3. Mixed Fuel Firing

Chemical Aspects of Industrial Utilization of Biofuels

1. Introduction
2. Fuel Burning Characteristics
3. Combustion Equilibria
4. Melting Equilibria and Ash Behavior
5. High Temperature Corrosion
6. Flue Gas Emission Chemistry
7. Mixed Fuel Firing

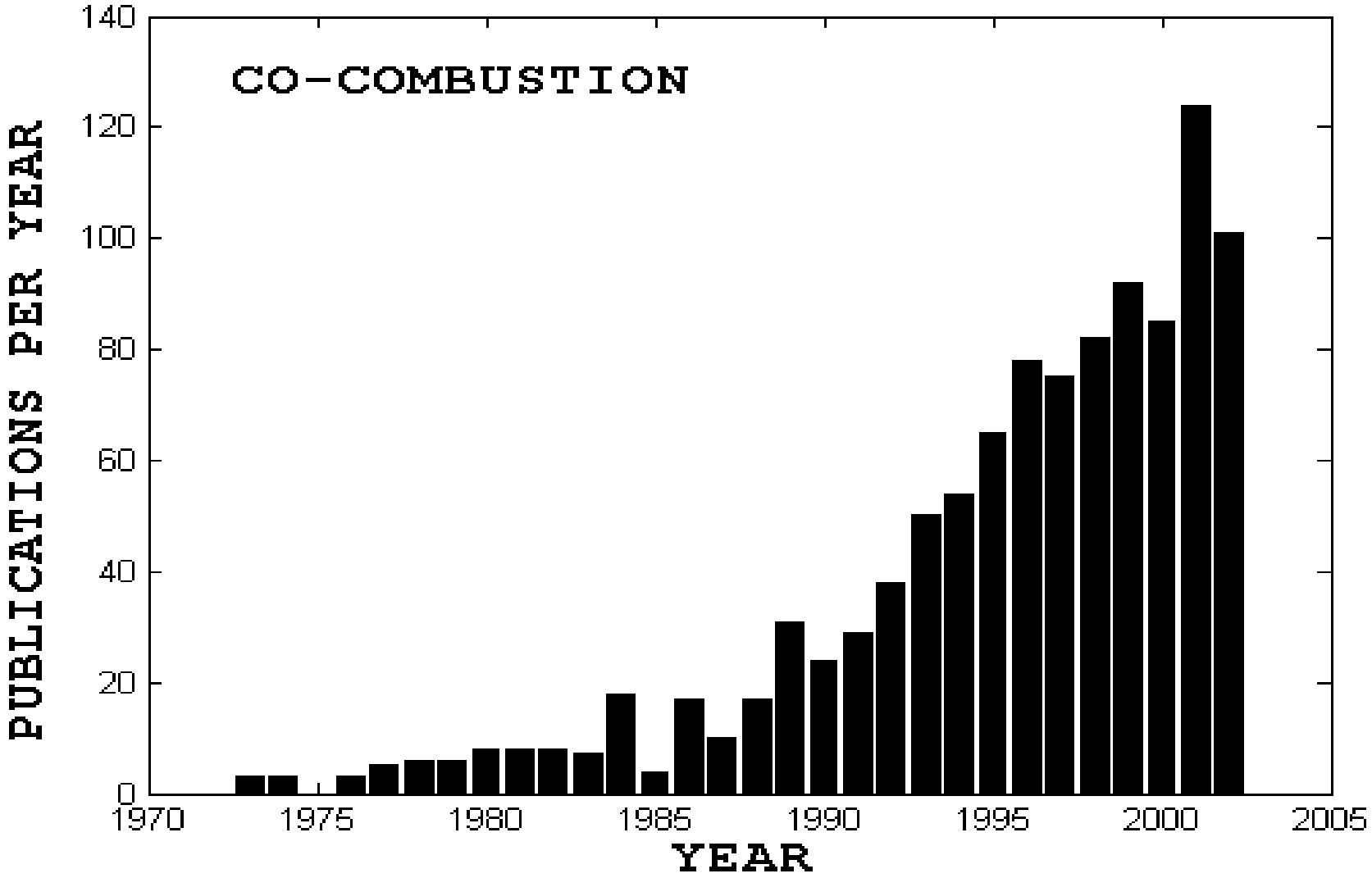
Challenges in Multi-Fuel Firing in FBC

- Emission Limits
- Fouling of Heat Surfaces
- Superheater Corrosion
- Bed Sintering
- Ash Utilization

Fuels in the Latest Major FBC Projects

- Wood fuels 16/23
- Peat 10/23
- Coal 8/23
- Sludges 8/23
- Pet Coke 4/23

- Multi-Fuel vs Single Fuel 20 vs 3



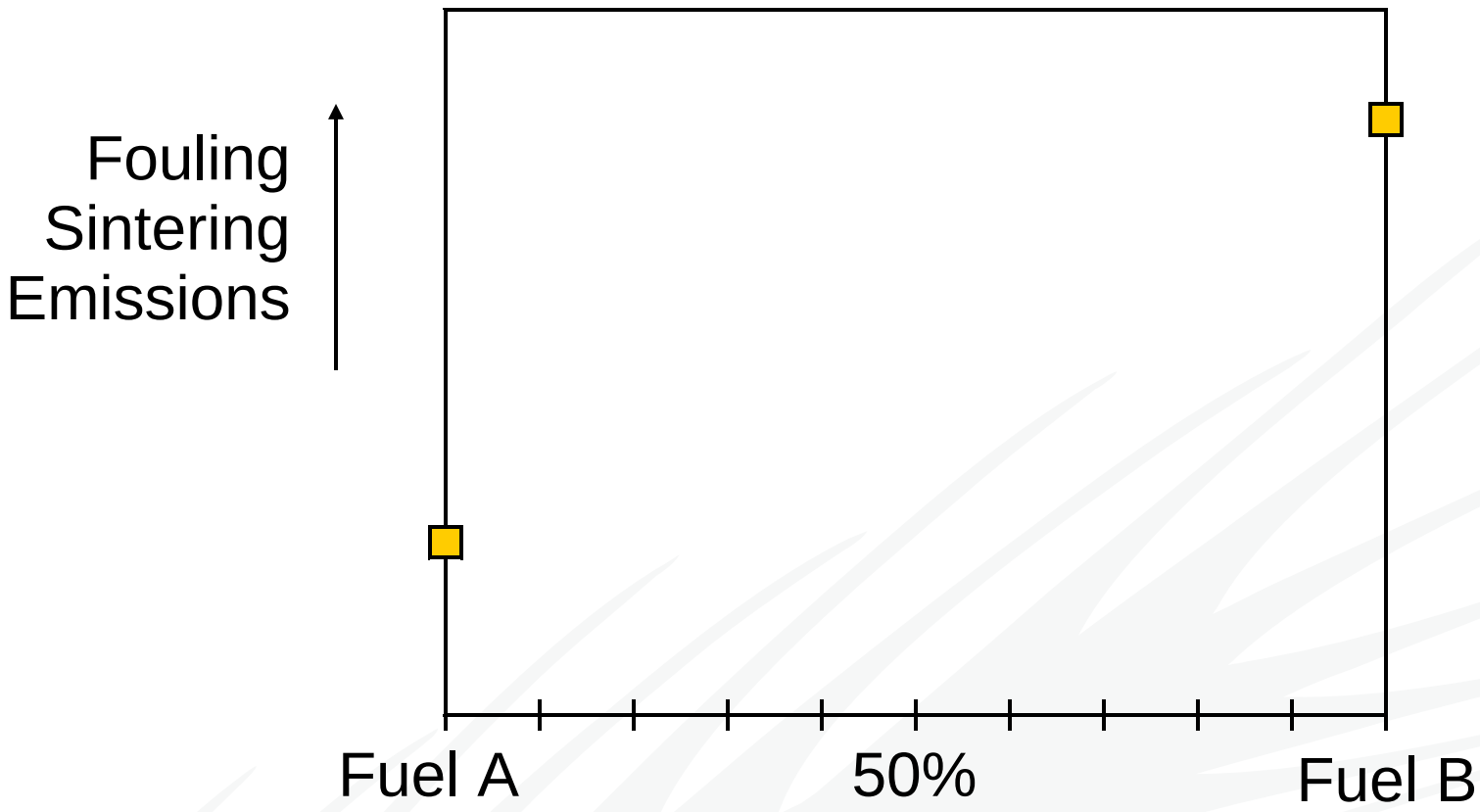
Number of Publications on “Co-combustion" or “Co-firing"

ScienceFinder, January 2003, after (Leckner 2003).

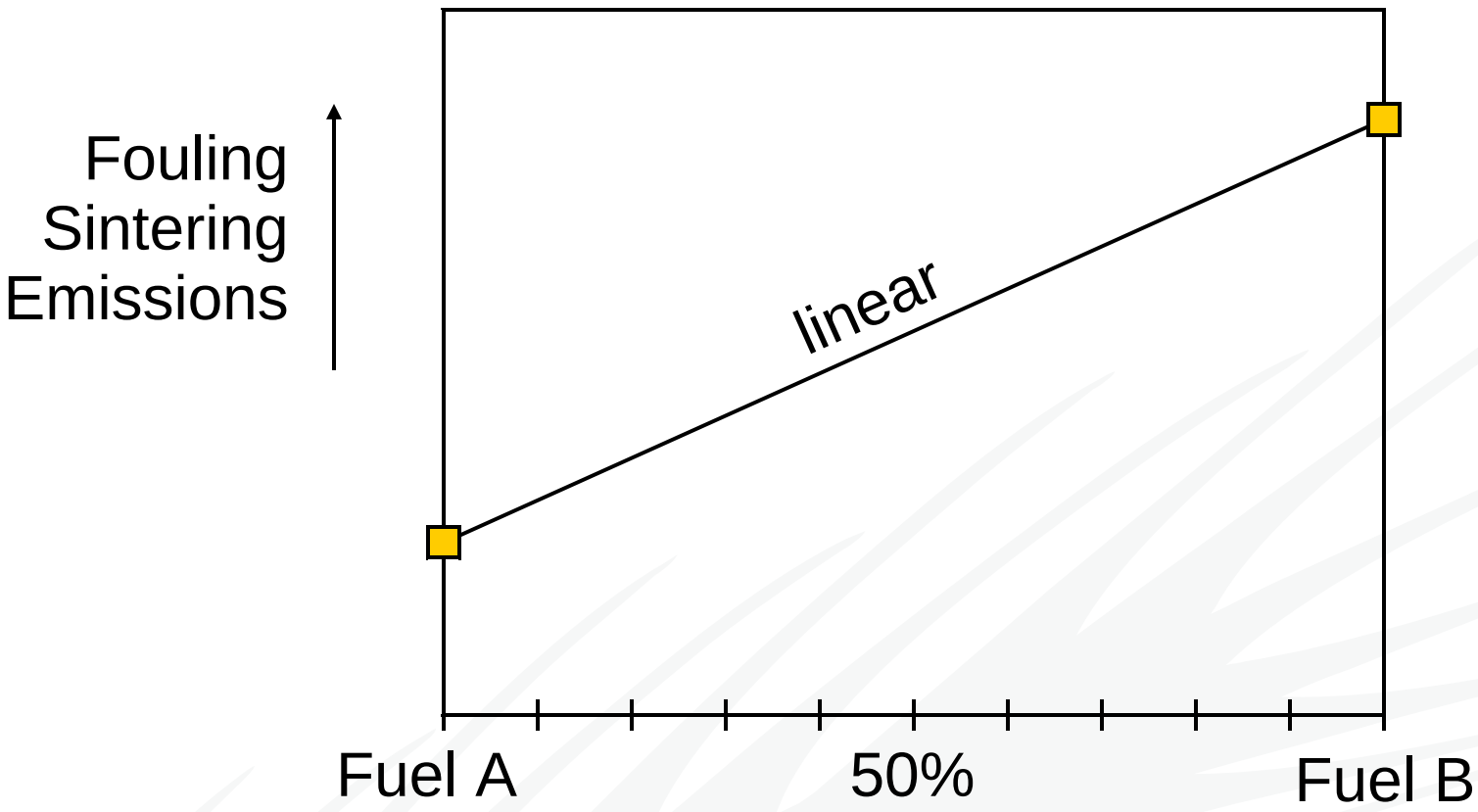
Challenges in Multi-Fuel Firing in FBC

How Can Fundamental Research Contribute?

