

**Supplementary file caption:**

**Fig. S1** Variable importance plot from random forest algorithm representing effects of available heavy metals (Pb, Cu, Cd, Cr, and Ni) on uptake by root, shoot, and grain.

**Fig. S2** Box-whisker plot comparing Geoaccumulation index ( $I_{geo}$ ), contamination factor ( $C_f$ ), contamination index (CI), pollution load index (PLI), and ecological risk index among the coal mine contaminated zones (zone 1 and 2) and uncontaminated zone (zone 3).

**Fig. S3** Source apportionment and factor profiles of heavy metals (Pb, Cu, Cd, Cr, and Ni) from the PMF model.

**Fig. S4** Spatial distribution HMs (Pb, Cu, Cd, Cr, and Ni) in coal mine contaminated zones (zone 1 and zone 2) and uncontaminated zone (zone 3).

**Fig. S5** Spatial distribution of four factors derived from the PMF model for contaminated zones (zone 1 and 2) from coal mine affected soil.

**Fig. S6** Comparison between observed and predicted HMs concentration resulted from FIAM analysis of rice grain grown in zone 1.

**Fig. S7** Comparison between observed and predicted HMs concentration resulted from FIAM analysis of rice grain grown in zone 2.

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**Table S5** Fuzzy TOPSIS performance score values of HMs concentrations in rice plant grown in coal mine contaminated soil

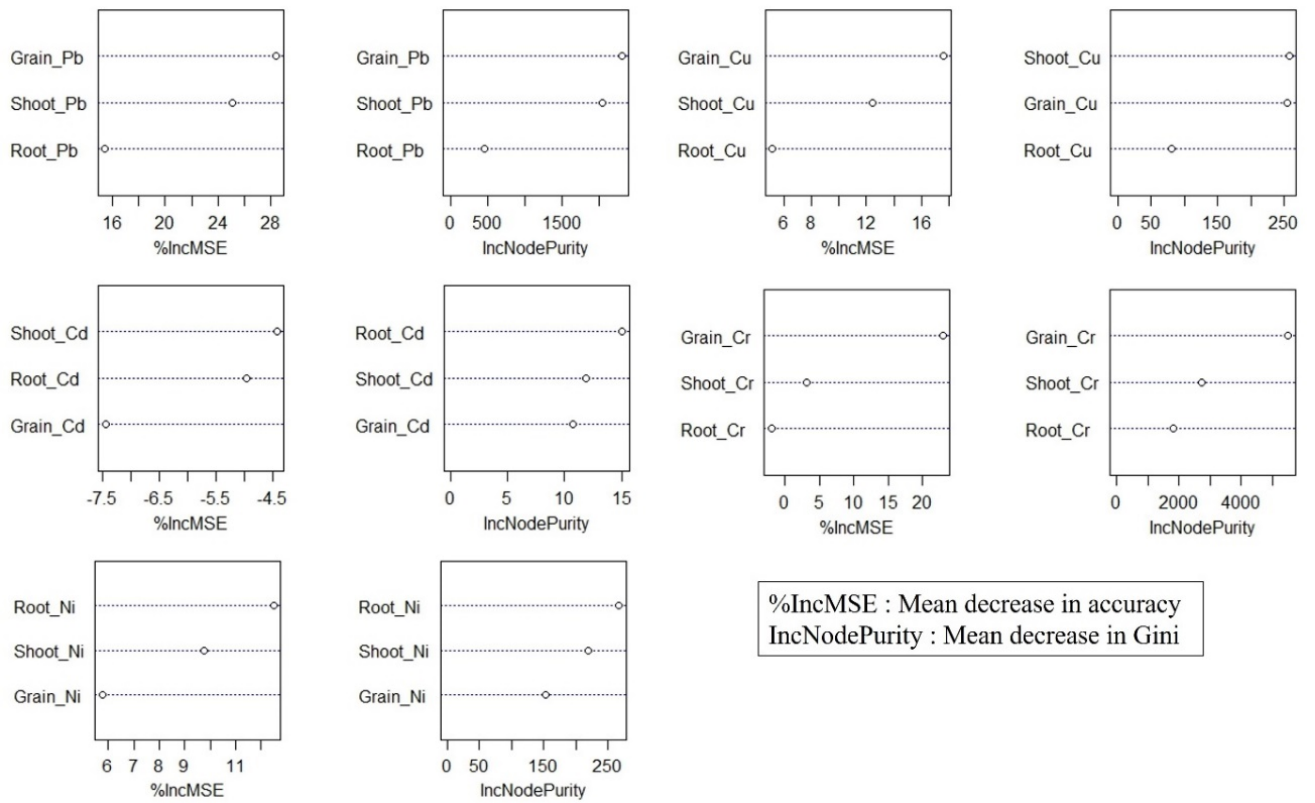
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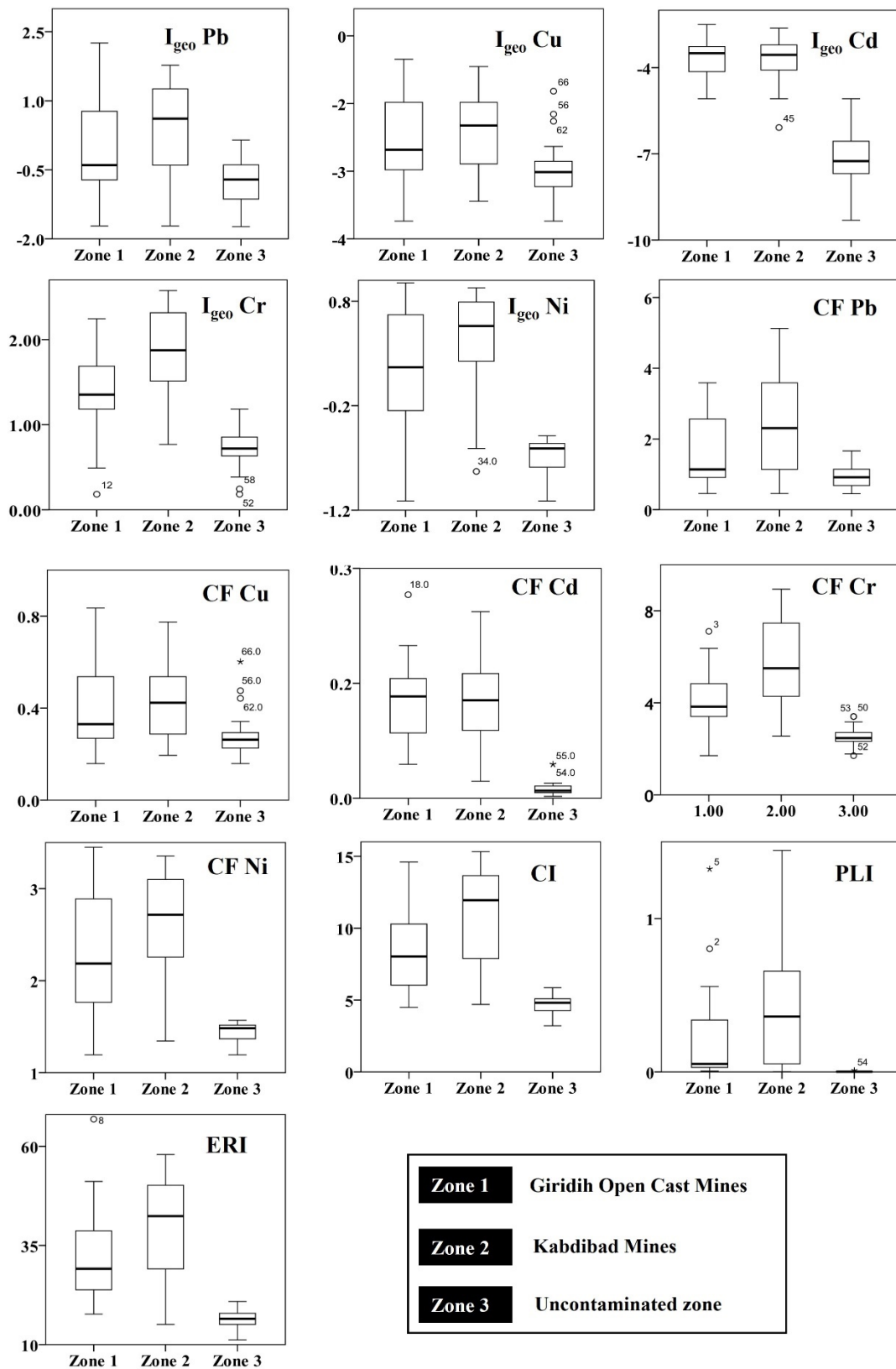
**Table S8** Carcinogenic risk (three exposure pathway) and total cancer risk values on adults and children

