

Elemental approaches to additives: mechanisms and dosage

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REFAWOOD objectives

The overall objective of REFAWOOD is to improve economic and environmental conditions and enlarge the market for the use of wood waste fuels in CHP-plants by using resource efficient additives such as recycled gypsum during combustion. Specific aims are as follows:

- To propose efficient and innovative fuel additive design concepts for reducing ash related operational problems (corrosion/fouling/slagging) in combustion of wood waste fuels
- To perform full-scale combustion tests to demonstrate effective fuel additive design concepts
- To show how wood waste fuels and new additive concepts can be integrated to the CHP plants in ways that are economical, benefit the environment, conserve natural resources and provide the CHP plant a fuel mixture with right quality
- To show how fuel additive design concepts are related to reduced operation and maintenance-costs (O&M costs).
- To propose recycling processes for ashes from waste wood combustion and additives to reduce the cost paid for landfilling.
- To determine the environmental and economic effects of using various additives in waste wood combustion in CHP/heating plants.

Additives and fuel design

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Challenges with waste wood as fuel

- Slagging or agglomeration – dominated by **silicate melt formation** where **alkali metals** contribute to lower ash melting points
- Fouling – deposit build-up caused by volatilized elements and entrained ash particles. Often related to **alkali metals, Zn, Pb**, that condense on heat exchanger surfaces causing adhesion.
- Corrosion – primarily through interaction of deposits with heat exchanger materials, often chloride dominated where the positive counter-ions typically are **alkali metals, Zn, and Pb**.

Challenges and strategies

Aluminosilicates
(Halloysite, coal fly ash)

Slagging and agglomeration

- Capture alkali in compounds with high melting temperatures

Fouling and corrosion

- Capture alkali in compounds that prevent volatilization

or

- Increase silicate melting temperatures

or

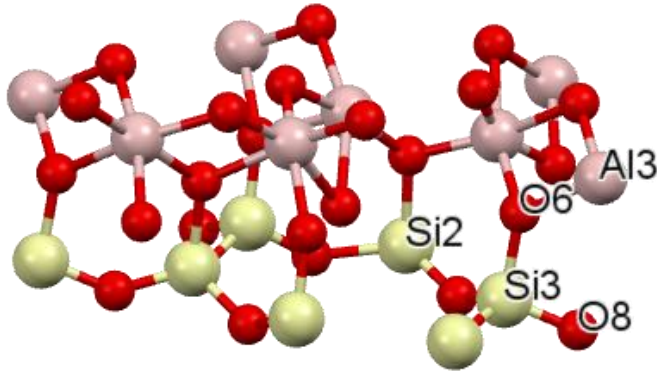
- Change deposit composition from chlorides to sulphates

Recycled waste gypsum

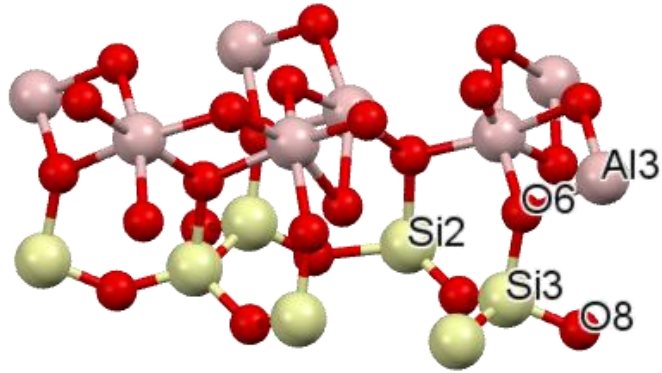
Iron(II)sulphide

Aluminosilicates

Halloysite, coal fly ash



- Aluminosilicate with reactive sites for Lewis acids (cations)
- Initially water molecules between aluminosilicate layers - above/below in figure
- Potential for formation of alkali-aluminosilicates
- Efficiency linked to diffusion of gaseous alkali components into the structure

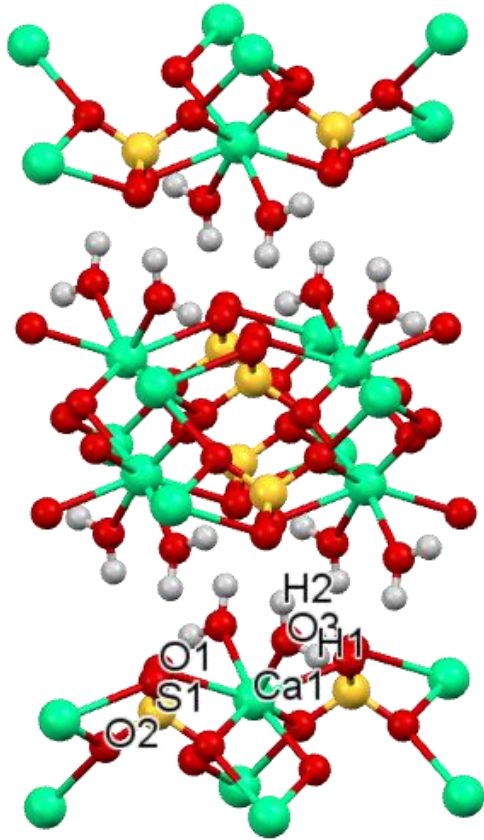


Aluminosilicates Halloysite, coal fly ash

- Reactive sites directly proportional to molar concentration of Al in additive (Al_{add}) – forming e.g. $KAlSi_2O_6$
- Elements inherent to the additive need to be taken into consideration (K_{add} , Na_{add} , Ca_{add} , Mg_{add})
- Efficiency up to 90% for mineral aluminosilicates (other work)
- Coal fly ash may have lower efficiency
- Additive amount calculated based on fuel composition

