Source apportionment, criteria derivation, and health risk assessment of soil heavy metals in the urban green spaces

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Supplementary material S1

USEPA PMF 5.0 was used to quantify the source apportionment of soil heavy metals in this study. The original matrix was decomposed into a contribution matrix and a factor profile matrix based on the reliable factorization algorithms under the non-negative constraint. The calculation of PMF receptor model as follows (USEPA, 2011b):

$$x_{ij} = \sum_{k=1}^{p} g_{ik} \times f_{kj} + e_{ij} \#(1)$$

Where x_{ij} is the concentration of j-th soil heavy metals in i-th sample (mg kg^{-1}), g_{ik} is the contribution matrix of k-th source in i-th sample, f_{kj} is the source profile of j-th soil heavy metals from k-th source factor, e_{ij} is the residual for j-th soil heavy metals in i number of samples. The optimal g_{ik} and f_{kj} are obtained via minimizing the objective function Q:

$$Q = \sum_{i=1}^{n}\sum_{j=1}^{m}\left[\frac{x_{ij} - \sum_{k=1}^{p} g_{ik} \times f_{kj}}{u_{ij}}\right]^2 = \sum_{i=1}^{n}\sum_{j=1}^{m}\left[\frac{e_{ij}}{u_{ij}}\right]^2 \#(2)$$

Where u_{ij} is the uncertainty of j-th soil heavy metal in the i-th sample. The uncertainty can be calculated as follows:

$$u_{ij} = \begin{cases} \frac{5}{6} \times MDL & x_{ij} \le MDL \\ \sqrt{(\delta \times x_{ij})^2 + (0.5 \times MDL)^2}, & x_{ij} > MDL \end{cases} \#(3)$$

Where δ is the relative standard deviation of the concentration of soil heavy metals, MDL is the species-specific method detection limit value.

Supplementary material S2

In this study, concentration-specific human health risk for adults and Children were calculated via human health risk assessment recommended by. Soil heavy metals could enter human body through direct ingestion, inhalation, and dermal contract. The algorithm of average daily intakes (AAD) through ingestion, inhalation, and dermal contract were calculated as follows:

$$ADD_{ing} = \frac{C \times IngR \times EF \times ED}{BW \times AT} \times 10^{-6}\#(1)$$

$$ADD_{inh} = \frac{C \times InhR \times EF \times ED}{PEF \times BW \times AT}\#(2)$$

$$ADD_{dermal} = \frac{C \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}10^{-6}\#(3)$$

Where ADD_{ing}, ADD_{inh}, and ADD_{dermal} (mg kg^{-1} day^{-1}) are average daily intakes through direct ingestion, inhalation, and dermal contract absorption, respectively, C is the concentration of soil heavy metals, the mean and values of other parameters were listed in the Table S3.

The hazard index (HI) represented the accumulation non-carcinogenic risk, and it could be assessed as follows (USEPA, 2011b; USEPA, 2009):

$$HI = \sum HQ = \sum \frac{ADD_p}{RfD_p}\#(4)$$

Where HI is the sum of the HQ of all the soil heavy metals, HQ is the non-carcinogenic risk of different pathway, RfD is the reference dose (mg kg^{-1} day^{-1}), p is the type of heavy metals (Table S4).

The algorithm of total carcinogenic risk (TCR) can be assessed as follows (USEPA, 2011b; USEPA, 2009):

$$TCR = \sum CR = \sum ADD_p \times SF_p\#(5)$$

Where TCR is the sum of the CR of all the soil heavy metals, CR is the carcinogenic risk via different pathway, SF is the carcinogenic slope factor, p is the type of heavy metals (Table S4).

Supplementary material S3

Source-specific human health risk in this study was developed combing with PMF model to assess the health risks contributed by each source. Soil heavy metals could enter human body through direct ingestion, inhalation, and dermal contract. The algorithm of AAD through ingestion, inhalation, and dermal contract combing with PMF were calculated as follows (USEPA, 2016; USEPA, 2011b):

$$ADD_{ijing}^{k} = \frac{C_{ij}^{k} \times IngR \times EF \times ED}{BW \times AT} \times CF\#(1)$$

$$ADD_{ijinh}^{k} = \frac{C_{ij}^{k} \times InhR \times EF \times ED}{PEF \times BW \times AT}\#(2)$$

$$ADD_{ijdermal}^{k} = \frac{C_{ij}^{k} \times SA \times AF \times ABF \times EF \times ED}{BW \times AT} \times CF\#(3)$$

Where ADD_{ijing}^{k}, ADD_{ijinh}^{k}, and $ADD_{ijdermal}^{k}$ are average daily intakes via oral ingestion, inhalation, and dermal contact for the j-th heavy metals in the i-th sampling site from k-th source (mg kd^{-1} day^{-1}), C_{ij}^{k} is the mass contributions of the j-th heavy metals from k-th source in the i-th sample (mg kg^{-1}), the definition and values of other parameters are listed in Table S3.

