Supplement of

Mapping mining-affected water pollution in China: Status, patterns, risks, and implications

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S1 The spatial distribution of natural resources in China

The spatial distribution of coal fields shows significant regional differences, with dense concentrations in the coal-bearing areas of North and South China (Fig. S1). Among them, the southern Inner Mongolia, Shaanxi, Shanxi, and Henan provinces have the highest density of coal mines and mine production capacity. Besides, the coal resources of the junction of Anhui and Shandong provinces as well as Yunnan, Guizhou, Sichuan, and other provinces in southwest China are relatively rich (Xiao et al., 2021). Besides, the total sulfur content in different coal-bearing areas in China is shown in Fig. S2.

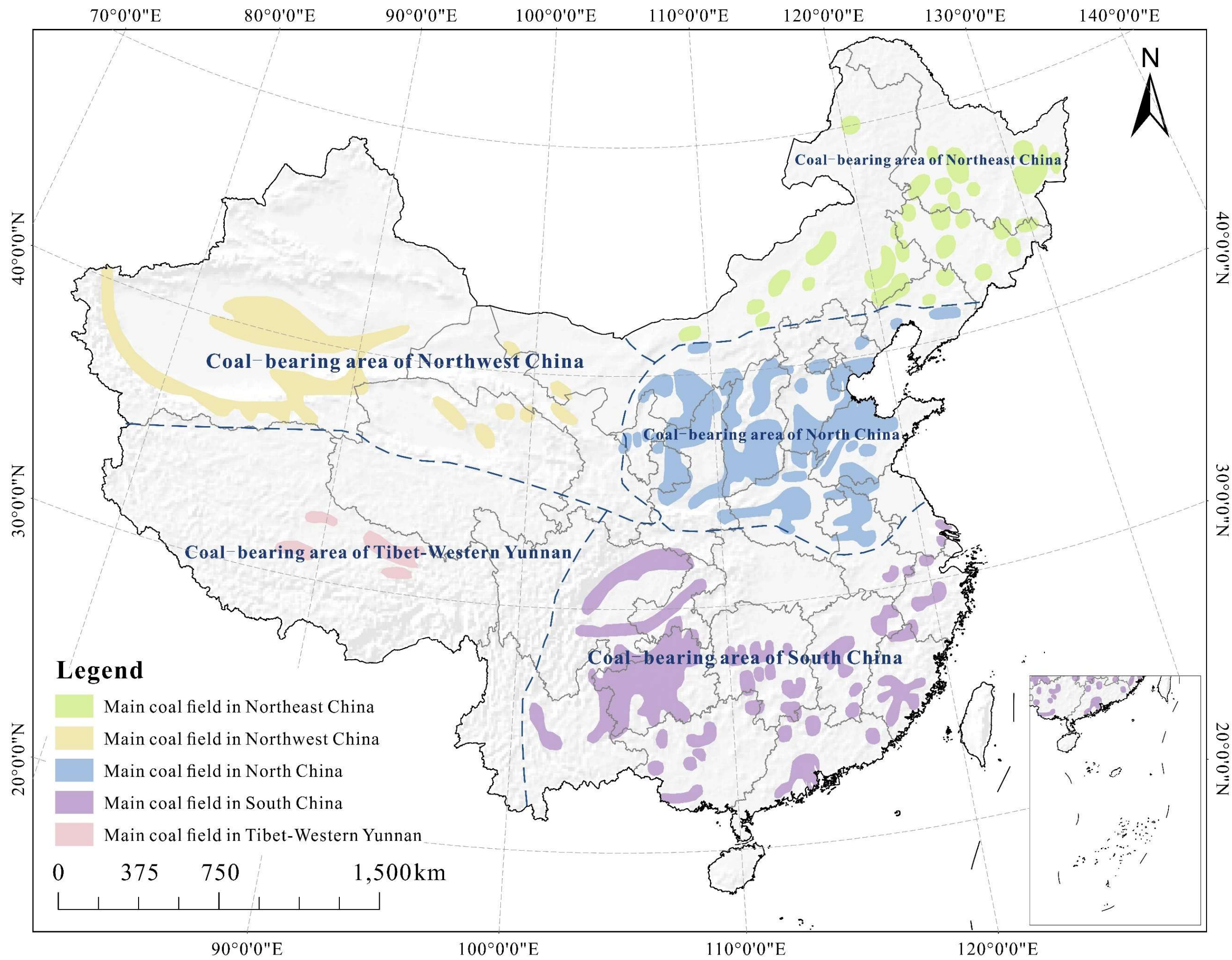

Figure S1. The spatial distribution of main coal-bearing areas in China (originated from China National Administration of Coal Geology).

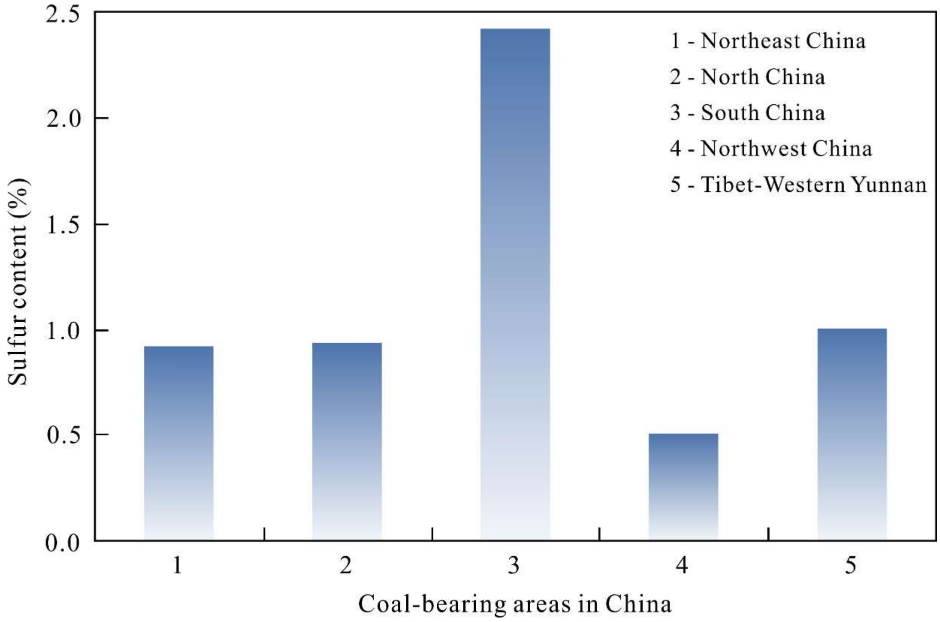

Figure S2. The total sulfur content (%) in different coal-bearing areas in China (adapted from Tang et al., 2015).

