GSC Advanced Research and Reviews
eISSN: 2582-4597 CODEN (USA): GARRC2
Cross Ref DOI: 10.30574/gscarr
Journal homepage: https://gsconlinepress.com/journals/gscarr/

(Research Article)

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Potential ecological risk from heavy metals in surface sediment from Lovononkaha Dam in north Côte d'Ivoire (Karakoro/ Korhogo)

TOE-Bi Kizito Katel Kahou [1,*], KPAN Oulai Jean-Gautier [1], DJEYA Kouamé Léger [2], GNAMBA Franck [1] and DGIBEHI Zeli Bruno [2]

[1] *Department Geosciences, University Peleforo GON COULIBALY, Korhogo, BP 1328 Korhogo, Côte d'Ivoire.*
[2] *Department of Marine Geosciences, UFR STRM, University Felix Houphouet- Boigny, Abidjan, 01 BP V 34 Abidjan 01, Côte d'Ivoire.*

GSC Advanced Research and Reviews, 2026, 28(02), 020–032

Publication history: Received on 24 June 2026; revised on 05 August 2026; accepted on 07 August 2026

Article DOI: https://doi.org/10.30574/gscarr.2026.28.2.0185

Abstract

Lavonnonkaha dam reservoir serve as vital source of water for local farmers. However, ecological and economic zone, has been heavily impacted by the discharge of agricultural waste, leading to significant heavy metal contamination. Ten (10) sediment samples from dam were examined for heavy metals contents in objective potential ecological risk status. their heavy metals concentrations were determined using Atomic Absorption Spectrometry (AAS). Ecological risk assessment was carried out using single (contamination factor, geo-accumulation index, enrichment factor) and multi-elemental (contamination degree, pollution index and modified pollution index) standard indices. The assess ment based on these methods demonstrated that sediments were polluted with Cd and the sediments quality guidelines confirmed these results. The mean concentration of heavy metals (mg/kg) of sediments are as follows: Cu (15,78), Cd (0,89), Zn (6), Al (45535,42), Cr (0,53) et Pb (0,006). The contamination factor (CF) and geo-accumulation index (Igeo) revealed that the all of sediment samples are highly polluted with Cd. The enrichment factor (EF) values ranged from 1,61 to 22,16, with Cd (EF = 15,67) and Cu (EF = 2,04) showing significant anthropogenic enrichment. The modified degree of contamination (mCd) results indicated a moderate degree of contamination in 50% of sites. calculated pollution index (PI) and modified pollution index (MPI) revealing that all the samples were severely polluted. Finally, the risk assessment showed that Cd in the sediments presented a very high potential ecological risk.

Keywords: Lavonnonkaha Dam; Sediments; Ecological Risk Index; Contamination Degree.

1. Introduction

In Côte d'Ivoire, the government has implemented several water infrastructure projects, including dams, in order to meet the growing needs for water, irrigation, and energy production. The Lovonnonkaha Dam is a vital infrastructure for the village of Lovonnonkaha, providing water for irrigation, domestic supply, and other essential purposes. Indeed, the implementation of vegetable farming development projects by the German Technical Cooperation Agency and the French Development Agency has promoted vegetable production activities along the banks of the Lovonnonkaha Dam [1]. The various activities involving the use of fertilizers and pesticides contribute to the enrichment of aquatic environments with heavy metals [2]. Heavy metals can also be derived from other sources (pedogenic processes, volcanoes, forest fires and transportation which are considered also causes of contamination in soils and sediments [2]. Anthropogenic activity has become the principal source of heavy metal contamination in numerous lakes across the world ([3], [4], [5]). Over the past decades, many studies have reported on sediment contamination by heavy metals, source identification, distribution pattern, degree of contamination, and health risks ([6], [7]). Heavy metals accumulated in sediments can mobilize to the water column and increase their bioavailability in both matrices and

* Corresponding author: TOE-Bi Kizito Katel Kahou.

