

USE OF CHEMICAL FRACTIONATION TO PREDICT BIOMASS FUEL ASH BEHAVIOUR

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ABSTRACT

Chemical Fractionation (CF) has been proposed by several researchers as a tool to assist in the advance prediction of biomass fuel ash behaviour. In this work, the relation between CF classes and alleged behaviour during pf combustion is studied experimentally. Samples of well-analysed fuel batches - wood, straw and chicken manure - have been subjected to a scheme of selective extractions. After each extraction, a subsample of the partly extracted material was used as a fuel in a lab-scale combustion and ash deposition test. Comparison of the ash deposits obtained with original and selectively extracted fuels yielded valuable information on the practical use of selective extraction for the prediction of biomass fuel ash behaviour. Suggestions for improvement of the extraction scheme are also given.

INTRODUCTION

Chemical Fractionation (CF) is a method to discriminate inorganic classes in biomass fuels according to their solubility in a sequence of increasingly aggressive solvents [Baxter, 1996]. The parts of the fuel found as either water soluble, ion exchangeable, hydrochloric acid soluble or residual (non-soluble) are subsequently related to their alleged behaviour in a process like e.g. pulverised fuel combustion. Generally, the water soluble and ion exchangeable classes include various salts of potassium and sodium which are considered to be easily vaporised in a high temperature process. Carbonates and sulphates are expected in the hydrochloric acid soluble class [Baxter, 1996], while the oxides, silicates and sulphides are not extracted and classified as residual. Both the hydrochloric acid soluble and residual matter are considered to be much less reactive in a thermal process.

The proportion of the elements of interest found in the first two classes is mostly interpreted as a measure for the release of reactive inorganic species to the gas phase. Their availability is subsequently related to enhanced deposition of ash on boiler and heat exchanging surfaces.

So far, ash deposition has been studied using fuels as a whole. In the current study, selective extraction has been applied to produce fuels lacking specific inorganic species. These fuels have been used in lab-scale deposition tests to verify the alleged relations with the currently used CF classes.

EXPERIMENTAL

Wood, straw and chicken manure with well-known inorganic compositions (threefold ICP-AES analysis per fuel) have been tested with respect to their ash deposition behaviour in a lab-scale combustion simulator. In Figure 1, a schematic view of the installation is given. By means of a staged gas burner and electrical furnace, the gas temperature and gas phase concentrations of O₂, CO, CO₂, H₂O, SO₂ and N₂ have been set to simulate typical combustion conditions in a pulverised fuel boiler. Fouling of superheaters was simulated by means of a temperature-controlled metal deposition surface, with a surface temperature of 600 °C at a gas temperature of 1200 °C. The surface temperature was recorded during the deposition test. The deposits were analysed off-line in 2D and 3D by means of SEM-EDX. The results serve as a reference for comparison with the deposition behaviour of partly extracted fuels.

The same fuels were subjected to a sequence of three selective extractions using water, a 1 M NH_4Ac solution and a 1M HCl solution. The procedure suggested by Baxter [1996], see Figure 2, was evaluated by a) comparing the composition of the extracted material with the extract concentrations, b) comparing parallel to sequential extraction, c) examining the effect of pH-control during the extraction and d) evaluating multiple extractions at a low L/S ratio versus a single extraction at a proportionally higher L/S ratio. From these tests, suggestions for improvement of the procedure are given. Extracted material has been taken from each extraction step to be used as a fuel in a deposition test in the facility described above. Again, SEM-EDX was used to examine the deposits and to compare the occurrence of specific species in these deposits with those obtained from burning the original fuels.

RESULTS

Extraction at a L/S ratio of 3 is not feasible for biomass such as wood or straw due to a very high water uptake. An L/S ratio of 10 or more should be used in stead.

The determination of extracted elements is much easier and cheaper by analysing the extract than by handling and opening up and analysing the extracted solid residue.

The pH-value after equilibration of the solvent with the solid phase is influenced by and depends on the biomass used. Control of the pH-value at a pre-set constant value may be considered but care must be taken not to replace a pH-influence on the extraction process by an influence of increased ion concentrations in the solvent.

Partly extracted fuels have been used in lab-scale ash deposition tests under simulated pf firing conditions. The deposits are compared to those obtained from the original fuels by means of 2D and 3D SEM-EDX analysis, identifying the presence and role of relevant species in the deposit. Heat fluxes through the growing deposit layers have been determined as a function of time as a more quantitative measure of deposit development. Definite results will be presented by the time of the symposium.

