

Unlocking the fertiliser potential of waste-derived biochar

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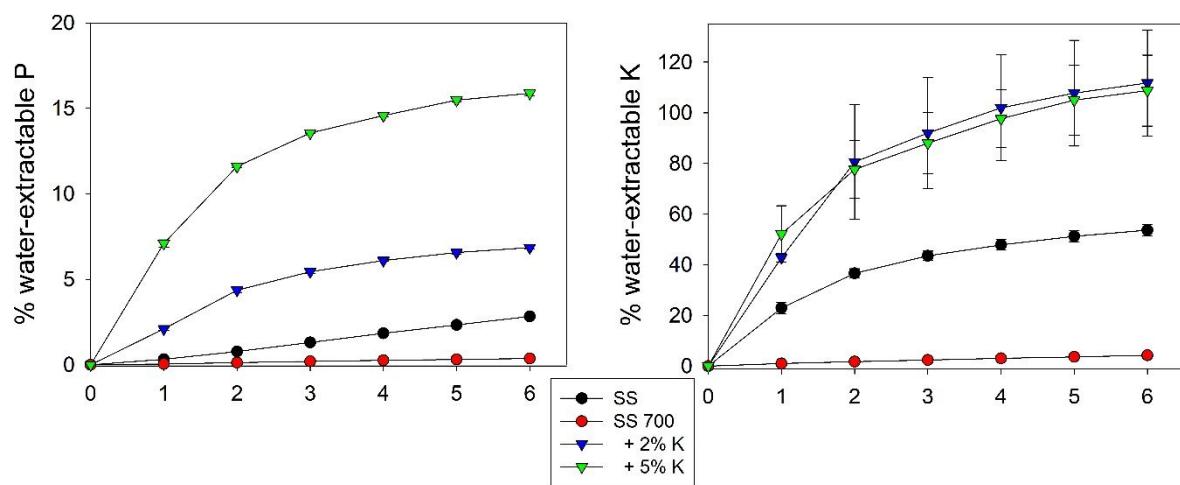


Figure S1-Sn: Cumulative nutrient release after extraction with unbuffered DI water in six repeated extractions in sewage sludge (SS) and sewage sludge biochar. Biochar was produced at 700°C without addition (SS 700) and with 2% and 5% K addition prior to pyrolysis. Mean and standard deviation of three replicates are shown.