As shown in Fig. S3, China is rich in non-ferrous metal mineral resources. The predominant types are copper, lead-zinc, tin deposits, etc., mainly distributed in the provinces of Jiangxi, Yunnan, and Inner Mongolia. For example, the Dexing copper mine in Jiangxi province ranks as one of the largest copper deposits in China, while the Gejiu tin mine in Yunnan province is a world-renowned tin-producing area. Additionally, substantial precious metal mineral resources (gold and silver deposits) are predominantly located in Shandong, Henan, and Guizhou provinces. For example, the Zhaoyuan gold mine in Shandong province is a historically significant gold-producing region.

It is noteworthy that the national mineral deposit database of China developed by Li et al. (2019), covering 232 mineral resources in 27,569 deposits in 29 provinces (cities or districts), is of great importance to study the national natural resources. It can help readers catch more authoritative information, such as ore species, deposit name, location, latitude (N), longitude (E), genetic type of deposit, paragenetic mineral, associated mineral, deposit scale, ore-forming age, and mining status, enabling comprehensive analysis of China's natural resources.

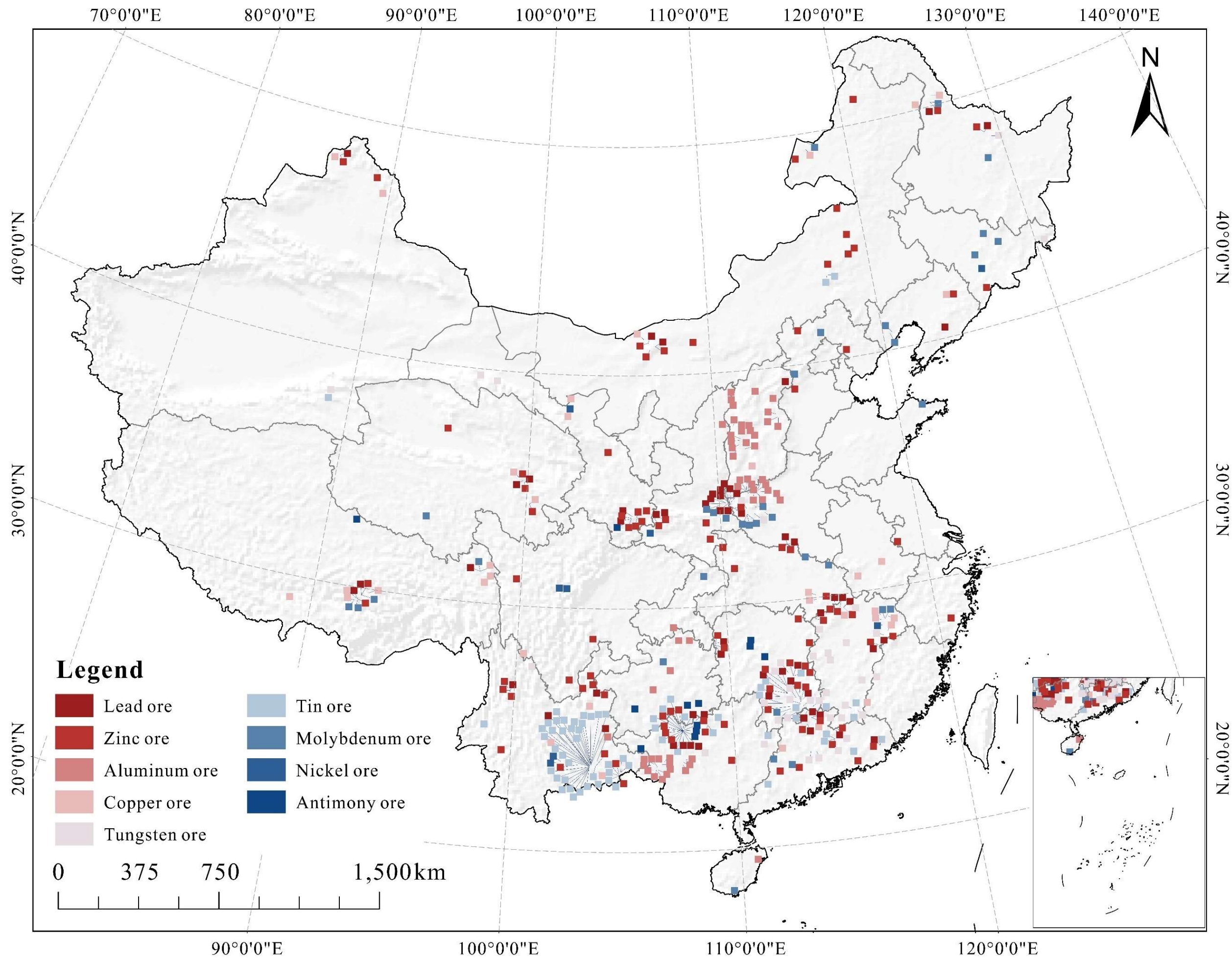

Figure S3. The spatial distribution of the major non-ferrous mineral resources in China (adapted from China Natural Resources Atlas, China Geological Survey, 2015, https://www.cgs.gov.cn/xwl/dzzl/201603/t20160309_304269.html).

S1-References

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S2 Database establishment

The typical mine lists are shown in Table S1 in the ESM2.xlsx document. The sources (*i.e.*, 293 research papers) of high-quality data are listed in the section of ***References*** at the end of the text.

S3 Risk assessment

Table S2. The main parameters used to assess the potential human health risks (*i.e.*, non-carcinogenic risks and carcinogenic risks) for adults and children in the study.