C_{ij}^{k} is estimated as follows:

$$C_{ij}^{k} = C_{ij}^{k*} \times C_{i}\#(4)$$

Where C_{ij}^{k} is the mass contribution of j-th heavy metals from k-th source in the i-th sample (mg kg^{-1}), C_{ij}^{k*} is the contribution of j-th heavy metals from k-th source in the i-th sample (mg kg^{-1}), C_{i} is the concentrations of soil heavy metals in the i-th sample (mg kg^{-1}).

The $HQ_{ij,P}^{k}$ represents the hazard quotient on the p-th exposure pathway from k-th source of j-th heavy metals in i-th samples, and HI_{ij}^{k} is the sum of $HQ_{ij,P}^{k}$. They are calculated as follows (USEPA, 2011b; USEPA, 2009):

$$HI_{ij}^{k} = \sum HQ_{ij}^{k} = \sum \frac{ADD_{ij,p}^{k}}{RfD_{p}}\#(5)$$

Where RfD is the reference dose of soil heavy metals and listed in Table S3.

The carcinogenic risk (CR_{ij}^{k}) represented the carcinogenic risk of the j-th heavy metal in the i-th samples from k-th source, and the total carcinogenic risk (TCR_{ij}^{k}) could be calculated by the sum of CR_{ij}^{k}. They were calculated as follows:

$$CR_{ij}^{k} = \sum CR_{ij,p}^{k} = \sum ADD_{ij,p}^{k} \times SF_{i,p}\#(6)$$

$$TCR_{ij}^{k} = \sum CR_{ij}^{k} \#(7)$$

Where SF is the carcinogenic slope factor of soil heavy metals and listed in Table S4.

Table S1. Data introduction and sources.

Basic data	Data Source	Type
Digital Elevation Model (30 m)	Geospatial Data Cloud (https://www.gscloud.cn)	Raster
Land use (30 m)	Globel land 30 (http://globeland30.org)	Raster

Table S2. Environmental indices with different classifications.

Environmental indices	Categories
Geo-accumulation index (I_{geo}) [a]	
Not to weakly contaminated	≤ 0
Weakly to moderately contaminated	$0 < I_{geo} \leq 1$
Moderate contaminated	$1 < I_{geo} \leq 2$
Moderate to strongly contaminated	$2 < I_{geo} \leq 3$
Strongly contaminated	$3 < I_{geo} \leq 4$
Strongly to extremely contaminated	$4 < I_{geo} \leq 5$
Extremely contaminated	$I_{geo} > 5$
Pollution factor (PF) [b]	
Low pollution	≤ 1
Moderate pollution	$1 < PF \leq 3$
Considerable pollution	$3 < PF \leq 6$
Very high pollution	$PF > 6$

[a] (Huang et al., 2021)

[b] (Rehman et al., 2018)

Table S3. Description and probability density functions (PDFs) of parameters in human health risk assessment to assess the health risks with Monte Carlo simulation.

Abbreviate for parameters	Parameters		Unit	Probabilistic distribution	Adults	Children	Reference
IngR	Ingestion rate		mg d^{-1}	lognormal	50th:74.5; 95th:257.5	50th:45; 95th:202	(Duan et al., 2014; Duan et al., 2016)
InhR	Inhalation rate		m^3 d^{-1}	lognormal	50th:14; 95th:17.9	50th:6.4; 95th:7.9	(Duan et al., 2014; Duan et al., 2016)
EF	Exposure frequency		d yr^{-1}	point	350	350	(Wu, 2022)
ED	Exposure duration		yr	uniform	24	12	(Wu, 2022)
BW	Average body weight		kg	point	64.3	21.8	(CCDC, 2015; CCDC, 2020)
AT	Average time	Non-carcinogenic risks Carcinogenic risks	d	point	70 × 365 24 × 365	70 × 365 6 × 365	(Duan et al., 2014; Duan et al., 2016)
PEF	Particle emission factor		m^3 kg^{-1}	point	1.36E+09	1.36E+09	(USEPA, 2001)
SA	Skin area exposed to soils		cm^2	lognormal	50th:5039; 95th:5938	50th:2074; 95th:2493	(Duan et al., 2014; USEPA, 2001)
AF	Skin adherence factor		mg cm^{-2}	Beta	0.07(0, 0.3)	0.2(0, 3.3)	(USEPA, 2011c)
ABF	Dermal adsorption factor		-	point	0.001(As:0.03)	0.001(As:0.03)	(USEPA, 2011c)

Table S4. Reference dose (*RfD*) and slope factor (SF) of soil heavy metals in different pathways.

