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POLLUTION LEVELS AND RISK ASSESSMENT OF HEAVY METALS IN SEDIMENT AT TENGI RIVER, SELANGOR

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Abstract

The pollution levels and impact of heavy metal (HM) contamination distribution caused by human activities on mangroves, rivers, estuaries, and coastal wetlands have recently gained attention. Waste discharged from agricultural runoff may increase pollution due to rapid population growth and socioeconomic development in Tanjung Karang, Selangor, areas such as boat manufacturing factories, residential areas, and port development, as well as waste discharged from agriculture runoff. As a result, anthropogenic radioactive materials could accumulate in sediments and infiltrate the food chain, affecting the natural system and directly endangering human health. This study determined the concentrations of heavy metals (Fe, As, Pb, Cu, and Cd) and radionuclides (Th-232, U-238, and K-40) in Tengi River sediment from 15 locations were collected using a PVC tube and Energy Dispersive X-ray Fluorescence Spectrometer (EDXRF). As a result, Cu (68.00-127.64 mg/kg), Pb (86.84-147.62 mg/kg), Fe (9.11-14.24 mg/kg), As (78.24-97.74 mg/kg), and Cd (0.11-10.02 mg/kg) while the average concentrations of radionuclides are Th>K>U with 91.96 mg/kg, 42.77 mg/kg, and 13.34 mg/kg, respectively. The data obtained were used to estimate pollution levels (I_{geo}, EF, CF, and PLI) using Sediment Quality Assessment (SQA) and to evaluate the potential impact of human activities on the ecosystem by calculating the Ecological Risk Index of Heavy Metals. The results show that the concentration of heavy metals and radionuclides in surface sediment may be caused by human activities near the study area. I_{geo}, CF, PLI, and ER indicated a heavy metal load with As and Cd in surface sediments, while Cu and Pb had a minimal degree. To conclude, Cu < Pb < Cd < As from ecological risk, As and Cd are most polluted in the surface sediment along the down streams of the river.

Keywords: Energy Dispersive X-ray Fluorescence Spectrometer (EDXRF), heavy metals, radionuclide, sediment, Tengi River

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Introduction

River systems played critical roles in hydrological cycles, functioning as drainage pathways for surface water and delivering crucial nutrients and debris to downstream habitats (Sugumaran et al., 2023). Furthermore, contamination with hazardous heavy metals (HMs) and naturally occurring radioactive materials (NORMs) has garnered significant attention from researchers worldwide in recent years due to their high pollution, toxicity, and non-biodegradability, posing a threat to natural ecosystems (Jasku & Sojka, 2022). These inorganic heavy metals proved particularly troublesome as they persisted in natural systems, originating from various sources, exhibiting hazards at low concentrations, and displaying a strong affinity for accumulating in sediments. Consequently, this affected the connected habitats.

Recent studies indicated that river sediments contributed to approximately 97% of the bulk transfer of HMs to oceans (Liu et al., 2009). After discharge, HMs could be transported throughout the river ecosystem, collecting water, sediments, river fauna and flora. It was observed that a minor number of HMs remained in the water column, while the rest accumulated in sediments. River sediments played a significant role in the sorption and transport of HMs in the aqueous environment (Jasku & Sojka, 2022). The uncontrolled dumping of solid waste, including plastics and electronic waste, along riverbanks, contributed to river pollution. These wastes took years to decompose, releasing harmful chemicals and heavy metals during that time, polluting water, and sediment. Selangor had a population of around 18,834 people, with a higher population density closer to the river on the shore. The average temperature in Selangor was 27.7 degrees Celsius, with an annual rainfall of 1987 millimeters. These factors highlighted human activities as a significant concern affecting pollution in the area (Saad et al., 2022)

