# The Fate of Trace Elements during Co-Combustion of Dried Sewage Sludge with Wood/Coal in a 12MW CFB Boiler

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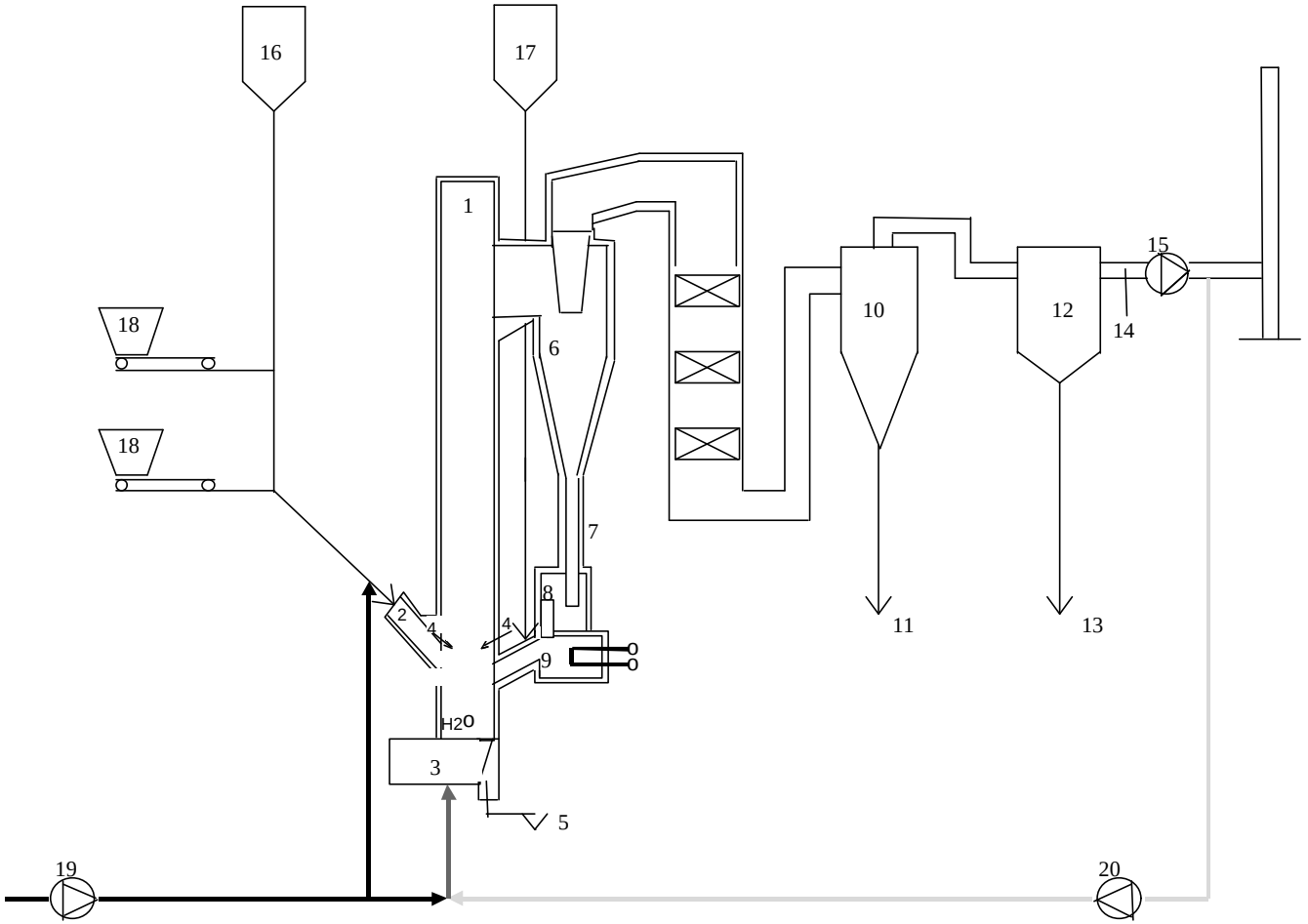
CTH

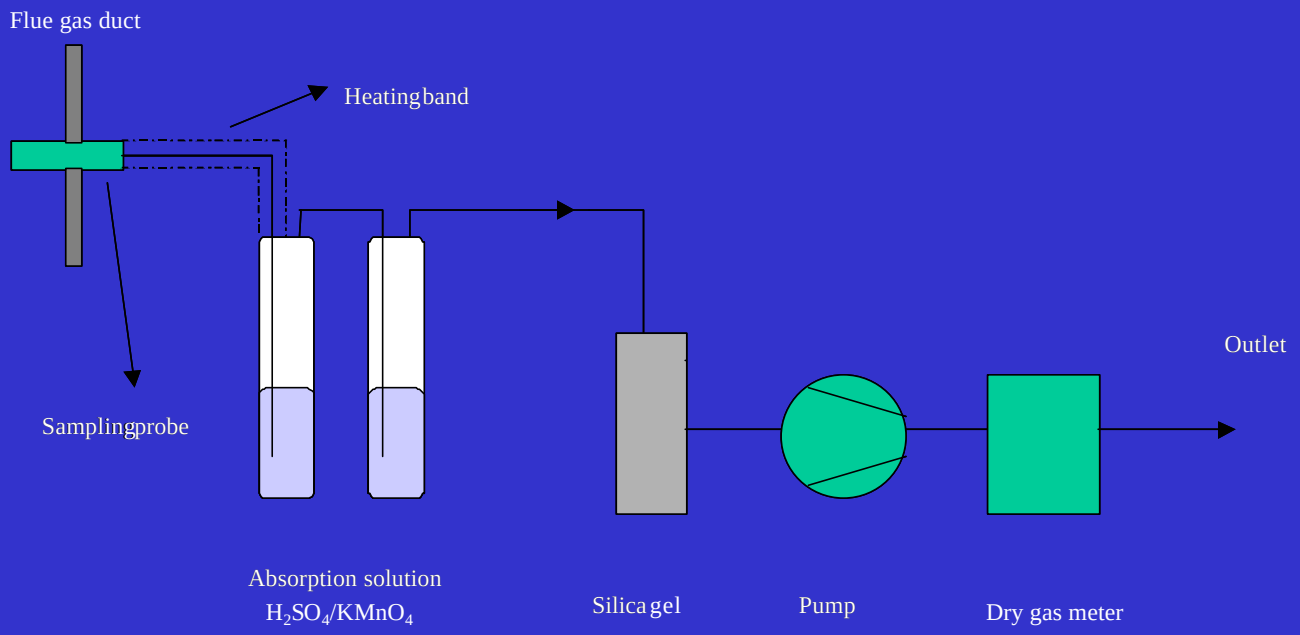
# This presentation:

- The research unit at CTH
- The test conditions
- The fuels
- Balance of ash and trace elements
- Ash distribution
- Concentration of trace  elements in the ash
- Emissions of trace elements to the stack
- On-line measurement of Hg
- Conclusions