Fuel Interaction in FBC



Fuel Interaction in FBC



Gaseous Emissions
SO_2 and NO_x

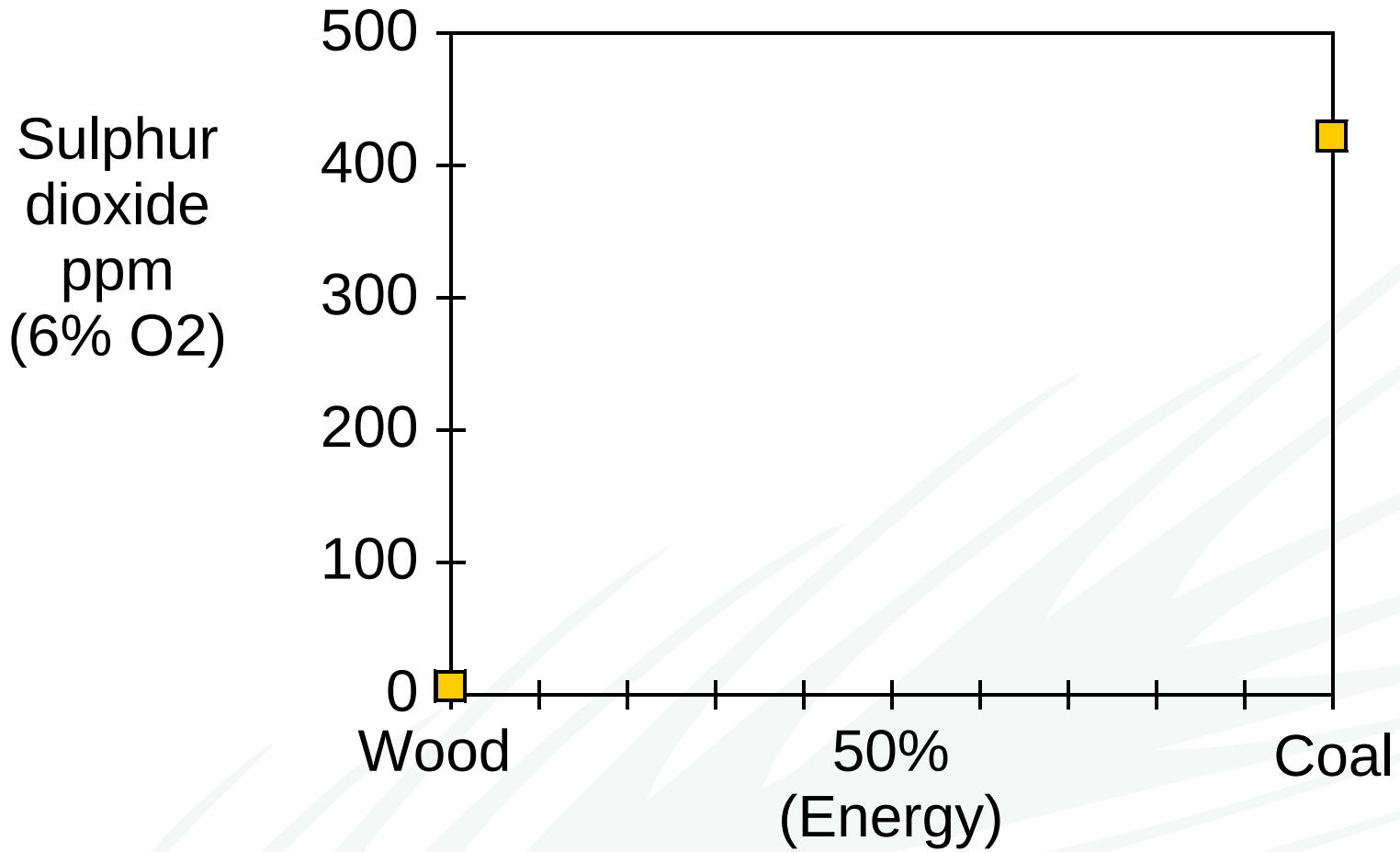
Chalmers CFBC Tests with Coal, Wood, Sludge

(Leckner, Åmand)

- 12 MW CFBC with external cooling
- Constant conditions (temp., air distribution)
- Results for fundamental analysis and modelling

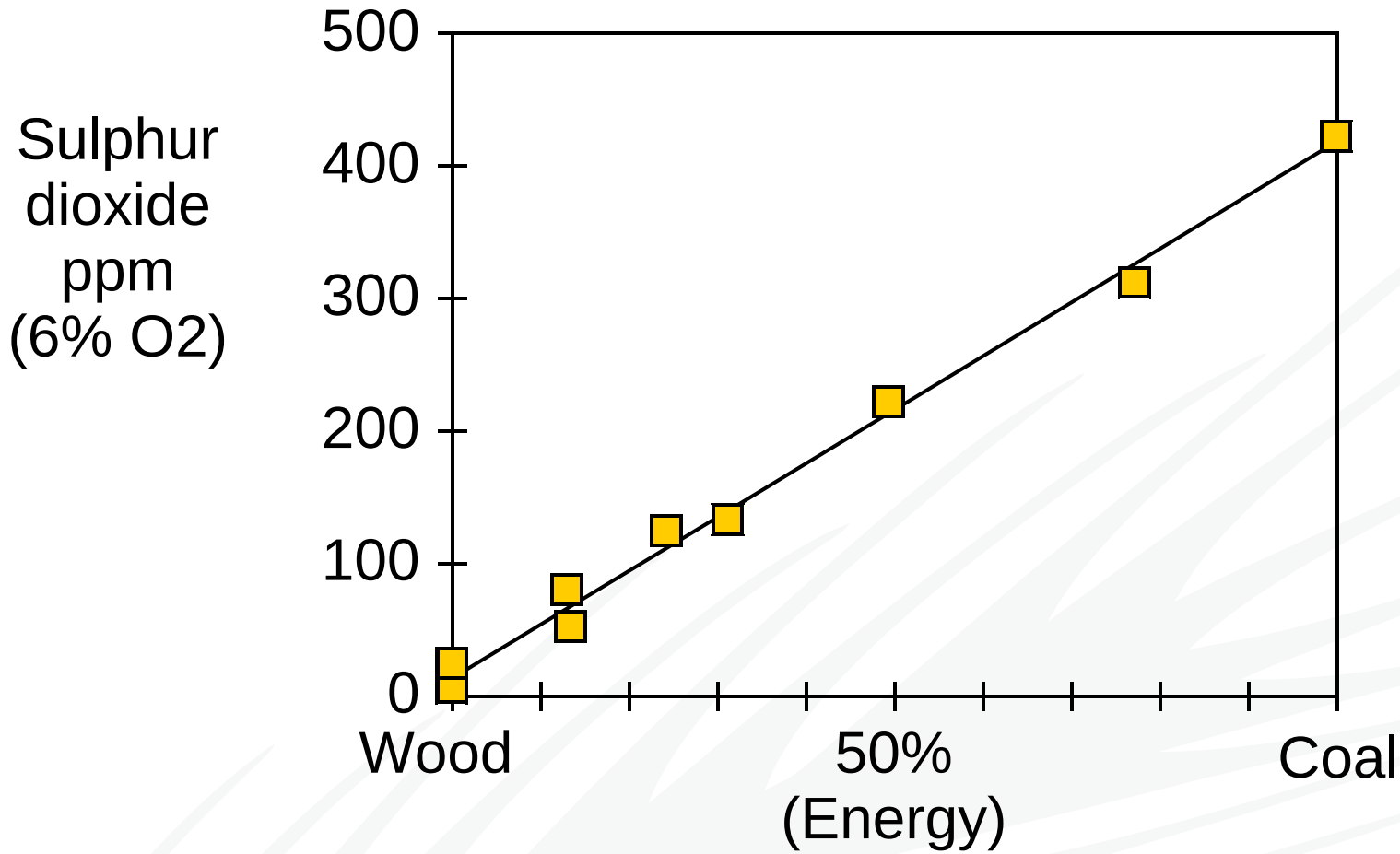
SO2 Emission with Wood-Coal

(Leckner et al.)



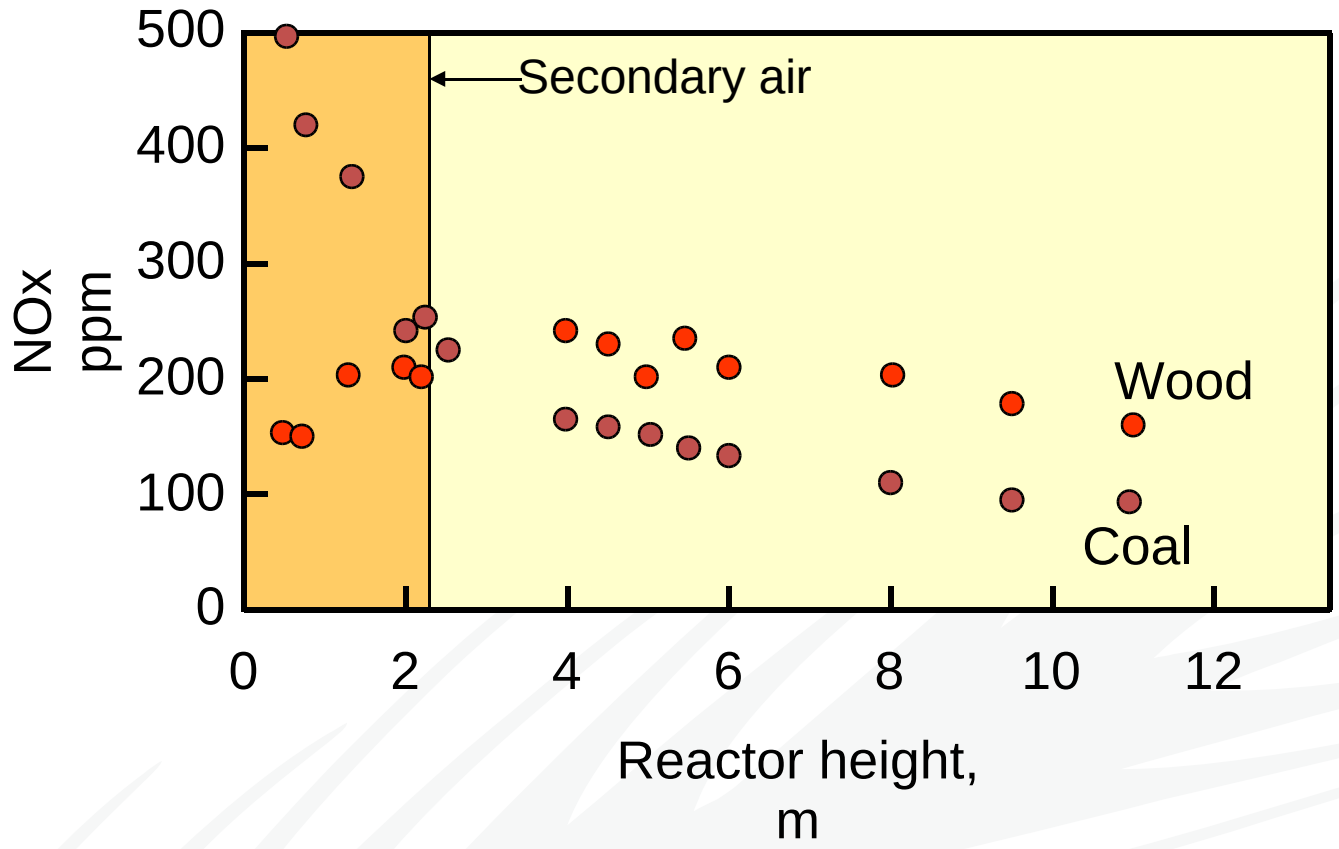
SO2 Emission with Wood-Coal

(Leckner et al.)



NO Profiles in CFBC

(Leckner et al.)