influence their bioaccumulation n in aquatic flora and fauna ([8], [9]). Heavy metals can enter the human body through a wide range of food chains and reach toxic amounts ([10], [11]). Prolonged exposure to heavy metals can alter the liver and kidneys and induce toxicity in many organs of the body with carcinogenic, teratogenic, and cardiovascular consequences ([12], [13]). The lovonnonkaha dam, located in the towm Karakoro, are of vital importance for the various ecosystem services they provide. The predominant activities dependent on these water bodies are mainly fish farming, water for human consumption and water for irrigation and recreation. Currently, there is no known research on the level of contamination and ecological risks of heavy metals in sediments of the dam. Therefore, this study aims to bridge this gap. A number of indices have been developed to accurately assess the metal contamination in sediments and its ecological risk. The common indicators mainly include contamination factor (CF), enrichment factor (EF), (modified) degree of contamination (Cd or mCd), (modified) pollution index (PI or MPI), sediment quality guidelines (SQGs), and (modified) potential ecological risk index (RI or MRI) ([14], [15], [16], [17]). In this study, 10 sediment samples collected from Lavonnonkaha dam (East Korhogo) were studied. The present study aimed to determine to evaluate the potential ecological risk of heavy metals in sediment of dam. In addition, the results will allow decision makers to propose and implement action measures to protect and conserve these ecosystems and reduce information gaps aligned with Sustainable Development Goal 6 (Clean Water and Sanitation).

2. Material and methods

2.1. Study Area

The Lovonnonkaha dam is located in the village of Lovonnonkaha, in the sub-prefecture of Karakoro (Korhogo department) in northern Côte d'Ivoire (Figure 1). The Lovonnonkaha dam was built in 1972 by the Animal Production Development Company (SODEPRA). It is an important water resource used for the irrigation of vegetable crops, watering animals, artisanal fishing, and various domestic uses. This dam has an area of 3 hectares. The watershed of the dam is dominated by wooded savannas and agricultural areas primarily used for food and vegetable crops. Agricultural activities practiced around the dam involve the application of fertilizers and pesticides, which can be transported into the water body by runoff during rainy episodes. Our study was carried out along the intensively cultivated shore of the dam, due to the establishment of an irrigated perimeter by the PRO2M project.

