Source-Specific Risk Inequality of Potentially Toxic Elements in Atmospheric Deposition: A Gini Index-Based Assessment for Prioritizing Control

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Contents

Table S1. Classification of contamination levels based on the geoaccumulation index (I_{geo})... 1
Table S2. Input parameters to characterize the daily exposure dose of PTEs via various exposure pathways. 1
Table S3. Values of the reference dose (*RfD*, mg kg^{-1} d^{-1}) and the slope factor (*SF*, kg d mg^{-1}) for PTEs. 1
Table S4. Descriptive statistics of PTE concentrations (mg kg^{-1}) in atmospheric deposition... 2
Table S5. Comparison of PMF model diagnostic metrics (R^2 and Q values) across different factor numbers. 2
Table S6. Percentage of scaled residuals within the ±3 range for target elements under different PMF factor solutions. 2
Table S7. The contribution rates (%) of PTE concentrations to ER and IERI. 2
Table S8. Contribution rates (%) of PTEs in atmospheric deposition to non-carcinogenic risk levels for children 3
Table S9. Contribution rates (%) of PTEs in atmospheric deposition to non-carcinogenic risk levels for adults. 3
Table S10. Contribution rates (%) of carcinogenic PTEs in atmospheric deposition to the carcinogenic risk index. 3
Table S11. Descriptive statistics of site-specific contribution rates (%) of the four sources to IERI. 3
Table S12. Descriptive statistics of site-specific contribution rates (%) of the four sources to $HI_{Children}$. 3
Table S13. Descriptive statistics of site-specific contribution rates (%) of the four sources to HI_{Adults}. 4
Table S14. Descriptive statistics of site-specific contribution rates (%) of the four sources to TCR. 4
Figure S1. Graph neural unit sample size allocation and clustering diagram. 4
Figure S2. Contribution proportions of each source to different levels of ecological and health risks. 5
Figure S3. The relative contributions of identified sources to the total carcinogenic risk under varying Cr(VI) proportion assumptions (from 1% to 40%). 5

Table S1. Classification of contamination levels based on the geoaccumulation index (I_{geo}).

I_{geo} value	Contamination level
$I_{geo} \leq 0$	Unpolluted
$0 < I_{geo} \leq 1$	Slightly polluted
$1 < I_{geo} \leq 2$	Moderately polluted
$2 < I_{geo} \leq 3$	Moderately to severely polluted
$3 < I_{geo} \leq 4$	Severely polluted
$4 < I_{geo} \leq 5$	Severely to extremely polluted
$I_{geo} > 5$	Extremely polluted

Table S2. Input parameters to characterize the daily exposure dose of PTEs via various exposure pathways.

Parameter	Description	Unit	Children	Adults
ED	Exposure duration	a	6	24
BW	Average bodyweight	kg	15.9	56.8
EF	Exposure frequency	d/a	350	350
AT_c	Average time for carcinogens	d	26280	26280
AT_n	Average time for non-carcinogens	d	2190	2190
I_{ngR}	Daily ingestion rate of dustfall	mg/d	200	100
I_{nhR}	Inhalation rate	mg/d	7.5	14.5
SA	Exposed skin area	cm^2	2848	5374
SL	Skin adherence factor	$mg/(cm^2 \cdot d)$	0.2	0.07
PEF	Particle emission factor	m^3/kg	1.36×10^9	1.36×10^9
ABS	Dermal absorption factor	Dimensionless	0.001	0.001

Note: The parameter values are mainly obtained from the previous studies [3, 11, 36].

Table S3. Values of the reference dose (*RfD*, mg kg^{-1} d^{-1}) and the slope factor (*SF*, kg d mg^{-1}) for PTEs.

PTEs	RfD_{ing}	RfD_{inh}	RfD_{dermal}	SF_{inh}
As	3.0×10^{-4}	3.0×10^{-4}	1.23×10^{-4}	15.1
Cd	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-5}	6.3
Co	2.0×10^{-2}	5.71×10^{-6}	1.6×10^{-2}	9.8
Cr	3.0×10^{-3}	2.86×10^{-5}	6.0×10^{-5}	42
Cu	4.0×10^{-2}	4.02×10^{-2}	1.2×10^{-2}	/
Hg	3.0×10^{-4}	8.57×10^{-5}	2.10×10^{-5}	/
Ni	2.0×10^{-2}	2.0×10^{-2}	5.4×10^{-3}	0.84
Pb	3.5×10^{-3}	3.52×10^{-3}	5.2×10^{-4}	0.042
Zn	0.3	0.3	0.06	/

Note: The parameter values are mainly obtained from the previous studies [3, 11, 13, 36].

