Hydrothermal carbonisation of effluent sludge

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Introduction

Hydrothermal carbonisation is a technique by which very moist biomass can be processed to a more valuable material, [1], [2]. The process involves heating the biomass in a water solution to 200-250°C under high pressure to avoid boiling. Acid or alkali for pH-adjustment or catalysts can be added. The aim of this RISE project was to experimentally investigate HTC treatment of different effluent sludges from the pulp and paper industry in a Parr-reactor. Sludge samples from one thermomechanical paper mill (TMP) and one kraft market pulp mill (NSWBK) have been evaluated. The following issues have been studied:

1. HTC-treatment time
2. Addition of acid and alkali
3. Dewatering properties of the resulting slurry
4. Non-process element (NPE) concentration in the original sludge, the filtrate and the filter cake

Experiments

A total of three experiments were done in the Parr-reactor, Table 1. The first two tests were identical in execution: the sludge was HTC-treated in the reactor and then filtered. The filter cake was first washed and then reslurried with hot deionized water. The solution was then HTC-treated a second time and filtrated. See Table 2 for results.

***Table 1**. Experimental setup for HTC treatment steps*

Trial	Sludge origin	HTC, step 1	pH step 1	HTC, step 2	HTC, step 3
HTC-1	TMP	200°C, 2 h	5.9	Washing, deionized H_2O, 70°C	200°C, 1 h
HTC-2	NSWBK	200°C, 2 h	7.2	Washing, deionized H_2O, 70°C	200°C, 1 h
HTC-3	NSWBK	200°C, 2 h	11.5	-	-

***Table 2** The chemical composition and the heating value were determined for solid samples in the two first tests.*

Analysis, dry sample (mass-%)	TMP raw	HTC-1-k3	NSWBK raw	HTC-2-k1
Ash	9.6	11.6	19.0	29.2
Chlorine (Cl)	0.02	<0.01	0.03	0.01
Sulphur (S)	0.86	0.65	2.1	1.2
Carbon (C)	48.7	54.4	43.1	46.4
Hydrogen (H)	6.1	6.0	5.8	5.1
Nitrogen (N)	3	1.6	5.3	3.3
Oxygen (O) (diff)	32	26	25	15
HHV, MJ/kg	20.4	23.8	18.4	20.4
LHV, MJ/kg	19.1	22.5	17.1	19.3

The potential of the HTC-process to separate the NPE elements from the sludge dry solids matter was evaluated by studying the carry-over NPE content and the NPE content of the sludge dry solids. The distribution after step 1 for trials HTC-1 and HTC-2 respectively were evaluated, Figure 1 and Figure 2.

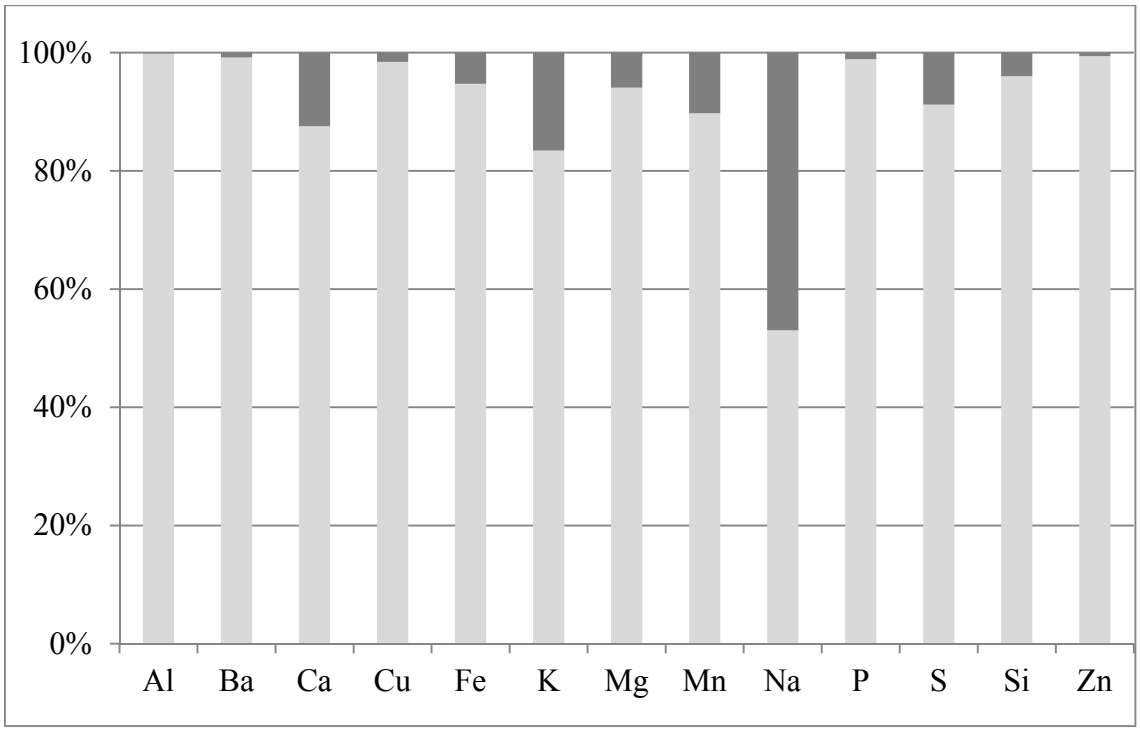

Figure 1. *Fraction of NPEs in HTC-1 filter cake (after step 1) carry over liquid (dark grey) and in sludge substance in the cake (light grey).*

