Physicochemical Comparison of Heavy Metal Sediments at Different Seasons in Sungai Jarum Mas, Matang Mangrove Forest, Perak

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Abstract. Forests of mangroves are one of the most common wetland types in Peninsular Malaysia and play an important role in our ecosystem. Mangrove forests are highly productive ecosystems that offer a diverse variety of goods and services to the coastal environment as well as to people and other animals. All of the advantages they give include natural coastline protection, soil stability, and nutrient retention as well as erosion prevention, aquatic life habitat, flood reduction, water quality enhancement, and carbon dioxide sequestration, to mention a few. This paper aims to determine the physicochemical properties of heavy metal sediments based on the comparison of seasonal differences (dry and wet). The samples were analyzed for their physicochemical properties such as sediment electrical conductivity (EC), pH in water, and 1 M KCl, as well as heavy metals (Zn, Pb, Fe, Cd, and Cu). The sediment of Sungai Jarum Mas was acidic, according to the observations. With a mean of 16.28[a] (±0.502), 3.48[a](±0.027), and 3.28[a](±0.024), the sediment EC, pH water, and 1 M KCl are all had higher mean values in the dry season. During the dry season, iron (Fe) concentrations in the sediment were higher, with an average of 8.908[a] (±1.140). Lead (Pb) and cadmium (Cd) concentrations were not affected by both seasons. The highest concentrations of zinc (Zn) and copper (Cu) were detected during the wet season, with mean values of 0.185[a] (±0.048) and 0.029[a] (±0.008), respectively. Heavy metals are found in sediment as a result of natural and human-made processes.

Keywords: mangrove forest, heavy metal, environmental, soil physicochemical, ecosystem

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1 Introduction

Mangroves are plants and bushes that grow along the coast's intertidal zone. Mangroves, which are found in saline water regions across tropical and subtropical coastlines, are among the most prolific habitats on earth [1]. The trees' dense mats of thick, stick-like roots that grow out of the muck and water make them clearly identifiable. These roots, known as "prop roots," restrict the flow of water when tides come in and out, enabling particles to deposit mostly on muddy bottoms. Sediments migrating down rivers and off the land are held in place by the dense root systems of mangrove forests. This contributes to the shoreline's stability and the prevention of erosion caused by waves and storms. Coastal regions are protected by mangroves from tidal surges, cyclones, and tsunamis. The health of the mangrove ecosystem may be harmed by pollution from human activities, industrialisation, and urbanization [2]. Malaysia has the world's sixth biggest mangrove system and is second only to Indonesia in terms of the richness of genuine mangrove species found there [3]. According to study conducted by reference [3], Perak's overall mangrove forest area is around 43,292 hectares, with the biggest areas in the districts of Larut and Matang and Kerian. Mangrove forests are a prominent wetland type in Peninsular Malaysia and have been identified as an essential component of the earth's natural life support system.

Mangrove forests are crucial for a variety of reasons, not the least of which is that they are home to various endangered species of flora and fauna. The research of reference [4] discovered that, Malaysian mangroves support a diverse range of fauna species, including twenty-two aquatic invertebrate species (which include four worm species, six shelled mollusc species, and eleven crustacean species), seventy-four bird species, thirty-six fish species, four mammal species, and four reptile species. Mangroves also provide a habitat for a large diversity of fauna species. Mangrove forests are extremely productive ecosystems that offer a diverse variety of goods and services to both the aquatic environment and the public. Natural coastal protection, soil stability, erosion prevention, nutrient retention, aquatic life habitat, water quality enhancement, flood reduction, and carbon dioxide sequestration are all benefits that they provide. Because of their intrinsic physical and chemical characteristics, mangrove sedimentation has an unusual potential to retain material discharged into the intertidal zone marine environment [5].

Anthropogenic activities such as farming and industrial waste contribute to the contamination of sediment in mangrove habitats. Heavily polluting metals are one of the elements contributing to environmental deterioration [6-8]. The heavy metals concentration in the sediment will pose a threat to ecosystems and the environment; the impact is more pronounced and is always associated with mangrove forests also the adjacent coastal habitat [9-11]. This article discusses the comparison of the chemical and physical properties of heavy metal between different seasons and depth. Sungai Jarum Mas is home to a variety of activities in addition to the mangrove forest, such as agricultural, industrial, and village activities that may influences the sediment quality as the mangrove forest in Sungai Jarum Mas contribute many services to the locals.