# The Research Unit at Chalmers:

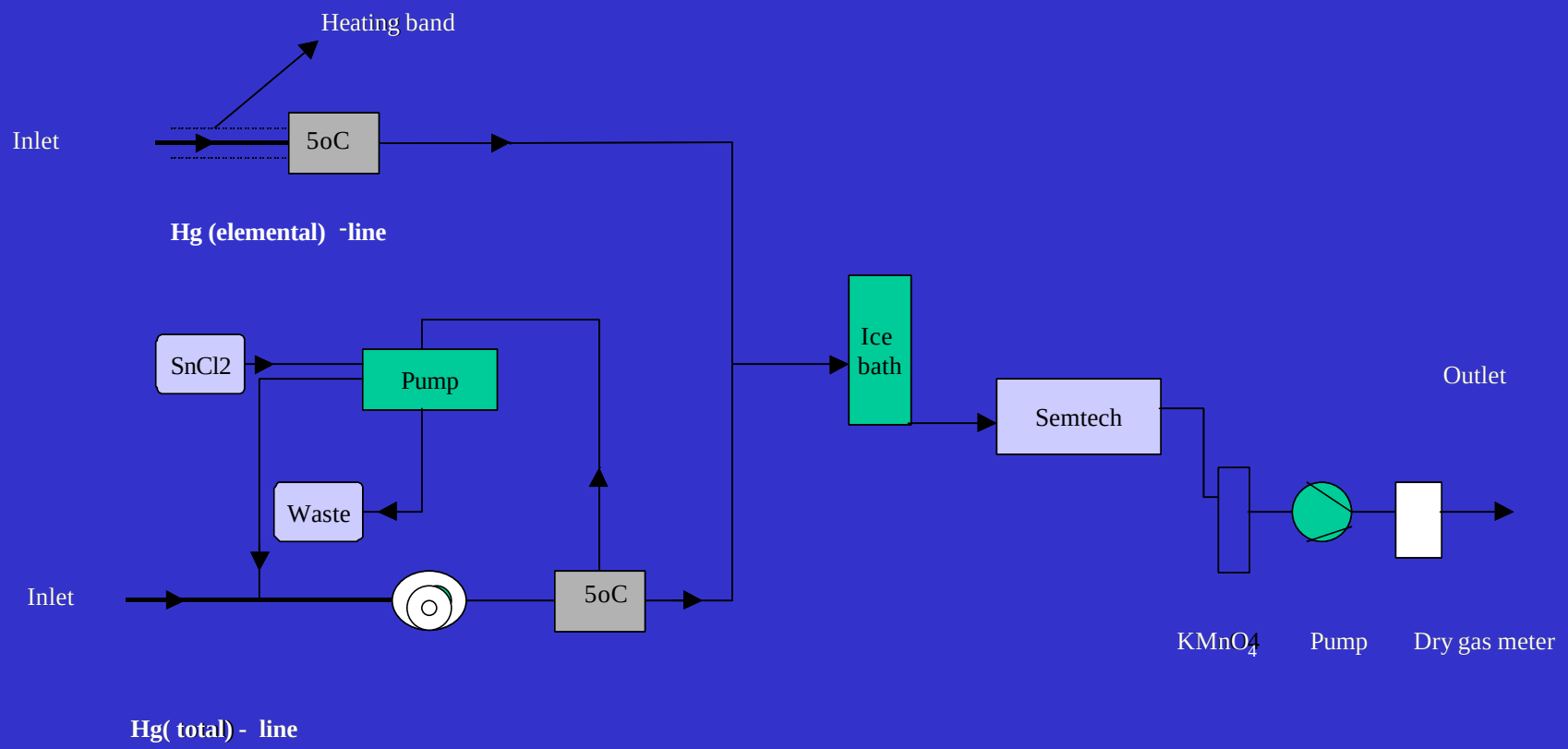


# Stack measurements of trace elements




Hg total sampling in $KMnO_4$ solution

# On-line measurement of Hg




System for on-line measurement of elemental and total mercury in the flue gas duct

# Principal runs

- Co-combustion with coal
  Test series one
- Co-combustion with wood-pellets,
  Test series two

# Operating conditions

| | Coal, CTH | Wood, CTH |
|---|---|---|
| Load, MW | 6.5±0.1 | 6.5±0.1 |
| Bed temp. °C (bottom) | 841±0 | 841±0 |
| Bed temp. °C (top) | 855±1 | 857±3 |
| Exit temp, after-burner chamber, °C | 772±4 (2) | 797±1(782)(1) |
| Temp. at inlet of sec. cyclone, °C | 150±0 | 150±0 |
| Temp. inlet of bag house filter, °C | 150±0 | 150±0 |
| Excess air-ratio | 1.23±0.01 | 1.23±0.01 |
| Combustor air_ratio | 1.05±0.01 | 1.04±0.01 |
| Superficial velocity, m/s | 5.3±0.4 | 4.6±0.1(4.1)(2) |
| Calcium addition, Ca/S molar ratio | 2.3±0.05 | 1.9±0.1(0)(1) |
| Ca/S with Ca in fuel included | 2.6±0.2 | 2.5±0.1(0)(1) |

(1) without sludge, (2) trend, increasing with amount of sludge

# Measurements during the 48 h test

- Solids sampling (Fuel, cyclone leg, secondary cyclone, bag house filter and exit particles)
- Flue gas sampling (FTIR and heavy metals)
- In-situ gas sampling: downstream cyclone and in case of time on the furnace centreline

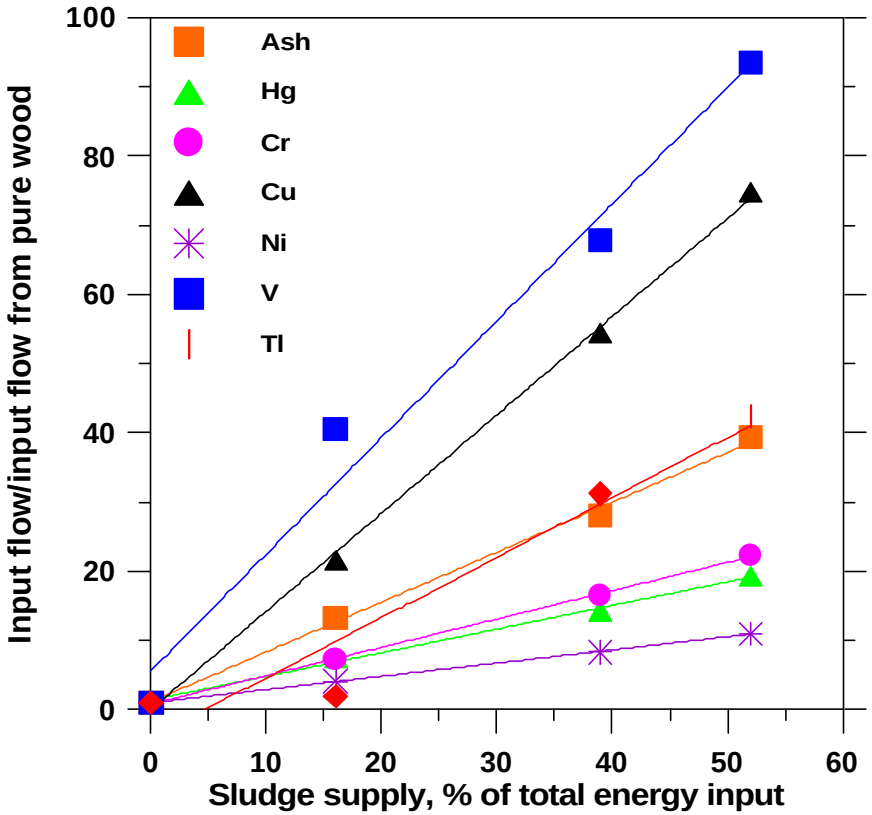
# Properties of the fuels

| | Bituminous coal | Wood pellets | Sewage sludge |
|---|---|---|---|
| *Proximate analysis* | | | |
| Water (wt-%, raw) | 8.6±1.1 | 9.2±0.2 | 19.0±5.4 |
| Ash (wt-%, dry) | 16.5±1.9 | 0.8±0.2 | 37.9±1.0 |
| Combustibles (wt-%, dry) | 83.5±1.9 | 99.2±0.2 | 62.1±1.0 |
| Volatiles (wt-%, daf) | 34.7±0.6 | 81.2±0.0 | 90.5±0.7 |
| *Ultimate analysis (wt-%, daf)* | | | |
| C | 82.5 | 50.5 | 53.2 |
| H | 5.0 | 6.0 | 7.1 |
| O | 9.9 | 43.4 | 30.6 |
| S | 0.90 | 0.02 | 1.90 |
| N | 1.70 | 0.14 | 7.10 |
| Cl | 0.07 | 0.01 | 0.05 |
| *Lower heating value (MJ/kg)* | | | |
| $H_u$, daf | 32.49 | 18.91 | 20.9 |
| $H_u$, raw | 24.58±0.9 | 16.78±0.05 | 10.05±1.04 |
| *Trace elements (mg/kg dry fuel)* | | | |
| Hg | 0.073±0.03 | <0.03±0 | 0.71±0.04 |
| Cd | 0.12±0.02 | 0.17±0.03 | 0.93±0.03 |
| Pb | 21±5 | 5±0 | 30±0 |
| Cr | 16±5 | 5±0 | 120±12 |
| Cu | 41±14 | 5±1.8 | 350±23 |
| Mn | 118±21 | 138±5 | 222±8.4 |
| Co | 5.8±1.5 | 3±0 | 7±0.6 |
| Ni | 19±3 | 2±0 | 26±1 |
| As | 1.6±0.5 | 0.3±0.0 | 4±0.1 |
| Sb | 0.4±0.06 | 0.3±0.0 | 1.3±0.4 |
| V | 39±2.9 | 0.2±0.2 | 27±4 |
| Tl | 0.09±0.01 | 0.02±0 | 0.078±0.005 |