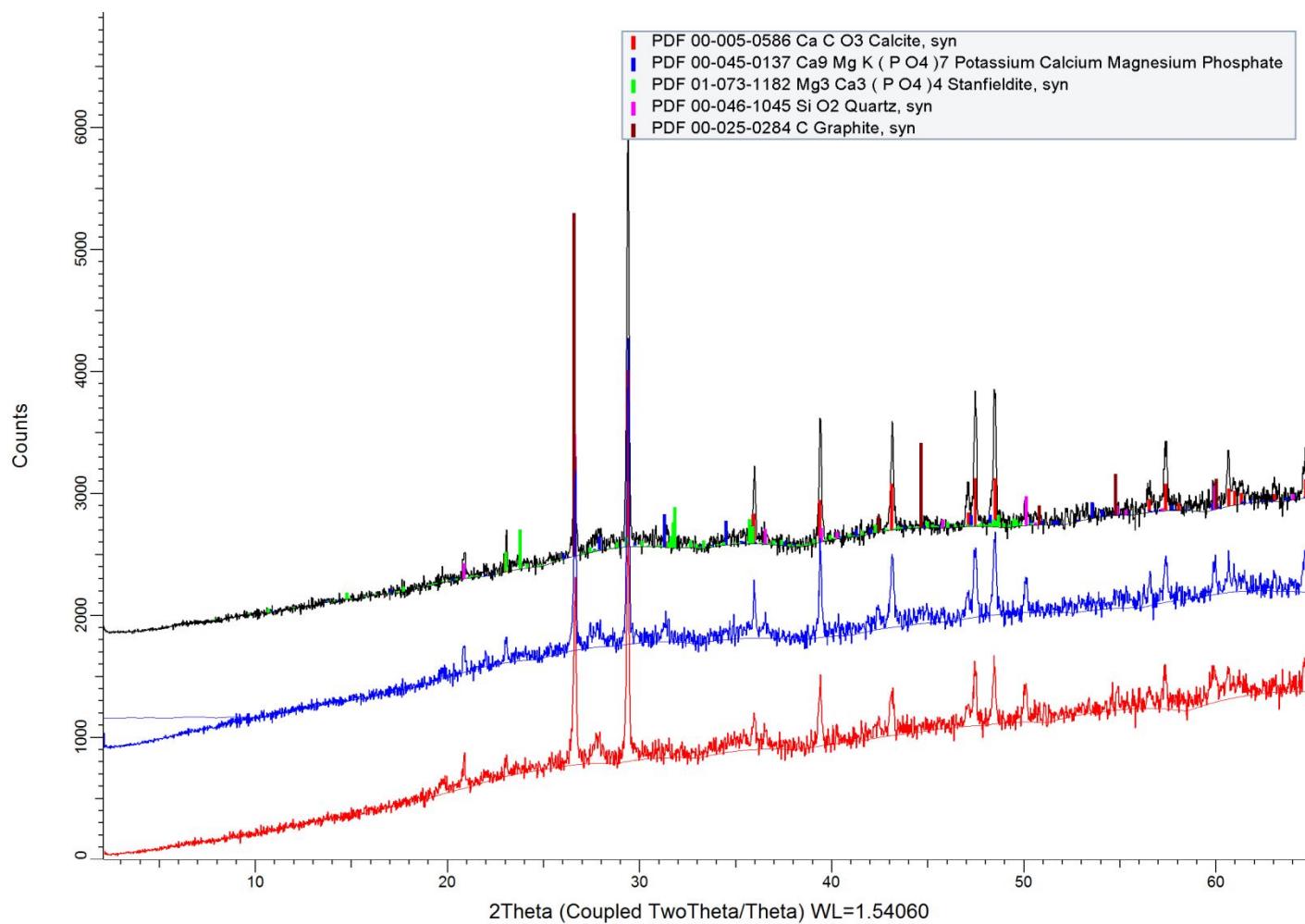


Figure S2-Sn: XRD spectra of sewage sludge biochar produced at 700°C (red line), doped with 2% K prior to pyrolysis (blue line) and doped with 5% K prior to pyrolysis (black line).

Table S1-Sn: Results from linear combination fitting (LCF) of the P K-edge XANES spectra for sewage sludge biochar (SS700) and 5% K-doped sewage sludge biochar (SS 700 + 5% K) (%). Replicates 3-5 of SS 700 + 5% K not shown as they did not show a good fit with the stated reference materials.

Reference Material	SS700 (1)	SS700(2)	SS700(3)	SS700(4)	SS700(5)	SS700+5%K(1)	SS700+5%K(2)
Ca ₅ (PO ₄) ₃ (OH)	4.5	1.0	2.9	60.2	77.8	2.8	16.1
K ₂ HPO ₄						58.5	56.2
AlPO ₄	95.5	98.8	97.1	39.8	22.2	38.7	27.7
<i>R</i> factor	0.04	0.09	0.1	0.03	0.005	0.02	0.02

Table S2-Sn: Total and available concentrations of various elements in sewage sludge and its biochar (mg kg^{-1}).