The problem statement emphasized that heavy metals dumped into the environment could immediately impact the surrounding water. Contaminated sediments in rivers, lakes, and coastal areas acted as significant heavy metal transporters in wet environments. These sediments release heavy metals into the water bodies, affecting live creatures depending on metal speciation, soil pH, organic content, and other parameters. Heavy metals did not disappear in water but accumulated in sediments and infiltrated the food chain, affecting the natural system and posing direct threats to human health. Elevated levels of heavy metals in sediment pose significant threats to aquatic ecosystems and human health. Heavy metals such as lead, cadmium, mercury, and arsenic accumulated in sediment over time (Baharom et al., 2022)

Based on the stated objectives in the proposal, the study aimed to determine the concentration of heavy metals (Fe, As, Pb, Cu, and Cd) and radionuclides (U, Th, K) in the sediment, assess pollution levels using Sediment Quality Assessment (SQA), and calculate the risk assessment of heavy metals and radionuclides on human health. The study would employ EDXRF to detect sediment heavy metals and radionuclides. Heavy metal contamination in sediment would occur as the pollution source traveled 7.15 kilometers through the Selangor River before reaching the sea. The study would select 15 spots for silt dredging, focusing on surface sediment. Pollution levels in sediment would be estimated using the Pollution Load Index (PLI), considering factors like the geo-accumulation index (I_{geo}), enrichment factor (EF), and contamination factor (CF). Additionally, the study will evaluate the potential impact of human activities on the ecosystem by calculating the Ecological Risk Index (ER) of Heavy Metals.

Methods

Study Area

Sediment samples were collected from the Tengi River in Selangor, Malaysia (3˚25’11” N 101˚10’53” E) as shown in Figure 1. The sampling area included a farm, a residential area, a zoo, and a factory. Ten different sampling locations were selected, with distances between each location ranging from 100 to 500 meters.

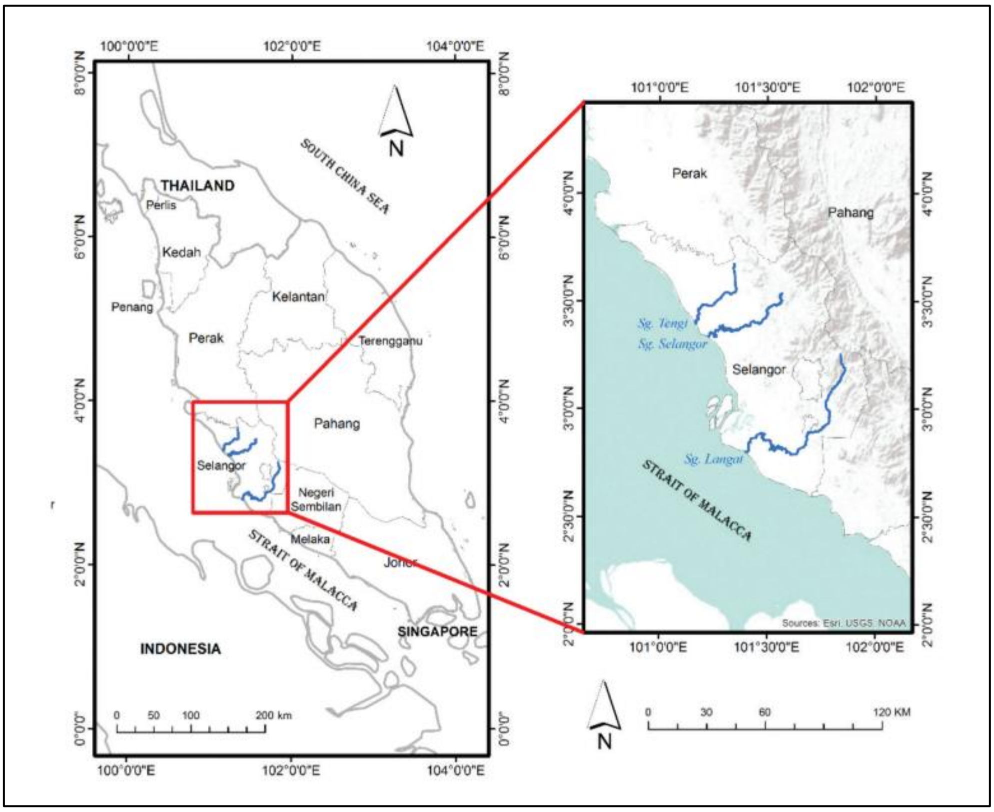

Figure 1. Map of the study area. (Mokhtar et al., 2018)

The coordinates of each sampling point were recorded using a hand-held Global Positioning System (GPS), as depicted in Figure 2.

