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# Investigation of mercury behavior in the flue gas cleaning path of a lab-scale firing system

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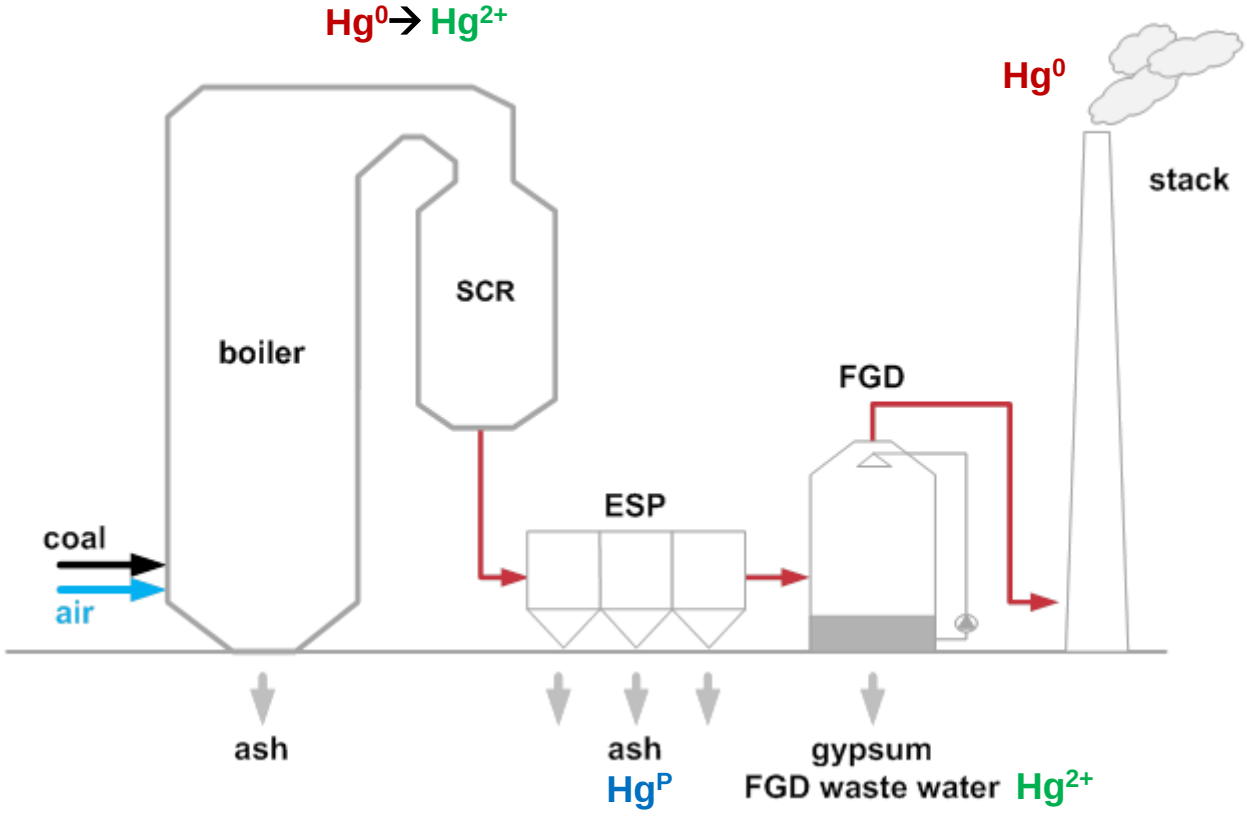
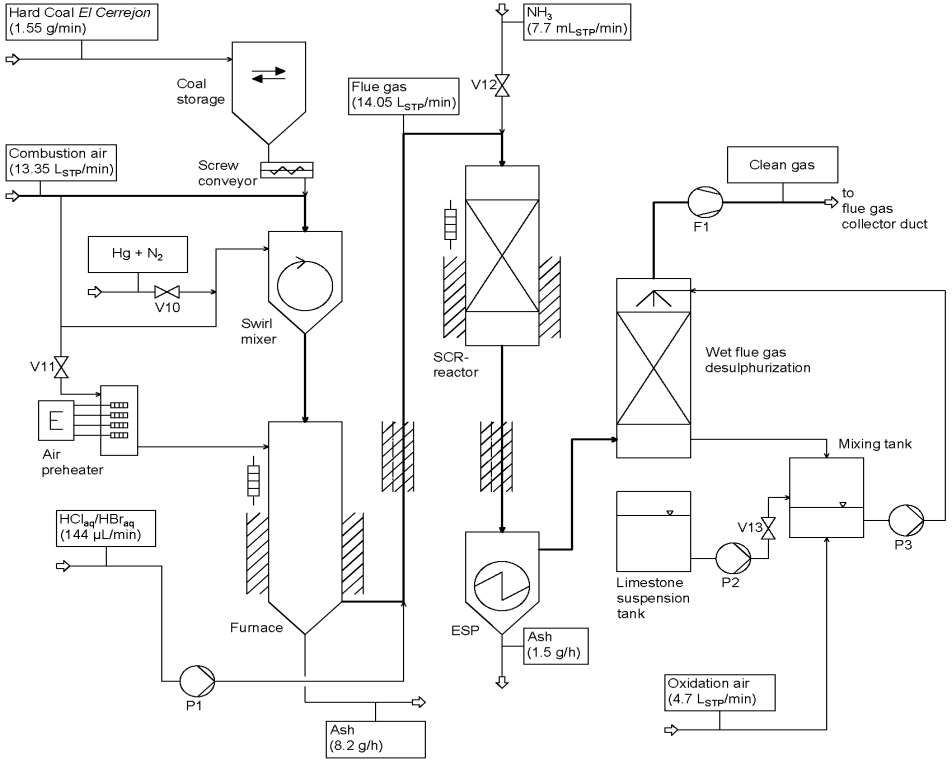
# Mercury in the flue gas path