	P	K	Ca	Mg	Al	Fe	B	Mn	Mo
<u>total</u>									
SS	10984 ± 354	1157 ± 42	9661 ± 74	4331 ± 38	12280 ± 201	21709 ± 235	6.0 ± 0.6	364 ± 10.1	11.2
SS 700	20309 ± 734	3277 ± 35	22874 ± 174	10671 ± 142	32136 ± 424	41536 ± 2058	13.7 ± 0.4	815 ± 3.1	11.2
+ 2% K	18965 ± 594	23316 ± 284	24063 ± 134	10778 ± 71	30435 ± 761	34680 ± 768	20.6 ± 0.2	669 ± 14.5	11.2
+ 5% K	19555 ± 265	37845 ± 320	21046 ± 287	9849 ± 136	31588 ± 209	34358 ± 894	23.2 ± 0.6	624 ± 5.9	11.2
<u>CaCl₂ extraction</u>									
SS	166 ± 2.3	239 ± 3.0	-205 ± 23	299 ± 4.9	17 ± 1.0	29.2 ± 1.9	< 3.2	17.9 ± 0.6	< 0.46
SS 700	1.1 ± 0.3	23 ± 1.6	46 ± 34	337 ± 5.1	22 ± 3.7	0.4 ± 0.2	5.3 ± 0.1	0.2 ± 0.0	< 0.46
+ 2% K	<0.3	7135 ± 746	-2444 ± 50	< 2.3	102 ± 39	0.2 ± 0.1	3.3 ± 0.1	< 0.01	0.8 ± 0.0
+ 5% K	339.7 ± 18.8	13580 ± 240	-2666 ± 3.8	< 2.3	394 ± 31	24.7 ± 0.3	7.3 ± 0.1	< 0.01	2.1 ± 0.1
<u>water extraction</u>									
SS	129 ± 7.0	206 ± 4.7	367 ± 14.2	92 ± 3.0	12.3 ± 1.3	24.5 ± 2.7	< 3.2	4.0 ± 0.1	< 0.46
SS 700	7.5 ± 1.5	32 ± 0.5	129 ± 3.7	174 ± 9.9	10.4 ± 3.3	0.5 ± 0.1	< 3.2	0.0 ± 0.0	< 0.46
+ 2% K	564 ± 21.5	6984 ± 352	9.8 ± 0.8	6.5 ± 1.3	459.4 ± 23	3.1 ± 0.3	3.2 ± 0.1	0.0 ± 0.0	0.6 ± 0.1
+ 5% K	1700 ± 35.0	13471 ± 80	7.7 ± 0.8	4.3 ± 0.4	991.3 ± 22	29.5 ± 0.8	5.1 ± 0.2	< 0.01	1.9 ± 0.1
<u>formic acid extraction</u>									
SS	1756 ± 151	771 ± 22	8445 ± 404	1036 ± 57	2212 ± 260	1683 ± 126	not measured	not measured	not measured
SS 700	592 ± 11	366 ± 1.9	4592 ± 43	1833 ± 12	986 ± 5.7	1071 ± 9.1	not measured	not measured	not measured
+ 2% K	2055 ± 29	13413 ± 86	5810 ± 91	2302 ± 20	2866 ± 70	2173 ± 50	not measured	not measured	not measured
+ 5% K	2920 ± 71	26760 ± 447	6702 ± 45	2250 ± 11	3037 ± 29	5102 ± 90	not measured	not measured	not measured
<u>% CaCl₂ of total</u>									
SS	1.5 ± 0.05	21 ± 0.79	-2.1 ± 0.24	6.9 ± 0.13	0.1 ± 0.01	0.13 ± 0.01	< 53.4	4.92 ± 0.22	both bdl
SS 700	0.0 ± 0.00	0.7 ± 0.05	0.2 ± 0.15	3.2 ± 0.06	0.1 ± 0.01	0.00 ± 0.00	38.5 ± 1.18	0.02 ± 0.00	both bdl
+ 2% K	0.0 ±	31 ± 3.22	-10.2 ± 0.22	< 0.02	0.3 ± 0.13	0.00 ± 0.00	16.1 ± 0.45	< 0.001	> 7.5
+ 5% K	1.7 ± 0.10	36 ± 0.70	-12.7 ± 0.17	< 0.02	1.2 ± 0.10	0.07 ± 0.00	31.3 ± 1.02	< 0.001	> 18.9
<u>% water of total</u>									
SS	1.2 ± 0.07	17.8 ± 0.76	3.8 ± 0.15	2.13 ± 0.07	0.1 ± 0.01	0.11 ± 0.01	< 53.4	1.09 ± 0.04	both bdl
SS 700	0.04 ± 0.01	1.0 ± 0.02	0.6 ± 0.02	1.63 ± 0.10	0.0 ± 0.01	0.00 ± 0.00	< 23.3	0.003 ± 0.00	both bdl
+ 2% K	3.0 ± 0.15	30.0 ± 1.55	0.04 ± 0.003	0.06 ± 0.01	1.5 ± 0.09	0.01 ± 0.00	15.7 ± 0.47	0.003 ± 0.00	> 5.4
+ 5% K	8.7 ± 0.21	35.6 ± 0.37	0.04 ± 0.004	0.04 ± 0.00	3.1 ± 0.07	0.09 ± 0.00	21.9 ± 1.03	< 0.001	> 17.4
<u>% formic acid of total</u>									
SS	16.0 ± 1.5	66.7 ± 3.0	87.4 ± 4.2	23.9 ± 1.3	18.0 ± 2.1	7.8 ± 0.6			
SS 700	2.9 ± 0.1	11.2 ± 0.1	20.1 ± 0.2	17.2 ± 0.3	3.1 ± 0.04	2.6 ± 0.1			
+ 2% K	10.8 ± 0.4	57.5 ± 0.8	24.1 ± 0.4	21.4 ± 0.2	9.4 ± 0.3	6.3 ± 0.2			
+ 5% K	14.9 ± 0.4	70.7 ± 1.3	31.8 ± 0.5	22.8 ± 0.3	9.6 ± 0.1	14.8 ± 0.5			

Table S3-Sn: Total and available concentrations of potentially toxic elements (PTEs) in sewage sludge and its biochar (mg kg^{-1}).

