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Short-Communication

Heavy Metal Concentration in Mangrove Soils under *Sonneratia caseolaris* Trees: The Case of Kampung Kuantan Fireflies Park

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ABSTRACT

The local ecosystem potentiality is pressurized by the getting up heavy metal concentrations, especially in Kampung Kuantan Fireflies Park. This mangrove forest park, which is dominated by *Sonneratia caseolaris,* is a well-known place to visit for people who like nature in Kuala Selangor Peninsular Malaysia. However, the investigations on heavy metal concentration in mangrove soils under *S. caseolaris* are still limited. This study aims to find out the concentration of heavy metal in mangrove soil under *S. caseolaris*. The soil samples were taken from under *S. caseolaris* trees zone. Five plots were built up on mangrove soils through the Selangor River. Five sub-plots, each measuring 2 m × 2 m, were made for sample collection in each plot. The heavy metal contents and the geo-accumulation index (*I-geo*) were evaluated. As the results, the concentration of heavy metals on soils such as zinc (Zn), copper (Cu), lead (Pb), chromium (Cr), and cadmium (Cd) under the *S. caseolaris* trees of 240.24 mg/kg, 6.89 mg/kg, 25.46 mg/kg, 34.88 mg/kg, and 0.14 mg/kg, respectively. The *I-geo* ratio indicated that the soils have low heavy metal deposits, with Cd having the lowest concentration and Zn having the highest. There is a significant difference between Zn and Cr concentrations on the soils in five plots, but there are no significant differences for Cu, Pb, and Cd. In general, the heavy metal contents throughout the sampling area were considered not polluted, since the amount of trace elements in the soil was relatively low compared to the average limit.

1. Introduction

The wetland ecosystem is where many living things live, including giving benefits to the people. One important wetland ecosystem is a mangrove forest (Murniasih et al. 2022). Mangrove forests are unique in many ways, such as carbon and nutrient cycles, typical of soil, and affected by tides. Anthropogenic activities have a significant impact on mangrove forests since they are near cities and give benefits to the people. Therefore, the mangrove forest had much pollution from nearby areas like factories, tourist spots, and residential areas around the mangrove forest (Gandaseca et al. 2011; Yan et al. 2017). The pollution comes from different activities and ends up in the aquatic system and the soils (Panda et al. 2013).

Mangroves are threatened by the expansion of pollutants (Maiti 2013), which may be imported into the mangrove ecosystem through the waters from waterways and streams. Metals are caught in mangrove soils by teaming up with sulfides, organic carbon particles, or iron oxyhydroxides (Afonso et al. 2023; De Lacerda et al. 2022). The dissemination, behavior, and collection of these imported chemicals within the environment are fundamentally characterized by the hydrology of the mangroves, the geochemical properties of soils, and the pollutants class.

Some heavy metal contamination in mangrove estuaries comes from human activities like factories, farming, disposing of waste into water, and discarded automobiles (Aris et al. 2014; Gandaseca et al. 2011; Kannan et al. 2016; Zarezadeh et al. 2017). The heavy metal contamination derived from these activities spreads through ice, water, or wind and falls to the ocean, where the deposition of soils takes place (Dronkers and Berg 2020). Soil is like a small-scale biological system that appears for different types of soil particles (Ali et al. 2021; Droppo 2001).

The abundance of heavy metals is a serious problem for the mangrove ecosystem. High levels of heavy metals in mangrove forests can harm all living things and can be passed on to other organisms and humans through the food chain (Uddin et al. 2021). Since living organisms cannot break down heavy metals, they get passed on and build up in plants from the soil. This can harm and affect plants for a long time. This is due to smaller molecule sizes (ElTurk et al. 2018; Hidalgo et al. 2020). Expanding levels of heavy metals have been known to have harmful effects on plants and microbial biomass essential for plant growth (Ali et al. 2019; Nagajyoti et al. 2010). Heavy metals are familiar with inhibiting plant growth and photosynthetic action. Moreover, they cause a decrease in the growth of different microbial communities.