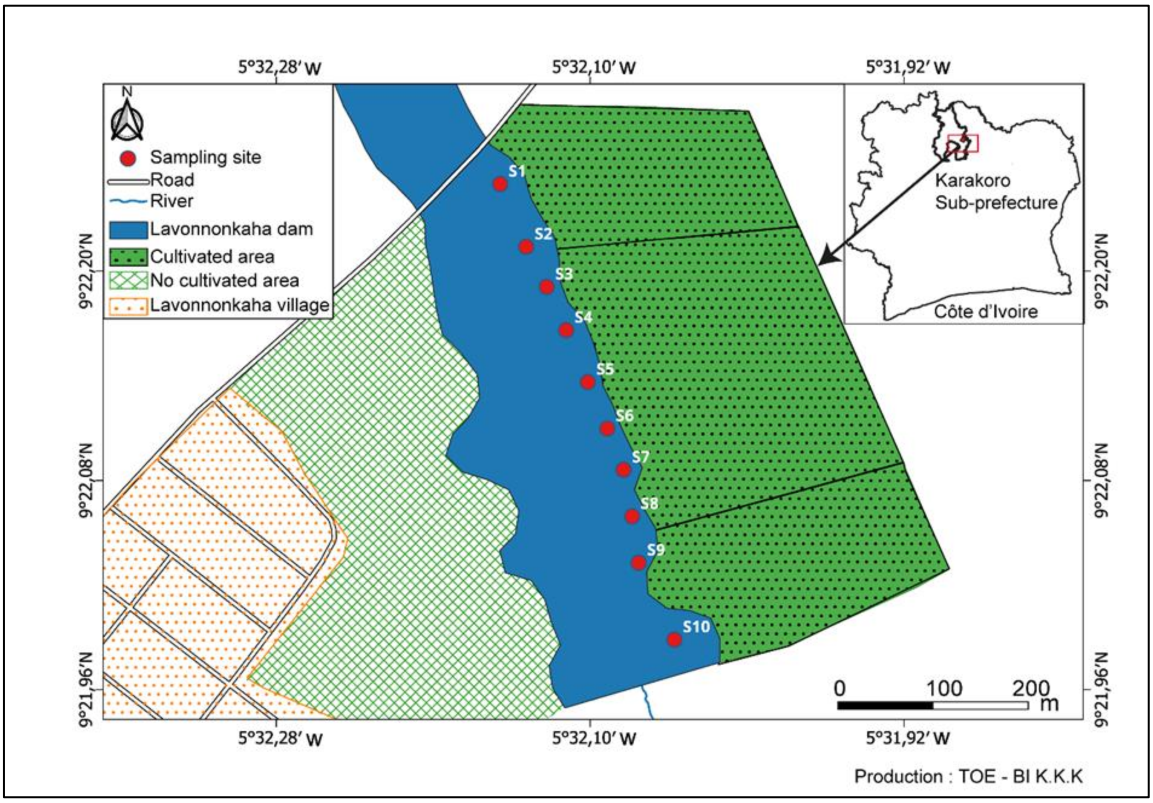

Figure 1 Sampling locations in Lavonnonkaha dam

2.2. Sample collection and laboratory analysis

Sediment sampling was carried out in shore of a dam. A total of ten samples were collected. The sampling took place in during the rainy season, to capture conditions influenced by increased runoff and water flow. Samples were collected using a Van Veen grab sampler, targeting a sediment depth of 0–30 cm. The exact geographical coordinates of each sampling site were recorded using a Garmin eTrex handheld GPS device. Collected sediments were immediately transferred into clean, labeled, hermetically closed to prevent contamination and preserve sample integrity. All samples were securely sealed and trans ported to the laboratory under controlled conditions for subsequent analysis. In the laboratory, 10 grams of each sediment sample were oven-dried at 60 ∘ C for 45 minutes. The dried samples were then finely ground using an agate mortar and passed through a 60-mesh sieve to ensure homogeneity. The processed samples were stored in a desiccator for further analysis. The total concentrations of these metals in the sediment samples were determined after digestion using a mixture of HCl, HNO_3, HF, and H_3BO3. The trace metals (Pb, Cd, Zn, Cu, Al and Cr) were quantified by Atomic Absorption Spectrophotometry (AAS). To ensure the accuracy of the analytical results, blanks and a certified reference sediment (BCR-320) were treated.

2.3. Heavy metal contamination and ecological risk assessment methods

2.3.1. Single element pollution indices

a) Contamination factor

This index was used to quantify the metal contamination status of the sediment for each metal (Table 2) evaluated [18]. It is calculated by the Equation.

$$\mathrm{CF} = \frac{C_{i\ sample}}{C_{i\ background}}$$

Where :

- C_i sample is the metal concentration in the sediment
- C_i background is the metal concentration in the upper continental crust (Table 1)

Table 1 Average concentrations of elements in the Upper Continental Crust [19]

ETM (mg/kg)	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Co	Mn	Fe	Al
UCC (Upper Continental Crust)	2	0,098	35	14	0,06	19	17	52	12	527	30 890	80 400

Table 2 Thresholds for Sediment Quality Classification for contamination factor [18]

Valeur du EF)	**Interprétation**
EF < 0,5	Appauvrissement
0,5 ≤ EF ≤ 1,5	Origine naturelle des métaux.
EF > 1,5	Apports anthropiques.

b) Enrichment Factors

The enrichment factor (EF) was computed to assess whether the elements present in the sediments from dam originated from anthropogenic or natural sources ([20], Table 3). By comparing the abundance of an element in the sediments to its abundance in a reference material, the enrichment factor reveals the degree to which the element is enriched ([21], Table 4). This index is defined by equation :

$$EF = \frac{\left(\frac{Metal}{Al}\right) Sample}{\left(\frac{Metal}{Al}\right) Background}$$

In this study, aluminum (Al) was used as the reference element for geochemical normalization.

Table 3 Thresholds for Sediment Quality Classification for enrichment factors [20]

cValeur de l'CF	Niveau d'enrichissement
CF < 1	Low contamination factor
1 ≤ CF < 3	Moderate contamination factor
3 ≤ CF < 6	considerable contamination factor
CF ≥ 6	High contamination factor

Table 4 EF values were interpreted as suggested by [21]

Valeur de l'EF	Niveau d'enrichissement
EF < 1	indicates no enrichment
1 ≤ EF < 3	means minor enrichment
3 ≤ EF < 5	moderate enrichment
5 ≤ EF < 10	mod erately severe enrichment
10 ≤ EF < 25	severe enrichment
25 ≤ EF < 50	Envery severe enrichment
EF ≥ 50	extremely severe enrich ment

c) Index of geo-accumulation (Igeo)

To establish the contamination status of the sediments of the Dam Lavononkaha, the geo-accumulation index (Igeo) was calculated for the samples accoring to their Igeo values ([22] ; Table 5). It is calculated by Equation :

$$I_{geo} = log_2(\frac{C_i}{1.5B_n})$$

Where :

- C_i is the metal concentration in the sediments,
- Bn is the metal concentration in the upper continental crust,
- 1.5 is a factor applied to minimize the effect of possible variations in background values.

