 25% wood	100% coal	HCL-add

Deposit formation rates (DFR) in g/(m2,h) and crystalline phases identified by XRD-analyses.

Case	DFR g/m²h	Crystalline phases on windward side	Crystalline phases on the flank	Crystalline phases on leeward side
wood	2.0	KCl, K_2SO_4, $CaCO_3$, $K_2Ca_2(SO_4)_3$, CaO	Analyzed together with the windward side	KCl, $CaCO_3$, K_2SO_4, MgO
40% coal + 60% wood	1.7	CaO, $K_{0.2}Na_{0.8}Cl$, $Ca(Fe,Mg)(CO_3)_2$	SiO_2, $CaSO_4$, $K_2Ca_2(SO_4)_3$, MgO, $K_2O_*3Al_2O_{3*}6SiO_2$	no deposit found
75% coal + 25% wood	0.9	Analyzed together with the flank	SiO_2, Ca SO_4, $MgFe_2O_4$, Fe_2O_3	no deposit found
coal	1.2	no deposit found	SiO_2, Ca SO_4, Fe_2O_3	no deposit found
HCl-add	20.8	KCl, (SiO_2, $CaCO_3$)	KCl, (SiO_2, $CaCO_3$)	KCl, ($CaCO_3$, $CaSO_4$)