Figure 2. Sampling points.

Sample Collection

The sediment collection involved using a stainless-steel bottom sampling dredge, specifically a grab sampler, to gather sediment from a depth of 0 to 15 cm in each location. To maintain sample homogeneity, sediments of various grain sizes were assessed and homogenized. The grab sampler was thoroughly cleaned with detergent and rinsed with distilled water before each use to minimize contamination. Subsequently, the sediment samples were carefully placed in new polyethylene zip-lock bags and stored in an ice-filled cooler at a temperature of 4°C.

Sample Preparation and Sample Measurements

After homogenizing the sediment samples, the researcher proceeded to air-dry the sample before placing it in an oven set at 105°C until achieving a constant weight. The dried sample was then ground into fine powder and homogenized, then pass through 250 µm sieve. Sample cup were prepared by putting Myla into it properly. Five samples were placed in the sample holder for measurement using the application, and the process was repeated three times.

Sample Analysis

The analysis of metals in the sediment samples was conducted using EDXRF Spectrometers, which employed high-energy photons (x-rays or gamma rays) to generate characteristic x-rays from the elements present in the samples. By subjecting the samples to intense X-ray bombardment, the atoms emitted distinct x-rays that were subsequently detected and examined to determine the elemental composition of the samples.

Data Analysis

The contamination levels of Fe, Cu, As, Cd, and Pb elements in surface sediment were assessed using the total mean concentration, geo-accumulation index (I_{geo}), enrichment factor (EF), contamination factor (CF), and ecological risk index (RI). The heavy metal contamination level data were assessed on the sediment quality based on global average shale values and compared with the SQGs using US EPA legislation as a model.

Geo-Accumulation Index (I_{geo})

I_{geo} is used to define and determine metal contamination in sediments by comparing current concentrations with pre-industrial levels. The index was calculated using the following Equation 1.

$$I_{geo} = log\,2(\frac{Ci}{1.5\,Bi}) \qquad \text{Equation 1}$$

Where, Ci is the measure concentration of metals (n) in the sediment, and Bi is the geological background concentration of metals (n) in different provinces. To determine Bi, values (mg/kg) of select heavy metals are summarized. The constant term 1.5 is the background matrix correction factor that involves potential lithological variations in the background value. The Igeo value for each metal can be estimated and classified into seven classes: Class 0 ($I_{geo} \leq 0$), uncontaminated; Class 1 ($0 < I_{geo} \leq 1$), uncontaminated to moderately contaminated; Class 2 ($1 < I_{geo} \leq 2$), moderately contaminated; Class 3 ($2 < I_{geo} \leq 3$), moderately to heavily contaminated; Class 4 ($3 < I_{geo} \leq 4$), heavily contaminated; Class 5 ($4 < I_{geo} \leq 5$), heavily to extremely contaminated; and Class 6 ($I_{geo} \geq 5$), extremely contaminated (Zhang et al., 2022) .

Enrichment factor (EF)

The enrichment factor (EF) as Equation 2 is an index used to normalize the heavy metals contamination in sediments to analyses the degree of metal enrichment and define the sources of natural and anthropogenic sources of pollution. The enrichment factor describes the stabilization of sediments relative to reference elements. In this study, anthropogenic metal enrichment is measured using iron (Fe) concentration. The EF is calculate using Equation 2.

$$EF = (Ci/Cfe)/(Bi/Bfe) \qquad \text{Equation 2}$$

Where, Ci is the concentration of heavy metals in the sediments (mg/kg), Cfe is the concentration of iron (Fe), Bi is the reference geochemical background value of each heavy metal, and Bfe is the reference geochemical background value of iron (Fe). The EF defined into seven categories: EF ≤ 1 (no enrichment), 1 < EF ≤ 3 (minor enrichment), 3 < EF ≤ 5 (moderate enrichment), 5 < EF ≤ 10 (moderately severe enrichment),10 < EF ≤ 25 (severe enrichment), 25 < EF ≤ 50 (very severe enrichment), 50 < EF (extremely severe enrichment) (Jasku & Sojka, 2022).

