Supplementary Materials:

Environmental implications of the soil-to-groundwater migration of heavy metals in mining area hotspots

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Table S1. Sampling locations with location description

Sampling location	E	N	Location description
GW1	21.9052025	44.3765720	Borehole in Debeli Lug settlement close to to the filtration unit
GW2	21.9155865	44.4162838	Borehole near Mechanical workshop next to the overburden transit station
GW3	21.9036816	44.3761259	Borehole near Filtration unit
GW4	21.9040206	44.3767426	Borehole near Filtration unit
GW5	21.9022473	44.3768158	Borehole in farmland in the surrounding of the Filtration unit toward the river
GW6	21.9015008	44.3766601	Borehole in farmland in the surrounding of the Filtration unit toward the river
GW7	21.9203926	44.4032048	Borehole near heavy vehicles service area around main building
GW8	21.9230903	44.4042841	Borehole near Secondary grinding facility
GW9	21.9646152	44.3957840	Borehole near dam “Vancev Potok”

Table S2. Groundwater pollution classification criteria according to the various pollution indices.

Pollution index	Classification criteria	Pollution level	Reference
PI	$PI \leq 0.7$	No pollution	(Han et al., 2023; Pan et al., 2023)
	$0.7 < PI \leq 1$	Warning pollution	
	$1 < PI \leq 2$	Light pollution	
	$2 < PI \leq 3$	Moderate pollution	
	$PI > 3$	Heavy pollution	
NPI	$NI \leq 0.7$	No pollution	(Eyankware et al., 2023; Han et al., 2023)
	$0.7 < NI \leq 1$	Warning pollution	
	$1 < NI \leq 2$	Light pollution	
	$2 < NI \leq 3$	Moderate pollution	
	$NI > 3$	Heavy pollution	
HPI	$HPI < 15$	Low pollution	(Pan et al., 2023; Vig et al., 2023)
	$15 \leq HPI \leq 30$	Medium pollution	
	$HPI > 30$	High pollution	
	$HEI > 20$	High pollution	

Table S3. Reference dose and dermal permeability coefficient of heavy metals in groundwater.

Heavy metal	RfD_{ing} (mg/kg-day)	RfD_{derm} (mg/kg-day)
As	0.0003	0.000123
Cd	0.001	0.00001
Cr	0.003	0.00006
Cu	0.04	0.012
Hg	0.0003	0.000021
Ni	0.02	0.0054
Pb	0.0035	0.000525
Mn	0.14	0.00184
Zn	0.3	0.06
Co	0.02	0.016

Table S4. Cancer slope factors of heavy metals in groundwater.

Heavy metal	SF_{ing} (mg/kg-day)	SF_{derm} (mg/kg-day)
Cr	0.5	20
Pb	0.0085	-
Cd	6.1	6.1
As	1.5	3.66

Table S5. Descriptive statistics of groundwater (μg/L) and soil (mg/kg) parameters.

Groundwater									
Variable	Minimum	Maximum	Mean	Median	SD	CV	Skewness	Kurtosis	WHO (2022)
As	2.7	20.1	11.2	11.4	6	53.7	0.25	-1.14	10
Cd	0.71	6.23	2.36	1.98	1.879	79.6	1.42	1.18	3
Cr	4.2	34.6	16.52	13.5	11.54	69.9	0.37	-1.47	50
Cu	57	2934	953	347	1091	114.5	1.02	-0.62	2000
Hg	0.05	0.29	0.16	0.14	0.09	57.5	0.34	-1.29	6
Ni	16	46	28.78	27	10.65	37.0	0.62	-0.99	70
Pb	4.1	47.8	16.3	16.1	13.6	83.2	1.69	3.63	10
Mn	23	51	37.89	38	9.62	25.4	-0.1	-1.2	80
Zn	88	495	234.7	197	144.6	61.6	0.93	-0.3	5000
Co	14	105	51.78	40	28.5	55.0	0.7	-0.11	/

Soil									
Variable	Minimum	Maximum	Mean	Median	SD	CV	Skewness	Kurtosis	UCC
As	12	49	27.44	28	12.95	47.2	0.49	-1.08	4.8
Cd	0.31	4.01	1.43	1.05	1.174	82.1	1.56	2.27	0.09
Cr	20	195	87.1	77	62.3	71.5	0.64	-0.73	92
Cu	31	1443	455	178	530	116.4	1.15	-0.21	28
Hg	0.24	1.81	0.95	0.93	0.56	59.2	0.57	-0.71	0.05
Ni	24	58	35.33	32	11.14	31.5	1.16	0.93	47
Pb	18	186	62	53	52.3	84.4	1.89	4.23	17
Mn	342	632	457.4	439	107.2	23.4	0.89	-0.37	997
Zn	128	611	289.6	207	179.6	62.0	1.08	-0.29	67
Co	9.7	39	19.3	16	9.59	49.7	1.22	0.98	17.3