Table 5 Geo-accumulation index (Igeo) and contamination levels

Sediment Igeo contamination	Levels	Pollution degree
Igeo ≤ 0	0	Practically unpolluted
0 < Igeo ≤ 1	1	Unpolluted to moderately polluted
1 < Igeo ≤ 2	2	Moderately polluted
2 < Igeo ≤ 3	3	Moderately to strongly polluted
3 < Igeo ≤ 4	4	Strongly polluted
4 < Igeo ≤ 5	5	Strongly to very strongly polluted
Igeo > 5	6	Very strongly polluted

2.3.2. Multi-element pollution indices

Multi-element pollution indices were used for the assessment of soil and sediment due to the limitations of single element pollution indices ([23], [16]). The most common multiple element indices are the modified contamination index (mCd) developed by [18] , the Nemerow pollution index (PI) [24] , and the modified pollution index (MPI) by [23]. The mCd calculates the average impact of all heavy metal elements at a sampling point to evaluate sediment pollution. Meanwhile, the PI allows the qualification of sediment quality that is much more considerate of the effect of a single element by using a weighted average (Table 6). To account, MPI would allow for the non-conservative behaviour of sediments due to normalization against an element (Table 6).

$$PI = \sqrt{\frac{(CF_{average})^2 + (CF_{max})^2}{2}}$$

$$MPI = \sqrt{\frac{(EF_{average})^2 + (EF_{max})^2}{2}}$$

Where : CFi, CFaverage, CFmax, and EFmax represent contamination factors for an individual element, average of CF, average of EF, maximum CF, and maximum EF, respectively

Table 6 Thresholds for Sediment Quality Classification for Multi-element Indices ([24], [23]).

Valeur du mCd	**Pollution degree**
mCd ≤ 1,5	uncontaminated to very low degree of contamination
1,5 < mCd ≤ 2	low degree of contamination
2 < mCd ≤ 4	moderate degree of contamination
4 < mCd ≤ 8	high degree of contamination
8 < mCd ≤ 16	very high degree of contamination
16 < mCd ≤ 32	extremely high degree of contamination
mCd > 32	ultra-high degree of contamination

The mCd (Modified degree of contamination) evaluates the degree of global contamination of sediments, integrating all the heavy metals evaluated in the ecosystem ([25], Table 8). It calculated using the Equation 5.

$$mCd = \frac{\sum_{i=1}^{n} CF_i}{n}$$

Where :

- CF is the contamination factor,
- i is the “ith” metal, and
- n is the number of metals evaluated

Table 7 mCd is classified in the ranges [25]

PI	**MPI**	**Pollution gradation**
PI < 0,7	MPI < 1	Unpolluted
0,7 < PI < 1,0	1 < MPI < 2	Slightly polluted
1,0 < PI < 2,0	2 < MPI < 3	Moderately polluted

-	3 < MPI < 5	Moderately-heavily polluted
2,0 < PI < 3,0	5 < MPI < 10	Severely polluted
PI > 3,0	MPI > 10	heavily polluted

2.3.3. Sediment Quality Guidelines

The ecotoxicological criterion associated with the presence of metals in bottom sediments was assessed with the help of criterion based on two threshold metal contents ([26], [27]) : Threshold Effect Concentration (TEC) and Probable Effect Concen tration (PEC). These criterions allow to estimate toxic effects of metals on organisms. The TEC and PEC values are presented in Table 8. Currently, there are no widely accepted consensus-based Sediment Quality Guideline (SQG) values for aluminum (Al), such as TEC (Threshold Effect Concentration) and PEC (Probable Effect Concentration), proposed by [26]. The consensus-based PECQ can be used to reliably pre dict toxicity of sediments [27]. The average PEC quotient (PECQ) for the metals was analyzed. For each sediment sample, the PECQ average was the average of the concentration ratio of each element to the corresponding PEC.

$$\text{PECQ} = \frac{1}{n}\sum_{1}^{n}\left(\frac{C_i}{PEC_i}\right)$$

Where :

- **Ci** = concentration ratio of each métal *i* in the sediment (mg·kg^{-1})
- **PEC*i*** = value Probable Effect Concentration of métal *i* (mg·kg^{-1}) ;
- **n** = is the number of metals evaluated

PECQ values < 0.5 indicate that sediment samples were not toxic (low potential toxicity to benthic fauna), whereas sediment samples with PECQ > 0.5 were toxic, which indicates toxicity of sediment samples and high potential risk for the bottom fauna ([26], [28]).

