

Research article

Distribution and Pollution Assessment of Heavy Metals in Surface Sediments from Prawet Burirom Canal, Bangkok, Thailand

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Abstract

This research investigated the spatial distribution and levels of heavy metal contamination in sediments along the Prawet Burirom Canal, Ladkrabang District, Bangkok, Thailand. Surface sediment samples were collected from the bottom of the canal between Wat Ratchakosa and Wat Lat Krabang on August 29, 2025. The samples were prepared for elemental analysis via microwave-assisted acid digestion and measured by ICP-OES. The mean concentrations of heavy metals in the sediments in decreasing order of contamination were: iron (Fe) > manganese (Mn) > zinc (Zn) > copper (Cu) > arsenic (As) > chromium (Cr) > lead (Pb) > cobalt (Co). Their ranges were determined to be 50.81-66.94 g/kg for Fe, 361.04-690.49 mg/kg for Mn, 71.26-198.41 mg/kg for Zn, 44.15-67.14 mg/kg for Cu, 15.28-84.56 mg/kg for As, 32.28-47.49 mg/kg for Cr, 17.87-47.32 mg/kg for Pb, and 8.26-11.75 mg/kg for Co, while cadmium (Cd) and nickel (Ni) were not detected. Five toxic metals, As, Pb, Cr, Zn and Cu, were used to evaluate pollution and ecological risk assessments. Based on the geo-accumulation index (I_{geo}), the sediments were classified as extremely contaminated with Pb and heavily to extremely contaminated with As. The contamination factors (CF) for As, Zn, and Cu indicated very high contamination while the pollution load index (PLI) displays a gradual decline in site quality. The overall ecological risk was categorized as considerable to high ecological risk. This study suggests that the high contamination levels of heavy metals, particularly As and Pb, were frequently related to anthropogenic activities in the surrounding environment.

Keywords: ecological risks; pollution assessment; heavy metals; surface sediment; Prawet Burirom Canal

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1. Introduction

Nowadays, heavy metal contamination in aquatic ecosystems is widely considered as a global environmental problem. These pollutants are highly toxic, non-biodegradable, widely available and persistent in the environment (Zeb et al., 2024). According to their properties, they tend to settle into sediments or bioaccumulate through aquatic food chains causing severe, long-term risks to ecosystems and human health (Cao et al., 2025; Wang et al., 2025a,b; Zeb et al., 2024; Kawichai et al., 2023). Hazardous metals like arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), and lead (Pb) induce oxidative stress and DNA damage. Even at low concentrations, these metals can cause chronic diseases such as cancer, cardiovascular diseases, and kidney damage (Ohiagu et al., 2022). Although trace amounts of copper (Cu), chromium (Cr), iron (Fe), cobalt (Co), manganese (Mn) and zinc (Zn) are biologically essential elements for living organisms, they become toxic at high concentrations (Alloway, 2013).

Heavy metals can enter riverine systems through several pathways via both natural processes and anthropogenic activities. They naturally arise from the release of metal elements stored in the earth's crust through various geochemical cycles, e.g., rock weathering, soil erosion and volcanic activity, which establish their baseline levels. However, these metals can become significant sources of contamination under specific environmental conditions such as acidic soil, waterlogged areas, and high temperature. Heavy metal pollution in aquatic systems is mainly driven by anthropogenic activities, including industrial effluents, mining activities, agricultural runoff, urban discharges, and waste disposal (Carvalho et al., 2022; Wang et al., 2026). Globally, over 80% of industrial and municipal wastewater is discharged into the environment without adequate treatment, leading to water quality deterioration (Lin et al., 2022). In addition, atmospheric deposition is an indirect pathway for heavy metal contamination of water bodies. Metallic particles and gases, primarily released from industrial activities and vehicular traffic, are transported and subsequently deposited onto water surfaces through wet or dry deposition processes (He et al., 2023; Zeb et al., 2024).

Sediments are important components in river ecosystems because they act as dynamic, long-term sinks as well as potential reversible sources for contaminants. They are largely composed of fine-grained particles and organic matter. Moreover, they display a large specific surface area, porosity, high reactivity, and abundant active sites. Based on their compositions and structural characteristics, sediments are highly effective in the adsorption of both organic and inorganic pollutants (Miranda et al., 2021). When heavy metals enter water columns, they rapidly bind to suspended solids through physical precipitation and chemical adsorption during the flow process. Fine-grained particles, especially clay minerals (e.g., kaolinite, illite, and montmorillonite), possess high specific surface areas and net negative surface charges, which enable them to electrostatically attach to heavy metal cations. Moreover, functional groups such as carboxylic and hydroxyl moieties in organic-rich particles form strong complexes with cationic species. Consequently, heavy metals significantly reduce their solubility and bioavailability, resulting in accumulation in bottom sediments (Wang et al., 2020; Zeb et al., 2024). However, the accumulated heavy metals can be released back into the water bodies due to changing environmental conditions such as pH, redox potential, temperature, salinity and flow velocity (Jiang et al., 2026). Thus, heavy metal concentrations are often considerably higher in sediments than in overlying water (Wang et al., 2020).

The Prawet Burirom Canal, a 46-kilometers-long man-made water channel in Bangkok, serves as a crucial waterway for transportation, regional irrigation, and drainage.

It connects the Chao Phraya River via the Phra Khanong Canal in eastern Bangkok to the Bang Pakong River in Chachoengsao province. At present, it is severely polluted, gives off foul odors and displays low oxygen levels. This pollution is due to industrial effluent, agricultural runoff, and residential discharges. Nowadays, heavy metal contamination in Thailand's major rivers is well-documented (Qiao et al., 2015; Asokbunyarat & Sirivithayapakorn, 2020; Kawichai et al., 2023; Yottiam et al., 2025), however, research on localized dynamics within narrow urban canal conduits remains limited. This study aimed to investigate localized heavy metal dynamics, ecological risks, and spatial variations in surface sediments along the Prawet Burirom Canal, Bangkok, specifically focusing on the stretch between Wat Ratchakosa and Wat Lat Krabang. The research provides specific data for targeted municipal pollution control and effective urban waterway management.