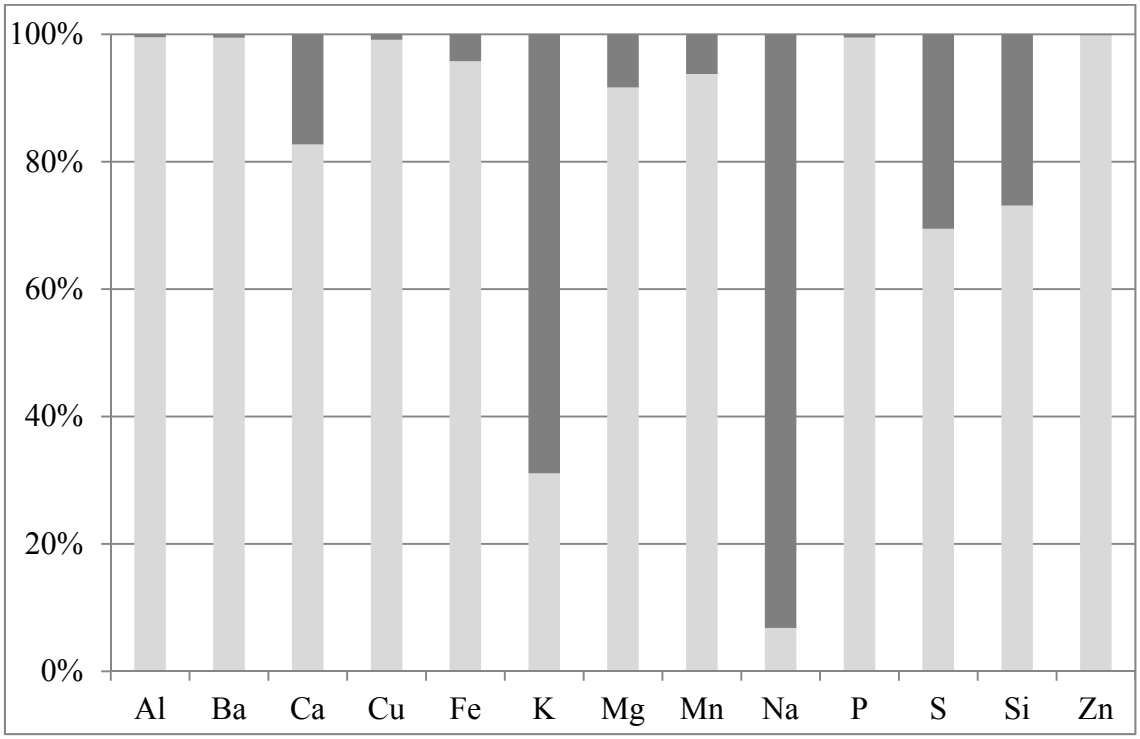

Figure 2. *Fraction of NPEs in HTC-2 filter cake (after step 1) carry over liquid (dark grey) and in sludge substance in the cake (light grey).*

The treated sludge will contain less or more energy than the untreated sludge depending on yield, dry solids and LHV improvement. The specific energy of sludge at a certain dry solids content can be calculated by subtracting the energy needed to vaporize the water fraction from the LHV and multiplying the result with the yield. The heating value of the organic matter in the filtrate is neglected.

Results

- HTC improved the fuel quality.
- Alkali metals (Na, K) are depleted in TMP and NSWBK sludge.
- In both cases, the sludge was easier to dewater. The dewatering properties were not quantified, only visually observed.
- The yield was better for TMP than NSWBK sludge.
- The yield losses affected the NSWBK sludge negatively.
- The TMP sludge is a viable boiler fuel already as it is and HTC-treatment improves the fuel qualities even further.
- From the recovery boiler point of view, the HTC treatment of the NSWBK sludge results in lower Cl and K. Lower fuel-N results in lower NO_X. HTC-treatment improves the LHV of this sludge, but this is counteracted by yield loss. The overall energy impact is negative compared to untreated NSWBK.
- From the recovery cycle point of view, HTC treatment offers mixed opportunities. The content of some problematic elements, as K and Cl, will effectively be lowered but the overall reduction seems to be small. Al and P seem to be removed to a very low degree. The problems that these elements have caused in the green liquor filtration or in the lime cycle will therefore not be solved by HTC treatment. The results for Si are inconclusive. There seems to be a potential to remove some 25% of the Si with HTC.
- It would be advantageous to focus further work on upgrading the fuel propertied of the NSWBK sludge in such a way that it would become a more attractive fuel for the bark boiler.
- Any further work in NPE removal should be focused on verifying the potential to remove Si.

Acknowledgement

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References

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2. Öhman, F, Fougner, K (2014): *Teknisk förstudie – biokol från bioslam*. Värmeforsk projekt S12-247