Jurnal Manajemen Hutan Tropika, *28*(1), 22–31, April 2022
EISSN: 2089-2063
DOI: 10.7226/jtfm.28.1.22

Scientific Article
ISSN: 2087-0469

Assessment of Mangrove Sediment Quality Parameters from Different Seasons, Zones and Sediment Depths

Ahmad Mustapha Mohamad Pazi[1*], Waseem Razaq Khan[2], Noraini Rosli[3], Ahmad Ainuddin Nuruddin[1], Seca Gandaseca[1,2*]

[1]Faculty of Forestry and Environment, Universiti Putra Malaysia Selangor, Malaysia 43400
[2]Institut Ekosains Borneo, Universiti Putra Malaysia, Kampus Bintulu Sarawak, Malaysia 97008
[3]Faculty of Agriculture and Forestry Sciences, Universiti Putra Malaysia, Kampus Bintulu Sarawak, Malaysia 97008

Received September 17, 2021/Accepted March 11, 2022

Abstract

Heavy metal concentrations have risen throughout Malaysia's coastline because of industrial wastewater discharge, affecting mangrove ecology significantly. Lead (Pb), Zinc (Zn), Chromium (Cr), and Nickel (Ni) were used to establish the Mangrove Sediment Quality Index (MSQi), which assesses and monitors the quality of mangrove sediment. This study was conducted at Matang Mangrove Forest Reserve (MFFR) in Perak, Malaysia to examine changes in MSQi features across seasons, mangrove zones, and sediment depths at three separate MMFR locations. Sediment samples were taken using auger in two different seasons (dry and wet seasons). After the silt was removed using aqua regia techniques, heavy metals were examined using an Atomic Absorption Spectrophotometer. According to MSQi criteria in various seasons at three different locations, the highest concentration of heavy metals (HMs) was detected in the dry season in the least disturbed region at three different locations. During dry seasons, only Cr and Ni levels are higher in moderately and highly disturbed areas. Pb and Zn levels in moderately and highly disturbed areas are higher than in least disturbed areas during the rainy season. MSQi parameters in different mangrove zones at three locations showed that most HMs content is highest in the landward zone and it can be concluded that HMs sources are anthropogenic. Furthermore, MSQi measurements at three locations revealed that heavy metals content is highest at 015 cm and lowest at other depths.

Keyword: *MSQi, mangrove, sediment, seasonal, zones, sediment depths*

**Correspondence author, email*: *muss.pazii@gmail.com and seca@upm.edu.my*

Introduction

Mangroves are considered as most productive ecosystem on the earth (Carugati et al., 2018). Mangroves provide a variety of ecosystem services such as fishery production (Friess et al., 2020) , coastal protection (Serrano et al., 2018), pollution buffering (Gandaseca et al., 2016) and carbon sequestration (Mitra, 2020). In addition, mangrove sediments have a high capacity to retain heavy metals from marsh water, freshwater and stormwater runoff (Aris et al., 2014). Mangrove often serve as a sink for heavy metals (Wang et al., 2019). The accumulation of heavy metals in a river mouth's bottom sediments depends not only on the distribution of the different fluvial inputs but also on the chemical interaction between metals and sediment constituents (Dong et al., 2012). Pollutants linked to sinking sediment particles are bound to inorganic or organic matrices by adsorption processes (Ren et al., 2020).

The health of mangroves is based on their environment and it can be determined by physical, chemical and biological properties of the soil, water drainage, current sediment moisture and flood frequency. Today, many mangrove forests are found near human settlements, which negatively effects mangrove forest directly and indirectly (Thakur et al., 2021). The increasing urbanisation, agriculture, aquaculture and industry are the main sources of mangrove destruction (Numbere, 2021). In recent decades mangrove forests have declined significantly due to inappropriate management practices (Zhou et al., 2010).

Mangrove Sediment Quality Index (MSQi) is an assessment of mangrove forests sediment quality and monitoring standards. The MSQi is measured using two factors: sediment contaminant concentrations and toxicity. It is also helpful in making decisions as a benchmark and conserving resources to avoid further contamination of specific areas. (Mohamad Pazi et al., 2021). MSQi is based on standard parameters that can be used and measured, allowing for more accurate data comparison between monitoring stations at the regional, national, and global levels. MSQi involved four important parameters, which is Pb, Zn, Cr and Ni (Mohamad Pazi et al., 2021). Therefore, this study was carried out at Matang Mangrove Forest Reserve (MFFR) Perak Peninsular Malaysia to investigate the changes of mangrove sediment quality parameters in different seasons, mangrove zones and sediment depths at three different locations of MMFR.