Parameter	Description	Unit	Value		Source
			Adult	Children	
IR	Ingestion rate	L/d	2.50	0.78	[1], [2]
EF	Exposure frequency	d/yr	350	350	[1], [2]
ED	Exposure duration	yr	24	6	[2]
ET	Time of contact	h/d	0.58	1.00	[3], [4]
SA	Skin surface area	cm^2	19652	6365	[1], [2]
CF	Conversion factor	L/cm^3	0.001	0.001	[2], [5]
BW	Body weight	kg	70	15	[1], [3], [4]
AT	Averaging time [a]	d	8760	2190	*ED*×365 d/yr
	Averaging time [b]	d	25550	25550	70×365 d/yr

Note: [a] averaging time used for non-carcinogenic risks (NCRs), and [b] averaging time used for carcinogenic risks (CRs), which is equal to a lifetime (70 yr in the study) ×365 d/yr. The parameter values used in the study are obtained from the following literature sources: [1] Meng et al. (2024); [2] Shi et al. (2023); [3] Tong et al. (2021); [4] Wang et al. (2021); and [5] Yuan et al. (2023).

Table S3. The values of main parameters including permeability coefficient of skin (K_p), reference dose (RfD_o), gastrointestinal digestion coefficient (ABS_{GI}), and slope factor (SF) for each element.

Parameter	K_p (cm/h)	RfD_o (mg/kg·d)	ABS_{GI} (-)	SF (kg·d/mg)	Source
Fe	0.001	0.7	0.2	-	[1], [2], [3], [4], [6]
Mn	0.001	0.024	0.04	-	[1], [2], [3], [4], [6]
Cr	0.002	0.003	0.025	0.5	[1], [3], [6], [7]
Ni	0.0002	0.02	0.04	-	[1], [2], [3], [4], [6], [7]
Cu	0.001	0.04	0.2	-	[1], [2], [3], [4], [6], [7]
Zn	0.0006	0.3	0.2	-	[1], [2], [3], [4], [5], [6]
As	0.001	0.0003	1	1.5	[1], [3], [7]
Cd	0.001	0.0005	0.05	0.38	[2], [3], [4], [6]
Pb	0.0001	0.0014	0.3	-	[1], [3], [6]

Note: The parameter values for each element are obtained from the following literature sources: [1] Meng et al. (2024); [2] Shi et al. (2023); [3] Tong et al. (2021); [4] USEPA (2002); [5] USEPA (2014); [6] Wang et al. (2021); and [7] Zheng et al. (2023).

S3-References

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S4 Overview of mining-affected water in China

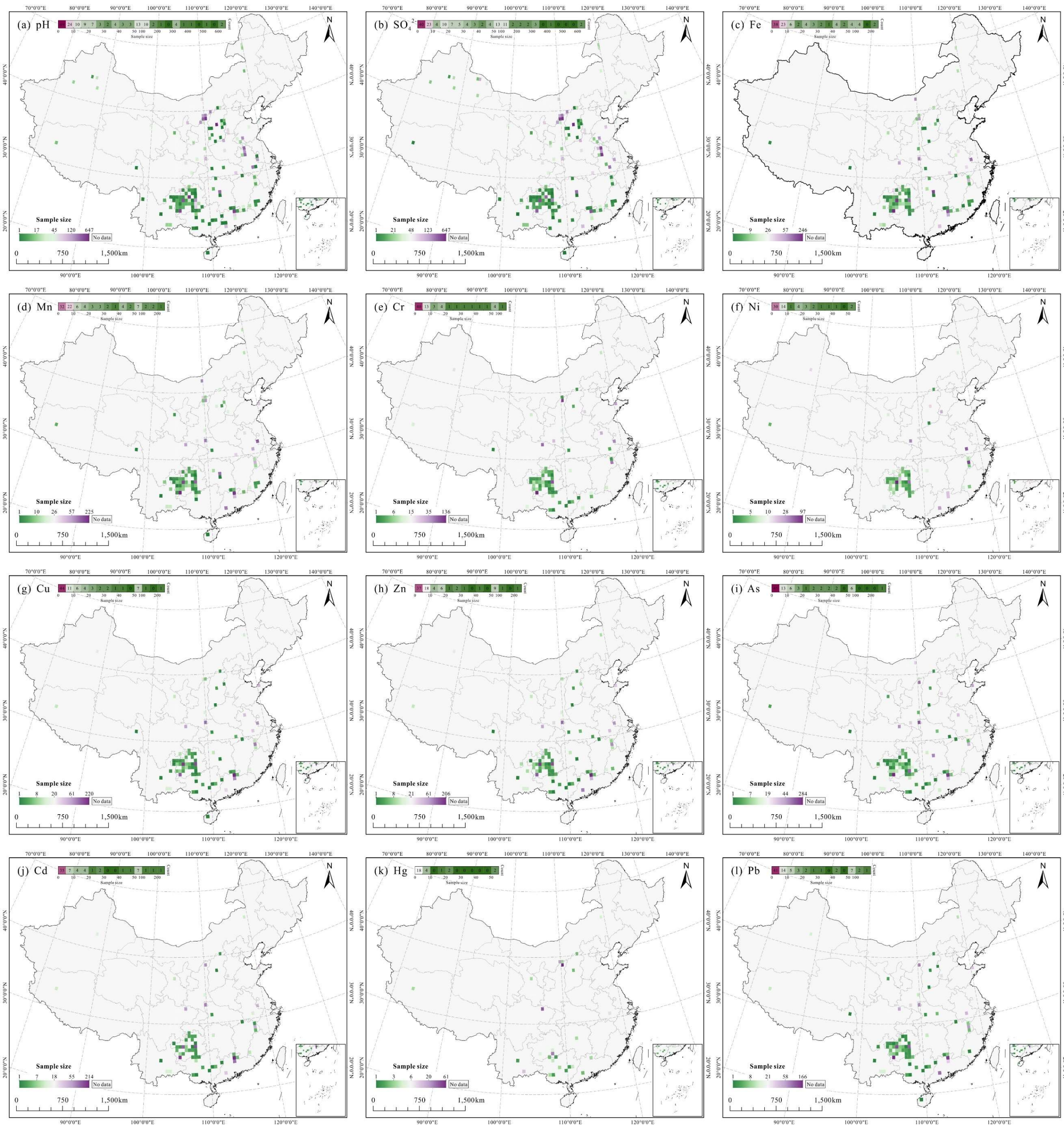

Figure S4. The spatial distribution of the sample size of (a) pH, (b) SO_4^{2-}, (c) Fe, (d) Mn, (e) Cr, (f) Ni, (g) Cu, (h) Zn, (i) As, (j) Cd, (k) Hg, and (l) Pb in mining-affected water on the 0.5° grid.