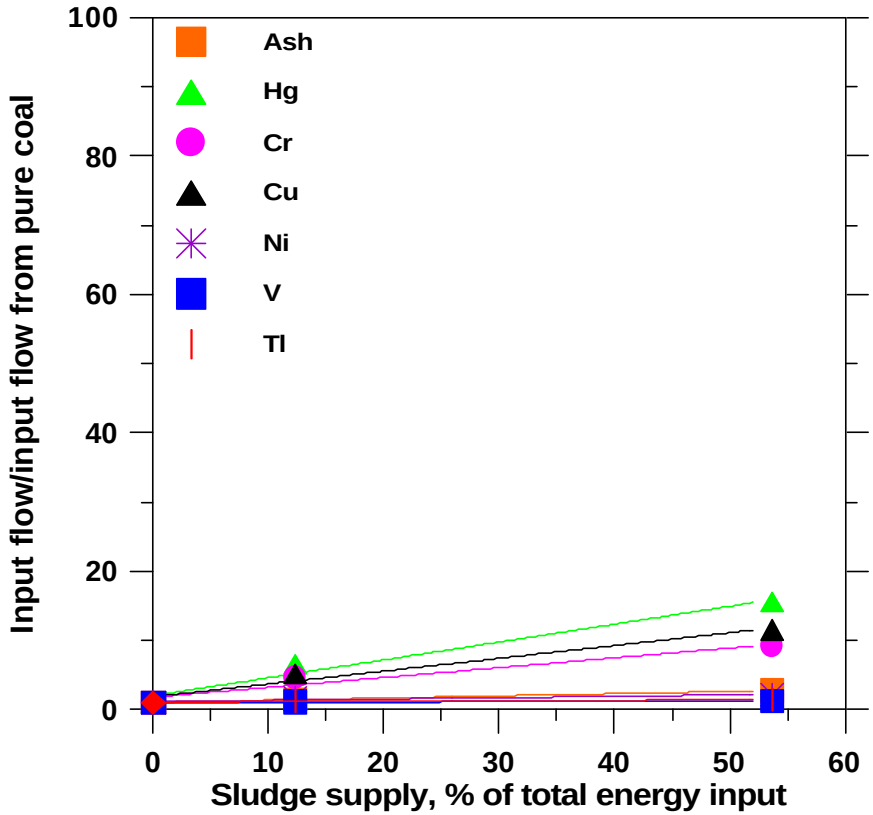
*daf= dry and ash free, raw= as received*

# Relative increase of trace elements to the CTH boiler

Base fuel: Wood pellets




Base fuel: Coal




Comparison of relative increase of input flow of ash, Hg, Cr, Cu, Ni, V, Tl, as function of sludge supply

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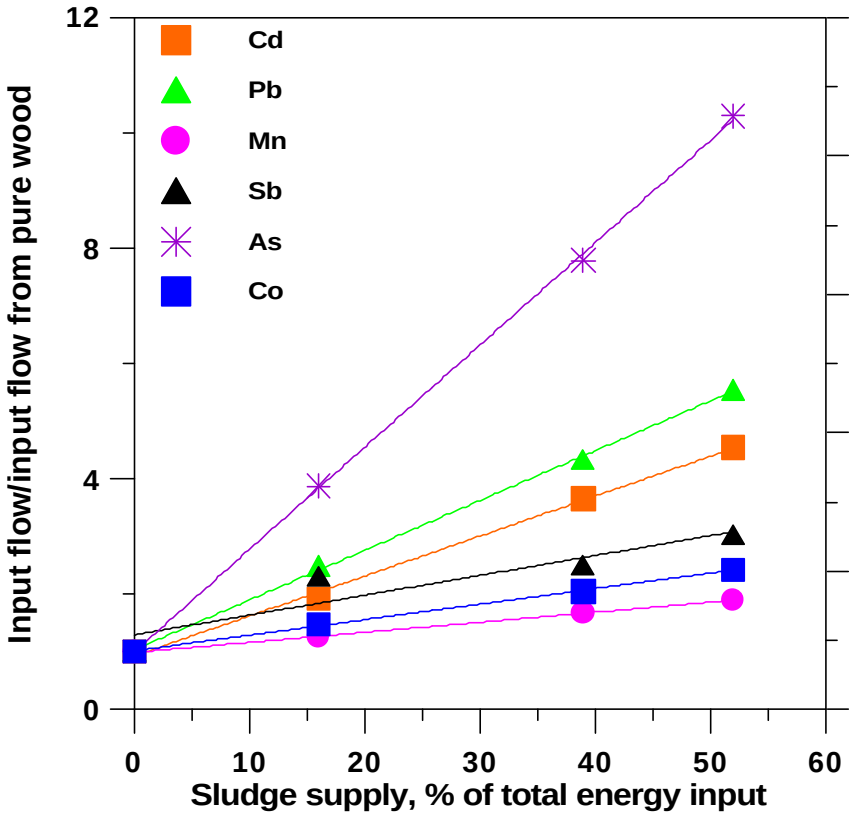


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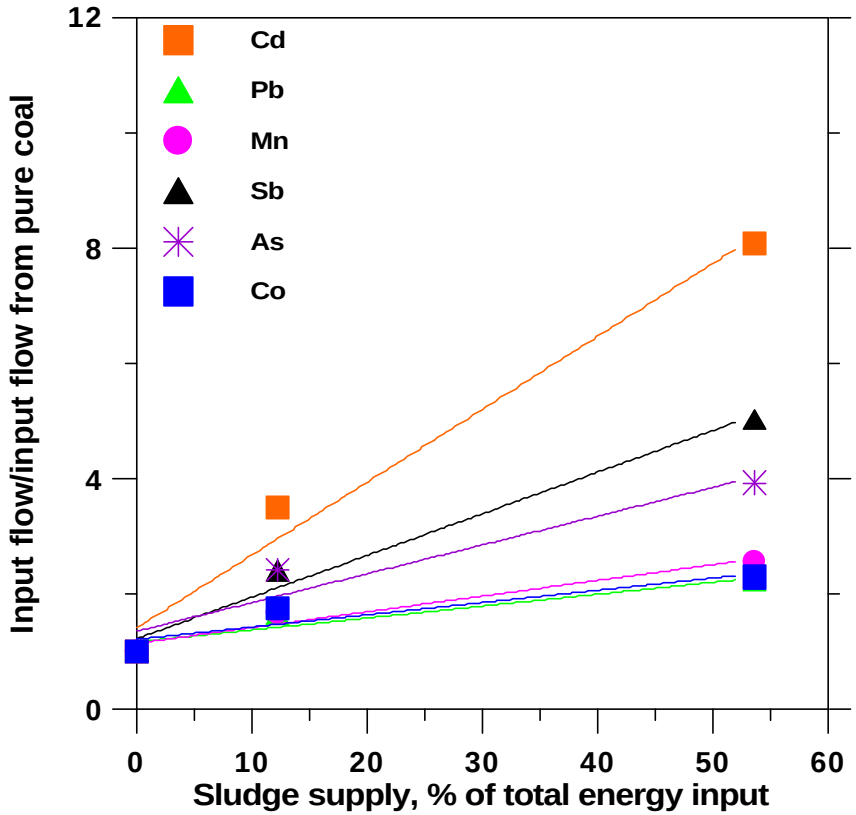
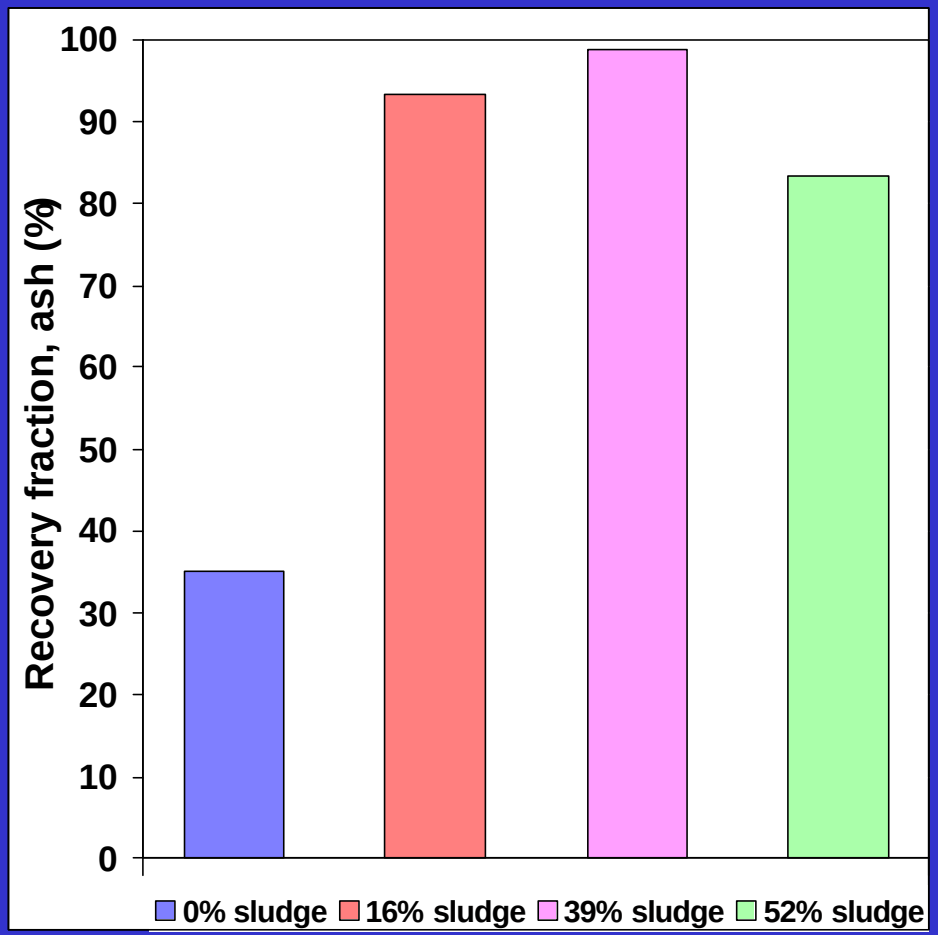