Contamination factor (CF)

CF as Equation 3 is a contamination factor defined for each studied heavy metals, it was used to determine the contamination state of the heavy metals in surface sediments, and it calculate from Equation:

$$CF = \frac{Ci}{Bi} \qquad \text{Equation 3}$$

Where, Ci is the concentration of heavy metals in the sediments (mg/kg) and Bi is the reference geochemical background value of each heavy metal (Shen et al., 2019)

Pollution Load Index (PLI)

The PLI as Equation 4 is defined as the nth root of the multiplications of the contamination factor of the target heavy metals (CF).

$$PLI = (CF1 \times CF2 \times CF3 \times \ldots \times CFn)\, 1/n \qquad \text{Equation 4}$$

Where, CF1 is the concentration of the first metal, CF2 is the concentration of the second metal, CF3 is the concentration of the third metal and CFn is the concentration of metal nth, and n is the total number of studied heavy metals in the sample (MacDonald et al., 2000).

Ecological risk (ER)

The ecological risk (ER) is used to assess the potential ecological risk of a given contaminant in sediments according to the toxicity of heavy metals and the response of the environment. The formulas of the potential ecological risk index described by Hankinson are expressed in Equation 5.

$$Er = T_r^i \times C_f^i \qquad \text{Equation 5}$$

Where, C_f^i is the contamination factor T_f^i is the toxic-response factor for a given substance (i.e., Cr = 2, Mn = Zn = 1, Co = Ni = Cu = Pb = 5, Cd = 30, As = 10); Er is the ecological risk index of the metal (Shen et al., 2019).

Result and Discussion

Concentration of Heavy Metal (HM)

Table 1.0 shows the concentration of heavy metals in sediment from the Tengi River. The results of Cu, Pb and As, Cd and Fe in sediment ranged from 68.00-127.64 mg/kg, 95.67-147.16 mg/kg, 78.24-97.74 mg/kg, 0.10-1.93 mg/kg and 9.11-14.24 % respectively. The threshold effect concentrations (TEC) and probable effect concentration (PEC) values for heavy metals were used to estimate the toxicity of sediment that may affect aquatic life in the Tengi River. The heavy metal contents of the sediments in the Tengi River were in descending order of Fe > Pb > Cu > As > Cd. The concentration of all elements exceeded TEC values in all sampling points. However, the concentration of heavy metals obtained in sediment at Tengi River was below PEC values except for As and Pb (S1). If the heavy metal concentrations in the sediment exceed PEC, toxic effects will likely occur (MacDonald et al., 2000; Talukder et al., 2022)

Table 1. Concentration of heavy metals in sediment (mg/kg).

No.	Cu	Pb	As	Cd	Fe (%)
S1	88.36 ± 3.53	147.16 ± 0.82	83.66 ± 3.20	1.93 ± 0.26	14.22 ± 0.05
S4	81.02 ± 5.87	116.48 ± 3.59	80.28 ± 3.20	0.13 ± 0.02	11.22 ± 0.07