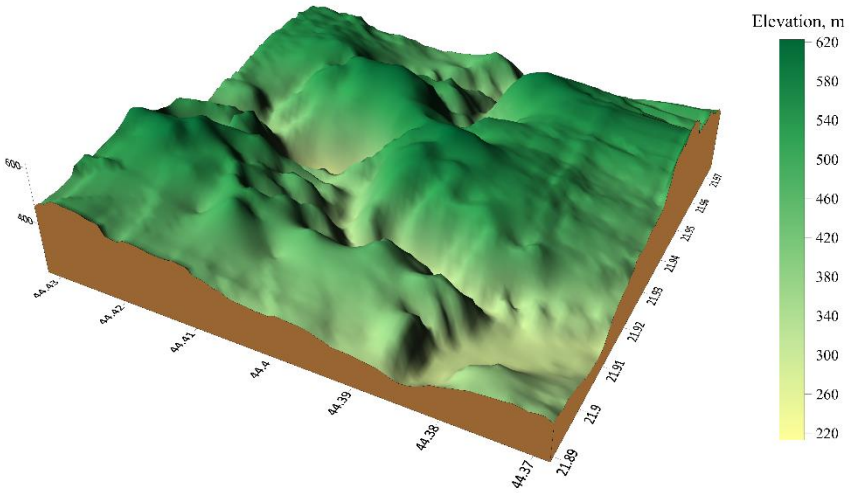


Figure S1. 3D topographic map of the study area

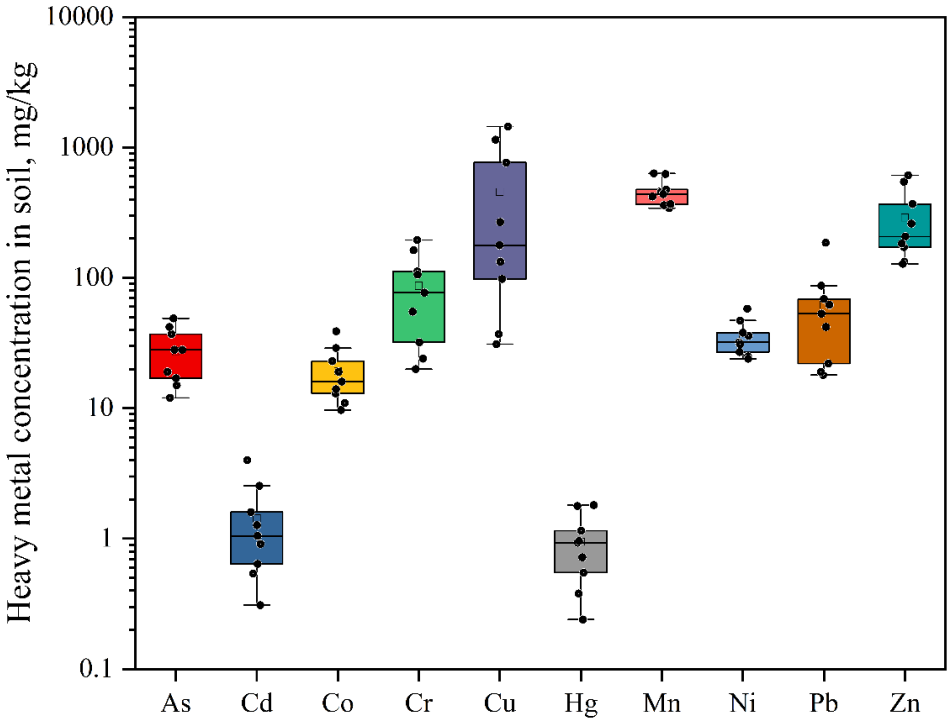


Figure S2. Box plots of heavy metals content in soil

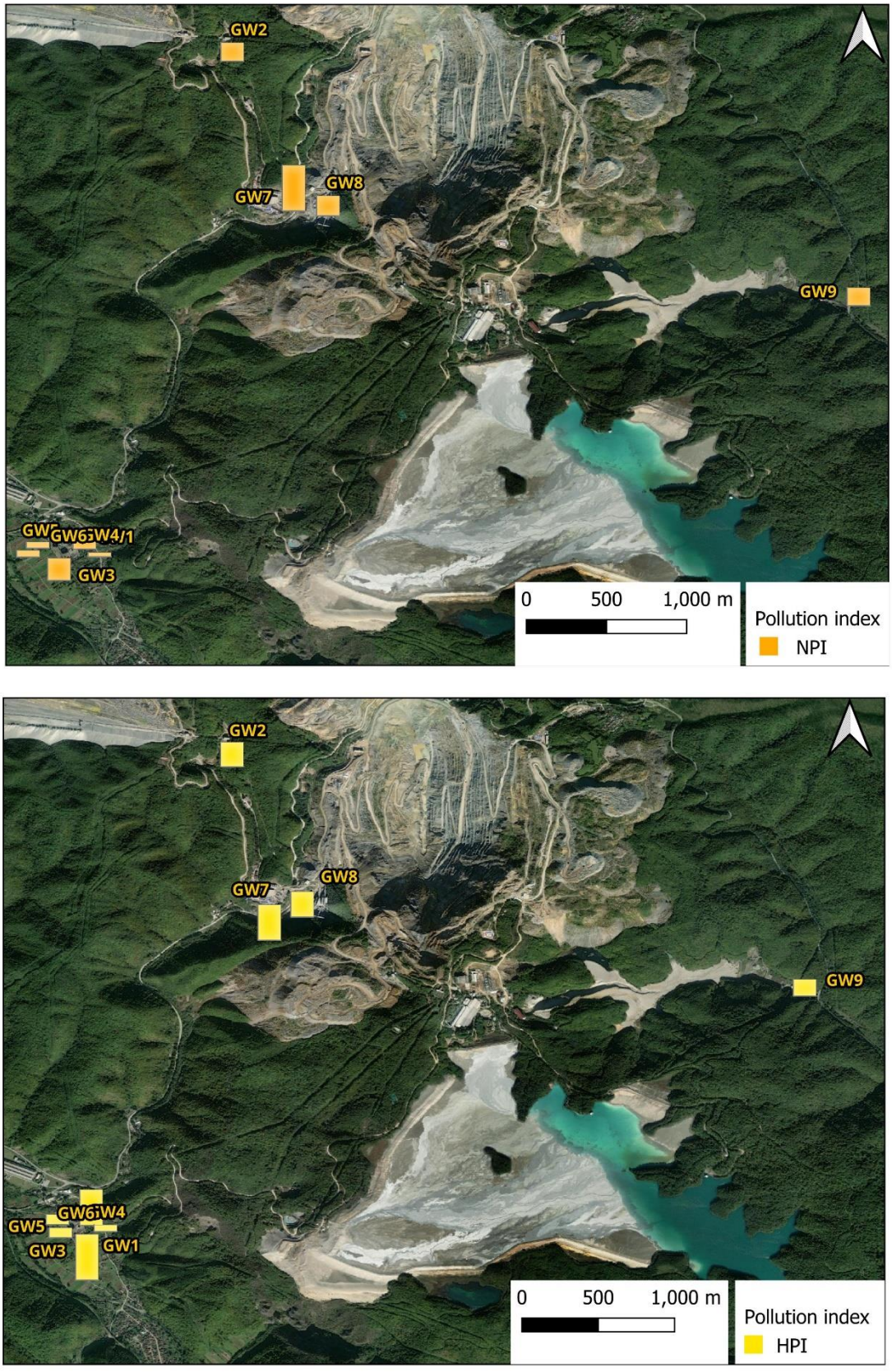