Methods

Study area This study was conducted at the Matang Mangrove Forest Reserve (MMFR) in Perak, Malaysia. MMFR is located at the borders of Malacca Strait and is shaped like a crescent moon (Figure 1). The MMFR stretch over a distance of 10.00 km from Kuala Sepetang to Taiping Town. The main townships in MMFR are Kuala Sepetang, Kuala Trong, and Kerang River. Meanwhile, fishing villages are Bagan Kuala Gula, Bagan Sangga Besar, Bagan Pasir Hitam, and Bagan Panchor. The climate in MMFR is mainly equatorial, with a mean annual temperature of 23–30 °C. The average rainfall ranges from 2,000–3,000 mm. Moreover, the reserve experiences semidiurnal tides ranging from 1.62.9 m. MMFR is dominated by *Rhizophora apiculata* and *Rhizophora mucronata* species.

In MMFR, working plans or management have been revised and implemented. The ten-year program provides detailed resources and schedules for harvesting, yield regulation, silvicultural operations, protection, and conservation. MMFR has been managed sustainably based on five work plans since Malaysia's Independence Day in 1957 (Mohamad Pazi et al., 2021). However, the MMFR, with its large expanse of sheltered waters, is home to 7,666 floating fish cages, and cockle culture covers an area of 4,726 ha, both within and outside the estuaries Forestry Department of Perak (2010) stated that mangrove forest ecosystems provide productive and complex marine habitats for diversified marine life. There are 163 species of fish, 37 species of shrimps and prawns, and 45 species of crabs that have been identified and recorded in the Sixth Revision of the Working Plan. The following are the rivers' specific characteristics:

Tiram Laut River (TLR) is located near the sea mouth at N4°52'30.30" and E100°38'8.04". The river's length was estimated to be around 8.98 km. TLR is classified as least disturbed since most of this area had transformed into a water body, dryland forest, and waterway for fishing boats (Ibharim et al., 2015).

Tinggi River (TR) is located near Kampung Pasir Hitam between N4°52'30.30" and E100°38'8.04"). The river's length is estimated to be around 8.1 km. Despite being closest to human development, this river is moderately disturbed due to minimal changes in mangrove land to water bodies, dryland forests, human development, agriculture, and aquaculture activities (Ibharim et al., 2015).

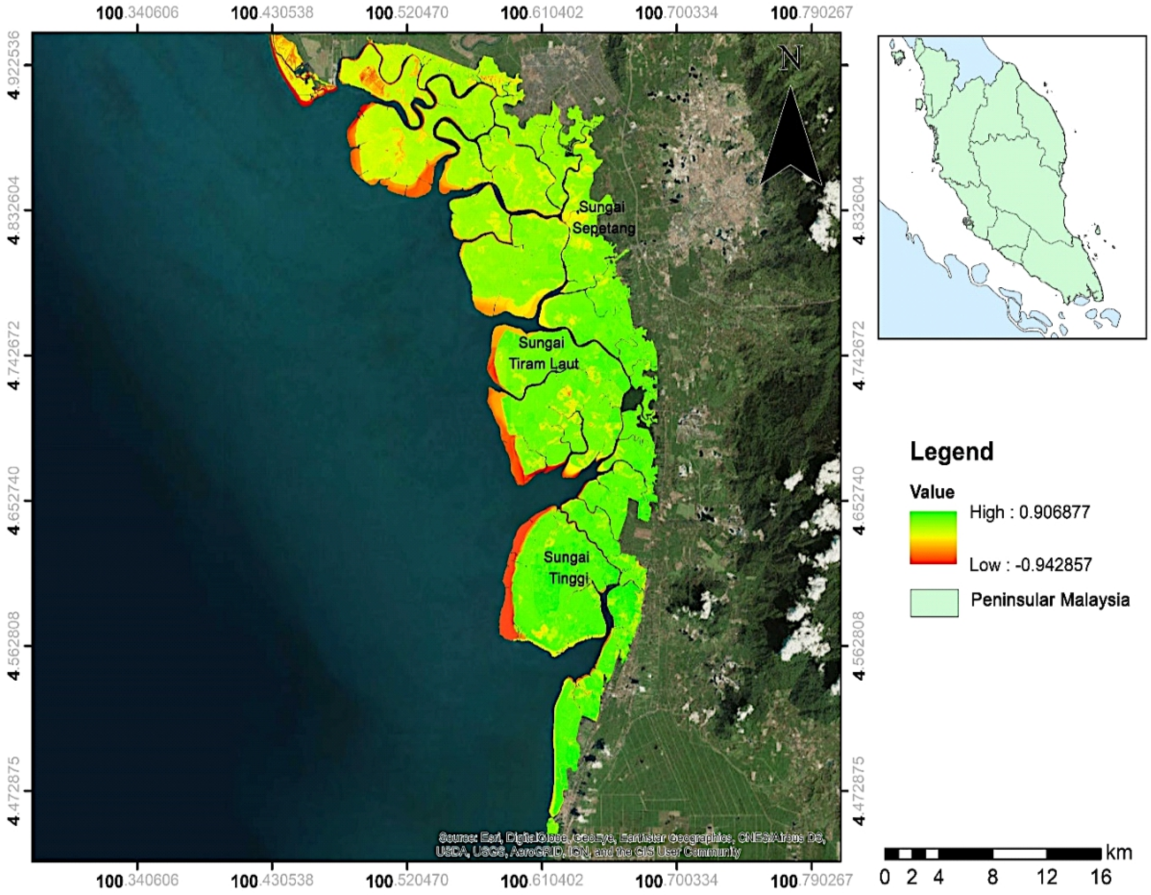

Figure 1 The location of the study area at TLR, TR, and SR in MMFR, Perak (green = least disturbed, yellow = moderately disturbed, and red = highly disturbed). Note: TLR = Tiram Laut River, TR = Tinggi River, and SR = Sepetang River.

