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BEHAVIOUR OF MINERAL MATTER IN RESIDUAL MATERIALS AND BIOMASSES STUDIED BY DIFFERENT ASHING METHODS

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MOTIVATION

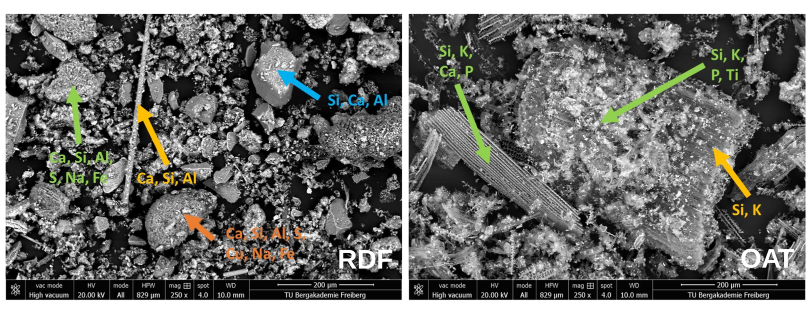
Realisable conversion processes for solid fuels are determined by the contained minerals, since agglomeration, sintering or melting of the resulting ash can strongly affect the process. Therefore, investigations of ash composition with selective vaporisation, mineral phases and ash fusion behavior are indispensable to enable a reliable operation.

MATERIALS AND METHODS

The studied feedstocks comprise two residual materials, a refuse-derived fuel (RDF) and sewage sludge (SWS), as well as two biomasses, oat husks (OAT) and bamboo (BAM). Ashes of those are produced via plasma treatment at a low temperature of ≤200 °C (LTA), at a medium temperature of 450/550 °C (MTA), and according to DIN 51719 at a high temperature of 815 °C (HTA). The ashes are subsequently studied by X-ray fluorescence (XRF) analysis according to DIN 51729-10, ash fusion tests (AFT) according to DIN 51730, X-ray diffraction (XRD), and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM/EDX).

RESULTS AND DISCUSSION

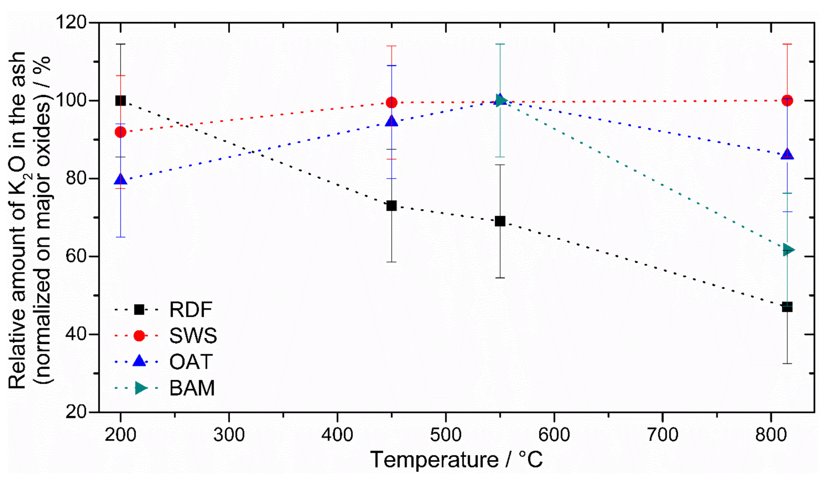
The distribution of elements in the LTA ashes studied by SEM/EDX (see Figure below) reflects the major ash components from the Table (below) and gives an impression of their spatial proximity. Those are nearly equally distributed in OAT with little changes in the contents of minor species. While, there are distinct differences in the major species for RDF due to its origin.



