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Baseline Distribution of Selected Critical Metals and Their Relationship with Some Soil Indicators in a Mining Province

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Critical metals (CMs) are essential elements for advanced technologies and green energy applications, driving increased global demand. Establishing baseline/background values for CMs is therefore a crucial topic. The aim of this study is to investigate the contents and baseline distribution of primary CMs (La, Ce, Nb, Zr, Co, V, Ti, Sr) and to reveal their relationships with Al, Si, Fe, Mn, Ca, K, and soil parameters (SOM, pH) in the soils of the Lori province. The contents of studied elements were determined using XRF (Rigaku NEX DE). The mean contents of La, Ce, Nb, Zr, Co, V, Ti, Sr, Al, Si, Fe, Mn, Ca, and K were 30.5, 49.2, 11.6, 230, 14.8, 84.5, 4166, 199, 70218, 241440, 43781, 1227, 16776, and 14390 mg/kg, respectively. Zr, Ti, and Mn exceeded their upper continental crust values by 1.2, 1.2, and 1.8 times, respectively. Boxplot analysis showed that, except for La, Ce, and Nb, the other elements displayed outliers and extreme values. The Shapiro-Wilk test indicated that Ce, Nb, Zr, Si, and Fe followed a normal distribution, while La and Sr exhibited a lognormal distribution. After removing outliers and extreme values, Co, V, Ti, Al, Mn, and K showed normal distributions, whereas Ca exhibited a lognormal distribution. Correlation analysis revealed significant positive intercorrelations among several groups: La, Ce, Nb, V, and Ti; Zr, La, Ce, Nb, and V; Ce, Co, V, Ti, Al, and Fe; Mn, Co, V, Ti, and Fe; Si, K, and Zr; Ca, Sr, and pH; SOM with Nb and Mn. Considering the compositional nature of geochemical data, hierarchical clustering performed on clr-transformed data revealed four clusters: (1) Co, Fe, V, Ti; (2) Sr, Ca; (3) Al, Si, Mn; (4) Zr, K, Ce, Nb. La was excluded from clustering due to 62% non-detect values. After removing outliers and extreme values, all studied elements displayed normal or lognormal distributions, and their median values were considered the geochemical background. The baseline ranges and background values of the studied elements are presented in Table 1.

Table 1

The baseline distribution and background values of studied elements (mg/kg)

Elements	Baseline range		Background values
	5%	95%	
La	22.8	40.6	29.8
Ce	32.0	66.1	48.4
Nb	6.05	17.9	11.5
Zr	144	301	237
Co	8.72	21.9	14.2
V	59.8	107	84.0
Ti	2959	5295	4086
Sr	99.8	313	175
Al	60243	81361	70236
Si	205520	277768	242597
Fe	29766	58994	42890
Mn	815	1677	1162
Ca	5770	28808	12539
K	7542	21060	13828