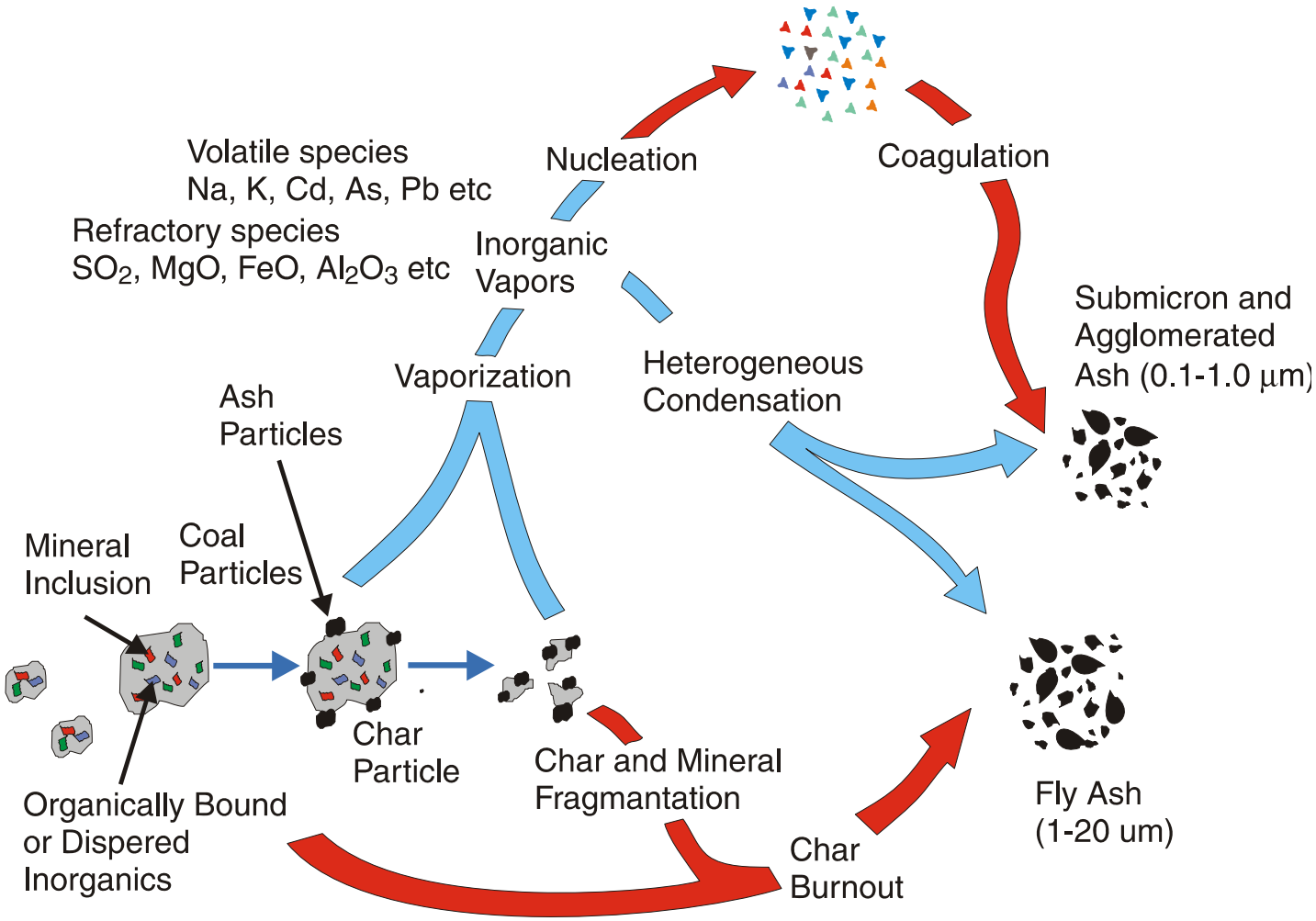
Conclusions, Part I

- Chlorine addition to wood resulted in severe deposits on tubes, whereas the same amount of chlorine added through co-combustion with coal did not result in deposits. On the contrary, addition of coal had a beneficial effect on deposits compared to wood.
- Co-combustion of coal and wood could be carried out without any operational difficulties.