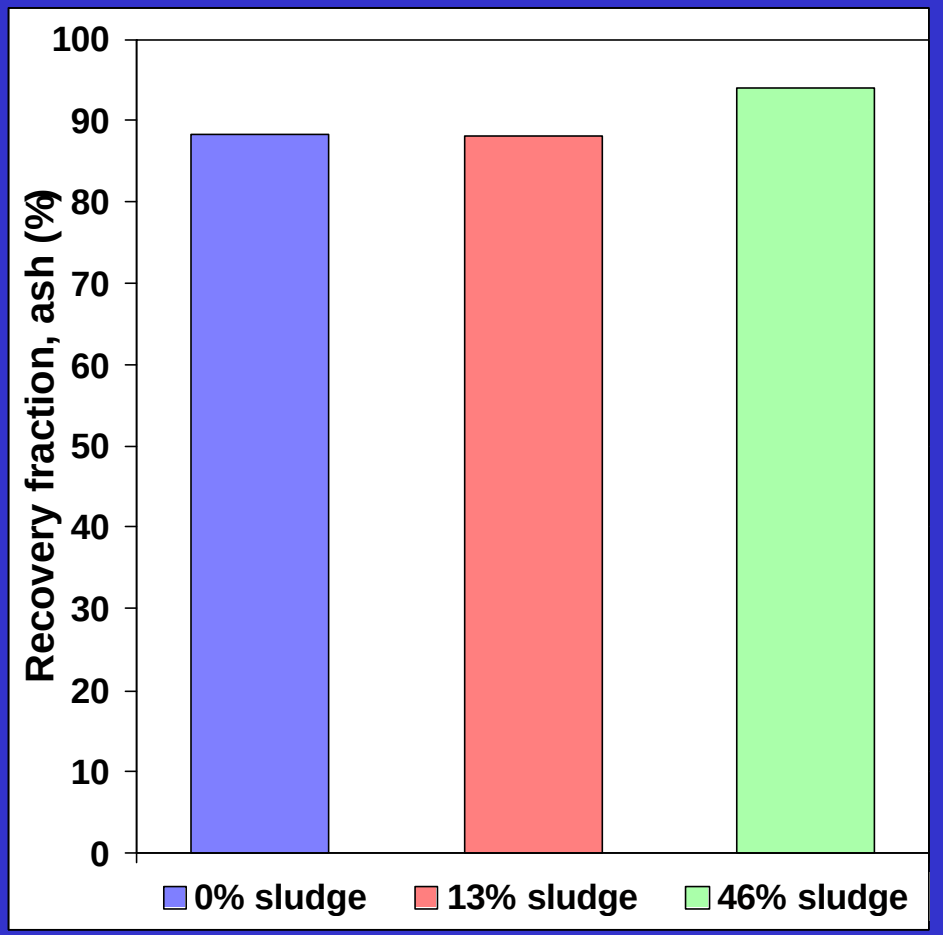

Comparison of relative increase of input flow of Cd, Pb, Mn, Sb, As and Co, as function of sludge supply

