Interaction of Biomass Fly Ashes with Different Fouling Tendencies

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52nd IEA – FBC Meeting
Vienna, Austria, May 20, 2006

Problem Definition

- Combustion of biofuels is a feasible alternative to burning fossil fuels
- Typical biofuels: saw dust, wood, energy crops, agricultural waste, straw, forest residue, grass, bark
- Ash contains large amounts of K, Cl, S
- Interaction of these compounds can lower the melting temperature of the ash
- Low melting ash may be sticky

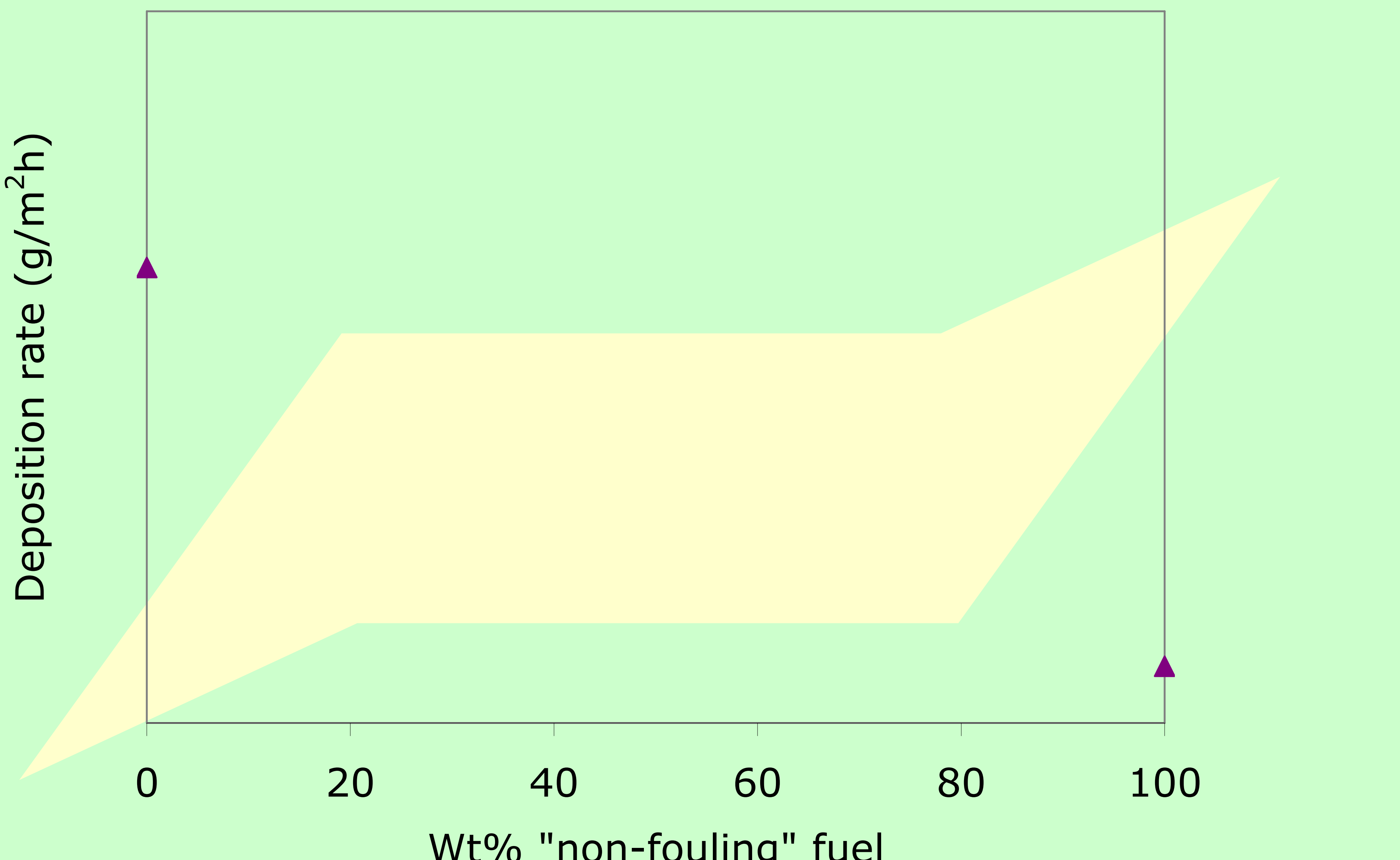
Problem Definition (cont'd)

- Build up of massive deposits leads to shutdowns

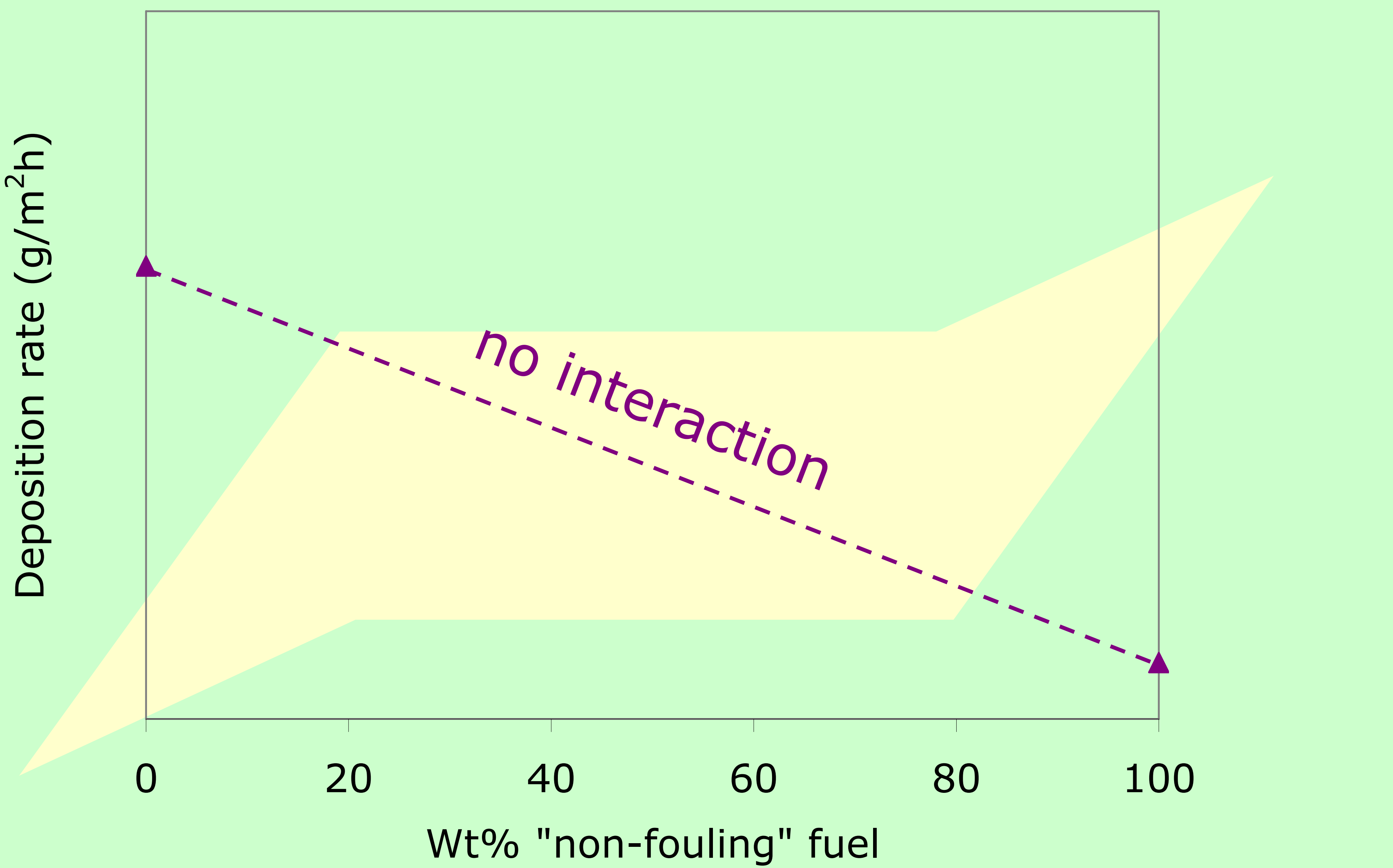
- Biofuels are often co-fired with coal
- Coal ash contains large amounts of Si, Al
- Ash melts at higher temperature