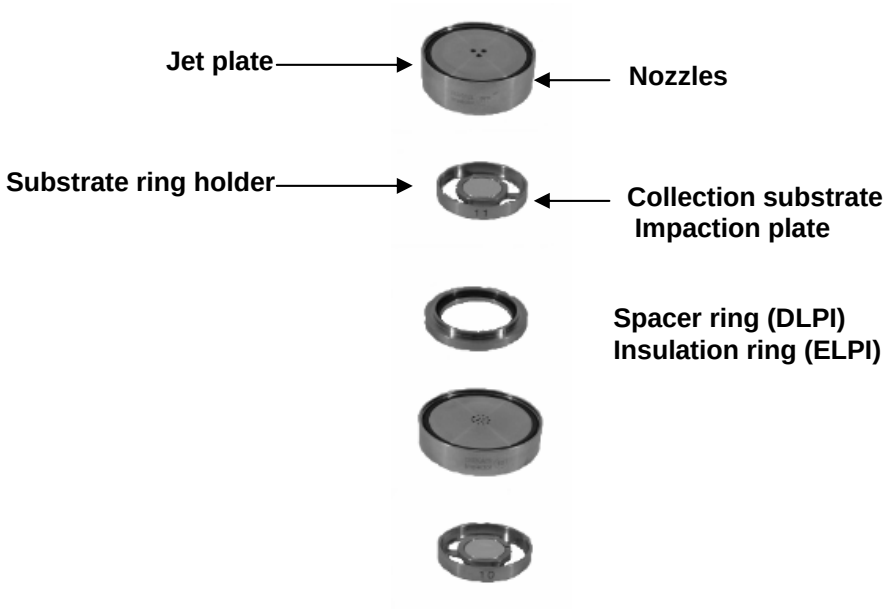
II. Wood—sewage sludge

- Zn was added during some tests to study the impact of wood waste. The zink proved not to have any effect that was of importance in the present context.
- Cl was added to wood to correspond to the amount of chlorine in sludge

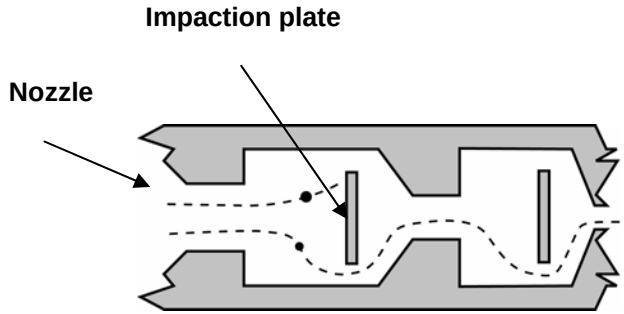
Mechanisms of formation of ash particles (Sarofim and Helble, 1993)