S5	81.72 ± 7.96	125.16 ± 1.63	95.72 ± 2.11	0.11 ± 0.01	11.91 ± 0.03
S6	69.92 ± 8.03	121.75 ± 3.03	97.74 ± 5.90	0.15 ± 0.04	11.56 ± 0.10
S7	71.02 ± 1.79	103.76 ± 1.66	92.50 ± 1.63	0.13 ± 0.02	11.54 ± 0.09
S8	68.00 ± 5.47	99.79 ± 1.82	78.65 ± 1.83	0.13 ± 0.02	10.05 ± 0.01
S9	127.64 ± 40.97	95.67 ± 2.02	78.24 ± 3.43	0.11 ± 0.01	9.11 ± 0.01
S10	106.81 ± 8.42	113.66 ± 2.86	80.94 ± 3.87	0.11 ± 0.01	11.11 ± 0.02
S11	107.18 ± 4.74	126.88 ± 2.94	86.36 ± 2.78	0.15 ± 0.01	13.10 ± 0.03
S12	94.24 ± 11.57	116.14 ± 3.05	84.44 ± 3.41	0.10 ± 0.01	11.09 ± 0.06
S13	69.38 ± 3.25	102.46 ± 2.60	79.31 ± 3.64	0.12 ± 0.031	10.31 ± 0.08
S14	88.29 ± 7.72	99.07 ± 1.66	80.56 ± 1.36	0.14 ± 0.01	10.52 ± 0.05
S15	73.81 ± 4.68	86.84 ± 1.51	84.24 ± 3.26	0.12 ± 0.02	9.62 ± 0.01
Range	68.00-127.64	95.67-147.16	78.24-97.74	0.10 – 1.93	9.11-14.22
TEC	31.6	35.8	9.79	0.99	NA
PEC	149	128	33	4.98	NA

NA: Not Available

Copper (Cu) , Lead (Pb) and Arsenic (As)

When an environmental condition changes, heavy metal accumulation in sediments can become a secondary source of water pollution. Consequently, evaluating heavy metal contamination in sediments becomes crucial for assessing the risks associated with aquatic environments. Sediment Quality Guidelines (SQGs) were utilized to evaluate the concentrations of metals in the sediment. Within the SQGs, a threshold effect concentration (TEC) was incorporated. Metal concentrations below the TEC value indicate the absence of biological effects from these metals. Conversely, metal concentrations surpassing the probable effect concentration (PEC) value suggest potential adverse biological effects caused by the metals (Ke et al., 2017; Talukder et al., 2022)

Figure 3 shows the concentration of Cu, Pb and As. Among the sampled stations, Station 9 exhibited the highest concentration at 127.64 mg/kg. The concentrations of Cu in the sediment exceeded the suggested TEC value (31.6). Conversely, the PEC value for Cu concentration was lower (149). This suggests an elevated risk of toxicity and potential harm to various organisms, including aquatic life, wildlife, and humans. The potential effects encompass hindered growth, reproduction, and development of organisms, as well as disruptions in ecosystem dynamics and functions. In these cases, Cu can be found in the ship paint. Other than that, domestic and municipal wastewater discharges can contain Cu from various sources, including household plumbing, wastewater treatment plants, and sewage systems. These discharges can introduce Cu into the river, leading to its accumulation in the sediment (Wei et al., 2023).

While for Pb, Station 2 exhibited the highest concentration at 147.62 mg/kg, whereas Station 15 had the lowest concentration at 86.84 mg/kg. Notably, all the Pb concentrations in the sediment samples collected from the Tengi River in Selangor exceeded both the TEC (35.8) and PEC values (128). This indicates an elevation in biological effects from these metals and suggests a likelihood of toxic effects occurring (Talukder et al., 2022; Ke et al., 2017). The source Pb comes from waste anthropogenic sources such as urban industrial, and agricultural discharges in that area (Ali Azadi et al., 2018)

Then, all the As concentrations in the sediment samples collected from the Selangor Tengi River exceeded the TEC (9.79) and PEC (33) values. Station 6 exhibited the highest concentration at 97.74 mg/kg, whereas Station 9 had the lowest concentration at 78.24 mg/kg.. This indicates an elevation in biological effects from these metals and suggests a likelihood of toxic effects occurring (Ke et al., 2017; Talukder et al., 2022). One of the reasons is human activities in this area, which come from waste disposal. Besides that, factors such as climate and the organic and inorganic components of the sediments might affect the level of arsenic in sediment (Saha et al., 2021).