Table 8 Metal sediment quality guideline values (µg/g)

	Cu	Cd	Zn	Cr	Pb
TEC	31,6	0,99	121	43,4	35,8
PEC	149	4,98	459	111	128

2.3.4. *Potential ecological risk (Ri)*

To assess the complex potential ecological risk caused by the presence of metals in sediments, the potential ecological risk index (PERI) was used [18]. This index determines the overall degree of ecological risk of heavy metals in sediment samples (Table 9). The values are calculated using Equation as follow :

$$E_i^T = T_i \times \frac{C_s^i}{C_n^i}\ ; \text{Ri} = \sum_{i=1}^{n} E_i^T$$

Where :

- E_i^T is the potential ecological risk factor for element i,
- Ti is the toxic response factor for element i, which depends on its toxicity and the sensitivity of the ecosystem to the element.
- C_s^i is the measured concentration of element I in the sediment (mg·kg⁻1),
- C_n^i is the background concentration of element I.
- Ri represents the comprehensive potential ecological risk index

Table 9 The classification standards for RI ([28], [30]).

Assessment criterion	Ecological risk index				
	Low	**Moderate**	**Considerable**	**High**	**Very high**
E_i^T	$E_i^T < 40$	$40 \le E_i^T < 80$	$80 \le E_i^T <160$	$160 \le E_i^T < 320$	$E_i^T \ge 320$
Ri	Ri < 150	150 ≤ Ri < 300	300 ≤ Ri < 600	Ri ≥ 600	

3. Results and discussion

3.1. Analysis and distribution of metals in sediments

The concentrations of Cu, Cd, Zn, Al, Cr and Pb in surface sediments of the Dam Lavononkaha illustrated in Figure 2. The measured concentrations varied as follows : Cu ranged from 7.5 to 25.3 mg·kg⁻1, Cd from 0.39 to 1.31 mg·kg⁻1, Zn from 2.7 to 9.1 mg·kg⁻1, Al from 23294.13 to 68077.15 mg·kg⁻1, Cr from 0.22 to 0.80 mg·kg⁻1, and Pb from 0 to 0.02mg·kg⁻1. The highest mean concentrations of Cu, Cd, Zn, and Pb were recorded at S7 (25,3 mg/kg ; 1,31 mg/kg ; 9,1 mg/kg and 0,02 mg/kg). The high est mean concentration of Al was recorded at S10 (68 077 mg/kg), and the high est mean concentration of Cr was recorded at S9 (0,80 mg/kg) (Figure 2). Among the metals, Cd showed the most significant elevation, with a mean concentration of 0. 86 mg·kg⁻1, surpassing the background value. The concentrations of Cu exceeded the background values at some sampling sites (S2, S6, S7, S8, S9 et S10). Finally, The concentrations of Zn, Al, Cr and Pd not exceeded the background values (Figure 2). These sediments have high quantities of metals that may be caused by which includes wastewater discharges, growing urbanisation, Agricultural activities, and air deposition, according to this study [31].