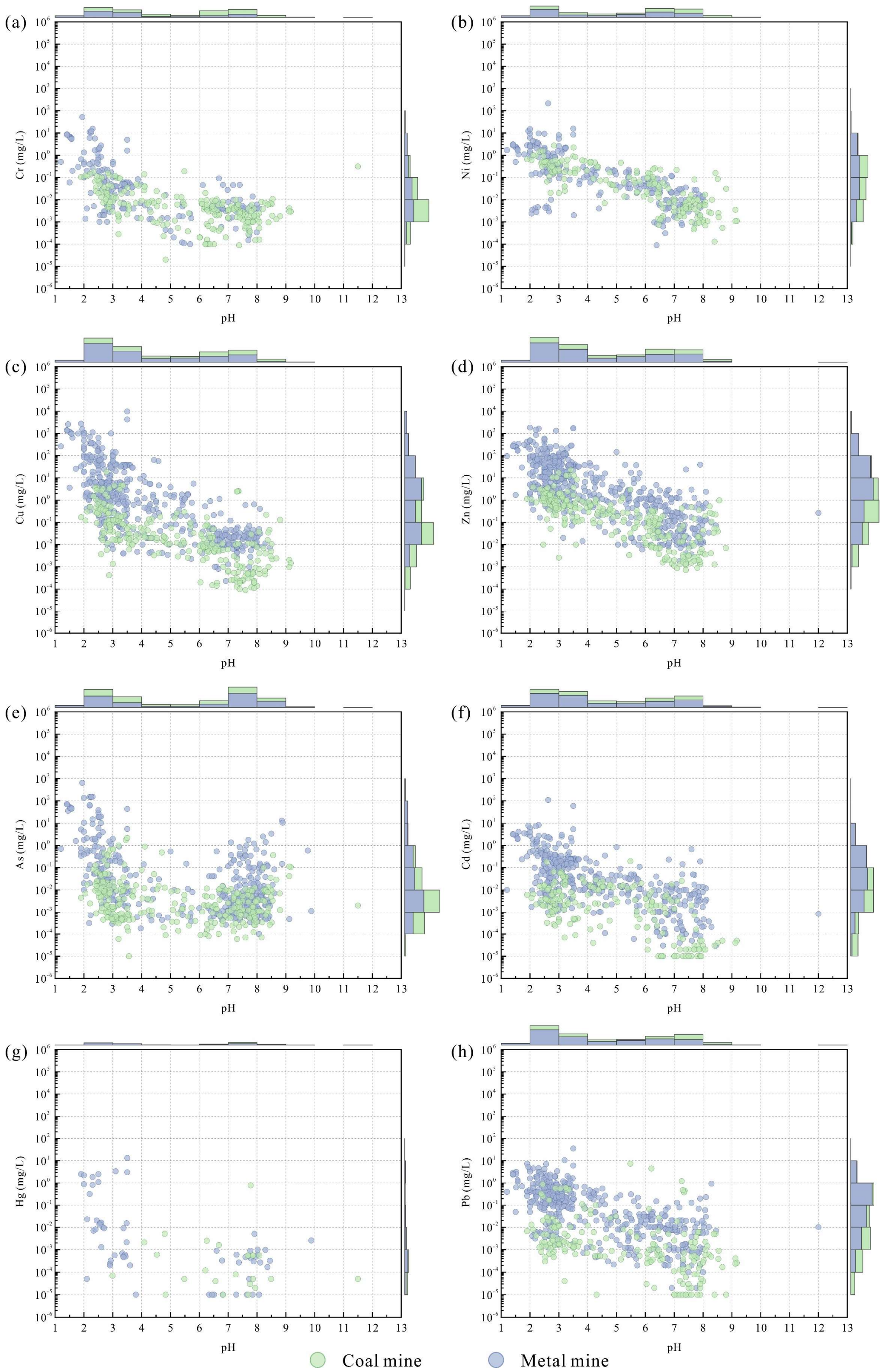

Figure S5. The relationship between pH and the respective concentrations including (a) Cr, (b) Ni, (c) Cu, (d) Zn, (e) As, (f) Cd, (g) Hg, and (h) Pb, in coal and metal mines. The binned frequency distribution of the samples is shown along the x and y axes.

