INFLUENCE OF ORGANIC DEPOSIT ON *Rhizophora* spp. GROWTH AND SEDIMENT CHEMICAL PROPERTIES IN TANJUNG PIAI MANGROVE FOREST, JOHOR

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FACULTY OF SCIENCE
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INFLUENCE OF ORGANIC DEPOSIT ON *Rhizophora* spp. GROWTH AND SEDIMENT CHEMICAL PROPERTIES IN TANJUNG PIAI MANGROVE FOREST, JOHOR

ABSTRACT

Mangrove ecosystems are critical for maintaining ecological processes and acting as natural barriers against erosive wave action, tsunami, and strong coastal winds. However, mangrove forests are currently in jeopardy as a result of urbanization, aquaculture expansion, and increased pollution loads. Marine debris containing organic deposits are intentionally or unintentionally dumped into the marine environment, which was reported to have the potential to alter the mangrove's natural environment. Therefore, this study was carried out to investigate the influence of organic deposit on growth of *Rhizophora* spp. and sediment chemical properties in Tanjung Piai mangrove forest, Johor. The first objective of this study is to characterize the chemical of organic deposits at three different locations. Samples of organic deposit were collected at Pulau Ketam in Perlis, Pantai Kelanang in Selangor and Tanjung Piai, Johor. The analysis of the organic deposit samples from these three different locations showed that organic deposit at Tanjung Piai contains the highest concentration of heavy metals, especially Cu, Pb and Zn with 21.50 mg kg^{-1}, 82.41 mg kg^{-1}, 133.12 mg kg^{-1} respectively. Concentrations of Cd, Cu and Pb at Tanjung Piai exceed the limits set for bio-compost of European countries and the United States. From this assessment, the influence of organic deposit on growth of *Rhizophora* spp. and sediment chemical properties in Tanjung Piai mangrove forest, Johor was carried out by measuring the growth performance, soil fertility and the fractionation of heavy metals between different localities having fresh, decomposed and without organic deposit material as the second and third objectives of this study. Four different sampling sites have been establish based on the presence of organic deposits at each plot; T1: site without organic deposit material, T2: site with new organic deposit material, T3: site with decomposed organic deposit material, T4: site with decomposed organic material. Generally, sites with decomposed organic deposit resulted in the highest growth increment of *Rhizophora* spp. compared with sites without organic deposit with total mean increment of 19 cm after one year of study. The highest nitrogen, organic carbon, CEC, Cu and Pb were also recorded at sites with decomposed organic deposit. pH at decomposed organic deposit (T3 and T4) was slightly acidic with the lowest pH recorded 4.78. Modified sequential extraction BCR method was adopted for the fractionation of heavy metals. Results showed Fe and Mn are highly mobile and available for the plant intake. The concentration of Fe and Mn in *Rhizophora* spp. leaves was high compared to the concentration of Cd, Pb and Zn.

The correlation between the *Rhizophora* spp. growth with physio-chemical properties shows positive correlation with N, C, CEC, Exch Mg, and Exch K. For the correlation between heavy metals with sediment fertility, Zn and Mn were only positively correlated with pH. While other heavy metals (Pb, Cd, Cu and Fe) were positively correlate with total nitrogen and organic carbon in the sediment. Overall, this study implies that upon decomposition and degradation of organic deposit, it increases some of the nutrients and also heavy metals in the sediment at Tanjung Piai mangrove forest.

Keywords: organic deposit, Tanjung Piai mangrove, soil fertility, fractionation

PENGARUH DEPOSIT ORGANIK TERHADAP *Rhizophora* spp. PERTUMBUHAN DAN SIFAT KIMIA SEDIMEN DI HUTAN BAKAU TANJUNG PIAI, JOHOR

