Forest and Society. Vol. 3(2): 278-288, November 2019
Received: 2019-04-21; Accepted: 2019-10-22
ISSN: 2549-4724, E-ISSN: 2549-4333

Regular Research Article

Heavy metals in mangrove sediments along the Selangor River, Malaysia

Laurna Nyangon [1], Ahmad Nur Syahmi Zainal [1], Ahmad Mustapha Mohamad Pazi [1], Seca Gandaseca [1*],

[1.] Faculty of Forestry, Universiti Putra Malaysia, Malaysia

***** Corresponding author: seca@upm.edu.my

Abstract: Mangroves are woody plants that grow at the interface between land and sea in tropical and subtropical latitudes where they exist in conditions of high salinity, extreme tides, strong winds, high temperature, and muddy anaerobic soils. The objectives of this study were to determine the selected heavy metals Copper (Cu), Zinc (Zn) and Lead (Pb) contamination in mangrove sediments at the Selangor River, Kampung Kuantan, Kuala Selangor, Selangor, Malaysia; and to compare heavy metals content in mangrove sediments between different plots and different sediment depths. Physical properties (sediment texture and sediment moisture) and chemical properties (pH water, electrical conductivity, and selected heavy metals) of sediments were determined by different plots and depths. The element of Pb was analyzed using the Inductively Coupled Plasma (ICP), whereas Cu and Zn using the Atomic Absorption Spectrometer (AAS). Data obtained were analyzed using the Statistical Analysis System (SAS) version 9.4 software. The results showed that the sediment texture was in the class of sandy clay, and soil moisture in all plots and at all depths were high. The contamination of sediment is affected by many factors, including soil pH and soil electrical conductivity. Cu, Zn and PB in sediment were determined around 1.00-10.60 mg/kg, 215.40-259.00 mg/kg and 18.83-28.59 mg/kg respectively, and were found to experience a significant difference between the plots, but not a significant difference between depths. The sediment in all plots and at all depths was contaminated with these heavy metals because of it being surrounded by residential and industrial areas, combined with particular recreational activities, agriculture and fishing along the Selangor River.

Keywords: Heavy metals; sediment; mangrove; Selangor River; contamination

1. Introduction

Mangrove forests are distributed in the intertidal region between the sea and the land in tropical and subtropical regions of the world. The forests are typically distributed from the sea level to the highest spring tide (Alongi, 2009). They grow in harsh environmental conditions e.g., those with high salinity, high temperature, extreme tides, high sedimentation, and muddy anaerobic soils. Mangrove forests around the globe are less than half of what they once were (Spiers, 1999). Mangroves are more widespread on the west coast of Peninsular Malaysia than the east coast. This may be due to the different wave patterns of water bodies bordering the east and west coasts of the peninsula. The west coast is bordered by the Straits of Malacca that has a limited wind fetch and is thus relatively calmer while the eastern side of Peninsular Malaysia is bordered by the South China Sea that has larger and more dramatic wave energy (Lokman & Yaakob, 1995).

Sediments are defined as the organic and inorganic materials found at the bottom of the water body. Sediment lacks the sand, clay, silt and other soil particles. It consists of the amassing of residue e.g., from rock, sand in streams, lakes or other marine environments (Ellison, 1999). Sediments can be contaminated in several ways including containing heavy metals.

The essential heavy metals e.g., Zn and Cu plays an important role in the biochemical and physiological process of both plants and sediments, although it could be toxic for mangrove habitats at high concentrations. Non-essential heavy metals like Pb have no role in biological processes and could be harmful to biological activities (Mirnategh et al., 2018). Sediments have been widely used as environmental indicators and the ability to trace contamination sources and monitor contaminants in sediments are largely recognized. They play important roles in the assessment of

 http://dx.doi.org/10.24259/fs.v3i2.6345

metal contamination in natural water (Islam, 2010).

The heavy metals pollution in sediment happens because of the excesses of heavy metals. The contamination is increasing because of the solid and liquid wastes emanating from industrial activities where toxic chemical contents such as chromium salts, sulphides as well as other substances, including heavy toxic trace metals (Rahimah, 2012). The release of contamination into the river by human activities result in a negative effect to the Berembang (*Sonneratia caseolaris)* tree and Fireflies (*Pteroptyx tener).* In fact, there is a huge area of oil palm plantation around the mangrove area and thus highlights the potential human interface with these traces of heavy metals. Overall, such conditions could become a very serious problem in mangrove environments.

Various contaminants arising from lithogenic and anthropogenic sources influence estuarine and coastal areas (Fomina & Gadd, 2014; Cavallo et al., 2016). Population growth and social-economic activities including industry, agriculture and aquaculture exacerbate pressures on the environment by producing large quantities of wastewater that contain metals, radionuclides, metalloids, as well as organic pollutants and nutrients. Thus, this study was conducted to determine the concentration of the selected heavy metals contamination in mangrove sediment at Selangor River, Kampung Kuantan, Kuala Selangor and to compare heavy metals content in mangrove sediment among different plots and different depths.

2. Materials and methods

2.1 Study area

The study was conducted within the Selangor River, Kampung Kuantan, Kuala Selangor, Selangor, Malaysia, which is shown in Figure 1. Kampung Kuantan is located in Kuala Selangor district and located around 7 km from Kuala Selangor town. It runs from Kuala Kubu Bharu in the east and empties into the Straits of Malacca at Kuala Selangor in the west. The latitude of Kampung Kuantan is (3°21'46.57"N), with a longitude of (101°18'4.80"E), and is located at an elevation of 8 m above sea level.