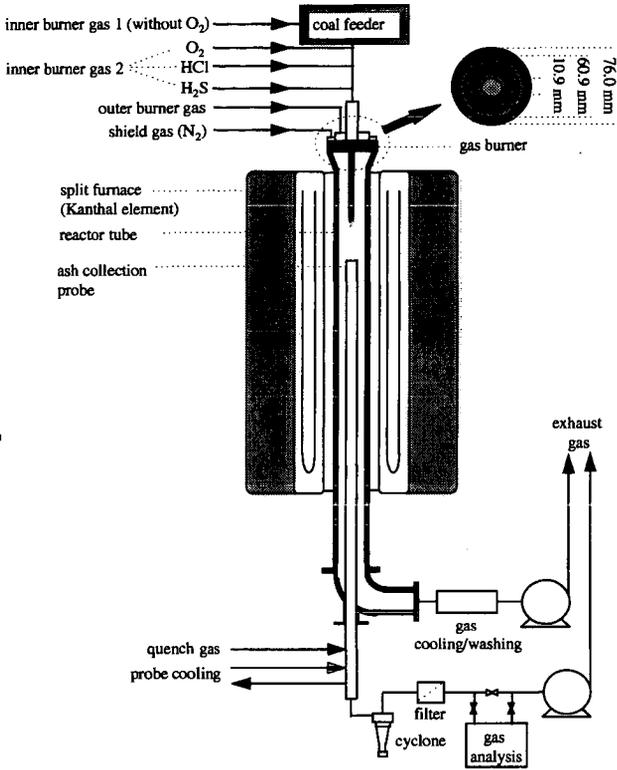
DISCUSSION AND CONCLUSIONS

- Selective extraction schemes which are currently used for predicting fuel ash behaviour have been designed - in the past - for the evaluation of leaching characteristics of soils. For a Chemical Fractionation analysis of biomassfuel inorganic matter, an adapted design should be aimed at the selective extraction of elements of interest applying specific pH-values and/or solvent ion concentrations. It may be necessary to control these conditions to eliminate effects of the fuel (biomass) matrix during the extraction. More work is needed to establish specific conditions for extracting key elements or species with a known behaviour in thermal processes.
- Up till now, only a gross difference between water soluble / ion exchangeable, strong acid soluble and non soluble inorganic species can be made using three selective extractions. A definite relation between extraction results and fuel ash behaviour can be obtained using fuels which have been partly extracted under well-controlled conditions in subsequent combustion tests aimed at ash deposition evaluation. From this, extraction schemes can be set up for the determination of specific, predefined inorganic species.

REFERENCES

L.L. Baxter, Chemical Fractionation Procedure, in: "Alkali Deposits Found in Biomass Power Plants, a Preliminary Investigation of Their Extent and Nature", Summary Report for National Renewable Energy Laboratory, by T.R. Miles, P.E., T.R. Miles jr., L.L. Baxter, R.W. Bryers, B.M. Jenkins and L.L. Oden, Golden, CO, USA (1996).

FIGURES



Typical particle feed rate (g/h)	1
Particle residence time (ms)	10 – 3000
Particle heating rate (°C/s)	> 10 ⁵
Gas supply inner burner	CH ₄ , CO, CO ₂ , H ₂ , N ₂ , O ₂ , H ₂ S
Gas supply outer burner	CH ₄ , CO, H ₂ , O ₂ , H ₂ S
Operating pressure (MPa)	0.1
Reactor tube inner diameter (m)	0.076
Reactor tube length (m)	1.0
Max. electrical heating temperature (°C)	1600
Probes for:	gas temperature/ composition measurement; ash & deposit collection

Figure 1. Schematic overview of the Atmospheric Entrained-Flow Gasification and Combustion simulator, and its main features.

**Chemical fractionation procedure
according to L.L. Baxter**

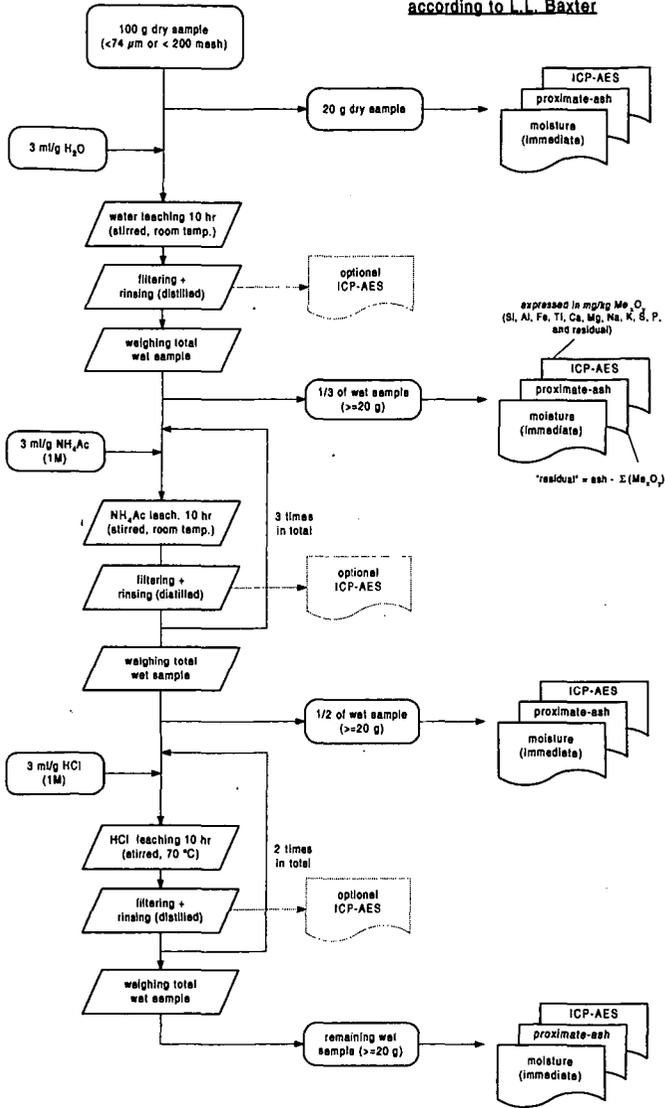


Figure 2. Extraction scheme used for Chemical Fractionation analysis of inorganic matter in biomass fuels (Baxter, 1996).