## Hard coal power plant



# Lab-scale firing system with flue gas cleaning

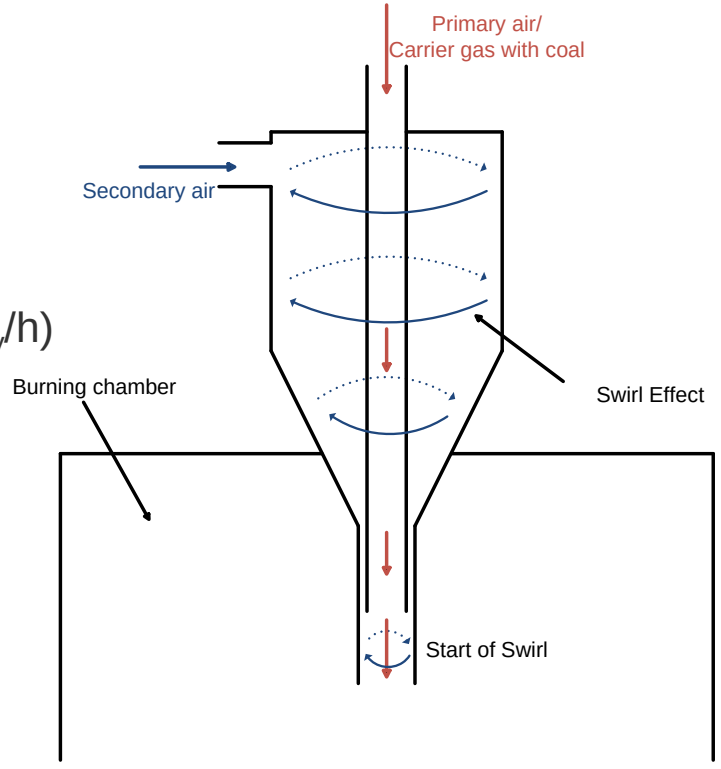
- Firing system
  - Pulverized fuel firing
  - Max thermal power of 2 $kW_{th}$
  - Downstream cooling path
- Flue gas cleaning
  - SCR-DeNOx
  - ESP
  - Wet limestone FGD
- Removal of:
  - $NO_x$
  - Fly ash
  - Halogens
  - $SO_2$
  - Hg



# Lab-scale firing system

## Burning chamber

- Burning chamber: D=150 mm, L=1500 mm
- Burning chamber temperature: up to 1200 °C
- Fuel dosing with a volumetric dosing unit
- Fuel mass flow: 0.3 kg/h (0.1 kg/h)
- Flue gas flow: up to 2.5 $m^3_{STP,dry}$/h (0.84 $m^3_{STP,dry}$/h)
- Fuels:
  - Hard coal
  - Lignite
  - Biomass mixtures (0-100%)
  - Fuel mixture with additives
  - Secondary fuels