Figure 1. Location of the study area at Selangor river at Kampong Kuantan Selangor, Malaysia. Source: Google earth Software 2019.

2.2 Sampling work and design

A systematic sampling design was established in the study area. A total of five plots (10 m x 10 m) were established along the *S. caseolaris* tree zonation. The distance among the plots was 50 m and each plot has five subplots. The sediment sample was collected at two different depths namely D1 (0-15)cm and D2 (15-30 cm). A total of 50 sediment samples were taken in this study using peat auger along the Selangor River in October 2018 during the wet season. The GPSMAP® 60CSx (Garmin, Kansas USA) was used to record the coordinates of plots and sampling points. The sediment samples were kept into a labelled plastic bag to prevent contamination during transportation to soil laboratory. For sediment preparation, the sediment samples were air-dried in room temperature and ground using pastel and mortar. All ground samples were sieved pass to 2 mm sieve and kept into a labelled zip bag.

2.3 Sediment and statistical analysis

Sediment physical properties, soil texture, was determined using the hydrometer method (Bouyoucos, 1962) and the result was referred to the soil texture triangle. Electrical conductivity (EC) applied the electrode EC meter. Sediment chemical properties, pH in water was determined using the electrode pH meter (Eutech Instruments pH 700, Massachusetts USA) using the method of Tan (2005) and heavy metal was extracted using aqua regia method and analyzed using ICP and AAS.

The obtained data were analyzed using the Statistical Analysis System (SAS) version 9.4 software (North Caroline USA). The analysis of variance (ANOVA) followed by Tukey's Studentized range test (HSD) at P≤0.05 was used to evaluate significant differences of heavy metals content between plots and sediment depths

3. Results and Discussions

3.1 Selected sediment properties in Selangor river

Table 1 and table 2 showed the result for the selected sediment physical and chemical properties by plots and depths (P1, P2, P3, P4, and P5) in the Selangor River. This study revealed that the soil texture was sandy clay. The soil fractions (sand, silt, and clay) showed that the percentages of sand, silt, and clay were ca. 51-63%, 2-9%, and 29-47%, respectively.

Table 1. The Selected Sediment Physical and Chemical Properties by Plots (P1, P2, P3, P4, and P5)

Plot	*Soil Fraction*			*Soil Class*	*Sediment Chemical Properties*					
	Sand %	Silt (%)	Clay (%)	Texture Class	EC	Sediment Moisture	pH Water	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)
P1	51.31	4.61	44.08	Sandy Clay	300.64 [a] (±4.40)	3.81 [ab] (±0.12)	5.07 [b] (±0.07)	9.80[a] (±0.63)	236.40[ab] (±5.63)	28.59[a] (±0.79)
P2	51.46	2.47	46.08	Sandy Clay	295.33[ab] (±4.72)	4.25 [a] (±0.69)	5.08 [b] (±0.06)	10.60[a] (±0.95)	247.60[a] (±8.21)	27.15[a] (±1.25)
P3	55.38	3.54	41.08	Sandy Clay	286.90[ab] (±5.27)	3.33 [ab] (±0.11)	5.55 [a] (±0.07)	7.80[ab] (±0.92)	259.00[a] (±4.25)	26.81[a] (±0.91)
P4	56.60	2.40	41.00	Sandy Clay	276.69 [b] (±2.90)	3.52 [ab] (±0.17)	5.54 [a] (±0.04)	5.24[b] (±1.02)	242.80[a] (±8.50)	25.36[a] (±0.99)
P5	62.35	8.61	29.04	Sandy Clay Loam	302.06 [a] (±8.19)	2.50 [b] (±0.19)	5.57 [a] (±0.04)	1.00[c] (±0.45)	215.40[b] (±5.79)	18.83[b] (±1.12)

Note: Different alphabets within a column indicate significant difference between mean of soil physical and chemical properties by plots using *Tukey test at p<0.05*.

Table 2. Physical Properties and Chemical Properties by Depth (D1=0-15 cm, D2=15-30 cm)

Depth	*Soil Fraction*			*Soil Class*	*Sediment Chemical Properties*					
	Sand	Silt	Clay	Texture Class	*EC*	*Sediment Moisture*	*pH Water*	Cu *(mg/kg)*	Zn *(mg/kg)*	Pb *(mg/kg)*
D1	56.74	3.36	39.9 0	Sandy Clay	293.71 [a] (±3.89)	3.25 [a] (±0.13)	5.36 [a] (±0.06)	6.80[a] (±0.86)	237.76[a] (±5.73)	25.26[a] (±0.92)
D2	54.10	5.29	40.6 1	Sandy Clay	290.94 [a] (±3.73)	3.71 [a] (±0.31)	5.36 [a] (±0.06)	6.98[a] (±0.91)	242.72[a] (±4.18)	25.43[a] (±0.95)

Note: Different alphabets within a column indicate significant difference between mean of soil physical and chemical properties by depths using *Tukey test at p<0.05*.

The range of soil moisture was 2-5% with significant differences found among the plots. The pH of sediment was 5-6 in water. There was significant difference among the plots. As for electrical conductivity, the range was obtained at 270-303 dS/m and there was a significant difference shown among the plots. The amount of Cu in the sediment was obtained at a low ratio. It was determined at around 1.00-10.60 mg/kg and the significant difference was found between the plots. For Zn, it was found around 215.40-259.00 mg/kg with significant different recorded. Pb was found around 18.83-28.59 mg/kg with significant difference recorded.