Heavy metals are causing serious environmental issues, especially in famous natural areas like Kampung Kuantan Fireflies Park. These heavy metals are highly toxic, last for a long time, and build up in the environment, including reducing the mangrove ecosystem (Ali et al. 2021; Raffa et al. 2021). The local ecosystem potentiality is pressurized by the getting up heavy metal concentrations, especially in Kampung Kuantan Fireflies Park. This mangrove forest park, which is dominated by *Sonneratia caseolaris,* is a well-known place to visit for people who like nature in Kuala Selangor Peninsular Malaysia. However, the investigations on heavy metal concentration in mangrove soils under *S. caseolaris* are still limited. The objective of this study is to find out the concentration of heavy metal in mangrove soil under *S. caseolaris*.

2. Materials and Methods

2.1. Study Area

The study was done on mangrove soils throughout the Selangor River at Kampung Kuantan Fireflies Park, Kuala Selangor, Malaysia. The study area is found almost 67 km south of Kuala Lumpur. This mangrove forest area is one of the well-known ecotourism spots in Peninsular Malaysia (Mohd-Shahwahid et al. 2016). The soil samples were obtained during low tides throughout the Selangor River under the *S. caseolaris* trees zone. **Fig. 1** shows the study area at Kuala Selangor in Peninsular Malaysia.

2.2. Sampling Plot Design

Soil samples were obtained from five plots throughout the Selangor riverbanks under the *S. caseolaris* trees zone. Five sub-plots (2 m × 2 m) were set up for sample collection in each plot.

The soil samples were collected five times for each sub-plot within two different depths (0–15 cm and 15–30 cm), using a peat auger and kept in a sealable polyethylene bag. The length of the five main plots was within 700 m along Selangor riverbanks, as shown in **Fig. 2** and **Fig. 3.**

The samples were air-dried in the laboratory within 1 or 2 weeks and then grounded using a mortar and pestle until passing a 2.0 mm sieve. The samples that have been grounded were kept in a sealable polythelyn bag and labeled accordingly. In general, 100 soil samples were collected within 2 times/years.

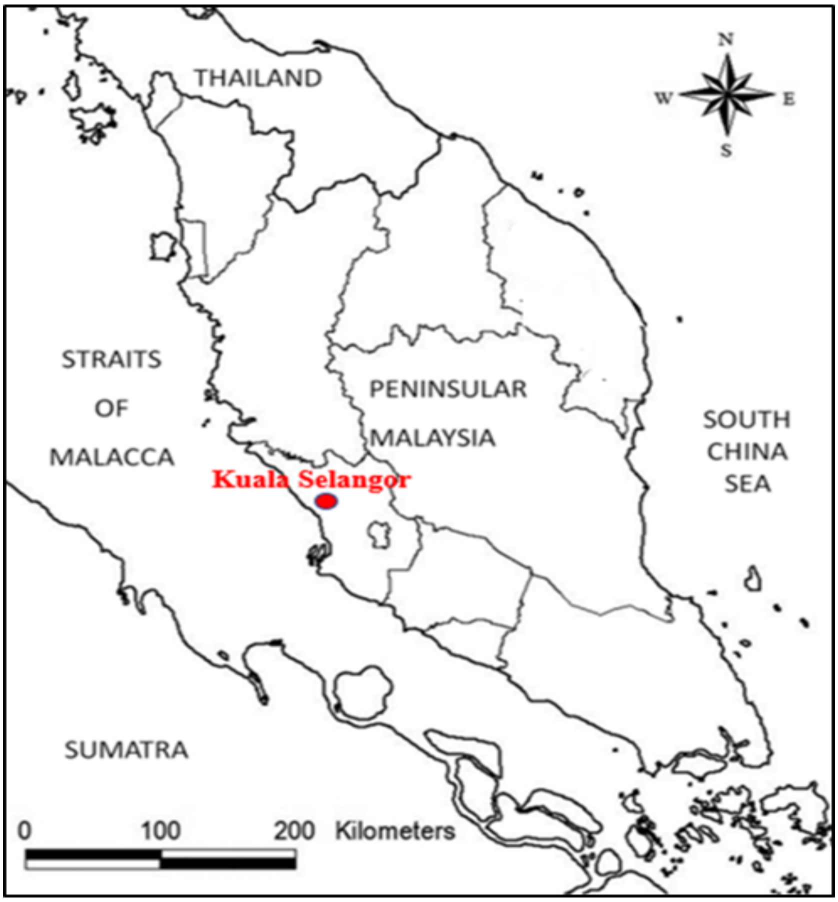

Fig. 1. The study area at Kuala Selangor in Peninsular Malaysia.