2 Materials and Methods

2.1 Study area

The research was carried out near Sungai Jarum Mas, which is a stream in Matang Mangrove Forest, Perak, Malaysia, at the latitude of (4058’6.67” N) and longitude of (100°65’37.17” E) and nearby to Hutan Rizab Sungai Tinggi, Kampung Permatang Laut, and Kampong Port Weld. Sungai Jarum Mas is about 5.4 km long, and it is one of the five major rivers which are composed of Selinsing, Sangga, Larut, and Trong, where the areas comprise of mudflats [12].

Fig. 1. The location of study area in Sungai Jarum Mas Mangrove Forest, Perak, Malaysia

Fig. 2. The sampling point along Sungai Jarum Mas. Points A, B, and C represent upstream, middle stream and downstream, respectively

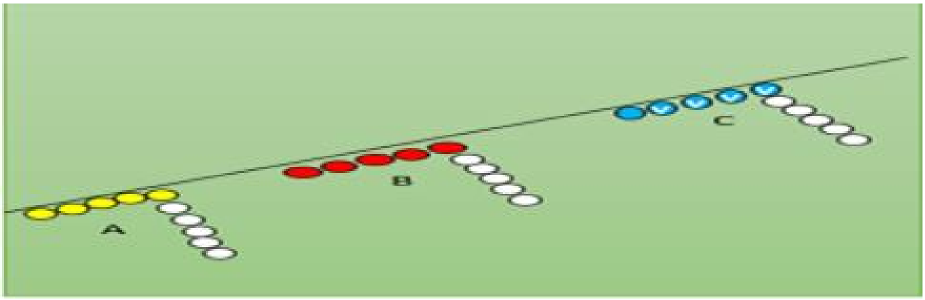

Fig. 3. The subpoints and depths along Sungai Jarum Mas

2.2 Method and sampling

Figures 2 and 3 show the sampling points where the sediment samples were taken. Points A, B, and C were the sampling points representing the river zonation of upstream, middle stream, and downstream. The river's total length is divided evenly to get the distance between points. Sampling was carried out for two seasons. Dry season sampling was done in March and April, and the wet season was in November and December 2015. A total of 150 sediment samples from the dry and wet seasons were collected at each point with five replications using a peat auger at five different depths, which are 0-15 cm, 15-30 cm, 30-50 cm, 50-100 cm, and >100 cm. To avoid contamination during transportation to the soil laboratory, the sediment samples are maintained in a labelled plastic bag. A pestle and mortar were used to grind the sediment samples after they had been left to air dry at room temperature. All of the samples were sieved using a 2 mm sieve, and the sieved samples were mixed and placed in a zip bag that was clearly labelled.

2.3 Soil analysis

In soil analysis, there are two components as physical and chemical properties. In sediment physical properties, are soil texture and bulk density. The element of soil chemical properties are pH, electrical conductivity (EC), and heavy metals components (Zn, Pb, Fe, Cd, and Cu). A version 9.4 of the Statistical Analysis System (SAS) software was used to examine the data obtained. The analysis of variance (ANOVA) was performed first, followed by the Tukey's range test or Honestly Significant Difference (HSD) when the p-value was less than 0.05. It was used to compute the difference between seasons and depths.

3 Results and Discussion

3.1 Comparison of physiochemical characteristic sediment between seasons and depths

Table 1 shows the results of sediment pH, EC, and selected heavy metals, which are lead (Pb), iron (Fe), cadmium (Cd), copper (Cu), and Zinc (Zn) in two different seasons and five different depths at Sungai Jarum Mas, Matang Mangrove Forest, Perak. Based on the table, it shows that the sediment pH in both dry and wet seasons was acidic (pH <3.59). The mean value of pH of water and KCl in the dry season ranged from 3.13 to 3.59, and the highest pH was found in the depth of 15–30 cm with a mean of 3.59^{a}(±0.060). The mean value of pH of water and KCl in the wet season ranged from 2.91 to 3.42, and the highest pH was found in the soil depth of 0–15 cm with a mean of 3.42^{a} (±0.052). The mean comparison of pH water value in the dry season by depth showed significant differences in depth >100 cm except in depths of 15–30 cm, 30–50 cm, and 50–100 cm indicates no significantly different (ANOVA, Tukey Test at P≤0.05) at the other hand, The mean comparison of pH water value in the wet season by depth indicates no significant different (ANOVA, Tukey Test at P≤0.05).