3.2 The selected sediment properties by plots

Figure 2 revealed the comparison of the selected sediment properties by different plots. It can be seen that sand was highest at P5, 62.36% followed by P4, P3 P2 and P1 (55.60%, 55.38%, 51.46%, and 51.31%). The highest silt content was at P5 with 8.61% followed by the P1, P3, P2 and P4 (4.61, 3.54, 2.47 and 2.40%). The highest mean clay was 46.08% (P2), followed by 44.08, 41.08, 41.00, and 29.04% for P1, P3, P4, and P5, respectively.

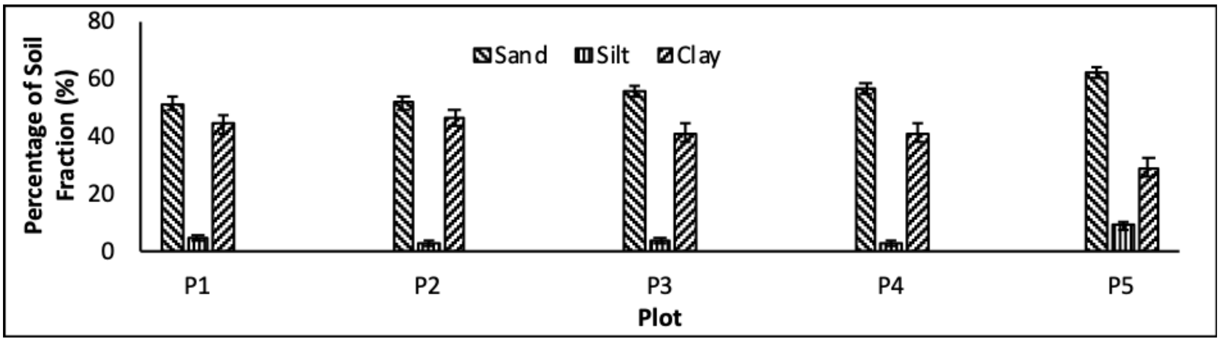

Figure 2. The comparison of soil texture between plots at Selangor river

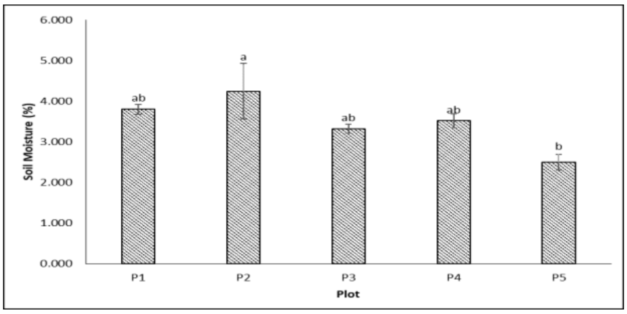

Figure 3. The comparison of soil moisture between plots at Selangor river

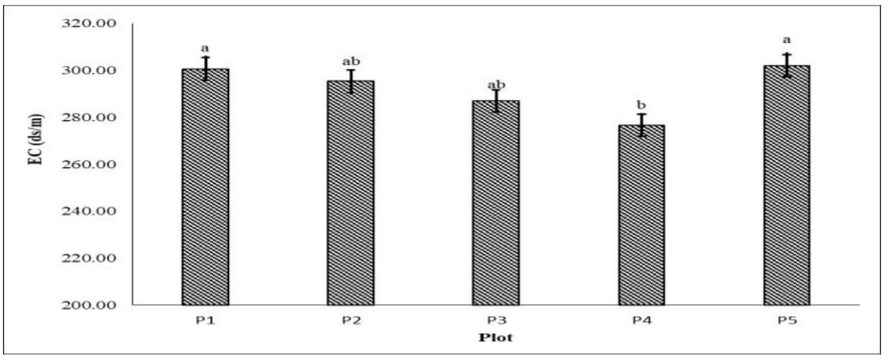

Figure 4. The comparison of soil EC between plots at Selangor River

The highest mean of the soil moisture was at P2 4.25% and followed by 3.81%, 3.52%, 3.33%, and 2.50% for P1, P4, P3 and P5, respectively. The mean comparison of soil moisture showed a significant difference between P2 as shown in Figure 3. However, for soil electrical conductivity (EC) it was determined that the highest level at P5 had a mean value of 302.06[a] (±8.19) dS/m and showed significant difference to P4. The trend followed the P1, P2, P3 and P4 (300.64[a] (±4.40), 295.33[ab] (±4.719), 286.9[ab] (±5.28) and 276.69[b] (±2.90) dS/m). The mean comparison of EC showed a significant difference between P1 and P5 with P4 using Tukey's Test ($P \leq 0.05$) as shown in Figure 4.