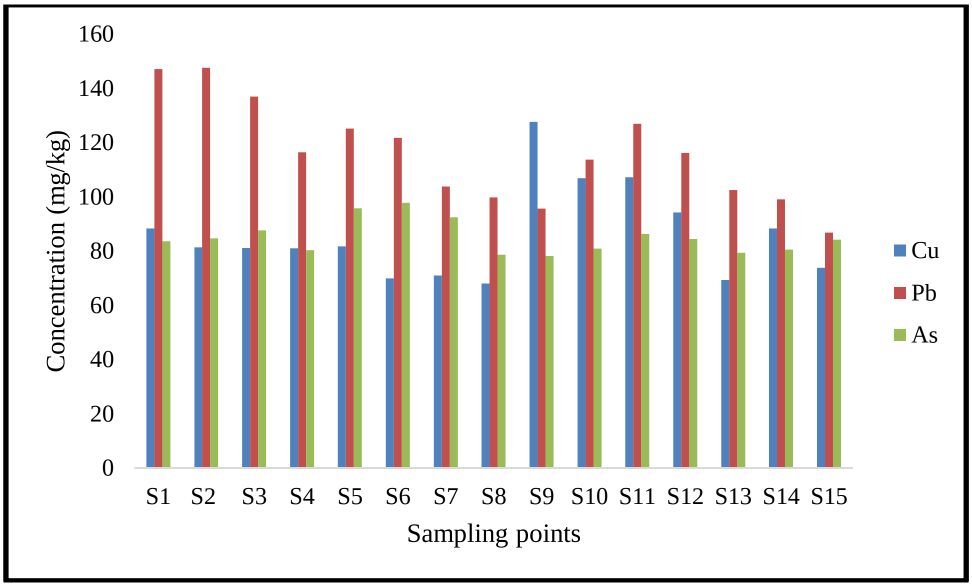

Figure 3. Concentration of Cu, Pb and As in sediments.

Cadmium

Station 2 exhibited the highest concentration at 10.02 mg/kg. Notably, all the Cd concentrations in the sediment samples collected from the Tengi River in Selangor exceeded both the TEC (0.99) and PEC (4.99) values. This indicates an elevation in biological effects resulting from these metals and suggests a likelihood of toxic effects occurring (Ke et al., 2017; Talukder et al., 2022). The source of Cd is mainly from increased anthropogenic activities like the use of fertilizers and pesticides, which have elevated Cd concentrations in the environment (Sidhu & Bali, 2022).

Heavy metal guidelines

Based on the data presented in Table 2, the Cu concentrations in most stations are classified as heavily polluted (>75 mg/kg), except for Station 8, Station 13, and Station 15, which are not heavily polluted. Similarly, all stations show heavy pollution for Pb, with concentrations exceeding 60 mg/kg. Arsenic concentrations in all stations are also categorized as heavily polluted. The pollution is attributed to human activities in the area, such as the fishing boat factory and waste disposal from residential areas. Additionally, factors like climate and the organic and inorganic composition of sediments may influence the levels of arsenic present in the sediment (Saha et al., 2021). As for Cd, concentrations in most stations (Station 1 and Stations 4-15) do not exceed 6 mg/kg, indicating no pollution. However, Station 2 and Station 3 are heavily polluted.

Table 2. EPA Heavy Metal Guidelines for Sediments (mg/kg).

Heavy metal	**Not polluted**	**Moderated polluted**	**Heavily polluted**	**Present study (mg/kg)**
Cu	<25	25-50	>75	85.99 ± 8.19
Pb	<40	40-60	>60	115.96 ± 2.09
As	<3	03-Aug	>8	84.99 ± 3.21
Cd	ND	ND	>6	1.54 ± 0.47