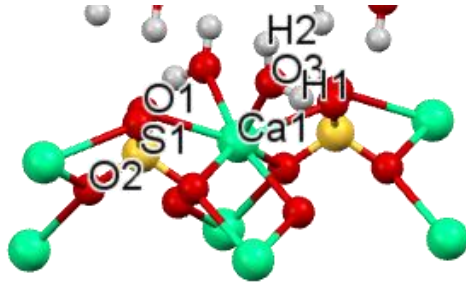
$$Alk_{cap} = Al_{add} - (K_{add} + Na_{add} + 2(Ca_{add} + Mg_{add}))$$

$$Amount_{add} = ((K_{fuel} + Na_{fuel}) / Alk_{cap}) / 0.90$$



Recycled gypsum ($\text{CaSO}_4 \cdot 1.5 \text{H}_2\text{O}$)

- Two-step decomposition – dehydration and breakdown of CaSO_4 into CaO and SO_2/SO_3
- CaO increases silicate melt temperatures
- SO_2/SO_3 reduces chloride formation
- Main limitation is decomposition of CaSO_4 into CaO and SO_2/SO_3

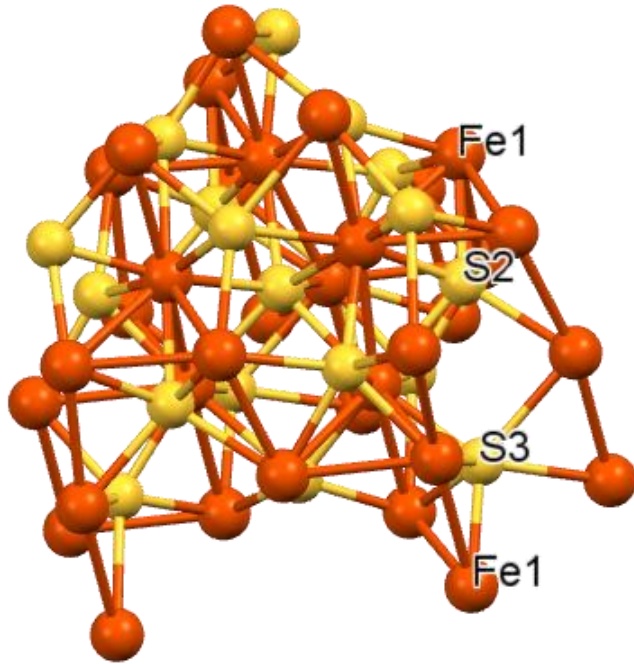


Recycled gypsum (CaSO₄ · 1.5 H₂O)

- Additive amount calculated based on expected sulphation potential
- Assumptions for efficiency difficult – limited by decomposition, SO_x reactions to form alkali sulphates
- Additionally, CaSO₄ may reform upon cooling!
- Sulphur content in fuel needs to be considered

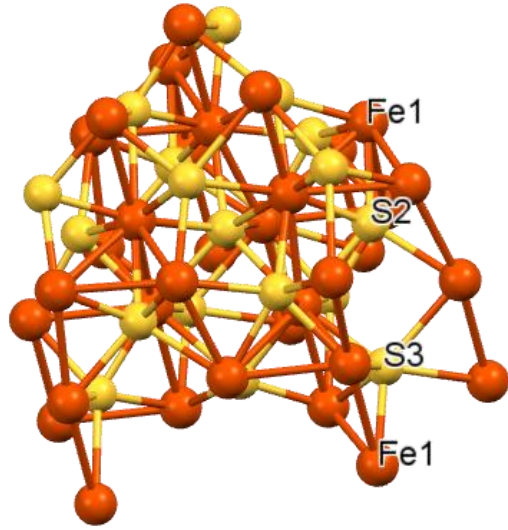
$$S_{\text{add}} = (F_{\text{stoich}} \cdot (((K_{\text{fuel}} + Na_{\text{fuel}})/2) + Zn_{\text{fuel}} + Pb_{\text{fuel}}) - \underline{0.64} S_{\text{fuel}}) / \underline{0.64}$$

Assuming 80% efficiency of both decomposition and sulphation reactions – better base data required for accurate assumptions!



Iron(II)sulphide

- Iron sulphide (Fe(II)S))
- Abundant waste stream from mining
- Highly exothermic decomposition through oxidation of Fe and S
- Potential for formation of SO_2/SO_3 for decreasing chloride formation



$$S_{\text{add}} = F_{\text{stoich}} \cdot (((K_{\text{fuel}} + Na_{\text{fuel}}) / 2) + Zn_{\text{fuel}} + Pb_{\text{fuel}}) - S_{\text{fuel}}$$

Iron(II)sulphide

- Efficiency not limited by reformation of additive, as for gypsum
- No assumption made for sulphation efficiency
- Iron mainly oxidizes into Fe_2O_3 – typically non-problematic at these process temperatures



Industrial scale application

- Relevant on-site fuel composition important – often outdated or incomplete!
- Calculated additive amounts in the range of a few wt-% for fuels in this work, feasible for most systems
- Efficiency limitations still require dedicated work (Coal fly ash, gypsum decomposition and reformation of CaSO_4)

Thank you for your attention!

Questions?



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