- Co-firing introduces 2 types of ashes
- Knowledge of interaction is limited

Possible Interactions between 2 ash types



Possible Interactions between 2 ash types



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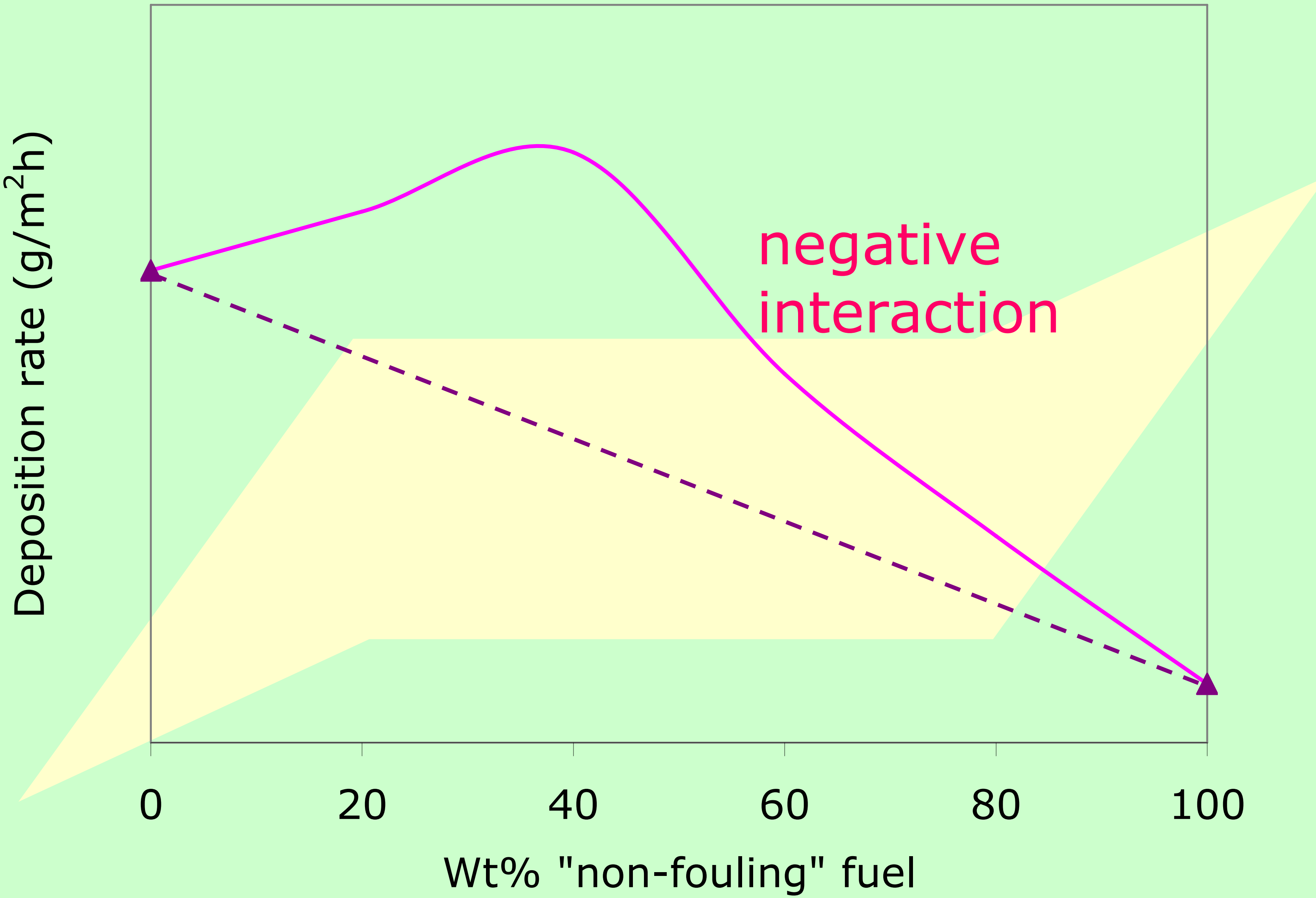
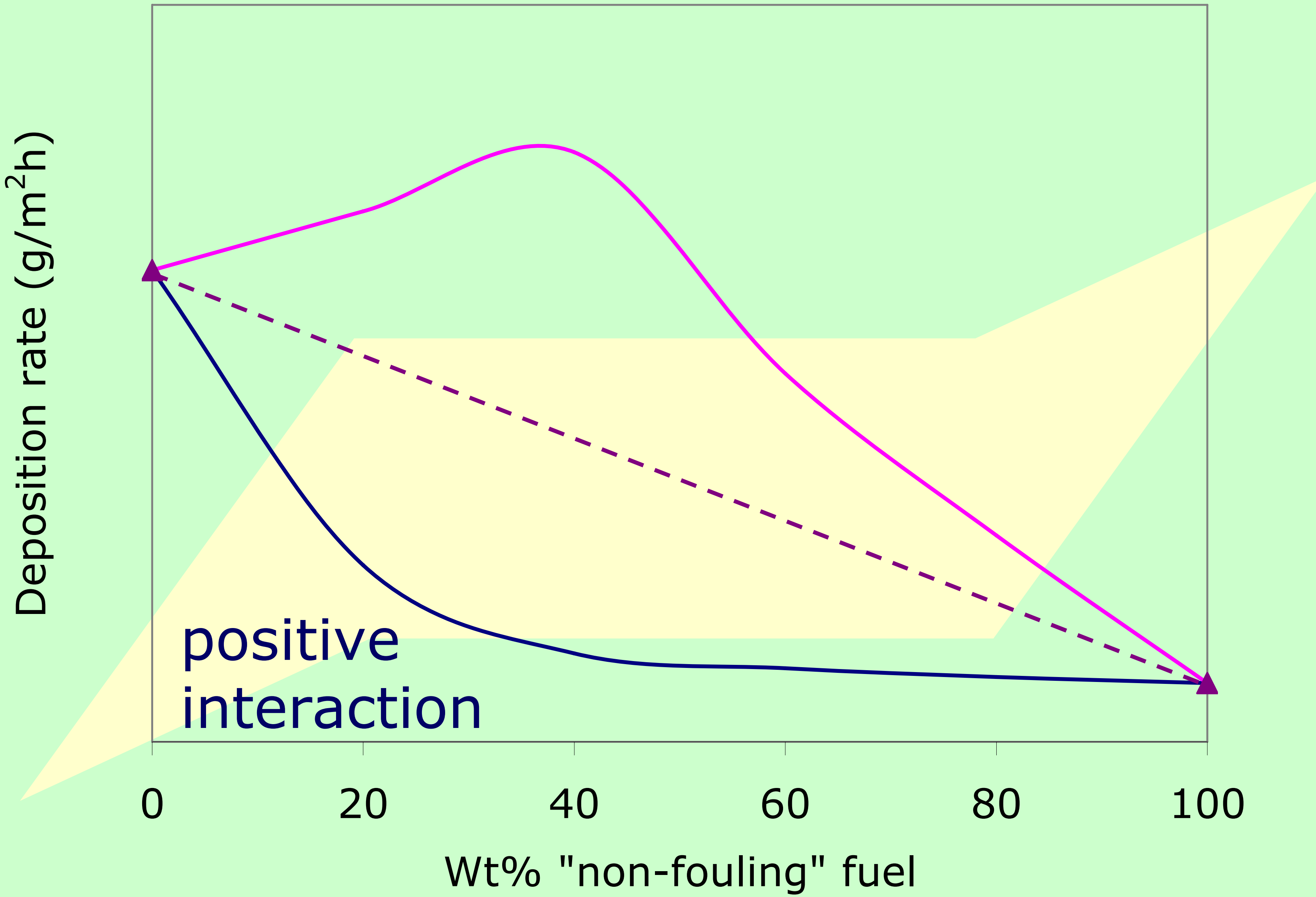
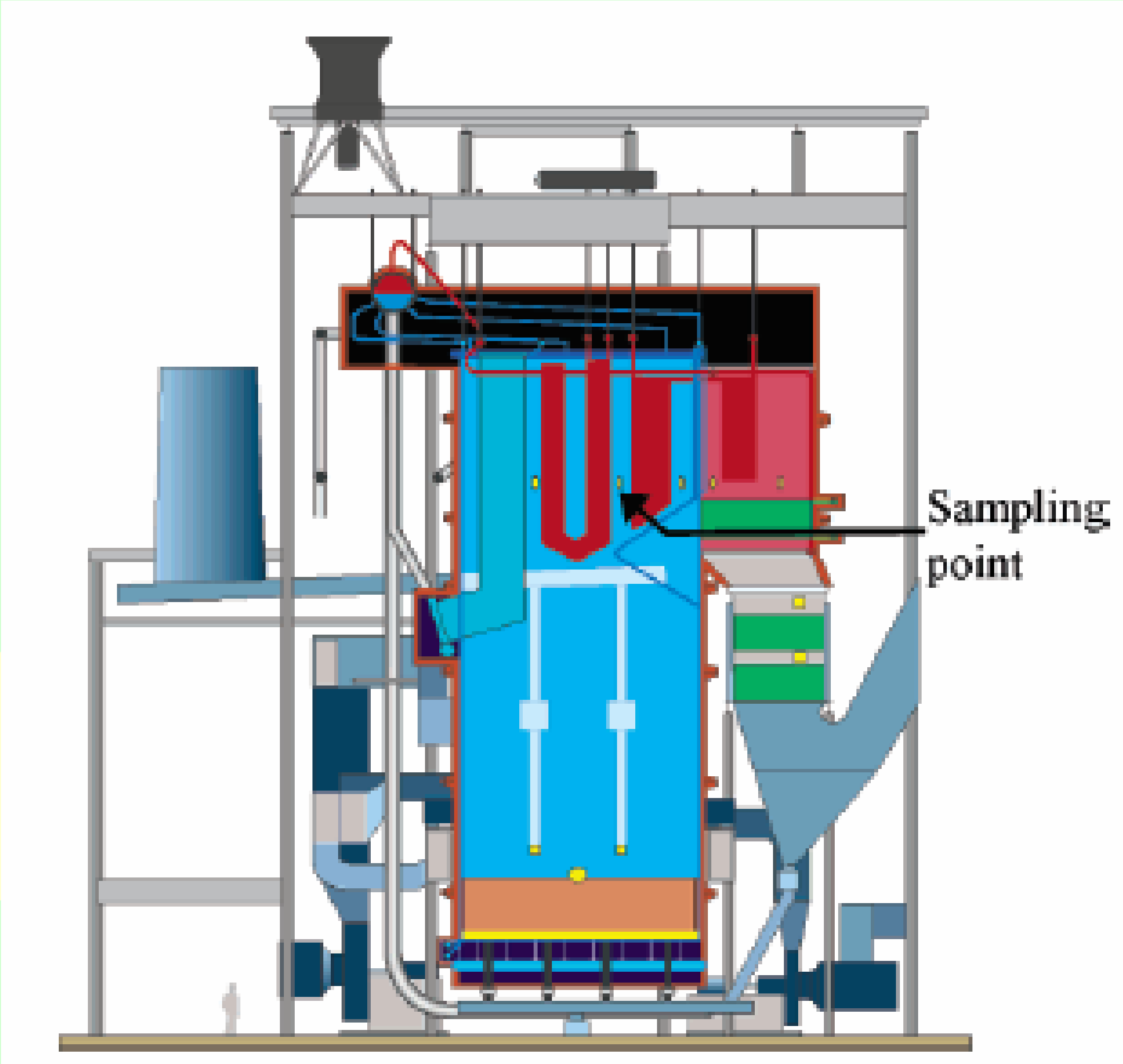