# Recovery fraction, ash Out/In*100

Base fuel: Wood pellets

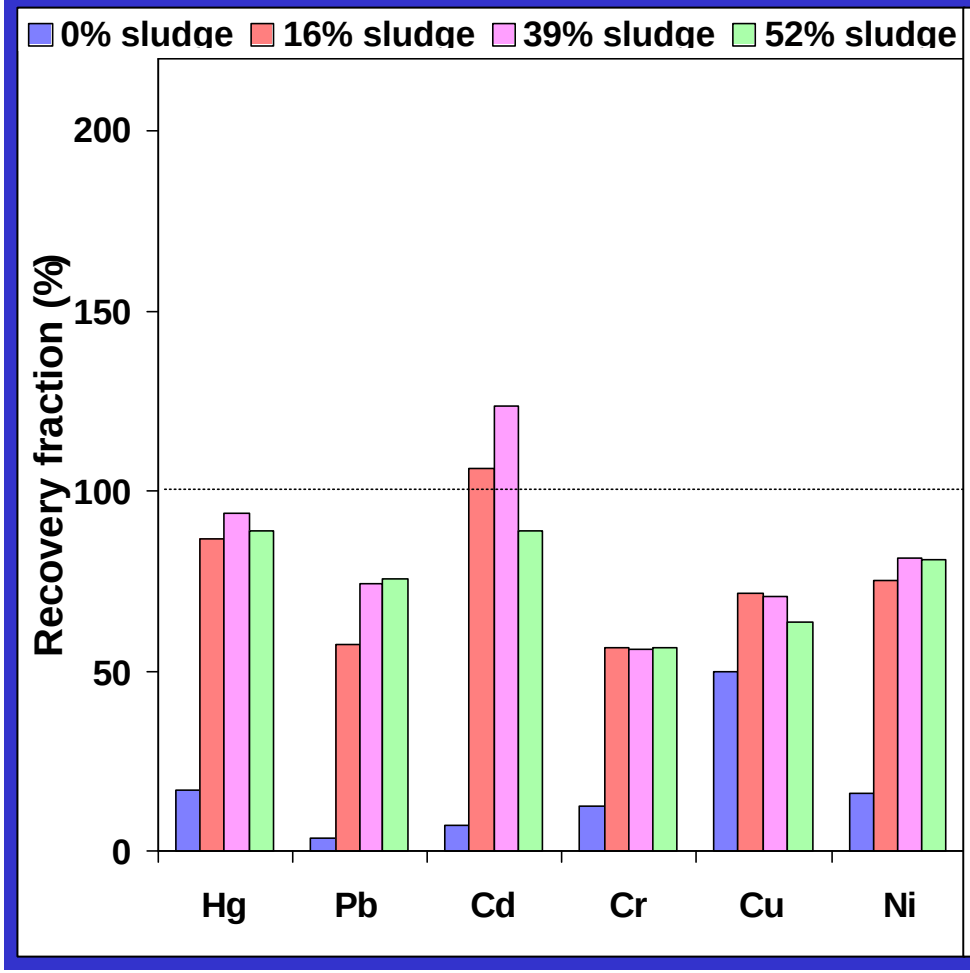



Base fuel: Coal

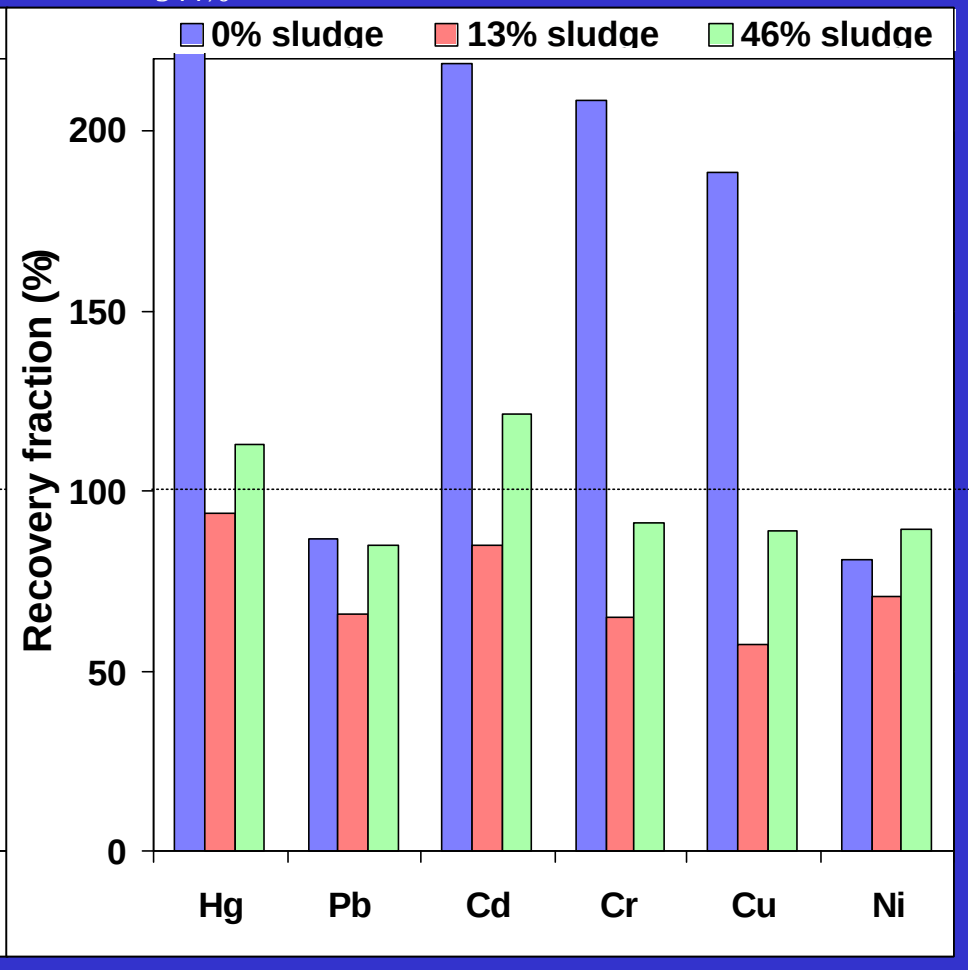


# Recovery fraction, Hg, Pb, Cd, Cr, Cu, Ni

Base fuel: Wood pellets

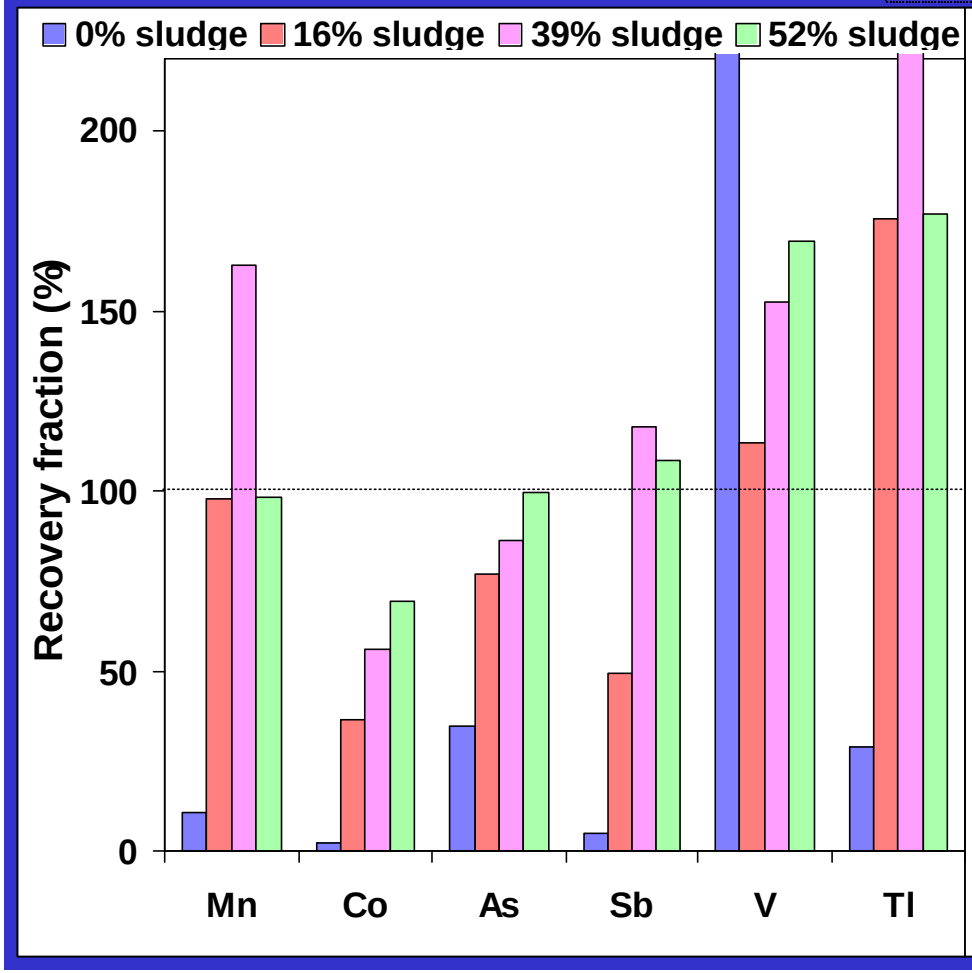