Table 1. Seasonal and depth-dependent variations in sediment physiochemical characteristics

Season	Depth	EC	pH Water	pH 1 M KCl	Fe (cmol/kg)	Pb (cmol/kg)	Zn (cmol/kg)	Cu (cmol/kg)	Cd (cmol/kg)
Dry	0-15	13.52^{b} (±2.365)	3.56^{a} (±0.038)	3.33^{a} (±0.019)	8.336^{a} (±1.702)	0.021^{a} (±0.001)	0.017^{a} (±0.001)	0.106^{a} (±0.006)	0.002^{a} (±0.000)
	15-30	17.80^{a} (±0.141)	3.59^{a} (±0.060)	3.39^{a} (±0.061)	8.908^{a} (±1.140)	0.019^{ab} (±0.000)	0.013^{a} (±0.001)	0.083^{a} (±0.006)	0.001^{a} (±0.000)
	30-50	17.34^{ab} (±0.215)	3.48^{ab} (±0.056)	3.32^{a} (±0.069)	8.082^{a} (±1.324)	0.017^{ab} (±0.001)	0.019^{a} (±0.004)	0.123^{a} (±0.025)	0.001^{a} (±0.000)
	50-100	16.73^{ab} (±0.188)	3.44^{ab} (±0.066)	3.21^{ab} (±0.026)	8.088^{a} (±1.296)	0.016^{b} (±0.001)	0.015^{a} (±0.001)	0.096^{a} (±0.009)	0.001^{a} (±0.000)
	> 100	16.03^{ab} (±0.191)	3.31^{b} (±0.056)	3.13^{b} (±0.033)	7.942^{a} (±1.390)	0.018^{ab} (±0.001)	0.017^{a} (±0.001)	0.106^{a} (±0.007)	0.002^{a} (±0.000)
Wet	0-15	16.91^{a} (±0.461)	3.42^{a} (±0.052)	3.21^{a} (±0.040)	4.761^{a} (±0.871)	0.018^{a} (±0.001)	0.016^{a} (±0.001)	0.103^{a} (±0.004)	0.002^{a} (±0.000)
	15-30	16.05^{a} (±0.411)	3.35^{a} (±0.031)	3.19^{a} (±0.036)	4.460^{a} (±0.668)	0.018^{a} (±0.001)	0.029^{a} (±0.008)	0.185^{a} (±0.048)	0.001^{a} (±0.000)
	30-50	15.76^{a} (±0.296)	3.33^{a} (±0.053)	3.13^{ab} (±0.054)	4.651^{a} (±0.599)	0.018^{a} (±0.001)	0.017^{a} (±0.001)	0.105^{a} (±0.005)	0.001^{a} (±0.000)
	50-100	15.66^{a} (±0.179)	3.32^{a} (±0.052)	2.91^{b} (±0.077)	4.054^{a} (±0.750)	0.018^{a} (±0.001)	0.017^{a} (±0.001)	0.111^{a} (±0.006)	0.001^{a} (±0.000)

> 100	15.60[a] (±0.242)	3.27[a] (±0.082)	3.03[ab] (±0.069)	4.399[a] (±0.679)	0.017[a] (±0.001)	0.018[a] (±0.001)	0.115[a] (±0.007)	0.001[a] (±0.000)

Notes: Different alphabets row indicate significant differences between the mean of physicochemical properties between seasons and depths (0-15 cm, 15-30 cm, 30-50 cm, 50-100 cm, and >100 cm) using the Tukey test at P≤0.05. Plus and minus symbols indicates the increase and decrease in each indicator. Values in parenthesis represent the standard error of the mean.

The mean value of EC concentration in the dry season varied from 13.52 to 17.80, and the largest EC concentration was observed in the depth of 15–30 cm at 17.80[a](±0.141). The mean comparison of EC concentration in the dry season by depth showed significant differences only in the depth of 0–15 cm (ANOVA, Tukey Test at P≤0.05). While the mean value of EC concentration in the wet season ranged from 15.60 to 16.91 and the highest EC concentration was found in the depth of 0–15 cm with a mean of 16.91[a](±0.461). The mean comparison of EC concentration in the wet season indicates no significant difference between the depth (ANOVA, Tukey Test at P≤0.05).