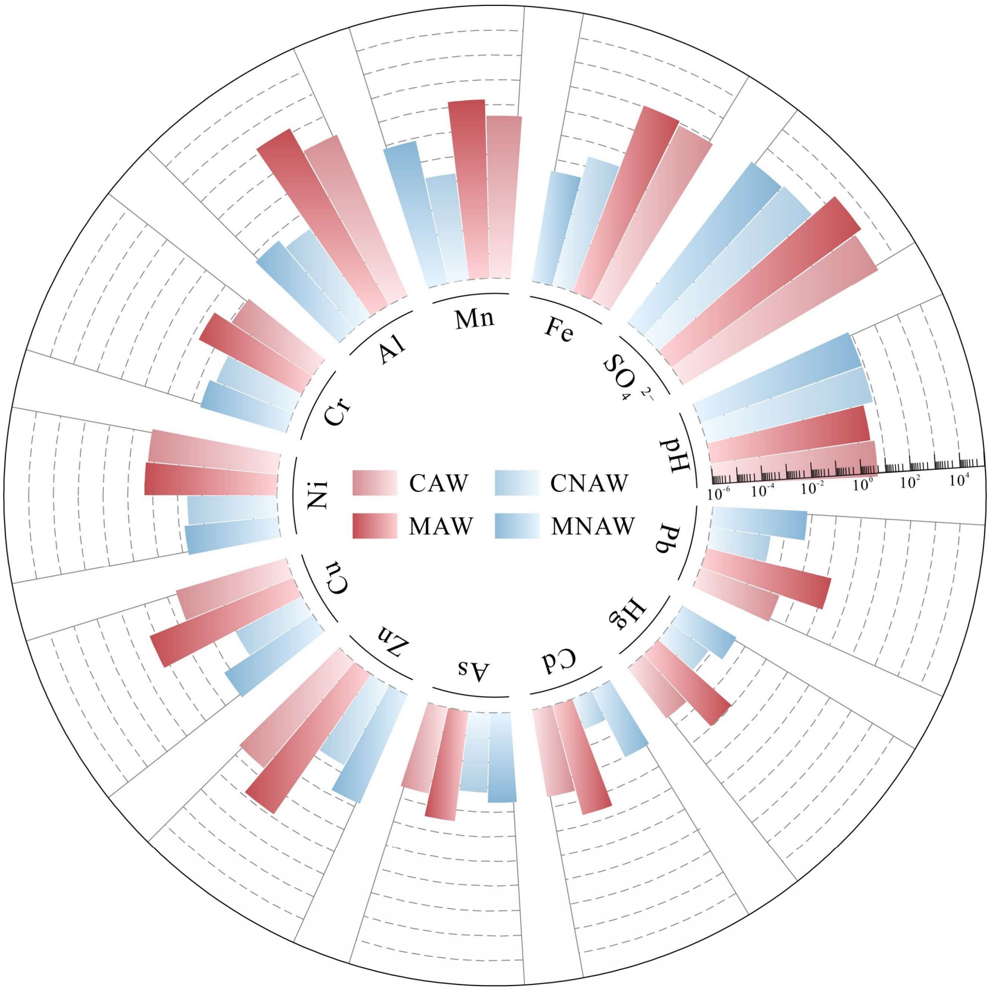

Figure S6. The median concentrations of the main species in mining-affected water from coal and metal mines (Units are mg/L except pH). CAW and MAW denote acid water from coal and metal mines; and CNAW and MNAW represent neutral/alkaline water from coal and metal mines, respectively.

Table S4. Statistical summary (minimum, median, average, and maximum) of the main species aggregated from all samples measured in acid or non-acid mining-affected water in China (Units are mg/L except pH).

Item	Acid mining-affected water						Non-acid mining-affected water					
	Coal mine			Metal mine			Coal mine			Metal mine		
	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
pH	1.90	4.50	6.50	1.20	3.10	6.50	6.51	7.82	11.51	6.51	7.70	12.60
Na^+	0.02	18.55	1305.33	0.00	13.72	1613	0.23	234.75	7594.32	0.55	27.30	9371
K^+	0.04	3.50	37.00	0.00	2.99	172.00	0.00	2.84	164.42	0.20	3.80	419.00
Ca^{2+}	0.83	277.84	987.97	1.70	310.00	893.00	0.00	61.38	689.10	0.01	80.20	4841.70
Mg^{2+}	0.01	59.60	1665	0.10	89.52	10992	0.00	19.09	485.44	0.10	18.54	12752
Cl^-	0.06	2.51	477.24	0.00	9.20	3097.40	0.00	65.20	6462.75	0.35	19.00	26265
SO_4^{2-}	15.00	1381.59	17870	0.56	2982	181000	0.01	193.51	10110	0.09	157.41	52915
HCO_3^-	0.00	0.00	532.96	0.00	15.51	769.00	0.00	280.60	4976.61	0.62	169.50	2482
NO_3^-	0.00	0.55	143.65	0.00	1.45	735.60	0.00	3.00	356.97	0.00	11.00	1774.95
F^-	0.00	0.67	238.34	0.01	0.80	67.40	0.00	0.91	11.65	0.01	0.72	100.00

Item	Acid mining-affected water						Non-acid mining-affected water					
	Coal mine			Metal mine			Coal mine			Metal mine		
	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
Fe	0.00	77.41	2331.86	0.00	113.77	65250	0.00	0.25	205.00	0.00	0.03	495.43
Mn	0.00	3.50	88.40	0.00	15.82	5050	0.00	0.02	5.02	0.00	0.76	200000
Al	0.00	12.87	440.00	0.00	152.00	13679	0.00	0.02	25.00	0.00	0.05	2.09
Cr	0.00	0.0080	0.19	0.00	0.0500	52.27	0.00	0.0022	0.31	0.00	0.0041	0.09
Ni	0.0007	0.1796	2.73	0.00	0.2142	216.00	0.0001	0.0040	0.23	0.00	0.0059	0.12
Cu	0.00	0.0431	18.50	0.00	1.7325	9777.77	0.0001	0.0010	2.56	0.00	0.0180	1.14
Zn	0.0026	0.4211	23.00	0.00	7.2000	1834	0.00	0.0048	0.98	0.00	0.0617	39.30
As	0.00	0.0034	2.16	0.00	0.0281	641.70	0.0001	0.0016	0.37	0.0001	0.0040	13.00
Cd	0.00	0.0036	0.19	0.00	0.0383	110.00	0.00	0.0000	0.03	0.00	0.0010	0.67
Hg	0.00	0.0004	0.01	0.00	0.0090	13.36	0.00	0.0001	0.78	0.00	0.0003	0.01
Pb	0.00	0.0023	7.43	0.00	0.1498	35.68	0.00	0.0003	1.22	0.00	0.0064	0.94

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Non-parametric tests do not rely on assumptions about the distribution of the data and are suitable for non-normally distributed datasets or those containing outliers. These methods statistically compare central tendencies, typically represented by medians, rather than means. The result of the Mann-Whitney U-test (p < 0.05) shows a statistically significant difference in the critical parameters (except Fe) of mining-affected water based on the different mine types (coal mine vs. metal mine), indicating the differences caused by geological factors, mining practices, surrounding environment, etc. Besides, Fig. S7 shows the Spearman correlation coefficients between the hydrochemical compositions in the mining-affected water. It can be seen that strong negative correlations are observed between pH and SO_4^{2-}, Fe, Mn, Al, and heavy metals, while positive correlations are observed between SO_4^{2-} and metal components, implying that the spatial consistency of acid water, high sulfate, high Fe and Mn, and high heavy metal mining-affected water.