Parameters	As	Co	Cr	Cu	Ni	Pb	Zn
RfD_{ing}	3.00E-04 [a]	3.00E-04 [c]	3.00E-03 [f]	4.00E-02 [a]	2.00E-02 [a]	3.50E-03 [a]	3.00E-01 [a]
RfD_{inh}	3.01E-04 [a]	2.80E-05 [c]	2.86E-05 [f]	4.02E-02 [a]	2.06E-02 [a]	3.52E-03 [a]	6.00E-02 [b]
RfD_{dermal}	1.23E-04 [c]	6.00E-05 [c]	6.00E-05 [f]	1.20E-02 [c]	5.40E-03 [c]	5.25E-04 [b]	6.00E-02 [c]
SF_{ing}	1.50E+00 [a]	-	5.00E-01 [g]	-	1.70E+00 [e]	-	-
SF_{inh}	1.51E+01 [a]	9.8 [c]	4.20E+01 [h]	-	9.01E+00 [a]	8.50E-03 [b]	-
SF_{dermal}	3.66E+00 [a]	-	2.00E+01 [c]	-	4.25E+01 [c]	-	-

a (USEPA, 1999)
b (Men et al., 2021)
c (Cao et al., 2016)
d (Ran et al., 2021)
e (USEPA, 2011c)
f (Rahman et al., 2019)
g (Chen et al., 2019)
h (Gong et al., 2019)

Table S5. Residual analysis of PMF base model results.

Elements	Category	R^2	Intercept	Intercept-SE	Slope	Slope-SE	Scaled-residuals	Normal-residual
As	Strong	0.999	0.000	0.002	1.000	0.000	-2.052 ~ 1.187	Yes
Co	Strong	0.999	0.017	0.017	0.999	0.001	-1.376 ~ 3.476	Yes
Cr	Strong	0.287	42.150	1.815	0.207	0.029	-0.814 ~ 0.554	No
Cu	Strong	0.693	7.450	0.846	0.633	0.037	-2.751 ~ 3.221	Yes
Ni	Strong	0.765	6.490	0.714	0.677	0.033	-1.999 ~ 4.621	Yes
Pb	Strong	0.998	0.130	0.078	0.992	0.003	-0.368 ~ 0.839	Yes
Zn	Strong	0.257	41.180	1.795	0.200	0.030	-0.733 ~ 0.690	No

Table S6. Factor analysis and contribution percentage (%) for heavy metals using PMF model.

Heavy metals	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**R^2**
As	0.51	3.18	10.36	**85.94**	0.999
Co	6.77	**52.68**	31.28	9.27	0.999
Cr	15.00	32.83	**46.90**	5.27	0.287
Cu	24.21	16.16	**54.91**	4.73	0.693
Ni	15.18	29.83	**52.66**	2.33	0.765
Pb	**66.51**	33.49	0.00	0.00	0.998
Zn	13.38	35.73	**45.00**	5.88	0.257

Table S7. Land use and receptor parameters of study area input into the CLEA model.

	Value		Unit
	Adults	Children	
Land use			
EF (soil and dust ingestion) [a]	243	243	day yr^{-1}
EF (consumption of homegrown produce)	0	0	day yr^{-1}
EF (skin contact, indoor)	0	0	day yr^{-1}
EF (skin contact, outdoor) [a]	243	243	day yr^{-1}
EF (inhalation of dust and vapor, indoor)	0	0	day yr^{-1}
EF (inhalation of dust and vapor, outdoor) [a]	243	243	day yr^{-1}
Occupancy Period (indoor)	0	0	hr day^{-1}
Occupancy Period (outdoor) [a]	3	3	hr day^{-1}
Soil to skin adherence factor (indoor)	0	0	mg cm^{-2} day^{-1}
Soil to skin adherence factor (outdoor) [b]	0.3	0.3	mg cm^{-2} day^{-1}
Soil and dust ingestion rate [c]	0.2	0.1	g day^{-1}
Receptor			
Body weight [d]	64.3	21.83	kg
Body height [d]	1.64	1.22	m
Inhalation rate [a]	14.1	14.1	m^3 day^{-1}
Max exposed skin fraction (indoor)	0	0	m^2 m^{-2}
Max exposed skin fraction (outdoor) [c]	0.48	0.48	m^2 m^{-2}

a (Wu, 2022)

b (Yang et al., 2022)

c (MEPRC, 2019)

d (CCDC, 2020)

Table S8. Soil and building properties of study area input into the CLEA model.