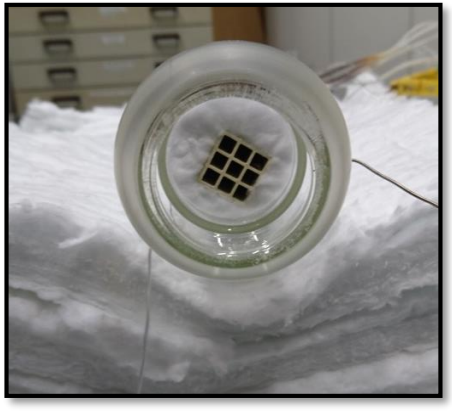


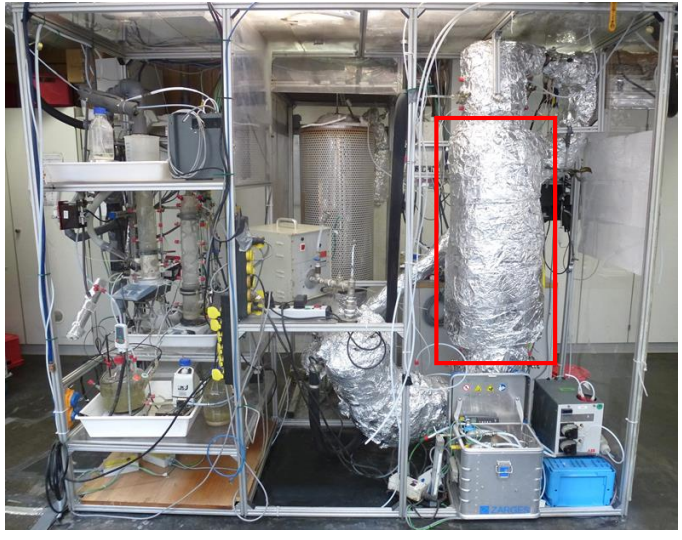
# Lab-scale firing system

# Lab-scale firing system

## SCR-DeNOx-Reactor

- Glass setup: D=35 mm, L=1000 mm
- Temperature range: 280°C to 420°C
- Plate or Honeycomb catalyst (3x3 Channels)
- Ammonia dosing
- Measurements of:
  - DeNOx-activity
  - Hg-Oxidation
  - $SO_2/SO_3$-conversion