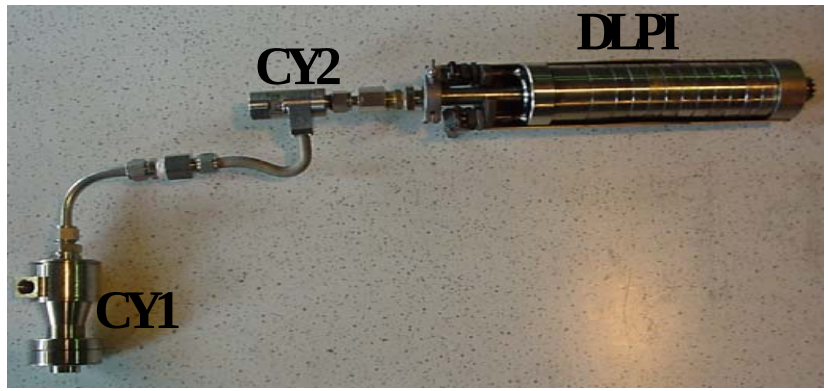


Low-Pressure Impactor



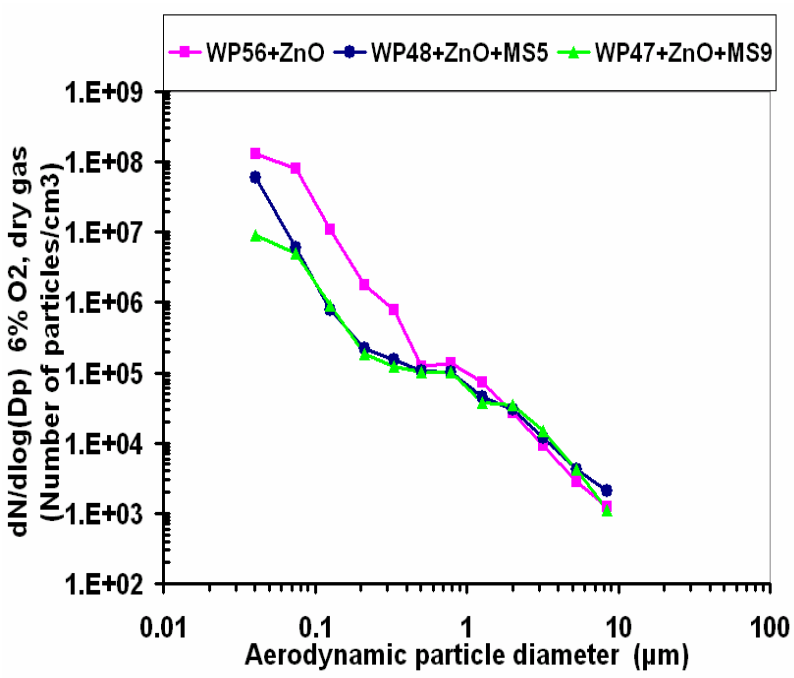
Principles of a cascade-impactor



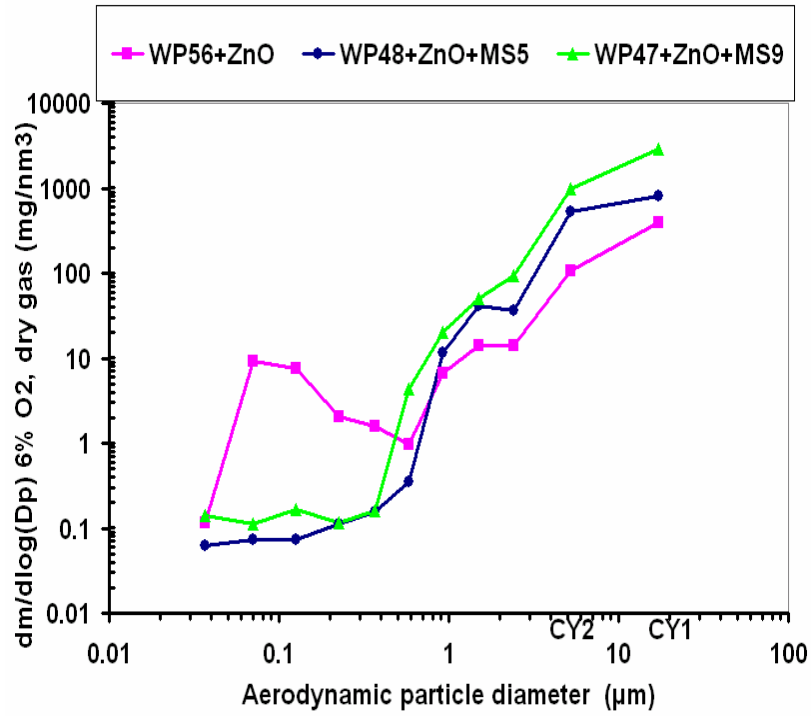


During combustion of wood the flue gas contains gases that condense as submicron particles. These particles disappear to a large extent when sludge is added.