	Value	Unit
Soil properties for	**Silty clay**	
Porosity, total [a]	0.46	cm^3 cm^{-3}
Porosity, air-filled [a]	0.14	cm^3 cm^{-3}
Porosity, water-filled [a]	0.32	cm^3 cm^{-3}
Residual soil water Content [b]	0.1	cm^3 cm^{-3}
Saturated hydraulic conductivity [c]	3.56E-03	cm s^{-1}
van Genuchten shape parameter (m) [c]	0.32	dimensionless
Bulk density [a]	1.46	g cm^{-3}
Threshold value of wind speed at 10 m [d]	17.2	m s^{-1}
Empirical function (Fx) for dust model [c]	1.22	dimensionless
Ambient soil temperature [c]	283	K
Building properties for	**No building**	
Building footprint	0	m^2
Living space air exchange rate	0	hr^{-1}
Living space height (above ground)	0	m
Living space height (below ground)	0	m
Pressure difference (soil to enclosed space)	0	Pa
Foundation thickness	0	m
Floor crack area	0	cm^2
Dust loading factor	0	μg m^{-3}
Air dispersion model		
Mean annual windspeed (10 m) [c]	3	m s^{-1}
Air dispersion factor at height of 0.8 m [c]	120	g m^{-2} s^{-1} per kg m^{-3}
Air dispersion factor at height of 1.6 m [c]	280	g m^{-2} s^{-1} per kg m^{-3}
Fraction of site with hard or vegetative cover [c]	0.5	m^2 m^{-2}
Vapor model		
Default soil gas ingress rate [c]	25	cm^3 s^{-1}
Depth to top of source (beneath building) [c]	0	cm
Depth to top of source (no building) [c]	50	cm
Thickness of contaminant layer [c]	0	cm
Time average period for surface emissions [c]	75	year
User defined effective air permeability [d]	7.18E-09	cm^2

a (Li et al., 2018)

b (MEPRC, 2019)

c (EA, 2009)

d (Yang et al., 2022)

Table S9. Concentration-specific health risk of soil heavy metals in park green spaces and protection area green spaces for adults and children.

Risk	Heavy metals	Park green spaces								Protection area green spaces							
		Adults				Children				Adults				Children			
		25th	50th	75th	95th	25th	50th	75th	95th	25th	50th	75th	95th	25th	50th	75th	95th
HI	As	1.81E-01	2.01E-01	2.24E-01	2.61E-01	4.58E-01	5.10E-01	5.67E-01	6.56E-01	1.20E+00	1.33E+00	1.48E+00	1.72E+00	3.03E+00	3.37E+00	3.75E+00	4.36E+00
	Co	1.74E-01	1.95E-01	2.18E-01	2.53E-01	4.34E-01	4.84E-01	5.38E-01	6.27E-01	1.16E+00	1.29E+00	1.43E+00	1.66E+00	2.88E+00	3.21E+00	3.58E+00	4.14E+00
	Cr	4.69E-01	5.16E-01	5.72E-01	6.60E-01	8.76E-02	9.68E-02	1.07E-01	1.23E-01	1.95E-01	2.15E-01	2.38E-01	2.74E-01	5.77E-01	6.38E-01	7.06E-01	8.15E-01
	Cu	1.27E-03	1.42E-03	1.58E-03	1.85E-03	3.13E-03	3.50E-03	3.90E-03	4.54E-03	8.43E-03	9.40E-03	1.05E-02	1.21E-02	2.08E-02	2.31E-02	2.57E-02	2.99E-02
	Ni	1.50E-02	1.67E-02	1.86E-02	2.16E-02	6.33E-03	7.05E-03	7.87E-03	9.12E-03	1.70E-02	1.89E-02	2.10E-02	2.45E-02	4.19E-02	4.67E-02	5.20E-02	6.03E-02
	Pb	1.53E-02	1.71E-02	1.90E-02	2.21E-02	3.85E-02	4.28E-02	4.74E-02	5.51E-02	1.01E-01	1.13E-01	1.25E-01	1.47E-01	2.56E-01	2.84E-01	3.16E-01	3.68E-01
	Zn	1.75E-04	1.95E-04	2.17E-04	2.53E-04	4.35E-04	4.84E-04	5.38E-04	6.25E-04	1.15E-03	1.28E-03	1.43E-03	1.67E-03	2.87E-03	3.19E-03	3.55E-03	4.12E-03
THI	Total	8.97E-01	9.54E-01	1.02E+00	1.12E+00	1.08E+00	1.15E+00	1.23E+00	1.35E+00	2.80E+00	2.99E+00	3.20E+00	3.52E+00	7.14E+00	7.63E+00	8.16E+00	8.96E+00
CR	As	1.21E-05	1.34E-05	1.48E-05	1.71E-05	3.49E-05	3.87E-05	4.28E-05	4.92E-05	7.98E-04	8.81E-04	9.76E-04	1.13E-03	2.31E-03	2.56E-03	2.83E-03	3.26E-03
	Co	2.43E-08	2.71E-08	3.03E-08	3.52E-08	3.25E-08	3.63E-08	4.07E-08	4.78E-08	1.60E-08	1.79E-08	1.99E-08	2.33E-08	2.16E-08	2.40E-08	2.68E-08	3.13E-08
	Cr	5.17E-05	5.29E-05	5.43E-05	5.65E-05	7.39E-05	7.05E-05	7.82E-05	9.03E-05	2.66E-04	2.93E-04	3.25E-04	3.76E-04	7.70E-04	8.51E-04	9.42E-04	1.09E-03
	Ni	3.21E-05	3.56E-05	3.95E-05	4.55E-05	6.80E-05	7.52E-05	8.31E-05	9.61E-05	7.72E-06	8.54E-06	9.43E-06	1.09E-05	2.13E-05	2.36E-05	2.61E-05	3.01E-05
	Pb	2.10E-11	2.35E-11	2.61E-11	3.05E-11	2.81E-11	3.14E-11	3.51E-11	4.10E-11	1.39E-11	1.55E-11	1.72E-11	2.02E-11	1.86E-11	2.08E-11	2.32E-11	2.72E-11
TCR	Total	9.59E-05	1.02E-04	1.09E-04	1.19E-04	1.77E-04	1.84E-04	2.04E-04	2.36E-04	1.07E-03	1.18E-03	1.31E-03	1.52E-03	3.10E-03	3.43E-03	3.80E-03	4.38E-03