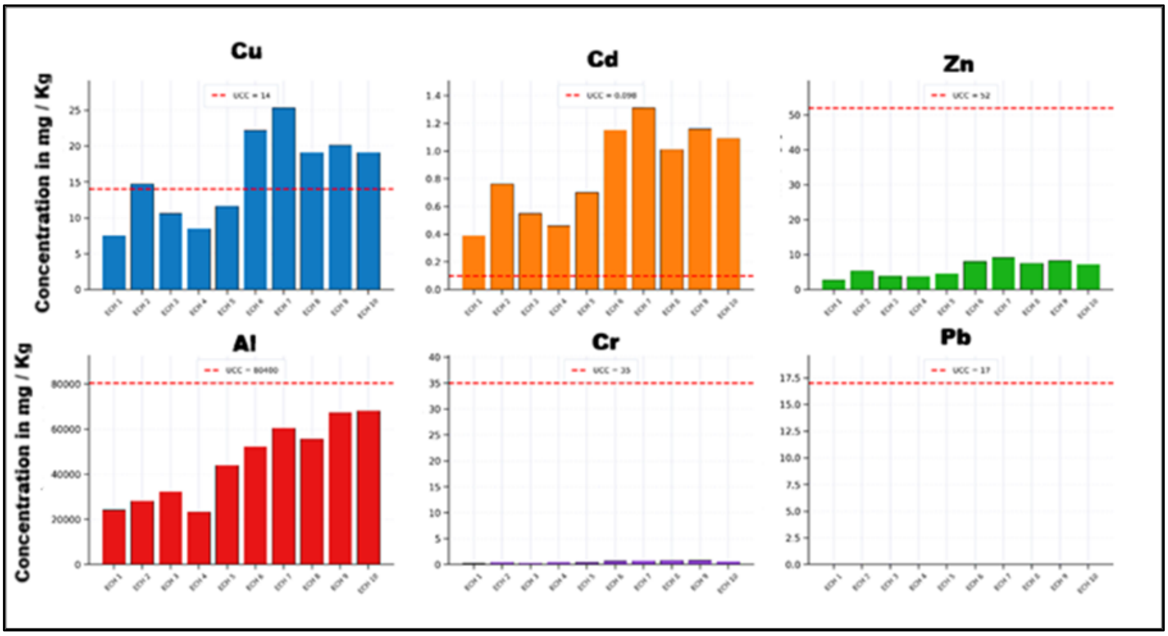

Figure 3 concentrations of trace metals in surface sediments from Dam of Lavononkaha.

Indeed according to [32] Small rivers have been used as a drainage channel for intensive runoff in densely populated urban areas or as a water source in agricultural areas. In comparison with big rivers, small rivers are more sensitive to changes in the surrounding environment and capable of tending to human activities and natural factors [31]. We concluded that the presence of metals in the sediments of the dam is primarily attributable to the discharge of agricultural waste into the reservoir. consequently, concentrations can be completely unique in every location. The physical and chemical properties of the sediment might explain why the levels of Cu, Fe, Cd, Cr, Mn, Ni, Pb, and Zn change in different places and times [33]. The concentration of Al in all sediments was much higher than that of other heavy metals. These findings suggested that the Fe and Mn detected in the sediments might have come from lithogenic sources. The discharge of metal Agricultural, automobile traffic, and sewage waste, drainage which have the potential to retain heavy metals was most likely the reason behind the increasing concentrations of these metals in dam [34] . Some factors (hydrological dynamics, human activities, and geomorphological factors) work synergistically to shape the movement of sediments and the distribution of contaminants throughout the river systems [33]. According to [35], Water velocity is a key driver of sediment erosion and down stream movement, especially during periods rainy season. The Pb contamination can be linked to leaded gasoline [36] because the Dam is close to the high way. The proximity of Dam to the farming areaindicates that Cd contamination is a result of the application of pesticides and fertilizers [36]. The Cu contamination may have been caused by the use of Cu-containing insecticides and fungicides around dam [36]. Moreover, Cu contamination may be associated with traffic, suchas tyreand brake wear because the dam was a road [36].