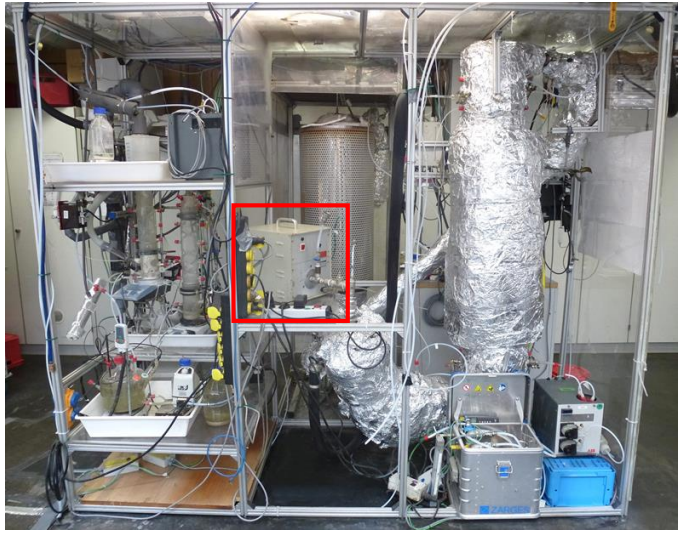


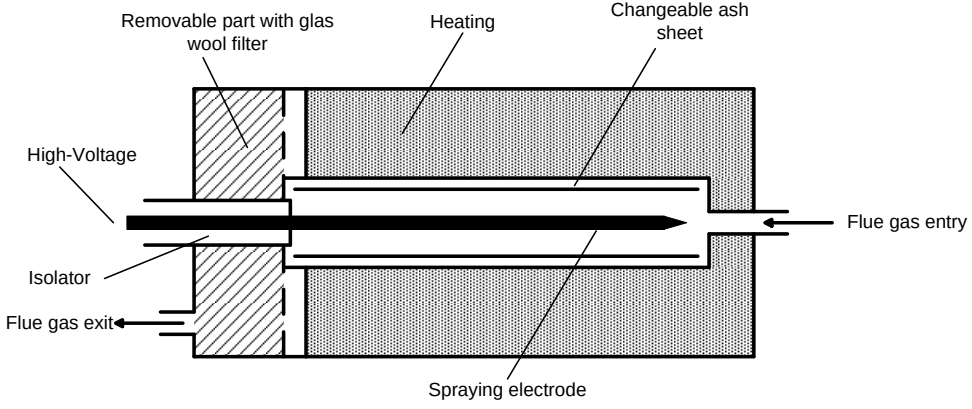


# Lab-scale firing system

## ESP

- Heated up to 200°C
- Voltage: 24 kV
- Current: 0.5 mA
- Removal rate > 99 %
- Particle size spectrum 0.1 to 10 µm

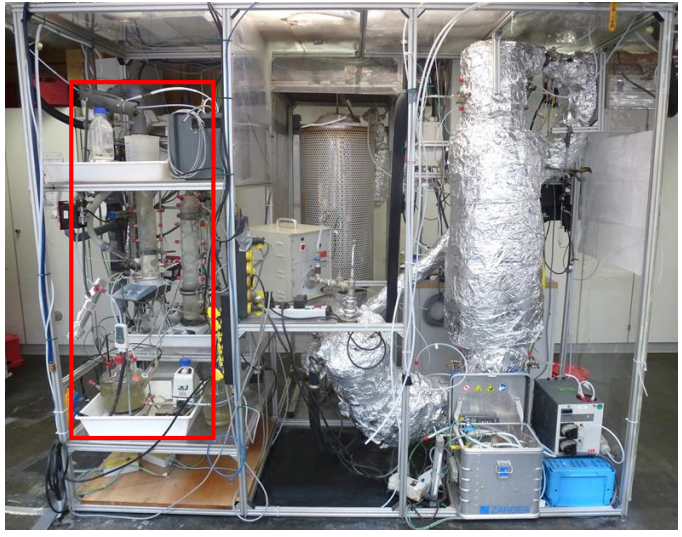




## Lab-scale firing system

Flue gas desulfurization

- Variable L/G ratio
- Automatic pH value control in the absorber
- External sump with oxidation air supply
- Variable aeration with air or oxygen
- Used media:
  - Calcium carbonate
  - Limestone
  - Quicklime
  - Additives