Table S10. Source-specific health risk of soil heavy metals in urban green spaces for adults and children.

Risk	Heavy	Source	Adults					Children				
			5th	25th	50th	75th	95th	5th	25th	50th	75th	95th
HI	As	Factor 1	7.58E-03	8.79E-03	9.81E-03	1.09E-02	1.27E-02	1.91E-02	2.21E-02	2.46E-02	2.74E-02	3.18E-02
		Factor 2	4.69E-02	5.45E-02	6.05E-02	6.74E-02	7.84E-02	1.19E-01	1.38E-01	1.53E-01	1.70E-01	1.97E-01
		Factor 3	1.52E-01	1.77E-01	1.97E-01	2.19E-01	2.56E-01	3.85E-01	4.47E-01	4.98E-01	5.53E-01	6.41E-01
		Factor 4	1.27E+00	1.47E+00	1.64E+00	1.82E+00	2.13E+00	3.20E+00	3.72E+00	4.13E+00	4.60E+00	5.31E+00
	Co	Factor 1	7.30E-03	8.52E-03	9.46E-03	1.06E-02	1.23E-02	1.82E-02	2.12E-02	2.35E-02	2.61E-02	3.04E-02
		Factor 2	1.21E+00	1.42E+00	1.58E+00	1.75E+00	2.05E+00	3.03E+00	3.52E+00	3.92E+00	4.36E+00	5.08E+00
		Factor 3	1.47E-01	1.71E-01	1.91E-01	2.12E-01	2.47E-01	3.66E-01	4.26E-01	4.74E-01	5.28E-01	6.16E-01
		Factor 4	4.52E-02	5.26E-02	5.85E-02	6.51E-02	7.59E-02	1.11E-01	1.31E-01	1.46E-01	1.62E-01	1.88E-01
	Cr	Factor 1	7.71E-03	8.85E-03	9.79E-03	1.08E-02	1.25E-02	2.26E-02	2.63E-02	2.91E-02	3.22E-02	3.70E-02
		Factor 2	2.50E-02	2.89E-02	3.19E-02	3.52E-02	4.08E-02	7.43E-02	8.55E-02	9.43E-02	1.05E-01	1.21E-01
		Factor 3	2.07E-01	2.38E-01	2.64E-01	2.93E-01	3.38E-01	6.15E-01	7.10E-01	7.87E-01	8.68E-01	1.00E+00
		Factor 4	1.24E-03	1.43E-03	1.59E-03	1.75E-03	2.02E-03	3.64E-03	4.22E-03	4.68E-03	5.18E-03	5.97E-03
	Cu	Factor 1	1.08E-03	1.25E-03	1.40E-03	1.55E-03	1.81E-03	2.65E-03	3.09E-03	3.43E-03	3.81E-03	4.44E-03
		Factor 2	3.29E-04	3.84E-04	4.28E-04	4.76E-04	5.55E-04	8.10E-04	9.44E-04	1.05E-03	1.17E-03	1.37E-03
		Factor 3	8.87E-03	1.04E-02	1.15E-02	1.29E-02	1.51E-02	2.19E-02	2.55E-02	2.84E-02	3.16E-02	3.70E-02
		Factor 4	5.32E-05	6.23E-05	6.94E-05	7.72E-05	9.01E-05	1.31E-04	1.53E-04	1.70E-04	1.89E-04	2.20E-04
	Ni	Factor 1	6.62E-04	7.71E-04	8.58E-04	9.57E-04	1.12E-03	1.64E-03	1.90E-03	2.11E-03	2.35E-03	2.74E-03
		Factor 2	2.16E-03	2.51E-03	2.81E-03	3.13E-03	3.66E-03	5.33E-03	6.21E-03	6.91E-03	7.72E-03	8.95E-03
		Factor 3	1.78E-02	2.08E-02	2.31E-02	2.58E-02	3.02E-02	4.43E-02	5.16E-02	5.73E-02	6.37E-02	7.44E-02
		Factor 4	1.06E-04	1.25E-04	1.39E-04	1.55E-04	1.82E-04	2.65E-04	3.09E-04	3.43E-04	3.82E-04	4.47E-04
	Pb	Factor 1	1.08E-01	1.25E-01	1.39E-01	1.54E-01	1.79E-01	2.70E-01	3.14E-01	3.49E-01	3.88E-01	4.52E-01
		Factor 2	1.29E-02	1.50E-02	1.67E-02	1.86E-02	2.16E-02	3.26E-02	3.79E-02	4.21E-02	4.69E-02	5.43E-02
		Factor 3	4.00E-03	4.64E-03	5.16E-03	5.71E-03	6.65E-03	1.00E-02	1.16E-02	1.29E-02	1.43E-02	1.67E-02

