**Table S1.** Soil basic chemical parameters for three contaminated soils.

| parameters | Dabao mountain (DBS) | Hulu Island (HD) | Shen Yang (SY) |
|---|---|---|---|
| pH | 5.51 ± 0.02 | 7.01 ± 0.02 | 7.99 ± 0.01 |
| Organic matter (g/kg) | 5.60 ± 0.06 | 2.57 ± 0.03 | 5.48 ± 0.05 |
| Total N (g/kg) | 0.96 ± 0.02 | 1.56 ± 0.01 | 0.96 ± 0.01 |
| Total P (g/kg) | 1.18 ± 0.01 | 1.16 ± 0.02 | 0.65 ± 0.00 |
| Total K (g/kg) | 0.87 ± 0.01 | 0.52 ± 0.00 | 0.73 ± 0.01 |
| CEC (c $mol^{+}$/kg) | 3.76 ± 0.10 | 5.50 ± 0.13 | 14.10 ± 0.18 |
| Total Cd (mg/kg) | 1.69 ± 0.02 | 64.43 ± 1.03 | 1.76 ± 0.02 |
| Total Pb (mg/kg) | 103.6 ± 0.2 | 252.2 ± 0.8 | 118.7 ± 0.2 |
| Total Fe (g/kg) | 50.9 ± 0.11 | 17.3 ± 0.03 | 28.3 ± 0.10 |
| Total Mn (g/kg) | 4.13 ± 0.00 | 0.33 ± 0.01 | 0.46 ± 0.01 |
| Total Al (g/kg) | 1.06 ± 0.01 | 1.01 ± 0.02 | 4.9 ± 0.01 |
| Sand (2-0.02 mm) | 73.8 % | 77.3 % | 63.9 % |
| Silt (0.02-0.002 mm) | 16.2% | 18.2 % | 29.1 % |
| Clay (< 0.002 mm) | 10.0% | 4.5 % | 6.8 % |

**Table S2.** The Hydrus-1D fitting results of $Cd^{2+}$ and $Pb^{2+}$ BTCs at different pH and ionic strength.

| Solution | pH | IS | Smax | $K_a$ | $K_d$ | $R^2$ |
|---|---|---|---|---|---|---|
| 100 mg·$L^{-1}$ soil colloids | 3.0 | 0.01 | | NA | | |
| | 5.0 | 0.01 | | NA | | |
| | 7.0 | 0.01 | 1.8639 | 0.1668 | 9.171E-05 | 0.9943 |
| | 9.0 | 0.01 | 1.2990 | 0.0682 | 1.735E-04 | 0.9820 |
| 10 mg·$L^{-1}$ $Cd^{2+}$ | 3.0 | 0.01 | 0.9536 | 0.2216 | 5.267E-02 | 0.9981 |
| | 5.0 | 0.01 | 1.5604 | 0.1352 | 9.171E-03 | 0.9840 |
| | 7.0 | 0.01 | 1.9732 | 0.2356 | 3.436E-03 | 0.9620 |
| | 9.0 | 0.01 | | NA | | |
| | 7.0 | 0 | | NA | | |
| | 7.0 | 0.005 | 2.8443 | 0.4892 | 5.072E-03 | 0.9958 |
| | 7.0 | 0.05 | 1.5983 | 0.1477 | 2.353E-03 | 0.9046 |
| 10 mg·$L^{-1}$ $Pb^{2+}$ | 3.0 | 0.01 | 2.2957 | 0.4062 | 3.134E-02 | 0.9926 |
| | 5.0 | 0.01 | | NA | | |
| | 7.0 | 0.01 | | NA | | |
| | 9.0 | 0.01 | | NA | | |
| | 5.0 | 0 | | NA | | |
| | 5.0 | 0.005 | | NA | | |
| | 5.0 | 0.05 | 1.7673 | 0.8247 | 3.764E-03 | 0.9055 |
| 100 mg·$L^{-1}$ soil colloids +10 mg·$L^{-1}$ $Cd^{2+}$ | 3.0 | 0.01 | 0.7994 | 0.1765 | 4.140E-02 | 0.9978 |
| | 5.0 | 0.01 | 1.7494 | 0.1368 | 5.454E-03 | 0.9768 |
| | 7.0 | 0.01 | 1.8264 | 0.1427 | 3.850E-03 | 0.9421 |
| | 9.0 | 0.01 | 2.0302 | 0.6290 | 5.326E-03 | 0.9938 |
| | 7.0 | 0 | 1.6568 | 0.1216 | 6.863E-03 | 0.9467 |
| | 7.0 | 0.005 | 1.9362 | 0.1235 | 4.066E-03 | 0.9024 |
| | 7.0 | 0.05 | 6.7009 | 0.0775 | 9.549E-04 | 0.1546 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 mg·L$^{-1}$ soil colloids +10 mg·L$^{-1}$ $Pb^{2+}$ + + | 3.0 | 0.01 | 2.0721 | 0.3676 | 2.188E-02 | 0.9962 |
| | 5.0 | 0.01 | | NA | | |
| | 7.0 | 0.01 | 2.5670 | 0.4057 | 1.149E-05 | 0.9920 |
| | 9.0 | 0.01 | 2.1300 | 0.2654 | 1.479E-05 | 0.9968 |
| | 5.0 | 0 | 1.7088 | 0.3304 | 4.347E-03 | 0.9154 |
| | 5.0 | 0.005 | | NA | | |
| | 5.0 | 0.05 | | NA | | |