Table S4. Descriptive statistics of PTE concentrations (mg kg^{-1}) in atmospheric deposition.

PTEs	Mean	Median	Min	Max	SD	Kurtosis	Skewness	CV (%)	B_i
As	179.86	137.75	5.00	754.00	162.89	3.50	1.78	90.57	9.8
Cd	61.00	49.40	1.40	234.20	51.12	2.03	1.48	83.80	0.065
Co	8.00	8.40	1.00	16.00	3.05	0.30	-0.17	38.09	11.5
Cr	111.81	105.90	3.80	402.60	55.94	6.41	1.68	50.03	63.2
Cu	249.84	168.90	5.30	2356.70	332.89	17.55	3.72	133.24	20
Hg	1.12	0.70	0.30	7.20	1.28	11.64	3.12	114.29	0.025
Ni	94.44	48.10	10.70	571.70	118.45	4.78	2.30	125.42	27.4
Pb	1711.36	1226.70	31.90	11310.30	1700.60	10.97	2.75	99.37	22.3
Zn	1445.03	982.90	60.20	9569.40	1660.91	11.91	3.29	114.94	62.5

Notes: SD = standard deviation, CV = coefficient of variation. The B_i was derived from the soil background value in Henan Province, China.

Table S5. Comparison of PMF model diagnostic metrics (R^2 and Q values) across different factor numbers.

Diagnostic item	Number of Factors		
	3	4	5
As-R^2	0.67	0.64	0.61
Cd-R^2	0.63	0.67	0.62
Co-R^2	0.59	0.77	0.86
Cr-R^2	0.25	0.28	0.19
Cu-R^2	0.61	0.67	0.55
Hg-R^2	0.01	0.07	0.06
Ni-R^2	0.01	0.79	0.80
Pb-R^2	0.51	0.95	0.91
Zn-R^2	0.70	0.98	0.97
Q (Robust)	5688.1	2660.5	3997.3
Q (True)	8638.1	3664.0	6528.6

Table S6. Percentage of scaled residuals within the ±3 range for target elements under different PMF factor solutions.

Number of factors	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
3	65.79	57.89	78.95	84.21	80.26	43.42	71.05	73.68	77.63
4	100.00	80.26	93.42	86.84	86.84	48.68	93.42	96.05	98.68
5	72.37	78.95	88.16	85.53	81.58	63.16	71.05	96.05	100.00

Table S7. The contribution rates (%) of PTE concentrations to *ER* and *IERI*.

Risk level	ER_i									IERI
	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	
Low risk	35.53	0.00	100.00	100.00	96.05	98.68	100.00	53.95	100.00	0.00
Moderate risk	30.26	1.32	0.00	0.00	3.95	0.00	0.00	31.58	0.00	1.32
Considerable risk	25.00	1.32	0.00	0.00	0.00	1.32	0.00	10.53	0.00	1.32
High risk	9.21	2.63	0.00	0.00	0.00	0.00	0.00	2.63	0.00	2.63

Extreme risk	0.00	94.74	0.00	0.00	0.00	0.00	0.00	1.32	0.00	94.74

Table S8. Contribution rates (%) of PTEs in atmospheric deposition to non-carcinogenic risk levels for children

Risk level	$HQ_{Children}$									$HI_{Children}$
	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	
Negligible risk	6.58	67.11	100.00	94.74	100.00	100.00	100.00	7.89	100.00	0.00
Potential risk	69.74	32.89	0.00	5.26	0.00	0.00	0.00	78.95	0.00	39.47
Chronic toxicity risk	23.68	0.00	0.00	0.00	0.00	0.00	0.00	13.16	0.00	60.53

Table S9. Contribution rates (%) of PTEs in atmospheric deposition to non-carcinogenic risk levels for adults.

Risk level	HQ_{Adults}									HI_{Adults}
	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	
Negligible risk	7.89	82.89	100.00	98.68	100.00	100.00	100.00	18.42	100.00	0.00
Potential risk	82.89	17.11	0.00	1.32	0.00	0.00	0.00	77.63	0.00	76.32
Chronic toxicity risk	9.21	0.00	0.00	0.00	0.00	0.00	0.00	3.95	0.00	23.68

Table S10. Contribution rates (%) of carcinogenic PTEs in atmospheric deposition to the carcinogenic risk index.