		Factor 4	6.40E-04	7.45E-04	8.29E-04	9.21E-04	1.08E-03	1.63E-03	1.88E-03	2.08E-03	2.31E-03	2.69E-03
	Zn	Factor 1	4.48E-05	5.26E-05	5.86E-05	6.51E-05	7.61E-05	1.13E-04	1.31E-04	1.46E-04	1.63E-04	1.88E-04
		Factor 2	1.46E-04	1.71E-04	1.90E-04	2.12E-04	2.48E-04	3.66E-04	4.27E-04	4.74E-04	5.28E-04	6.15E-04
		Factor 3	1.22E-03	1.42E-03	1.58E-03	1.76E-03	2.04E-03	3.04E-03	3.54E-03	3.92E-03	4.36E-03	5.07E-03
		Factor 4	7.29E-06	8.48E-06	9.42E-06	1.05E-05	1.23E-05	1.81E-05	2.11E-05	2.35E-05	2.62E-05	3.04E-05
THI	Total	Factor 1	1.32E-01	1.53E-01	1.70E-01	1.89E-01	2.20E-01	3.34E-01	3.89E-01	4.32E-01	4.80E-01	5.58E-01
		Factor 2	1.30E+00	1.52E+00	1.69E+00	1.88E+00	2.20E+00	3.26E+00	3.79E+00	4.21E+00	4.69E+00	5.47E+00
		Factor 3	5.38E-01	6.23E-01	6.93E-01	7.70E-01	8.95E-01	1.45E+00	1.68E+00	1.86E+00	2.06E+00	2.39E+00
		Factor 4	1.32E+00	1.52E+00	1.70E+00	1.89E+00	2.21E+00	3.32E+00	3.86E+00	4.29E+00	4.77E+00	5.51E+00
CR	As	Factor 1	2.92E-07	3.39E-07	3.78E-07	4.20E-07	4.89E-07	6.06E-07	7.01E-07	7.75E-07	8.60E-07	9.92E-07
		Factor 2	1.81E-06	2.10E-06	2.34E-06	2.60E-06	3.03E-06	3.79E-06	4.35E-06	4.81E-06	5.31E-06	6.15E-06
		Factor 3	5.87E-06	6.83E-06	7.61E-06	8.45E-06	9.87E-06	1.23E-05	1.42E-05	1.57E-05	1.73E-05	2.00E-05
		Factor 4	4.89E-05	5.68E-05	6.31E-05	7.04E-05	8.24E-05	1.02E-04	1.18E-04	1.30E-04	1.44E-04	1.66E-04
	Co	Factor 1	8.61E-12	1.01E-11	1.13E-11	1.26E-11	1.47E-11	5.62E-12	6.57E-12	7.33E-12	8.16E-12	9.60E-12
		Factor 2	1.44E-09	1.68E-09	1.88E-09	2.10E-09	2.47E-09	9.33E-10	1.09E-09	1.22E-09	1.36E-09	1.60E-09
		Factor 3	1.74E-10	2.03E-10	2.27E-10	2.53E-10	2.96E-10	1.12E-10	1.32E-10	1.47E-10	1.65E-10	1.93E-10
		Factor 4	5.35E-11	6.25E-11	6.98E-11	7.78E-11	9.09E-11	3.47E-11	4.07E-11	4.55E-11	5.07E-11	5.93E-11
	Cr	Factor 1	9.01E-07	1.04E-06	1.15E-06	1.27E-06	1.47E-06	1.25E-06	1.45E-06	1.61E-06	1.78E-06	2.05E-06
		Factor 2	2.93E-06	3.38E-06	3.74E-06	4.13E-06	4.79E-06	4.11E-06	4.73E-06	5.22E-06	5.79E-06	6.68E-06
		Factor 3	2.42E-05	2.79E-05	3.09E-05	3.43E-05	3.96E-05	3.41E-05	3.93E-05	4.35E-05	4.80E-05	5.54E-05
		Factor 4	1.45E-07	1.68E-07	1.86E-07	2.05E-07	2.37E-07	2.01E-07	2.34E-07	2.59E-07	2.86E-07	3.30E-07
	Ni	Factor 1	2.60E-06	3.00E-06	3.32E-06	3.67E-06	4.26E-06	3.48E-07	4.00E-07	4.43E-07	4.90E-07	5.68E-07
		Factor 2	8.49E-06	9.80E-06	1.08E-05	1.20E-05	1.40E-05	1.13E-06	1.31E-06	1.44E-06	1.60E-06	1.85E-06
		Factor 3	7.02E-05	8.10E-05	8.95E-05	9.93E-05	1.15E-04	9.41E-06	1.08E-05	1.20E-05	1.33E-05	1.53E-05
		Factor 4	4.19E-07	4.85E-07	5.37E-07	5.96E-07	6.91E-07	5.62E-08	6.49E-08	7.18E-08	7.94E-08	9.22E-08
	Pb	Factor 1	1.25E-12	1.46E-12	1.63E-12	1.82E-12	2.13E-12	8.10E-13	9.51E-13	1.06E-12	1.19E-12	1.39E-12