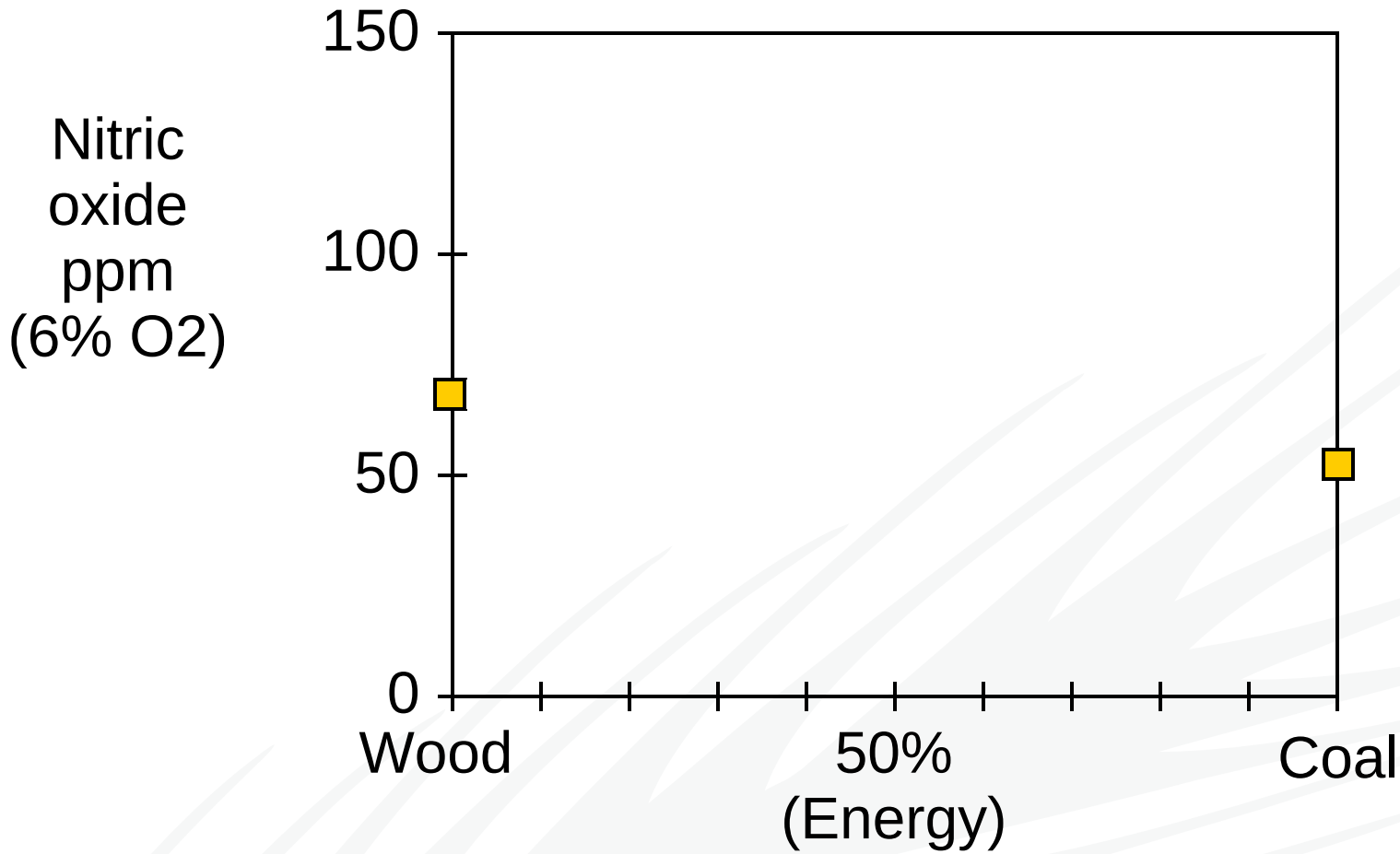


Nitrogen Oxides with Coal and Wood
(Leckner et al.)

	Coal	Wood
Volatile, % db	40	80
$N_{(fuel)}$, % db	1.6	0.14
CFBC NO, ppm	50	60

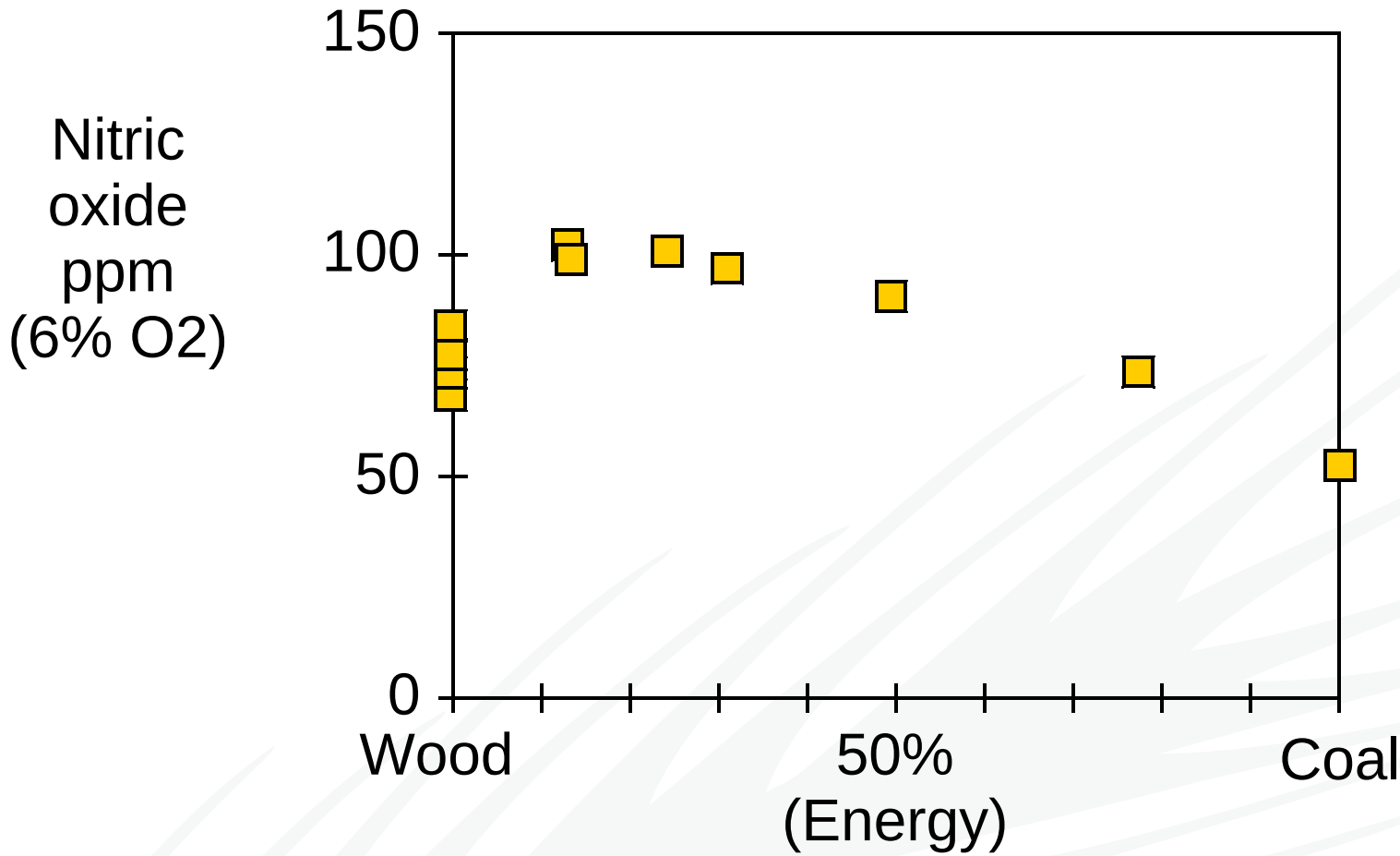
NO Emission with Wood-Coal

(Leckner et al.)

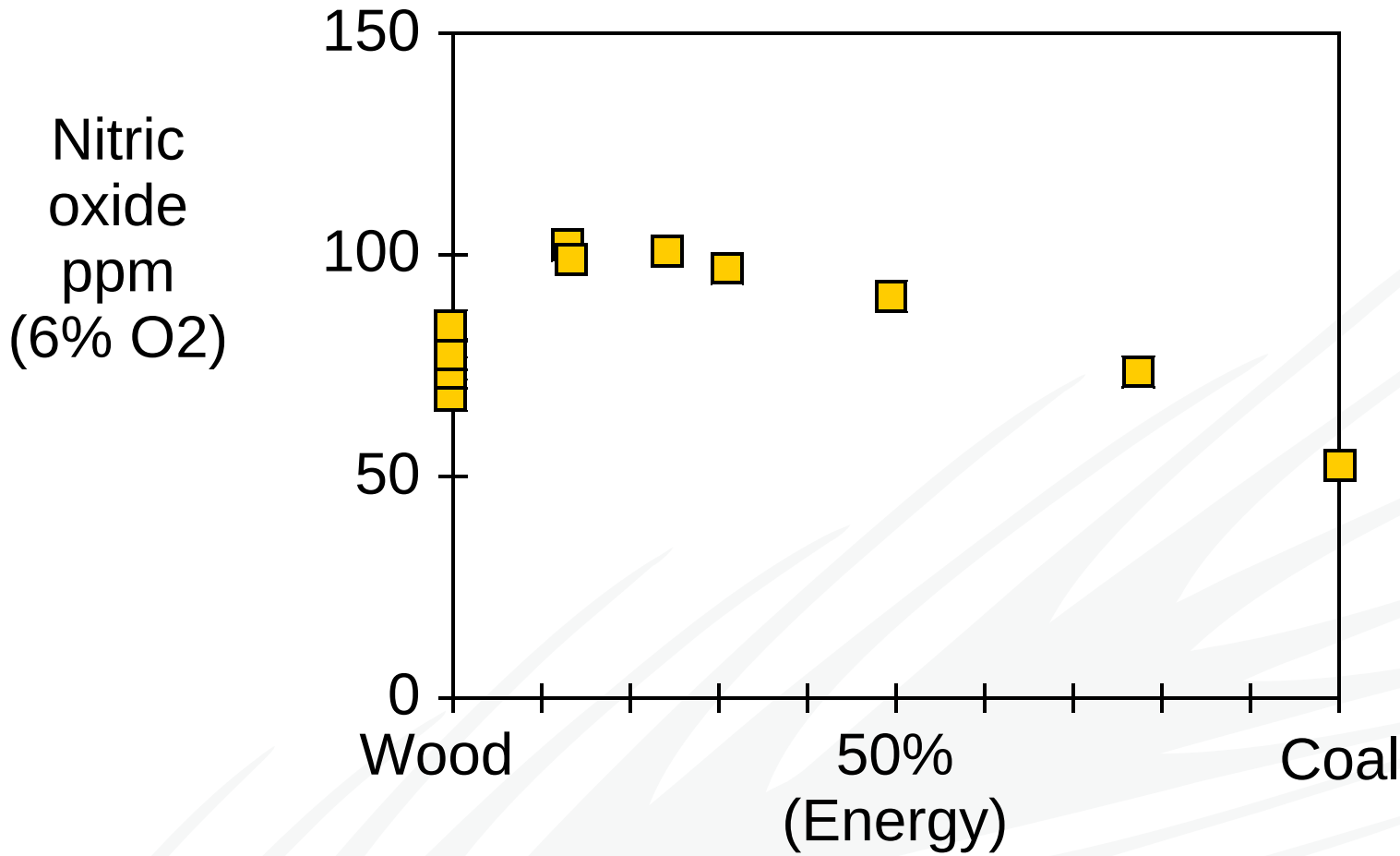


NO Emission with Wood-Coal

(Leckner et al.)