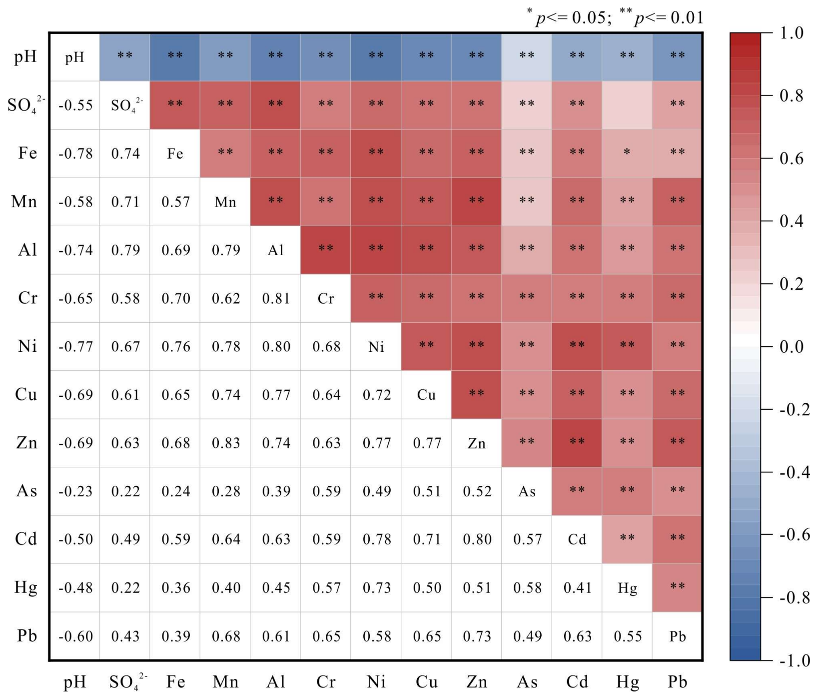

Figure S7. The Spearman correlation coefficient between the hydrochemical compositions in the mining-affected water (* is $p \leqslant 0.05$ and ** is $p \leqslant 0.01$).

S5 Spatial patterns of mining-affected water pollution in China

Table S5. The categories of the Environmental Quality Standards for Surface Water (GB 3838-2002).

Item	Class I	Class II	Class III	Class IV	Class V
pH			6.0 – 9.0		
SO_4	-	-	-	-	-
Fe	-	-	-	-	-
Mn	-	-	-	-	-
Cr	0.01	0.05	0.05	0.05	0.1
Ni	-	-	-	-	-
Cu	0.01	1.0	1.0	1.0	1.0
Zn	0.05	1.0	1.0	2.0	2.0
As	0.05	0.05	0.05	0.1	0.1
Cd	0.001	0.005	0.005	0.005	0.01
Hg	0.00005	0.00005	0.0001	0.001	0.001
Pb	0.01	0.01	0.05	0.05	0.1

Table S6. The categories of the Standard for Groundwater Quality (GB/T14848-2017).

Item	Class I	Class II	Class III	Class IV	Class V
pH		6.5 – 8.5		5.5 – 6.5 and 8.5 – 9.0	< 5.5 and > 9.0
SO4	50	150	250	350	> 350
Fe	0.1	0.2	0.3	2.0	> 2.0
Mn	0.05	0.05	0.1	1.5	> 1.5
Cr	0.005	0.01	0.05	0.1	> 0.1
Ni	0.002	0.002	0.02	0.1	> 0.1
Cu	0.01	0.05	1.0	1.5	> 1.5
Zn	0.05	0.5	1.0	5.0	> 5.0
As	0.001	0.001	0.01	0.05	> 0.05
Cd	0.0001	0.001	0.005	0.01	> 0.01
Hg	0.0001	0.0001	0.001	0.002	> 0.002
Pb	0.005	0.005	0.01	0.1	> 0.1