2. Materials and Methods

2.1 Study area

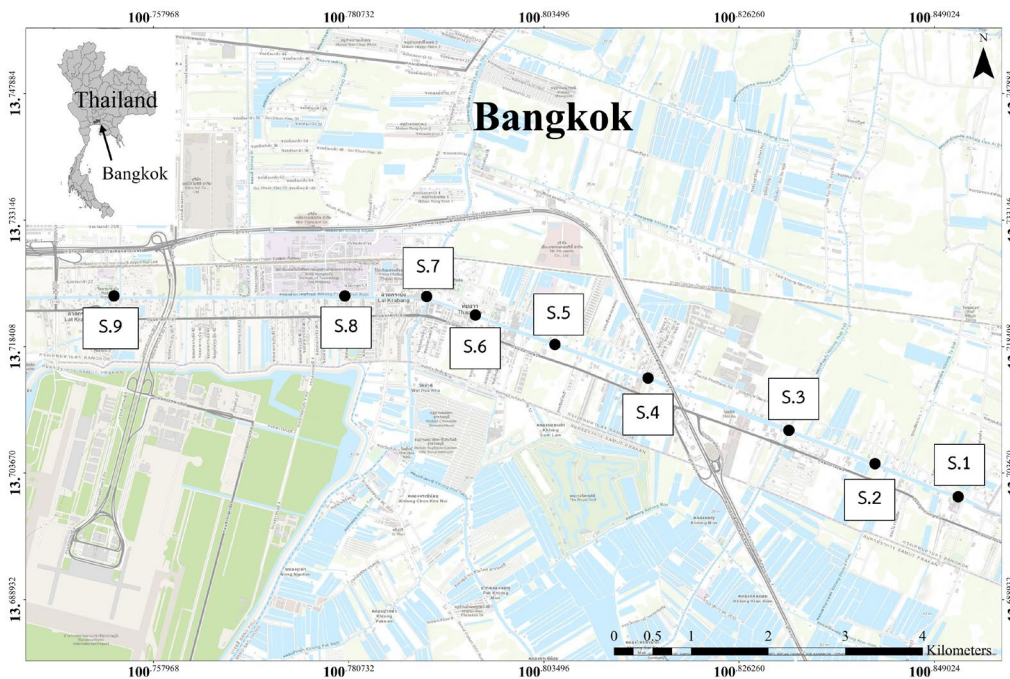
This research was conducted at the Prawet Burirom Canal focusing on the stretch between Wat Ratchakosa and Wat Lat Krabang, Ladkrabang District, Bangkok, Thailand. In this study, sampling sites across various land-use zones were selected to assess anthropogenic impacts on local ecosystems. The sampling locations were determined using a portable Global Positioning System (GPS) device to record the precise geographic coordinates. The land use activities and surrounding environmental characteristics were also observed as listed in Table 1.

2.2 Sample collection and preparation

In this study, nine distinct sampling points were used to assess the spatial distribution of heavy metals, as shown in Figure 1. Sediment samples were collected on August 29, 2025, from the Prawet Burirom Canal following standard method (U.S. EPA, 2001) to analyze heavy metals. Approximately 1 kg of surface sediment (1-15 cm depth) was collected using an Ekman grab sampler (GEM 520, Harikul Science Co., Ltd., Thailand). Upon opening the top flap, sub-samples were retrieved from the center of the device using an acid-cleaned plastic spatula to minimize contamination and then kept in a sealed transparent polyethylene bag. All samples were transported to the laboratory in an ice box. Subsequently, they were stored in a freezer (Haier, DW-40L92 model, Haier Biomedical, China) at temperature of -20°C for 1 to 2 days. Afterwards, the sediments were freeze-dried at -40°C using a freeze dryer (LaboGene Scanvac, CoolSafe 110-4 model, LaboGene, Denmark) until they reached a constant weight. The dried sediments were sieved through a 2-mesh nylon sieve to remove coarse debris. The sieved sediments were ground in an agate mortar to obtain a fine, homogeneous powder and then passed through a 63 µm nylon sieve to isolate the silt and clay fraction. Subsequently, the powdered samples were kept in a desiccator for further analysis. All devices and containers were acid-cleaned using 10% HNO₃, thoroughly rinsed with ultrapure water, and air dried before use.

Table 1. Sampling location characteristics

Sampling Point	Geographic Coordinates		Land Use Activities and Surrounding Environmental Characteristics
	Latitude	Longitude	
S1	13.700806 N	100.851944 E	Khumthong bridge, heavily populated area
S2	13.704611 N	100.842000 E	Heavily populated area, chicken farm
S3	13.7085572 N	100.8320314 E	Heavily populated area, auto parts manufacturer, duck farm
S4	13.714722 N	100.815639 E	Heavily populated area, garage, restaurant
S5	13.718444 N	100.805111 E	Restaurant, recycling shop, factories, hotel
S6	13.721972 N	100.795472 E	Heavily populated area, metal works
S7	13.7240238 N	100.7898711 E	Huatakae Junction, heavily populated area, factories,
S8	13.724167 N	100.781611 E	Prawet Burirom 2 bridge, heavily populated area, university area
S9	13.724138 N	100.752731 E	Ladkrabang temple, heavily populated area

**Figure 1.** Map of the study area (the Prawet Burirom Canal) and sampling site locations

2.3 Sample analysis

2.3.1 Water characteristics

Characteristics of surface and bottom water (such as pH, DO, E.C., TDS, temperature) were measured in situ using a Portable Meter (WTW Multi 3430 IDS, Multiparameter), ensuring real-time accuracy. The depths of the canal were determined using a weighted plummet line.

2.3.2 Grain size characteristics of sediments

Grain size compositions of all sediment samples were determined using a Laser Diffraction method. Before analysis, the sediments were pre-treated with 10% H₂O₂ (Carlo Erba, Italy) to remove organic matter and dried in a hot air oven at 60°C for 2-3 days to prevent aggregation. Approximately 3-5 g of each dried sediment was dispersed and homogenized in water. The solutions were then analyzed with a Laser Scattering Particle Distribution Analyzer (LA-950 model, Horiba, Ltd., Japan) to measure particle sizes ranging from 10 nm to 3 mm. The mean grain size of the sediments was calculated using the Matrix method. Each sediment was categorized using the scheme of the USDA soil texture classification.

2.3.3 Heavy metal analysis

Pseudo-total metal concentrations in sediment samples were extracted by a microwave-assisted acid digestion procedure according to U.S. EPA 3051A (U.S. EPA, 2007). Approximately 0.5 g of powdered sediment was weighed with a 4-digit microbalance (MS204TS, Mettler Toledo, Switzerland) to ensure high precision and then placed into a polytetrafluoroethylene (PTFE) vessel. A total of 12 mL of freshly prepared aqua regia (a 3:1 mixture of nitric acid (HNO₃ 69%, Loba Chemie, India) and hydrochloric acid (HCl 37%, Thermo Fisher Scientific, USA)) was added into the vessel. Next, the sample was treated in a microwave oven (MPS 320 Microwave Digestion System, Perkin Elmer, England) using the 2-step temperature program. The sample was heated to 175°C and held for 10 min at pressure limit of 30 bars to increase the oxidation potential of the acids, allowing for efficient digestion of organic and inorganic samples. After that, the sample was stabilized by reducing temperature to 50°C for 15 min. Each mixture was then allowed to settle and cool down to avoid potential losses of volatile compounds. Later, the digested sediments were filtered using No. 42 Whatman® filter paper. The filtrate was subsequently diluted to a final volume of 100 mL with ultrapure water. Before analysis, the sample solution was filtered with a 0.45 µm syringe filter. Afterwards, the concentrations of solubilized metals were measured by an Inductively Coupled Plasma - Optical Emission Spectrophotometer (ICP-OES) (Avio 550 Max model, Perkin Elmer, England). A heavy metal standard solution (Multi Element ICP QC Standard solution (QCS-01) (23E), Chem-Lab, Belgium) was used as a calibration standard for the determination of heavy metals. A field blank sample was also measured using the same method as used for the sample. All samples were investigated in triplicate. All chemicals used in this study were of analytical reagent (AR) grade. All equipment used was pre-treated by soaking in a 10%(v/v) HNO₃ solution for 24 h, followed by thorough rinsing with ultrapure water to remove any contaminants.