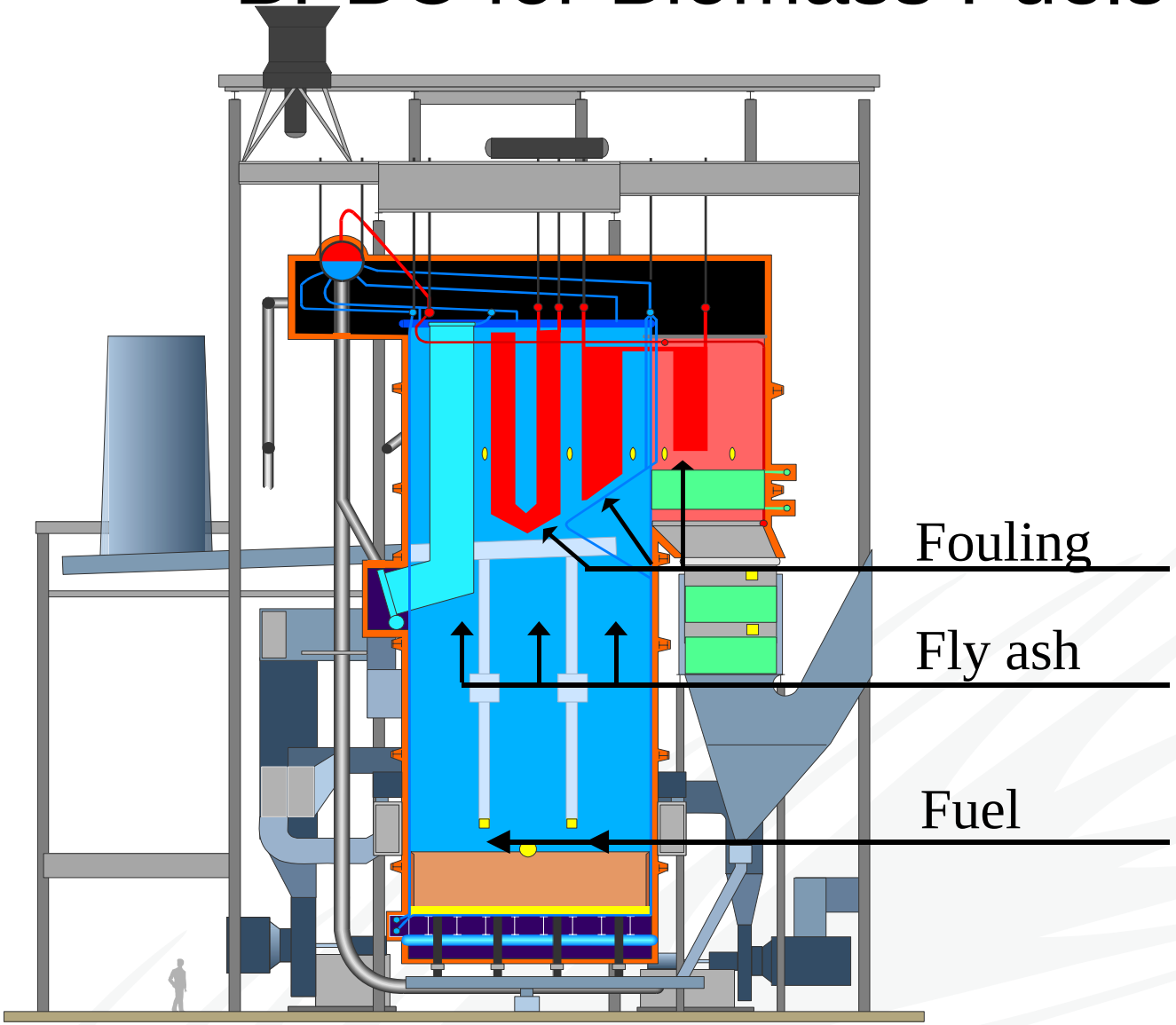


NO Emission with W&C (Leckner et al.)



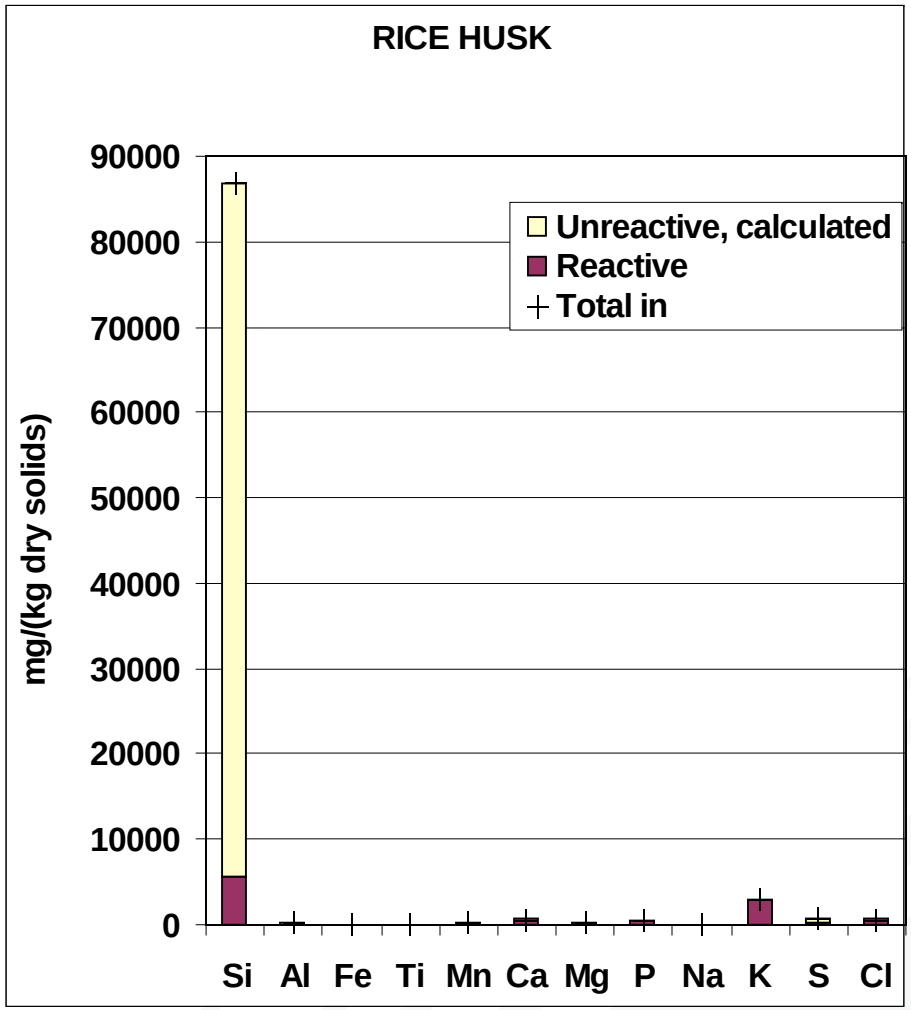
Superheater Fouling in BFBC

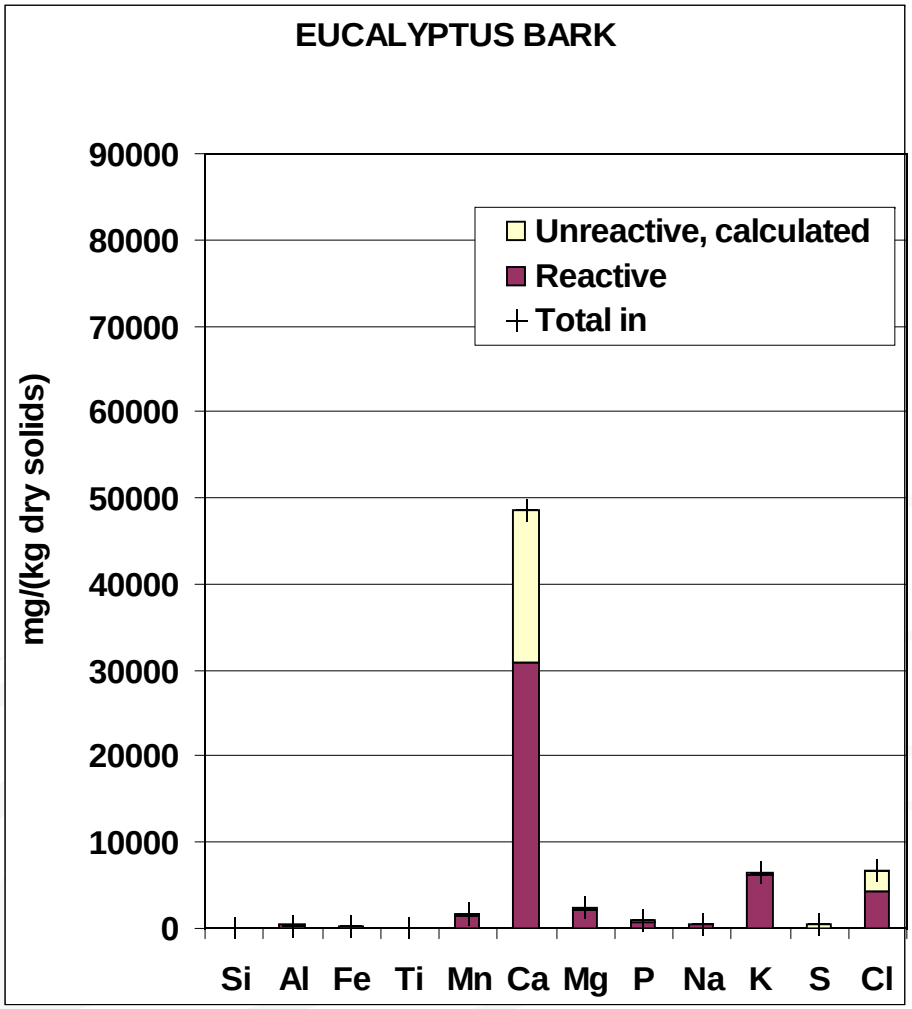
BFBC for Biomass Fuels



Rice husk
Eucalyptus bark

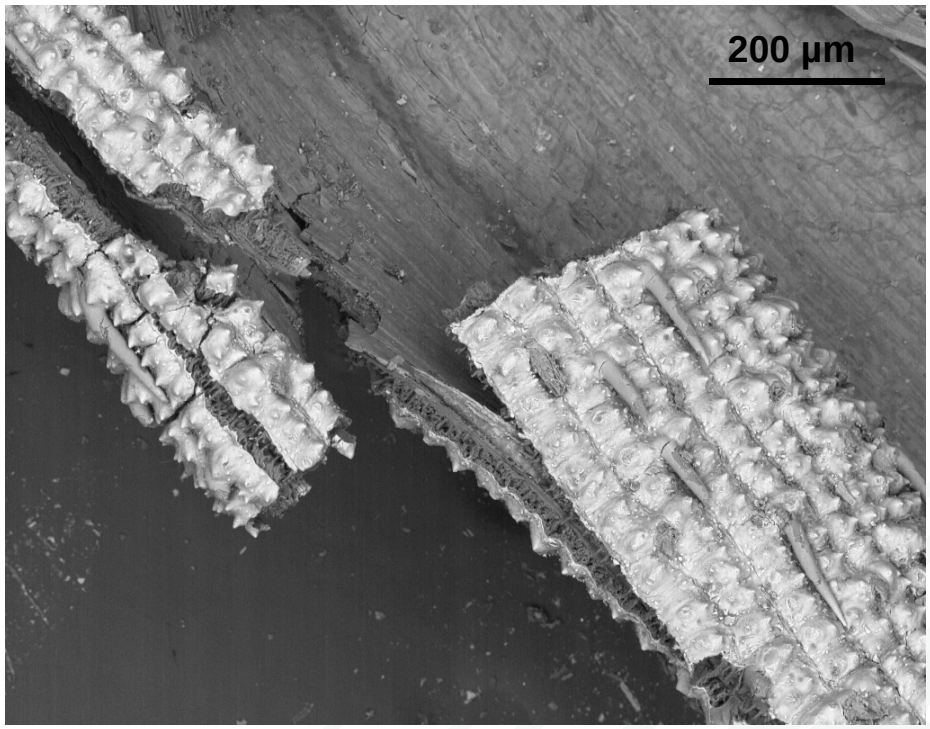
Ash Forming Elements in Rice Husk and Eucalyptus Bark