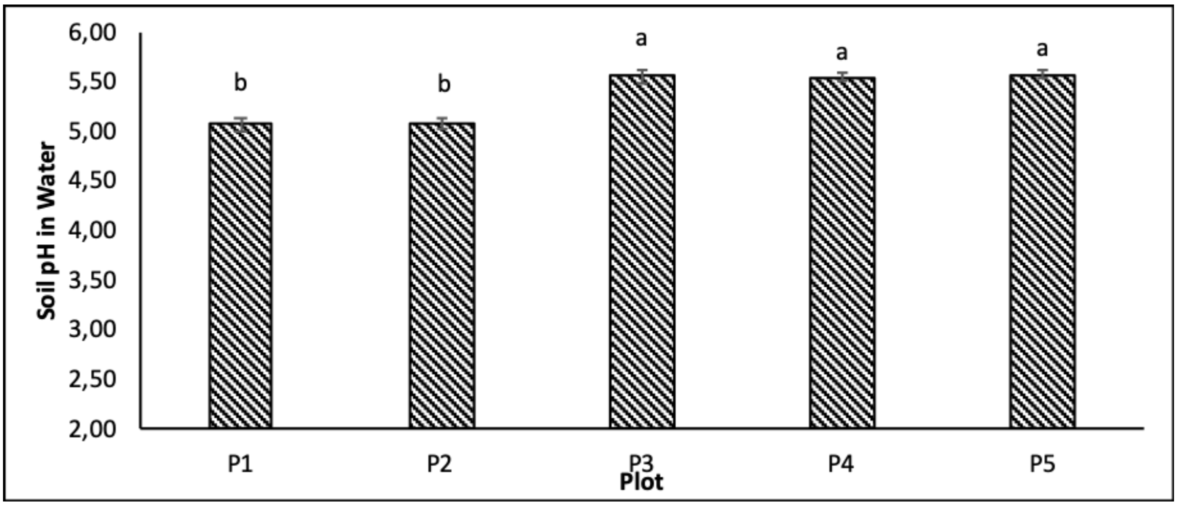

Figure 5. The comparison of soil pH in water between plots at Selangor river

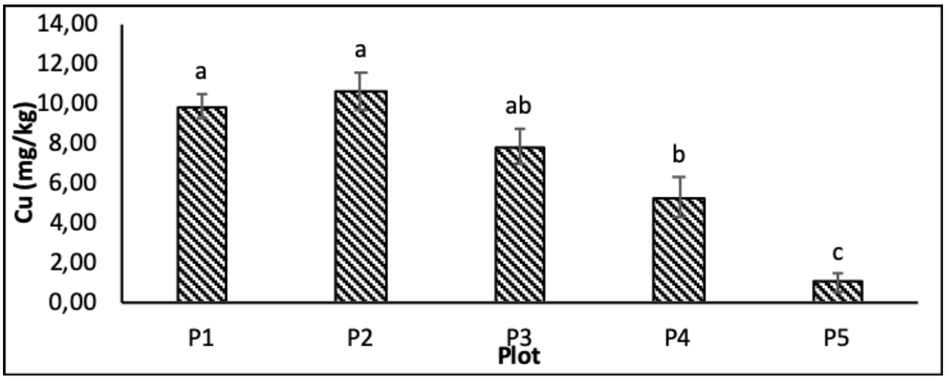

Figure 6. The comparison of Cu between plots at Selangor river

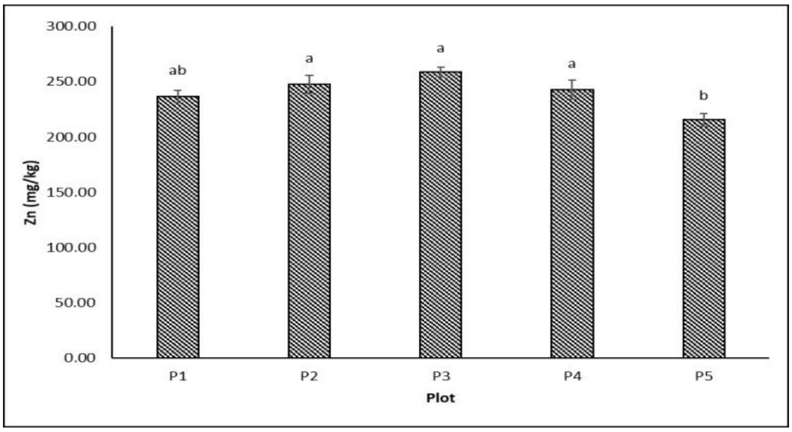

Figure 7. The comparison of Zn between plots at Selangor river

Figure 5 showed the comparison of soil pH between plots at the Selangor River. The soil pH in Selangor River was the highest at P5 with 5.57[a] (±0.04) and followed by the pH in P3, 5.55[a] (±0.07). The third highest sediment pH was P4 with 5.54[a] (±0.04), then followed by P2, 5.08[b] (±0.06). The lowest mean was P1 with 5.07[b] (±0.07). The significant differences were found between the soil pH in P5, P4, and P3 to P2 and P1 by using the Tukey's Test ($P \leq 0.05$).

The result of selected heavy metals was according to plot (P1, P2, P3, P4, and P5). Cu was highest in the P2 with the mean value 10.60[a] (±0.95) mg/kg followed by P1, P3, P4, and P5 (9.80[a] (±0.63), 7.80[ab] (±0.92), 5.24[b] (±1.02), and 1.00[c] (±0.45) mg/kg). The mean comparison of Cu showed P1 and P2 was given a significant difference between P4 and P5. In addition P3 and P4 also give a significant difference with P5 by using the Tukey's Test ($P \leq 0.05$).

Zn was recorded at the highest value at the P3, 259.00[a] (±4.25) mg/kg and followed by P2 (247.60[a] ±8.21 mg/kg), P4 (242.80[a]±8.50 mg/kg), P1 (236.40[ab] ±5.63 mg/kg), and P5 (215.40[b] ±5.79 mg/kg). The mean comparison of Zn showed P2, P3, and P4 were given a significant difference with P5 by using the Tukey's Test ($P \leq 0.05$). Lead was determined highest in plot 1 with mean value 28.59[a] ±0.79 mg/kg followed by P2 P3 P4 and P5 (27.15[a] ±1.25, 26.81[a] ±0.91, 25.36[a] ±0.99, 18.83[b] ±1.12 mg/kg). The mean comparison of Pb showed significant differences between P1, P2, P3, and P4 toward P5 as shown in Figure 8 by using the Tukey's Test ($P \leq 0.05$).