Possible Interactions between 2 ash types



Example Bark / Rice Husk

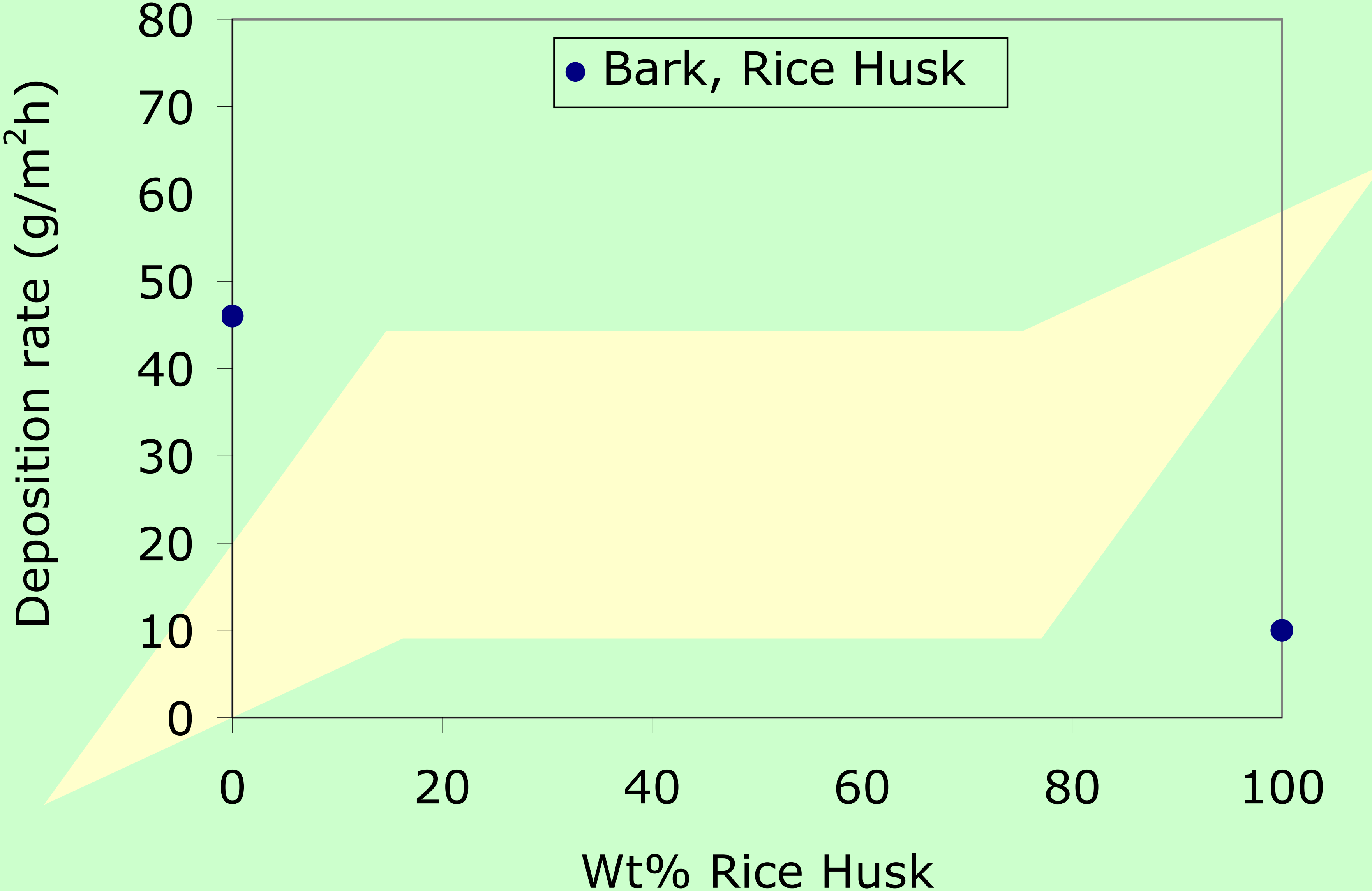


(3 h, 500 °C)

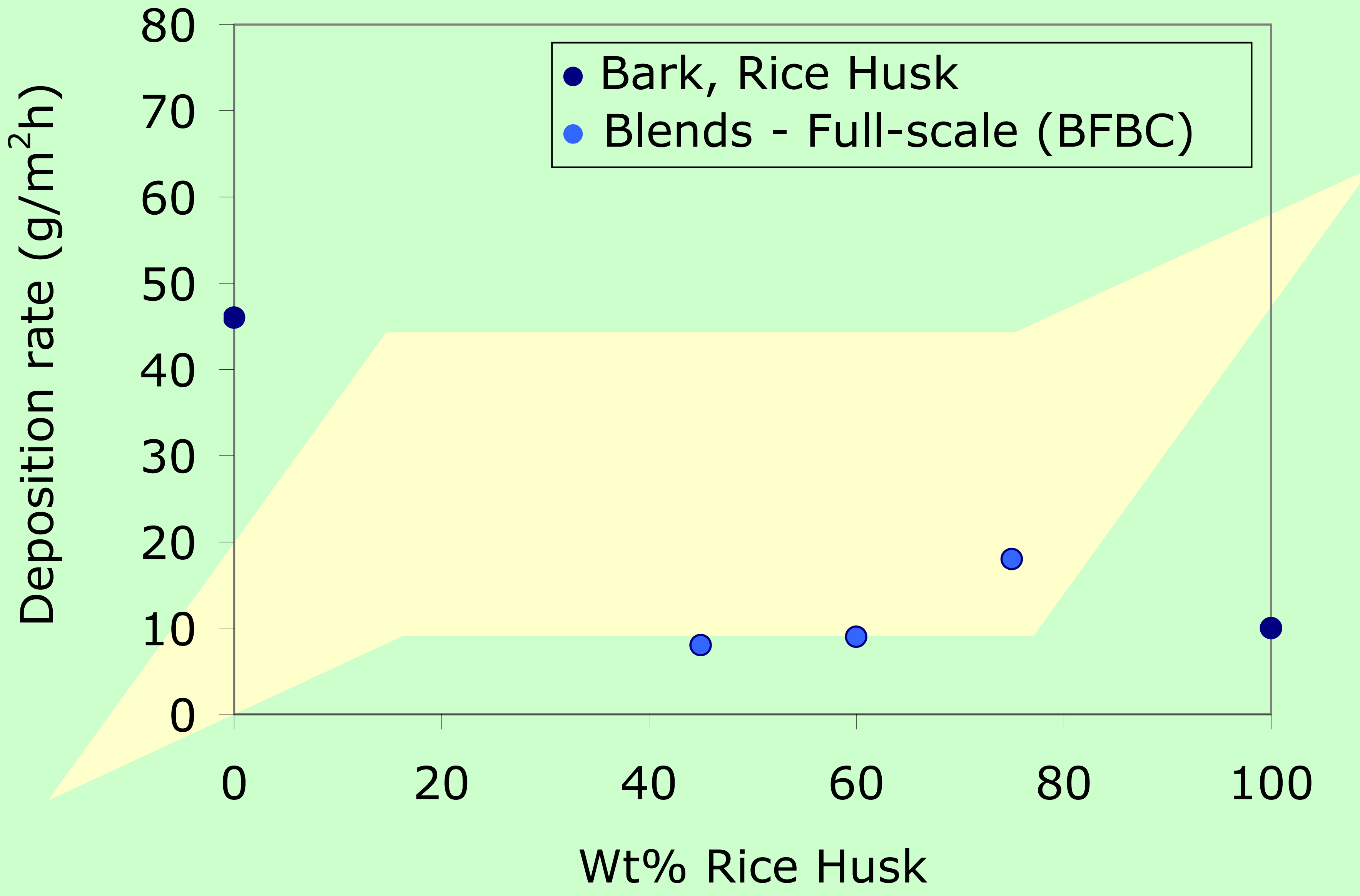
157 MW BFBC

//Skrifvars et al.