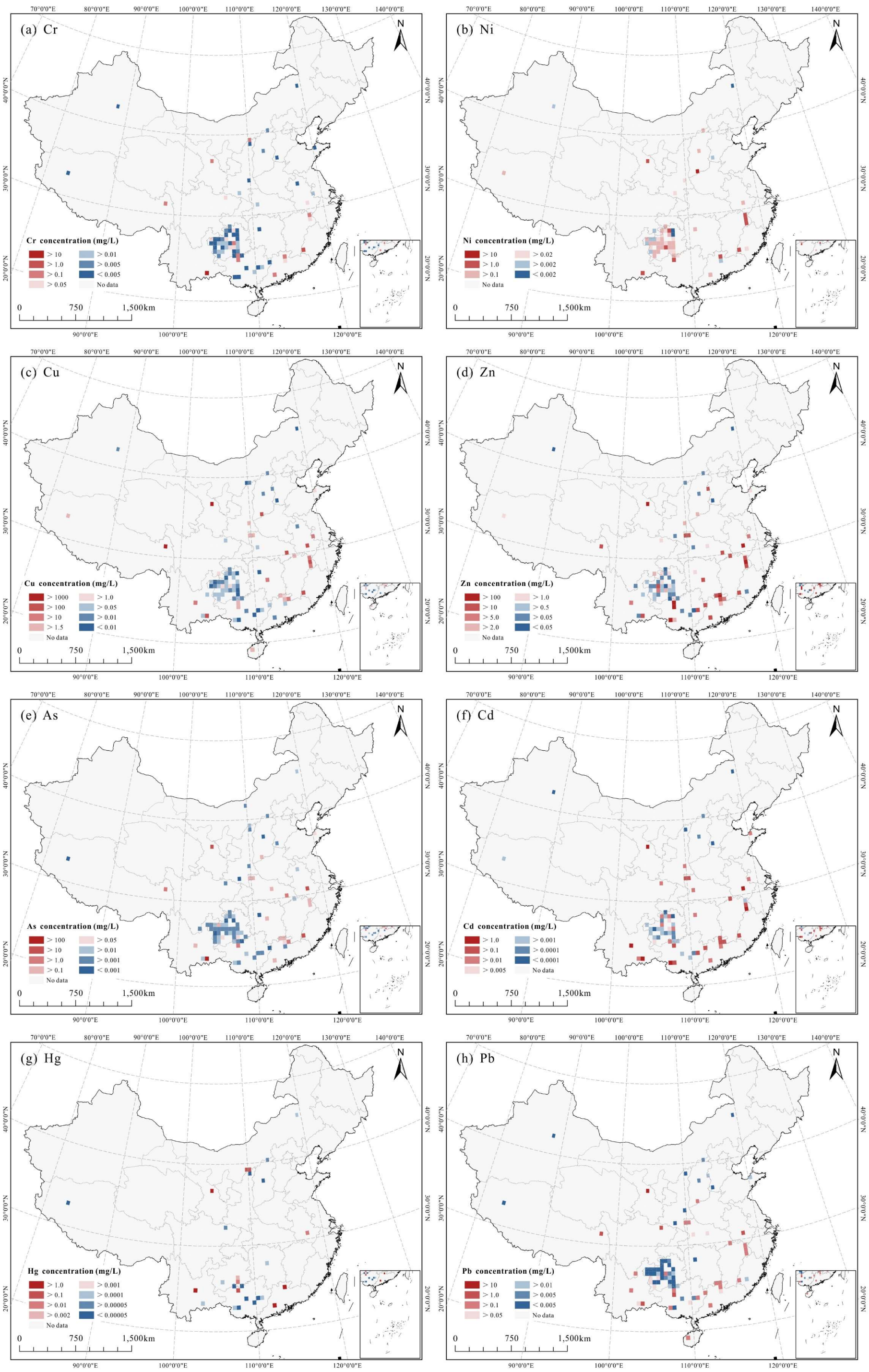

Figure S8. The spatial distribution of mean concentration of individual components (mg/L) showing respective (a) Cr, (b) Ni, (c) Cu, (d) Zn, (e) As, (f) Cd, (g) Hg, and (h) Pb in mining-affected water on the 0.5° grid. The classification thresholds for the main components are based on the distribution of all collected data, as well as regulatory benchmarks from GB 3838-2002 and GB/T 14848-2017 in China.

S6 Risks of mining-affected water in China

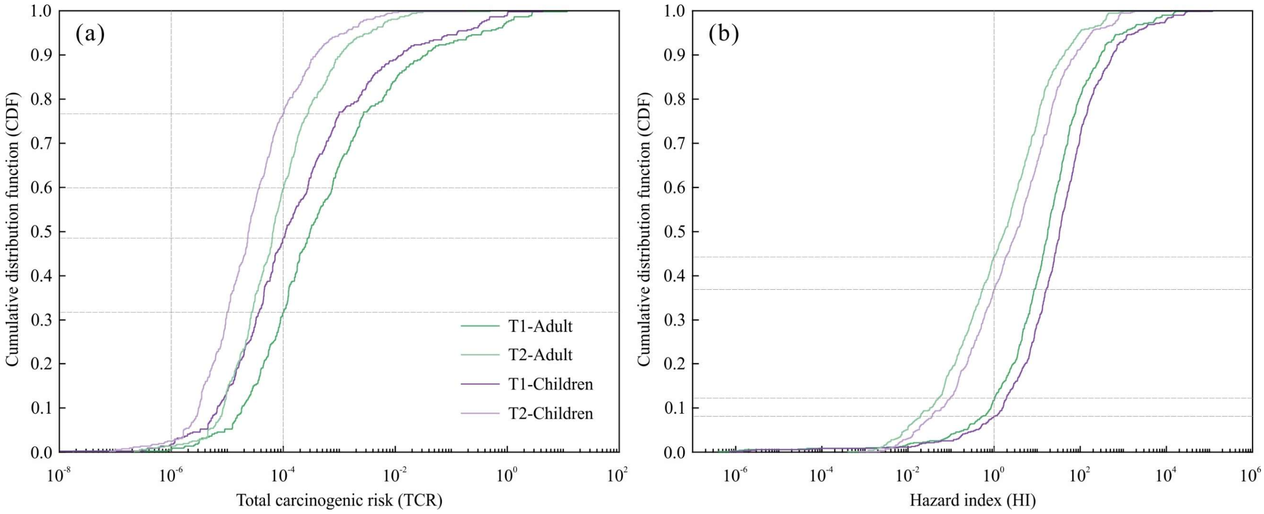

Figure S9. The cumulative distribution function (CDF) of (a) total carcinogenic risk (TCR) and (b) hazard index (HI) in mining-affected water. TCR > 10^{-4} signifies a significant risk to human health, while $10^{-6} \leq$ TCR $\leq 10^{-4}$ represents an acceptable risk level. Similarly, HI > 1 suggests potential adverse health effects, whereas HI < 1 indicates no non-carcinogenic risk (NCR). T1 category includes mine drainage, mine water, and leachate water, while T2 category indicates mining-affected surface water and groundwater.