2.4 Pollution assessment of heavy metals

2.4.1 Geo-accumulation index (I_{geo})

The geo-accumulation index (I_{geo}), developed by Muller (1969), is used to evaluate heavy metal pollution in surface sediments by comparing current concentrations with background levels. It is calculated using equation 1:

$$I_{geo} = \log_2 \left[\frac{C_n}{1.5B_n} \right] \quad (1)$$

where C_n is the heavy metal concentration n in the sediment sample (mg/kg) and B_n is the geochemical background value of element n . The factor of 1.5 is used for the background matrix correlation factor and the concentration categories classified by lithogenic effects. Based on Taylor's references, the heavy metal background values of As, Pb, Cr, Zn and Cu were 1.8, 75, 100, 70 and 12.5 mg/kg, respectively (Taylor, 1964). The I_{geo} values were divided into 7 classes as follows: $I_{geo} < 0$ - practically uncontaminated; $0 \leq I_{geo} < 1$ - uncontaminated to moderately contaminated; $1 \leq I_{geo} < 2$ - moderately contaminated; $2 \leq I_{geo} < 3$ - moderately to heavily contaminated; $3 \leq I_{geo} < 4$ - heavily contaminated; $4 \leq I_{geo} < 5$ - heavily to extremely contaminated and $I_{geo} \geq 5$ - extremely contaminated.

2.4.2 Contamination factors (CF)

The contamination factor (CF) is a standardized index used in environmental studies. It is used to assess the extent of heavy metal pollution in sediments relative to natural background levels. It is calculated by measuring the ratio between the heavy metal concentration in the sediment and the background value as shown in equation 2.

$$CF = \frac{C_i}{C_0} \quad (2)$$

where C_i is the measured concentration of heavy metal in the sediment sample, C_0 is the mean concentration of heavy metal in the natural background. The background concentrations for As, Pb, Cr, Zn, and Cu detected in sediments of Inner Gulf of Thailand, were 4.76, 11.93, 21.64, 13.11 and 5.61 mg/kg, respectively (Yottiam et al., 2025). The CF levels were commonly categorized into 4 classes to assess heavy metal pollution as follows: $CF < 1$ - low contamination (or no contamination); $1 \leq CF < 3$ - moderate contamination; $3 \leq CF < 6$ - considerable contamination; $CF \geq 6$ - very high contamination (Hakanson, 1980; Fardullah et al., 2025).

2.4.3 Pollution load index (PLI)

The pollution load index (PLI) is a comprehensive and comparative tool used to assess the quality of sediments. It provides a quick assessment of site contamination. It is defined as the n^{th} root of the multiplication of the contamination factors (CF) of the analyzed heavy metals as illustrated in equation 3.

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n)^{1/n} \quad (3)$$

where CF_1 , CF_2 , CF_3 , and CF_n represent the CF values of metals 1, 2, 3, and n , respectively. n represents the total number of metals studied in the samples. The PLI values are interpreted at 3 levels as follows: 0 – no contamination (perfection), 1 - only baseline levels of contaminants, and >1 – a gradual decline in site quality (Tomlinson et al., 1980; Fardullah et al., 2025).

2.4.4 Potential ecological risk (PER)

The potential ecological risk (PER) is a comprehensive indicator used to evaluate the ecological impact of toxic pollutants. It is calculated by the sum of the individual ecological risk factors as shown in equation 4. The ecological risk factor (E_r) is determined by multiplying the contamination factor (CF) by the toxic-response factor (T_r) as follows (equation 5):

$$PER = \sum_{r=1}^n E_r \quad (4)$$

$$E_r = T_r \times CF \quad (5)$$

where E_r is the ecological risk of the i^{th} heavy metal; CF is the contamination factor for each metal; T_r is the toxic response factor. The toxic-response factors for As, Pb, Cr, Zn and Cu were 10, 5, 2, 1 and 5, respectively (Hakanson, 1980; Fardullah et al., 2025). The PER levels were commonly categorized into 5 levels to assess ecological risk as follows: $E_r < 40$ – less ecological risk; $40 \leq E_r < 80$ – moderate ecological risk; $80 \leq E_r < 160$ – considerable ecological risk; $160 \leq E_r < 320$ – high potential ecological risk; $E_r \geq 320$ – very high ecological risk (Hakanson, 1980; Fardullah et al., 2025).

2.5 Statistical analysis

Analyses were performed at a significance level of 0.05 ($\alpha = 0.05$) using Minitab. A one-way analysis of variance (ANOVA) with Tukey's post hoc test was applied to assess the mean differences of heavy metal levels among sampling locations. The linear relationships between the concentrations of various heavy metals across different sampling sites were determined by a Pearson's correlation coefficient matrix.

3. Results and Discussion

3.1 Water characteristics

The characteristics of surface and bottom water derived from the Prawet Burirom Canal were shown in Table 2. The measured pH levels of surface water ranged from 6.97 to 7.43 while those of bottom water were between 7.08 and 7.22. These results indicated that water conditions were neutral to slightly alkaline. According to their consistent pH values throughout the vertical column, it strongly suggested active vertical mixing. The E.C. levels of surface water ranged from 666 to 799 $\mu\text{S}/\text{cm}$ whereas those of bottom water were between 692 and 815 $\mu\text{S}/\text{cm}$. The salinity levels of surface and bottom water were 0.30 ppt indicating fresh to slightly brackish water. The DO levels of surface water ranged from 2.42 to 7.10 mg/L while those of bottom water were between 1.82 and 3.42 mg/L. The DO levels of bottom water were slightly lower than those of surface water except for the S9 location. This may be because of the lack of photosynthesis and high oxygen consumption through

respiration from bacterial decomposition of organic matter. However, the dissolved oxygen levels of surface and bottom water were not significantly different. This may result from shallow water systems (0.70-1.80 m ranges) leading to well-mixed dissolved oxygen due to atmospheric conditions. At the S9 location, the DO level at the surface was 7.10 mg/L, which was significantly higher than at the bottom (3.25 mg/L). This was likely due to the presence of a Chaipattana aerator located at this site to add oxygen into the water.