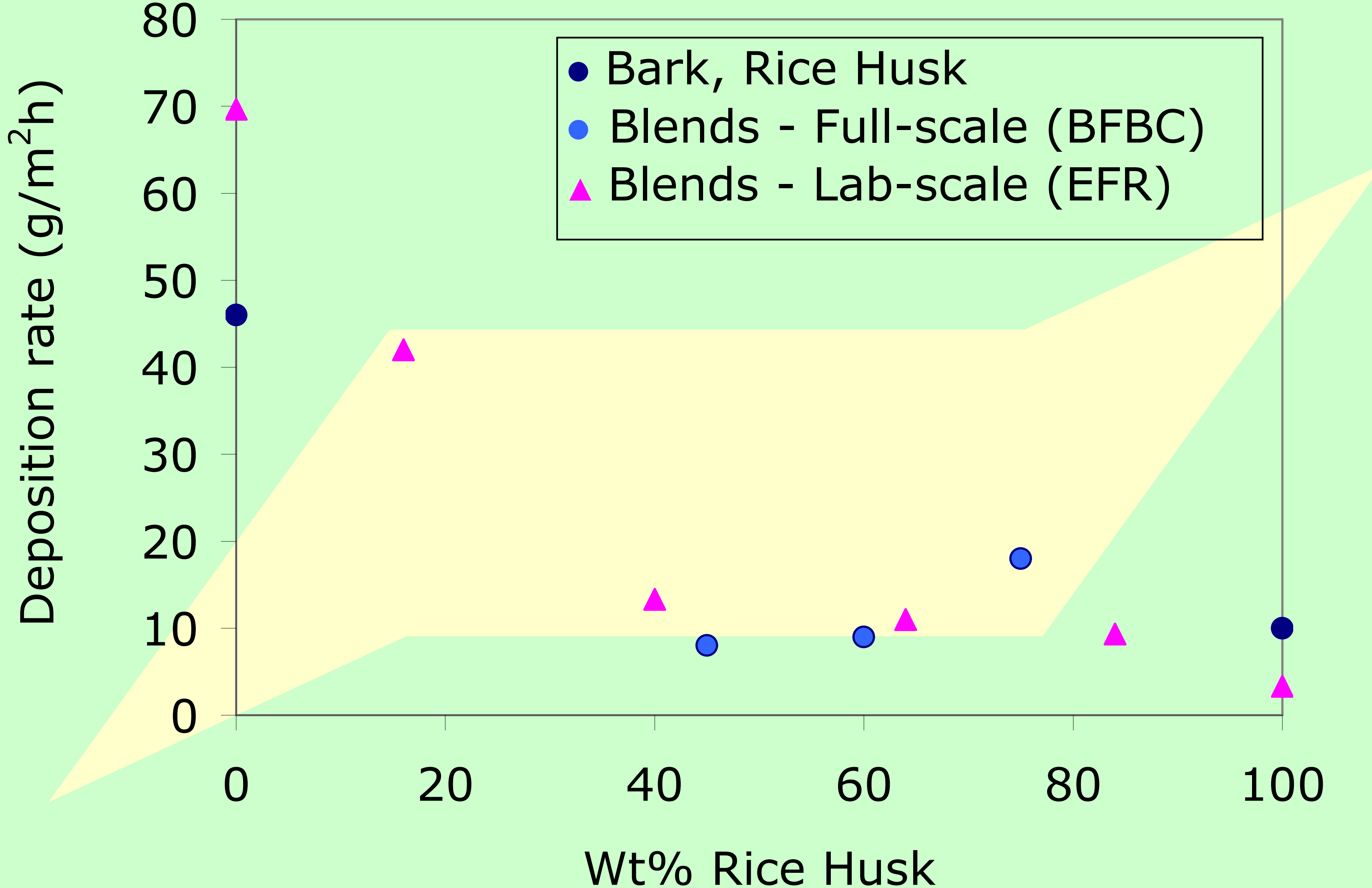
Example Bark / Rice Husk

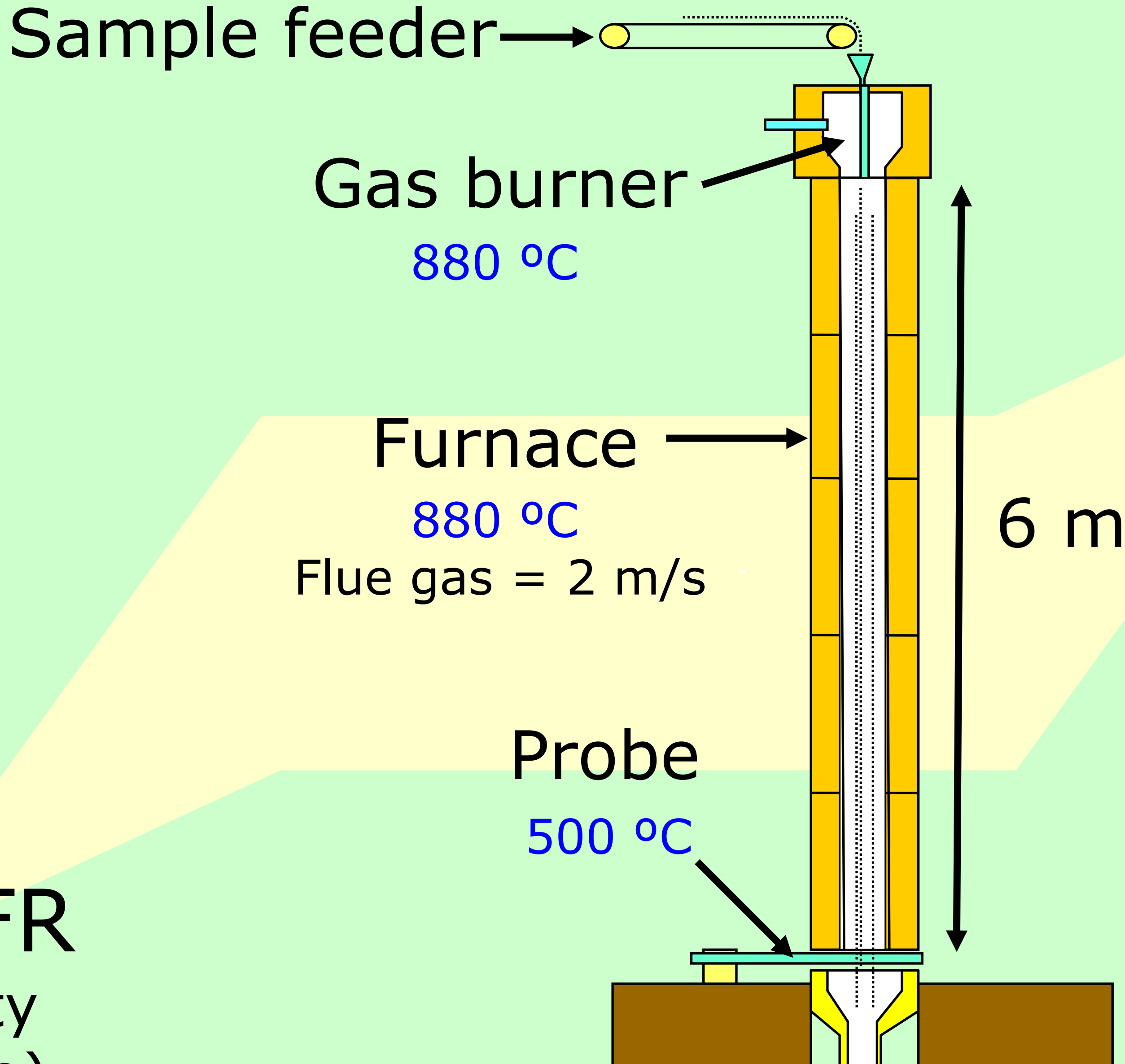


Example Bark / Rice Husk



Example Bark / Rice Husk





The EFR

(University of Toronto)

Thesis Objective

1. Study fundamental principles of interactions between fouling and non-fouling ashes
2. Provide consistent data for development of deposition submodels in CFD

Approach

- Demonstrate deposition behaviour of mixtures in an Entrained Flow Reactor (EFR)
  - Straw and bark as fouling fuel/ash
  - Peat as non-fouling fuel/ash
  - Alkali-depleted fuels
  - Peat replaced by quartz sand
  - Straw and bark replaced by model ash
- Examine deposits by Scanning Electron Microscopy/Energy dispersive x-ray (SEM/EDX)

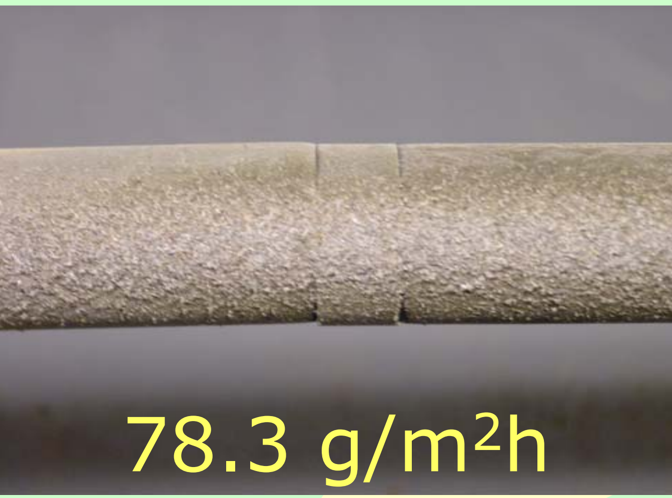
EFR Sampling Section

Standard Ash Analysis

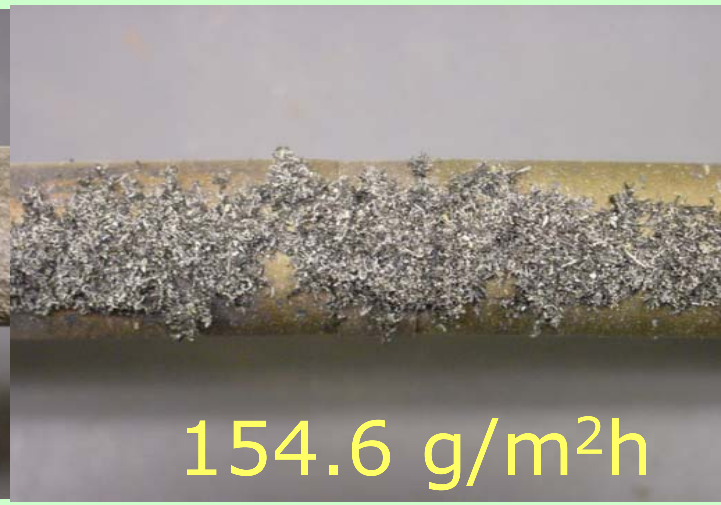
Ash composition (wt% dry)	Bark	Straw	Peat
SiO_2	8.1	31.4	36.9
Al_2O_3	2.5	3.9	19.8
Fe_2O_3	0.9	1.8	13.6
TiO_2	0.1	0.2	0.3
MnO	1.3	0.1	0.1
CaO	46.6	10.0	9.8
MgO	8.8	3.7	2.1
Na_2O	1.5	0.6	0.1
K_2O	7.5	22.4	1.1
SO_3	2.8	4.1	11.9
Cl	5.8	1.8	0.9
P_2O_5	1.9	5.1	2.7
Ash content	4.8	5.9	3.8