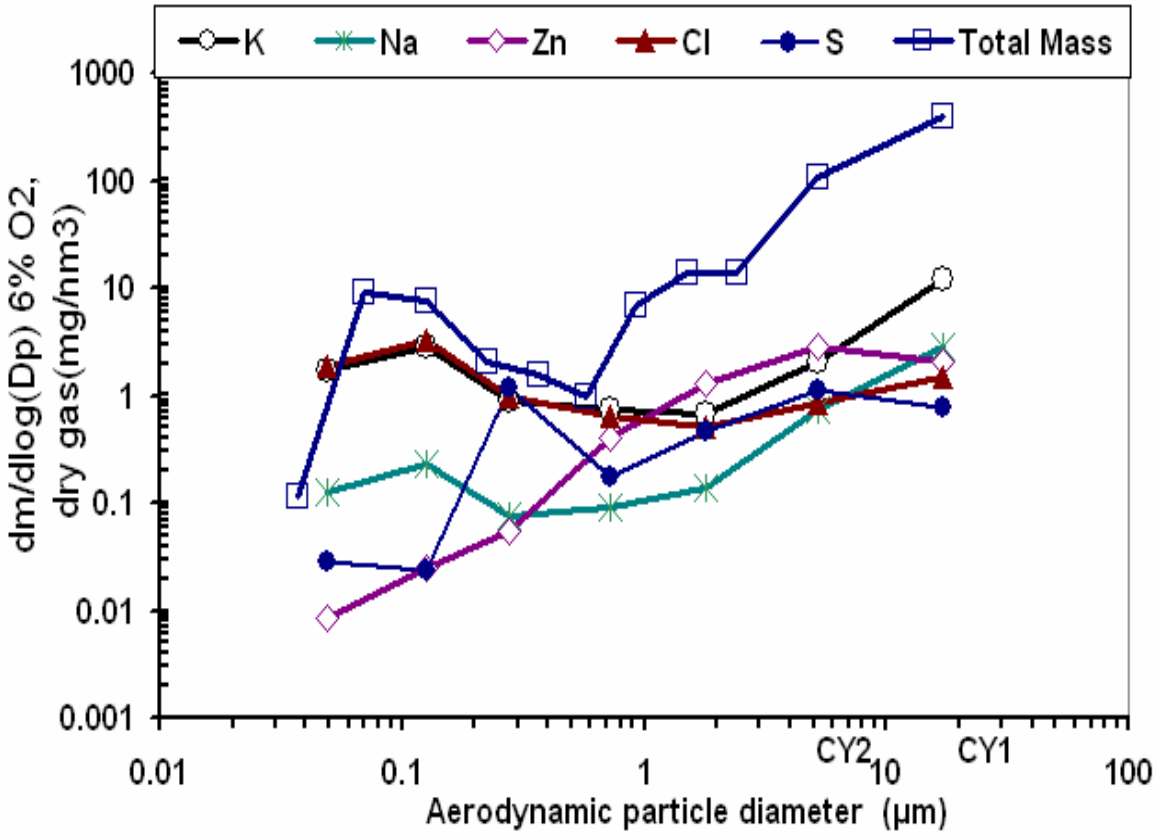
Number-size distribution

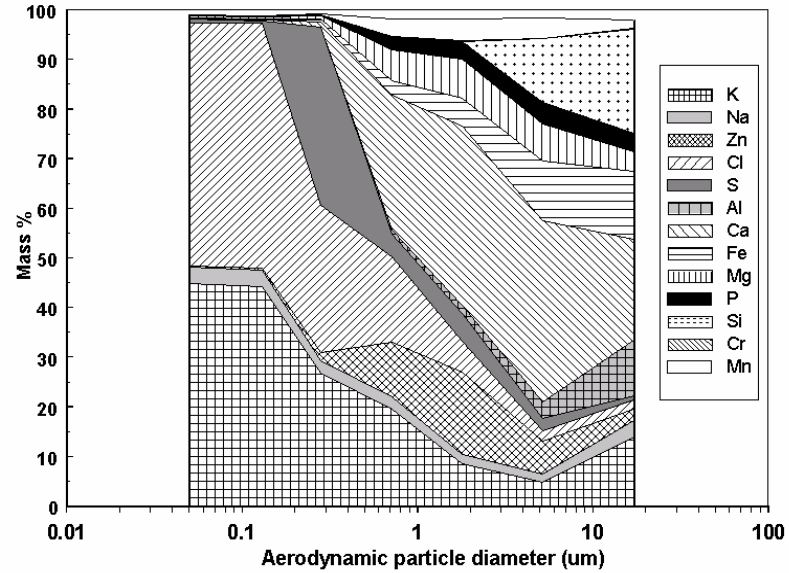


Mass-size distribution

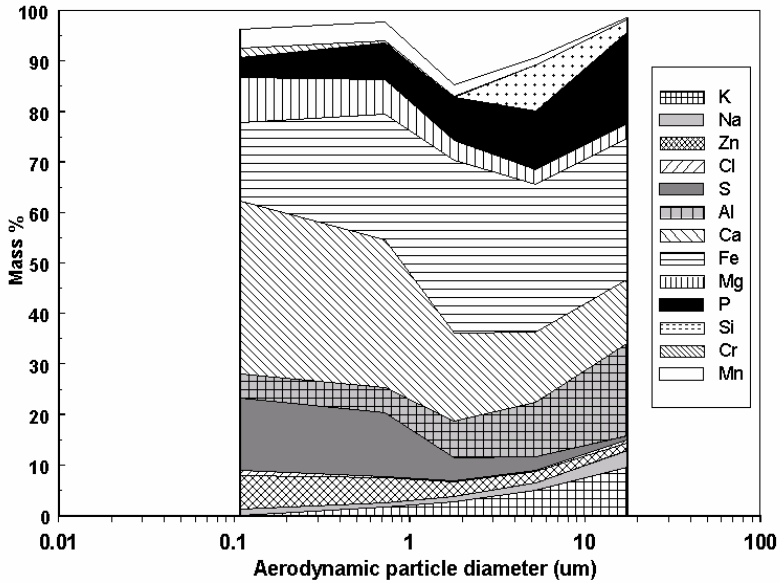


The submicron particles consist mostly of KCl. The gap at sizes above a micron is filled by particles consisting of Si and Al among others