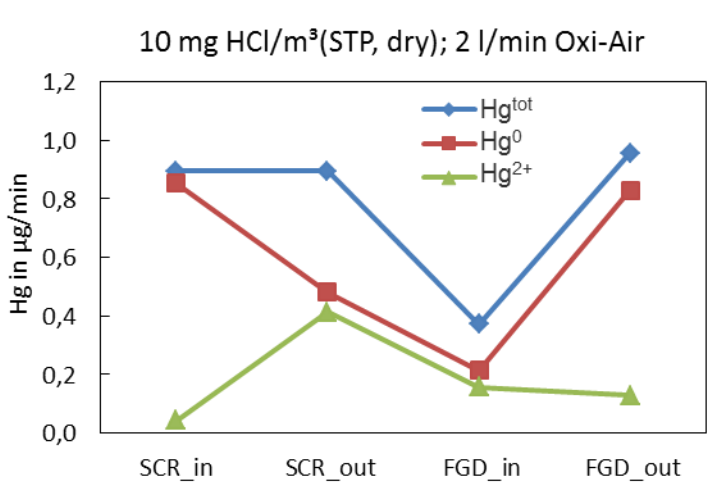
# Test conditions

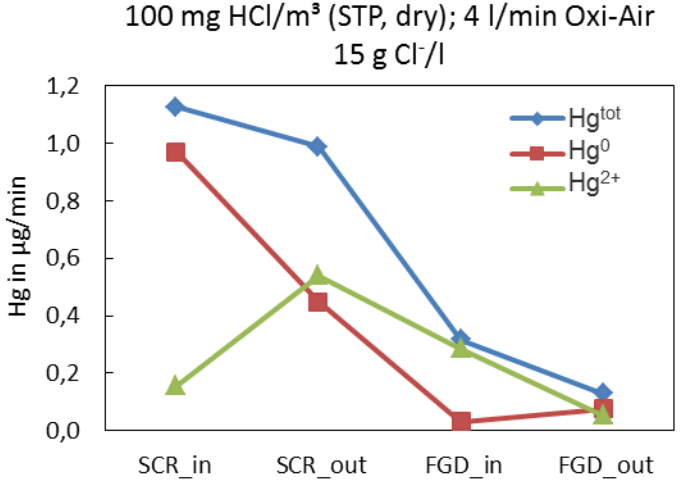
| | | | Set point |
|---|---|---|---|
| Firing | λ | - | 1.3 |
| | V | $l/min_{(STP,wet)}$ | 14.045 |
| | $m_C$ | g/min | 1.68 |
| | $NH_3/NO$ | - | 0, 0.9 |
| | $C(HCl)_{Gas}$ | $mg/m^3_{(STP,dry)}$ | 10,100 |
| | $C(HBr)_{Gas}$ | $mg/m^3_{(STP,dry)}$ | 0, 10 |
| | $Hg_{el./ox}$ | $\mu g/m^3_{(STP,dry)}$ | 50 |
| | $H_2O$ | vol.-% | 7 |
| FGD | L/G | $l/m^3$ | ~45 |
| | Oxidation-Air | $l/min_{(STP,dry)}$ | 2, 4 |
| | $C(Cl^-)_{Slurry}$ | g/l | 0, 15 |
| | T-Slurry | °C | 60 |
| | pH | - | 5.1 |

| Run | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| α | | 0 | 0 | 0.9 | 0 |
| C(HCl) | $mg/m^3_{(STP,dry)}$ | 10 | 100 | 100 | 0 |
| C(HBr) | $mg/m^3_{(STP,dry)}$ | 0 | 0 | 0 | 10 |
| $C(Cl^-)$ | g/l | 0 | 15 | 15 | 15 |
| Oxi-Air | l/min | 2 | 4 | 4 | 4 |

# Effect of HCl concentration in flue gas and oxidation air

## Hg in flue gas

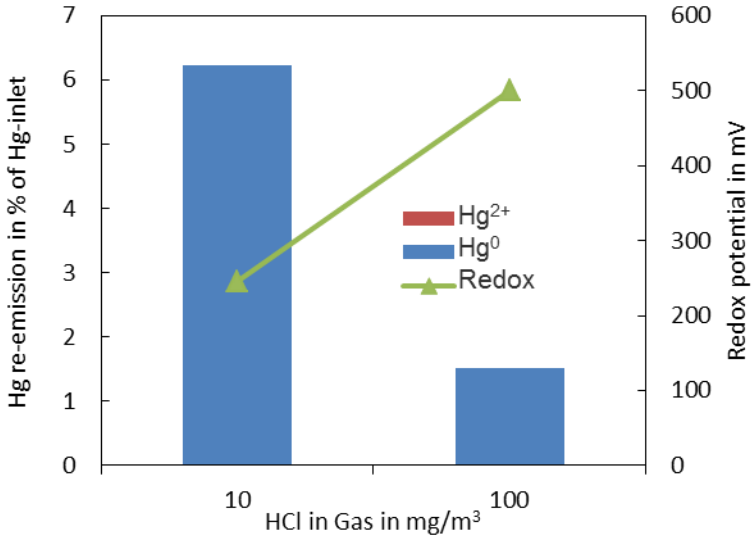


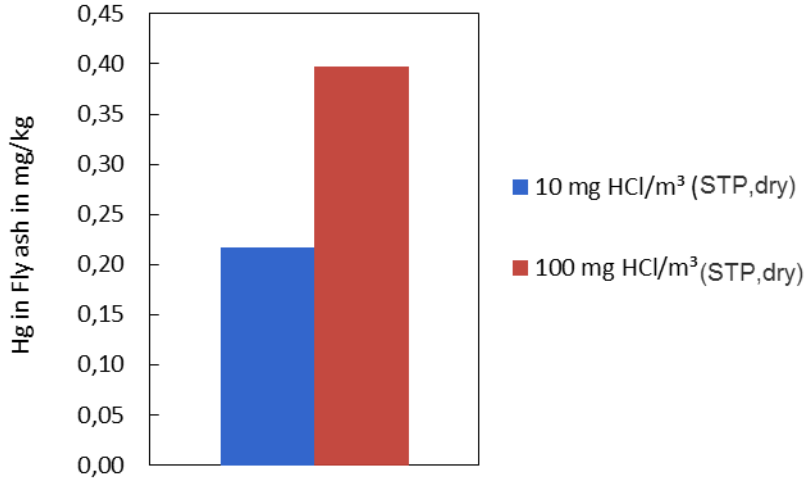




- HCl in flue gas affects homogeneous and heterogeneous Hg oxidation
- Effect of Oxi-Air and $Cl^-$ concentration in the slurry on Hg removal and re-emission
  - Higher $Cl^-$-concentration → complex formation
  - Oxi-Air → lower sulfite in slurry