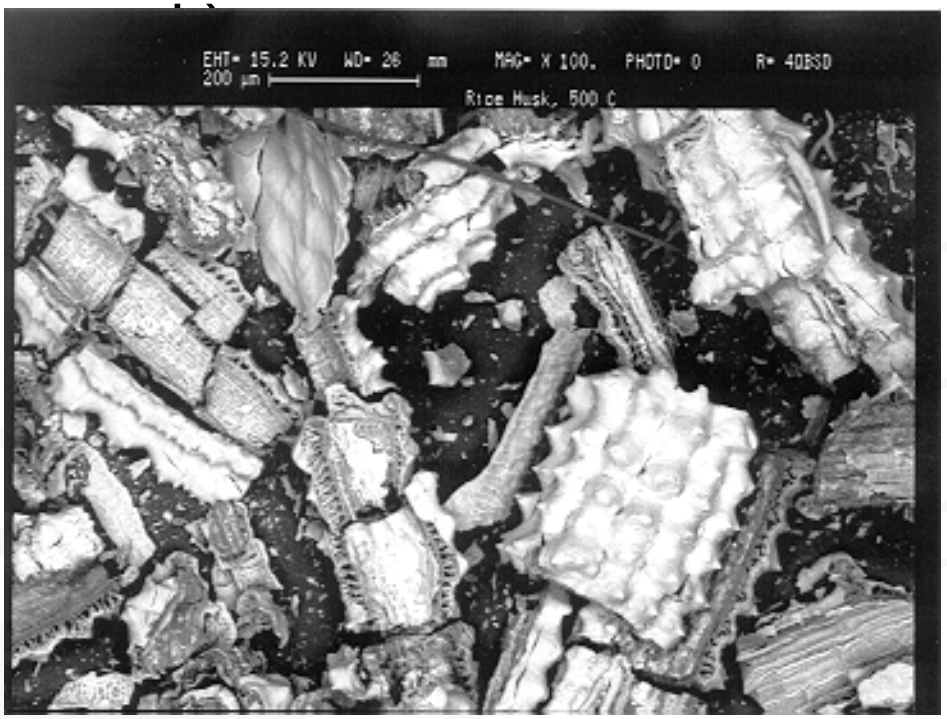


Rice Husk & Rice Husk Ash

Rice husk,

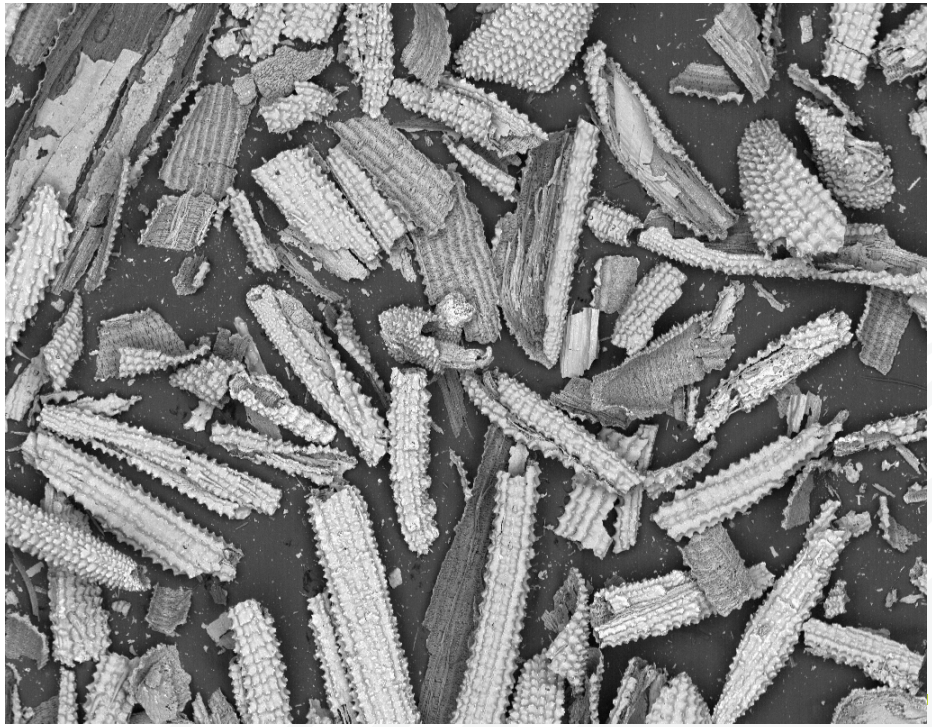


Rice husk ash (laboratory

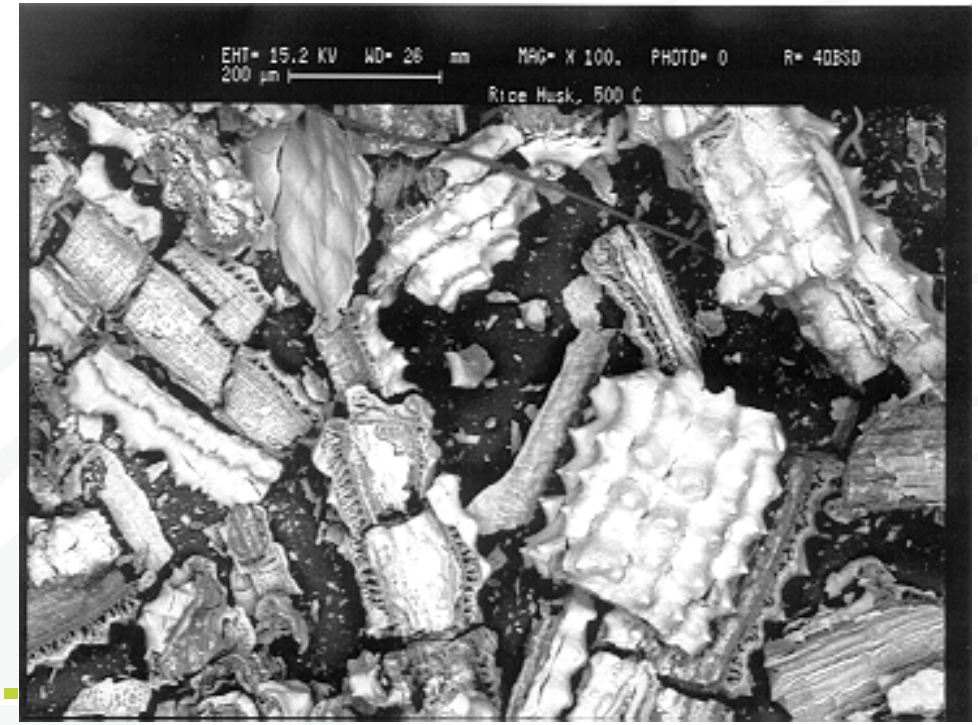


Rice Husk:
Boiler Fly Ash vs. Laboratory Ash

2nd pass ash from the boiler



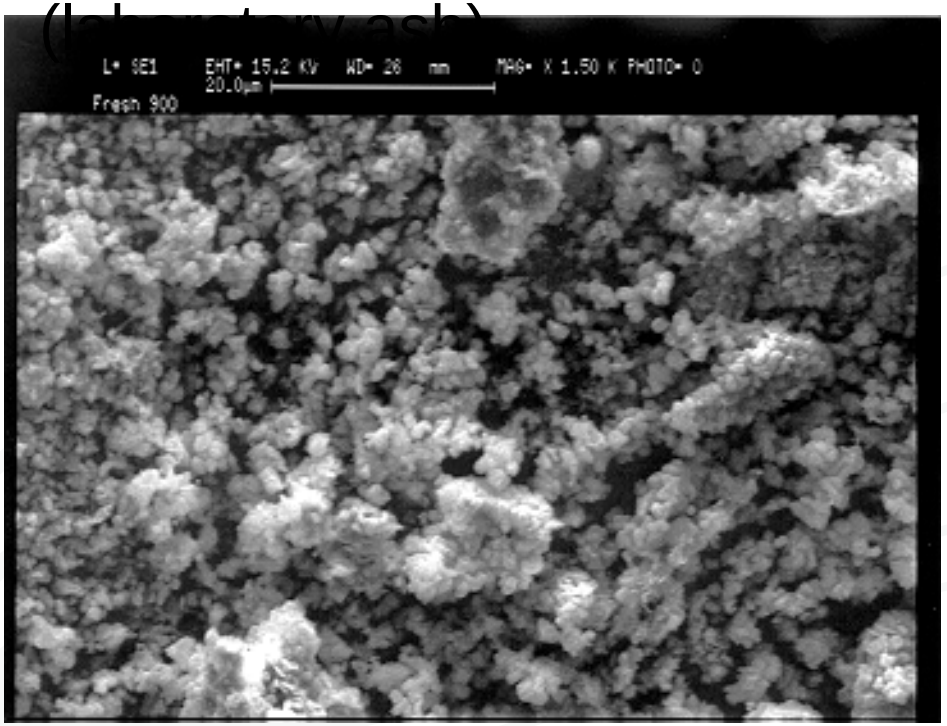
Rice husk laboratory ash



Eucalyptus Bark & Eucalyptus Bark Ash

Eucalyptus bark, untreated

Eucalyptus bark ash (laboratory ash)