**Table S9** Regression diagnostics test parameters recovered from the PMF (positive matrix factorization)

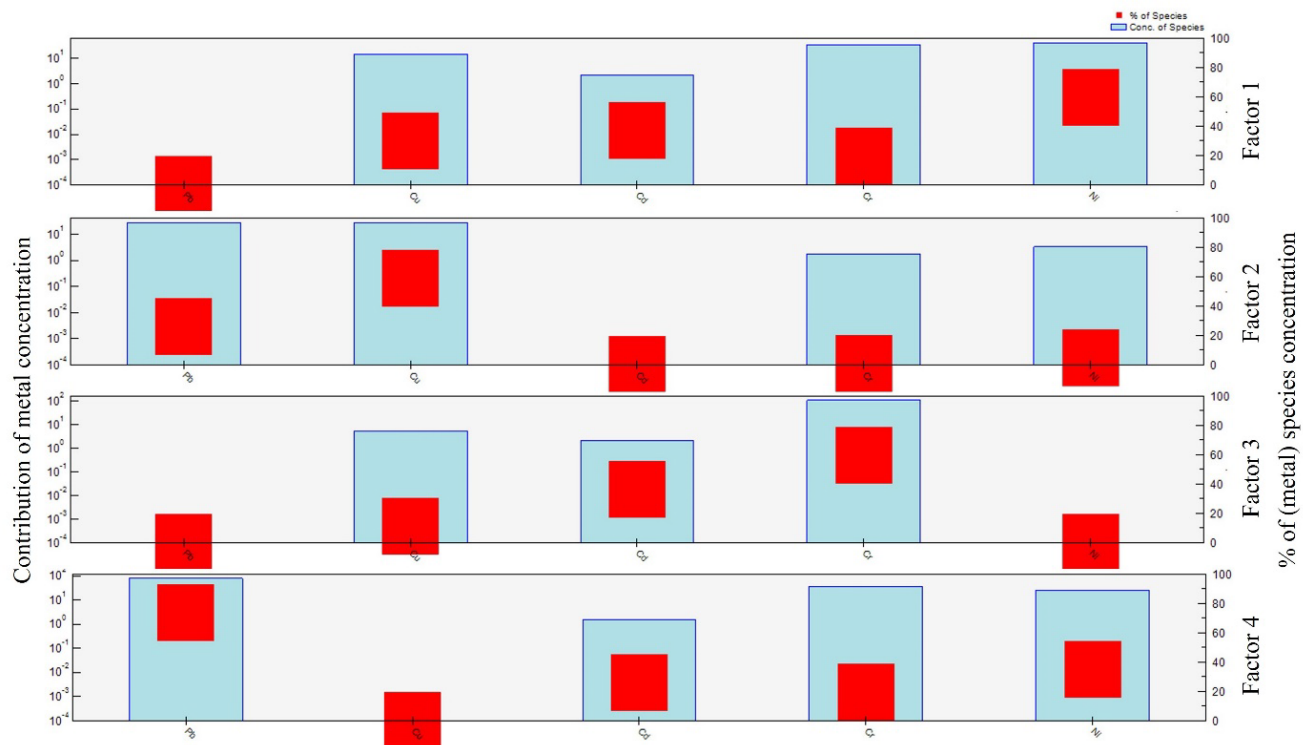
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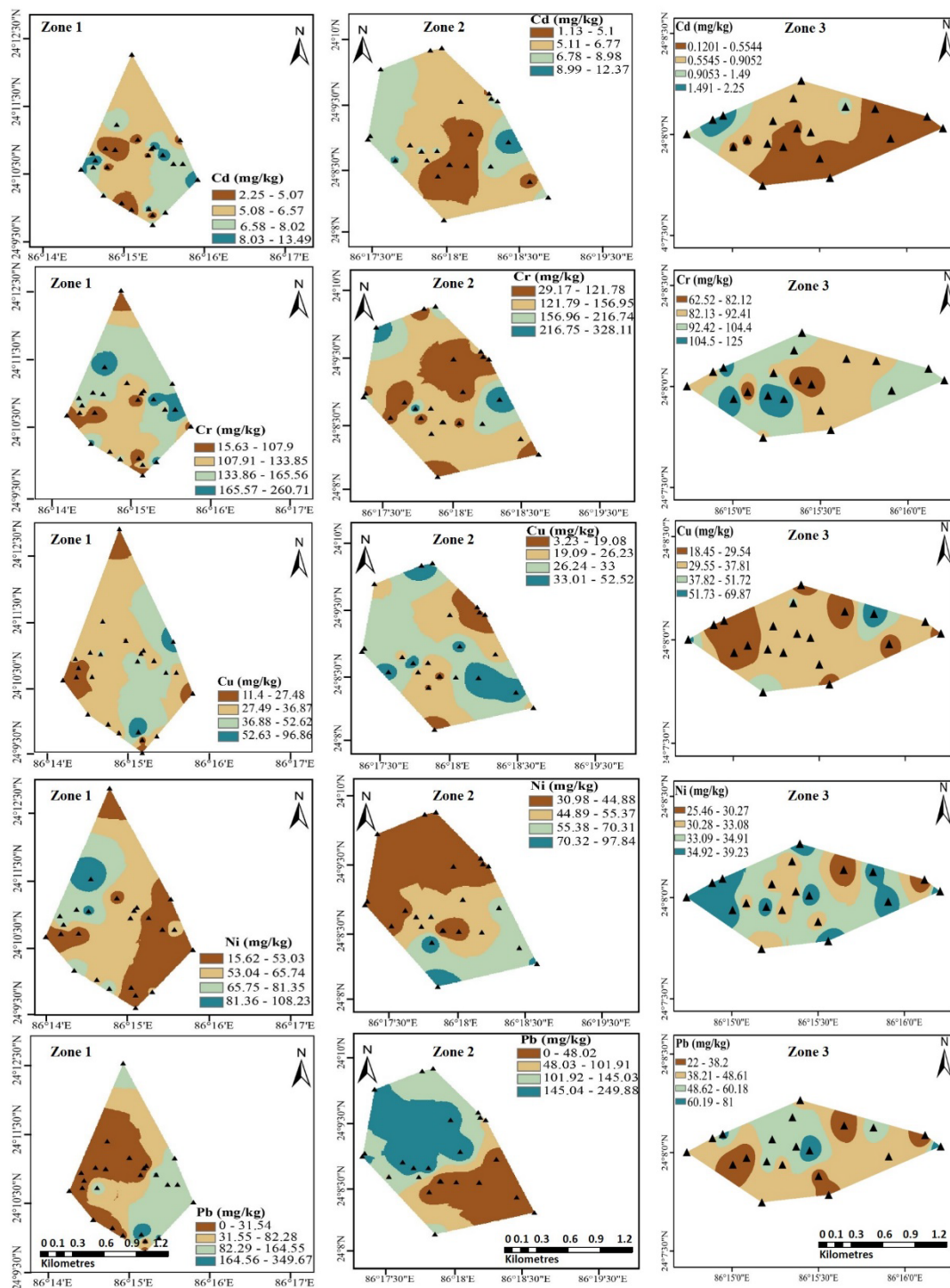