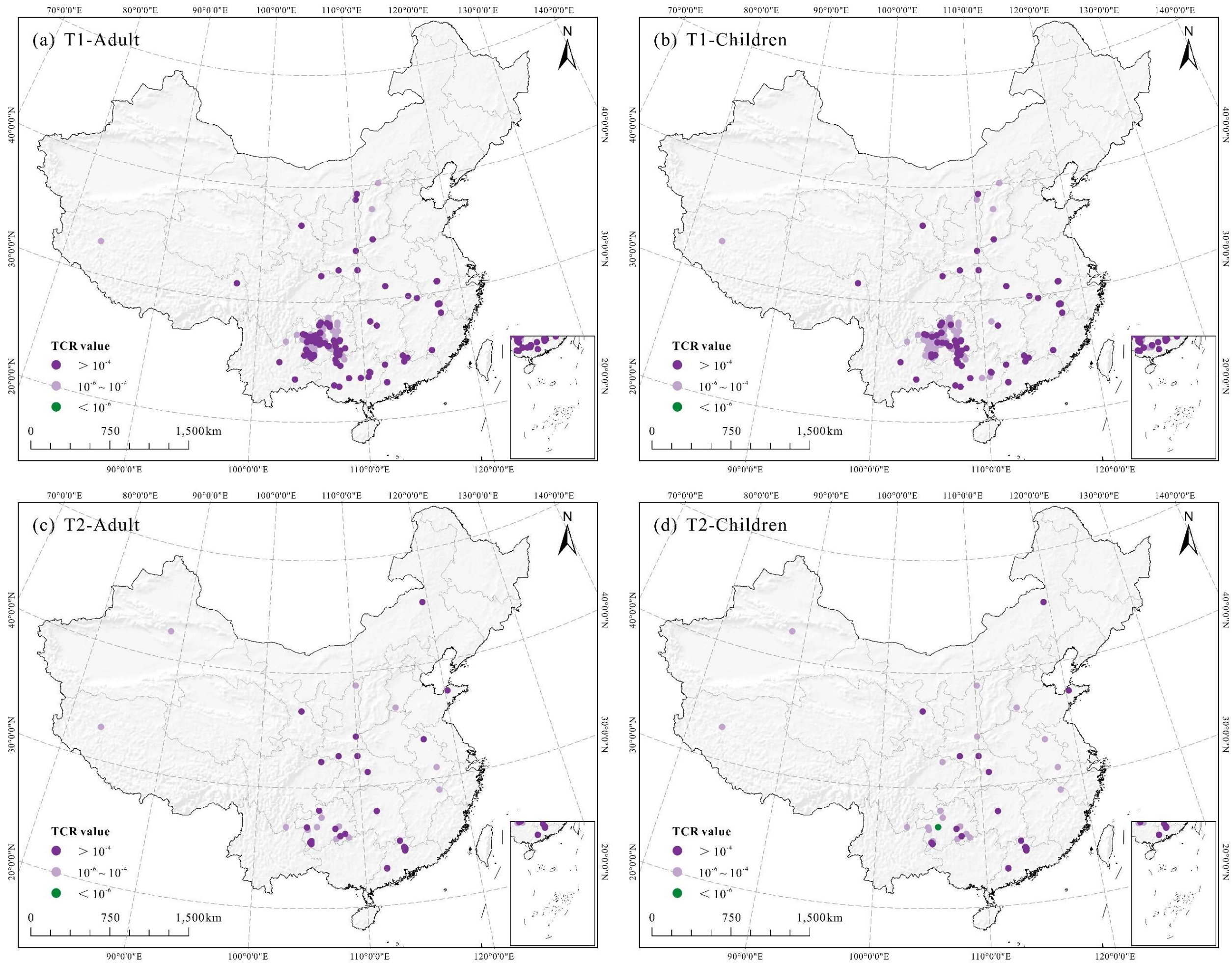

Figure S10. The spatial distribution of total carcinogenic risk (TCR) levels for (a) T1-Adult, (b) T1-Children, (c) T2-Adult, and (d) T2-Children. TCR > 10^{-4} signifies a significant risk to human health, while $10^{-6} \leq$ TCR $\leq 10^{-4}$ represents an acceptable risk level. T1 category includes mine drainage, mine water, and leachate water, while T2 category indicates mining-affected surface water and groundwater.

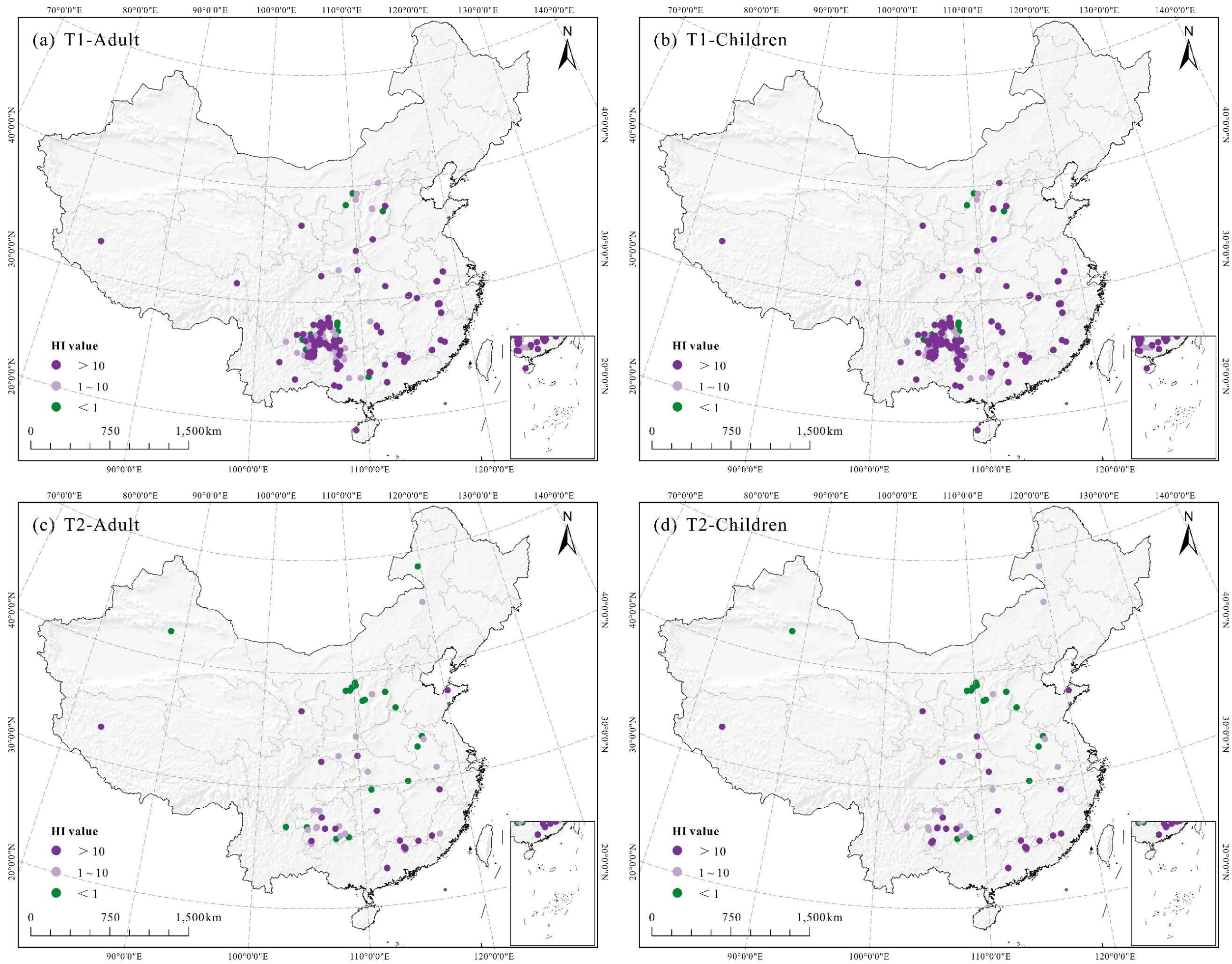

Figure S11. The spatial distribution of hazard index (HI) levels for (a) T1-Adult, (b) T1-Children, (c) T2-Adult, and (d) T2-Children. HI > 1 suggests potential adverse health effects, whereas HI < 1 indicates no non-carcinogenic risk (NCR). T1 category includes mine drainage, mine water, and leachate water, while T2 category indicates mining-affected surface water and groundwater.

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