Fly Ash of Rice Husk and Eucalyptus Bark

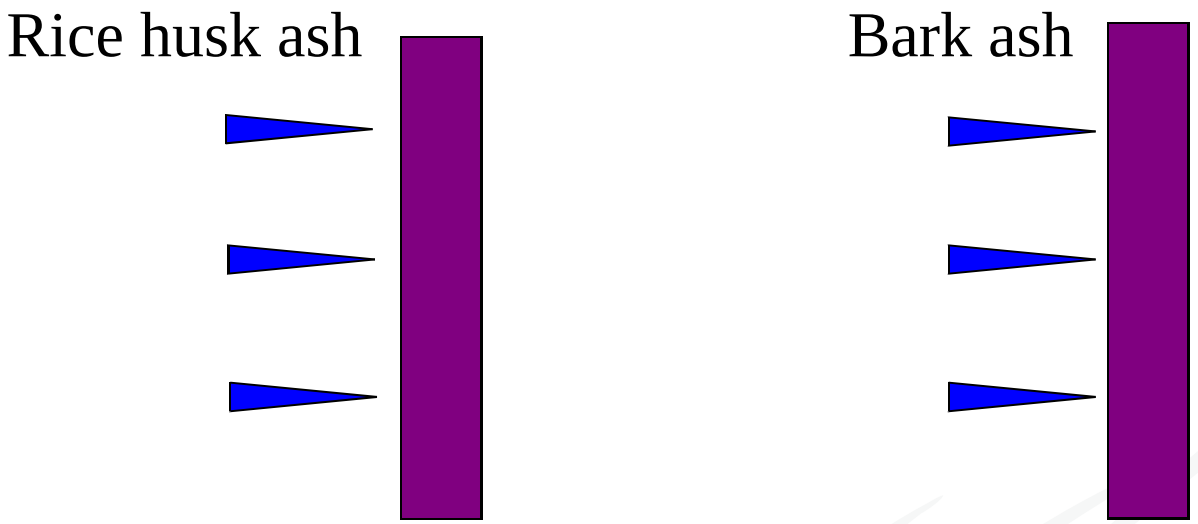
Rice husk ash

- Silica (SiO_2)
- Not Molten
- Large Particles

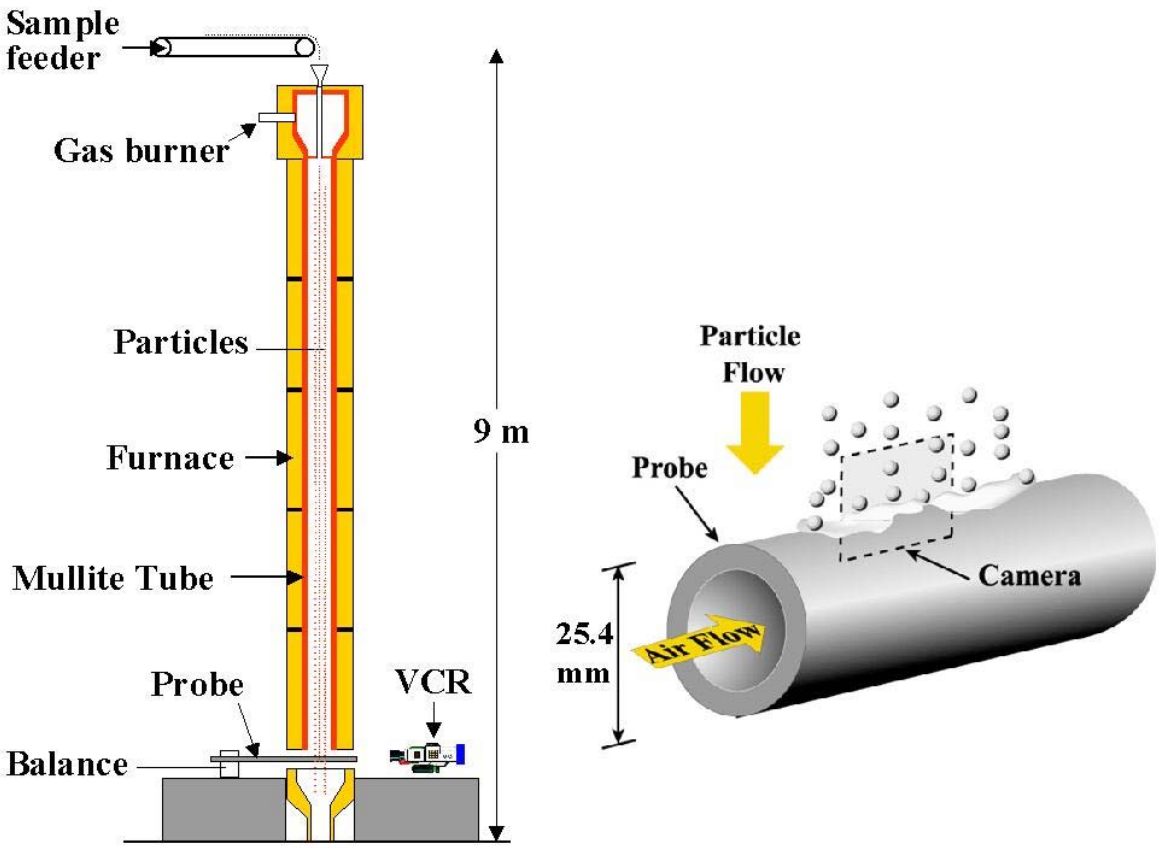
Eucalyptus bark ash

- Chlorides and Sulphates of K, Na, and Ca
- Partially Molten > 700ºC
- Vapours, Small Particles

Fly Ash Particles Approaching Tube Surfaces



Fouling Test Facility (University of Toronto)



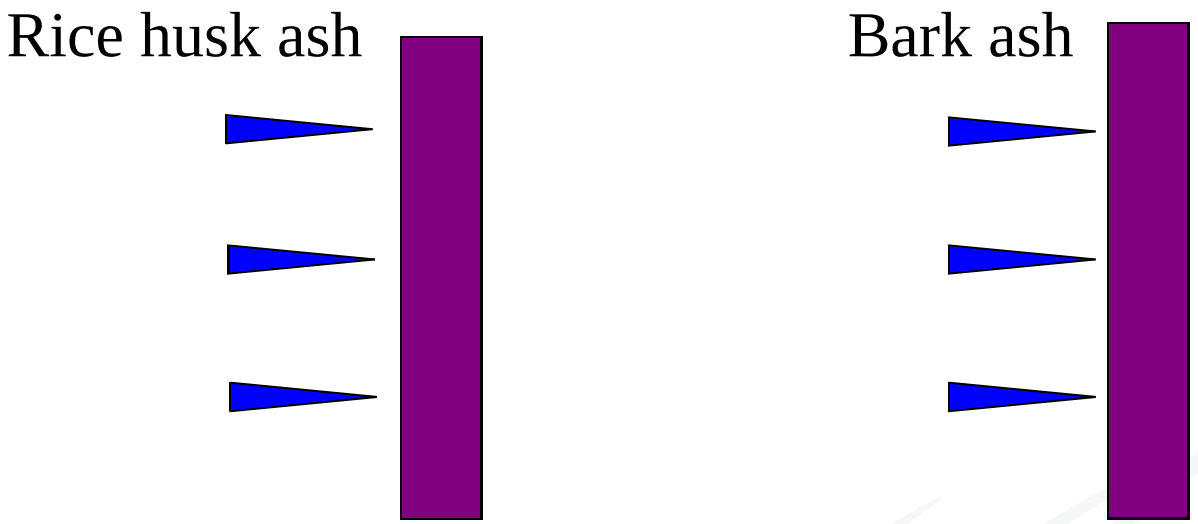
100% Rice Husk

After 40 minutes

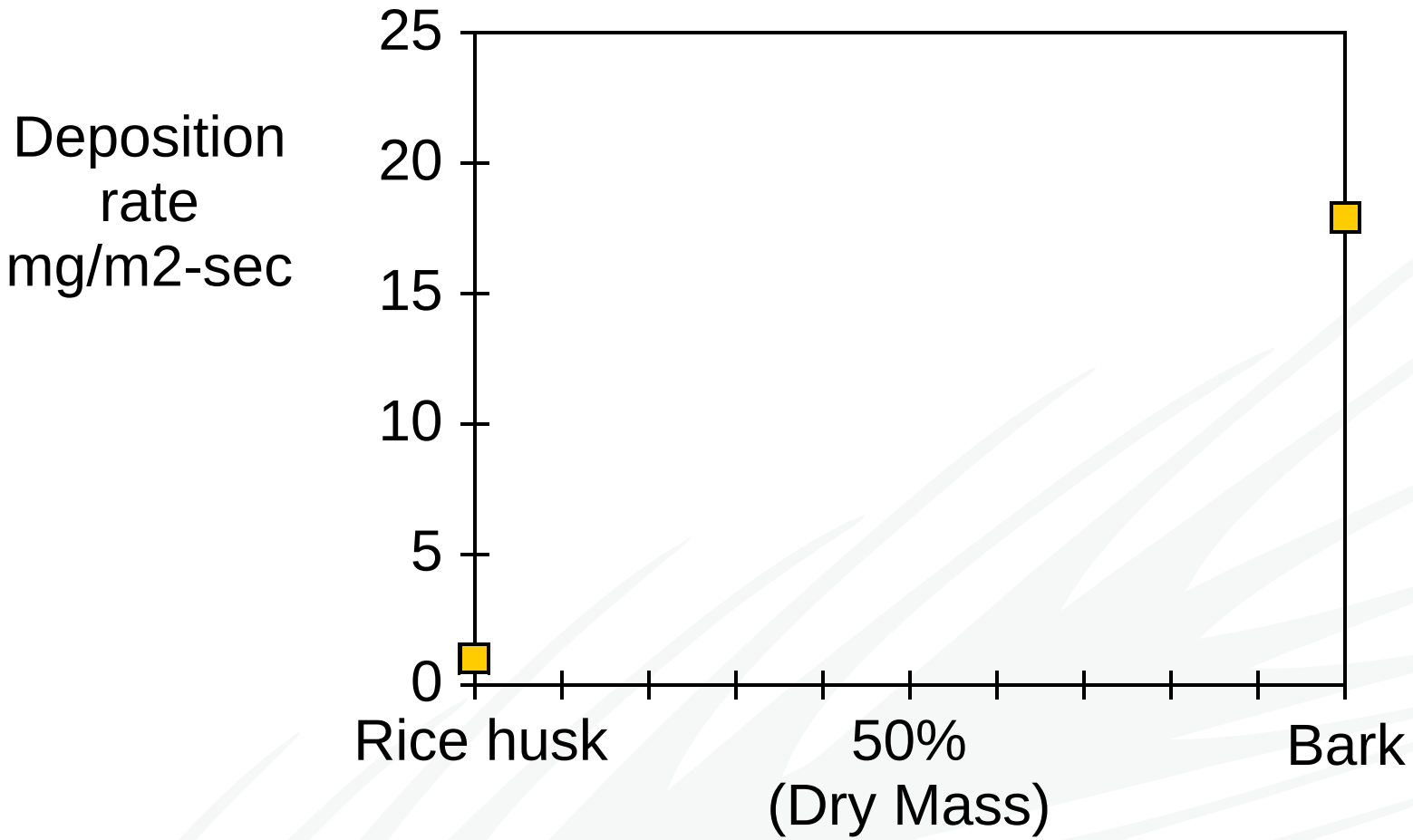
100% Bark

After 40 minutes

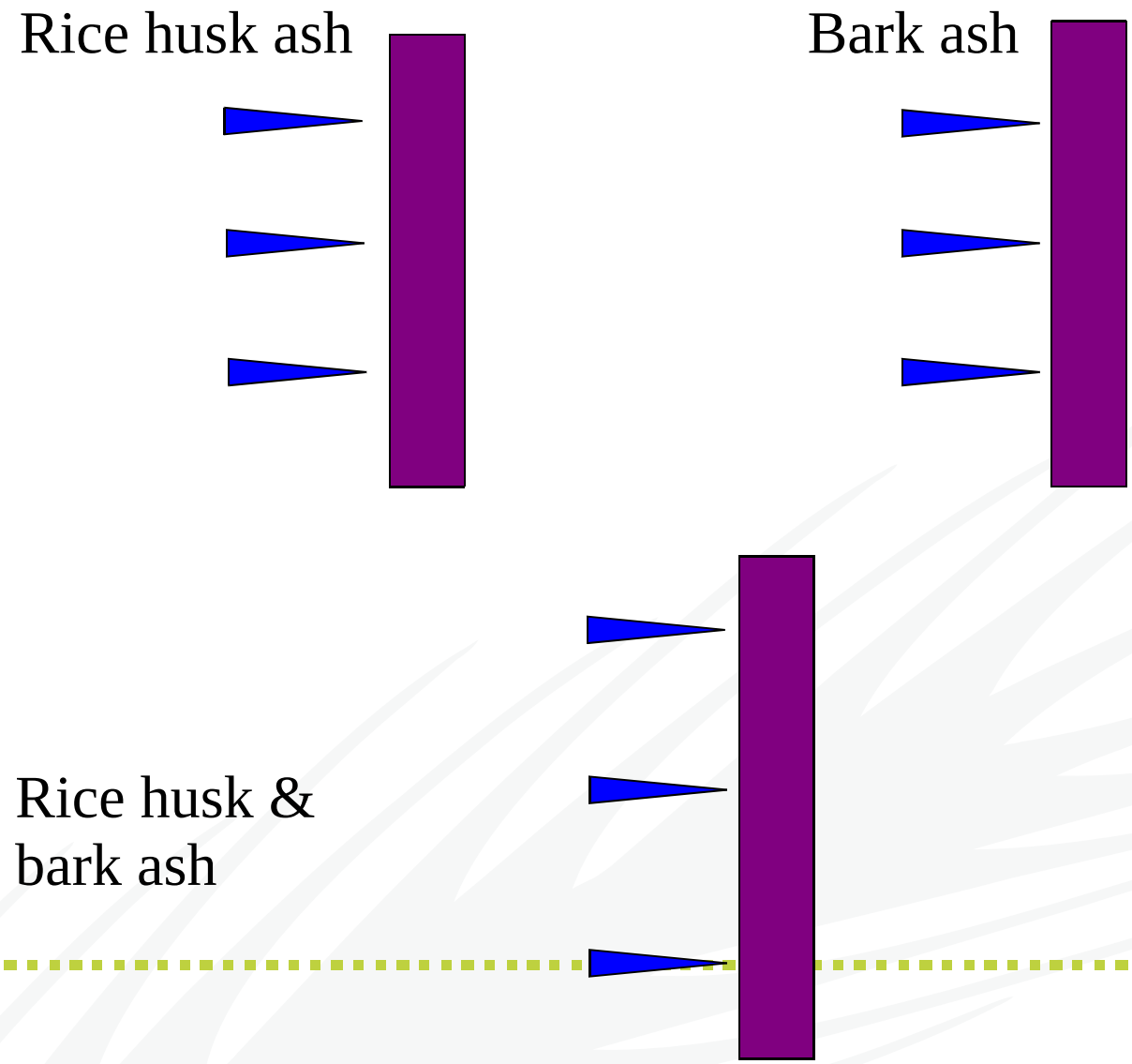
Fly Ash Particles Approaching Tube Surfaces



