Fractionation of Heavy Metals in Soils Applied with Sewage Sludge Biochar

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Introduction & Objectives

The production of sewage sludge has been increasing with sewage sludge system coverage in Japan(1). However, securing landfill spaces is becoming a serious problem. A production of sewage sludge biochar (SSB) has been used as an alternative way of sludge disposal. The SSB is expected to provide essential plant nutrients when applied to soils. However, heavy metals in the sludge may be concentrated during carbonization process(2), therefore soil pollution by heavy metals from SSB application may be of great concern. In this study, absorption of heavy metals by a plant grown in soils applied with SSB and their fractionation in postharvest soils were investigated.

Materials & Methods

Two different soils used in this study were a low-humic Andisol (<2mm) sampled in Tokyo and commercially available sandy decomposed granite soil (<2mm). SSB produced at low temperature (300°C; SSB-L) and high temperature (800°C; SSB-H) were sieved to <300 μm (Fig.1).

A bioassay experiment was conducted using Japanese mustard spinach (*Brassica rapa var.*).

Bioassay experiment

SSB-L and SSB-H were applied to two soils at rates of 10% (v/v) respectively, in a 1 L pot. Chemical fertilizer was applied in each pot at recommended rates by standards of the Tokyo metropolitan government.

Fractionation of heavy metals

One gram of soil after bioassay experiment was used for modified BCR four-step sequential extraction procedure (water-soluble by 40 mL of deionized water extraction; acid-soluble by 0.11M acetic acid; reduced by 1M hydroxyl ammonium chloride; oxidized by 1M ammonium acetate; and residual fractions).

Table 1. Basic properties of soils and biochars used

	pH	T-C	T-N	T-Cu	T-Zn	T-Cd	T-Pb
		— g kg^{-1} —		——— mg kg^{-1} ———			
Andisol	6.5	0.27	0.09	27.1	1.54	0.04	1.96
Sandy soil	7.3	2.09	2.60	4.53	1.55	1.39	0.91
SSB-L	5.6	532	34.1	346	455	1.36	13.0
SSB-H	6.6	528	54.8	68.7	237	1.48	12.5

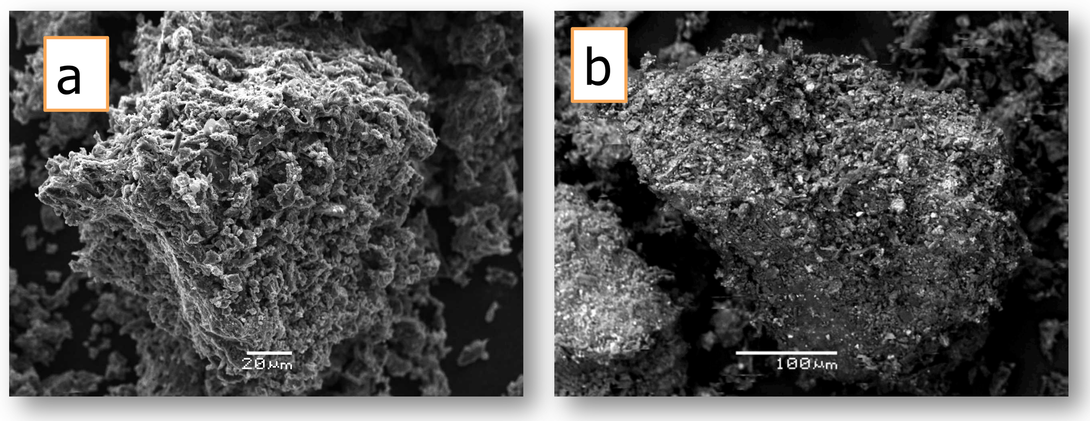

Fig.1. SEM images of SSB-L :a, SSB-H :b

Heavy metals (Cu, Zn, Cd, and Pb) in samples were analyzed by atomic adsorption spectrometer (ParkinElmer, Analyst 200).

Bioassay Experiment

Dry matter yield

The spinach dry matter in Andisol was 2.91 g in control, 2.73 g in SSB-H, and 0.16 g in SSB-L (Fig.2). The spinach in sandy soil did not grow with SSB-L treatment, and yielded 1.77 g with control and 2.15 g with SSB-H, which were not significantly different.

Heavy metal concentration in plants

All heavy metal concentrations in plant shoot were highest in SSB-L treatment compared with those in other treatments (Fig.3). In SSB-L treatment, the plant absorbed 89.0 mg Cu kg^{-1} and 122.7 mg Zn kg^{-1}, which were more than what plant needed for growth (20 mg Cu kg^{-1} and 100 mg Zn kg^{-1}). Furthermore, 17.6 mg Cd kg^{-1} was in a toxicity level for the spinach(3).

All of heavy metal concentrations in plants were negatively related to dry matter yield (r^2=0.62~0.77).

Bioassay experiment results suggested that SSB-L may negatively affect plant growth.