ABSTRAK

Ekosistem bakau sangat penting untuk mengekalkan proses ekologi dan bertindak sebagai penghalang semula jadi terhadap erosif dari gelombang, tsunami, dan angin pesisir yang kuat. Namun, hutan bakau kini semakin terancam akibat daripada aktiviti pembangunan, pengembangan akuakultur, dan peningkatan pencemaran alam sekitar. Serpihan laut yang mengandungi deposit organik dibuang ke persekitaran laut dengan sengaja atau tidak sengaja, dimana ia telah dilaporkan berpotensi untuk mengubah persekitaran semula jadi bakau. Oleh itu, kajian ini dilakukan untuk mengkaji pengaruh deposit organik terhadap pertumbuhan *Rhizophora* spp. dan sifat kimia sediment di hutan bakau Tanjung Piai, Johor. Objektif pertama kajian ini adalah penentuan ciri kimia mendapan organik deposit di tiga lokasi yang berbeza. Sampel deposit organik diambil di Pulau Ketam di Perlis, Pantai Kelanang di Selangor, dan Tanjung Piai, Johor. Analisa sampel organik dari tiga tempat yang berbeza ini menunjukkan deposit organik di Tanjung Piai, Johor mengandungi kepekatan logam berat tertinggi, terutamanya Cu, Pb, dan Zn dengan masing-masing 21.50 mg kg^{-1}, 82.41 mg kg^{-1}, 133.12 mg kg^{-1}. Kepekatan Cd, Cu, dan Pb di Tanjung Piai melebihi had yang telah ditetapkan untuk kompos bio bagi negara-negara Eropah dan Amerika Syarikat. Dari penilaian ini, pengaruh deposit organik terhadap pertumbuhan *Rhizophora* spp. dan sifat kimia sedimen di hutan bakau Tanjung Piai, Johor dikaji dengan mengukur prestasi pertumbuhan *Rhizophor*a spp., tahap kesuburan sedimen dan pemecahan logam berat di antara kawasan kajian yang mengandungi deposit organik baru, deposit organik terurai dan tanpa deposit organik sebagai objektif kedua dan ketiga untuk kajian ini.

Empat kawasan kajian telah dikaji berdasarkan kehadiran deposit organik di setiap petak kajian; T1: plot tanpa deposit organik, T2: plot dengan deposit organik baru, T3: plot dengan deposit organik terurai, T4: plot dengan deposit organik terurai. Secara amnya, plot kajian dengan deposit organik terurai mencatat peningkatan pertumbuhan *Rhizophora* spp. tertinggi berbanding dengan kawasan kajian tanpa deposit organik dengan min keseluruhan 19 cm untuk tempoh kajian selama setahun. Kandungan nitrogen, karbon organik, CEC, Cu dan Pb juga adalah tinggi di kawasan kajian yang mempunyai deposit organik terurai. Bacaan pH di plot deposit organik terurai (T3 dan T4) sedikit berasid dengan pH terendah iaitu 4.78. Kaedah BCR pengekstrakan berurutan yang telah diubahsuai digunakan untuk pemecahan logam berat. Hasil kajian menunjukkan logam berat yang mudah alih dan tersedia untuk pengambilan tanaman adalah Fe dan Mn. Ia juga terbukti kerana kepekatan Fe dan Mn di dalam sampel daun *Rhizophora* spp. adalah tinggi berbanding dengan Cd, Pb dan Zn.

Hubungan antara pertumbuhan *Rhizophora* spp. dengan sifat fisio-kimia menunjukkan korelasi positif dengan N, C, CEC, Exch Mg, dan Exch K. Untuk hubungan antara logam berat dengan kesuburan sedimen, Zn dan Mn hanya berkorelasi positif dengan pH. Sementara logam berat yang lain (Pb, Cd, Cu dan Fe) berkorelasi positif dengan nitrogen dan karbon organic di dalam sedimen. Secara keseluruhannya, kajian ini mennjukkan bahawa degradasi dan penguraian deposit organik dapat meningkatkan beberapa nutrien dan juga logam berat di dalam sedimen di hutan bakau Tanjung Piai, Johor.

Kata kunci: deposit organik, hutan bakau Tanjung Piai, keseburan tanah, pecahan, logam berat

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LIST OF SYMBOLS AND ABBREVIATIONS

BCR	:	Community Bureau of Reference
Cd	:	Cadmium
CEC	:	Cation exchange capacity
CH_4	:	Methane
CO_2	:	Carbon dioxide
Cu	:	Copper
Exch Ca	:	Exchangeable Calcium
Exch Mg	:	Exchangeable Magnesium
Exch K	:	Exchangeable Potassium
FAS	:	Ferrous ammonium sulphate
Fe	:	Iron
H^+	:	Hydrogen ion
HCl	:	Hydrochloride acid
HNO_3	:	Nitric acid
H_2O_2	:	Hydrogen peroxide
H_2SO_4	:	Sulphuric acid
K	:	Potassium
$K_2Cr_2O_7$	:	Potassium dichromate
N	:	Nitrogen
NaOH	:	Sodium hydroxide
NH_4F	:	Ammonium fluoride
N_2O	:	Nitrogen dioxide