Sepetang River (SR) is near the Kuala Sepetang town, at latitude N4°52'30.30" and longitude E100°38'8.04". The river's length is estimated to be around 20.4 km. As observed during sampling activities, this river is classified as highly disturbed due to its proximity to human settlements, agriculture, aquaculture, industrial operations, and jetty. The land had been converted into oil palm plantations, horticulture, paddy fields, aquaculture, urban settlements, and dryland forests (Ibharim et al., 2015).

Normalize differential vegetation index (NDVI) is used to identify the vegetation health. NDVI is used to segregate the mangrove compartments on the basis of health. So, authors determine the sampling points based on vegetation health. This method determined different levels of mangrove disturbance (green = least disturbed, yellow = moderately disturbed, and red = highly disturbed) (Figure 1). Landsat 8 imagery acquired from (https://earthexplorer.usgs.gov/) (path: 126, row: 57) with resolution 30 m for the year 2017 were used to quantifies vegetation by using the difference vegetation index (NDVI) (Figure 2). The NDVI measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). The value of NDVI is ranging between -1 and 1 which value 1 is indicate the high vegetation index and -1 is very low vegetation index (Gandhi et al., 2015; Zaitunah et al., 2018; Pisman et al., 2020). The high vegetation plant characterized by plants with large and healthy canopies. The NDVI were calculated by using Equation *[1]*.

$$NDVI = \frac{NIR-Red}{NIR+Red} \qquad [1]$$

note: NIR is near-infrared band (Band 5 = 0.850.88 λ) and red is (Band 4 = 0.640.67 λ). This NDVI analysis was carried out in ArcGIS 10.5 software version. Previously, Othman et al. (2018) had applied NDVI for monitoring deforestation in Pahang, Malaysia. They study able to identify the forest vegetation to observe the deforestation activities. Other than that, Yasin et al. (2019) used NDVI to observe land use changes in Sepang, Selangor and able to identify the major factor of land use changes. Besides that, Yasin et al. (2020) had used NDVI to observe the mangrove changes in Sepang, Selangor. They able to identify the changes in density, types, and total areas of mangroves over the past 25 years. The NDVI capable to determine and differentiate the difference between the vegetation and non-vegetation based on the value. Thus, the NDVI process applied in this study capable to quantifies the vegetation of the mangrove in MMFR, Perak.

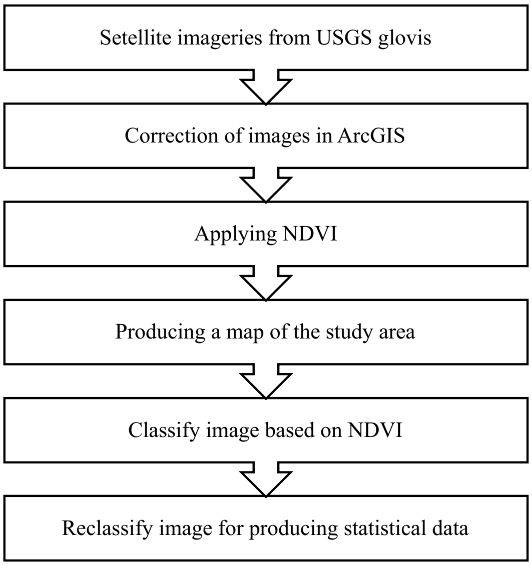

Figure 2 Flow chart of the NDVI process.

Experimental design A systematic sampling (Carter et al., 2007) was applied in this study, with three main plots of 450 m × 25 m established as the primary study plot from the landward, central, and seaward zones of each river. Each main plot contained five 5 m × 5 m subplots, with a distance of 100 m between each subplot. Five 1 m × 1 m mini subplots were established for sediment sampling (Figure 3). GPSMAP® 60CSx Garmin with accuracy 5 was used to record the sampling points for sediment sampling during dry and wet seasons.