Deposition Rate and Deposit Appearance

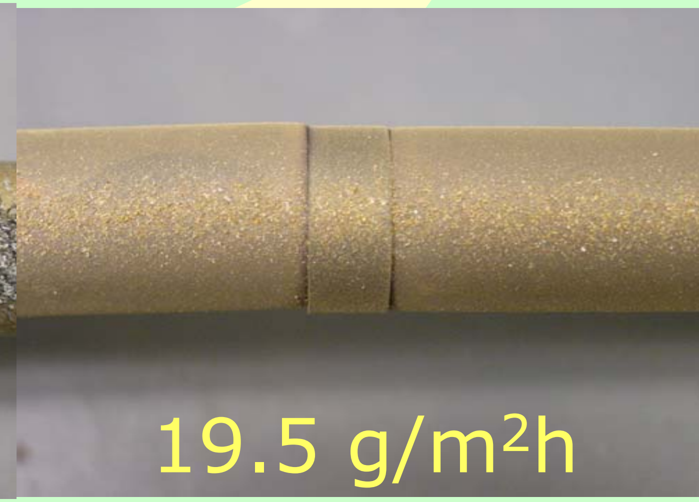
Bark



Straw



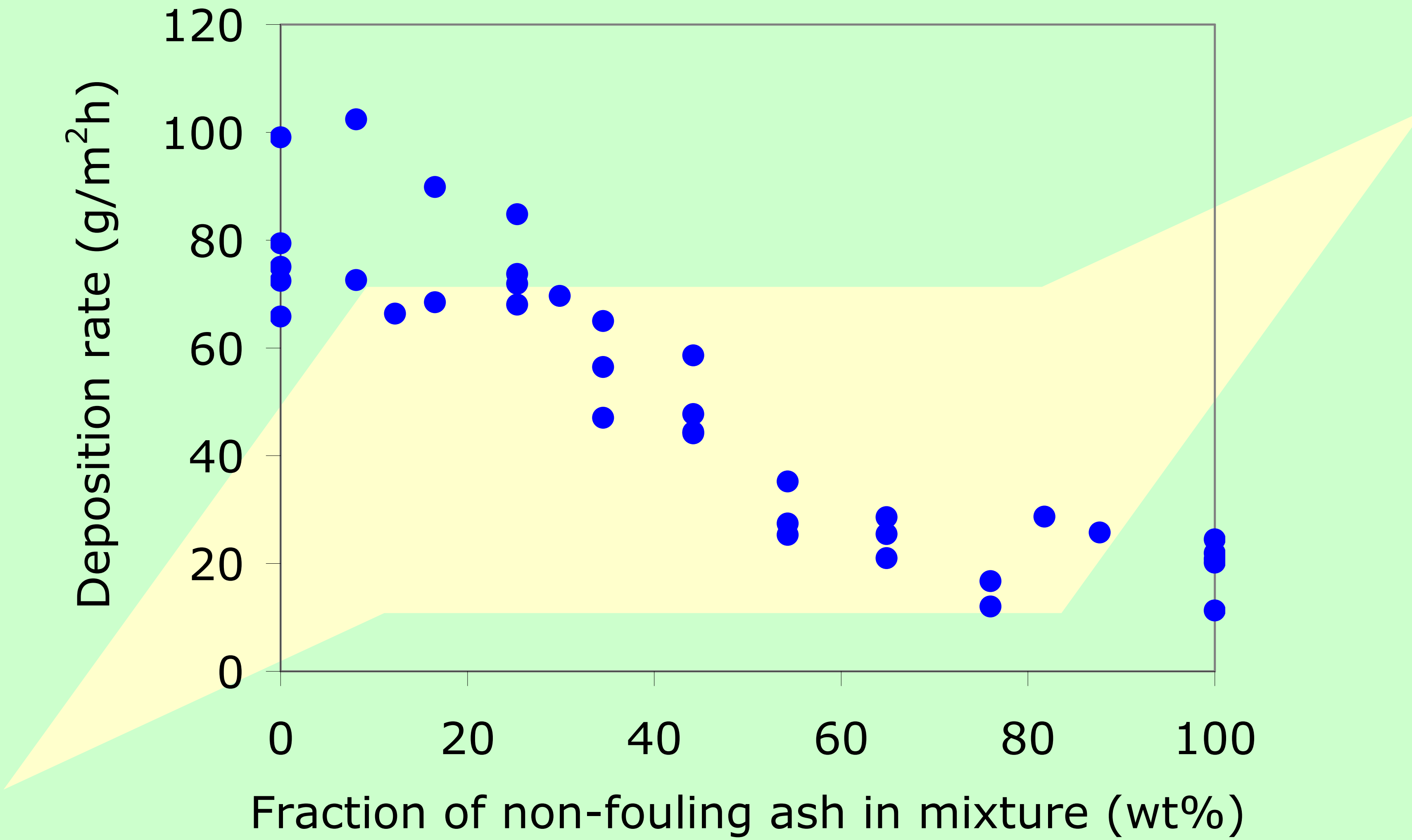
Peat



EFR = 1000 °C; probe = 550 °C

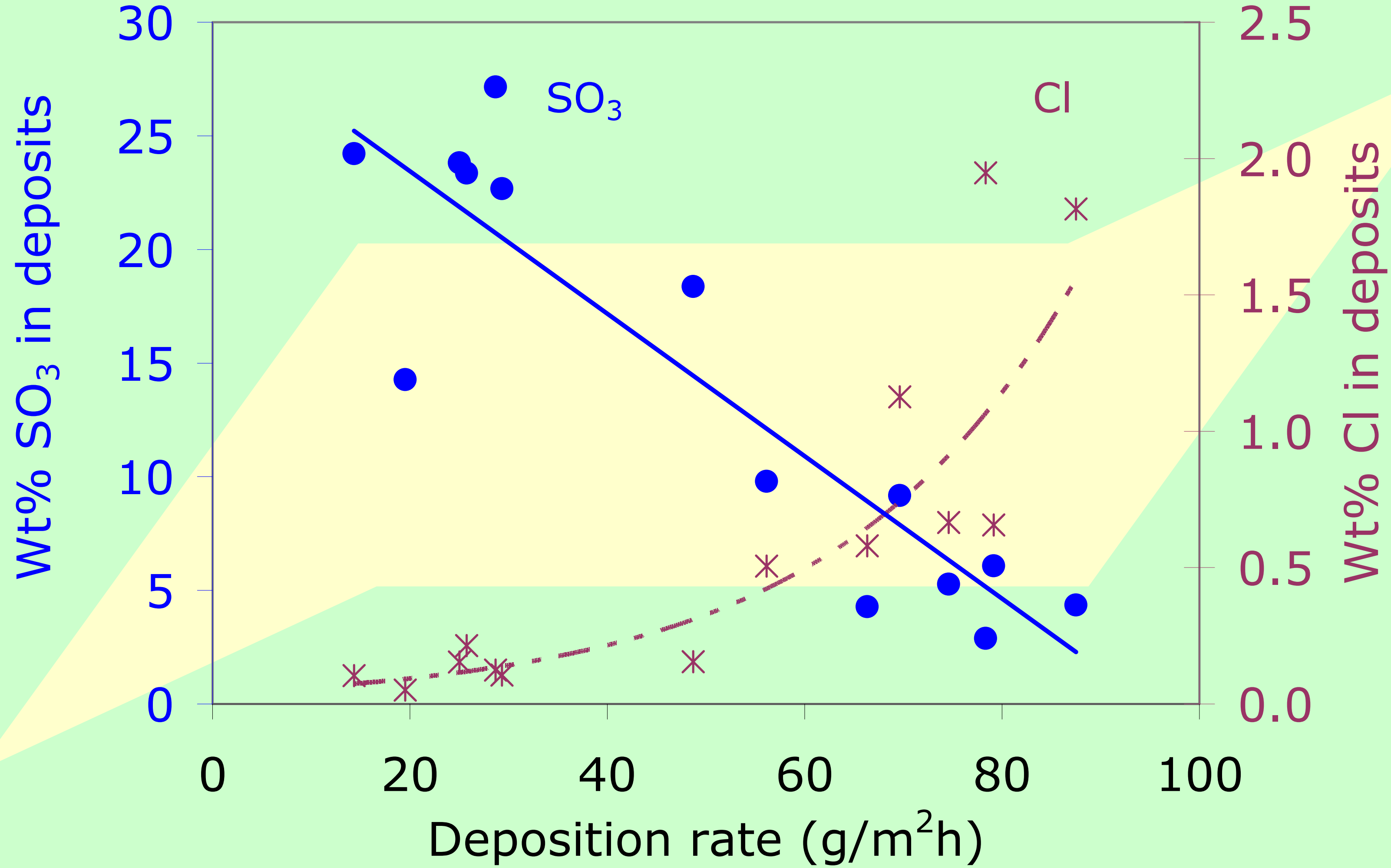
Feed = 500 g in 40 min

Bark and Peat



Deposit composition vs. deposition rate

$$2\,KCl + SO_2 + \tfrac{1}{2}\,O_2 + H_2O \rightarrow K_2SO_4 + 2\,HCl$$



Pre-treatment of bark

Goal: Remove alkali compounds

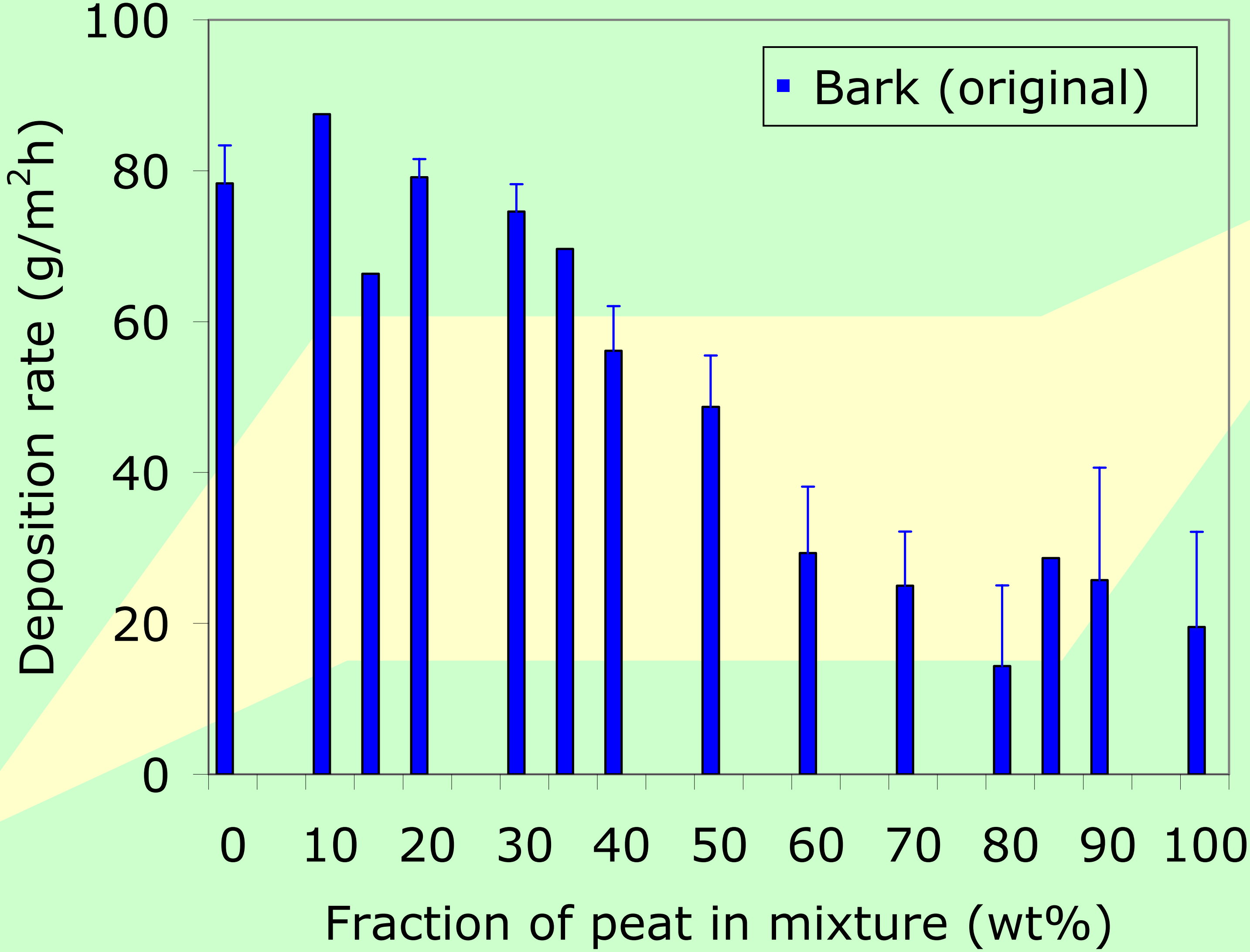