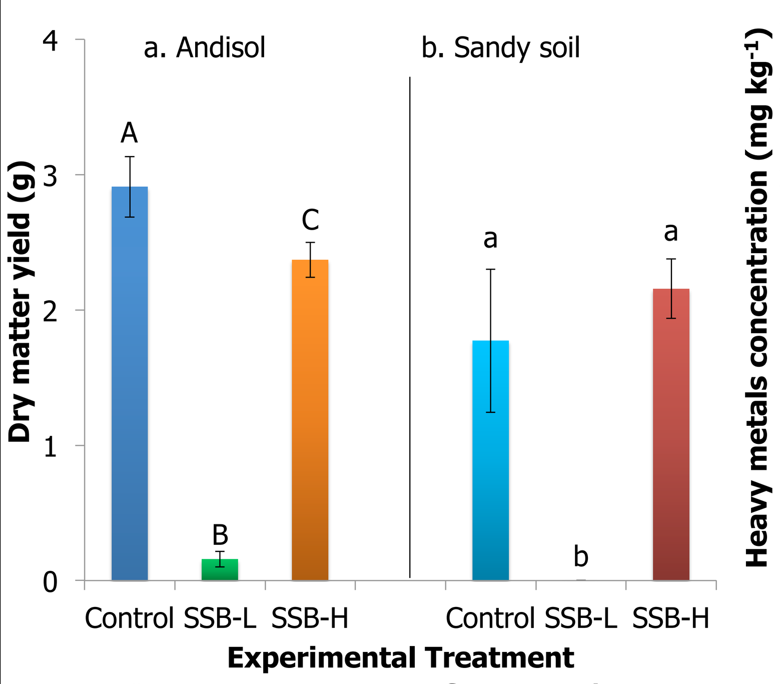

Fig.2. Dry matter of spinach grown in a: Andisol and b: sandy soil

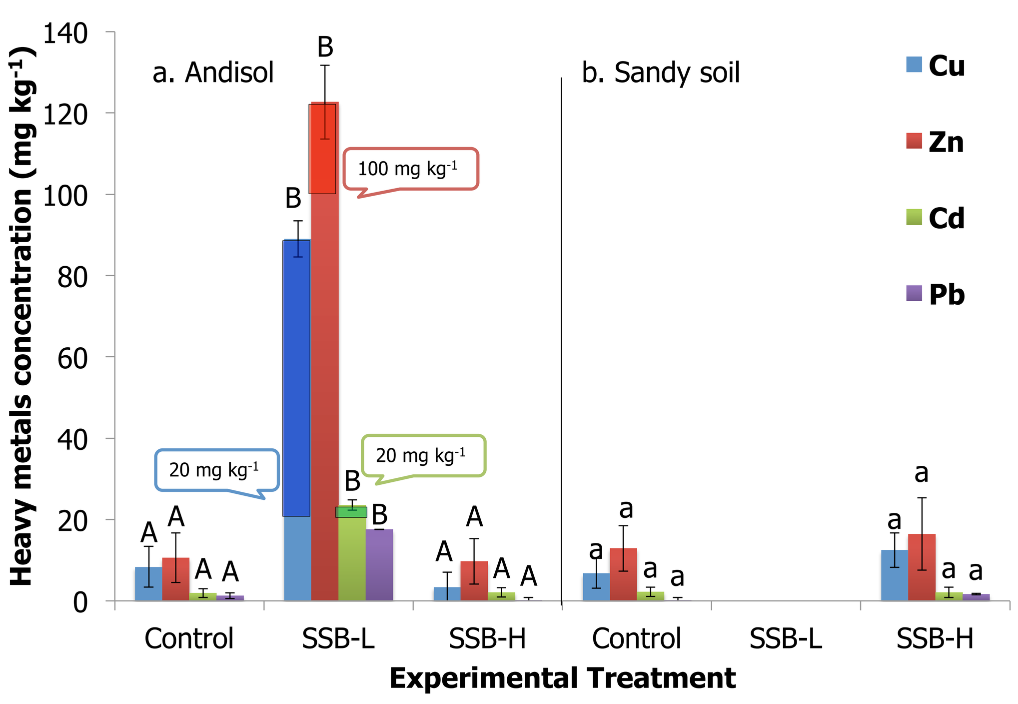

Fig.3. Heavy metal concentrations in plants grown in a: Andisol and b: sandy soil

Fractionation of Heavy Metals

BCR sequential extraction showed the highest percentages of residual fraction among other fractions in all treatments and heavy metals (Fig. 4). Plant available fractions (water-soluble and acid-soluble) were low in all treatments and metals except for a few treatments.

Nevertheless, there were no particular relationships found among the plant available fractions and the types of SSB nor metals. However, the acid-soluble Cu fraction in sandy soil with SSB-L (Fig. 4a) was almost 50% of all fractions, where the plant did not grow at all (Fig. 2b). High plant available Cu in soil solution can negatively effect germination and root expansion(4).