# Effect of HCl concentration in flue gas and oxidation air

## Hg re-emission & Hg in fly ash

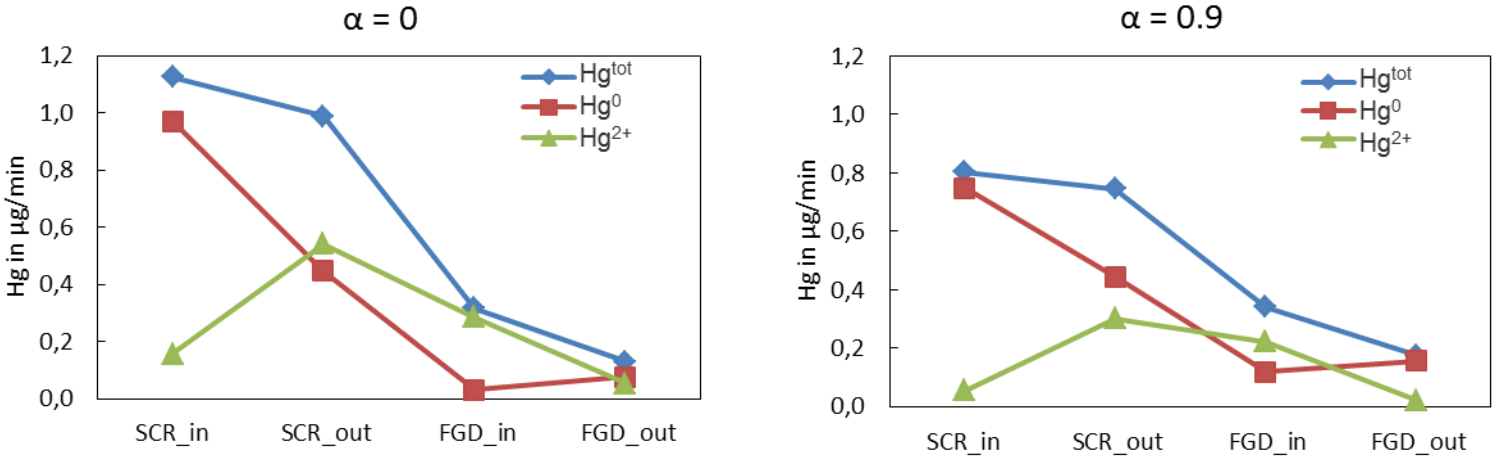



- Hg re-emission → elemental Hg → at low HCl concentration
- Presence of $Cl^-$ in slurry → higher redox potential
- More $Hg^{2+}$ due to higher HCl concentration → higher Hg adsorption at fly ash