Sediment sampling and laboratory analysis Seven hundred and fifty sediment samples were collected from five mini subplots along the same transect. This study follows the same procedure of Development of Mangrove Sediment Quality Index in Matang Mangrove Forest Reserve, Malaysia: A Synergetic Approach (Mohamad Pazi et al., 2021). The sediment samples were taken using a peat auger (Mohamad Pazi et al., 2021) in two seasons: November and December 2017 (wet season) and March and April 2018 (dry season). This study obtained a total of 2,250 sediment samples at five depths, i.e., 0–15, 15–30, 30–50, 50–100, and 100–150 cm, because sediment depths can also influence pollution (Mohamad Pazi et al., 2021). The sediment samples were placed into a labelled plastic bag and stored in the ice box before being transported to the soil laboratory for analysis.

Sediment samples were characterised for chemical properties. Aqua regia method was used to extract and digest the sediments (Mohamad Pazi et al., 2021). Finally, samples were analysed for heavy metals using an atomic absorption spectrophotometer (AAS, Model Shimadzu AA-6800) with specific flame and wavelength settings.

Statistical analysis The data were analysed using a statistical analysis system (SAS) software version 9.4. Paired T-test was used to test the significant effect of MSQi parameters between two different seasons within three locations. Analysis of variance (ANOVA) followed by post-hoc test Tukey's Studentized range test (HSD) was used to test the significant effect of MSQi parameters in different zonation and sediment depth at three locations with *p*-value 0.05.

Results and Discussion

Comparison of mangrove sediment quality index parameters between two different seasons at three

locations of Matang Mangrove Forest Reserve Lead content in different seasons at three locations of MMFR is illustrated in Figure 4. Tiram Laut River, Tinggi River and Sepetang River were found with significantly highest content of Pb during wet than during dry season. The trend of Pb content of MMFR in different seasons was found as Wet > Dry. The main source of Pb was gasoline, as tetraethyl lead (PbEt4) is used in some petrol grades (Buajan & Pumijumnong, 2010), and Pb is also a major component of lead-acid used extensively in batteries. The increment of Pb content during the wet season is due to runoff of Pb content from human activities such as boating and waste disposal from municipal (Islam et al., 2015). On the hand, lower concentration of Pb content during the dry season is due to dilution of runoff and unpolluted water. In addition, Pb content may also be influenced by changes in lithological inputs, hydrological effects, geological features and type of vegetation cover (Van Santen et al., 2007).

Zinc content at different seasons at three locations of MMFR is illustrated in Figure 5. There are 2 different trends, where Tiram Laut River was found with highest Zn content during the dry season than during wet seasons. While Tinggi River and Sepetang River were constituted with highest Zn content during wet season than during dry season. Zn content during wet season is probably due to the characteristic of the location which is considered as moderate and highly disturbed area. Most of these areas were converted to water body, dryland forest, agriculture, aquaculture and industry (Ibharim et al., 2015). During wet season, high water leaching causes large amounts of debris and contaminants to be deposited into rivers and streams (Ahmad et al., 2012). For example, the application of trace elements is widely used in fertiliser, pesticides and aquaculture pallet. Therefore, these activities influenced the changes of Zn content in mangrove sediment. A lower concentration of metals in dry season is due to decreased dilution by precipitation and uncontaminated water (Jain et al., 2007).

Chromium content at different seasons in three locations illustrated in Figure 6. Tiram Laut River, Tinggi River and Sepetang River were found significantly highest for Cr content during dry season. Trend of Cr content of MMFR in different seasons was found as Dry > Wet. High content of Cr during dry season at Sepetang River and Tinggi River due to low precipitation and absorption of metals in sediment (Duncan et al., 2018).

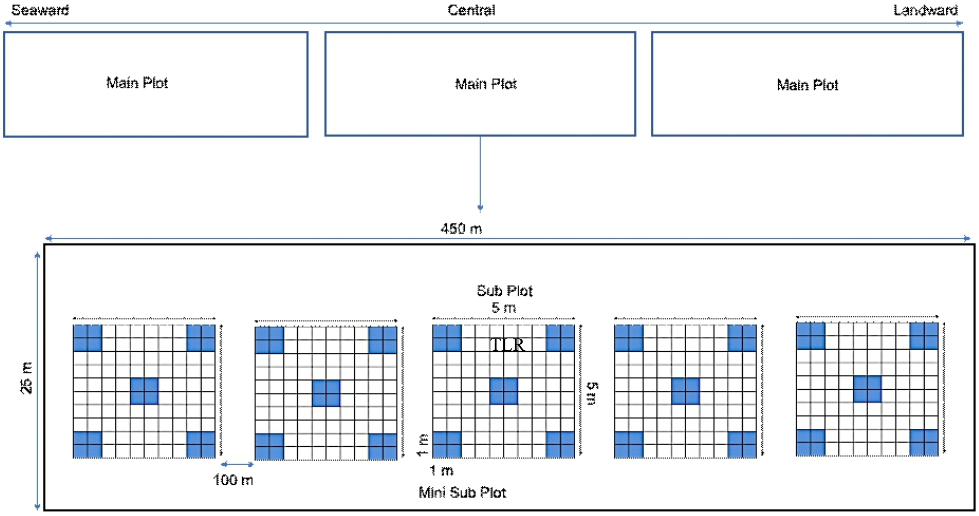

Figure 3 Sampling plot design from landward to seaward.