The texture of the soil is in the sandy clay class, as the percentage of sand was the highest compared to silt and clay. Sandy clay is the particle which is sand mixed into the soil and can create a shape but it can also break easily. According to Tripathi and Misra (2012), soil texture influences physical parameters of the soil and plays a very important role in plant species establishment and development. There are 3 main types of mineralogical compositions and the predominance of sand existence can be categorized in the primary minerals according to Soil Textural Triangle. Allen and Pilbeam (2007) stated that the weathering and rainfall rate prevalently affected the classification of the mineral size. In these soils, the structure is not a major problem because they are easily penetrated by plant roots, and when the rock percentage increases, the pore spaces are further increased in case the oxygen flowing with milk and honey water seeps in creating oxidized fundamentals in the soil.

According to Azlan et al., (2012) tree coverage is also a factor that affects soil temperature and moisture despite soil texture. Tree coverage can influence the soil temperature as it serves as the cooling agent for the atmosphere and acts as a precipitation induced factor which eventually affecting the soil water content. Apart from that, Mahmood et al., (2011) proved by investigating the relationship between soil moisture, greenness fraction and the different land use type and a relationship was determined among the variables. Zotarelli et al., (2010) explain that soil moisture indicates the ability of the soil to hold water which is affected by the soil texture. It is also mentioned that the sandy texture should have the lowest ability to hold water in the soil, which is contradicted to the result obtained.

Soil EC becomes higher because salts cannot be leached from and gave a bouquet zone and cache on the surface. Besides, Soil EC is caught by cropping, irrigation, land evaluate, and review of leaf mould, mulch, and compost. Arya (1981) showed infiltration raw material can by the same taken interact by the whole of the underlying edge that weathers releasing salts which creates sodium chloride solution seeps to what place it exists. Lin and Sternberg (2005) explained mangrove maintains water for primary production and growth. It is also evident that the mangrove biomass production low adversely affected by salinity fluctuations level of sediment water.

This result indicated the soil in the P5 was lower acidic compared to the other plots. In general, water with a pH below 7 is considered acidic and pH over 7 considered alkaline. According to Gruba and Mulder (2015), natural process; decompositions of organic matter, leaching of cation, and human actions, for example, liming materials from fertilizing caused soil pH trends. Chen and Lin

(2001) explained the high pH because of heavy metal from sediment, the pH directly or indirectly affects metal retention by sediment.

Another study, Chaiyara, Ngoendee, and Kruatrachue (2013) showed that Cu was higher than those of the water because the dilution effect can cause precipitation of large amounts of metals into the sediments as a result of the increased pH and salinity of the water. In addition, also it comes from various sources in residences and industrial wastewaters. Montalvo et al., (2014) reported the wastewater discharges and hydrocarbons related to high copper concentrations. Nazir et al., (2015) found that the high concentration of Zn can be toxic to the organism and the sources for the enrichment of these metals are intensive fishing and industrial activities (Rahimah, 2012).