3.2 Grain size compositions of sediments

The sedimentary grain size compositions at each sampling location are illustrated in Table 3. Based on USDA soil texture triangle, samples S1 and S9 were classified as silt due to their extremely high silt content (>80%) and low clay content. They felt silky when wet and exhibited high water retention capacity and low permeability. While samples S2-S8 were categorized as silt loam because of their dominant silt content (typically 50-80%) and moderate amount of clay (<27%). They had high water retention capacity, moderate drainage and high fertility. These results implied that the sediments contained extremely high silt content (80-90%), indicating a silty-textured alluvial or a deposit from a floodplain environment. These results were in agreement with the study of Qiao et al. (2015), who found that sediments in the Chao Phraya River and Bang Pakong River, especially near their estuaries in the upper Gulf of Thailand, were composed of fine-grained silt with particle sizes <30 μm .

3.3 Concentrations and spatial distribution of heavy metals

The experimental results indicated that heavy metals found in the sediment samples were arsenic (As), lead (Pb), chromium (Cr), zinc (Zn), copper (Cu), cobalt (Co), iron (Fe), and manganese (Mn), as illustrated in Figure 2. While cadmium (Cd) and nickel (Ni) were not detected.

The mean arsenic (As) concentrations in surface sediment samples from all identified locations indicated high contamination, ranging from 15.28 to 84.56 mg/kg as shown in Figure 2(a). Their concentrations in descending order were as follows: S4>S2>S3>S5>S9>S1>S8>S7>S6. However, there were no significant differences at sites S1-S5 and S9. The As concentrations at all stations exceeded both Thai national standards for sediment quality (>10 mg/kg) (NEB, 2023) and U.S. EPA guidelines (>8 mg/kg) (U.S. EPA, 1977). The sediments from all sites were classified as heavily polluted. These contaminations likely resulted from agricultural activities, including over-use of fertilizers and arsenical pesticides, particularly in areas surrounding the sampling sites. These results were in agreement with the work of Kawichai et al. (2023), who reported that As concentrations in the surface sediments of the Mae Chaem River in Chiang Mai, Thailand were found to range from 14.1 to 95.5 mg/kg. Kawichai et al. (2023) explained that the high arsenic (As) concentrations were predominantly linked to agricultural practices and residential areas along the river.

The average lead (Pb) concentrations in surface sediments from all locations were found to be between 17.87 and 47.32 mg/kg, as shown in Figure 2(b). Their concentrations in decreasing order were: S4>S3>S2>S5>S9>S8>S6>S7>S1. However, no significant differences in Pb concentrations were observed between locations S2-S5, and S9. Only the surface sediment at location S4 exceeded the Thai standard threshold of 36 mg/kg (NEB, 2023). According to U.S. EPA guidelines, the sediment from location S4 was classified as moderately polluted (40-60 mg/kg), while those of the remaining sites were categorized as not polluted. The Pb contamination probably originated from anthropogenic

activities including the over-use of pesticides, and from paints, automobile emissions and atmospheric deposition (Ali et al., 2016). These results were consistent with those reported in the Bang Pakong River (27-36 mg/kg) and slightly lower than those investigated in the Chao Phraya River (33-86 mg/kg) (Qiao et al., 2015).

The mean chromium (Cr) concentrations in surface sediments from all locations detected were between 32.28 and 47.49 mg/kg, as shown in Figure 2(c). Their levels decreased in the following order: S4>S8>S9>S3~S6>S2>S5>S7>S1. There were no significant differences in Cr concentrations among sampling locations except site S1. Only the mean Cr concentrations at sites S4 and S8 exceeded the Thai standard of 43.4 mg/kg (NEB, 2023). According to U.S. EPA guidelines, the sediments from all sampling locations were classified as moderately polluted (25-75 mg/kg). The Cr pollution may be derived from both natural background levels and anthropogenic activities such as the application of fertilizers, agricultural lime, and manure. These findings were significantly lower than those reported in the Bang Pakong River (73.90-94.28 mg/kg) and the Chao Phraya River (82.12-274.11 mg/kg) (Qiao et al., 2015). This was primarily because of the natural, high-energy erosion processes in the rivers, compared to the controlled, low-velocity environment of the canal. The average zinc (Zn) concentrations in surface sediments from all locations ranged from 71.26 to 198.41 mg/kg, as shown in Figure 2(d). Their levels decreased in the following order: S7>S6>S5>S8>S9>S4>S3>S2>S1. The Zn concentrations in sediment samples from sites S5-S9 exceeded the Thai standard of 120 mg/kg (NEB, 2023). These findings were comparable to those reported in the Bang Pakong River (90-107 mg/kg) and significantly lower than those observed in the Chao Phraya River (99-361 mg/kg) (Qiao et al., 2015). The Zn pollution in the sediments was likely derived from industrialization and urbanization, including vehicular emissions, tire wear, waste oils, electronic scrap and manufacturing processes (Wardhani et al., 2022). The mean copper (Cu) concentrations in surface sediments from all locations ranged from 44.15 to 67.14 mg/kg. Their levels decreased in the following order: S1>S9>S6>S7>S5>S4>S8>S2>S3. Their concentrations in all sediment samples significantly exceeded both Thai national standards for sediment quality (>31.5 mg/kg) (NEB, 2023) and U.S. EPA guidelines (25-50 and > 50 mg/kg), as shown in Figure 2(e). There were no significant differences among all sampling sites. According to U.S. EPA guidelines (U.S. EPA, 1977), the sediments from sites S2-S3 were classified as moderately polluted (25-50 mg/kg) while those obtained from sites S1, and S4-S9 were classified as heavily polluted (> 50 mg/kg). These results were slightly higher than those found in the Bang Pakong River (28-31 mg/kg) but largely lower than those revealed in the Chao Phraya River (31-242 mg/kg) (Qiao et al., 2015). These levels suggest mild to moderate contamination, potentially from anthropogenic sources like agricultural runoff and industrial waste. The average concentrations of cobalt (Co), iron (Fe) and manganese (Mn) in surface sediments from all identified locations were found to be between 8.26 and 11.75 mg/kg, 50.81 and 66.94 g/kg and 361.04 and 690.49 mg/kg, as shown in Figures 2(f), 2(g), and 2(h), respectively. There are currently no Thai sediment quality standards for Co, Fe and Mn. According to U.S. EPA guidelines, the sediments from all sites were classified as heavily polluted for Fe (> 25 g/kg). While the sediments from sites S2 and S4-S8 were classified as moderately polluted for Mn (300-500 mg/kg) and those from sites S1, S3 and S9 were categorized as heavily polluted for Mn (> 500 mg/kg). The contamination of Co, Fe, Mn likely originated from a combination of natural geological weathering and anthropogenic activities such as industrial discharge, agricultural runoff, and urban effluents (Zarei et al., 2023). Based on the analysis of sediment characteristics, the high concentrations of heavy metals were directly related to the presence of fine-grained particles, specifically silt and silt loam as shown in Table 3.