<u>Procedure</u>

- 10 minute water wash (120 °C)
- 5 min steam wash (160 °C)
- 30 min drying by pressure (60 bar)
- 48 h drying on air

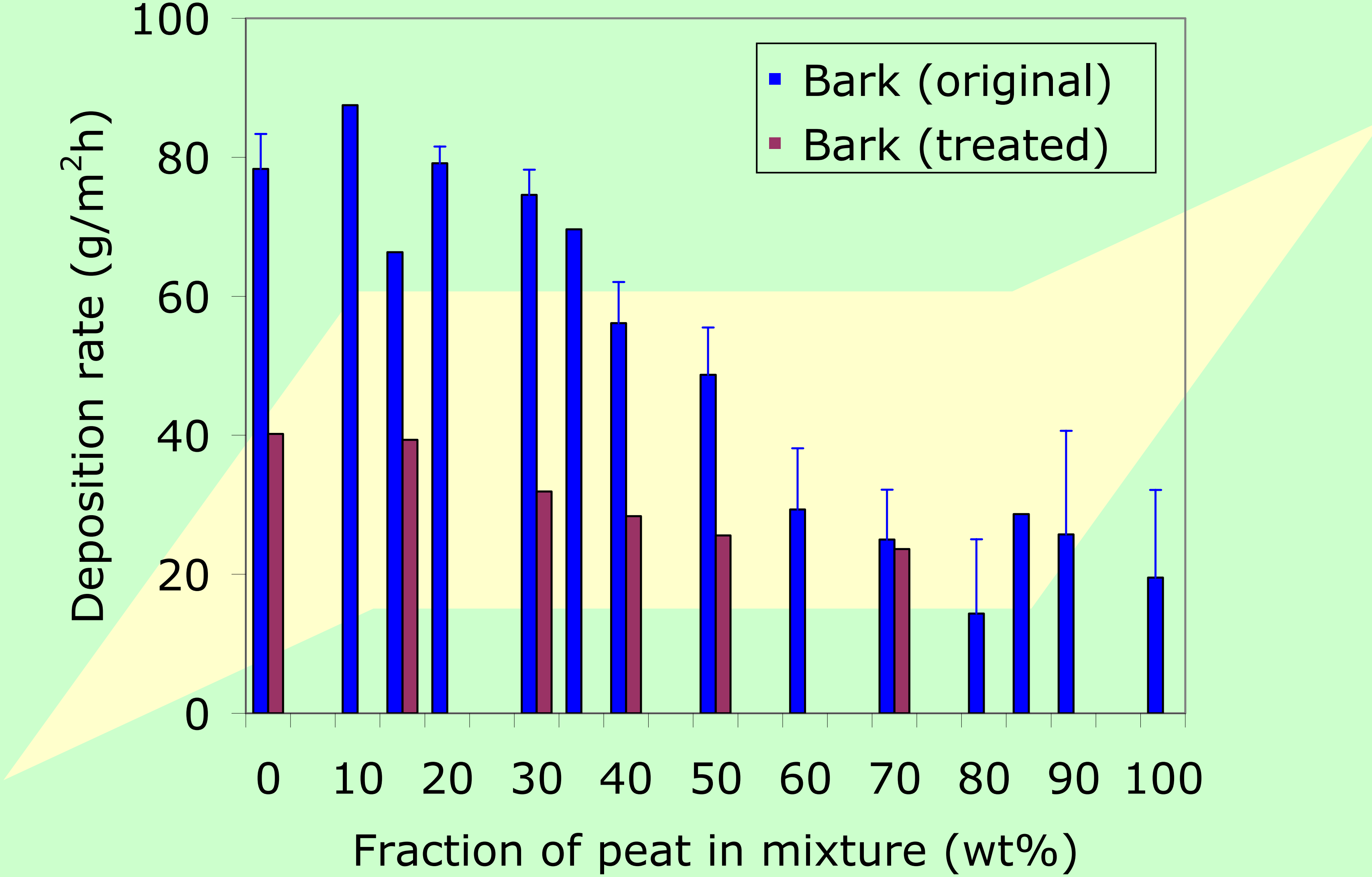
Standard Ash Analysis

Ash composition (wt% dry)	Original Bark	Treated Bark
SiO_2	8.1	11.5
Al_2O_3	2.5	3.0
Fe_2O_3	0.9	1.6
TiO_2	0.1	0.1
MnO	1.3	1.2
CaO	46.6	41.7
MgO	8.8	4.9
Na_2O	1.5	0.6
K_2O	7.5	2.3
SO_3	2.8	1.1
Cl	5.8	0.3
P_2O_5	1.9	0.7
Ash content	4.8	4.5