Risk level	CR						TCR
	As	Cd	Co	Cr	Ni	Pb	
Negligible risks	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	97.37%
Acceptable risks	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.63%
Unacceptable risk	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table S11. Descriptive statistics of site-specific contribution rates (%) of the four sources to *IERI*.

	Factor 1	Factor 2	Factor 3	Factor 4
Mean	67.57	11.01	9.92	11.63
Max	73.94	11.07	11.33	13.15
Min	67.38	10.88	9.85	11.60
SD	0.74	0.02	0.16	0.18
CV (%)	1.09	0.16	1.64	1.51

Table S12. Descriptive statistics of site-specific contribution rates (%) of the four sources to $HI_{Children}$.

	Factor 1	Factor 2	Factor 3	Factor 4
Mean	52.74	25.86	7.67	13.74
Max	76.55	42.10	17.40	15.75
Min	33.80	7.77	1.69	13.31
SD	8.76	7.35	2.90	0.39
CV(%)	16.60	28.41	37.80	2.86

Table S13. Descriptive statistics of site-specific contribution rates (%) of the four sources to HI_{Adults}.

	Factor 1	Factor 2	Factor 3	Factor 4
Mean	52.68	25.77	7.82	13.73
Max	76.52	41.90	17.83	15.73
Min	34.09	7.78	1.71	13.30
SD	8.70	7.28	2.97	0.39
CV(%)	16.50	28.27	37.95	2.86

Table S14. Descriptive statistics of site-specific contribution rates (%) of the four sources to *TCR*.

	Factor 1	Factor 2	Factor 3	Factor 4
Mean	56.35%	7.51%	20.08%	15.33%
Max	77.19%	10.04%	48.28%	25.97%
Min	28.11%	5.70%	1.64%	13.85%
SD	10.85%	0.70%	10.43%	1.77%
CV(%)	19.26%	9.31%	50.12%	11.53%

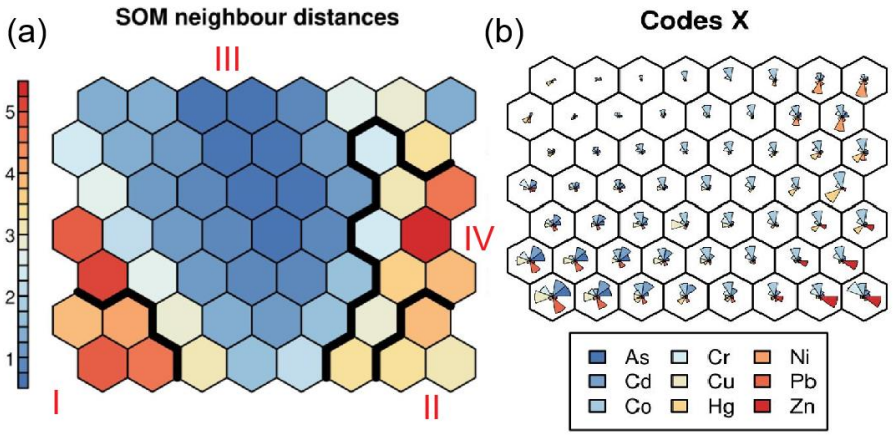


Figure S1. Graph neural unit sample size allocation and clustering diagram.