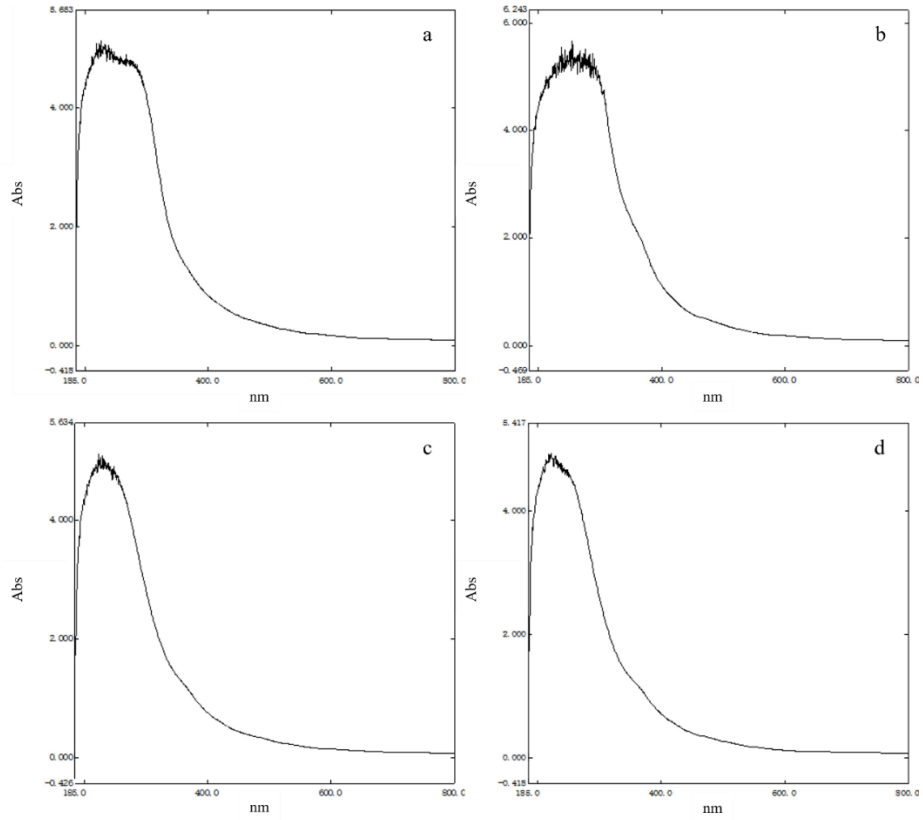


**Figure S1.** UV full wavelength scanning signal graph of soil colloids (a: DBS, pH = 5.5; b: SY, pH = 8.0; c: HD, pH = 7.0; d: HD background, pH = 7.0).