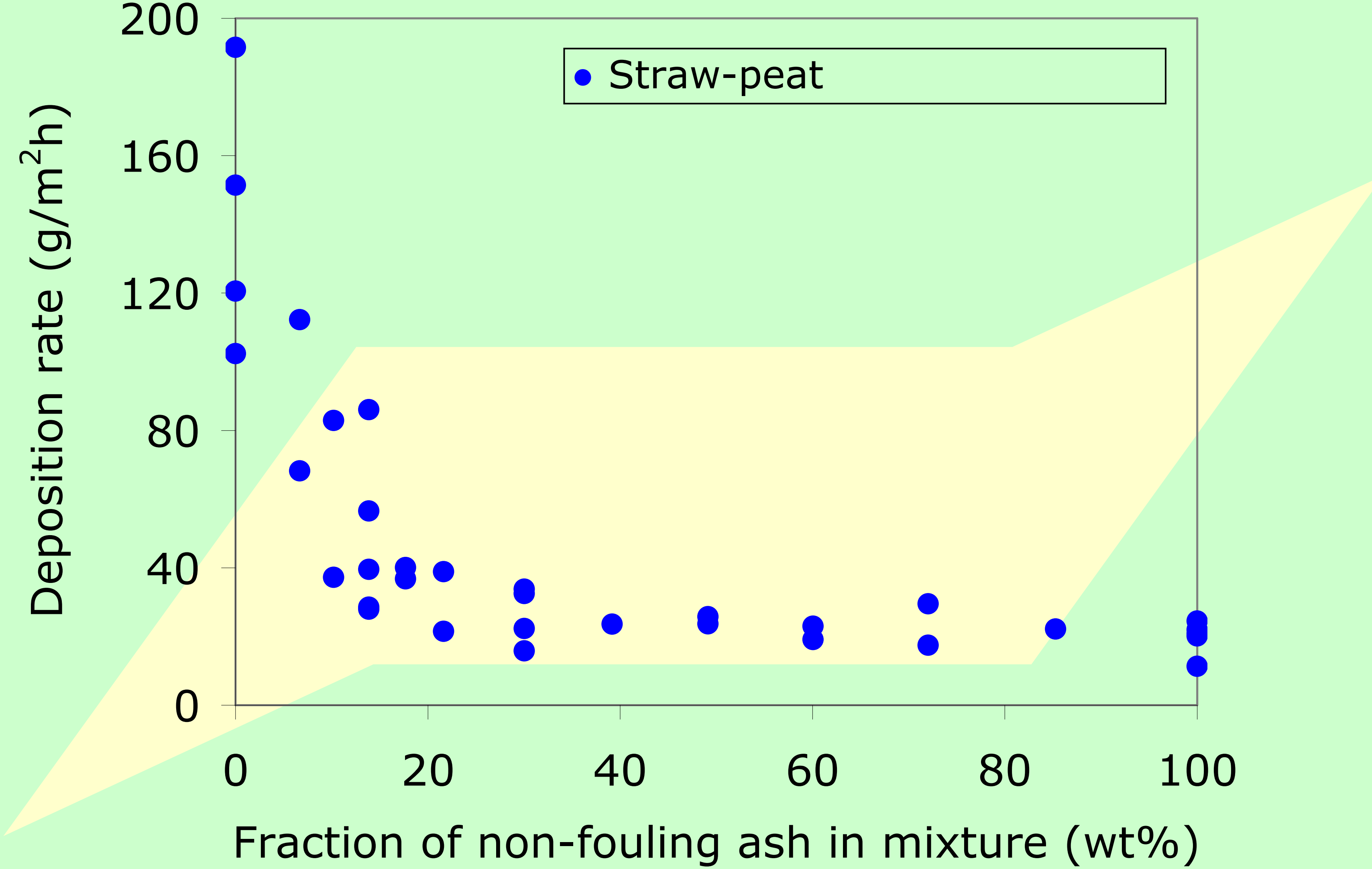
Deposition Rates
Mixtures Peat / Original Bark



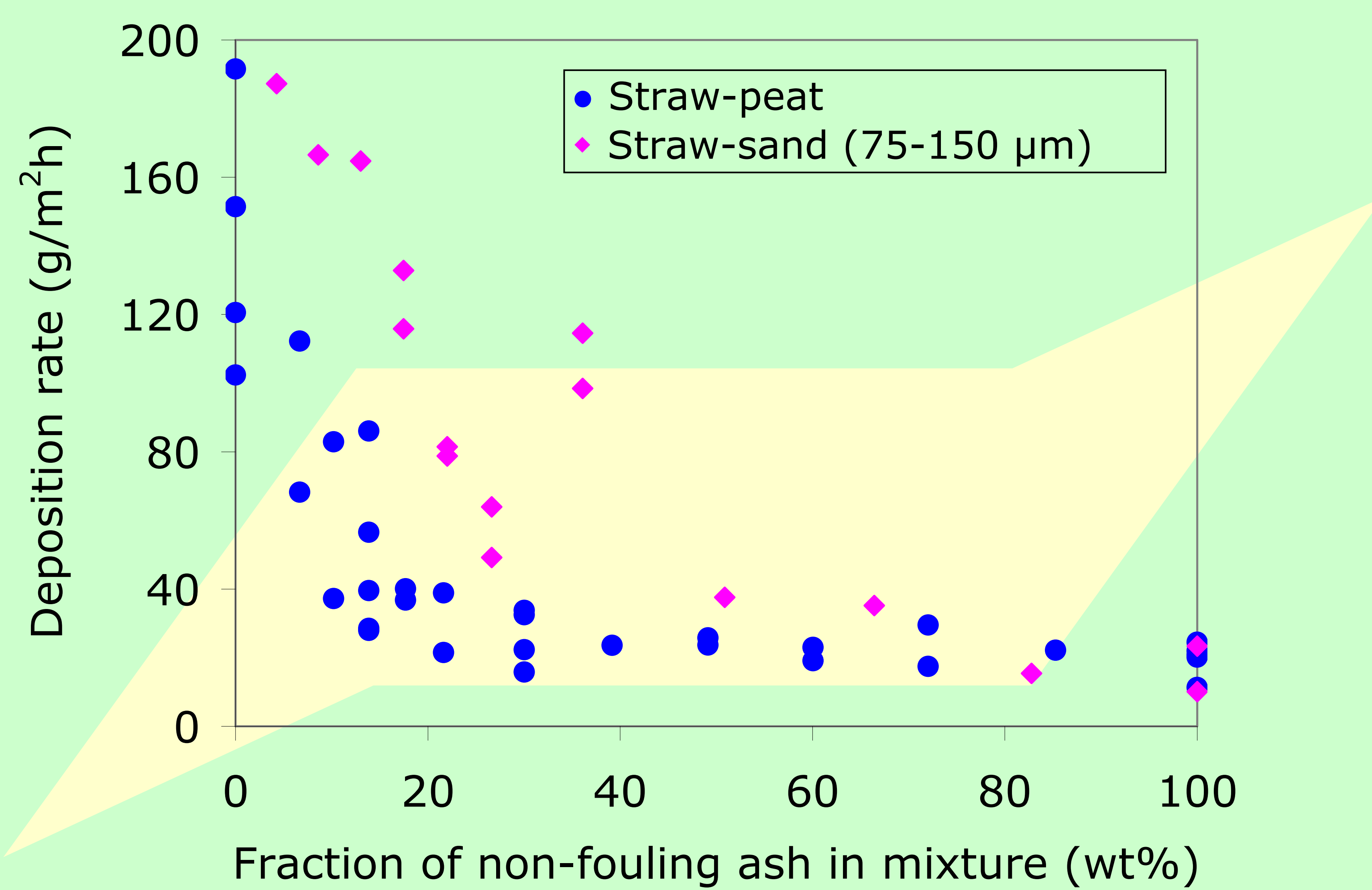
Deposition Rates
Mixtures Peat/Treated Bark