The mean value of iron (Fe) concentration in the dry season ranged from 7.942 to 8.908 cmol/kg, and the highest Fe concentration was found in the depth of 15–30 cm with a mean of 8.908[a](±1.140) cmol/kg. While the mean value of Fe concentration in the wet season varied from 4.054 to 4.761 cmol/kg. Value of lead (Pb) concentration in the dry season varied from 0.016 to 0.021 cmol/kg and the maximum Pb concentration was observed in the depth of 0-15 cm at 0.021[a] (±0.001) cmol/kg. While the mean value of Pb concentration in the wet season varied from 0.017 to 0.018 cmol/kg. The Pb concentration in depth >100 cm is not much different from the other depths. Zinc (Zn) concentration in the dry season varied from 0.016 to 0.021 cmol/kg, and there is no significant difference of mean comparison between the depths.

While in the wet season, Zn concentration showed a mean value ranging from 0.016 to 0.029 cmol/kg. Copper (Cu) concentration in the dry season showed a mean value varied from 0.083 to 0.123cmol/kg. The maximum Cu concentration was observed in the depth of 30–50 cm with a mean value of 0.123[a](±0.025) cmol/kg. While in the wet season, the mean value varied from 0.103 to 0.185 cmol/kg and the highest Cu concentration was found in the depth of 15–30 cm with a mean of 0.185[a] (±0.048) cmol/kg. Cadmium (Cd) in both dry and wet seasons ranged from 0.001 to 0.002 cmol/kg, and there is no significant difference in the mean comparison of Cd concentration between the depths. The mean value of heavy metals in Sungai Jarum at wet and dry seasons showed no significant differences.

3.2 The pH Value of Sediment at Different Depths in Different Seasons

Figure 4 illustrates a comparison of sediment pH in water and 1 M KCl between depths in the dry season. The pH of sediment in water varied from 3.31 to 3.59 at five different soil levels, whereas pH KCl varied from 3.13 to 3.39. During the rainy season, the pH of sediment in water in five different soil levels varied from 3.27 to 3.42, while the pH of 1 M KCl varied from 2.91 to 3.21. Mean value comparison of the pH in water showed no significant difference while pH in 1 M KCl showed significantly different depths in the depth of 50-100 cm during wet and dry seasons.

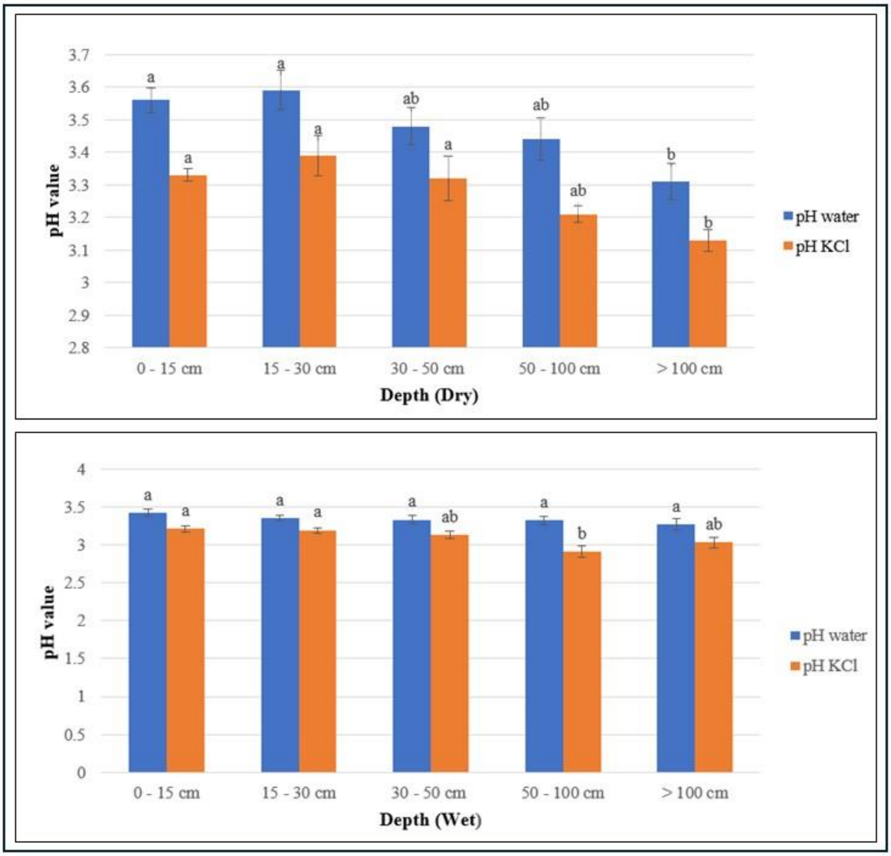

Fig. 4. Comparison of pH water and KCl by depths in both seasons at Sungai Jarum Mas

