**Spatial distribution of potentially toxic element and the potential ecological risk of wolfberry-soil system in genuine producing area of Ningxia，China**

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Table S1 Pearson correlations between PTEs content in wolfberry and soil indexes

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| In soil  In wolfberry | | Ni | Cu | Zn | As | Pb | Cr | Hg | pH | SOM | CEC |
| Ni | Pearson Correlation | -0.246 | -0.026 | -0.221 | 0.249 | 0.06 | 0.199 | -0.069 | -0.071 | 0.308 | 0.089 |
| aSig. | 0.143 | 0.881 | 0.189 | 0.137 | 0.723 | 0.237 | 0.686 | 0.677 | 0.063 | 0.599 |
| Cu | Pearson Correlation | -0.065 | 0.225 | -0.099 | b0.377 | 0.212 | -0.163 | 0.268 | -0.029 | 0.129 | c 0.441 |
| aSig. | 0.704 | 0.181 | 0.56 | 0.022 | 0.208 | 0.334 | 0.108 | 0.864 | 0.447 | 0.006 |
| Zn | Pearson Correlation | 0.131 | 0.073 | -0.137 | 0.122 | 0.122 | -0.161 | 0.07 | 0 | 0.189 | b 0.346 |
| aSig. | 0.439 | 0.669 | 0.419 | 0.473 | 0.471 | 0.341 | 0.679 | 0.999 | 0.263 | 0.036 |
| As | Pearson Correlation | 0.247 | -0.136 | -0.241 | -0.154 | -0.046 | 0.183 | -0.022 | 0.185 | 0.275 | 0.128 |
| aSig. | 0.14 | 0.421 | 0.151 | 0.362 | 0.786 | 0.277 | 0.897 | 0.272 | 0.1 | 0.452 |
| Cd | Pearson Correlation | -0.019 | -0.172 | -0.133 | -0.094 | -0.055 | -0.058 | 0.092 | 0.222 | 0.179 | 0.018 |
| aSig. | 0.911 | 0.309 | 0.431 | 0.58 | 0.747 | 0.735 | 0.589 | 0.186 | 0.289 | 0.916 |
|  |
| Pb | Pearson Correlation | -0.312 | 0.092 | -0.28 | -0.162 | 0.099 | -0.092 | -0.204 | b 0.358 | 0.198 | -0.042 |  |
| aSig. | 0.06 | 0.588 | 0.093 | 0.339 | 0.559 | 0.589 | 0.225 | 0.029 | 0.24 | 0.807 |  |
| Cr | Pearson Correlation | 0.078 | 0.096 | 0.015 | 0.043 | 0.276 | -0.073 | 0.32 | -0.018 | -0.075 | 0.275 |  |
| aSig. | 0.645 | 0.573 | 0.929 | 0.802 | 0.098 | 0.668 | 0.053 | 0.916 | 0.659 | 0.099 |  |

a Sig. means significance.

b Correlation is significant at the 0.05 level (2-tailed).

c Correlation is significant at the 0.01 level (2-tailed).

Table S2 Multiple linear regression equation between PTEs content in wolfberry and soil indexes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | a Regression equation | F | P | r |
| Cu | -13.978+1.496CEC+0.545CCu+0.15OM+0.486 CAs | entry 0.15  removal 0.2 | 0.002 | 0.629 |
| Zn | -17.283+3.505CEC+0.349OM | entry 0.15  removal 0.2 | 0.028 | 0.436 |
| Pb | -3.393+0.556pH-0.012CNi-1.869CHg | entry 0.15  removal 0.2 | 0.002 | 0.598 |
| Ni | -0.271+0.028OM+0.072CAs | entry 0.15  removal 0.2 | 0.048 | 0.405 |
| As | 0.041+0.012OM +0.007CNi-0.009CZn | entry 0.15  removal 0.2 | 0.053 | 0.453 |
| Cr | 1.879+10.664CHg | entry 0.15  removal 0.2 | 0.053 | 0.320 |
| Cd | -0.413+0.066pH | entry 0.2  removal 0.25 | 0.186 | 0.222 |

a CCu, CAs, CNi, CHg and CZn are the content of Cu, As, Ni, Hg and Zn in soil. CEC is the cation exchange capacity of soil. OM is the organic matter of soil. pH is the pH value of soil.