Straw and Peat



Straw and Peat/Sand



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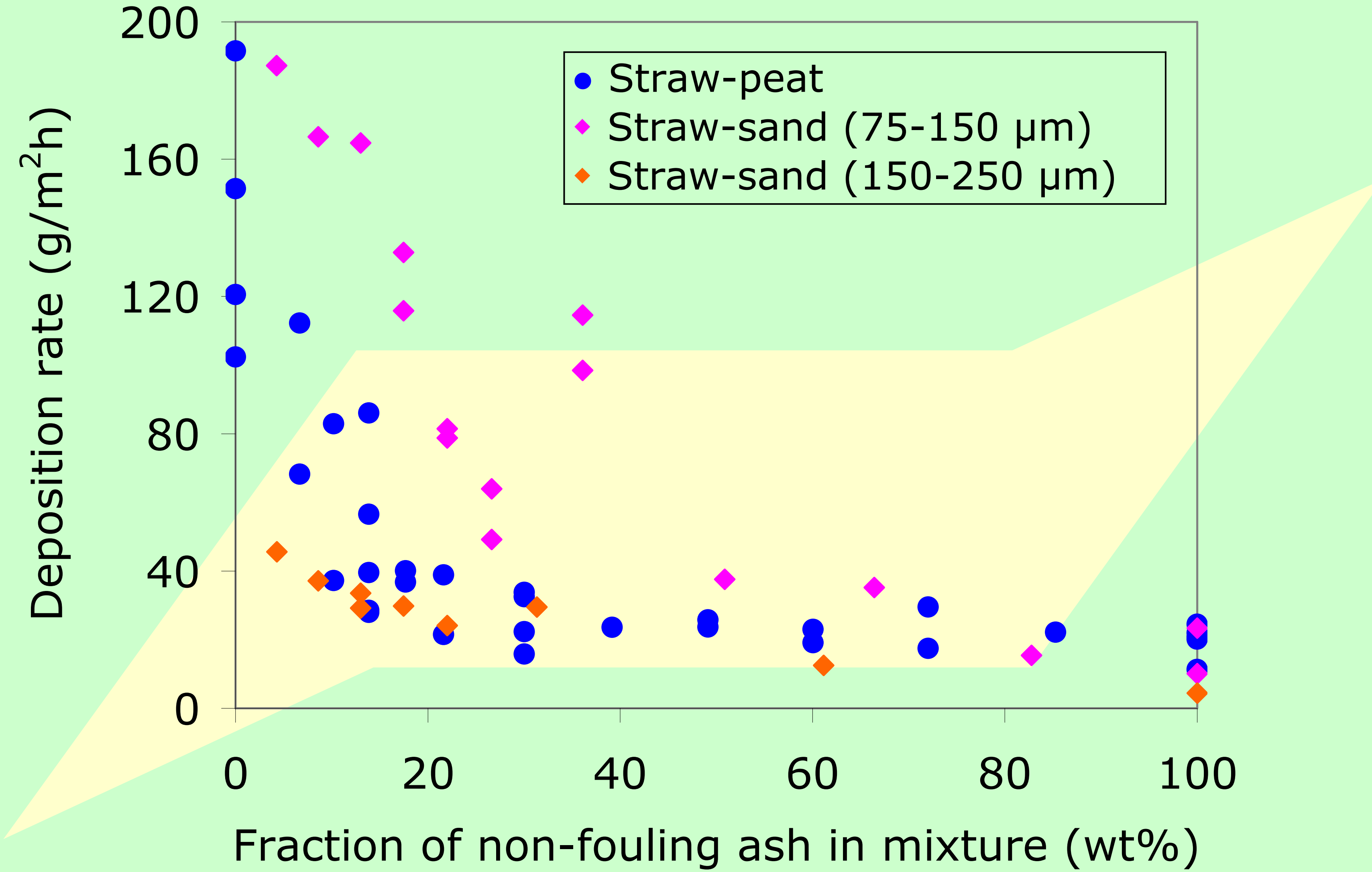
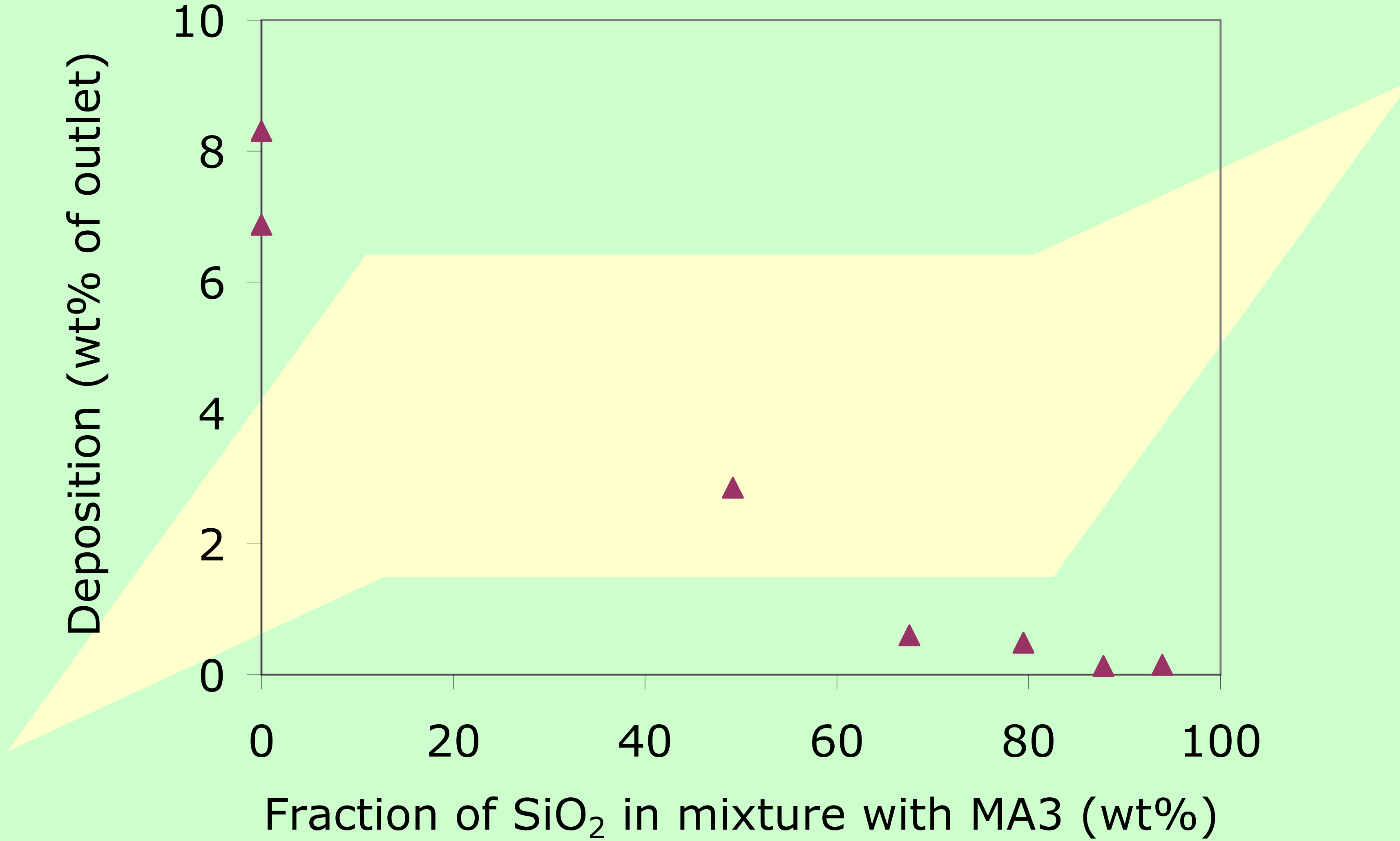


Reproduction with alkaline model ash

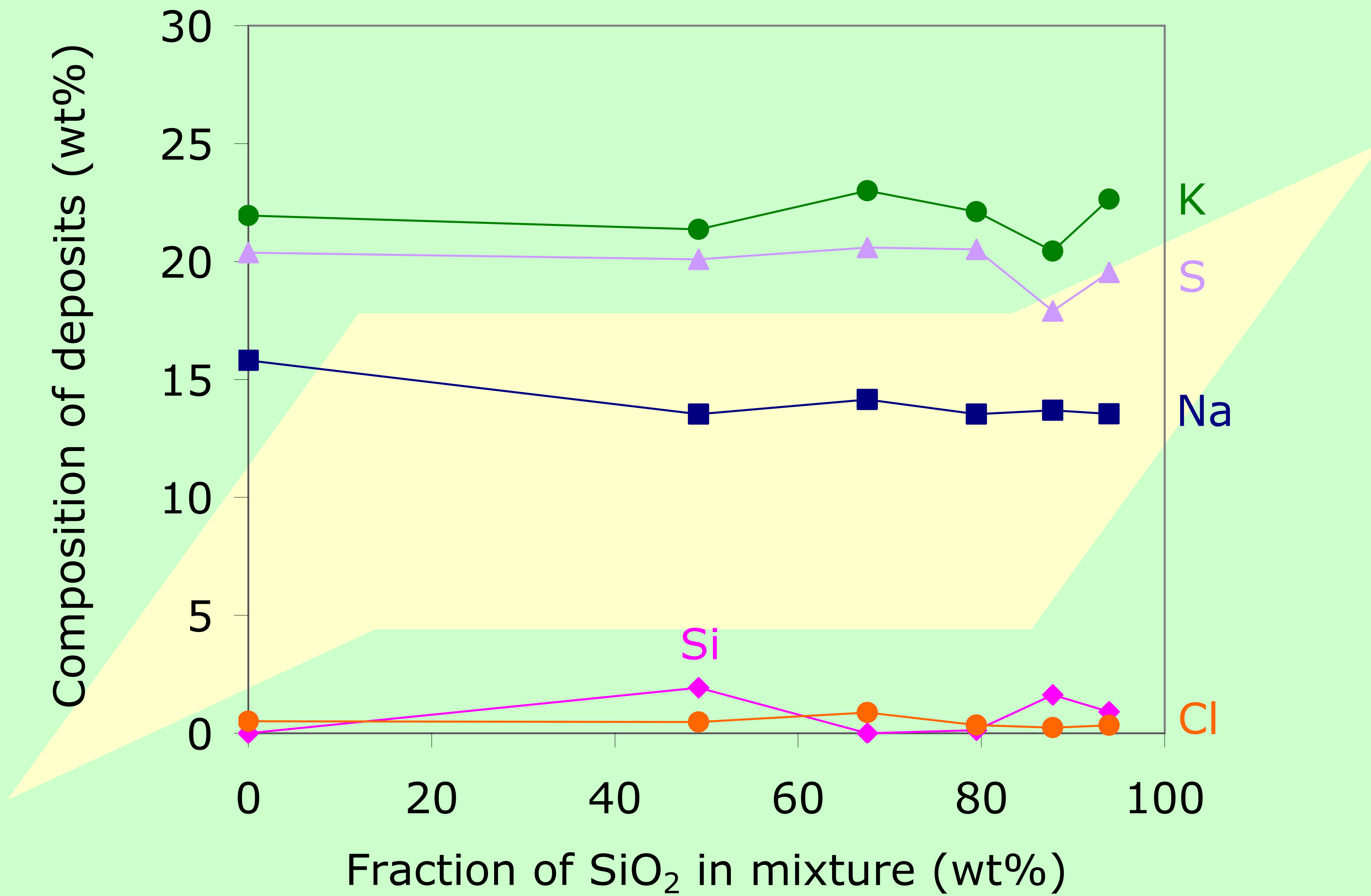
- Known ash composition
- Known melting behaviour
- Known particle size distribution
- ➢ Useful data for deposition sub-models
    - Example ”Model Ash 3”

K_2SO_4	50 wt%
Na_2SO_4	49 wt%
KCl	1 wt%

Model Ash 3 / Sand Mixtures



Composition of Deposits



Conclusions

- Bark & peat and straw & peat co-fired
- Non-linear deposition behaviour
- Bark/peat: Cl/S chemistry important
- Straw/peat: Erosion important
- Reproduction of biomass/peat mixtures by model ash and sand
- Generation of consistent data for deposition models

Acknowledgements

Åbo Akademi
Process Chemistry Centre

PULP& PAPER
UNIVERSITY OF TORONTO

Andritz Oy, Foster Wheeler Energia Oy,
International Paper Inc., Kværner Power Oy, Metsä-Botnia Ab,
Vattenfall Utveckling Ab, TEKES, GSCE