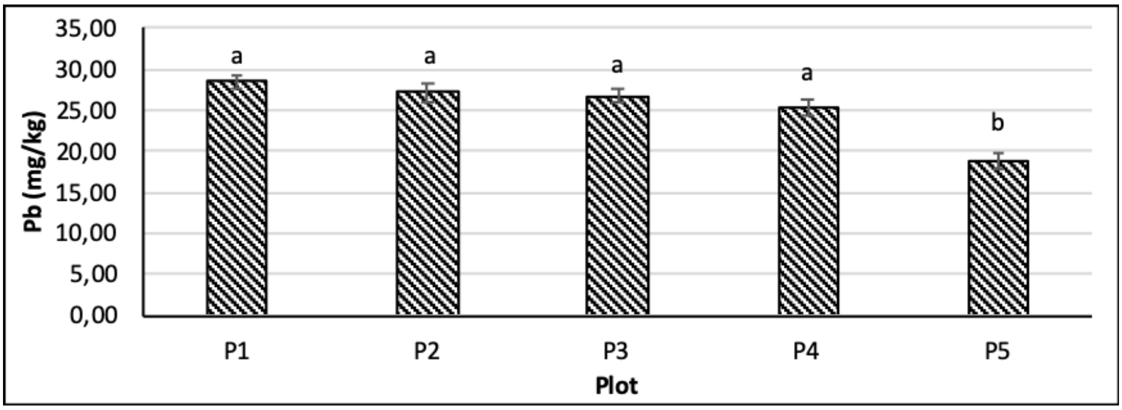

Figure 8. The comparison of Pb between plots at Selangor River

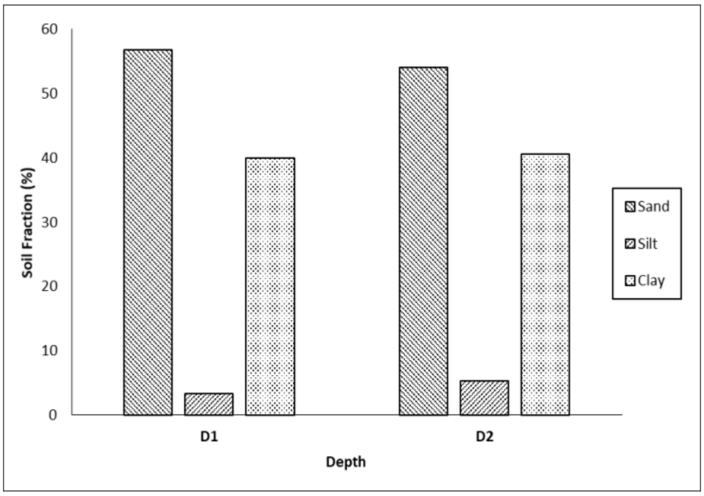

Figure 9. The comparison of soil texture between depths at Selangor River

3.3 The selected sediment properties by depths

Table 2 showed the comparison of the selected soil properties by different sediment depths layer. The sand was highest in percentage at depth 1, 56.74% followed by depth 2 with 54.10%. The silt was higher at depth 2 with 5.290% followed by depth 1, 3.362%. The mean clay percentage was higher at depth 2 with 40.61% followed by depth 1, 39.90%. The comparison of soil texture between depths was shown in Figure 9.

Soil moisture was higher in-depth 2 ($3.71^a \pm 0.31$ %) than depth 1 with $3.25^a \pm 0.13$ %. There were no significant differences found between depth 1 and depth 2 for this parameter. The comparison of soil moisture between depths presented in Figure 10. For soil EC, it was determined the higher in the depth 1 with the mean value was $293.71^a \pm 3.89$ dS/m. The trend followed by depth 2 with the mean value was 290.94[a] (±3.73) dS/m. There were no significant differences detected between depths by using Tukey's Test (P≤0.05).

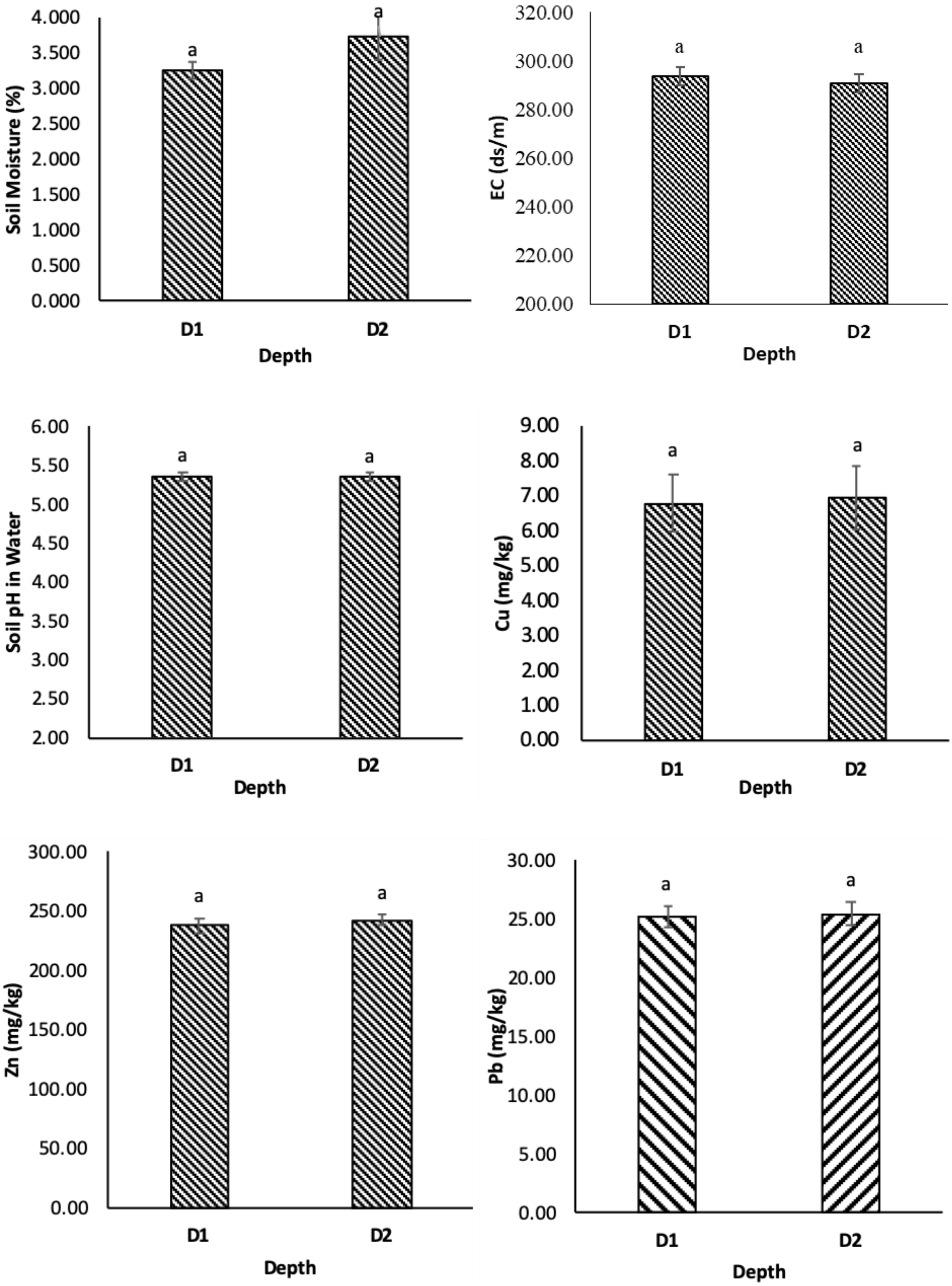

Figure 10. The comparison of sediment properties at Selangor river between the depth