Table 2. Characteristics of surface and bottom water derived from the Prawet Burirom Canal

Sites	Surface Water						Bottom Water						Water Characteristics
	pH	EC ($\mu\text{s}/\text{cm}$)	DO (mg/L)	Salinity (ppt)	Temp. ($^{\circ}\text{C}$)	Depth (m)	pH	EC ($\mu\text{s}/\text{cm}$)	DO (mg/L)	Salinity (ppt)	Temp. ($^{\circ}\text{C}$)	Depth (m)	
S1	7.13	666	3.42	0.30	29.80	0-0.30	7.10	803	3.42	0.30	30.00	0.70	No odor
S2	7.06	719	2.90	0.30	30.00	0-0.30	7.12	795	2.84	0.30	29.90	1.70	No odor
S3	7.03	795	2.84	0.30	30.20	0-0.30	7.10	815	1.82	0.30	30.20	1.80	Polluted black water, Unpleasant odor
S4	7.14	788	2.42	0.30	30.10	0-0.30	7.11	784	2.30	0.30	29.00	1.70	Polluted black water
S5	7.08	789	2.93	0.30	30.90	0-0.30	7.22	805	2.90	0.30	29.80	1.60	Polluted black water, No odor
S6	7.05	799	4.31	0.30	30.00	0-0.30	7.16	800	3.27	0.30	30.50	1.70	No odor
S7	7.09	710	3.70	0.30	30.20	0-0.30	7.17	692	2.46	0.30	29.90	1.80	Unpleasant odor, Fish dead
S8	6.97	701	3.79	0.30	30.70	0-0.30	7.08	705	3.18	0.30	29.50	1.80	Polluted black water, Unpleasant odor
S9	7.43	797	7.10	0.30	31.60	0-0.30	7.20	791	3.25	0.30	30.10	1.80	No odor

Table 3. Grain size composition of sediments

Sampling Location	Sediment Size Percentage Content			USDA Soil Texture Classification
	Clay (< 2 μm)	Silt (2 - 63 μm)	Sand (> 63 μm)	
S1	3.89	88.40	7.71	Silt
S2	7.40	91.33	1.27	Silt loam
S3	13.08	82.82	4.11	Silt loam
S4	12.49	82.47	5.04	Silt loam
S5	21.44	74.28	4.28	Silt loam
S6	12.70	84.07	3.24	Silt loam
S7	7.51	87.26	5.24	Silt loam
S8	4.22	85.88	9.90	Silt loam
S9	5.31	93.52	1.17	Silt

According to Table 4, a strong positive correlation between arsenic (As) and lead (Pb) ($r = 0.918$) strongly suggests that both elements originated from common anthropogenic sources and shared the same environmental pathways, particularly via atmospheric deposition and combustion-related activities e.g., coal and oil burning, smelting, and vehicular emissions (Huang et al., 2020; Nilkarnjanakul et al., 2022). The strong positive correlation between cobalt (Co) and iron (Fe) ($r = 0.888$) and the moderate correlation between iron (Fe) and manganese (Mn) ($r = 0.551$) strongly imply a robust geochemical coherence, demonstrating that these trace metals were predominantly controlled by natural geological processes rather than anthropogenic contamination (Xu & Li, 2024). The statistically significant correlation between arsenic (As) and iron (Fe) ($r = 0.699$) indicates a strong geogenic bond between arsenic and iron minerals, proving arsenic is adsorbed or co-precipitated with iron oxides and oxyhydroxides (Warren et al., 2019). The positive correlation between lead (Pb) and chromium (Cr) ($r = 0.683$) indicates shared industrial contamination sources, e.g., metallurgy, leather tanning, and pigment production (Ramessur & Ramjeawon, 2002; Huang et al., 2020). The Pearson correlation coefficient (r) of 0.499 between lead (Pb) and cobalt (Co) and 0.545 between lead (Pb) and iron (Fe) indicates moderate positive linear relationships. This means that increases in lead concentrations were generally accompanied by rises in cobalt and iron levels (Huang et al., 2020). The moderate correlation coefficient between arsenic (As) and chromium (Cr) ($r = 0.451$) indicates geogenic backgrounds where both trace elements were released into aqueous environments via the reductive dissolution of iron and manganese oxides (Huang et al., 2020). The moderate correlation coefficient between arsenic (As) and manganese (Mn) ($r = 0.400$) indicates that the breakdown of manganese oxides in anaerobic environments led to the simultaneous release of co-precipitated arsenic (de Meyer et al., 2023). The moderate correlation coefficient between cobalt (Co) and manganese (Mn) ($r = 0.395$) strongly suggests they shared geogenic backgrounds and similar geochemical pathways (Li et al., 2001).