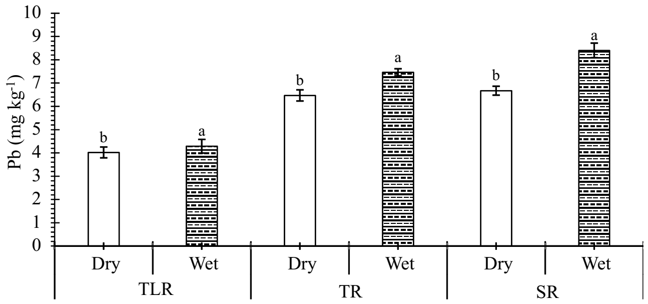

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Figure 4 Lead content in different seasons at three locations.

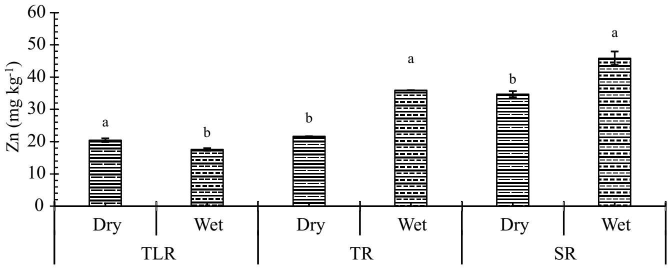

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Figure 5 Zinc content in different seasons at three locations.

Nickel content at different seasons at three locations is illustrated in Figure 7. Tiram Laut River, Tinggi River and Sepetang River were found significantly highest for Ni content during dry season than during wet season. Trend of Ni content in MMFR in different seasons was found as Dry > Wet. The present content of Ni during wet season could be due to runoff from landward areas influenced by human activities, i.e., disposal of batteries and metal waste from industries (Chiba et al., 2011). However, this metal was found at a low concentration in nature but is commonly used in industrial activities (Järup, 2003).

Comparison of mangrove sediment quality index parameters between mangrove zones at three locations of Matang Mangrove Forest Reserve Lead content at different mangrove zones at three locations of MMRF is illustrated in Figure 8. Tiram Laut River, Tinggi River and Sepetang River were found with highest content of Pb at landward zone. Trend of Pb content in MMFR in different mangrove zones was found as Landward > Central > Seaward. A statistical result shows that mean of Pb content at mangrove zones is not significantly different. Tiram Laut River received the highest Pb content at landward followed by seaward and central. Trend of Pb content at TLR was recorded as Landward > Seaward > Central. Mean comparison of Pb content in mangrove zones were not significantly different. Tinggi River was found with highest Pb content at landward followed by seaward and central. Trend of Pb content at TR was recorded as Landward > Seaward > Central. Mean comparison of Pb content in mangrove zones were not significantly different. Meanwhile, Sepetang River was found with highest Pb content at landward followed by central and seaward. Trend of Pb content at SR was recorded as Landward > Central > Seaward. Mean comparison of Pb content in mangrove zones showed that the seaward zone was significantly different from landward and central zones using the Tukey Test with p0.05. Pb content at landward zone might be due to runoff from landward areas influenced by human activities such as aquaculture, agriculture, irrigation and industries (Ibharim et al., 2015; Islam et al., 2015).

Zinc content at different mangrove zones at three locations is illustrated in Figure 9. Tiram Laut River, Tinggi River and Sepetang River were found with highest Zn content at landward zone. Trend of Zn in MMFR in different mangrove zones was found as Landward > Central > Seaward. Tiram Laut River was found with the highest Zn content at landward followed by central and seaward. Trend of Zn content at TLR was recorded as Landward > Central > Seaward. Mean comparison of Zn content in mangrove zones show Zn content in seaward was significantly different than landward and central. Tinggi River was found with the highest Zn content at landward followed by central and seaward. Trend of Zn content at TR was recorded as Landward > Central > Seaward. Mean comparison of Zn content in all mangrove zones are not significantly different. Meanwhile, Sepetang River was obtained with the highest Zn content at landward with followed by central and seaward. Trend of Zn content at TLR was recorded as Landward > Central > Seaward. Mean comparison of Zn

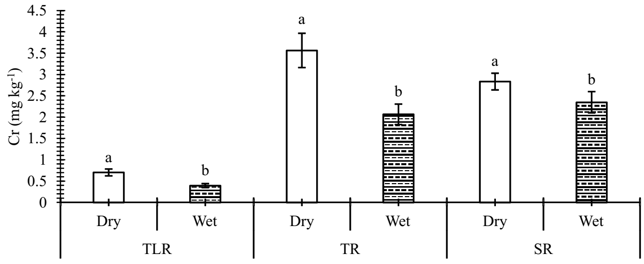

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Figure 6 Chromium content in different seasons at three locations.