Figure 10 showed the comparison of pH water between the sediment depths. The sediment pH was acidic at depth 1 with mean value 5.364^{a} ±0.06 and followed by sediment pH in depth 2, 5.36^{a} ±0.06. pH in different depths was not significantly different. Cu was higher in the depth 2 than depth 1 (6.98^{a} ±0.91 mg/kg and 6.80^{a} ±0.83 mg/kg) and the statistical test showed Cu in differ depths were not significantly differences. Figure 7 showed the comparison of Cu between depths at Selangor River For Zn, the higher value was obtained at the depth 2, 242.72^{a} (±4.18) mg/kg and followed by depth 1 with mean value 237.76^{a} (±5.73) mg/kg. The significant differences were not shown between the depths. Figure 7 showed the comparison of Zn between the sediment depths. Pb was higher in depth 2 with mean value 25.43^{a} ±0.95 mg/kg than depth 1, 25.26^{a} ±0.92 mg/kg. The significant differences were not shown between the depths (Figure 10).

The different percentages across the depths might be due to the high rate of erosion or the damage of clay in the topsoil of the particle, steeper slope or as the effect of human and livestock activities (Siddique et al., 2014). Furthermore, it is also mentioned that this unstable damage will slow down the rate of weathering. The trend of this sediment moisture in differs sediment depths showed limited difference across depths. Meerveld and Mcdonnell (2006) explain that the transpiration rate during the growing season and the vegetation patterns can affect the soil moisture in soil depth. This study also suggests that there are no spatial patterns in term of soil moisture with depth or across the slope. According to Allen and Pilbeam (2007), water storage capacity is low in sandy soil, but most of the stored water is available.

In general, EC increases as clay content increases. Factors influencing the electrical conductivity of soils include the amount and type of soluble salts in solution, porosity, soil texture (Stott and Martin, 1989). The sediment pH in Selangor River was the highest at depth 1 and Webb et al., (2014) showed that the trend of soil pH across the depth can be affected by the interactions between soil series, particle size class and the slope position. The pH values in most of the mangrove site less than pH 7 which is acidic. The pH becomes acidic because of the more organic matter. According to Satrio et al., (2009) H^{+} ions from organic matter contribute to acidify the soil.

The human activities such as industrial, recreational, throwing rubbish, agriculture and wastewater caused the sediment to have Cu heavy metal. Because of mining, production of goods and the use of zinc create situations where emissions to the atmosphere, soil, and water can occur (Ismail, 2007). Islam (2010) found that one of the major sources of Zn to the aquatic environment is the discharge of domestic wastewater. There is a residential area near Selangor River. Lead is present in the fuel, and therefore the concentration of lead may be due to its content in the fuel from the shipping activities which is deposited in the sediment (Ismail, 2007). Watching fireflies using the boat at night occur at Selangor River.

4. Conclusions

The sediment texture was higher with sand and clay. Sediment moisture and pH were recorded at the highest value in all plots and depths. The concentration of the selected heavy metals Cu, Zn and Pb in mangrove sediment at Selangor River, Kampung Kuantan was recorded moderate. Cu, Zn and PB in sediment were determined around 1.00-10.60 mg/kg, 215.40-259.00 mg/kg and 18.83-28.59 mg/kg respectively, and were found significant difference between the plots, but not significance different between depths. There are many factors that influence the mangrove sediment, and the increase of development and the opening of plantation areas near the Selangor River contribute to sedimentation and degraded water quality levels. Maintaining the mangrove forest environment is important for sustaining the ecosystem and balancing it.

Acknowledgements

We wish to thank Universiti Putra Malaysia for funding this project. The contribution and assistance from the Faculty of Forestry, Universiti Putra Malaysia is greatly appreciated.

References

Alongi, D. M. (2009). *The Energetics of Mangrove Forest*. Townsville: Springer Press.

Allen, V. B. & Pilbeam, D. J. (2007). *Handbook of Plant Nutrition*. Boca Raton: CRC Press.

Arya, L. M., & Paris, J. F. (1981). A physic empirical model to predict the soil moisture characteristic from particle-size distribution and bulk density data. *Soil Science Society of America Journal*, 45(6), 1023-1030.

Azlan, A., Aweng, E.R., Ibrahim, C.O., & Nooraidah, A. (2012). Correlation between Soil Organic Matter, Total Organic Matter and Water Content with Climate and Depths of Soil at Different Land use in Kelantan, Malaysia, *Journal of Applied Sciences and Environmental Management*, 16(4), 353-358.

Bouyoucos, G. J. (1962). Hydrometer Method Improved for Making Particle Size Analyses of Soils. *Agronomy Journal*, 54, 464-465. doi:10.2134/agronj1962.00021962005400050028x

Cavallo, M., Torras, X., Mascaró, O., & Ballesteros, E. (2016). Effect of temporal and spatial variability on the classification of the Ecological Quality Status using the CARLIT Index. MPB, 102(1), 122–127. https://doi.org/10.1016/j.marpolbul.2015.11.047

Chaiyara, R., Ngoendee, M., & Kruatrachue, M. (2013). Accumulation of Cd, Cu, Pb, and Zn in water, sediments, and mangrove crabs (Sesarma mederi) in the upper Gulf of Thailand. *ScienceAsia*, 39, 376–383. http://doi.org/10.2306/scienceasia1513-1874.2013.39.376

Chen, S.Y., & Lin, J.G. (2001). Bioleaching of Heavy Metals from Sediment: Significance of pH. *Chemosphere*, 44, 1093-1102.