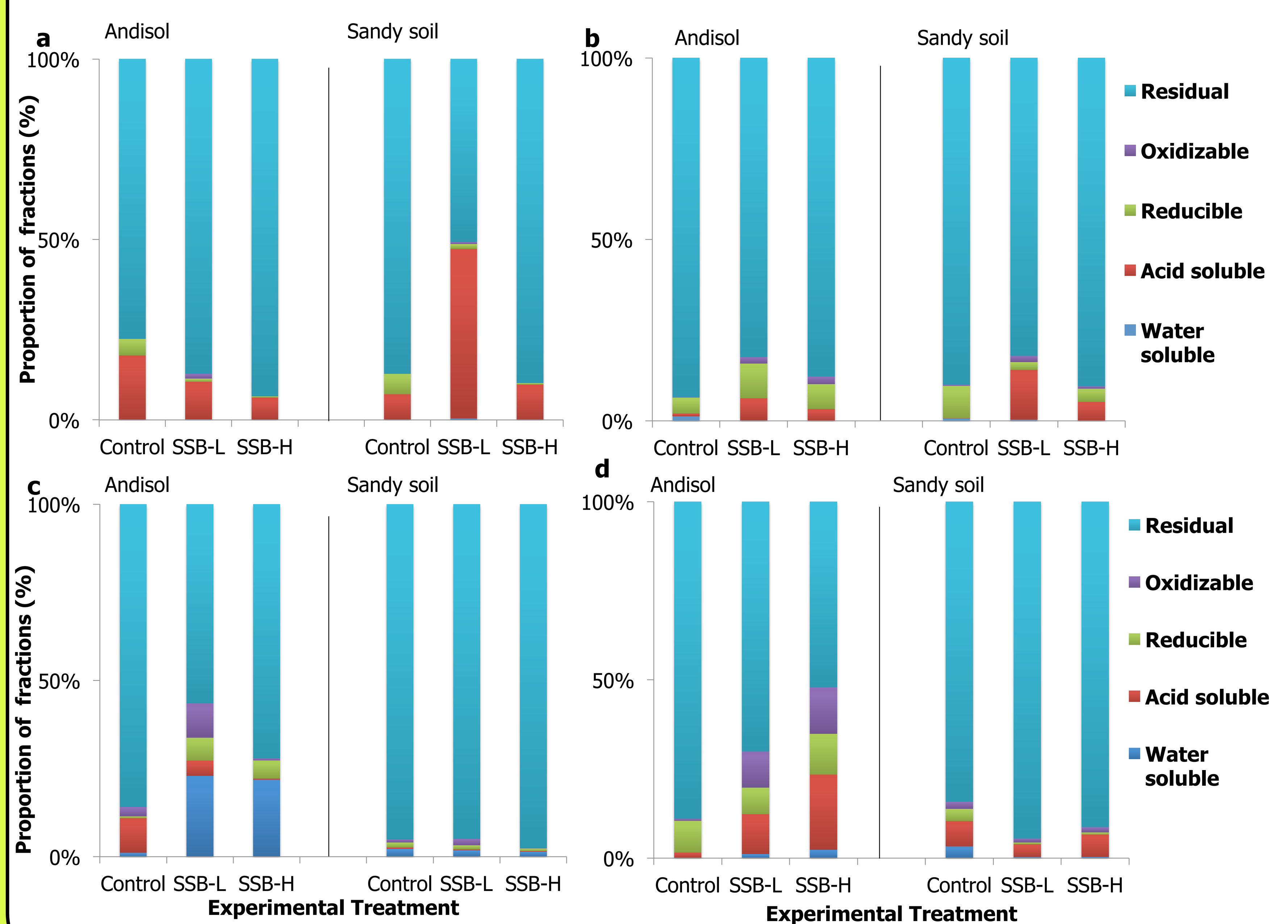

Fig.4. BCR sequential fractions for a: Cu, b: Zn, c: Cd and d: Pb in soils after bioassay.

Conclusion

(1) Heavy metals in SSBs tend to be in the residual fraction and much of them are not available to plants after application to soil.
(2) Some SSB may dissolve high heavy metal concentrations enough to negatively affect the plant growth.
(3) Heavy metal absorption by the plant after SSB application may vary depending on the types of soil, SSB pyrolysis temperature, and the metals.
(4) The application of SSB to soils needs to be carried out with cautions for substances that may affect the plant growth.

Acknowledgement

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Reference
(1) Japan Sewage Works Association. "Recycling rate and the amount of sewage sludge" 2008. http://www.jswa.jp/data-room/data.html. (referenced 2012.7.26)
(2) Yoko Kawano, Junta Yanai, Hidekazu Yamada, Kenta Nakajima. Physico-chemical properties of carbonized sewage sludge and effects on plant growth. 2012.
(3) Masao Shibuya, Takeo Koyama, Hisao Watanabe. Measurement methods of heavy metals. Hakuyu-Sha. 2002.
(4) Shoko Inaba, Hiroshi Kubota, Yoko Saito, Chisato Takenaka. Copper distribution around the mine waste deposit in arboricultural research institute. 2004.