Probe Deposits: Rice Husk - Bark



Fly Ash Particles Approaching Tube Surfaces



36% Bark - 64% Rice Husk

After 40 minutes

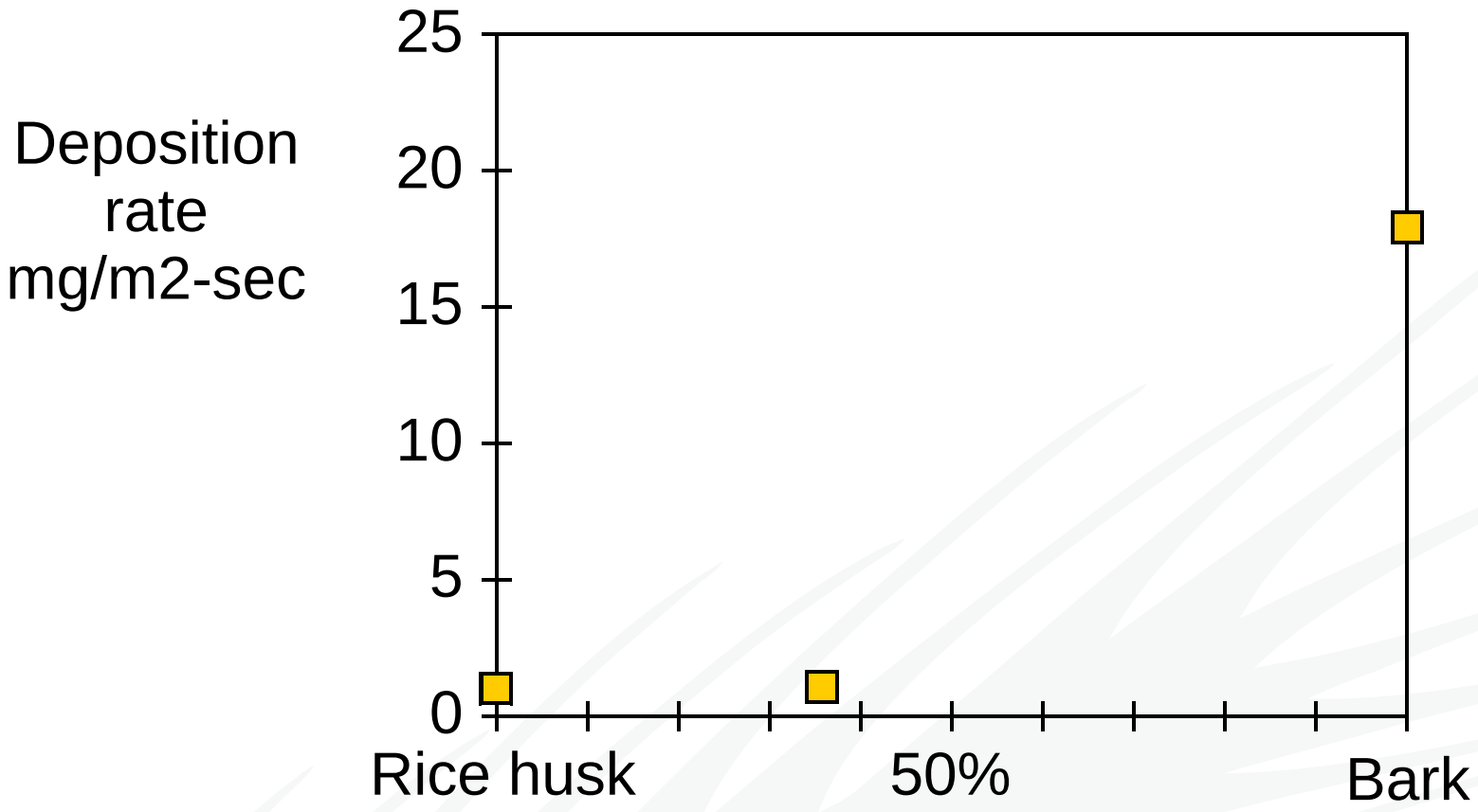
Test Tube Surfaces after Exposure (40 min)

100% Rice husk,
Deposit Mass = 10 mg

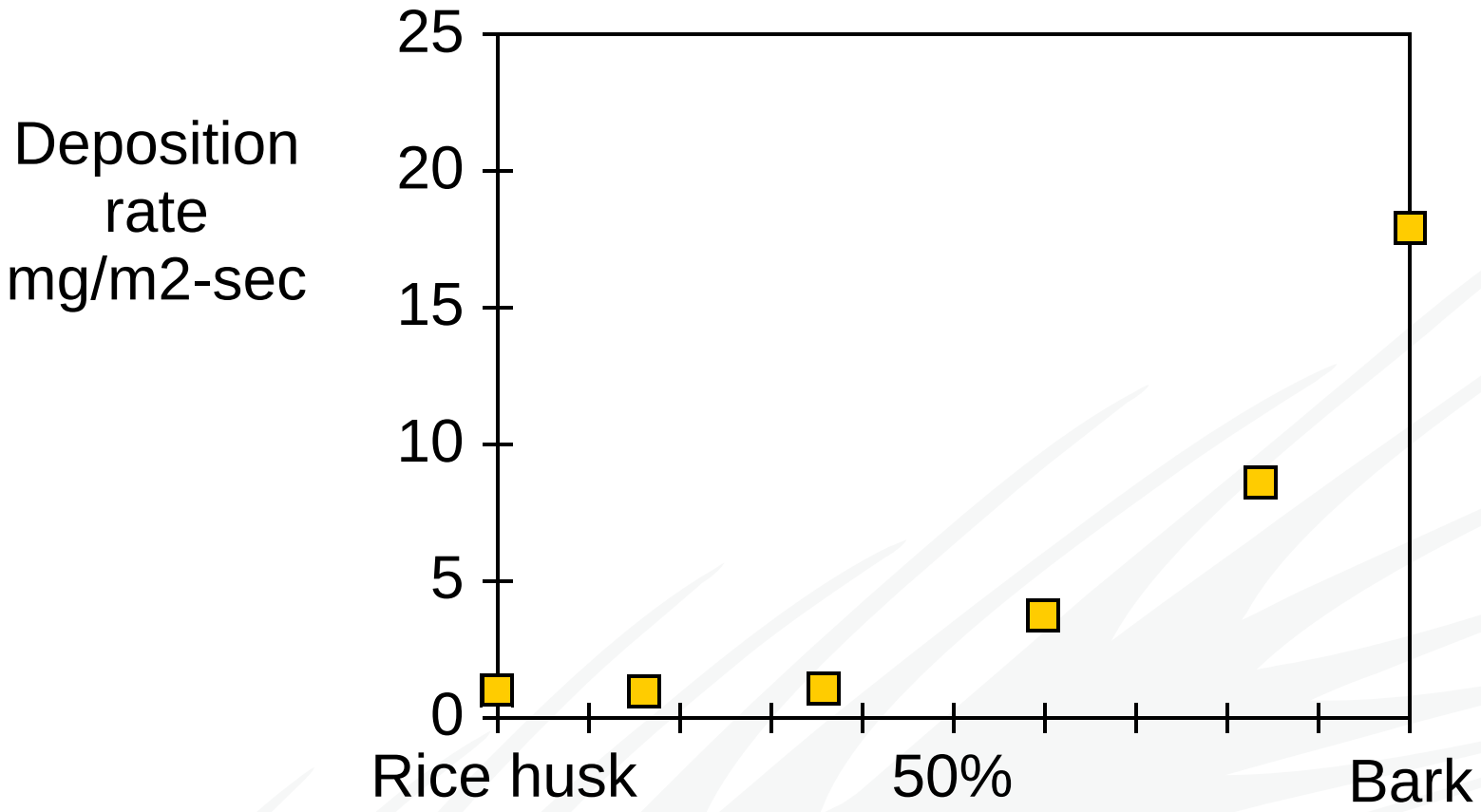
Rice/Eucalyptus 64/36 %
Deposit Mass = 13 mg