Mn	:	Manganese
P	:	Phosphorous
Pb	:	Lead
Zn	:	Zinc

CHAPTER 1: INTRODUCTION

1.1 Introduction

Mangrove ecosystems have the ecological importance and great economic as it maintains the crucial ecosystem functions with high economic and biomass values such as supporting estuarine fisheries, nutrient filtering and forming a protective barrier which lowering the changes of the low-lying coastal land being damage by storms (Lee et al., 2014). Mangrove forests are likewise high-yielding ecosystems, with primary production rates comparable to the tropical humid evergreen forests (Alongi, 2014). Mangrove trees are very unique as the mangrove trees survive in salty conditions whereby majority of other trees cannot and they also reduce the pollution by filtering suspended material, preserve water quality and assimilating dissolved nutrients as the trees have the natural ability to act as a sink of anthropogenic and industrial pollutants (Maiti & Chowdhury, 2013).

Mangrove forests not only play multiple biological task that are vital to the environments around it, yet it also serve as natural barriers against tragic events, such as tidal bores, erosive wave action, tsunami, and strong coastal winds (Onrizal, Ahmad, & Mansor, 2016). This very unique ecosystem is now under threat due to urban development, overexploitation of timber, aquaculture expansion and also increases of pollution load (Rahman & Asmawi, 2016) (Onrizal et al., 2016). Human activities and climate changes such as altered rainfalls and sea level rise becomes the major threats to the mangrove habitats (Ellison & Zouh, 2012). Mangroves forest host an important fraction of coastal biodiversity but they also be among the first to experience the impacts of global changes (Solan et al., 2006).

The anthropogenic activities such as shipping, urban wastewater discharges and dredging associated with heavy metals put the mangrove at risk from these environmental pollutants. Nevertheless, the indirect and direct anthropogenic pressures from the human activities along the coastlines more or less contributed to the toxicity of the mangrove sediments (Santos, Cunha-Lignon, Schaeffer-Novelli, & Cintrón-Molero, 2012). As the human population increases, the water discarded from the industrialization into the environment began to increase tremendously and this led to environmental pollution (Ojekunle et al., 2014).

Human activities generate considerable amounts of waste that often escape management schemes and end up in rivers, stormwater, wind, or sewage, or can be disposal of directly at beaches and sea (Consoli et al, 2020). Mangrove ecosystems had become among the most threatened in the past century, mangroves are generally able to recover quickly to natural perturbations than human-induced disturbances (Gorman, 2018). Mangrove wetland systems receive a number of pollutions and have become a massive pollution sink in recent decades as a result of anthropogenic activities (Wang & Gu, 2021). The interaction between environmental and human activities such as fisheries, aquaculture, tourism and dumping influences the wide distribution of marine debris. Marine litter represents not only a major threat for marine living organisms and habitat, but it also has negative impact on economic sectors as well as on human health (Hua et al., 2018).

Metal, wood, plastic, paper, rubber, and clothing are among the items that have been purposefully or unintentionally dumped into the sea (Galgani et al., 2015). It has the potential to increase the transport of organic and inorganic contaminants, which is known to be harmful to marine organisms and human health (Rochman et al., 2013). Natural debris such as driftwood and drift seeds are also present among the floating marine debris that washes ashore and tends to accumulate along the coastlines (Bergmann et al., 2017). The magnitude of the problem of marine debris, as well as its potential to harm biodiversity, has not been widely assessed (Holmes et al., 2014). In 2012, Tanjung Piai National park was faced with oil spills and marine debris containing organic deposit which had killed approximately 7,000 mangrove trees. The organic deposit turned into toxic materials as they absorbed the oil during the ship cleaning process. This organic deposit was not only acidic, but also contained high levels of heavy metals, which causes the decay of mangrove roots and eventually kills the tree (Kadir et al., 2015). The authors also found that this organic material lead to mortality of mature standing *Rhizophora* trees in Tanjung Piai, most likely due to high acidity and, to a lesser extent, low conductivity levels of organic deposit at rooting depth layers.

A good establishment of mangrove stands depends on the properties of the sediments and this has been reported by several authors (Nguyen et al., 2020, Salmo et al., 2019). Physical characteristics of mangrove like sediments texture, salinity and pH play a vital role in determining the health of the ecosystem (Banerjee et al., 2018). Sediments provide a good source of nutrient for growth and strong physical structure for anchorage and stability for mangrove (Gillis et al., 2019). As a medium of growth, sediments should have enough nutrients and good characteristics to ensure better tree performance and to strengthen the forest ecosystem for economic value, wildlife conservation, and most importantly, to balance environmental conditions (Gann et al., 2019). Changing land use patterns, climate change, and the growing population had a significant impact on nutrient release into the environment (Grimm et al., 2008).