ND: Not Detected

Concentration of Radionuclide

Based on the Table 3, the concentration of radionuclides (uranium, thorium, and potassium) in 15 different locations is presented. The average concentrations of radionuclides are Th>K>U with 91.96

mg/kg, 42.77 mg/kg, and 13.34 mg/kg, respectively. The highest concentration of radionuclides is observed in location 3, specifically for potassium, with a value of 98.44%. Conversely, the lowest concentration of radionuclides is found in location 7, with a value of 11.06%. The variation in radionuclide concentrations among the 15 locations can be attributed to various factors, including the geological characteristics of the area, the presence of industrial activities, and the use of fertilizers. It is important to note that the elevated levels of radionuclides in certain locations may pose health risks to residents in those areas. Based on the Upper Continental Crustal (UCC) value, all the radionuclides exceeded the limit due to the high influence of human activities.

Table 3. Concentration of Radionuclide.

Station	U (mg/kg)	Th(mg/kg)	K (%)
S1	14.56 ± 0.61	91.47 ± 0.57	38.3 ± 1.95
S2	14.56 ± 0.61	91.47 ± 0.57	32.04 ± 2.12
S3	14.88 ± 0.49	88.89 ± 2.93	98.44 ± 2.3
S4	14.24 ± 0.45	88.63 ± 0.23	66.38 ± 2.47
S5	14.14 ± 0.41	80.95 ± 1.43	30.81 ± 2.64
S6	14.88 ± 0.25	91.96 ± 7.34	12.65 ± 2.81
S7	14.45 ± 0.37	89.47 ± 0.59	11.06 ± 2.98
S8	12.63 ± 0.32	76.5 ± 0.76	87.88 ± 3.15
S9	12.13 ± 0.13	70.49 ± 0.65	92.15 ± 3.32
S10	12.95 ± 0.18	73.88 ± 0.18	11.85 ± 3.66
S11	12.11 ± 0.14	76.21 ± 0.54	12.16 ± 4.00
S12	13.59 ± 0.46	81.5 ± 1.19	94.43 ± 4.34
S13	12.00 ± 0.19	73.25 ± 2.37	20.71 ± 4.68
S14	13.24 ± 0.51	75.69 ± 2.17	20.07 ± 5.02
S15	13.10 ± 0.35	84.68 ± 0.84	12.56 ± 5.36
Range	11.27-14.88	68.62-91.96	11.06-98.44
UCC	2.7	9.6	2.1

UCC- Upper Continental Crustal average

Correlation between Metals and Sediment

Based on the Pearson correlation coefficients as shown in Table 4, numerous metals exhibit significant correlations ($p < 0.01$). The Pearson matrix in this study indicates a strong association between heavy metals, particularly between Pb and Fe, Pb and Cd, as well Fe and Cd. Notably, the significantly positive correlation between Cu and Pb ($r = 0.953$) suggests that these elements share the same source, likely stemming from anthropogenic activities such as the use of pesticides and fertilizer by paddy farmers (Elfikrie et al., 2020; Jalaludin et al., 2019).

Table 4. Pearson correlation matrix of heavy metals in Tengi River, Selangor

	Cu	Pb	Fe	As	Cd
Cu	1				
Pb	0.00951	1			
Fe	-0.0768	**0.953**	1		
As	-0.337	0.328	0.361	1	
Cd	-0.111	0.647	0.668	0.0665	1

Pollution assessment

Geo-accumulation index (I_{geo})

According to Table 5, the geo-accumulation index (I_{geo}) is used to assess the contamination level of a sediment sample with a specific element. It is classified into six classes, ranging from class 1 (unpolluted) to class 6 (extremely polluted). In this study, I_{geo} calculated sediment samples from 15 stations. Based on Table 5, it can be concluded that sediment samples from Stations 2 and 3 are extremely polluted with Cd, and all stations have an extremely polluted level with As. On the other hand, the sediment samples from the remaining stations are moderately polluted, except for Station 9, which is unpolluted in terms of Fe.

Table 5. Geo-accumulation Index (I_{geo}).