Base fuel: Coal



# Recovery fraction, Mn, Co, As, Sb, V, Tl

Base fuel: Wood pellets

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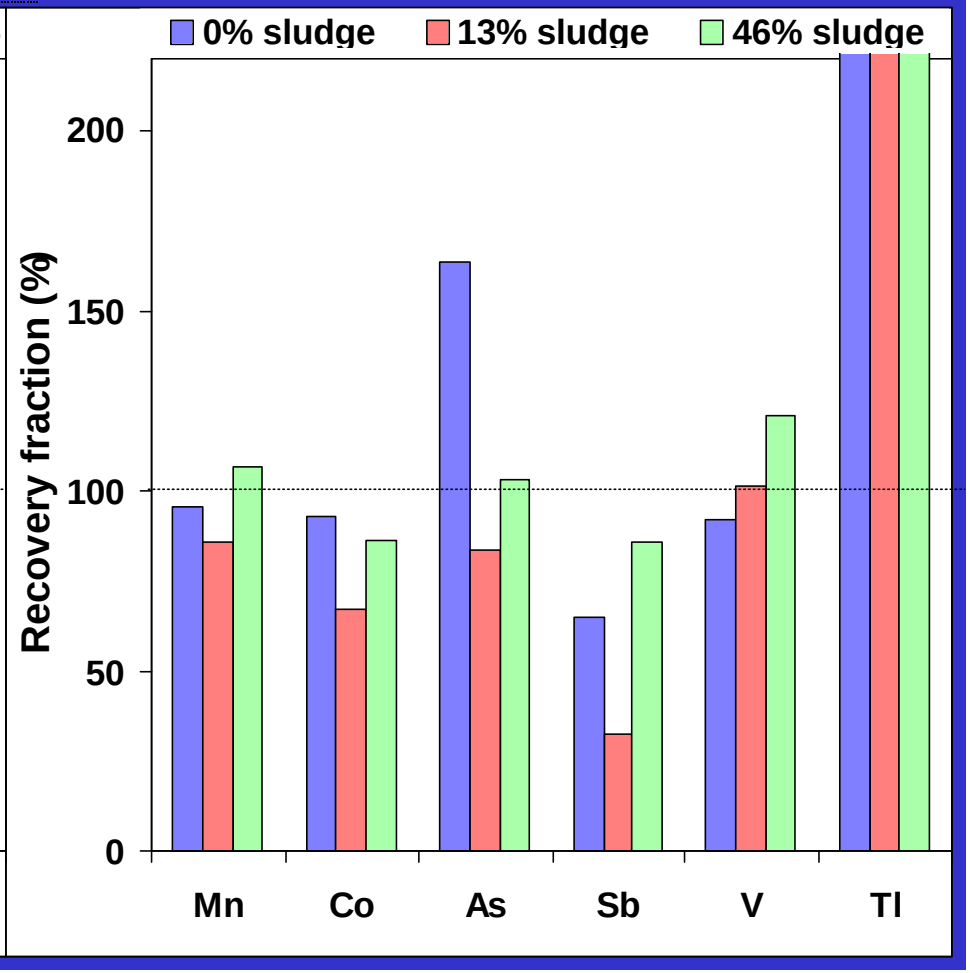
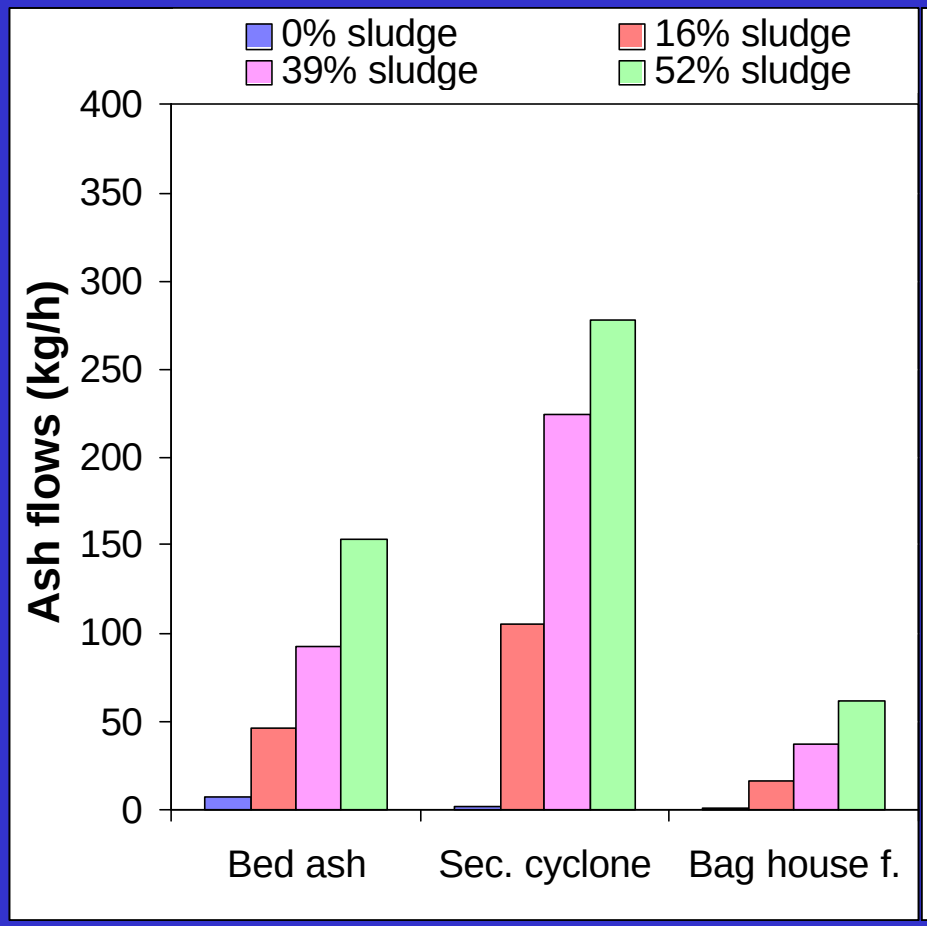
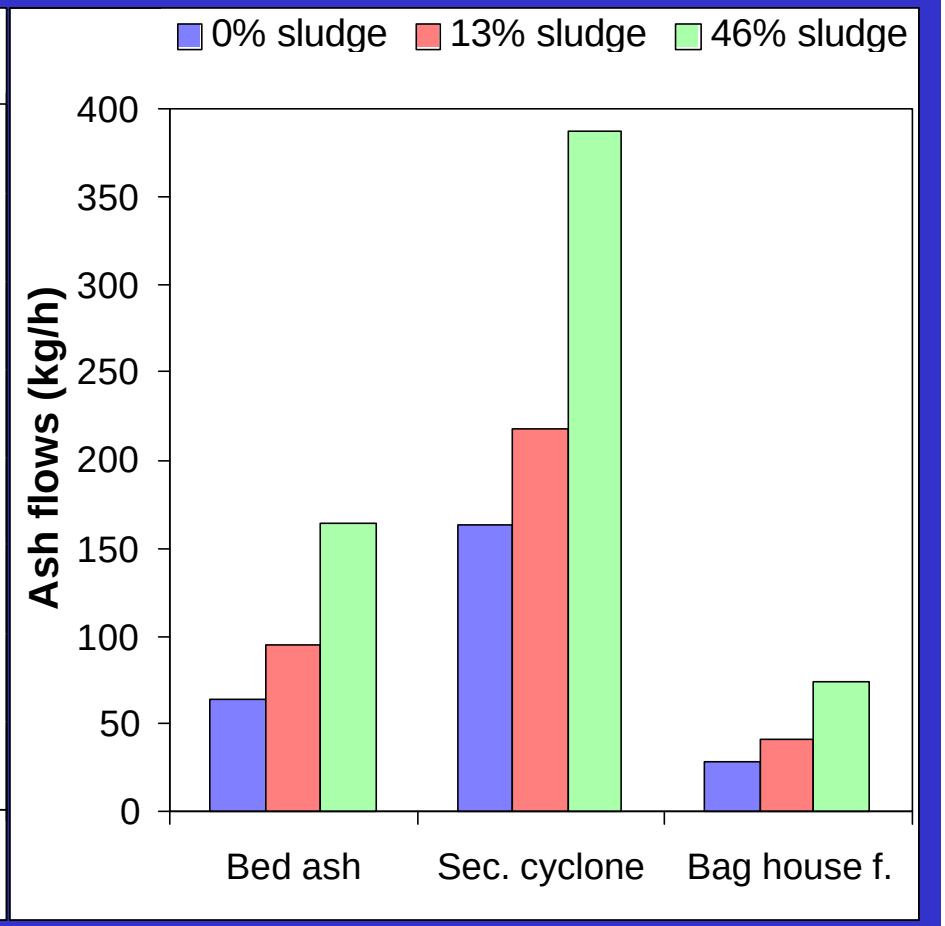