100% Eucalyptus bark,
Deposit Mass = 195

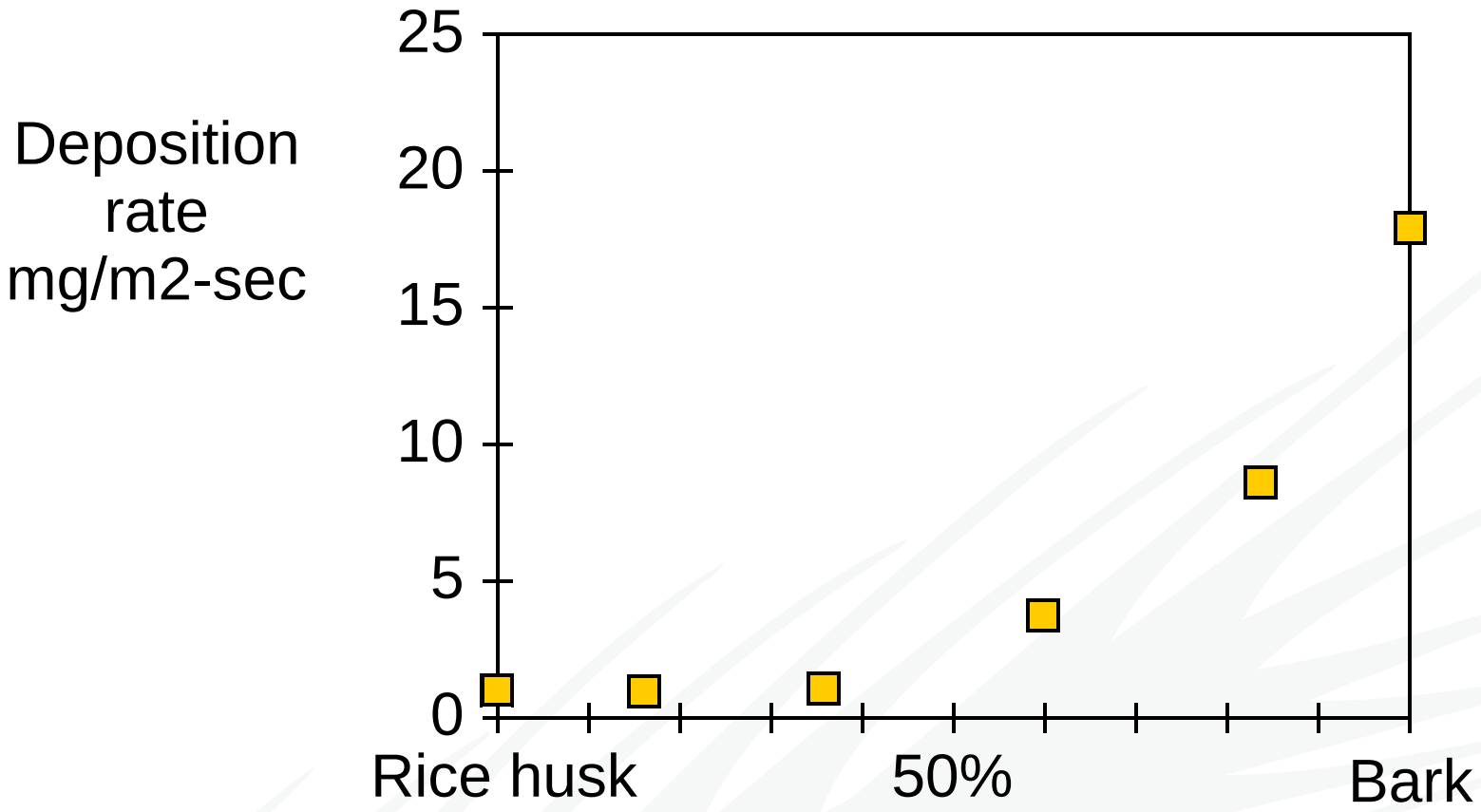
Probe Deposits: Rice Husk - Bark



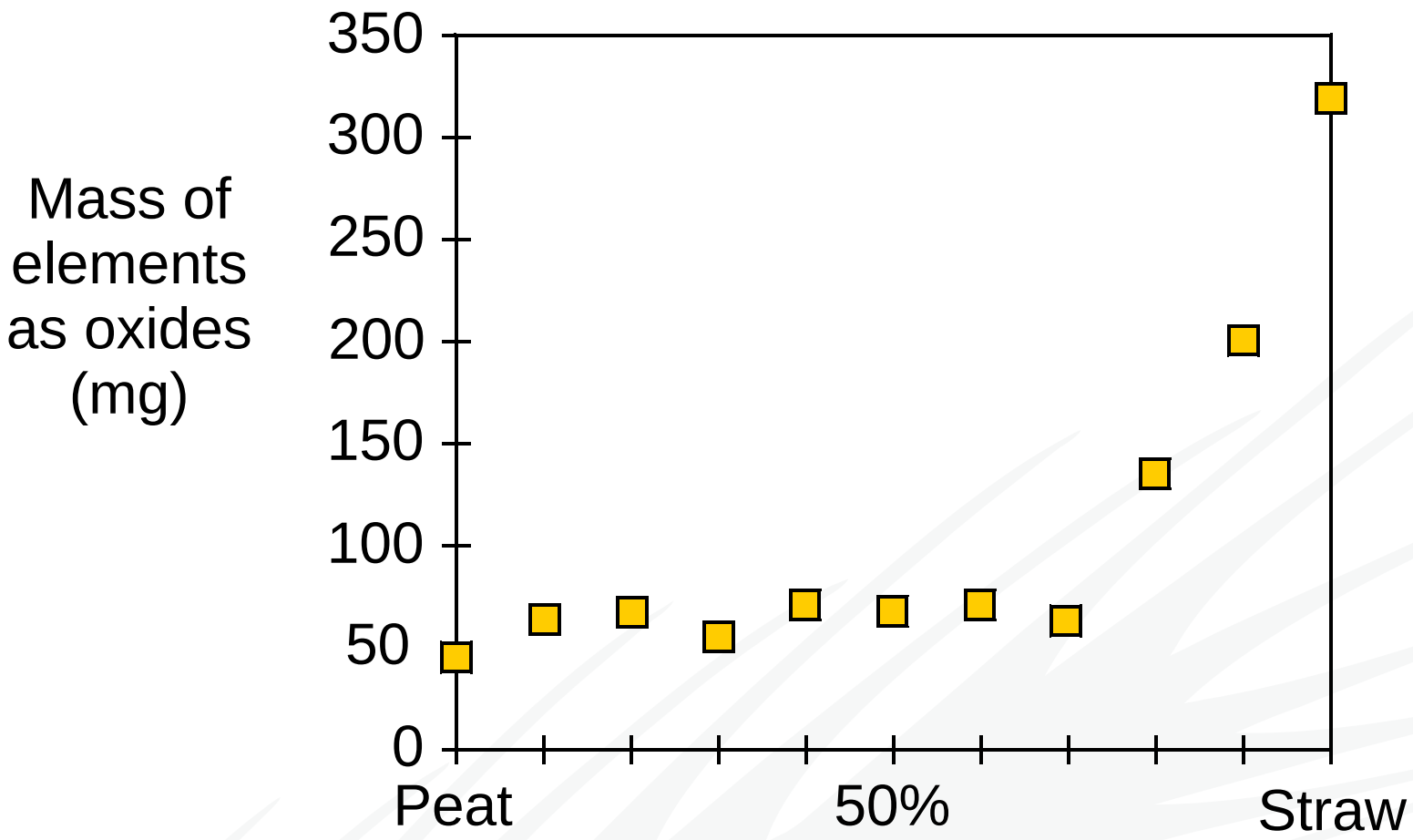
Probe Deposits: Rice Husk - Bark



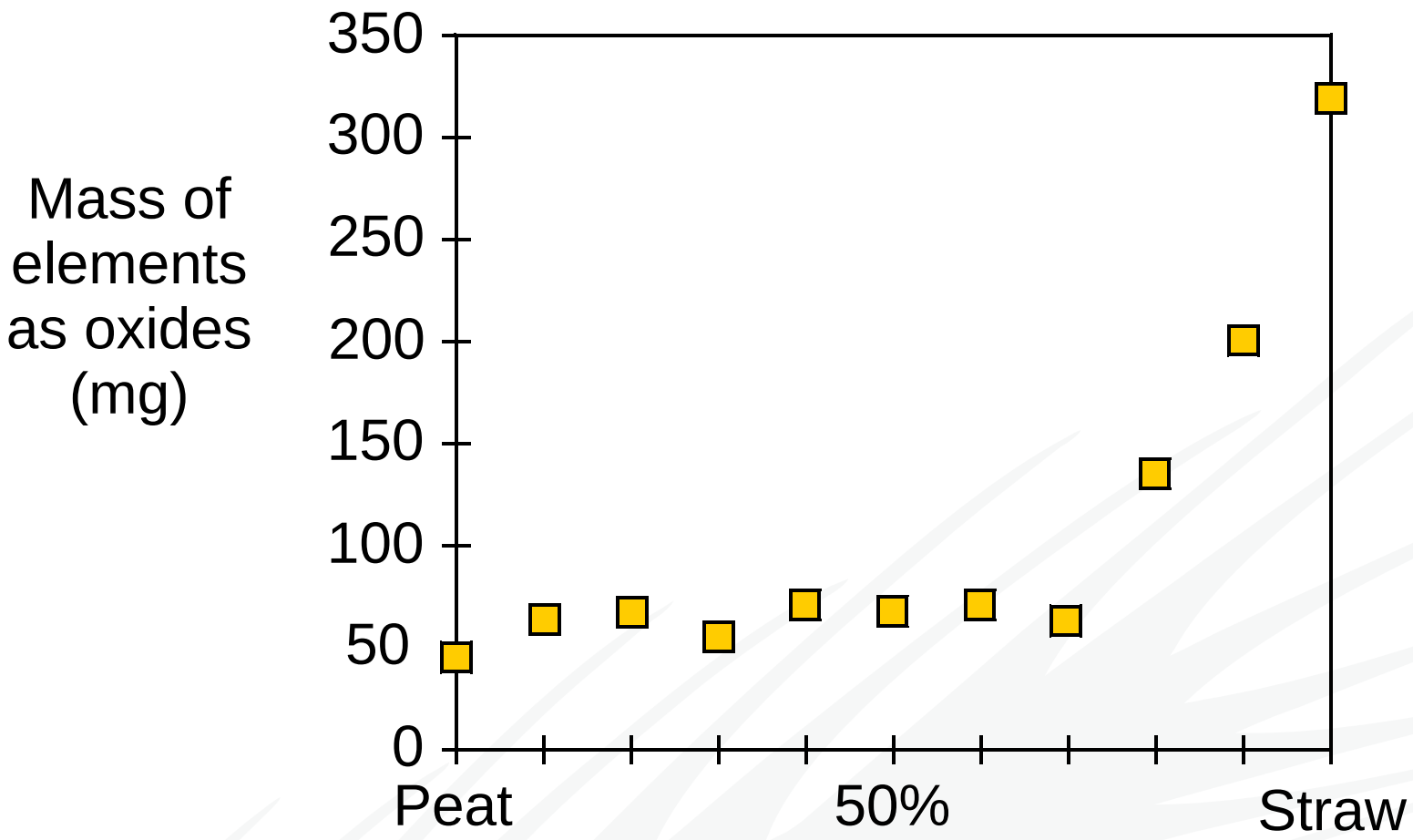
Probe Deposits: Rice Husk - Bark



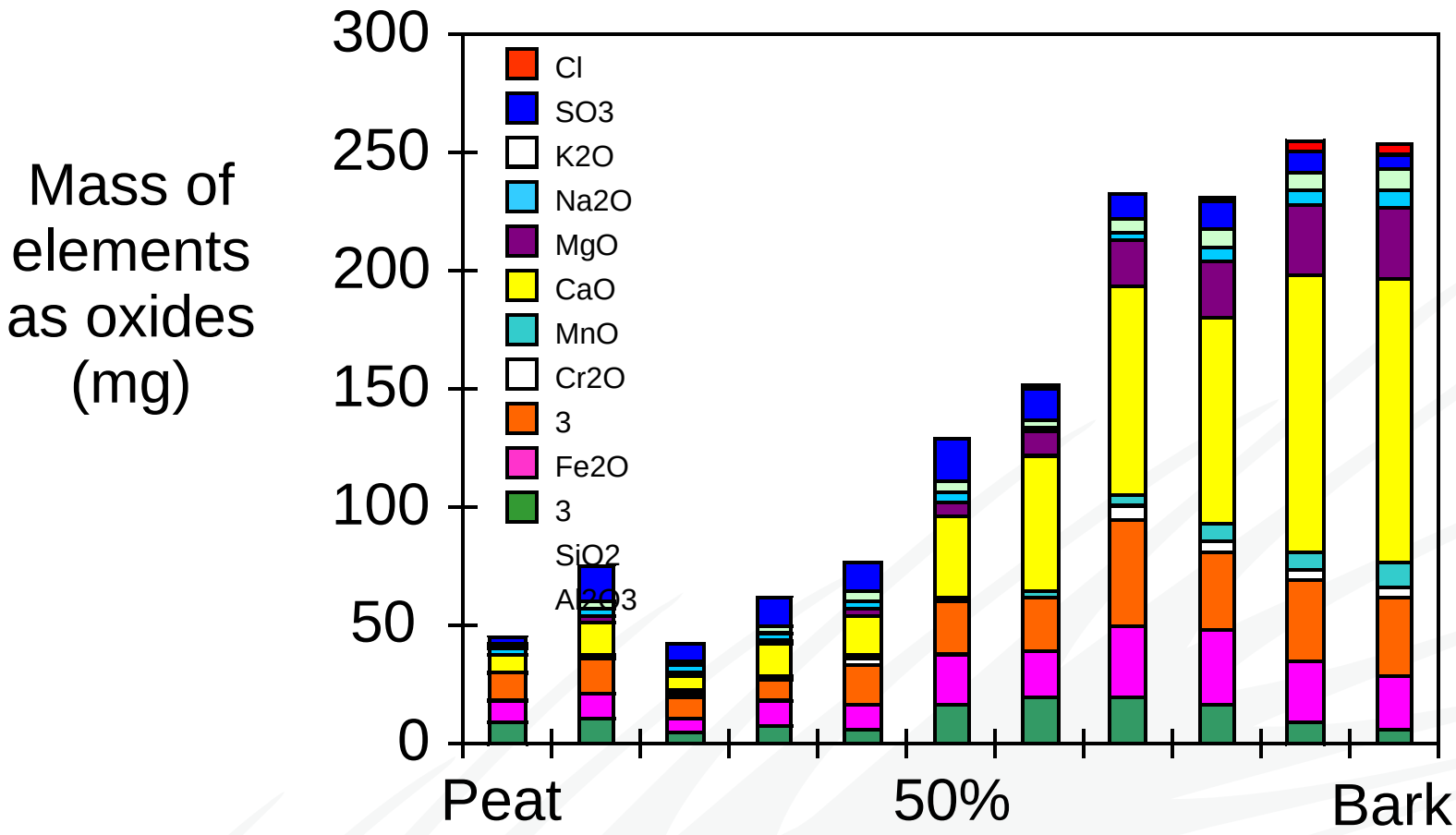
Probe Deposits: Peat - Straw



Probe Deposits: Peat - Straw



Mass of Element Oxides in Deposits



Conclusions (i)

- Mixed-Fuel Firing Great Potential for FBC
- Major Challenge to Boiler Manufacturers & Operators:
  - Emission Control
  - Bed Sintering and Fouling Control
  - Corrosion Control
- Fuel Interaction May Cause Surprises (Non-Linear Relationships)

Conclusions (ii)

- How Can Fundamental Research Contribute?

- We Need Fundametal Studies on
  - Emission Chemistry Interactions
  - Ash Interactions
  - Fuel Characterization for Mixed-Fuel Firing
  - Modelling of Mixed Fuel Systems

...to Interprete Pilot and Full Scale Experiences