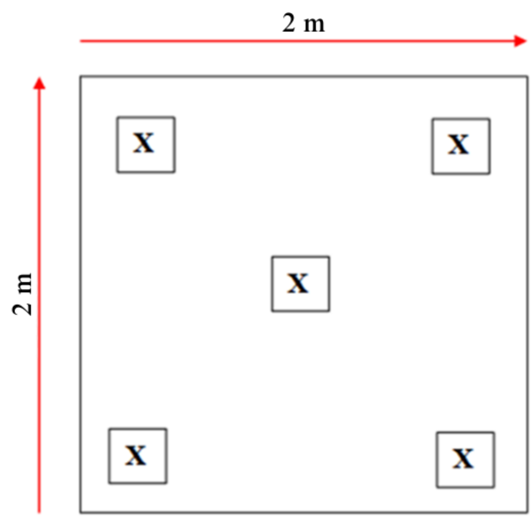

Fig. 2. The soil sample locations in each sub-plot.

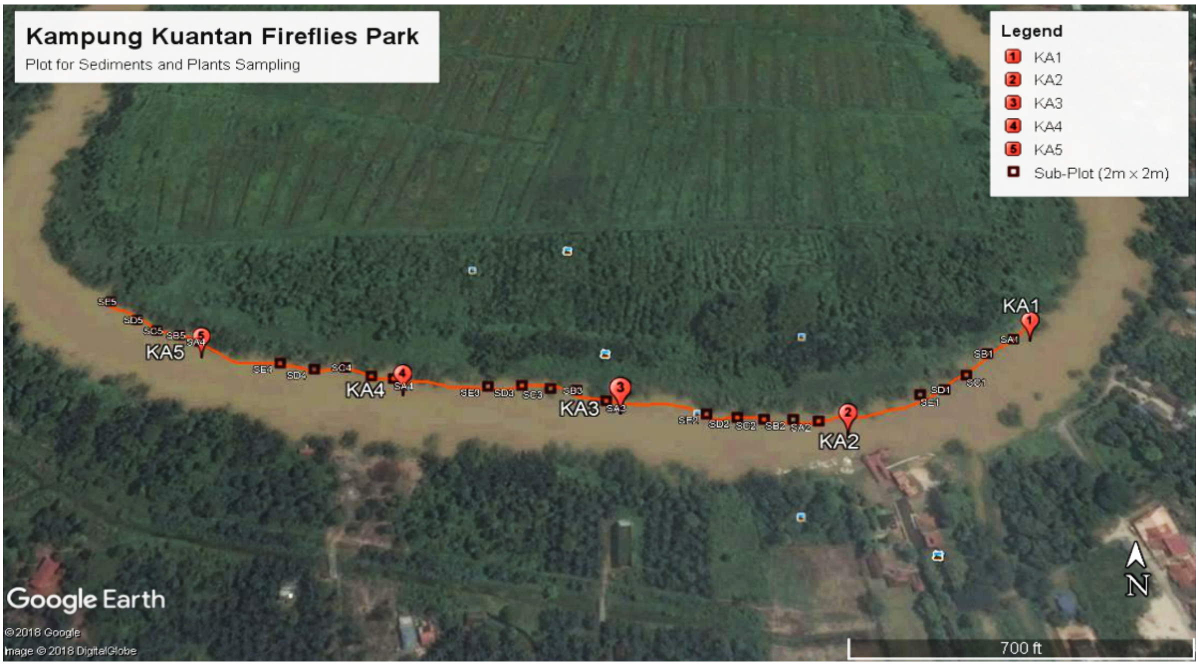

Fig. 3. Location of the five plots and each sub-plot along Selangor River.

2.3. Heavy Metal Analysis

2.3.1. Heavy metal contents

The Aqua Regia method was used to measure the amount of heavy metal substances in soils. The reagent used was aqua regia solution, a blend of HCl:HNO_3 in a ratio of 3:1 (Hseu et al. 2002; Sungur et al. 2020). A 0.5 g of soil that had been dried in the air was measured and put into assimilation tubes. Aqua Regia solution of 8 mL (6 mL HCl + 2 mL HNO_3) was added into the digestion tubes, and the digestion process was started at 110°C until 1 mL remains and held up until the solution cools down. A while later, 10 mL of a solution containing 1.2% HNO_3 was poured in, and the blend was heated again at 80°C for a duration of 30 minutes. The solution was changed to a final volume of 10 mL utilizing deionized water, and then it was heated for 30 more minutes. Afterward, it was diluted to 20 mL with deionized water and filtered using the Whatman No. 42 filter paper. The clear solution was left to cool down in a container before being mixed with 100 mL of deionized water. Liquid samples of 10 mL were put into plastic bottles and marked with labels. The liquid samples were analyzed using a machine called Inductively Coupled Plasma Mass Spectrometry (7850 ICP-MS).