	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
<u>total</u>									
SS	3.8 ± 0.4	3.2 ± 0.1	87.2 ± 0.8	107.6 ± 2.7	113 ± 5.9	< 5.8	18.7 ± 0.6	104 ± 1.3	412 ± 11
SS 700	7.4 ± 0.9	6.8 ± 0.1	204.3 ± 2.5	253.6 ± 3.1	261 ± 3.7	10.6 ± 1.6	46.4 ± 0.1	249 ± 0.9	940 ± 17
+ 2% K	6.4 ± 0.6	5.6 ± 0.4	173.6 ± 1.6	162.7 ± 8.7	246 ± 4.7	12.3 ± 2.4	44.5 ± 0.4	222 ± 28	646 ± 15
+ 5% K	6.8 ± 0.6	5.3 ± 0.1	171.8 ± 3.8	155.4 ± 2.9	226 ± 5.2	16.9 ± 2.0	40.9 ± 0.6	192 ± 3.7	575 ± 11
<u>CaCl₂ extraction</u>									
SS	0.8 ± 0.1	< 0.12	0.4 ± 0.0	0.1 ± 0.01	5.3 ± 0.01	< 0.9	1.3 ± 0.0	< 0.12	7.3 ± 0.4
SS 700	< 0.13	< 0.12	< 0.01	0.1 ± 0.00	0.01 ± 0.002	< 0.9	0.0 ± 0.0	< 0.12	< 0.01
+ 2% K	< 0.13	< 0.12	< 0.01	0.0 ± 0.01	< 0.004	< 0.9	< 0.01	0.3 ± 0.0	< 0.01
+ 5% K	0.2 ± 0.0	< 0.12	0.1 ± 0.0	0.1 ± 0.03	0.01 ± 0.01	< 0.9	0.0 ± 0.0	1.1 ± 0.1	< 0.01
<u>water extraction</u>									
SS	1.1 ± 0.1	< 0.12	0.6 ± 0.1	0.1 ± 0.02	5.9 ± 0.1	< 0.9	1.1 ± 0.0	7.4 ± 0.5	3.9 ± 0.0
SS 700	0.7 ± 0.1	< 0.12	0.3 ± 0.0	0.1 ± 0.01	0.4 ± 0.0	< 0.9	0.2 ± 0.0	7.2 ± 0.2	0.2 ± 0.0
+ 2% K	1.1 ± 0.1	< 0.12	0.2 ± 0.0	0.2 ± 0.01	0.4 ± 0.2	< 0.9	0.1 ± 0.1	8.1 ± 0.5	0.3 ± 0.0
+ 5% K	1.1 ± 0.3	< 0.12	0.3 ± 0.1	0.1 ± 0.01	0.4 ± 0.1	< 0.9	0.2 ± 0.0	8.6 ± 0.6	0.3 ± 0.0
<u>% CaCl₂ of total</u>									
SS	20 ± 3.9	< 3.8	0.4 ± 0.02	0.1 ± 0.01	4.7 ± 0.25	both bdl	7.1 ± 0.25	< 0.1	1.8 ± 0.10
SS 700	< 1.7	< 1.8	< 0.01	0.04 ± 0.002	0.005 ± 0.001	< 8.2	0.1 ± 0.02	< 0.05	< 0.001
+ 2% K	< 2.0	< 2.2	< 0.01	0.01 ± 0.003	< 0.002	< 7.0	< 0.02	0.1 ± 0.02	< 0.002
+ 5% K	2.3 ± 0.29	< 2.3	0.1 ± 0.001	0.1 ± 0.02	0.01 ± 0.004	< 5.1	0.0 ± 0.01	0.6 ± 0.05	< 0.002
<u>% water of total</u>									
SS	28.3 ± 5.2	< 3.8	0.6 ± 0.06	0.13 ± 0.02	5.21 ± 0.28	both bdl	5.8 ± 0.19	7.1 ± 0.53	0.9 ± 0.03
SS 700	9.9 ± 2.1	< 1.8	0.1 ± 0.01	0.05 ± 0.003	0.14 ± 0.01	< 8.2	0.4 ± 0.06	2.9 ± 0.07	0.03 ± 0.004
+ 2% K	16.9 ± 2.6	< 2.2	0.1 ± 0.01	0.10 ± 0.01	0.16 ± 0.07	< 7.0	0.3 ± 0.15	3.7 ± 0.52	0.1 ± 0.01
+ 5% K	15.4 ± 4.5	< 2.3	0.2 ± 0.05	0.06 ± 0.01	0.17 ± 0.04	< 5.1	0.5 ± 0.10	4.5 ± 0.33	0.0 ± 0.00