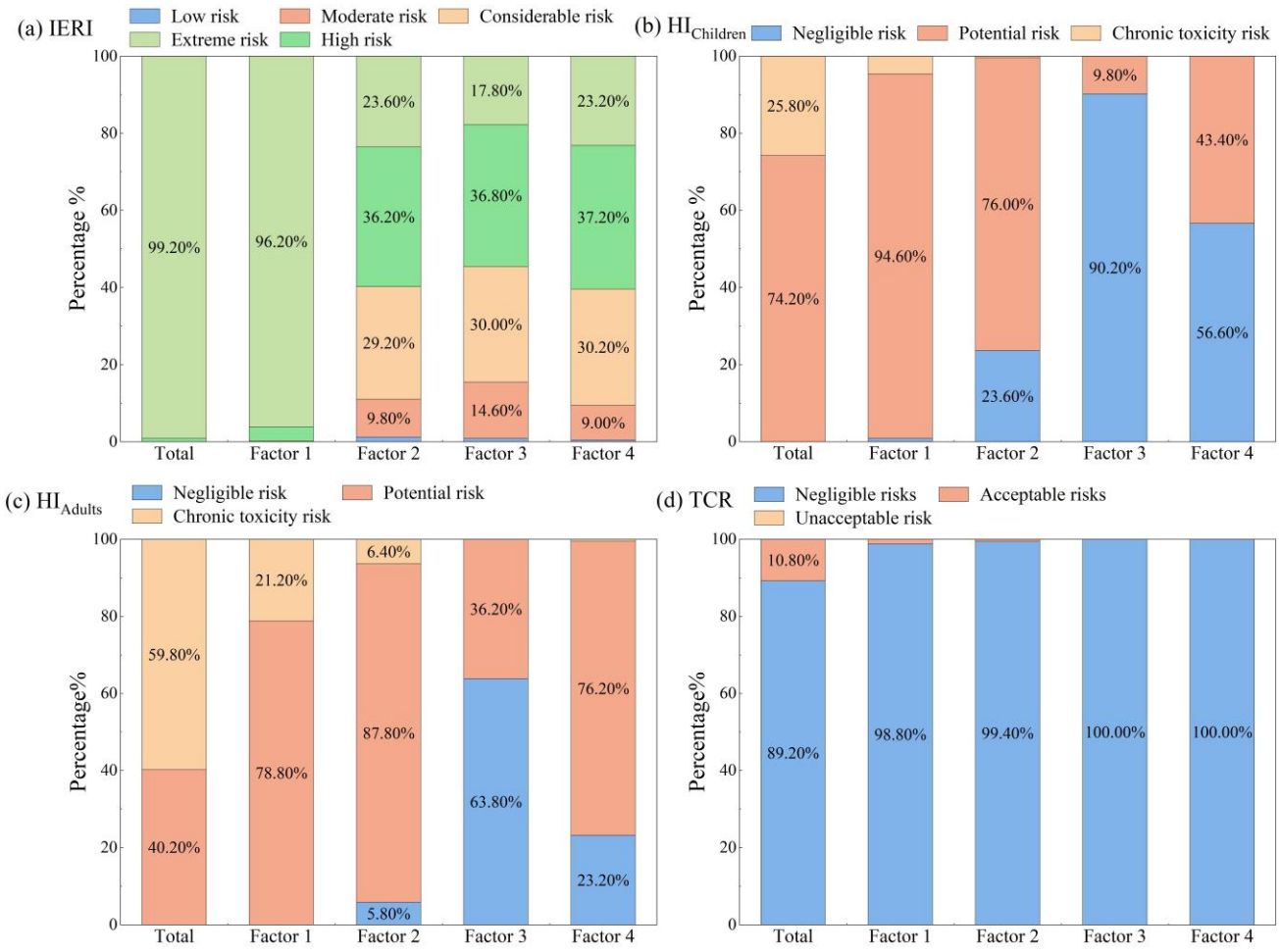


Figure S2. Contribution proportions of each source to different levels of ecological and health risks.

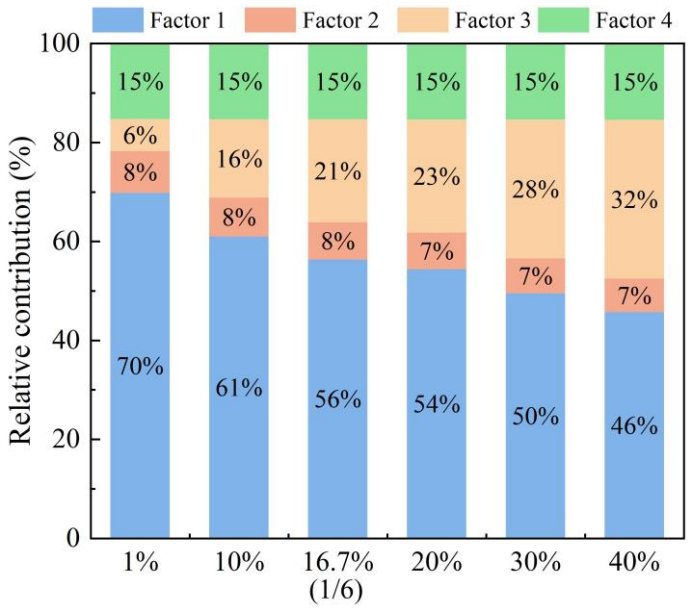


Figure S3. The relative contributions of identified sources to the total carcinogenic risk under varying Cr(VI) proportion assumptions (from 1% to 40%).