Figure S3. *NPI* and *HPI* values at each sampling location

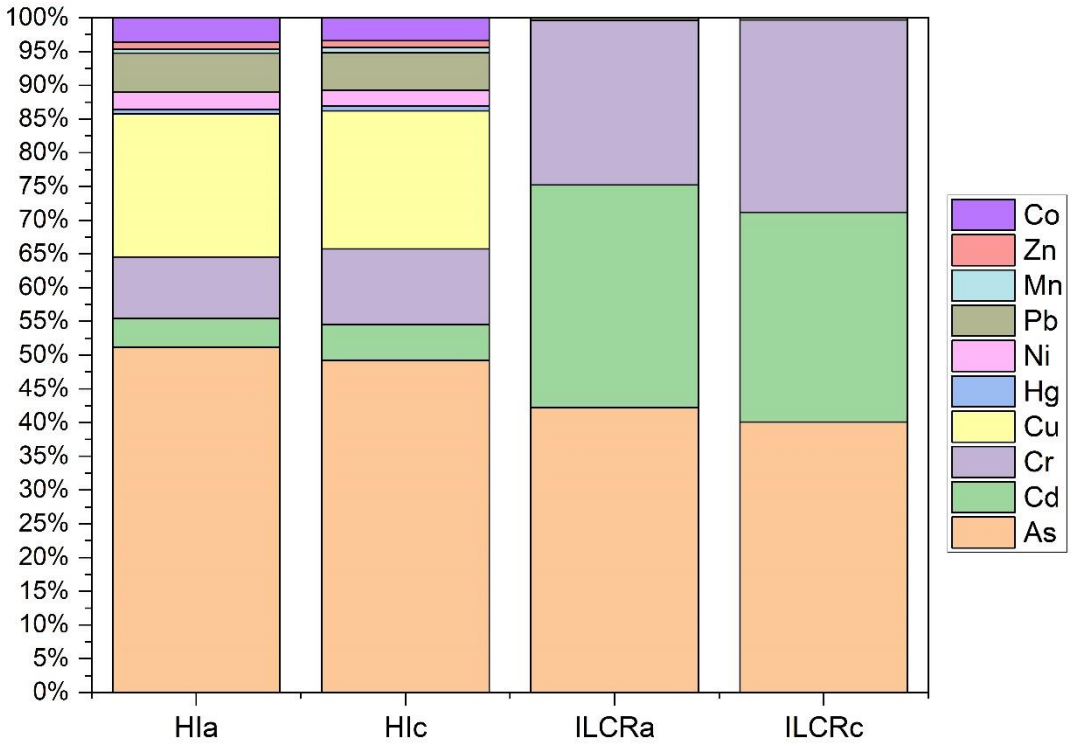


Figure S4. The proportion of each of the investigated heavy metals in non-carcinogenic and carcinogenic risk for adults and children