3.3 Electrical Conductivity (EC)

Figure 5 shows the comparison of electrical conductivity (EC) in five different depths by both seasons. The EC ranged from 13.52 to 17.80 during the dry season. The sediment EC was highest in the depth of 15–30 cm with a mean of 17.80^{a}(±0.141). The EC value showed a significantly different only in the depth of 0–15 cm. In the wet season, the EC varied from 15.60 to 16.91. The sediment EC was highest in the depth of 0–15 cm with a mean of 16.91^{a}(±0.461). The mean comparison of EC value showed no significant difference among the depths but was highest in the dry season.

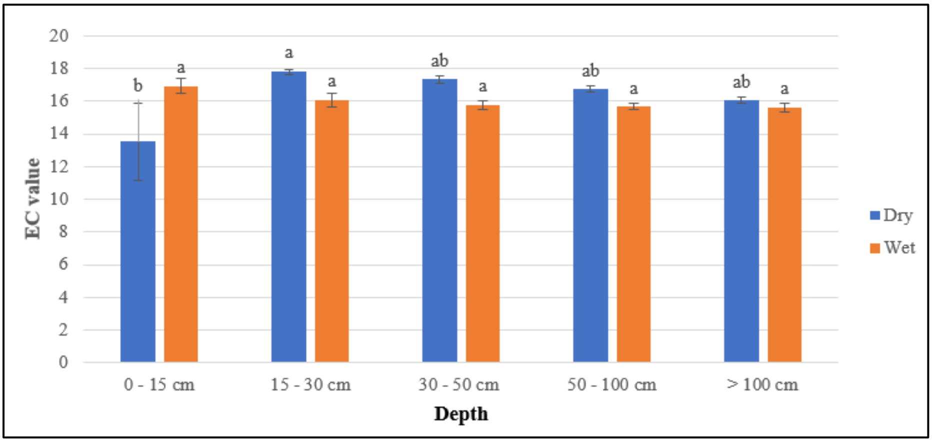

Fig. 5. The comparison of electrical conductivity (EC) by depths in both seasons at Sungai Jarum Mas

3.4 Heavy metals (Zn, Pb, Fe, Cd, and Cu)

Figure 6 shows the comparison of heavy metals (Zn, Pb, Fe, Cd, and Cu) between depths by season. The Fe concentration ranged from 7.942 to 8.908 cmol/kg in the dry season and 4.054 to 4.761 cmol/kg in wet seasons. By data value of Fe, we found Fe value is higher in dry season. There is no significant difference between depths by Fe concentration in Sungai Jarum Mas. In terms of Pb concentration in the dry season, it varied from 0.016 to 0.021 cmol/Kg. While in the wet season, the Pb concentration ranged from 0.017 to 0.018 cmol/kg. The mean comparison of Pb concentration indicates no significant difference in both seasons. During the dry season, the Zn concentration varied from 0.013 to 0.019 cmol/kg. While Zn concentration varied from 0.016 to 0.029 cmol/kg in the wet season. The mean comparison of Zn concentration showed no significant difference between the seasons. Cu concentration ranged from 0.083 to 0.123 cmol/kg in the dry season and 0.103 to 0.185 cmol/kg in the wet season. The mean comparison of Cu concentration showed no significant difference between the seasons. In the dry season, the Cd concentration varied from 0.001 to 0.002 cmol/kg. While in the wet season, the Cd concentration ranged from 0.001 to 0.002 cmol/kg. The mean comparison of Cd concentration indicates no significant difference in both seasons. Same as Pb, the concentration of Cd does not have seasonal effects. This indicates that Sungai Jarum Mas is still in controllable condition as Cd is one of the most toxic heavy metals than other elements. Therefore, if an element of Cd in the Jarum Mas River is high, it will be fatal to human life around it.