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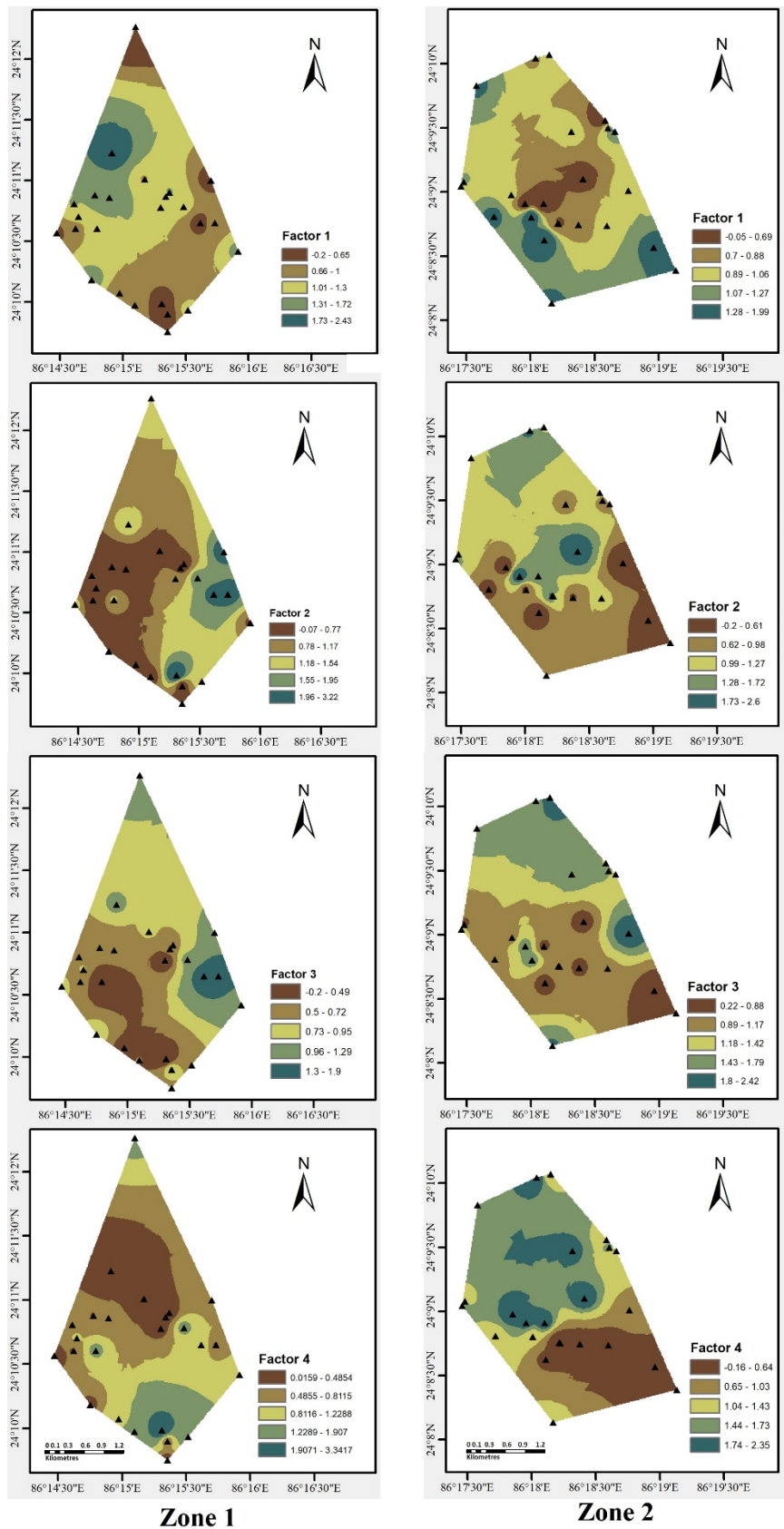
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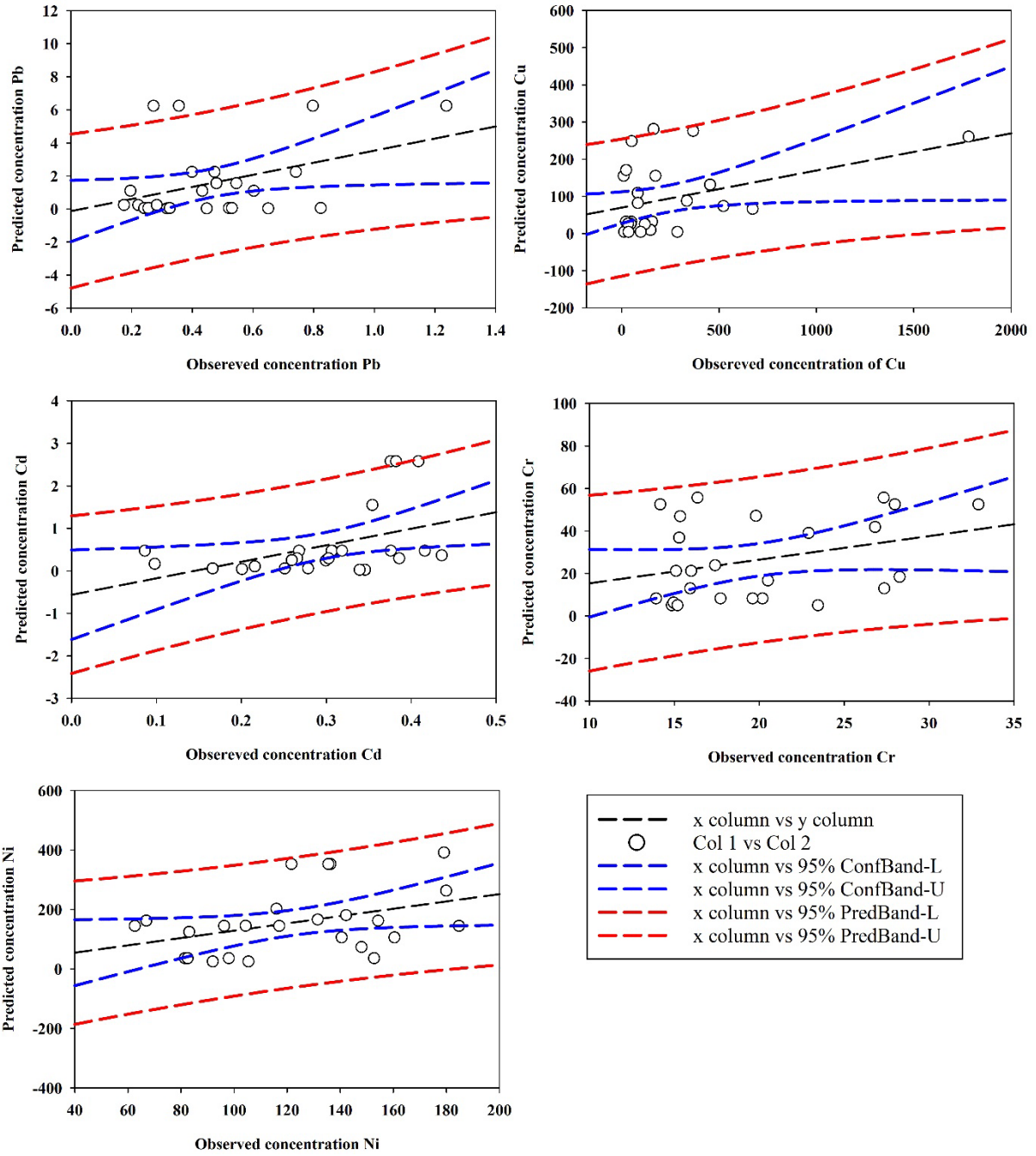
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