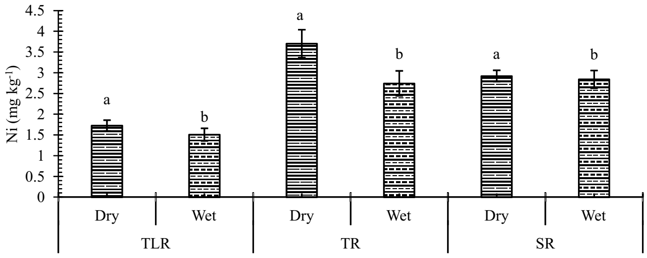

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Figure 7 Nickel content in different seasons at three locations.

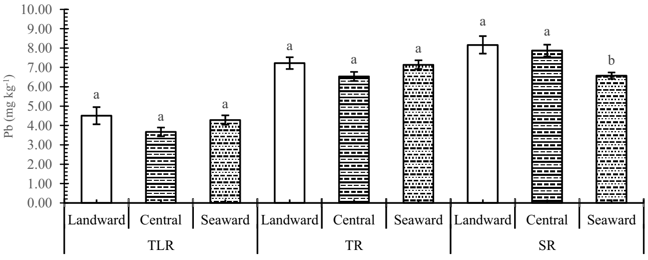

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Figure 8 Lead content in different mangrove zones at three locations.

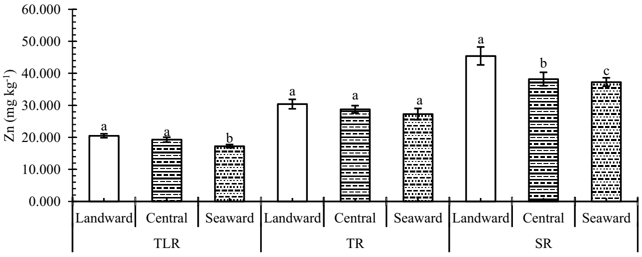

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Figure 9 Zinc content in different mangrove zones at three locations.

content was significantly different in all zones using the Tukey Test with p-value 0.05. Zn content occurrence in MMFR is due to wastewater disposal from agriculture and manufacture activities around the area (Khan et al., 2020). Thus, this metal is coming from landward zone and suspended into sediment layers (Whitfield & Becker, 2014).

Chromium content at different mangrove zones at three locations is illustrated in Figure 10. Tiram Laut River, Tinggi River and Sepetang River were found with highest Cr content at landward zone. There are two trends of Zn content in MMFR at different mangrove zones. First, TLR and TR were found as Landward > Central > Seaward and second SR was found as Landward > Seaward > Central. Tiram Laut River was obtained with the highest Cr content at landward followed by central and seaward. Trend of Cr content at TLR was recorded as Landward > Central >Seaward. Mean comparison of Cr content in mangrove zones found seaward zone is significantly different from landward and central. Tinggi River was found with the highest Cr content at landward followed by central and seaward. Trend of Cr content at TR was found as Landward > Central > Seaward. Mean comparison of Cr content in mangrove zones show seaward is significantly different from landward and central zones. Meanwhile, Sepetang River was found with the highest Cr content at landward followed by seaward and central. Trend of Cr content at SR was recorded as Landward > Seaward > Central. Mean comparison of Cr content in mangrove zones show that landward zone gave a significantly different result in all zones. The presence of Cr at landward zone might be due to runoff from landward areas that are influenced by human activities such as aquaculture, agriculture, irrigation and industries (Ibharim et al., 2015; Islam et al., 2015).

Nickel content at different mangrove zones at three locations of MMFR is illustrated in Figure 11. Tiram Laut River had the highest Ni content at the central zone. While Tinggi River and Sepetang River had the highest Ni content at the landward zone. Tiram Laut River had the highest Ni at central zone followed by landward and seaward. Trend of Ni content at TLR was recorded as Central > Landward > Seaward. Mean comparison of Ni content in mangrove zones show that central zone was significantly different from seaward zone. Tinggi River was obtained with the highest Ni content at landward followed by central and seaward. Trend of Ni content at TR was recorded as Landward > Central > Seaward. Mean comparison of Ni content in mangrove zones show that seaward zone was significantly different from all mangrove zones. Sepetang River had the highest Ni content at landward followed by central with and seaward. Trend of Ni content at SR was recorded as Landward > Central > Seaward. Mean comparison of Ni content in mangrove zones show that landward zone is significantly different from seaward zone. The presence of Ni at the landward zone might be due to runoff from landward areas, which are influenced by human activities such as aquaculture, agriculture, irrigation and industries (Islam et al., 2015).