3.2. Assessment of Sediment Contamination

A comprehensive assessment of the overall pollution risks associated with Cu, Cd, Zn, Al, Cr, and Pb is presented in Table …, using multiple environmental pollution indicators. The analysis of sediments from the research area reveals varying levels of contamina tion by different heavy metals. (Zn), Chromium (Cr), (Al), and Lead (Pb) exhibit relatively low contamination levels in all sites. The CF showed that Cu presented the moderate levels of contamination in sites S2, S6, S7, S8, S9, S10. Also, The CF showed that Cd presented the highest levels of contamination in all sites. Also, The enrichment indexe of Cd in all samples were the highest. However, when categorizing these values, minor enrichment of Cu was observed across all samples, with the exception of S2. The enrichment of Cd and Cu, indicating that the study area is impacted by human activities (agriculture,urbanization, etc.). In contrast, other heavy metals evaluated were in a safe state. Indeed in all samples, the value du Zinc, Cr et Pd indicate no enrichment. The geo-accumulation index (Igeo) is summarized in Table 9. Results indicate varying pollution levels for different metals based on Igeo values. Cd exhibited the highest pollution level, with an average Igeo of 2,43 (ranging from 1,41 to 3,16), classified as moderately to strongly polluted . Conversely, Cu, Zr, Cr et le Pb showed a relatively low pollution level with an average Igeo of -1,82 (ranging from-7,90 to 0,27), indicating a clean status. The concentration of metals in the sediment samples were compared with the consensus-based TEC and PEC values (Table 8). The results show that TEC value was exceeded only in the case of Cd (50 % samples). In contrast, cadmium (Cd) concentrations remained below the PEC value in all sediment samples analyzed. The concentrations of Pb, Cu, Zn, and Cr were below the TEC and PEC thresholds in 100% of the samples. The concentration of Cd in sediments for half samples exceeds the value, which exhibits an adverse effects on ecosystem. All stations, mean values of PECQ ranged from 0,027 to 0,092. It means that all the sediment samples were potentially nontoxic (PECQ < 0,5) [26]. heavy metal pollution in sediments is influenced by various heavy metals, this study used multi-element indices (mCd, PI, and MPI) to assess the influence of multiple contamination species at a site. The Modified degree of contamination (mCd) results (Figure 8) indicated a " uncontaminated to very low degree " of contamination, in 50% of sites (S1, S2, S3, S4 and S5) and showed a moderate degree of contamination in 50% of sites (S6, S7, S8, S9 and S10). The values of PI for sediments indicated that the pollution was heavily polluted, in the study area, with a mean value of 6,4. In the case of the study area, 10 (S1) and 90% (S2, S3, S4, S5, S6, S7, S8, S9, S10) of the sample stations were Severely polluted and heavily polluted by PI, respectively. These results indicated that Cd, whose very high contamination factor (3,98 to 13,37), dominated the calculation of the PI. Consequently, all samples, except S1, which is at the upper limit of the moderately polluted category, are classified as heavily polluted. This conclusion is consistent with the high CF values observed for Cd. According to [23], the weighted average rather than just the average CF of PI makes amore likely, higher value for the index, and the trigger thresholds are lower than those for the other indices. Accordingly, the PI is more likely to identify high levels of contamination for a suite of elements. The values of MPI for sediments indicated that the pollution was heavy pollution, in the study area, with a mean value of 11,41. The MPI values for 30 % of the sample stations (S1, S5 and S10) indicate severe pollution, and 70 % denoted heavy pollution (Table 10). The high MPI is mainly due to Cd, whose EF values range from 13,06 to 22,16, corresponding to severe enrichment. Cu shows minor to moderate enrichment, while Zn, Cr, and Pb showed negligible enrichments. Therefore, the overall quality of the sediments is severely degraded mainly by the contribution of Cd.

3.3. Ecological risk assessment

The values of Er and RI of respective metals at different sampling sites are shown in Table 7. The Er was found in the order of : Cd > Cu > Zn > Pb, where the highest mean value of Er was (262,7) for Cd and the lowest was (0,001) for Pb. Cd (333,67 - 401,02) in sites S6, S7, S9 and S10 was the most severe and implied a very high-risk condition, followed by 168,37 at 309, in sites S2, S3, S5 and S8 implied a high-risk condition. whereas Cd showed Considerable -risk condition in sites S1 and S4 . Also, le Cu, le (Zn), Cr and plomb (Pb) presented values lower than 40, suggesting a low ecological risk. The potential ecological risk index (RI) obtained

Table 10 shows sediments such as S6,S7, S8, S9 and S10 are much more hazardous than soils such as S1, S2, S3, S4 and S5.

Table 10 Nemerow Multifactor Pollution Index (NPI), modified contamination degree(mCd), Probable Effect Concentration Quotient (PECQ), potential ecological risk (Ri), site rank index (SRI) for enrichment factor (EF), and contamination factor (Cf) of metals in sediment of DAm.

Sample	PI	mCd	PECQ	MPI	Ri
ECH1	2,874	0,812	0,027	9,626	122,13
ECH2	5,591	1,545	0,053	16,113	238,03
ECH3	4,042	1,142	0,038	10,209	172,25
ECH4	3,386	0,946	0,032	11,746	143,95
ECH5	5,163	1,436	0,046	9,478	218,54
ECH6	8,478	2,357	0,081	13,072	360,16
ECH7	9,670	2,687	0,092	12,884	410,28
ECH8	7,474	2,088	0,071	10,826	316,20
ECH9	8,561	2,382	0,078	10,348	362,48
ECH10	8,050	2,248	0,073	9,749	340,67

Table 11 Enrichment factor, contamination factor, geoaccumulation index, and ecological risk of metals in sediments of Dam**.**