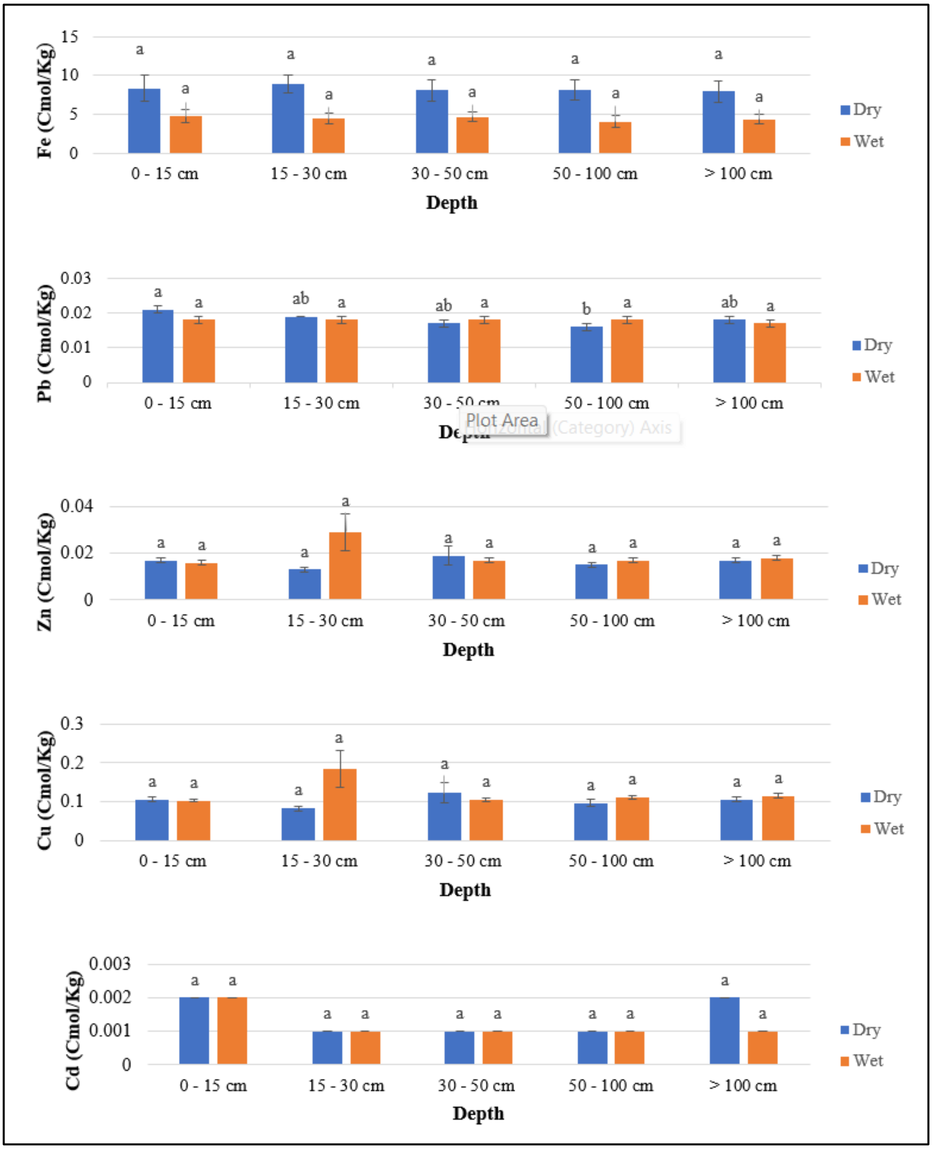

Fig. 6. The comparison of heavy metals by depths in both seasons at Sungai Jarum Mas

4 Discussion

The soil pH in sodium chloride (KCl) tends to be lower than soil pH in water as the hydrogen ions of the soil solution minimize the change in pH value [13]. The pH seasonality might be related to the entrance and decomposition of debris in the region, as well as an imbalance level of H^+ ions input from surface run-offs during the rainy season, according to the study of reference [14]. Besides that, rainfall combines with carbon dioxide before precipitating and influences the water towards acidity [15], thus resulting in an acidic condition for the sediment in the wet season. pH tends to increase by depth due to upper horizons getting the most leaching by rainfall and by dissolved carbonic acid and organic acids that remove metal cations and replace them with H^+ ions. The pH becomes more acidic because more organic metal is present in each depth [16]. Based on reference [17] state the larger particle size, such as coarse soil, will show a slightly high soil pH, the trend of soil pH through depth can be influenced by particle size class, interactions between soil series, and slope orientation. On the other hand, extremely acidic mangrove soil is caused by human disturbance (excavation) which leads to soil oxidation [18].