# Effect of $NH_3$ on Hg removal

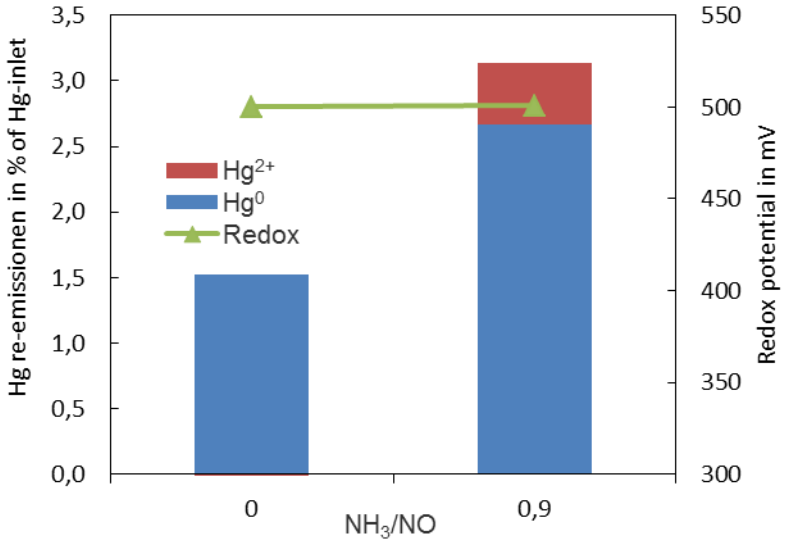
Hg in flue gas

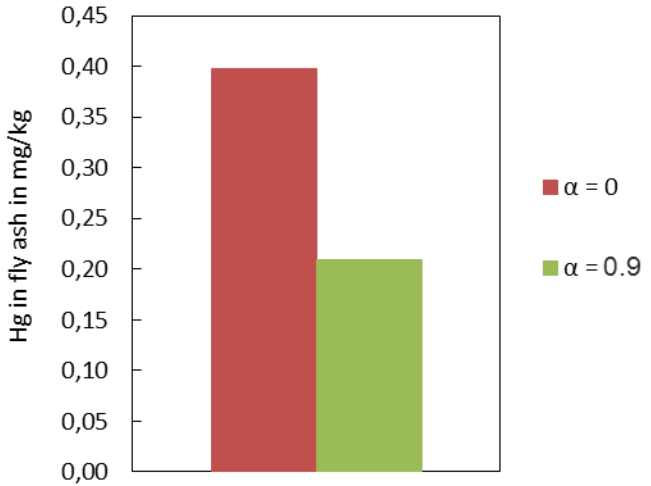



- Effects of $NH_3$ on Hg oxidation at the same $Cl^-$-concentration in flue gas → DeNOx is the dominant reaction → lower Hg oxidation
- Lower Hg adsorption on fly ash at presence of $NH_3$
- Without $NH_3$ lower Hg concentration at stack, even with higher Hg inlet concentration

# Effect of $NH_3$ on Hg removal

## Hg re-emissionen & Hg in fly ash

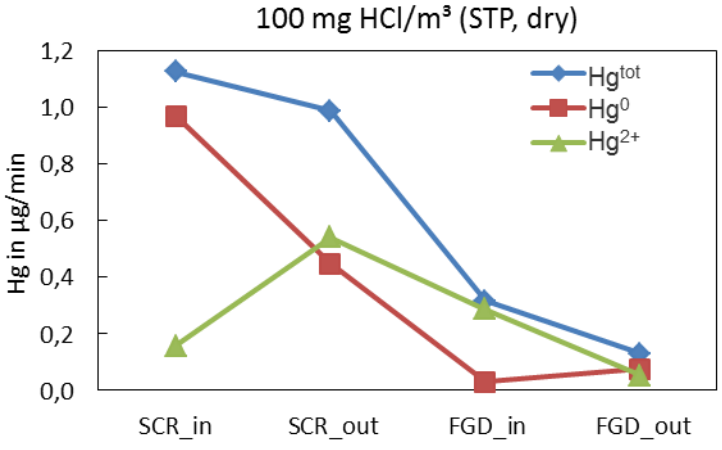


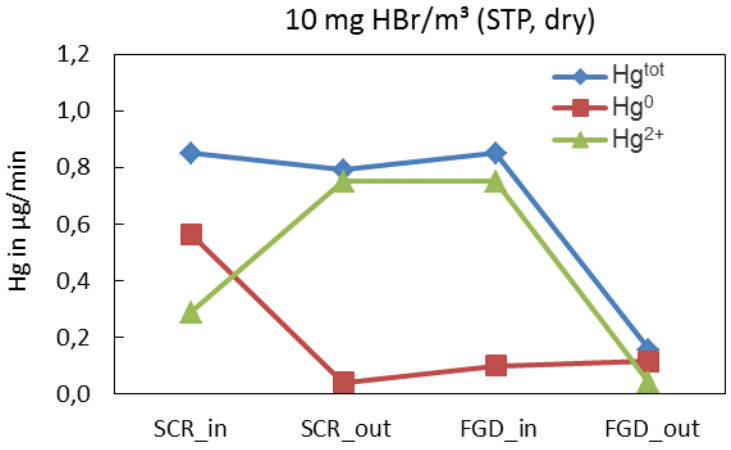




- Hg re-emission in the presence of $NH_3$ is higher and contains also $Hg^{2+}$
- Hg adsorption on fly ash is lower at the presence of $NH_3$