2.3.2. Heavy metal degree of contamination

In this study, the geo-accumulation index (*I-geo*) was utilized to measure the level of soil metal pollution. The equation by Muller's was used to determine how polluted the soil is with heavy metals (Muller 1979).

$$I\text{-}geo = \log_2 (C_n/1.5\ B_n) \quad (1)$$

where C_n is the concentration of the element in the soil samples, and B_n is the geochemical background value in average shale.

The constant 1.5 is used to study how much a substance in the environment can change naturally and how human activities can affect it. Muller (1979) defined seven classes of geo-accumulation index as shown in **Table 1**.

Table 1. Geo-accumulation index (*I-geo*) classification

Class	Value	Soil/sediment quality
0	*I-geo* ≤ 0	Unpolluted
1	0 < *I-geo* ≤ 1	Slightly polluted
2	1 < *I-geo* ≤ 2	Moderately polluted
3	2 < *I-geo* ≤ 3	Moderately to severely polluted
4	3 < *I-geo* ≤ 4	Severely polluted
5	4 < *I-geo* ≤ 5	Severely to extremely polluted
6	*I-geo* > 5	Extremely polluted

2.3.3. Statistical analysis

The data was analyzed using Statistical Analysis System (SAS) version 9.0. The one-way analysis of variance (ANOVA) was used to compare the concentration mean of a subject based on different categorical grouping followed by the posthoc Tukey's Honestly Significant Difference test to find out which group contrasted from the others.

3. Results and Discussion

3.1. Heavy Metal Content

Table 1 shows the levels of heavy metal contents in soils and the statistics distribution of these results. Descriptive statistics summarizes the data usually presented in the form of the mean. Defining sample variability in descriptive statistics involves the computation of standard deviation as a measure of dispersion, while standard error of the mean provides knowledge on accuracy from the deviation of multiple samples in a sampling population. Since the sampling population of this study comprised five samples collected from five sampling plots (N = 25), the standard error was foremost presented over standard deviation as a summary of entire data unbounded by spatial factors. Measurements and distribution of heavy metal contents are summarized in **Table 1**.

Table 1. Heavy metal contents on soil and distribution

Element	Mean (mg/kg)	SE	Shapiro-Wilk Statistic (*W*)	Significance
Zn	240.240	4.007	0.978	0.852
Cu	6.888	0.804	0.917	0.045
Pb	25.456	0.861	0.92	0.052
Cr	34.882	1.264	0.919	0.048
Cd	0.141	0.004	0.98	0.884

Notes: SE= standard error. Zn = zinc, Cu = copper, Pb = lead, Cr = chromium, and Cd = cadmium.

Results from the normality test hinted that the majority of samples were not credible for further statistical analysis; therefore, there is a need to trace the influences of the experimental setup with the variables measured. The subsection highlights the distinction among heavy metals measured respective to sample types and their locations. Data is presented in the form of bar charts in order to visualize differences or similarities between samples location-wise. Each column represents the mean from five samples for each plot, while the error bar centered on the column's peak signals range of variability derived from the standard deviation computed. Letters on top of error bars indicate sample grouping under posthoc tests following comparisons between samples based on collection areas (plot) from one-way ANOVA.

The selected heavy metals from the present study for Cu, Zn, and Pb in the soils were 6.89 mg/kg, 240.24 mg/kg, and 25.46 mg/kg, respectively. The previous results for these three selected heavy metals in this mangrove area were around 5.8 mg/kg (1.00–10.60 mg/kg), 237.20 mg/kg (215.40–259.00 mg/kg) and 46.89 mg/kg (18.83–28.59 mg/kg) respectively (Nyangon et al. 2019), and it shows the heavy metal concentration for Cu and Zn is not significantly different and for Pb which is significantly different in the present study. Compared to another result in the West Coast of Peninsular Malaysia (Buhari and Ismail 2020), the selected heavy metals for Cu, Zn, and Pb in the soils were 77.10 mg/kg, 368.00 mg/kg, and 129.00 mg/kg, respectively, and it shows the heavy metal concentrations for Cu and Zn in the West Coast of Peninsular Malaysia were significantly higher than the heavy metal in this present study.