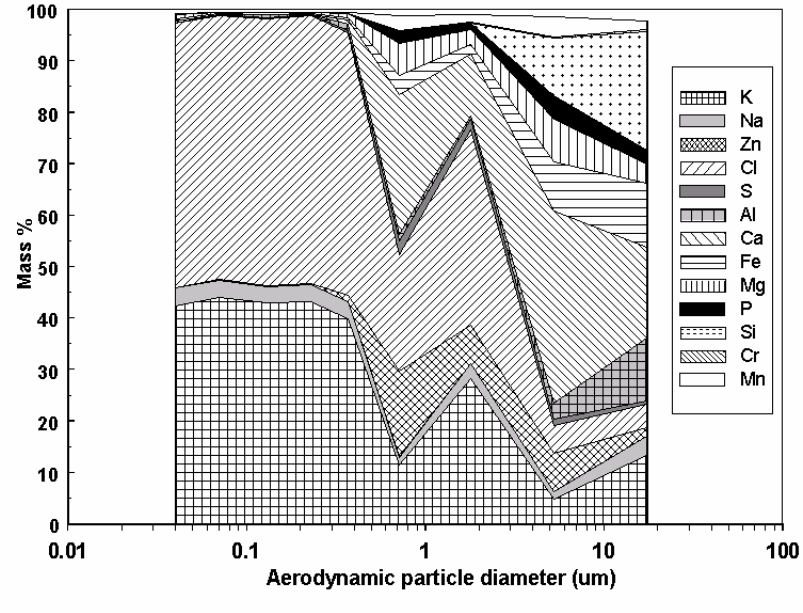




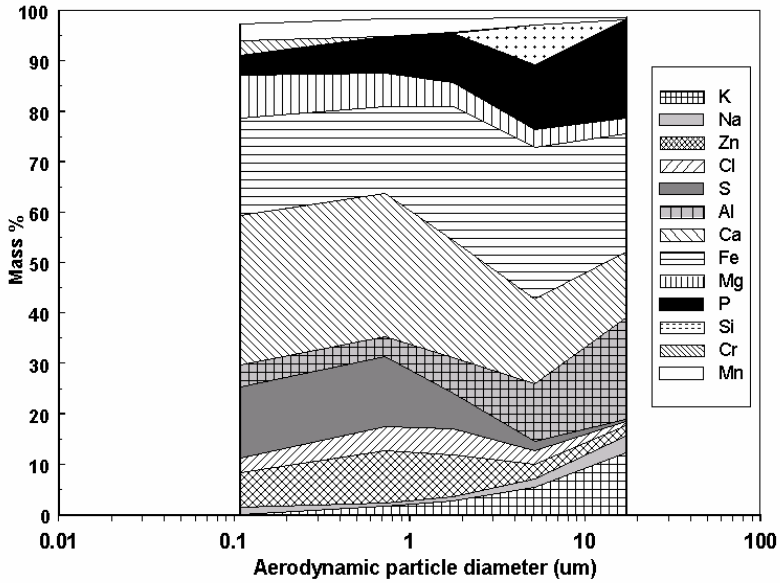
Wood



Wood+sludge

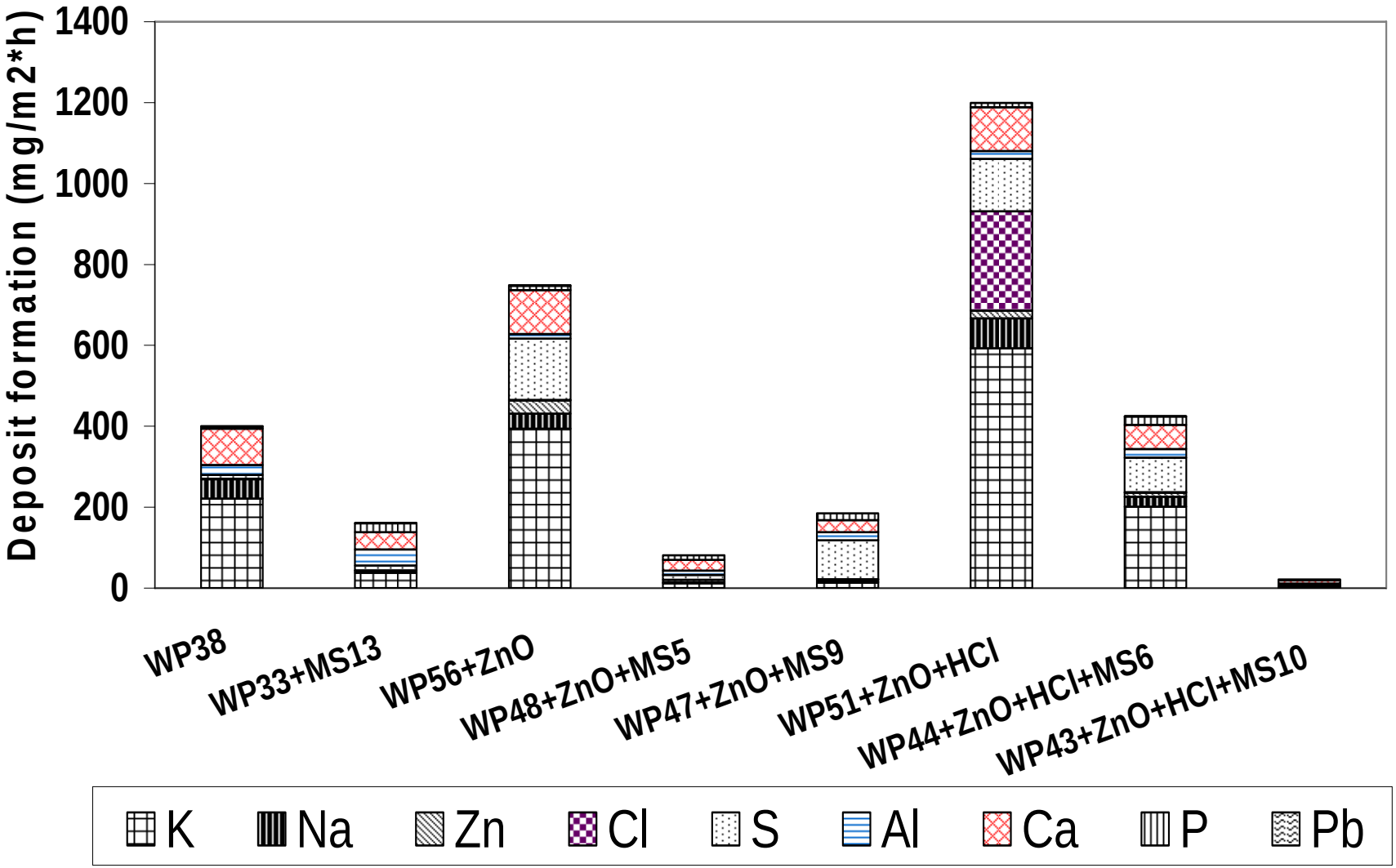


Wood+HCl



Wood+sludge+HCl

When sludge (MS) is present together with wood (W), deposition on tubes is reduced, even when HCl was added



Conclusions, Part II

- Potassium is a major constituent in deposits during wood combustion. When the amount of chlorine is small, K_2SO_4 is found, otherwise KCl.
- The potassium compounds are released in gaseous phase during combustion, condense on cold surfaces or form submicron particles as the temperature falls.
- Municipal sewage sludge removes the fine potassium particles and reduces deposits considerably.
- The role of sulphur is more complex than that of chlorine. Clear conclusions regarding S need further studies.

General conclusion

- Co-combustion of wood or other biomasses with coal, and particularly sewage sludge, can be carried out in any fuel mix as long as the bed temperature can be mantained (that is, the energy balance of the bed).
- The presence of free potassium (biofuel) together with chlorine may lead to serious deposits in mono-combustion of biomass.
- Coal, and particulary sludge, removes potassium compounds originating from biofuels from depositing on heat transfer surfaces.
- In the case of sludge the reason is most likely that zeolites (alumino-silicates) capture the potassium. A similar explanation (alumino-silicates) may be the reason also in the case of coal.