Effect of biochar and zeolite addition on the toxicity of anaerobically digested sewage sludge

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Abstract

In the present experimental study, biochar and zeolite were mixed with anaerobically digested sewage sludge, to improve its quality in order to be used as soil amendment for the cultivation of crops in the Mediterranean region. Biochar was produced after slow pyrolysis of sawdust, obtained from a carpentry workshop, at 350 °C for 60 min. The mixtures were prepared after mixing sewage sludge with 1 or 5% w/w biochar and commercial zeolite and then were moistened and incubated for 20 days at room temperature, prior to use. The quality of the mixtures was assessed in terms of reduction of contaminants leaching. Finally, phytotoxicity tests were carried out using cress and barley seeds

Materials and methods

Anaerobically digested sewage sludge (SS) was obtained from an urban wastewater treatment plant located in Molina de Segura, province of Murcia, Spain. For the production of biochar, sawdust (Sd) obtained from a carpentry workshop in the region of Chania, Crete, Greece, was subjected to slow pyrolysis at 350 °C for 60 min. Commercial zeolite "Zeolita Natural AGRO", Zeocat Soluciones Ecologicas S.L.U., has been also used.

The experimental design is shown in Table 1. Leaching tests were carried out in the mixtures. Their potential phytotoxicity was assessed through seed germination tests in Petri dishes using cress (*Lepidum Sativum L.*) and barley (*Hordeum vulgare L.*). Aqueous extracts were obtained by shaking 1 or 3 g of each mixture in 100 mL of distilled water (1 or 3% w/v). A control treatment under the same conditions with the use of distilled water was also carried out. The germination index (GI %) values are assessed according to the following scale effect: GI<50% phytotoxic (red line), 50%<GI<80% moderate phytotoxic (blue line), GI>80% no phytotoxic, GI>100% phyto-nutrient or phyto-stimulant (green line).

Table 1. Experimental design (values in % w/w)

Material	100SS	100B	99SS+1B	95SS+5B	99SS+1Z	95SS+5Z	90SS+5B+5Z
Anaerobically digested sewage sludge (SS)	100	-	99	95	99	95	90
Biochar (B)	-	100	1	5	-	-	5
Zeolite (Z)	-	-	-	-	1	5	5

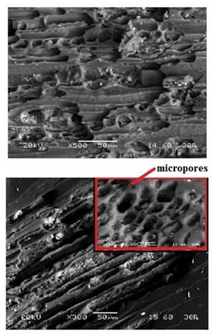

Fig. 1. SEM images of the biochar (B) (x500 and x300)

Table 4. Heavy metals and other elements concentration in the leachates of the mixtures containing SS, B and Z (in mg/L)

	100SS	100B	99SS+1B	95SS+5B	99SS+1Z	95SS+5Z	90SS+5B+5Z
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.03
Pb	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cu	0.77	<0.01	0.79	0.50	0.88	0.51	0.56
Ni	1.39	<0.01	1.41	1.10	1.36	1.17	1.17
Mn	13.43	<0.01	13.81	11.57	13.44	11.91	-
Mg	3187.00	3.60	3456.00	2760.80	3321.80	2853.50	2713.50
Zn	1.71	<0.01	0.96	0.87	1.15	1.01	1.05
Fe	14.05	0.75	12.22	11.39	12.27	13.77	13.72
K	878.50	56.27	768.25	805.00	906.50	937.25	929.50

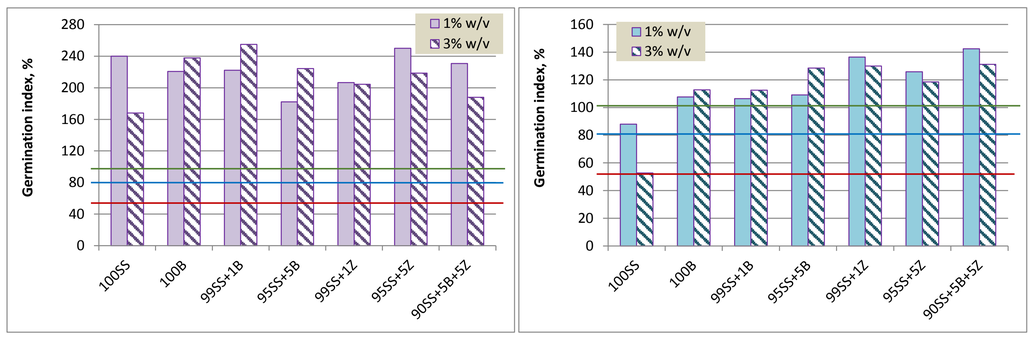

Fig. 2. GI (%) for cress and barley seeds (left to right) grown in the extracts from mixtures containing SS, B and Z

Results

Table 2. Characterization of the anaerobically digested sewage sludge (SS)

pH	7.76	*Fe, g/kg*	35.3	*As, mg/kg*	1.31
EC, mS/cm	3.34	*Na, g/kg*	2.8	*Be, mg/kg*	<0.5
OC, %	36.8	*Ca, g/kg*	28.8	*Bi, mg/kg*	<0.5
Moisture, %	81.6	*Mg, g/kg*	6.7	*Co, mg/kg*	7.49
VOM, %	67.7	*B, mg/kg*	38.2	*Li, mg/kg*	3.73
N_{tot}, *g/kg*	61.6	*Mn, mg/kg*	111.4	*Mo, mg/kg*	49.76
P_{tot}, *g/kg*	16.3	*Cd, mg/kg*	0.67	*Sb, mg/kg*	<0.5
K_{tot}, *g/kg*	2.1	*Cu, mg/kg*	222.6	*Se, mg/kg*	8.82
NH_4^+, *g/kg*	11.45	*Cr, mg/kg*	45.95	*Sr, mg/kg*	478.33
S, g/kg	42.7	*Ni, mg/kg*	33.1	*Ti, mg/kg*	152.40
E. Coli, CFU/g	$5.2*10^5$	*Pb, mg/kg*	45.05	*Tl, mg/kg*	61.53
Salmonella/25g	presence	*Zn, mg/kg*	603.4	*V, mg/kg*	22.22

Table 3. Characterization of sawdust (Sd) and biochar (B) produced after Sd pyrolysis

	y_P, %	pH	EC, mS/cm	% VM	% char	SA, m^2/g	% C	% H	% N	% O
Sd	-	5.7	0.38	89.6	10.4	-	46.7	5.8	0.5	47.0
B	30.6	3.8	0.20	42.9	57.1	2.6	63.2	2.1	0.3	34.4

Conclusion

The use of anaerobically digested sewage sludge either aloneor after mixing with biochar produced by pyrolysis of sawdust at 350 °C for 60 min and/or commercial zeolite, maybe considered as soil amendment in the Mediterranean region. Mixing of sewage sludge with 5% w/w biochar and/or zeolite prevents leaching of Cu, Ni, Zn and Mn due to their adsorption on the surface of the additives. For all mixtures considered, the germination index (GI) for cress and barley varied between106 and 255% indicating a phyto-nutrientor phyto-stimulant effect.

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