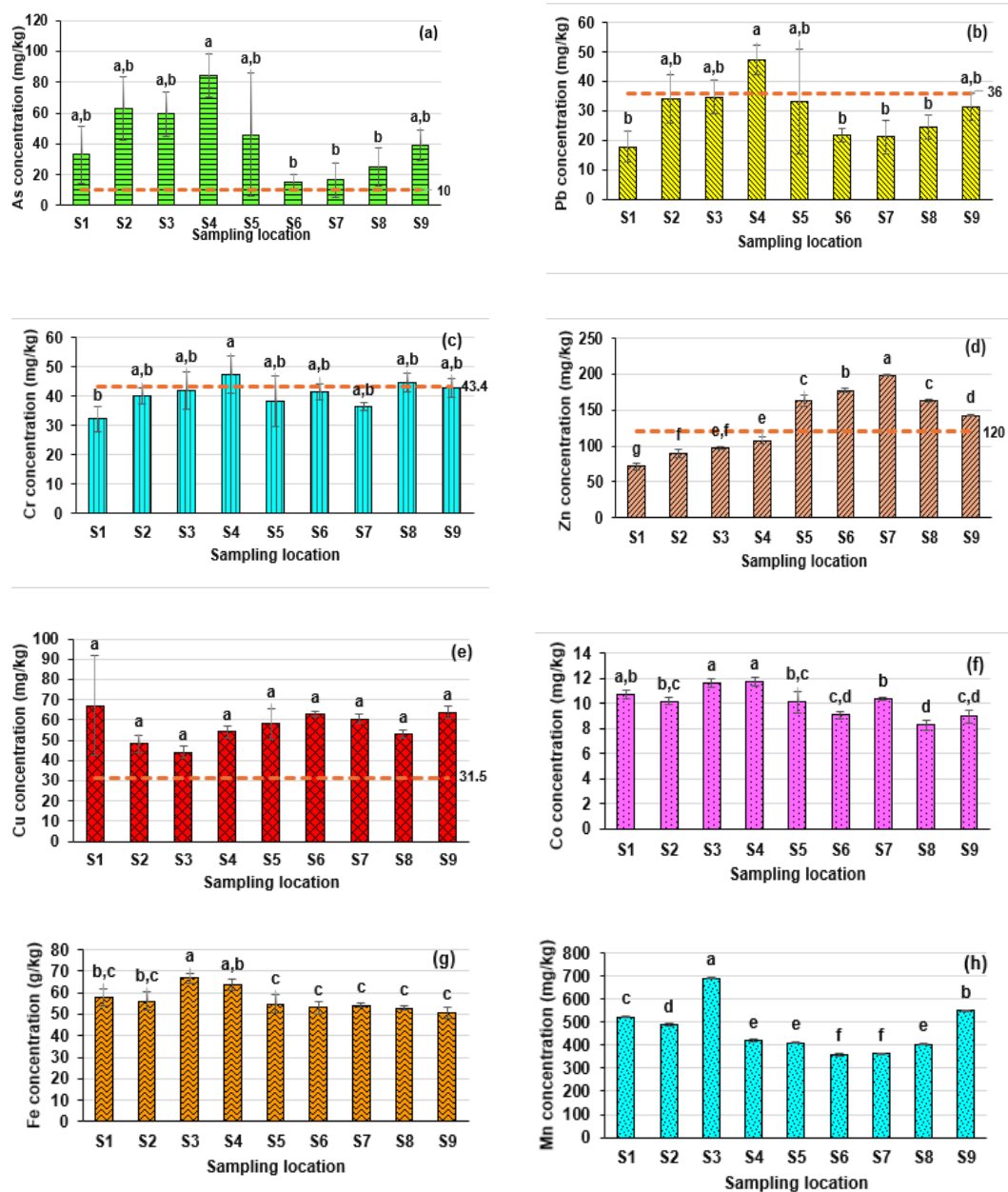


Figure 2. Arsenic (a), lead (b), chromium (c), zinc (d), copper (e), cobalt (f), iron (g) and manganese (h) concentrations in surface sediments

Remarks: A dashed line represents a maximum permissible limit of heavy metal standard level. The values with different superscript letters (a, b, c, d, e, f, g) above the chart denote statistically significant differences.

Table 4. Pearson's correlation coefficients between heavy metals in the Prawet Burirom Canal (n=9)

	As	Pb	Cr	Zn	Cu	Co	Fe	Mn
As	1	0.918**	0.451	-0.647	-0.577	0.671*	0.699*	0.400
Pb		1	0.683*	-0.314	-0.566	0.499	0.545	0.219
Cr			1	0.088	-0.467	-0.094	0.176	-0.023
Zn				1	0.282	-0.552	-0.611	-0.676
Cu					1	-0.337	-0.584	-0.401
Co						1	0.888**	0.395
Fe							1	0.551
Mn								1

Remarks: **Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed)

Table 5 illustrates a comparison of regional background concentrations of heavy metals among the Prawet Burirom Canal, the Bang Pakong River, the Chao Phraya River and the inner Gulf of Thailand. It was found that heavy metal concentrations in sediments were typically lower in the Prawet Burirom Canal than the Bang Pakong River and the Chao Phraya River. This was primarily because the Prawet Burirom is a relatively enclosed, suburban waterway, whereas the other two are major industrial and estuarine systems. However, heavy metal levels in sediments were significantly higher in the Prawet Burirom Canal than the inner Gulf of Thailand. This was likely because restricted water flow in the canal creates a stagnant sink that prevents contaminants from dispersing. In contrast, the inner Gulf of Thailand benefits from higher wave energy, stronger tidal currents, and a much larger volume of water, which dilutes and disperse contaminants more effectively.

Table 5. A comparison of regional background concentrations of heavy metals (mg/kg) in Prawet Burirom Canal, the Bang Pakong and Chao Phraya Rivers, and the inner Gulf of Thailand

Heavy Metal Type	Concentrations of Heavy Metal (mg/kg)			
	Prawet Burirom Canal	Bang Pakong River	Chao Phraya River	The Inner Gulf of Thailand
	(This study)	(Qiao et al., 2015)	Qiao et al., 2015)	(Yottiam et al., 2025)
As	15.28-84.56	-	-	4.76
Pb	17.87-47.32	27-36	33-86	11.93
Cr	32.28-47.49	73.90-94.28	82.12-274.11	21.64
Zn	71.26-198.41	90-107	99-361	13.11
Cu	44.15-67.14	28-31	31-242	5.61
Co	8.26-11.75	-	-	4.14
Fe	50,810-66,940	-	-	13,733.54
Mn	361.04-690.49	-	-	285.44

3.4 Pollution assessment of heavy metals

In this study, pollution and ecological risk assessments were evaluated for five toxic metals: As, Pb, Cr, Zn and Cu. The geo-accumulation index (I_{geo}) levels of arsenic (As), ranging

from 2.50 to 4.97, indicated severe to extreme arsenic (As) contamination. Sediments were moderately to heavily contaminated at sites S6-S7 ($2 \leq I_{geo} < 3$), heavily contaminated at sites 1 and S8-S9 ($3 \leq I_{geo} < 4$) and heavily to extremely contaminated across sites S2-S5 ($4 \leq I_{geo} < 5$). The I_{geo} values of lead (Pb) between 9.80 and 11.21 indicated that sediments were extremely contaminated ($I_{geo} \geq 5$) across all sampling sites. The I_{geo} levels of copper (Cu), ranging from 1.24 to 1.84, showed that all sample sites were classified as moderately polluted. The high I_{geo} values for Pb, As and Cu suggest that these metals in sediments were significantly enrichment above natural crustal weathering. They predominantly originated from anthropogenic sources like industrial discharges, mining waste, or agricultural runoff. The I_{geo} levels of chromium (Cr) between -2.22 and -1.66 showed that all sample sites were classified as practically uncontaminated ($I_{geo} < 0$). The I_{geo} levels of zinc (Zn), ranging from -0.56 to 0.92, reflected predominantly natural baseline conditions with mild anthropogenic enrichment. Sediments were practically uncontaminated ($I_{geo} < 0$) at sites S1-S3 and uncontaminated to moderately contaminated ($0 \leq I_{geo} < 1$) at sites S4-S9. The low I_{geo} values for Cr and Zn revealed that these metals in sediments were not significantly influenced by anthropogenic sources. They primarily originated from the natural weathering as well as erosion of local parent bedrock and surrounding soil as shown in Figure 3(a).