Ellison, J. C. (1999). Impacts of Sediment Burial on Mangroves. *Marine Pollution Bulletin*, 37(8-12), 420-426. doi:DOI: 10.1016/S0025-326X(98)00122-2

Fomina, M., & Gadd, G. M. (2014). Biosorption: current perspectives on concept, definition and application. Bioresource Technology, 160, 3–14. https://doi.org/10.1016/J.BIORTECH.2013.12.102

Gruba, P., & Mulder, J. (2015). Tree species affect cation exchange capacity (CEC) and cation binding properties of organic matter in acid forest soils, *Science of The Total Environment*, 511, 655–662.

Islam, K. N. (2010). *Heavy Metal Contamination and Sediment Quality*. Dhaka: Lambert Academic Publishing.

Ismail, R. (2007). Distribution and Concentration of Heavy Metals and Polyaromatic Hydrocarbons in Surface Sediments of Kuala Sepetang, Perak. Serdang, Selangor. Universiti Putra Malaysia.

Lin, G., & Sternberg, L.D. (2005). Effects of Salinity Fluctuation on Photosynthetic Gas Exchange and Plant Growth of the Red Mangrove (Rhizophora mangle L.). *Journal of Experimental Botany*, 44, 9-16.

Lokman, H., & Yaakob, R. (1995), 'Beach erosion variability during a northeast monsoon: The Kuala Setiu coastline, Terengganu, Malaysia', Pertanika Journal of Science & Technology, 3(2), 337–348.

Mahmood, R., Leeper, R., & Quintanar, A. (2011). Sensitivity of planetary boundary layer atmosphere to historical and future changes of land use/land cover, vegetation fraction, and soil moisture in Western Kentucky, USA. *Change*, 78, 36–53.

Meerveld, H. J. T., & Mcdonnell, J. J. (2006). On the Interrelations between Topography, Soil Depth, Soil Moisture, Transpiration Rates and Species Distribution at the Hillslope Scale On the interrelations between topography, soil depth, soil moisture, transpiration rates and species distribution at the hillslope scale, (February). https://doi.org/10.1016/j.advwatres.2005.02.016

Montalvo, C., Aguilar, C. A., Amador, L. E., Cerón, J. G., Cerón, R. M., Anguebes, F., & Cordova, A. V. (2014). Metal contents in sediments (Cd, Cu, Mg, Fe, Mn) as indicators of pollution of Palizada River, Mexico, *Environment and Pollution*, 3(4): 89-98. http://dx.doi.org/10.5539/ep.

Mirnategh, S. B., Shabanipour, N., & Sattari, M. (2018). Seawater, Sediment and Fish Tissue Heavy Metal Assessment in Southern Coast of Caspian Sea. *International Journal Of Pharmaceutical Research And Allied Sciences*, *7*(3), 116-125.

Nazir, R., Khan, M., Masab, M., Rehman, H.U., Rauf, N., Shahab, S.A., Ameer, N.T., Sajed, M., Ullah, M., Rafeeq, M., & Shaheen, Z. (2015). Accumulation of Heavy Metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water Collected from Tanda Dam Kohat. Department of Chemistry, 89-97.

Rahimah, A. (2012) Heavy metals distribution in water, sediment and aquatic species from Matang Mangrove Forest Reserve, Perak, Malaysia / Rahimah Abdullah. Masters thesis, University of Malaya.

Satrio, A. E., Gandaseca, S., Ahmed, O. H., Muhamad, N., & Majid, A. (2009). Influence of Chemical Properties on Soil Carbon Storage of a Tropical Peat Swamp Forest, (November), 1969–1973. https://doi.org/10.3844/ajassp.2009.1969.1972a

Siddique, M. D., Noor, E. A., Islam, M. D., Halim, A., Kamaruzzaman, M. D., Sultana, J., & Karim, D. (2014). Mapping of Site-Specific Soil Spatial Variability by Geostatistical Technique for Textural Fractions in a Terrace Soil of Bangladesh, *Journal of Bioscience and Agriculture Research (JBAR)*, 1, 8–16.

Spiers, A.G. (1999). Review of international/ continental wetland resources. Global review of wetland resources and priorities for wetland inventory (ed. by C.M. Finlayson and A.G. Spiers). *Supervising Scientist Report*, 144, 63–104.

Stott, D.E., & J.P. Martin. (1989). Organic matter decomposition and retention in arid soils. *Arid Soil Research and Rehabilitation*. 3,115-148.

Tan, K. H. (2005). Soil Sampling, Preparation, and Analysis 2nd Edition. New York: CRC Press.

Tripathi, A., & Misra, D. R. (2012). A study of physico-chemical properties and heavy metals in contaminated soils of municipal waste dumpsites at Allahabad, India, 2(4), 2031–2040. https://doi.org/10.6088/ijes.00202030087

Webb, K. T., Wang, C., Astatkie, T., & Langille, D. R. (2014). Spatial and temporal trends in soil properties at a soil quality benchmark site in central Nova Scotia, (November 2000). https://doi.org/10.4141/S99-104

Zotarelli, L., Dukes, M. D., and Morgan, K. T. (2010). Interpretation of soil moisture content to determine soil field capacity and avoid over-irrigating sandy soils using soil moisture sensors. IFAS Publication AE460. Gainesville: University of Florida Cooperative Extension Service. http://edis.ifas.ufl.edu/ae460