Support Information

Thermal gradient-driven heavy metal speciation and risk evolution in municipal and industrial sludge biochars: A 300-700°C pyrolysis perspective

Ke Zhao [a,b,c], Chundi Si [a,b,], Pei Zhang [c], Yaning Cui [a,b]*

[a] School of Traffic and Transportation, Shijiazhuang Tiedao University, Shijiazhuang, Hebei Province 050043, China

[b] Hebei Key Laboratory of Traffic Safety and Control, Shijiazhuang, Hebei Province 050043, China

[c] Shijiazhuang University, Shijiazhuang, Hebei Province 050035, China

*Corresponding author: Chundi Si, Email address: sichundi@stdu.edu.cn

1 Heavy Metal Risk Assessment Methods

1.1 Risk Assessment Index

The Risk Assessment Code (RAC) was used to evaluate the biological toxicity of heavy metals in biochar. Based on the proportion of the bioavailable fraction (F1) in the total heavy metal content (<1%, 1–10%, 10–30%, 30–50%, and >50%), the potential environmental risk of heavy metals was classified into five levels: no risk (NR), low risk (LR), medium risk (MR), high risk (HR), and very high risk (VHR).

1.2 Potential Ecological Risk Index

The potential ecological risk index (RI) was used to assess the potential risk of heavy metals. The calculation method is as follows:

$$C_f = C_n / C_m \quad (1)$$

$$E_r = T_r \times C_f \quad (2)$$

$$RI = \sum E_r \quad (3)$$

In the equation, C_n and C_m represent the contents of heavy metals (F1+F2+F3) and F4, respectively; C_f denotes the contamination factor of a single heavy metal; T_r is the toxic response factor of a single heavy metal, with values of 1, 2, 5, 5, 30, and 6 for Zn, Cr, Cu, Pb, Cd, and Ni, respectively; E_r represents the potential ecological risk coefficient of a single heavy metal in the sample; and RI is the sum of the potential ecological risks of all heavy metals in the sample. The specific evaluation criteria and classification for C_f, E_r, and RI are provided in Table S1.

Table S1 Classification of Potential Ecological Risk Levels

Single heavy metal pollution factor（C_f）	contamination level	Potential ecological risk factor for single heavy metals（E_r）	Ecological risk level	Potential ecological risk index（RI）	Ecological risk level
$C_f \leq 1$	Clean	$E_r \leq 40$	lower	$RI \leq 50$	lower
$1 < C_f \leq 3$	lower	$40 < E_r \leq 80$	moderate	$50 < RI \leq 100$	moderate
$3 < C_f \leq 6$	moderate	$80 < E_r \leq 160$	Considerable	$100 < RI \leq 200$	Considerable
$6 < C_f \leq 9$	Considerable	$160 < E_r \leq 320$	High	$RI > 200$	High
$C_f > 9$	High	$E_r > 320$	Very high	-	-