# Comparison of ash distribution

Base fuel: Wood pellets

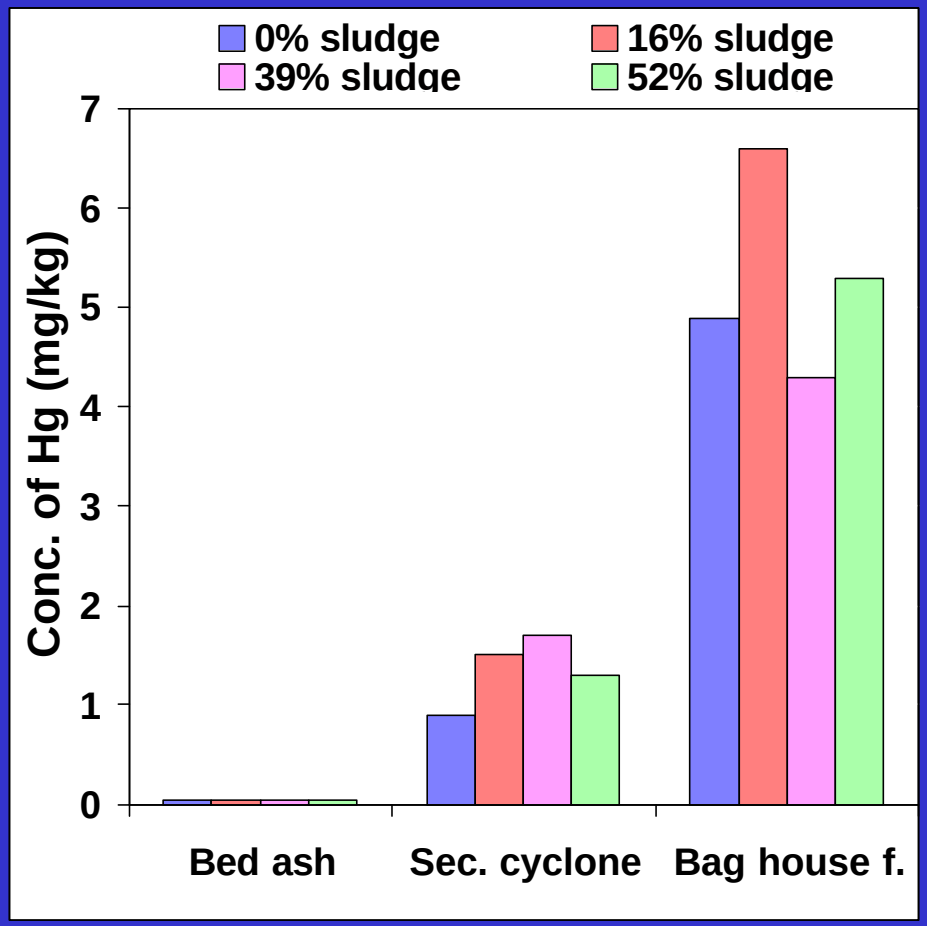



Base fuel: Coal



# Concentration of Hg in the ashes

Base fuel: Wood pellets

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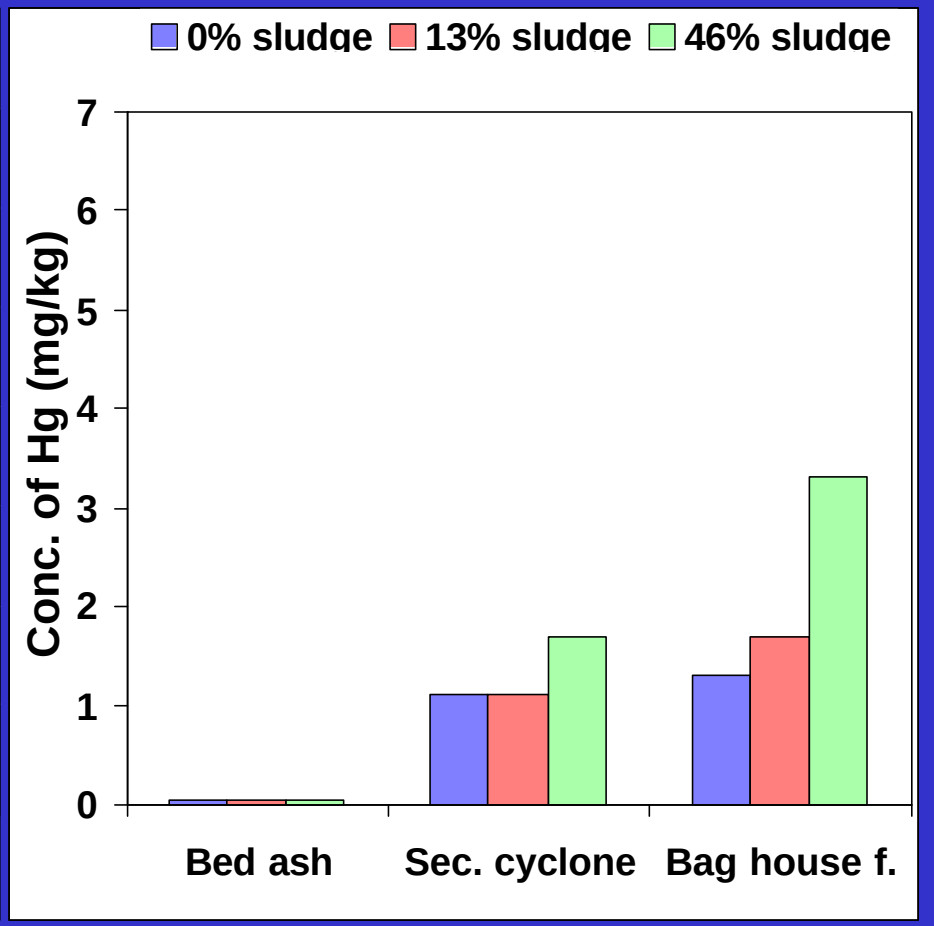
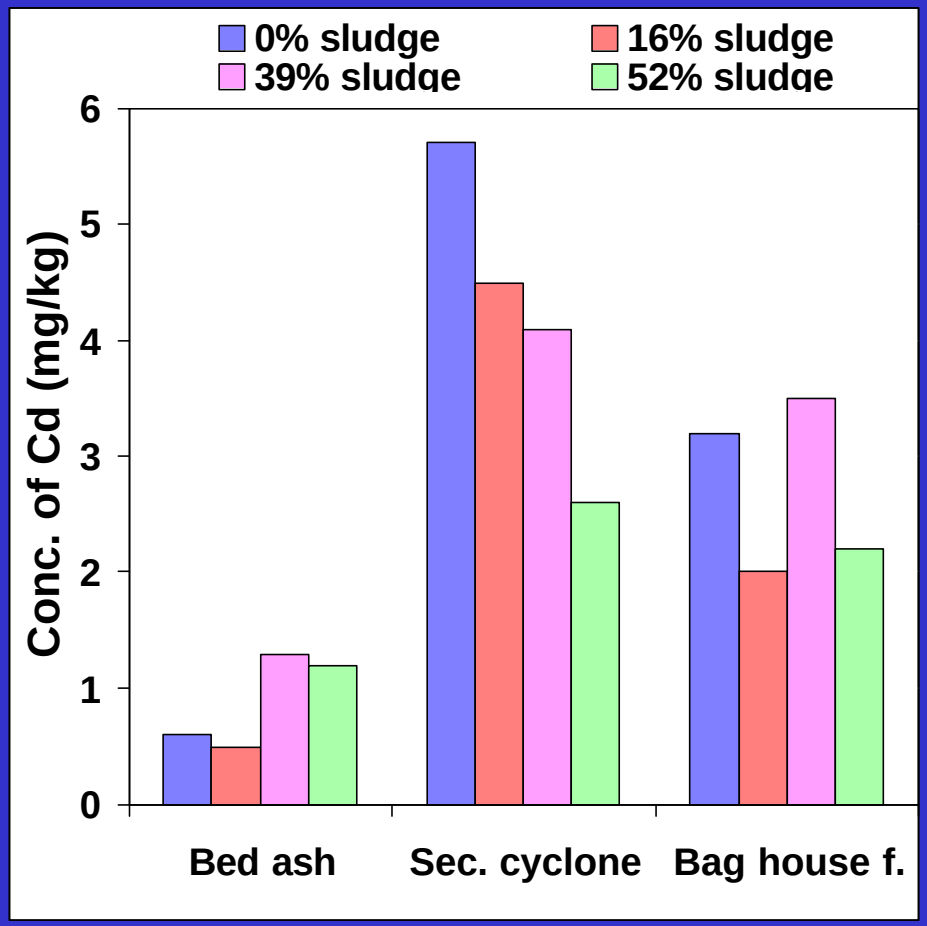
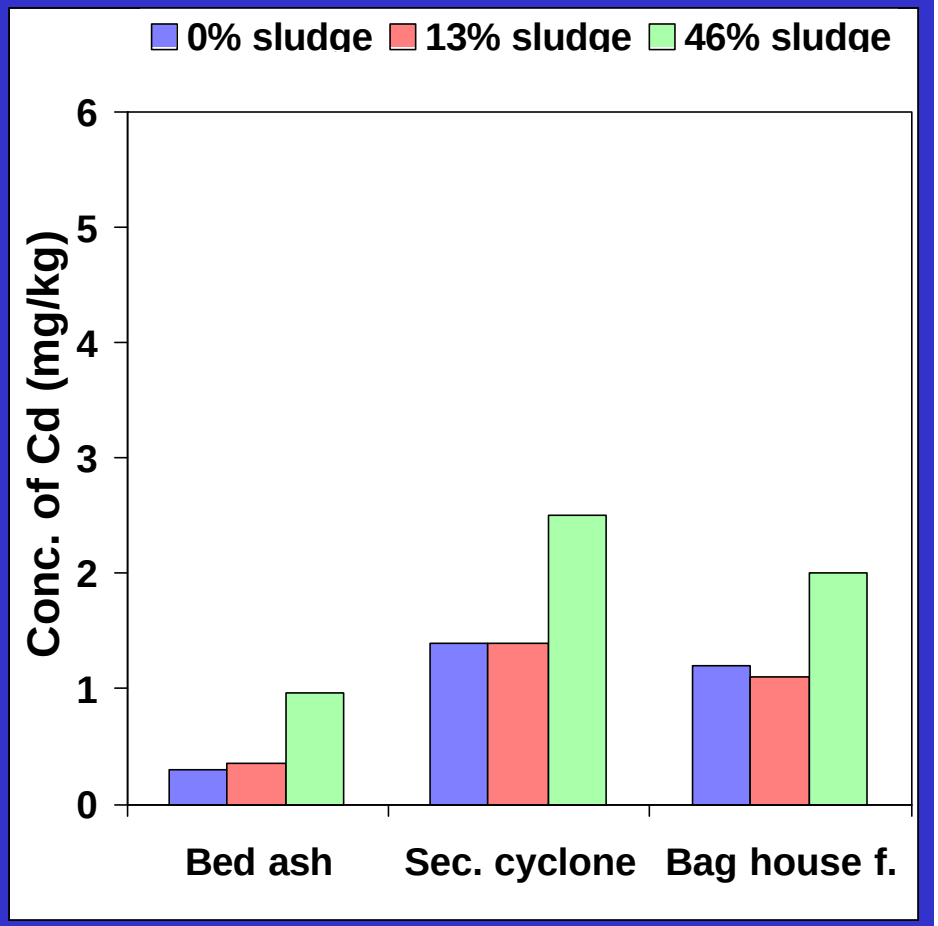