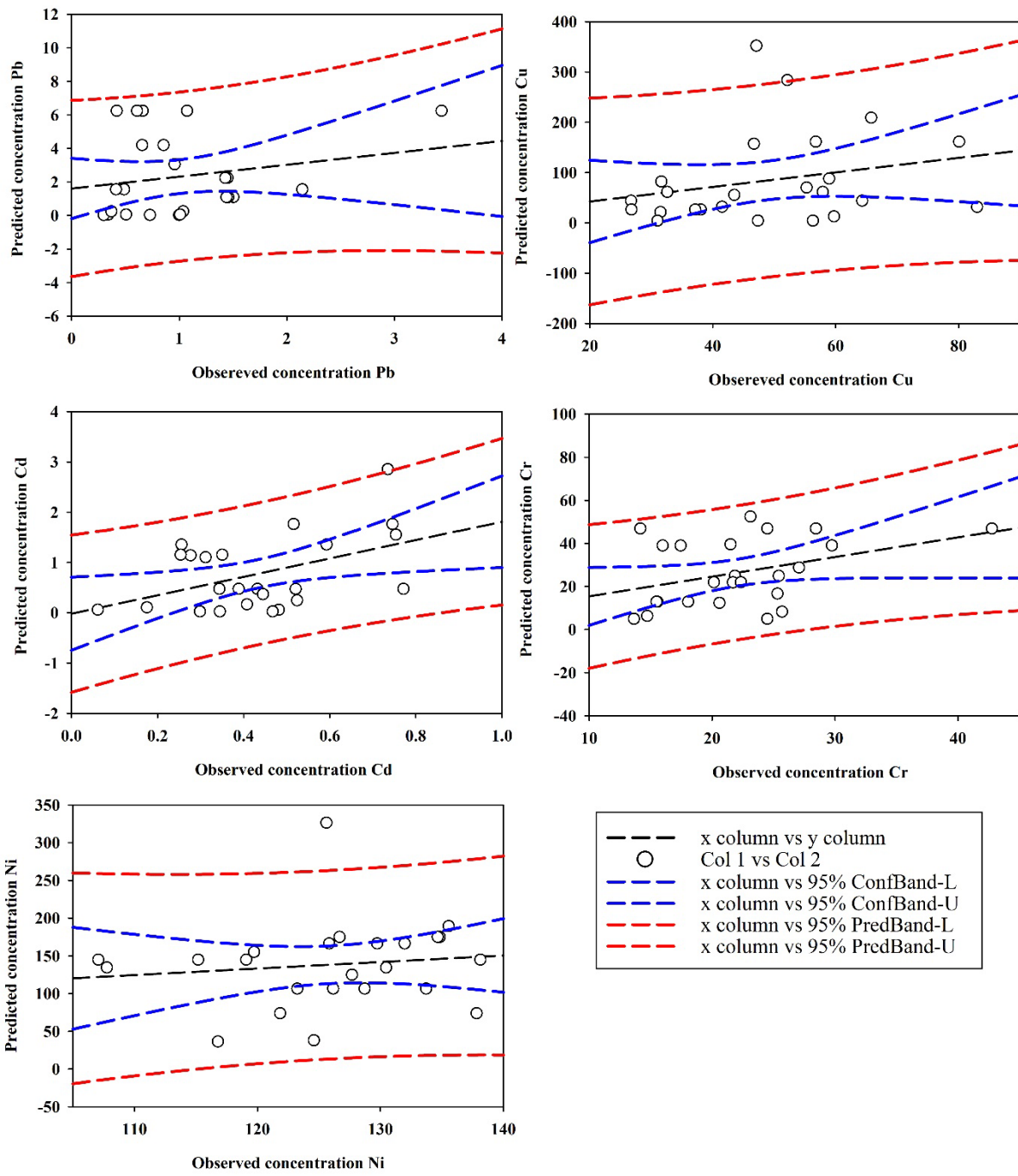
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**Fig. S6** Comparison between observed and predicted HMs concentration resulted from FIAM analysis of rice grain grown in zone 1.