Less precipitation during the dry season causes a high evaporation rate which increases soil salinity. In addition, higher EC values during the dry season are caused by higher evaporation rates leading to salt accumulation [19]. Reference [20] indicated that soil EC rises because salts cannot be leached from the surface, resulting in a fragrant zone and cache. According to reference [21], Electrical conductivity (EC) measures soil salinity and can be used for dissolvable supplements present evaluation. Seasonal variations in EC were most likely caused by external hydrologic flushing, such as entering the water from upstream and precipitation [22]. Porosity, soil texture, and the amount and type of soluble salts in solution are all factors that influence soil electrical conductivity [23]. In general, when clay content rises, EC rises as well [24]. This is supported by a study from reference [13], stating that the soil texture in Sungai Jarum Mas is sandy loam which is highest in sand and clay. Based on reference [25], in some mangrove systems, severe variations in precipitation may affect seasonal average salinity.

According to reference [26], higher mean values of Fe concentration were recorded in sediment during the dry season than in the wet season due to dilution of the sample at the time of rainfall. The increase in Fe concentration may be due to the metal accumulation from the leached top soils that were washed-off or not taken up by plants during the wet season [27]. According to reference [9], geochemical processes along rivers and organic matter decomposition cause Fe levels to rise. As a result, sediment absorbs the chemical and becomes Fe-polluted. Seasonal variation does not affect much Pb concentration in the sediment. Lead is present in the gasoline, according to reference [28], thus, the increase in the lead might be attributed to its concentration in the fuel from shipping activities deposited in the sediment. Another concern is the source potential of the element Pb metal pollution caused by fishermen using motorboats to capture fish in the river [29]. Higher enrichment of Zn indicated anthropogenic input, including domestic waste dumping and runoff from the land [30]. According to reference [31], increasing Cu concentration may be due to rainfall that precipitates on the pilling up of various types of garbage, household material, and cans from the nearest village in Sungai Jarum Mas. According to previous studies by references [8, 32-34], Cd has been reported to cause damage to the liver, lung, testicular, kidney, bone, and placenta. Seasonal variations in the heavy metals concentrations could cause differences in individual metal solubility, pH, and leaching by acidic rain during the wet season [35]. During the rainy season, irrigation of land with industrial effluent, and other agronomic activities caused heavy metal concentrations to fluctuate in the study area [36]. Heavy metal levels may be reduced during the rainy season due to high precipitation, leaching, erosion, and plant uptake [37]. Reference [36] also supported that the pollution was lowest because of heavy rainfall, dilution and other runoff processes. While greater heavy metal concentrations during the dry season could be attributed to a limited influx of fresh water and a higher evaporation rate [27]. According to reference [38-40] state that soil in a mangrove ecosystem, in addition to having a very wide salinity gradient, is also in temporary or permanent conditions and are rich in organic matter that can affect changes in pH values and other physicochemical variables, one of them is an oxide reduction process.

5 Conclusion

The sediment pH in Sungai Jarum Mas is acidic after being compared with different seasons. Iron (Fe) was recorded as the highest concentration in Sungai Jarum Mas. Besides that, some heavy metal elements were not affected by seasonal variation and the concentration was still in the control condition. In studying heavy metals in sediments, sediment properties are vital because they closely influence the accumulation of heavy metals. The main factors that might affect the increase of heavy metals in sediments are environmental-related factors and human-induced events. The environmental factors could be the precipitation rate, seasonal conditions, bioaccumulation in sediment, nutrient uptake by the plant, sediment transport flow and the sediment mineral layer nature. The human-induced factors mostly come from water transportation such as boats, deforestation, industrial and agricultural activities. All these factors will somehow be resulted in the divergence of heavy metals concentration in sediment. The study on heavy metals in sediment at Sungai Jarum Mas should be broadened to verify the quality of the mangrove ecosystem. The scope of this study should be expanded by studying other elements as well that are present in mangrove sediment. As we know, there are many factors that affect sediment in mangroves and human activities, especially near the Sungai Jarum Mas. Good sediment quality may sustain the mangrove ecosystem and environment. Protecting the mangrove forest environment is very important to maintain the ecosystem and balance it.

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