Comparison of mangrove sediment quality index parameters between sediment depths at three locations of Matang Mangrove Forest Reserve Lead content at different sediment depths at three locations in MMFR is illustrated in Figure 12. Tiram Laut River was obtained with the highest Pb at depth 0–15 cm. Trend of Pb content in different sediment depths at TLR was recorded as 0–15 > 50–100 > 15–30 > 100–150 > 30–50 cm. Mean comparison showed Pb content at different sediment depths at TLR is not significantly different. The present of Pb content in Tiram Laut River might be due to boating activities, thus the gasoline or diesel from boating may influence the increase of Pb content in the sediment river. Tinggi River was obtained with the highest Pb at depth 30–50 cm. Trend of Pb content at different sediment depth at TR was recorded as 30–50 >100–150 > 0–15 > 15–30 > 50–100 cm. Mean comparison showed Pb content at different sediment depths at Tiram Laut River are not significantly different. Sepetang River was obtained with the highest Pb at depth 0–15 cm. Trend of Pb content at different sediment depths at SR was recorded as 0–15 > 15–30 > 100–150 > 30–50 > 50–100 cm. Mean comparison of Pb content in different sediment depths at SR show that sediment depth 0–15 cm and 15–30 cm are significantly different from sediment depth 30–50 cm. The presence of Pb content in sediment depth at Tiram Laut River, Tinggi River and Sepetang River are due to boating activities for tourism and timber transportation. Pb is widely used in gasoline or diesel for boat engine (Mosisch & Arthington, 1998; Mohamad Pazi et al., 2021). Thus, a leaking or spilled gasoline from engine boat can increase Pb content in the sediment river, especially in upper sediment depth (Whitfield & Becker, 2014).

Zinc content at different sediment depths at three locations is illustrated in Figure 13. Tiram Laut River was obtained with the highest Zn at depth 0–15 cm. Trend of Zn

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Figure 10 Chromium content in different mangrove zones at three locations.

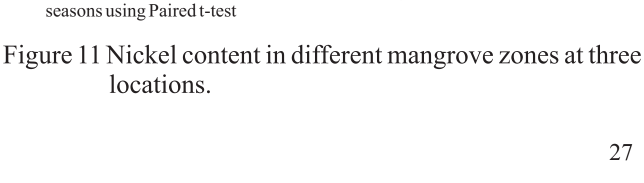

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Figure 11 Nickel content in different mangrove zones at three locations.

content at different sediment depth was recorded as 0–15 > 50–100 > 100–150 > 30–50 > 15–30 cm. Mean comparison of Zn content at different sediment depths at TLR show that sediment depth 0–15 cm is significantly different from sediment depths 15–30 and 30–50 cm. Tinggi River had the highest Zn at depth 100–150 cm. Trend of Zn content at different sediment depth at TR was recorded as 100–150 > 30–50 > 0–15 > 50–100 > 15–30 cm. Mean comparison showed Zn content at different sediment depths at TR were not significantly different. Sepetang River was obtained with the highest Zn at depth 0–15 cm. Trend of Zn content at different sediment depth at SR was found as 0–15 > 15–30 > 30–50 > 50–100 > 100–150 cm. Mean comparison of Zn content at different sediment depths showed that sediment depth 015 cm is significant among other sediment depths. The presence of Zn content at sediment depth at Tiram Laut River, Tinggi River and Sepetang River are due to boating activities for tourism and timber transportation. Zn is widely used in agriculture and aquaculture activities in fertiliser or pesticides (Mohamad Pazi et al., 2021). In a long time period, this metal will be stored in a deeper layer in a low amount. Nevertheless, the deeper sediment layer varies in Zn content due to the tidal and high-water flow from the shore (Gerbersdorf et al., 2005).

Chromium content at different sediment depths at three locations is illustrated in Figure 14. Tiram Laut River had the highest Cr content at depth 0–15 cm. Trend of Cr content in different sediment depths of TLR was recorded as 0–15 > 15–30 > 100–150 > 50–100 > 30–50 cm. Mean comparison of Pb content in different sediment depths showed that sediment depth 0–15 cm at TLR was significantly different from all sediment depth. Tinggi River had the highest Cr content at depth 0–15 cm. Trend of Cr content at different sediment depths of TR was recorded as 0–15 > 15–30 > 100–150 > 50–100 > 30–50 cm. Mean comparison of Cr content at different sediment depths showed that sediment depth 0–15 cm was significantly different from sediment depth 30–50, 50–100, and 100–150 cm. Sepetang River was obtained with the highest Cr content at sediment depth 0–15 cm. Trend of Cr content at different sediment depths of SR was recorded as 0–15 > 15–30 > 100–150 > 50–100 > 30–50 cm. Mean comparison of Cr content in sediment 015 cm was significantly different from sediment depth 30–50, 50–100, and 100–150 cm. The presence of Cr content in sediment depth at Tiram Laut River, Tinggi River and Sepetang River are due to boating activities for tourism and timber transportation. Chromium is widely used in agriculture and aquaculture activities in fertilizer or pesticides (Sany et al., 2012; Savci, 2012). Thus, this can lead to increase of Cr content in the sediment river, especially in upper sediment depth (Che, 1999).

