

Article

Artisanal Mining Contamination of Metal(Loid)s in Madre De Dios River Sediments (Amazon) and Ecological Risk Assessment

Anthony Silvera ¹, Norvin Requena ^{1,*} and Frederico Fábio Mauad ²

¹ Grupo de Investigacion en Residuos para el Desarrollo Sostenible (GIRDS), Facultad de Ingenieria Ambiental, Universidad Nacional de Ingenieria, Av. Tupac Amaru 210, Rimac, Lima 1333, Peru; asilverap@uni.pe

² Graduate Program in Environmental Engineering Sciences (PPG-SEA), São Carlos School of Engineering, University of São Paulo, São Carlos 13566-590, SP, Brazil; mauadffm@sc.usp.br

* Correspondence: nrequenas@uni.edu.pe

Table S1

Value intervals and description of the categories of individual and integrated sediment quality indices

Indices	Categories	
	Value	Description
Cf	$Cf < 1$	Low contamination
	$1 \leq Cf < 3$	Moderate contamination
	$3 \leq Cf < 6$	Considerable contamination
	$Cf \geq 6$	Very high contamination
Igeo	$I_{geo} \leq 0$	Uncontaminated
	$0 < I_{geo} \leq 1$	Uncontaminated to moderately contaminated
	$1 < I_{geo} \leq 2$	Moderately contaminated
	$2 < I_{geo} \leq 3$	Moderately to heavily contaminated
	$3 < I_{geo} \leq 4$	Strongly contaminated
	$4 < I_{geo} \leq 5$	Strongly to extremely contaminated
	$I_{geo} > 5$	Extremely high contaminated
Er	$Er < 40$	Low potential ecological risk
	$40 \leq Er < 80$	Moderate potential ecological risk
	$80 \leq Er < 160$	Considerable potential ecological risk
	$160 \leq Er < 320$	High potential ecological risk
	$Er \geq 320$	Very high ecological risk at hand for the substance in question
EF	$EF \leq 2$	Depletion to minimal enrichment
	$2 < EF \leq 5$	Moderate enrichment
	$5 < EF \leq 20$	Significant enrichment
	$20 < EF \leq 40$	Very high enrichment
	$40 > EF$	Extremely high enrichment
Cdeg	$Cdeg < 8$	Low degree of contamination
	$8 \leq Cdeg \leq 16$	Moderate degree of contamination
	$16 \leq Cdeg \leq 32$	Considerable degree of contamination
	$32 \leq Cdeg$	Very high degree of contamination
mCdeg	$mCdeg \leq 1.5$	Nil to very low contamination
	$1.5 \leq mCdeg \leq 2$	Low degree of contamination
	$2 \leq mCdeg \leq 4$	Moderate degree of contamination
	$4 \leq mCdeg \leq 8$	High degree of contamination
	$8 \leq mCdeg \leq 16$	Very high degree of contamination
	$16 \leq mCdeg \leq 32$	Extremely high degree of contamination
	$32 \leq mCdeg$	Ultra high degree of contamination
PLI	$PLI > 1$	Polluted
	$PLI = 1$	Baseline
	$PLI < 1$	Unpolluted
Nemerow PI	$PI < 0.7$	Unpolluted
	$0.7 \leq PI < 1$	Slightly polluted
	$1 \leq PI < 2$	Moderately polluted
	$2 \leq PI < 3$	Heavily polluted
	$3 \geq PI$	Severely polluted
PERI	$PERI < 150$	Low ecological risk
	$150 \leq PERI < 300$	Moderate ecological risk
	$300 \leq PERI < 600$	Considerable ecological risk
	$PERI \geq 600$	Very high ecological risk

Table S2.

KMO and Bartlett Test

Kaiser-Meyer-Olkin measure of sampling adequacy		0.599
Approx. Chi-square		92.826
Bartlett's sphericity test	gl	10
	significance	0.000

Notes: Samples with concentrations below the detection limit were removed from the dataset to avoid bias in the statistical results

Interpretation:

The Kaiser–Meyer–Olkin (KMO) value (0.599) indicates acceptable suitability for multivariate analysis, while Bartlett's test of sphericity was highly significant ($p < 0.001$), confirming that the correlation matrix is statistically distinct from an identity matrix and, therefore, suitable for PCA.

Figure S1.

Temporal variation of (a) the geoaccumulation index (Igeo) and (b) the enrichment factor (EF) for metals and metalloids in sediments collected during the river flood season between 2013 and 2020. In each period, four sediment samples distributed across the entire study area were analyzed. Dashed lines indicate the classification thresholds corresponding to the different categories of the environmental indices