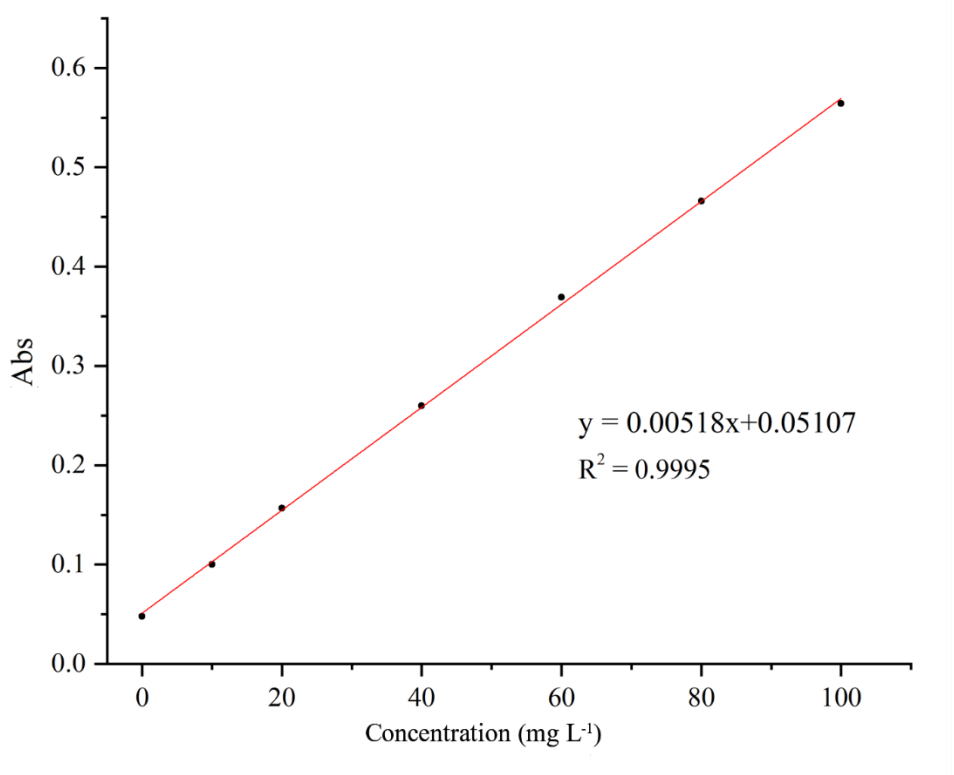


**Figure S2.** Relationship between soil colloid concentration and absorbance at 254 nm.

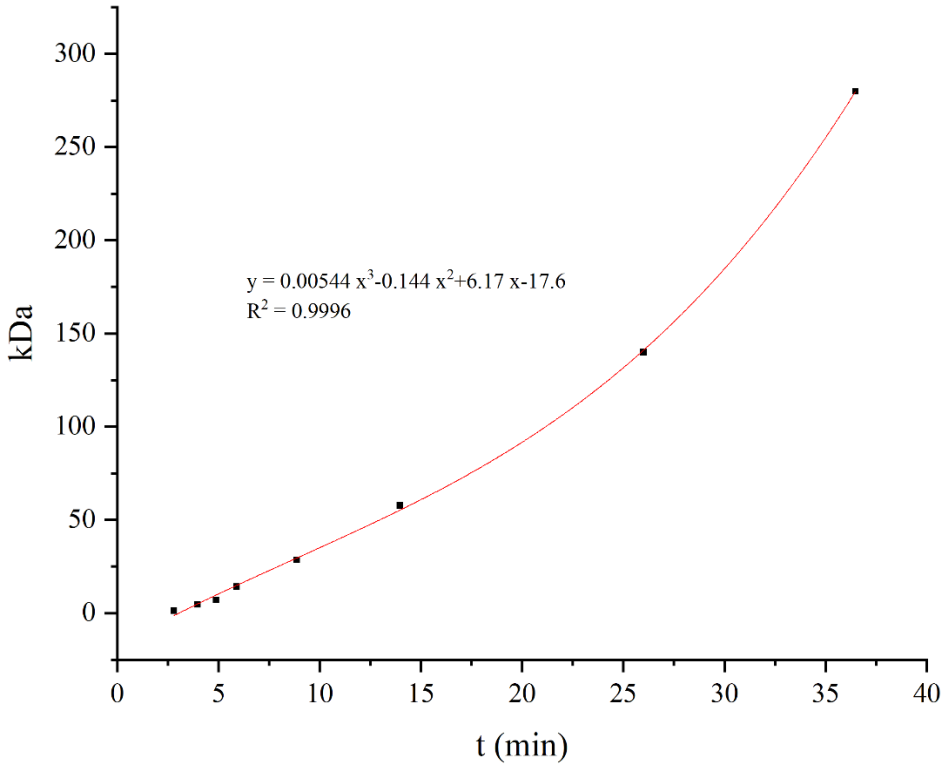


**Figure S3.** Relationship between polystyrene sulfonate standards and elution time.

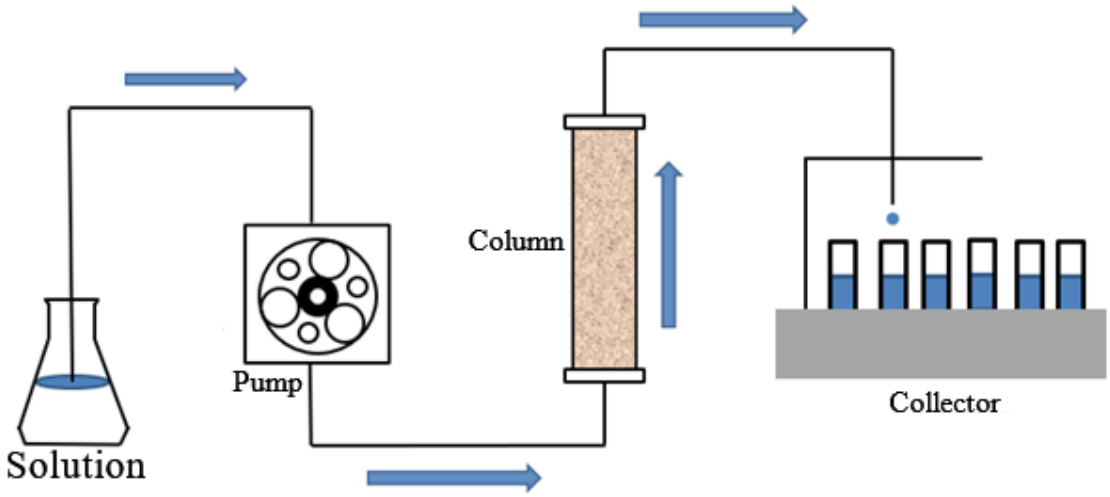


**Figure S4.** Schematic diagram of the experimental equipment for saturated sand column.