Fuel	Refuse-derived fuel			Sewage sludge			Oat husks			Bamboo	
Mass / wt.%	*LTA**	*MTA*	*HTA*	*LTA**	*MTA*	*HTA*	*LTA**	*MTA*	*HTA*	*MTA*	*HTA*
CO_2	45.66	4.86	0.77	53.42	1.86	0.28	20.97	1.18	0.50	15.93	16.20
Na_2O	2.23	2.83	2.71	0.12	0.69	0.66	0.31	0.29	0.76	2.36	6.78
MgO	1.38	2.11	2.12	1.87	4.60	5.04	2.20	2.62	2.75	3.80	3.79
Al_2O_3	7.23	10.90	10.92	4.61	9.85	9.74	1.26	0.36	0.41	0.32	0.47
SiO_2	17.52	43.07	44.17	18.65	35.80	36.39	45.70	62.09	65.07	8.63	10.50
P_2O_5	0.66	0.80	0.84	6.75	16.05	16.78	5.08	6.48	7.15	12.75	14.04
SO_3	2.58	4.22	4.61	1.86	3.80	0.85	2.44	3.10	2.57	2.74	2.55
Cl	0.46	3.90	3.97	0.10	-	-	0.11	0.91	0.09	1.36	0.03
K_2O	0.93	1.18	1.23	0.59	1.49	1.57	12.72	19.03	17.04	31.65	22.48
CaO	15.53	19.63	21.30	3.32	9.96	10.77	3.54	3.43	3.18	3.40	4.71
TiO_2	2.42	1.79	1.97	0.39	1.24	1.36	3.98	0.01	0.01	0.01	0.01
Fe_2O_3	2.51	3.37	3.83	3.41	14.19	15.99	1.19	0.30	0.28	11.53	12.39
Traces#	0.88	1.34	1.56	4.91	0.48	0.56	0.49	0.21	0.18	5.53	6.07

* For LTA certain matrix effects may occur due to the high content of residual organic material. # Includes various trace metals and their oxides.

The release of K_2O into the gas phase (causing fouling) as a function of ashing temperature is displayed in the Figure below (including a typical error range). Herein, the relative amounts of K_2O in SWS and OAT are not affected by the ashing temperature, since both have featured K_2O-containing mineral phases, like microcline and arcanite as well as the incorporation into slag by the eutectic system K_2O-SiO_2 [1]. The spatial distance between potential bonding partners in RDF, e.g. Al_2O_3 and SiO_2, is too high to enable a reaction. In the case of BAM, those oxides are nearly entirely missing.



The ash fusion behaviour of the ashes is strongly influenced by both ashing temperature and atmosphere. Under reducing atmosphere, the characteristic points of DT and ST are frequently reduced. Whereas, HT and FT are less affected by the atmosphere. The ashes of OAT have demonstrated the lowest deformation temperatures, since those ashes have offered the eutectic K_2O-SiO_2. While, RDF and SWS are mainly compiled by silicates, simple oxides, and slightly some other phases [1]. BAM has contained a certain amount of carbonates, too.

Fuel	Refuse-derived fuel		Sewage sludge		Oat husks		Bamboo	
Ash	*MTA*	*HTA*	*MTA*	*HTA*	*MTA*	*HTA*	*MTA*	*HTA*
Ash fusion temperatures under oxidising conditions (air) / °C								
DT	1163	1151	1100	1130	931	1076	1297	1207
ST	1167	1156	1181	1191	1181	1230	1305	1220
HT	1177	1167	1237	1245	1227	1266	1320	1250
FT	1409	1408	1350	1325	1381	1331	1338	1275
Ash fusion temperatures under reducing conditions (65 vol.-% CO + 35 vol.-% CO_2) / °C								
DT	1163	1058	1053	1119	825	918	1230	1207
ST	1168	1168	1126	1124	1098	1100	1313	1220
HT	1182	1177	1172	1178	1288	1153	1324	1239
FT	1356	1415	1326	1285	1427	1368	1350	1299

SUMMARY

The results of the different ashing methods are briefly summarised:

- A temperature-sensitive vaporisation of K_2O is detected for some feedstocks. That effect is strongly depending on the ability of mineral phases to incorporate K_2O as well as the inherent availability and distribution of such bonding partners.
- The ash fusion behaviour is significantly influenced by the temperature used for ashing. Clear differences are found between oxidising and reducing atmosphere. Thus, the formed mineral phases have to be studied in addition to a coarse consideration of the chemical composition.

[1] M. Reinmöller, M. Schreiner, S. Guhl, M. Neuroth, B. Meyer, *FUEL*, 202 (2017) 641-649.

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