Station	Cu	Pb	Fe	As	Cd
S1	2.04	2.53	1.62	4.80	3.66
S2	1.92	2.53	1.62	4.82	6.03
S3	1.92	2.42	1.55	4.87	5.98
S4	1.92	2.19	1.28	4.74	-0.24
S5	1.93	2.30	1.36	4.10	-0.48
S6	1.70	2.26	1.32	5.03	-0.03
S7	1.73	2.02	1.32	4.95	-0.24
S8	1.66	1.97	1.12	4.71	-0.24
S9	2.57	1.91	0.98	4.70	-0.48
S10	2.32	2.16	1.26	4.75	-0.48
S11	2.32	2.31	1.50	4.85	-0.03
S12	2.14	2.19	1.26	4.81	-0.61
S13	1.69	2.01	1.15	4.72	-0.35
S14	2.04	1.96	1.18	4.75	-0.13
S15	1.78	1.77	1.05	4.81	-0.35
Mean	1.98	2.17	1.30	4.76	0.80

Pollution Load Index (PLI)

The pollution load index (PLI) as an aggregative explanation of the overall level of metal pollution, was investigated and the obtained results revealed that all studied areas, have PLI values greater than 1. All elements are classified as excessively polluted with heavy metals.

Sediment Quality Guidelines

Based on Table 6, the mean values of As in the Enrichment Factor (EF), Contamination Factor (CF), and Ecological Risk (ER) are 8.55, 42.52, and 425.17, respectively. These values indicate that the sediment is highly polluted with As. On the other hand, the mean value for Cu in EF is the lowest at 1.29, indicating minimal enrichment, and in ER, it shows a low ecological risk with a value of 29.73. For Fe in CF, the mean value is 3.64, indicating only considerable contamination.

Table 6. Sediment Quality Guidelines, SQGs for (EF, CF, and ER)

Heavy metal	Enrichment factor (EF)			Contamination factor (CF)			Ecological risk (ER)		
	Mean	EF value	classification	Mean	CF value	classification	Mean	ER Value	classification
Cu	1.29	<2	Minimum enrichment	5.95	≤ 6	considerable contamination	29.73	<40	Low ER
Pb	1.38	<2	Minimum enrichment	6.58	> 6	very high contaminations	32.92	<40	Low ER
Fe	1.45	<2	Minimum enrichment	3.64	3 ≤ CF ≤ 6	considerable contamination	NA	NA	NA
As	8.55	<20	Adequate enrichment	42.52	> 6	very high contaminations	425.17	>320	Very high risk

Cd	3.11	<5	Medium enrichment	13.90	> 6	very high contaminations	417.06	>320	Very high risk

NA: Not Available

Conclusion

In conclusion, the assessment of heavy metals in selected section at Tengi River indicated a high degree of pollution in the surface sediment. The analysis revealed a decreasing rank order of elemental concentrations, Pb > Cu > As > Fe > Cd. According to EPA guidelines, sampling locations were heavily polluted with Pb, Cu and As. Additionally, the average concentrations of radionuclides were Th > K > U, respectively. In this study, the indices I_{geo}, EF, CF, PLI, and Er were calculated to determine the degree of heavy metal pollution in Sungai Tengi surface sediments and assess their potential ecological risk. The results of I_{geo}, CF, PLI, and ER indicated a heavy metal load with As and Cd in surface sediments due to anthropogenic activities. Generally, I_{geo} and CF suggested that the average concentrations of heavy metals analyzed in the sediment were higher than the background value. However, minimal pollution was identified for Cu and Pb. According to the potential ecological risk of individual metals (ER), the values were influenced by the heavy metals in the following sequence Cu < Pb < Cd < As. This shows that As and Cd pose a threat to the ecosystem. Additionally, the concentrations of U, Th, and K in the sediment samples exceeded upper continental crust values, indicating potential health risks associated with these elements.

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Author Contribution

ZA Mohd Zainuddin-lab work, N Mohd Saidi-sampling, AT Abdul Rahman – review paper, NA Nik Ariffin-supervision, review, S Md Yunus – supervision, writing, review, editing.

Conflict of Interest

The authors declare no conflict of interest.

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