# Behavior of Hg at the presence of HBr & HCl in flue gas

## Hg in flue gas




- HBr → higher homogeneous and heterogeneous Hg oxidation

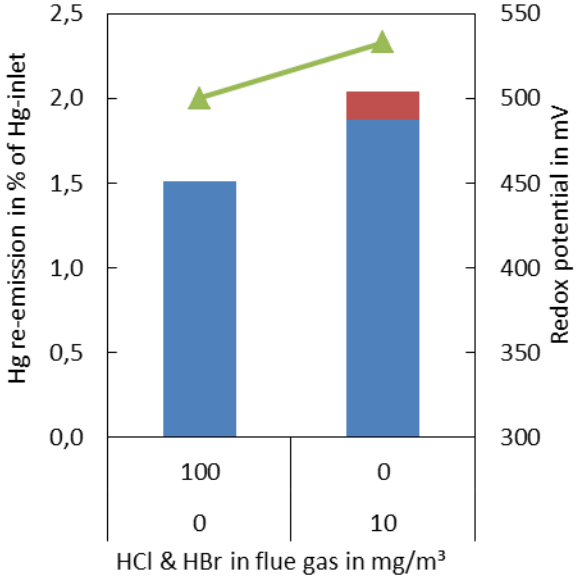
  → lower Hg adsorption on the fly ash

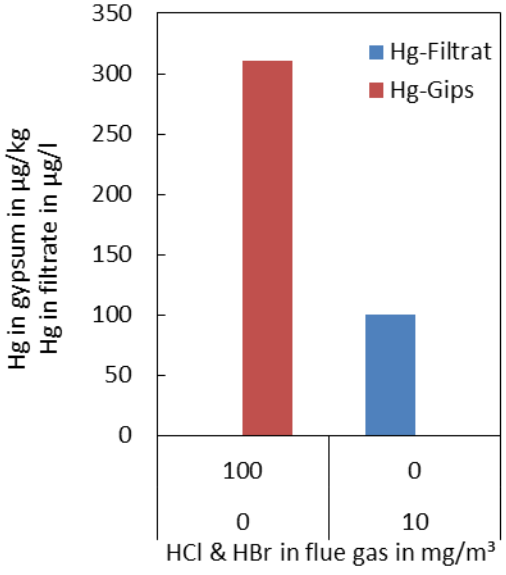
  → higher removal efficiency, even at higher Hg-inlet to FGD

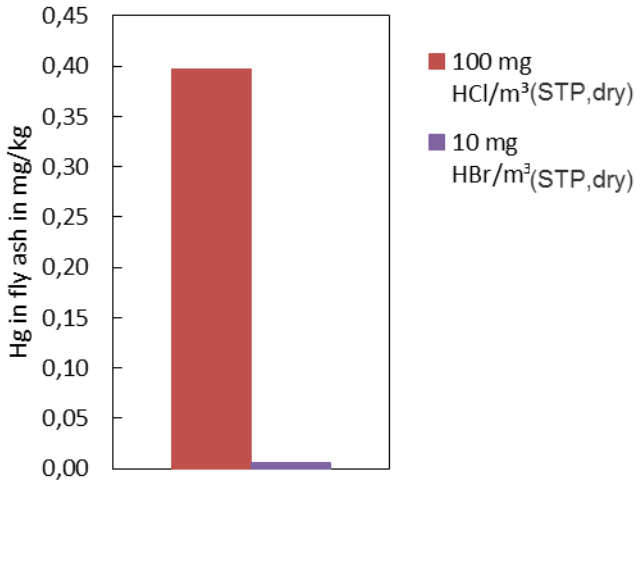
- The slurry contained no $Br^-$ at the beginning→ from the combustion of Br-containing coal

# Behavior of Hg at presence of $Br^-$ & $Cl^-$ in flue gas

## Hg re-emissionen & Hg in fly ash




- In the case of Br → $Hg^{2+}$ re-emission and higher redox potential

  → Hg accumulates more in filtrate than in gypsum

  → lower Adsorption on the fly ash, even with higher $Hg^{2+}/Hg^0$

# Summary

- HCl in flue gas
  - → increases the homogenous and heterogeneous Hg oxidation
  - → increase Hg adsorption on fly ash
  - → increasing $Cl^-$ concentration can prevent Hg re-emission
- At presence of $NH_3$
  - → prevents Hg oxidation at the catalyst
  - → reduced Hg adsorption in fly ash
  - → leads to higher Hg re-emission (also as $Hg^{2+}$)
- HBr in flue gas
  - → much higher Hg oxidation
  - → low Hg in fly ash and gypsum
  - → high Hg removal efficiency in FGD

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# Thank you!

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