Table S3 Spatial autocorrelation of PTEs in soil

|  |  |  |  |
| --- | --- | --- | --- |
|  | P-Value | Moran's I | Z scores |
| Ni | 0.224 | 0.066 | 1.216 |
| Cu | 0.136 | -0.148 | -1.492 |
| Zn | 0.000 | 0.648 | 8.351 |
| As | 0.396 | 0.041 | 0.850 |
| Pb | 0.000 | 0.337 | 4.554 |
| Cr | 0.000 | 0.515 | 6.785 |
| Hg | 0.130 | 0.087 | 1.432 |

Table S4 Fitting of semivariogram parameters for Kriging interpolation of soil PTEs content

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Model Type | Nugget C0 | Sill C+C0 | Proportion C0/(C+C0) | R2 | range major | range minor | range |
| Ni anisotropic variograms | Gaussian | 71.4 | 336 | 0.213 | 0.442 | 99731.49 | 99731.49 |  |
| Cu anisotropic variograms | Gaussian | 0.111 | 0.836775 | 0.133 | 0.492 | 791547.2 | 791547.2 |  |
| Zn isotropic variograms | Spherical | 1.5 | 49.39 | 0.030 | 0.676 |  |  | 14690 |
| As anisotropic variograms | Gaussian | 1.954 | 7.091359 | 0.276 | 0.398 | 810946.2 | 99419.7 2 |  |
| Pb isotropic variograms | Spherical | 0.08 | 6.854 | 0.012 | 0.433 |  |  | 6870 |
| Cr isotropic variograms | Spherical | 0.0063 | 0.2426 | 0.026 | 0.879 |  |  | 31790 |
| Hg isotropic variograms | Gaussian | 24.3 | 119.6 | 0.203 | 0.381 |  |  | 94067.68 |

Table S5 Classification standard of potential ecological risk of heavy metal pollution in soil

|  |  |  |
| --- | --- | --- |
| Ei | Etotal | Risk level |
| Ei<40 | Etotal<150 | Low |
| 40≤Ei<80 | 150≤ Etotal<300 | Medium |
| 80≤Ei<160 | 300≤ Etotal<600 | Heavy |
| 160≤Ei<320 | Etotal≥600 | High |
| Ei≥320 |  | Serious |

Table S6 Normality test and transformation of PTEs content in wolfberry

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mode | Skewness | Kurtosis | P |
| Ni | untransformed | 0.091 | 0.018 | 0.983 |
| Cu | untransformed | 0.168 | -0.748 | 0.220 |
| Zn | untransformed | -0.013 | -1.189 | 0.095 |
| As | Log transformed | -0.305 | 0.541 | 0.903 |
| Pb | untransformed | 0.051 | -0.065 | 0.546 |
| Cd | untransformed | -0.068 | -0.788 | 0.424 |
| Cr | Log transformed | 0.388 | 0.759 | 0.141 |

Table S7 Fitting of semivariogram parameters of PTEs in wolfberry

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Model Type | Nugget (C0) | Sill (C+C0) | Proportion (C0/(C+C0)) | R2 | Range major | Range minor | Range |
| Ni (isotropic variograms) | Spherical | 0.0134 | 0.0646 | 0.207 | 0.63 | - | - | 81100 |
| Cu (isotropic variograms) | Exponential | 2.08 | 7.493 | 0.278 | 0.298 | - | - | 243300 |
| Zn (isotropic variograms) | Spherical | 1.5 | 49.39 | 0.030 | 0.676 | - | - | 14690 |
| As (isotropic variograms) | Spherical | 0.1502 | 0.4164 | 0.361 | 0.712 | - | - | 35560 |
| Pb (anisotropic variograms) | Gaussian | 0.0274 | 0.1031 | 0.266 | 0.224 | 9086338.5 | 9086338.5 | - |
| Cd (anisotropic variograms) | Gaussian | 0.000287 | 0.000813 | 0.353 | 0.173 | 9088070.6 | 9088070.6 | - |
| Cr (anisotropic variograms) | Gaussian | 0.015 | 0.059692 | 0.251 | 0.305 | 763314.8 | 224473.8 | - |