The concentrations of heavy metals in this mangrove area occur naturally in the environment and are also caused by certain anthropogenic activities, such as local industries and ecotourism activities, which can contribute to the release of these heavy metals concentrations. Then, the relative concentration of heavy metal content is needed to clarify the level of heavy metal contamination in this mangrove area.

3.2. Relative Concentration of Heavy Metal Content

The relative concentration is calculated by comparing the amount of heavy metal contents found in the sample to the known amount of the same metal, resulting in a ratio. The ratio helps to understand how strong the sample is compared to the indicator that defines the power of the sample measured over the compared information. Further extension of ratio measuration included adjustments made on focused subject measurement to fit with the compared information. In this study, the geo-accumulation index (*I-geo*) was the derived form of ratio calculation in classifying the state of heavy metal contamination of the sampled area relative to the average world shale of identical ecosystems (Buhari and Ismail 2020). Besides that, the calculation of the ratio applied in this study involves the distinction of *S. caseolaris* physiological capabilities in relation to heavy metals accumulation measured in samples.

Table 2. Geo-accumulation index (*I-geo*) of soil samples

Location	***I-geo* of each element**				
	Zn	**Cu**	**Pb**	**Cr**	**Cd**
Plot 1	-0.066	-4.521	-2.062	-1.773	-2.262
Plot 2	0.001	-4.408	-2.120	-1.796	-2.042
Plot 3	0.066	-4.850	-2.158	-1.973	-2.179
Plot 4	-0.028	-5.424	-2.247	-1.866	-2.347
Plot 5	-0.200	-7.814	-2.676	-2.456	-2.018
Overall	-0.043	-5.030	-2.237	-1.952	-2.164

Notes: Zn = zinc, Cu = copper, Pb = lead, Cr = chromium, and Cd = cadmium.

World average shale for deep-sea soils (Turekian and Wedepohl 1961) referred to as the benchmarking value for samples *I-geo* computation (Zn = 0.14, Cu = 0.13, Pb = 0.27) and the result done in the West Coast of Peninsular Malaysia (Buhari and Ismail 2020) (Zn = 0.20, Cu = 0.59, Pb = 2.07). Index computed from soils heavy metal contents based on referred shale value tabulated in **Table 2**. The highest *I-geo* magnitude was detected in Zn sampled from Plot 3 at 0.066, while the lowest in Cu from Plot 5 was at -7.814. Most ratios computed from measured elements with 1.5 times the world average shale yield to the value of less than one as log transformation, with two as the base number outputs the negative index value. The entire measurement from plots was averaged before index computation to represent the sampled area as a whole. In general, the elements content measured aggregated an index below zero, hence, the clarified area sampled was not contaminated, as trace elements contained in the soils were relatively lower than the threshold average.

Even though the soil samples under *S. caseolaris* were not contaminated, it needs to know the heavy metal contents on the tree and which parts of the tree species strongly associate with the fireflies. Also, it needs to know whether this species has the ability to uptake certain heavy metals from the mangrove soil. So, this study recommends measuring the heavy metal content on *S. caseolaris* in this active ecotourism area of Kampung Kuantan Fireflies Park, where Fireflies gather on this tree to mate and feed on their sap.

4. Conclusions

The heavy metals concentration in mangrove soils, such as Zn, Cu, Pb, Cr, and Cd, under the *S. caseolaris* trees were 240.24 ppm, 6.89 ppm, 25.46 ppm, 34.88 ppm, and 0.14 ppm, respectively. There is a significant difference in selected heavy metal concentration on soil between five plots for Zn and Cr, and no significant difference for Cu, Pb, and Cd. Overall elements content measured aggregated an index below zero, hence, the clarified area sampled was not contaminated, as trace elements contained in the soil were relatively lower than the threshold average. In general, the content of the elements measured aggregated an index below zero; hence, the area sampled was not in high contamination or not polluted, as trace elements contained in the soils were relatively lower than the threshold average. This study recommends measuring the heavy metal content on *S. caseolaris* in this active ecotourism area of Kampung Kuantan Fireflies Park, where fireflies gather on this tree to mate and feed on their sap.

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