**Fig. S7** Comparison between observed and predicted HMs concentration resulted from FIAM analysis of rice grain grown in zone 2.

**Table S1** Coordinates of soil sample collected from contaminated zone (zone 1 and 2) and uncontaminated zone (zone 3)

Zone 1 (Giridih Open Cast Mines)			Zone 2 (Kabdibad Mines)			Zone 3 (Uncontaminated Zone)		
Sample ID	Latitude	Longitude	Sample ID	Latitude	Longitude	Sample ID	Latitude	Longitude
G1	24.17361	86.265278	K1	24.16386	86.2929763	C1	24.13232	86.254853
G2	24.16556	86.258611	K2	24.14679	86.2952714	C2	24.13259	86.25334246
G3	24.1775	86.262222	K3	24.15135	86.2913227	C3	24.13289	86.25140054
G4	24.17675	86.2465793	K4	24.15834	86.3100862	C4	24.13232	86.25007553
G5	24.17972	86.258056	K5	24.15171	86.3068546	C5	24.1349	86.24910313
G6	24.20444	86.251667	K6	24.15788	86.3110131	C6	24.13456	86.24811422
G7	24.1775	86.260278	K7	24.14672	86.3001223	C7	24.13337	86.24563622
G8	24.16641	86.25517002	K8	24.13556	86.302778	C8	24.13446	86.25386367
G9	24.18333	86.261667	K9	24.15934	86.309729	C9	24.13385	86.25618069
G10	24.18168	86.25614601	K10	24.16745	86.3006423	C10	24.13352	86.25747432
G11	24.18115	86.25567968	K11	24.14851	86.3016964	C11	24.13136	86.25833673
G12	24.17963	86.25503061	K12	24.14965	86.2975128	C12	24.12976	86.25931414
G13	24.18349	86.25285998	K13	24.15786	86.3053027	C13	24.12912	86.25287476
G14	24.181	86.2482079	K14	24.16789	86.3024554	C14	24.13633	86.25581704
G15	24.1813	86.24626116	K15	24.15072	86.290963	C15	24.13778	86.25657022
G16	24.18711	86.24855584	K16	24.14849	86.2992838	C16	24.13563	86.26080468
G17	24.1801	86.24350344	K17	24.14593	86.3035563	C17	24.13546	86.26363341
G18	24.17839	86.24409366	K18	24.1459	86.3036914	C18	24.13301	86.26509951
G19	24.16969	86.24584505	K19	24.14376	86.3018148	C19	24.13386	86.27011303
G20	24.16787	86.24956686	K20	24.14573	86.3062473	C20	24.13482	86.26860667
G21	24.16622	86.25159452	K21	24.14562	86.3099559			
G22	24.16494	86.25591818	K22	24.15019	86.3127231			
G23	24.16252	86.2559185	K23	24.13981	86.318885			
G24	24.17672	86.24368916	K24	24.14276	86.3160225			
G25	24.1761	86.2411845						

**Table S2** Physio-chemical, total and DTPA extractable HMs in soil collected from coal mine contaminated zones (zone 1 and zone 2) and uncontaminated zone (zone 3).

	<b>Zone 1 (Giridih open cast mines)</b>	<b>Zone 2 (Kabdibad mines)</b>	<b>Zone 3 (uncontaminated zone)</b>
<b>Parameter</b>	Mean	Mean	Mean
<b>pH</b>	6.01±0.5	6.21±0.51	6.93±0.3
<b>EC (mS cm<sup>-1</sup>)</b>	0.03±0.02	0.04±0.02	0.05±0.02
<b>OC (%)</b>	1.33±0.96	2.16±1.23	0.94±0.14
<b>Total HMs concentration (mg kg<sup>-1</sup>)</b>			
<b>Pb</b>	108.24±72.97	139.56±69.46	46.33±17.02
<b>Cu</b>	57.26±23.91	69.89±19.86	33.03±12.41
<b>Cd</b>	8.44±2.76	8.95±2.57	0.70±0.57
<b>Cr</b>	180.05±46.90	245.46±70.66	93.83±17.70
<b>Ni</b>	70.79±25.06	95.46±22.89	34.18±3.89
<b>DTPA-extractable HMs concentration (mg kg<sup>-1</sup>)</b>			
<b>Pb</b>	16.46±10.60	22.56±9.74	1.49±0.34
<b>Cu</b>	5.67±4.23	6.5±4.48	2.92±0.39
<b>Cd</b>	2.43±0.91	2.67±1.06	0.08±0.05
<b>Cr</b>	30.37±10.50	44.35±13.56	9.38±1.78
<b>Ni</b>	15.67±3.64	16.72±3.73	3.44±0.36

**Table S3** FIAM parameters for predicting uptake of HMs by rice as a function of pH, Walkley Black organic-C and DTPA extractable PTEs, FIAM-HQ for intake of HMs through consumption of rice grains grown on coal mine contaminated soil

	<b>Zone 1</b>				<b>Zone 2</b>				<b>Zone 3</b>			
	Constant	$\beta_1$	$\beta_2$	HQ	Constant	$\beta_1$	$\beta_2$	HQ	Constant	$\beta_1$	$\beta_2$	HQ
<b>Pb</b>	0.31	-0.12	0.26	1.61	1.25	-0.24	0.13	2.14	1.72	-0.11	-0.01	0.08
<b>Cu</b>	0.48	-0.41	0.69	0.10	-0.64	-0.12	0.24	0.09	-0.22	-0.05	-0.06	0.03
<b>Cd</b>	2.10	-0.21	-0.20	3.81	1.08	-0.21	0.14	4.53	0.91	-0.15	0.02	0.15
<b>Cr</b>	-0.16	-0.07	-0.04	9.39	-0.72	0.00	0.02	9.60	0.91	-0.15	0.02	0.15
<b>Ni</b>	1.66	-0.24	0.09	3.45	-1.55	0.13	0.41	3.38	-0.05	-0.09	0.04	0.51

**Table S4** Dietary risk (SAMOE and TCR) of HMs from rice grains grown on coal mine contaminated soil

<b>Metal</b>	<b>Zone 1</b>	<b>Zone 2</b>	<b>Zone 3</b>
<b>SAMOE</b>			
<b>Pb</b>	0.570	0.430	2.65
<b>Cu</b>	0.920	0.940	1.06
<b>Cd</b>	0.160	0.150	2.71
<b>Cr</b>	0.060	0.050	0.23
<b>Ni</b>	0.040	0.030	0.13
<b>TCR</b>			
<b>Pb</b>	2.37E-04	3.15E-04	5.13E-06
<b>Cd</b>	1.45E-03	1.72E-03	9.27E-05
<b>Cr</b>	1.41E-02	1.44E-02	6.29E-04
<b>Ni</b>	6.29E-02	6.16E-02	1.97E-04