			Metals			
Samples	**Cu**	**Cd**	**Zn**	**Al**	**Cr**	**Pb**
Contamination factor						
ECH1	0,536	3,980	0,052	0,300	0,006	0,000
ECH2	1,050	7,755	0,102	0,350	0,012	0,001
ECH3	0,757	5,612	0,073	0,401	0,009	0,001
ECH4	0,607	4,694	0,071	0,290	0,013	0,000
ECH5	0,829	7,143	0,087	0,547	0,010	0,000
ECH6	1,586	11,735	0,154	0,650	0,018	0,001
ECH7	1,807	13,367	0,175	0,751	0,021	0,001
ECH8	1,364	10,306	0,144	0,691	0,022	0,001
ECH9	1,436	11,837	0,158	0,836	0,023	0,000
ECH10	1,364	11,122	0,138	0,847	0,016	0,000
Enrichment factor						
Samples	**Cu**	**Cd**	**Zn**	**Al**	**Cr**	**Pb**
ECH1	1,786	13,267	0,173	-	0,021	0,000
ECH2	3,000	22,157	0,291	-	0,034	0,002
ECH3	1,886	13,982	0,182	-	0,022	0,001
ECH4	2,096	16,201	0,246	-	0,044	0,000
ECH5	1,515	13,064	0,158	-	0,018	0,000
ECH6	2,440	18,054	0,237	-	0,028	0,001

ECH7	2,405	17,790	0,233	-	0,028	0,002
ECH8	1,974	14,912	0,209	-	0,031	0,001
ECH9	1,716	14,150	0,189	-	0,027	0,000
ECH10	1,611	13,136	0,164	-	0,019	0,000
Geoaccumulation index						
Samples	**Cu**	**Cd**	**Zn**	**Al**	**Cr**	**Pb**
ECH1	-1,49	1,41	-4,85	-2,32	-7,90	0
ECH2	-0,51	2,37	-3,88	-2,10	-6,97	-11,32
ECH3	-0,99	1,90	-4,36	-1,90	-7,40	-11,32
ECH4	-1,30	1,65	-4,40	-2,37	-6,87	0
ECH5	-0,86	2,25	-4,12	-1,46	-7,23	0
ECH6	0,08	2,97	-3,29	-1,21	-6,36	-11,32
ECH7	0,27	3,16	-3,10	-1,00	-6,17	-10,32
ECH8	-0,14	2,78	-3,38	-1,12	-6,11	-11,32
ECH9	-0,06	2,98	-3,25	-0,84	-6,04	0
ECH10	-0,14	2,89	-3,44	-0,82	-6,53	0
Ecological risk (Er)						
Samples	**Cu**	**Cd**	**Zn**	**Al**	**Cr**	**Pb**
ECH1	2,68	119,39	0,05	-	0,01	0,00
ECH2	5,25	232,65	0,10	-	0,02	0,00
ECH3	3,79	168,37	0,07	-	0,02	0,00
ECH4	3,04	140,82	0,07	-	0,03	0,00
ECH5	4,14	214,29	0,09	-	0,02	0,00
ECH6	7,93	352,04	0,15	-	0,04	0,00
ECH7	9,04	401,02	0,18	-	0,04	0,01
ECH8	6,82	309,18	0,14	-	0,04	0,00
ECH9	7,18	355,10	0,16	-	0,05	0,00
ECH10	6,82	333,67	0,14	-	0,03	0,00

4. Conclusion

The constant agriculture development around the Lavonnonkaha dam goes hand in hand with the strong pressure experienced by these ecosystems and the demand for good quality water. The present study examined the concentrations and contamination of heavy metals in sediments of Lavonnonkaha dam. The concentrations of Cu, Zn, Al, Cr and Pb in sediments across all sampling sites in Lavonnonkaha dam don't exceed the background values for soils in Lavonnonkaha dam. However, Cd (0,86 $mg\cdot kg^{-}1$) showing the most pronounced contamination, surpassing the background value by a factor of 0,098. The results demonstrated that there had been considerable enrichment in the levels of Cd (0,86 $mg\cdot kg^{-1}$) and Cu (15,87) in sediment in the study area. The source of these enrichments was mainly attributed to agriculture activities. The pollution index (PI) and modified pollution index (MPI) derived from contamination factors and Enrichment Factors respectively, showed that, due to Cd concentration, sediments were severely polluted. assessment of Igeo and CF also indicated that the sediments were strongly polluted with Cd. The risk assessment showed that Cd in the sediments presented a very high potential ecological risk. This study reveals that Cd poses the highest ecological risk among the four metals, with its predominantly bioavailable forms making it highly susceptible to environmental changes and, thus, a significant threat to the ecosystem. These findings highlight the need for continuous, targeted management strategies to mitigate Cd contamination and reduce its ecological impact in the Lavonnonkaha dam.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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