# Concentration of Cd in the ashes

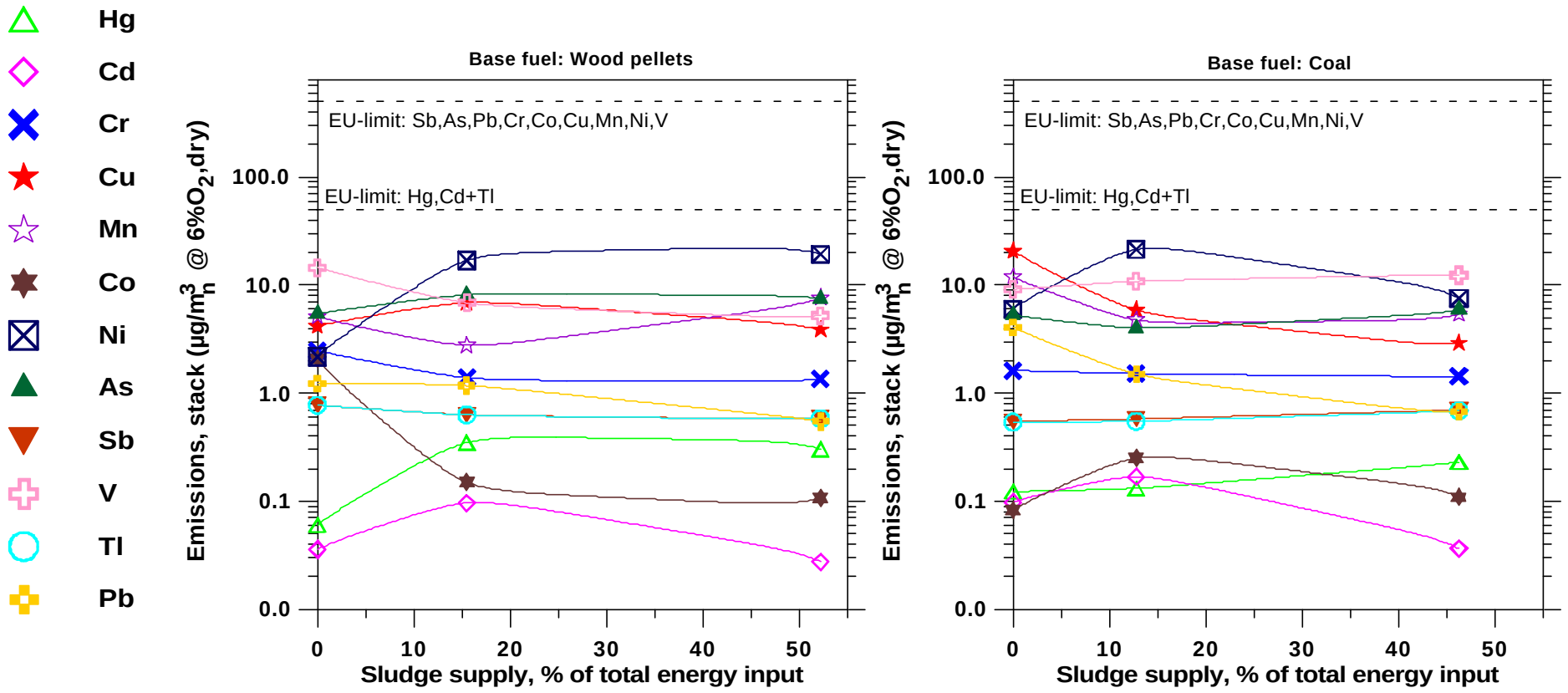
Base fuel: Wood pellets



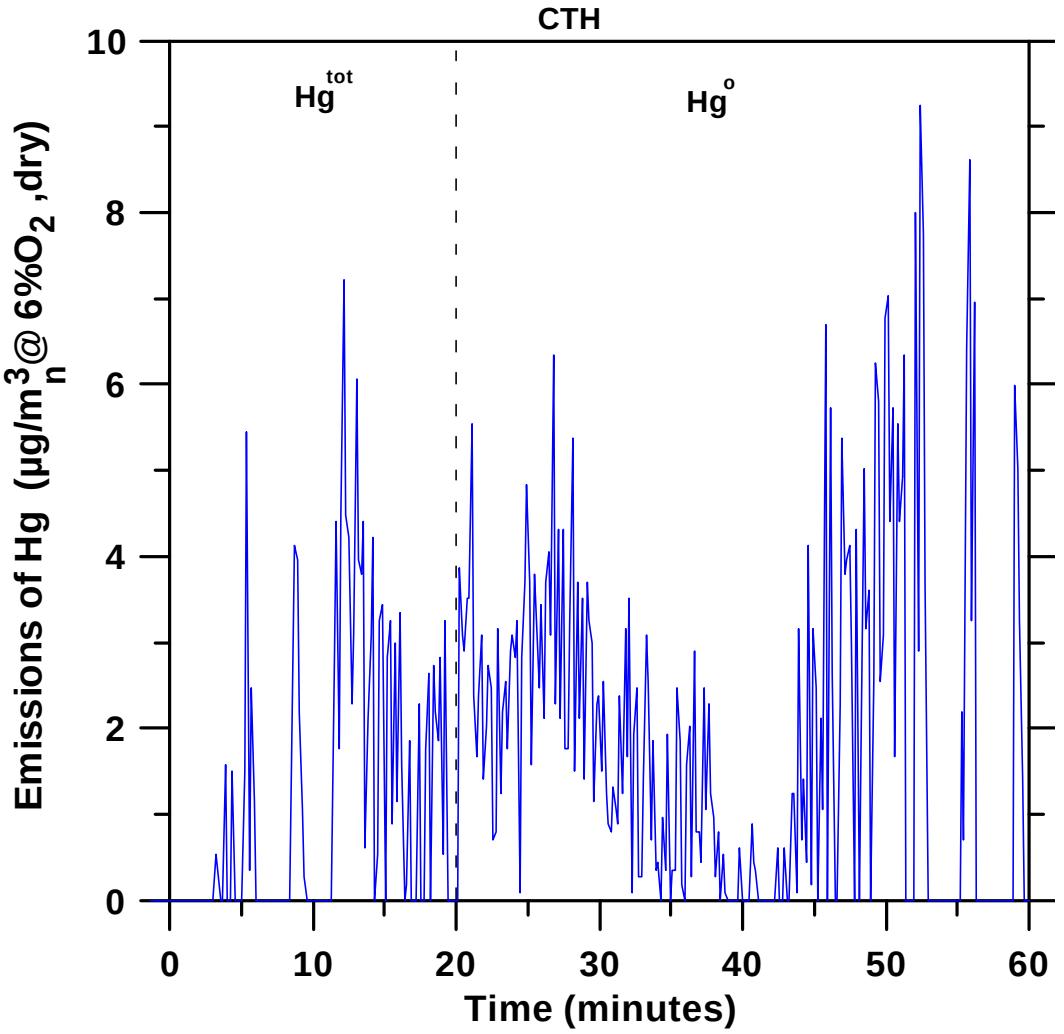

Base fuel: Coal



# Emissions of trace elements



# On-line measurement of Hg



# Conclusions:

- Total mass and species balances have been made for co-combustion of sludge with both coal and wood as base fuel. In general a good closure is achieved.
- Both the influence of the increased ash content and the increased concentration of some trace elements in the sludge are reflected in the effluent ash streams.

# Conclusions:

- The distribution of volatile trace elements, especially Hg, depends on the temperature. Especially important is the temperature of the separation devices for fly ash. In the present tests, the secondary cyclone and bag house filter capture even mercury (Hg).

# Conclusions:

- The particle loading in the cold part of the gas path of a CFB and the content of carbon and/or $CaO/CaSO_4$ could be of importance for the capture efficiency of volatile trace elements but this needs to be further studied.