		Factor 2	1.50E-13	1.76E-13	1.97E-13	2.19E-13	2.56E-13	9.82E-14	1.14E-13	1.28E-13	1.43E-13	1.67E-13
		Factor 3	4.62E-14	5.42E-14	6.07E-14	6.75E-14	7.88E-14	3.00E-14	3.52E-14	3.93E-14	4.40E-14	5.13E-14
		Factor 4	7.43E-15	8.73E-15	9.76E-15	1.09E-14	1.27E-14	4.88E-15	5.69E-15	6.34E-15	7.09E-15	8.29E-15
TCR	Total	Factor 1	3.79E-06	4.38E-06	4.85E-06	5.36E-06	6.22E-06	2.21E-06	2.55E-06	2.83E-06	3.13E-06	3.61E-06
		Factor 2	1.32E-05	1.53E-05	1.69E-05	1.87E-05	2.18E-05	9.03E-06	1.04E-05	1.15E-05	1.27E-05	1.47E-05
		Factor 3	1.00E-05	1.16E-05	1.28E-05	1.42E-05	1.64E-05	5.57E-05	6.43E-05	7.12E-05	7.86E-05	9.08E-05
		Factor 4	4.95E-05	5.75E-05	6.38E-05	7.12E-05	8.33E-05	1.02E-04	1.18E-04	1.30E-04	1.44E-04	1.66E-04

Table S11. Probability density functions (PDFs) of soil heavy metals concentrations and heavy metals concentrations from each source.