Nickel content at different sediment depths at three locations has been illustrated in Figure 15. Tiram Laut River obtained the highest Ni at sediment depth 0–15 cm. Trend of Ni content at different sediment depths of TLR was recorded as 0–15 > 15–30 > 100–150 > 50–100 > 30–50 cm. Mean

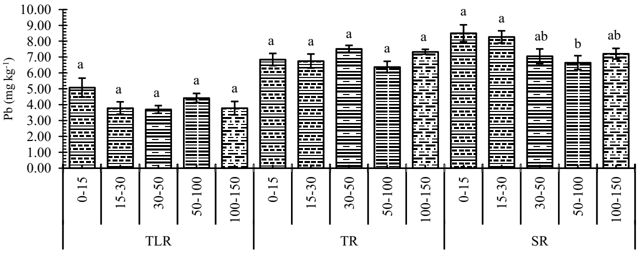

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Figure 12 Lead content in different sediment depths at three locations.

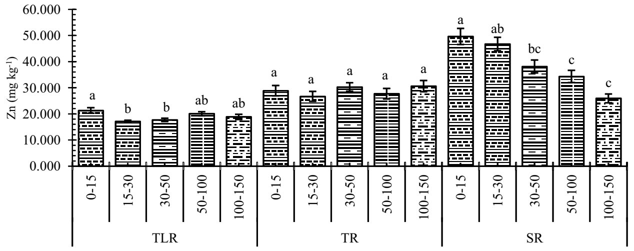

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Figure 13 Zinc content in different sediment depths at three locations.

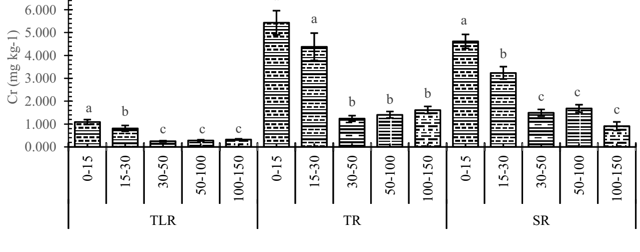

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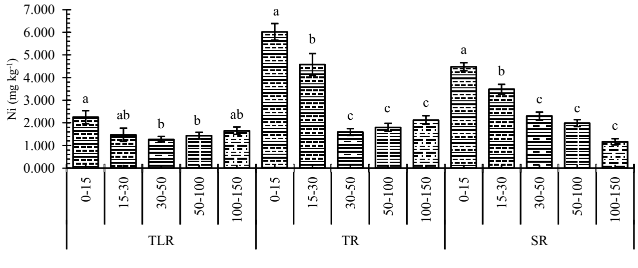
Figure 14 Chromium content in different sediment depths at three locations.



*Different alphabet within row showed a significant different between the seasons using Paired t-test

Figure 15 Nickel content in different sediment depths at three locations.

comparison of Ni content at different sediment depths 015 cm was significantly different from sediment depth 30–50 and 50–100 cm. Tinggi River attained the highest Ni content at sediment depth 0–15 cm. Trend of Ni content at different sediment depth of TR was recorded as 0–15 > 1530 > 100150 >50–100 > 30–50 cm. Mean comparison of Ni content at sediment depths 0–15 cm at Tiram Laut River is significantly different from other sediment depths. Sepetang River attained the highest Ni at depth 0–15 cm. Trend of Ni content at different sediment depths of SR was recorded as 0–15 > 15–30 > 30–50 > 50–100 > 100–150 cm. Mean comparison of Ni at sediment depth 015 cm of the SR was significantly different from other sediment depths. The presence of Ni content in sediment depth at Tiram Laut River, Tinggi River and Sepetang River are due to boating activities for tourism and timber transportation (Mohamad Pazi et al., 2021; Saifullah et al., 2002).

Conclusion

Mangrove sediment quality (MSQi) parameters in different seasons at three different locations showed that during dry season the least disturbed area is with highest concentration of heavy metals. While in moderately and highly disturbed areas, only Cr and Ni are highest during dry seasons. During wet season Pb and Zn content were highest at moderately and highly disturbed areas than least disturbed area. MSQi parameters in different mangrove zones at three locations showed that most HMs content is highest in the landward zone and it can be concluded that HMs sources are anthropogenic. Moreover, MSQi parameters at different sediment depths at three locations showed that heavy metals content is the highest at sediment depth 0-15 cm than at other sediment depths. MSQi study can be used as baseline to study sediment quality parameters in different seasons. With this study, contaminated areas can be identified which will be used as resource saving or as guideline to avoid the further contamination.

Acknowledgment

The authors would like to extend their special thanks to Universiti Putra Malaysia for funding this project. The contribution and assistance from the Perak Forestry Department and all staffs from the Faculty of Forestry and Environment, Universiti Putra Malaysia are much appreciated. Our research team really appreciate the contribution of (Late) Dr. Mohd Bakri Adam (20 August 2021). No one can replace you.

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