**Table S5** Fuzzy TOPSIS performance score values of HMs concentrations in rice plant grown in coal mine contaminated soil

<b>HMs</b>	<b>Zone 1</b>				<b>Zone 2</b>				<b>Zone 3</b>			
	<b>Si+</b>	<b>Si-</b>	<b>Pi</b>	<b>Rank</b>	<b>Si+</b>	<b>Si-</b>	<b>Pi</b>	<b>Rank</b>	<b>Si+</b>	<b>Si-</b>	<b>Pi</b>	<b>Rank</b>
<b>Pb</b>	0.378637	0.100775	0.210205	5	0.360902	0.123079	0.254306	5	0.38127	0.164544	0.301465	4
<b>Cu</b>	0.198209	0.271195	0.577743	2	0.168593	0.260535	0.607126	2	0.207322	0.365437	0.63803	1
<b>Cd</b>	0.41816	0.147846	0.26121	4	0.395921	0.143283	0.265731	4	0.398914	0.200442	0.334429	5
<b>Cr</b>	0.259273	0.274694	0.51444	3	0.259653	0.226501	0.465903	3	0.330437	0.227994	0.408276	3
<b>Ni</b>	0.153611	0.364463	0.703497	1	0.108069	0.375445	0.776493	1	0.172404	0.29359	0.63003	2

**Table S6** Average daily dose (ingestion, inhalation, and dermal) values on children and adults

<b>HMs</b>	<b>Child</b>			<b>Adult</b>		
	ADD <sub>ing</sub>	ADD <sub>inh</sub>	ADD <sub>der</sub>	ADD <sub>ing</sub>	ADD <sub>inh</sub>	ADD <sub>der</sub>
<b>Zone 1</b>						
<b>Pb</b>	6.07E-04	1.69E-08	6.98E-07	6.50E-05	9.56E-09	9.76E-08
<b>Cu</b>	3.11E-04	8.68E-09	3.57E-07	3.33E-05	4.90E-09	5.00E-08
<b>Cd</b>	4.23E-05	1.18E-09	4.87E-08	4.54E-06	6.67E-10	6.81E-09
<b>Cr</b>	9.87E-04	2.76E-08	1.13E-06	1.06E-04	1.55E-08	1.59E-07
<b>Ni</b>	4.33E-04	1.21E-08	4.97E-07	4.63E-05	1.55E-08	6.96E-08
<b>Zone 2</b>						
<b>Pb</b>	7.86E-04	2.20E-08	9.04E-07	8.42E-05	1.24E-08	1.26E-07
<b>Cu</b>	3.28E-04	9.17E-09	3.77E-07	3.51E-05	5.17E-09	5.28E-08
<b>Cd</b>	4.18E-05	1.17E-09	4.80E-08	4.48E-06	6.58E-10	6.72E-09
<b>Cr</b>	1.42E-03	3.96E-08	1.63E-06	1.52E-04	2.23E-08	2.28E-07
<b>Ni</b>	4.96E-04	1.39E-08	5.71E-07	5.32E-05	2.23E-08	7.98E-08
<b>Zone 3</b>						
<b>Pb</b>	3.05E-04	8.51E-09	3.50E-07	3.26E-05	4.80E-09	4.90E-08
<b>Cu</b>	2.17E-04	6.07E-09	2.50E-07	2.33E-05	3.42E-09	3.49E-08
<b>Cd</b>	4.59E-06	1.28E-10	5.28E-09	4.92E-07	7.23E-11	7.38E-10
<b>Cr</b>	6.17E-04	1.72E-08	7.10E-07	6.61E-05	9.72E-09	9.93E-08
<b>Ni</b>	2.25E-04	6.28E-09	2.58E-07	2.41E-05	9.72E-09	3.62E-08

**Table S7** Non-carcinogenic risk in terms of HQ (ingestion, inhalation, and dermal) and HI on children and adults

HMs	Child				Adult			
	HQing	HQinh	HQder	HI	HQing	HQinh	HQder	HI
<b>Zone 1</b>								
<b>Pb</b>	1.73E-01	4.84E-06	1.32E-03	1.75E-01	1.86E-02	2.73E-06	1.84E-04	1.88E-02
<b>Cu</b>	7.77E-03	1.93E-07	8.93E-06	7.78E-03	8.32E-04	1.09E-07	1.25E-06	8.34E-04
<b>Cd</b>	4.23E-02	2.08E-05	4.87E-05	4.24E-02	4.54E-03	1.17E-05	6.81E-06	4.55E-03
<b>Cr</b>	6.58E-04	9.19E-04	3.78E-04	1.95E-03	7.05E-05	5.18E-04	5.29E-05	6.42E-04
<b>Ni</b>	2.16E-02	4.83E-07	2.49E-05	2.17E-02	2.32E-03	6.22E-07	3.48E-06	2.32E-03
<b>Zone 2</b>								
<b>Pb</b>	2.25E-01	6.28E-06	1.71E-03	2.26E-01	2.41E-02	3.54E-06	2.39E-04	2.43E-02
<b>Cu</b>	8.20E-03	2.04E-07	9.43E-06	8.21E-03	8.79E-04	1.15E-07	1.32E-06	8.80E-04
<b>Cd</b>	4.18E-02	2.05E-05	4.80E-05	4.18E-02	4.48E-03	1.15E-05	6.72E-06	4.49E-03
<b>Cr</b>	9.44E-04	1.32E-03	5.43E-04	2.81E-03	1.01E-04	7.44E-04	7.60E-05	2.81E-03
<b>Ni</b>	2.48E-02	5.55E-07	2.85E-05	2.48E-02	2.66E-03	8.93E-07	3.99E-06	2.66E-03
<b>Zone 3</b>								
<b>Pb</b>	8.70E-02	2.43E-06	6.61E-04	8.77E-02	9.32E-03	1.37E-06	9.25E-05	9.42E-03
<b>Cu</b>	5.43E-03	1.35E-07	6.24E-06	5.44E-03	5.82E-04	7.60E-08	8.73E-07	5.83E-04
<b>Cd</b>	4.59E-03	2.25E-06	5.28E-06	4.60E-03	4.92E-04	1.27E-06	7.38E-07	4.94E-04
<b>Cr</b>	4.11E-04	5.75E-04	2.37E-04	1.22E-03	4.41E-05	3.24E-04	3.31E-05	4.01E-04
<b>Ni</b>	1.12E-02	2.51E-07	1.29E-05	1.12E-02	1.20E-03	3.89E-07	1.81E-06	1.21E-03