Heavy metals	**PDFs for concentration**	**PDFs for Factor 1**	**PDFs for Factor 2**	**PDFs for Factor 3**	**PDFs for F4**
As	LN (3.12, 2.98)	LN (0.02, 0.02)	LN (0.10, 0.09)	LN (0.32, 0.31)	LN (2.68, 2.56)
Co	LN (12.08, 1.50)	LN (0.82, 0.10)	LN (6.36, 0.79)	LN (3.78, 0.47)	LN (1.12, 0.14)
Cr	LN (57.96, 24.63)	LN (8.69, 3.69)	LN (19.03, 8.09)	LN (27.19, 11.55)	LN (3.06, 1.30)
Cu	LN (21.65, 6.85)	LN (5.24, 1.66)	LN (3.50, 1.11)	LN (11.89, 3.76)	LN (1.02, 0.32)
Ni	LN (20.96, 4.94)	LN (3.18, 0.75)	LN (6.25, 1.47)	LN (11.04, 2.60)	LN (0.49, 0.12)
Pb	LN (18.24, 7.10)	LN (12.13, 4.72)	LN (6.11, 2.38)	LN (2.38E-09, 9.28E-10)	LN (3.99E-08, 1.55E-08)
Zn	LN (55.65, 22.07)	LN (7.45, 2.95)	LN (19.88, 7.89)	LN (25.04, 9.93)	LN (3.27, 1.30)

Table S12. Results of principal component analysis of soil heavy metal concentration.

Items	PC1	PC2	PC3
As	0.144	-0.003	**0.960**
Co	0.241	**0.750**	0.188
Cr	**0.973**	0.120	0.133
Cu	**0.680**	0.157	0.631
Ni	**0.763**	0.524	0.135
Pb	0.089	**0.819**	-0.046
Zn	**0.976**	0.114	0.115

Table S13. Limited values of heavy metal elements in the soil quality standards/criteria (mg kg^{-1}).

Elements	Canada [a]	Netherlands (Target value /Intervene value) [b]	Australia (Health/Ecological investigation value) [c]	France (Target value /Intervene value) [d]	Briain [e]	USA (Eco-screening value) [f]
As	12	29/55	100/50	19/73	20	18
Co	-	9/240	-	-	-	-
Cr	64	100/380	400/75 (Cr^{3+})	-	130	-
Cu	63	36/190	230/30	95/190	-	70
Ni	-	-	560/10	-	50	38
Pb	70	85/530	1000/270	200/400	-	120
Zn	200	140/720	1300/25	4500/9000	-	160

a (CCME, 2011)

b (NIHE, 2015)

c (NEPC, 2013)

d (Stephen, 2011)

e (EA, 2011)

f (USEPA, 2011a)

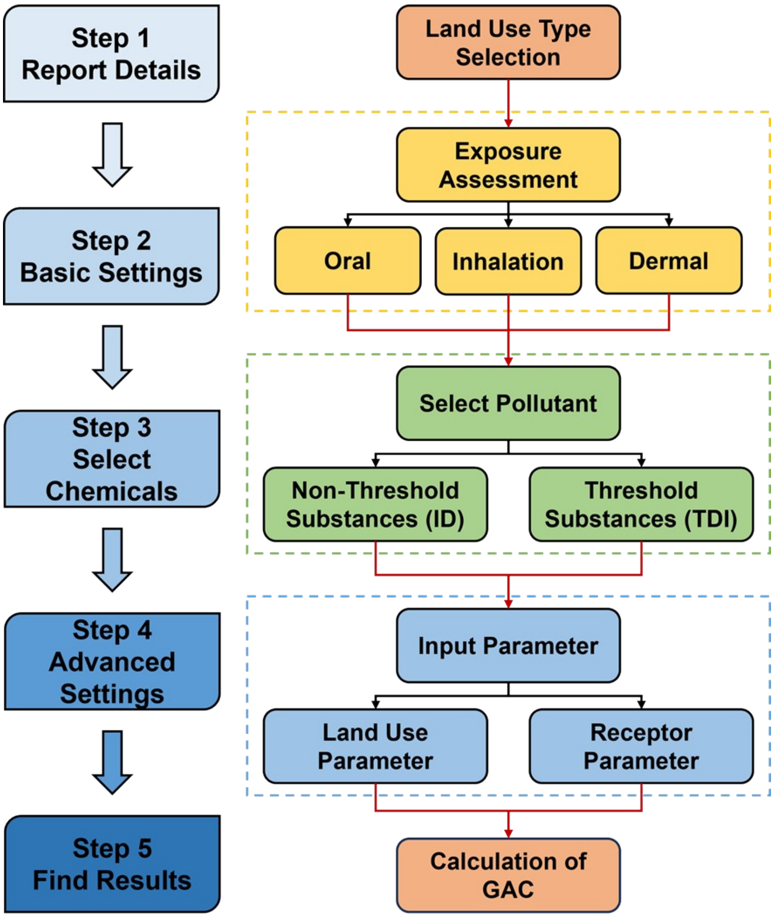

Fig. S1. The derivation principle and procedure for GAC in CLEA model.

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