Table S8 Main instruments used in the experiment

|  |  |  |
| --- | --- | --- |
| Name | Model | Quantity |
| One Over Ten-thousand Analytical Balance | AUW220 | 1 |
| Atomic fluorescence spectrophotometer | AFS-8220 | 1 |
| Atomic absorption spectrophotometer | Ice 3500 | 1 |
| Low temperature combined digester | ED54-iTouch | 1 |
| Ultra-pure water system | UPT-I-40L | 1 |

Table S9 Method basis of PTEs and physicochemical properties

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Method | aBasis | Units | Detection limit |
| Cr | Soil and sediment—Determination of copper, zinc, lead, nickel and chromium—Flame atomic absorption spectrophotometry | HJ 491-2019 | mg/kg | 4 |
| As | Soil quality—Analysis of total mercury,arsenic and lead contents—Atomic fluorescence spectrometry—Part 2:Analysis of total arsenic contents in soil | GB/T 22105.2-2008 | mg/kg | 0.01 |
| Cd | Soil quality—Determination of lead,cadmium—Graphite furnace atomic absorption spectrophotometry | GB/T 17141-1997 | mg/kg | 0.01 |
| Pb | Soil and sediment—Determination of copper, zinc, lead, nickel and chromium—Flame atomic absorption spectrophotometry | HJ 491-2019 | mg/kg | 10 |
| Hg | Soil quality—Analysis of total mercury,arsenic and lead contents—Atomic fluorescence spectrometry—Part 1:Analysis of total mercury contents in soil | GB/T 22105.1-2008 | mg/kg | 0.002 |
| Cu | Soil and sediment—Determination of copper, zinc, lead, nickel and chromium—Flame atomic absorption spectrophotometry | HJ 491-2019 | mg/kg | 1 |
| Zn | Soil and sediment—Determination of copper, zinc, lead, nickel and chromium—Flame atomic absorption spectrophotometry | HJ 491-2019 | mg/kg | 1 |
| Ni | Soil and sediment—Determination of copper, zinc, lead, nickel and chromium—Flame atomic absorption spectrophotometry | HJ 491-2019 | mg/kg | 3 |
| pH | Soil-Determination of pH-Potentiometry | HJ 962-2018 | - | - |
| SOM | Soil Testing—Part 6: Method for determination of soil organic matter | NY/T1121.6-2006 | g/kg | - |
| CEC | Soil quality—Determination of cation exchange capacity（CEC）—Hexamminecobalt trichloride solution-Spectrophotometric method | HJ 889-2017 | coml+/kg | 0.8 |

a From *the agricultural industry standards of the people's Republic of China*, *the national standards of the people's Republic of China* and *the national environmental protection standards of the people's Republic of China*.

Table S10 Normality test and transformation of PTEs content in soil

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mode | Skewness | Kurtosis | P |
| Ni | untransformed | -0.085 | -0.505 | 0.747 |
| Cu | Log transformed | -0.184 | -0.230 | 0.072 |
| Zn | untransformed | -0.198 | -0.656 | 0.285 |
| As | untransformed | -0.102 | -0.419 | 0.818 |
| Pb | Box-Cox transformed (alambda=-0.66) | -0.776 | 0.231 | 0.056 |
| Cr | Log transformed | 0.193 | -1.057 | 0.071 |
| Hg | Box-Cox transformed (alambda=0.41) | 0.901 | 5.312 | 0.197 |

a Lambda is the coefficient of Box-Cox transformation

Table S11 Toxicity response coefficient and soil background value of PTEs

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Hg | As | Cu | Zn | Ni | Cd | Pb | Cr |
| a Ti | 40 | 10 | 5 | 1 | 5 | 30 | 5 | 2 |
| b Soil background value（mg/kg） | 0.02 | 11.9 | 22.1 | 58.8 | 38.4 | 0.112 | 20.6 | 60 |

a Ti is the Toxicity Coefficient of each PTEs.

b From *Background values of soil elements in China*.

Figure S1 Box-Cox Plot of *Etotal*of the soil 

Figure S2 Box-Cox Plot of Hg concentration in the soil 

Figure S3 Box-Cox Plot of Pb concentration in the soil