**Table S8** Carcinogenic risk (three exposure pathway) and total cancer risk values on adults and children

HMs	CR		TCR	
	Child	Adult	Child	Adult
<b>Zone 1</b>				
Pb	1.09E-06	9.37E-07	3.99E-05	3.42E-05
Cd	6.91E-07	5.92E-07		
Cr	2.12E-05	1.82E-05		
Ni	1.69E-05	1.45E-05		
<b>Zone 2</b>				
Pb	1.42E-06	1.21E-06	5.19E-05	4.45E-05
Cd	6.82E-07	5.84E-07		
Cr	3.04E-05	2.61E-05		
Ni	1.94E-05	1.66E-05		
<b>Zone 3</b>				
Pb	5.5E-07	4.71E-07	2.27E-05	1.94E-05
Cd	7.49E-08	6.42E-08		
Cr	1.33E-05	1.14E-05		
Ni	8.79E-06	7.52E-06		

**Table S9** Regression diagnostics test parameters recovered from the PMF (positive matrix factorization)

Species	Intercept	Slope	SE	r <sup>2</sup>	KS Test Stat	KS Test P Value
<b>Pb</b>	-0.00629779	0.999997501	0.022177713	1	0.109253	0.602365
<b>Cu</b>	-0.009972451	1.000043539	0.043716712	0.999996	0.106952	0.629414
<b>Cd</b>	4.283191812	0.226657227	1.667066904	0.116359	0.117345	0.509725
<b>Cr</b>	0.689386979	0.996900879	0.637364726	0.999913	0.111115	0.580235
<b>Ni</b>	0.997373879	0.987705692	1.091000346	0.997975	0.114346	0.543454

**Table S10** Semi-variogram characteristics parameters used in geostatistical modelling of total PTEs content. RMSE – root mean square error; AIC – Akaike Information Criterion; MSE – mean square error; RMSSE – root mean square standard error; G – Goodness-of-prediction; ASE – average standard error

<b>Total HMs</b>	<b>Nugget</b>	<b>Partial sill</b>	<b>Spatial dependency</b>	<b>Model</b>	<b>AIC</b>	<b>RMSE</b>	<b>MSE</b>	<b>RMSSE</b>	<b>G</b>	<b>ASE</b>
<b>Zone 1</b>										
<b>Pb</b>	4,339.70	1,315.52	Moderate	Spherical	198.5506	74.57028	-0.00937	1.009584	79.32624	73.72411
<b>Cu</b>	436.2854	142.3696	Moderate	Gaussian	170.2623	23.37763	-0.01344	0.975032	98.53943	24.10028
<b>Cd</b>	7.606961	0	Strong	Gaussian	62.53456	3.026474	-0.02697	1.05916	99.9832	2.869005
<b>Cr</b>	191.3227	2,386.87	Moderate	Gaussian	219.2733	37.87941	0.023777	1.002513	85.32468	41.41993
<b>Ni</b>	465.5605	136.4925	Moderate	Circular	184.4964	28.26059	0.044063	1.078711	97.41641	25.86813
<b>Zone 2</b>										
<b>Pb</b>	0	6,965.03	Strong	Circular	211.5536	57.22033	0.004292	0.878583	82.82071	68.93089
<b>Cu</b>	394.5141	0	Strong	Gaussian	172.6476	20.05908	0.035759	0.977233	98.89684	20.66577
<b>Cd</b>	2.127732	7.44621	Strong	Gaussian	85.48904	2.563003	-0.06407	1.04124	99.98795	2.420661
<b>Cr</b>	1491.329	3,619.90	Moderate	Spherical	232.8255	67.6139	-0.0374	1.065352	15.03446	61.93481
<b>Ni</b>	597.982	0	Strong	Gaussian	189.2399	24.13211	-0.01125	0.928681	97.88454	26.20351
<b>Zone 3</b>										
<b>Pb</b>	1231.53	4,312.53	Moderate	Gaussian	173.3306	68.50013	-0.00815	1.084135	88.76525	81.91142
<b>Cu</b>	242.32	0	Strong	Gaussian	183.6772	27.0318	0.021652	0.988442	98.97146	22.58959
<b>Cd</b>	2.48622	6.887	Strong	Gaussian	72.95604	2.37531	-0.01366	1.015145	99.97624	2.872645
<b>Cr</b>	163.1984	2,532.06	Moderate	Spherical	197.3583	43.2148	-0.01875	0.976244	65.91862	38.98256
<b>Ni</b>	687.5621	0	Strong	Gaussian	173.5423	21.98485	-0.08743	1.087153	97.98527	28.97642