

Fate of hazardous elements from biomass burned in stoves and boilers

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Biomass burning as an alternative energy supplier may play an essential future role due to the sighted reduction of the greenhouse gas effect, the shortage of fossil energy sources and the striving autonomy from fossil fuels. The growing contribution of biomass burning may have adverse effects such as higher emissions of harmful inorganic and organic substances in contrast to fossil fuels such as oil and gas.

Especially for in-house facilities burning biomass reliable measurements of concentrations and fluxes of heavy metals in the flue gas are lacking. For a reliable reconstruction of element fluxes and for input/output balances, the originating ashes such as grate ash, heat exchanger ash and fly ash are collected.

In the ideal case the amount of an element contained in the fuel should be identical with the combined element amounts in the different ash fractions. Systematic burning experiments with wood and straw in boilers reveal that significant amounts of heavy metals such as the environmentally and health relevant elements Cr, Co, Ni, Cu, Zn, Mo, Cd, Sn, Sb, Tl, and Pb are missing illustrated as the recovery rate of these elements (Fig. 1). This suggests that they either leave the chimney as molecules or ultrafine particles or that they “disappear” in the refractory lining material. The volatile property of these elements can be affirmed by a crucial lower presence in others than fly ashes.

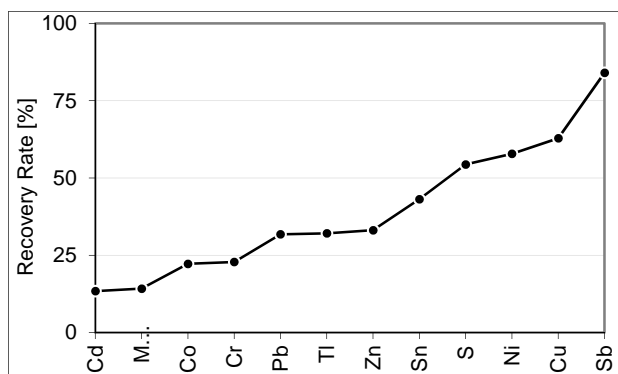


Fig. 1: Recovery rate (%) of elements by burning wood-chips in a 30 kW boiler (combined element amounts in grate ash, internal heat exchanger ash and fly ash divided by the element amounts contained in the wood chips).

We tested if elements pass the filter by percolating the air behind the filter through absorption solutions of $\text{HNO}_3\text{-HCl-H}_2\text{O}$ and $\text{HNO}_3\text{-H}_2\text{O}_2\text{-H}_2\text{O}$ respectively (VDI-guideline 3868). The measured concentrations are close to the detection limit and by far below the expected concentrations (Table 1). This means a leaving of this missing amount of these elements through the chimney can be suspended.

Tab. 1: Expected element concentration in the absorption solution determined from the balance calculations (Fig. 1) and measured element concentration in the absorption solution.

| Element | Expected concentration [ppm] | $\text{HNO}_3 + \text{HCl}$ | $\text{H}_2\text{O}_2 + \text{HNO}_3$ |
|---------|------------------------------|-----------------------------|---------------------------------------|
| S | 5,04 | <0,02 | <0,3 |
| Cr | 0,172 | <0,002 | <0,01 |
| Co | 0,06288 | <0,00006 | <0,0001 |
| Ni | 0,058 | <0,004 | <0,008 |
| Cu | 0,085 | <0,006 | <0,007 |
| Zn | 1,55 | <0,002 | <0,002 |
| Mo | 0,0092 | <0,0002 | <0,0003 |
| Cd | 0,03189 | <0,00001 | <0,00002 |
| Sn | 0,0019 | <0,0002 | <0,0002 |
| Sb | 0,0001 | <0,0002 | <0,0002 |
| Tl | 0,002560 | <0,000002 | <0,000002 |
| Pb | 0,039 | <0,006 | <0,02 |

The second explanation for the low recovery rate could be fixation by refractory lining materials such as chamotte. First experiments of a part of the refractory lining material from the roof of a stove show a large potential to act as a sink. The concentration in the unaffected material after correction with the fuel is still high and nearly unvaried and it shows that it is possible to store large element amounts in this material. The enrichment of some elements may be facilitated by the large open porosity (>20%) of this material and may explain in part small recovery rates. But very high extraction efficiencies would be necessary to remove appreciable amounts of these elements from the flue gas. For example: about 80% of Cd released during wood burning should be stored in the lining. Also the requirements on such a material can make a difference, e.g. the lining material of a boiler seems to have a lower retention potential for emitted elements.

Tab. 2: Calculation of the potential of the refractory lining of a stove with beech wood - log as fuel to act as a sink.

| | Cd | Zn | Tl | Pb | Bi | Sb |
|--|------|------|--------|-------|--------|--------|
| Used baffle [ppm] | 1,07 | 167 | 1,28 | 89,7 | 1,22 | 2,49 |
| Content in the baffle [mg] ¹⁾ | 6,42 | 996 | 7,68 | 538,2 | 7,32 | 14,9 |
| Beech wood - log [ppm] | 0,05 | 3,58 | 0,0015 | 0,1 | 0,0005 | 0,0024 |
| Content in the burned beech wood - log [mg] ²⁾ | 1 | 716 | 0,3 | 20 | 0,1 | 0,48 |
| Content [mg] in the baffle after subtraction of the content added by the fuel. | 5,42 | 280 | 7,38 | 518,2 | 7,22 | 13,46 |
| Concentration [ppm] of the baffle without potential content supply by the fuel | 0,9 | 46,7 | 1,23 | 86,4 | 1,20 | 2,24 |

¹⁾Weight of the baffle: ~6 kg

²⁾Mass of burned beech wood - log until dismounting of the baffle: 200 kg.

To assess the environmental impact of a furnace, flux calculations for elements are much more relevant than listing of simple concentration data. In addition, only element fluxes enable the comparison of emissions from different furnaces and fuels under different burning conditions, etc. But the fate of elements with low recovery rates has to be ascertained (retention in refractory lining material, contamination of the fuel, unknown sinks in the flue gas path).