The contamination factor (CF) values of arsenic (As), ranging from 3.21 to 17.76, indicate severe, localized arsenic (As) enrichment. Sediments were considerably contaminated at sites S6-S8 ($3 \leq CF < 6$) and showed very high contamination at S1-S5 and S9 ($CF \geq 6$). The CF values for lead (Pb) between 1.50 and 3.97 indicated that the sediments across most sites had moderate contamination ($1 \leq CF < 3$). However, site S4 exhibited considerable contamination ($3 \leq CF < 6$), strongly pointing to localized anthropogenic pollution sources. The CF values of chromium (Cr), ranging from 1.49 to 2.19, exhibited widespread, moderate chromium (Cr) pollution ($1 \leq CF < 3$) across all sampling sites. The CF values for zinc (Zn) between 5.44 and 15.13 represented significant zinc accumulation typically linked to anthropogenic activities. Based on these values, sediments across most sites exhibited very high contamination ($CF \geq 6$), except for site S1, which presented considerable contamination ($3 \leq CF < 6$). The CF values for copper (Cu), ranging from 7.87 to 11.97, indicated very high contamination ($CF \geq 6$) across all sampling sites. This pointed to severe localized copper pollution driven primarily by anthropogenic sources such as mining or industrial runoff, rather than natural background levels, as shown in Figure 3(b).

A Pollution Load Index (PLI) between 3.99 and 6.57 represented a gradual decline in site quality ($PLI > 1$), as shown in Figure 4(a). The Potential Ecological Risk (PER) assessment revealed that heavy metal contamination in the sediments was highly uneven. Sites S1 and S6-S8 posed a considerable risk ($80 \leq E_r < 160$) while sites S2-S5 and S9 presented a high potential ecological risk ($160 \leq E_r < 320$), as shown in Figure 4(b). These results demonstrate that the heavy metal concentrations and their associated risk were not uniform across all sites, displaying high spatial heterogeneity. This non-uniform distribution was likely driven by varying degrees of anthropogenic activities.

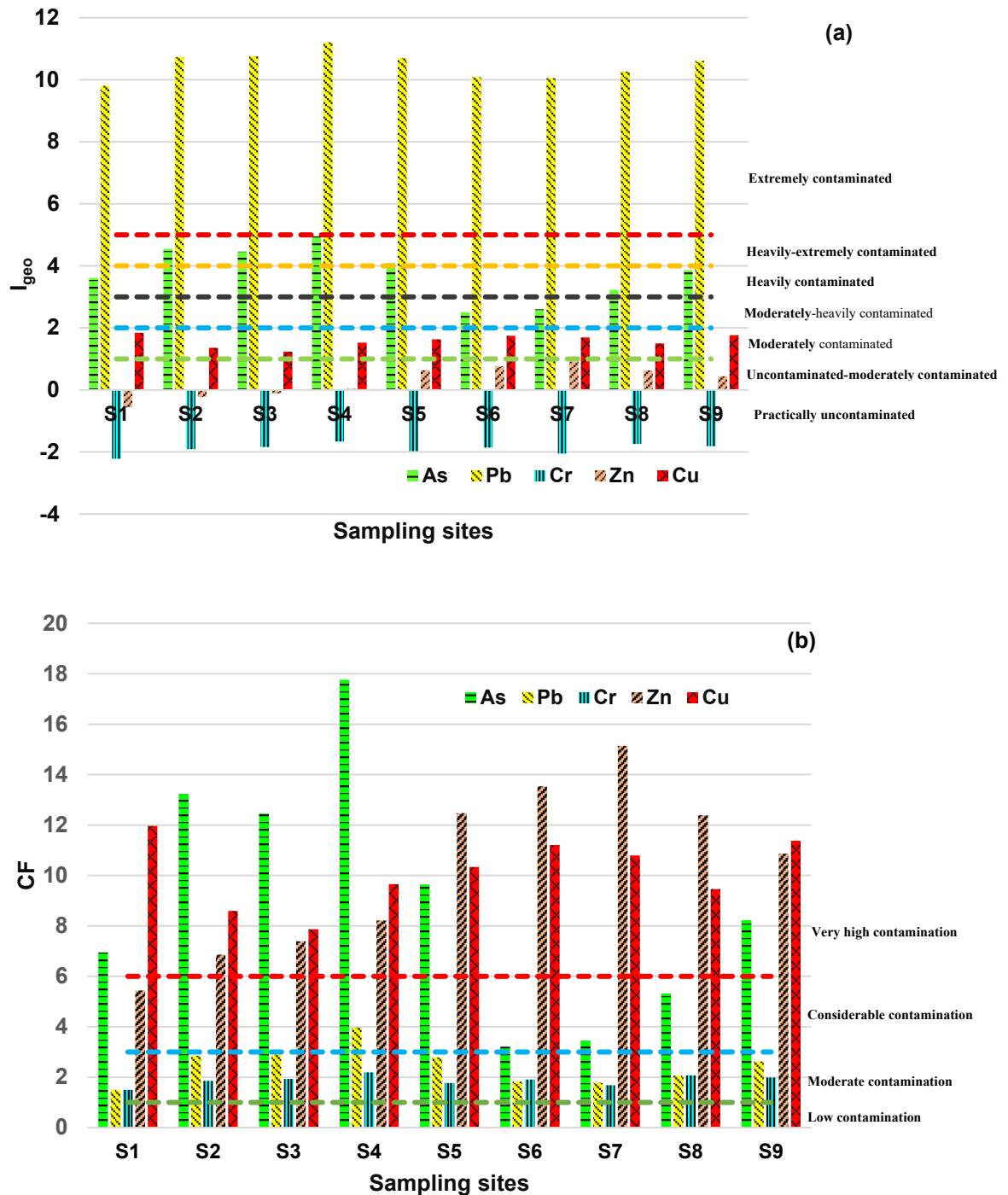


Figure 3. Pollution and ecological risk assessment of heavy metals: (a) index of geo-accumulation (I_{geo}), (b) contamination factor (CF)

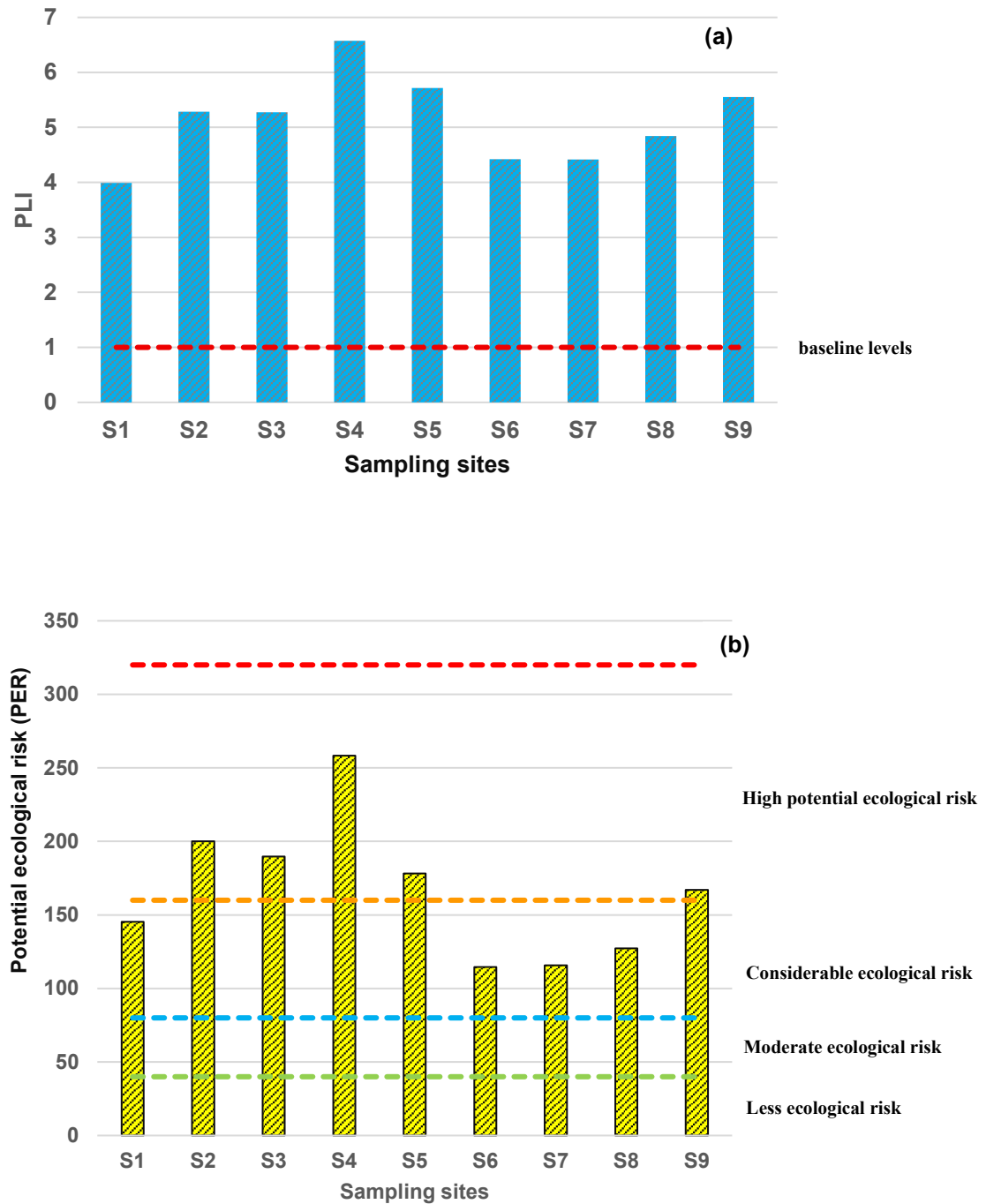


Figure 4. Pollution and ecological risk assessment of heavy metals: (a) pollution load index, (b) potential ecological risk (PER)

4. Conclusions

The heavy metals arsenic (As), lead (Pb), cobalt (Co), chromium (Cr), zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) were found in the surface sediments at all sampling points in this study, but no cadmium (Cd) and nickel (Ni) were identified. The metal concentration profile can be described as follows: Fe and Mn were the most abundant, followed by Zn, Cu, As, Cr, Pb, and Co. It was found that the sediment samples were heavily contaminated, particularly with As (42.41 ± 23.14 mg/kg) and Cu (56.89 ± 7.61 mg/kg), the levels exceeding both Thai national standards (10 mg/kg and 31.5 mg/kg, respectively) and U.S. EPA guidelines (>8 mg/kg and >50 mg/kg, respectively). The mean concentrations of Zn (134.46 ± 44.32 mg/kg) exceeded Thai national standards (120 mg/kg). The mean concentrations of Pb (29.56 ± 9.16 mg/kg) were within acceptable limits (<40 mg/kg) according to Thai national standards, meaning that the sediments were not polluted with lead. The mean concentrations of Cr (40.58 ± 4.56 mg/kg) did not exceed Thai national standards (43.4 mg/kg), identifying as moderately polluted category (25-75 mg/kg). There were no specific Thai national standards for Co, Fe and Mn. With reference to U.S. EPA sediment quality guidelines, the mean concentrations of Fe (56.72 ± 5.38 g/kg) and Mn (468.17 ± 107.11 mg/kg) were classified as heavily polluted (>25 g/kg) for Fe and moderately polluted (300-500 mg/kg) for Mn. Based on USDA soil texture classification, samples S1 and S9 were classified as silt whereas samples S2-S8 were categorized as silt loam. The high concentrations of heavy metals were directly related to the presence of fine-grained particles. As, Pb, Cr, Zn and Cu were the heavy metals used to evaluate sediment pollution and ecological risk assessments. The sediments in the studied canal were classified as extremely contaminated with Pb (I_{geo} : 10.47 ± 0.44) and heavily to extremely contaminated with As (I_{geo} : 3.76 ± 0.86), indicating significant anthropogenic influence while Cr (I_{geo} : n.d.) and Zn (I_{geo} : 0.28 ± 0.51) revealed low anthropogenic impact. The Cu levels showed moderate pollution, with an I_{geo} of 1.59 ± 0.20 . Based on the pollution load index (PLI) assessment, all sampling sites presented a gradual decline in site quality ($PLI > 1$), suggesting progressive deterioration. The average Potential Ecological Risk Factor (PER) for heavy metals in sediments at sites S1 and S6-S8 indicated considerable ecological risk ($80 \leq E_r < 160$). High potential ecological risks were identified at sites S2-S5 and S9 ($160 \leq E_r < 320$). These findings indicated that the heavy metal concentrations and their associated risks were not uniform across all sites, which displayed high spatial heterogeneity. This non-uniform distribution was strongly related to the variation of land-use patterns and anthropogenic emission activities. Water quality management for the Prawet Burirom Canal, which traverses heavily populated, agricultural, and industrial zones, is essential. Future studies should focus on shifting seasonal changes to evaluate temporal distribution patterns and magnitude of seasonal runoff. A land use survey is also required for mapping current activities.

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6. Authors' Contributions

Suwannee Junyapoon, Glinsukol Suwannarat, Narainrit Chinfak, Alongorn Siri: designed research; Pulawach Boonpa, Pobnipit Chumwong, Aekkaphat Yindeerak, Suwannee Junyapoon, Glinsukol Suwannarat, Narainrit Chinfak, Alongorn Siri: performed research; Sacorn Sorpong, Chatchai Latthilakana, Monthol Saengsawang: contributed reagents/analytic tools; Suwannee Junyapoon: analyzed data; Glinsukol Suwannarat, Narainrit Chinfak, Alongorn Siri: coordinated research; and Suwannee Junyapoon: wrote the paper

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7. Conflicts of Interest

The authors declare that there are no conflicts of interest. Our research mainly evaluates spatial distribution of heavy metals in the waterway for environmental monitoring and ecological risk assessment. We have no financial interests or personal connections that could inappropriately influence our work.

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