The concentrations of nutrients in mangrove sediments and growth of mangrove can also be affected by anthropogenic activities such as sewage discharge or waste dumping (Wang & Gu, 2021). Consequently, nutrient availability could threaten ecological balance in mangrove ecosystems. Nevertheless, studies on the effects of organic deposits on sediments characteristics and growth of mangrove are still lacking. Therefore, the intention of this research is to study how organic deposits affect *Rhizophora* spp. growth and sediment chemical properties within the Tanjung Piai mangrove forest in Johor. The aims of this study are to determine the growth and the survival of *Rhizophora* spp. in Tanjung Piai mangrove forest and to investigate the physiochemical properties of mangrove sediments at in Tanjung Piai mangrove forest depending on the presents of organic deposits at the study sites.

1.2 Objectives of study

1. To characterize the chemical characteristic of organic deposits at three different locations.
2. To determine the growth, nutrient and heavy metals contents of *Rhizophora* spp. at mangrove forest in Tanjung Piai, Johor at different localities.
3. To investigate the physico-chemical properties, heavy metals contents and fractionation of heavy metals content of mangrove sediment at different localities.
4. To correlate the sediment physico-chemical properties between plant growth and heavy metals content.

CHAPTER 2: LITERATURE REVIEW

2.1 Mangrove in Asia

Asia has the world's largest mangrove forest, accounting for 42% of all mangroves (Giri et al., 2011). The largest mangrove areas in Asia are in Malaysia and Indonesia. With an estimated 34,000 miles of coastlines, Indonesia lays claims to the most extensive mangrove on earth and some of the trees are also among the world's tallest mangrove, reaching 144 feet (Cambell & Brown, 2015). The vast majority of mangrove forest in Indonesia are on the coasts of Papua, Sumatra and Kalimantan (Murdiyarso et al., 2015). Indonesia has lost 40% of its mangrove in the last three decades, making it the country with the fastest rate of mangrove degradation in the world (Campbell & Brown, 2015). Mangrove deforestation accounts for 6% of Indonesia's total annual forest loss, according to the Ministry of Forest Republic of Indonesia (2014). The destruction of coastal ecosystems, such as mangrove, sea grass, and marshes, due to the decline of mangrove forests in Indonesia, it contributes approximately 42 percent of global greenhouse gas emissions (UNEP, 2014).

China, Asia's largest country, has a natural distribution of mangroves covering 25,000 hectares. (Romanach et al., 2018). Mainland China's mangrove forest covers only 0.14 percent of the world's mangrove acreage, yet it is home to one-third of the world's mangrove species (Wang, 2007). As a result, mangrove protection in China is critical to the conservation of biodiversity in the world's mangrove forest. There are 49 Ramsar Convention sites in China such as Shankou Mangrove Nature Reserve, Dongzhaigang Mangrove Nature Reserve, Guangxi Beilun Estuary National Nature Reserve and Fujian Zhangjianhkou National Nature Reserve (Chen et al., 2009). China has gone through three stages of mangrove forest land conversion: (1) aquaculture in mangrove forests in the 1980s, (2) conversion to agricultural regions in the 1960s and 1970s, and (3) contemporary urbanization via docks, ports, and commercial districts (Wang, 2007). In the mangrove wetland ecology, human conduct has also produced major pollution, increased disease spread, and insect damage, including pollution from pesticides and animal waste (Ren et al., 2009).

2.2 Mangrove in Malaysia

Malaysia is one of the countries in Southeast Asia with the most extensive mangrove ecosystems. According to Hamdan et al., (2018), Malaysia contains approximately 630,000 ha of mangroves, with 61 percent in Sabah, 22 percent in Sarawak, and 17 percent in Peninsular Malaysia. Mangrove forest has been identified as one of the key life support systems on earth as it is also one of the major wetland types in Malaysia (Jusoff & Taha, 2008). The west Coast of Peninsular Malaysia has the most mangrove forest because it is more protected from strong winds and waves than the East Coast, which is generally characterized by sandy beaches and has comparatively little mangrove forest due to its exposure to the more turbulent South China Sea (hashim & Shahruzzaman, 2017).

The Matang Mangrove Forest, in the state of Perak, is Malaysia's largest mangrove forest. The Matang mangrove forest, which covers an area of around 40,000 hectares and has been recognized as a Permanent Forest Reserve since 1904, is Malaysia's oldest mangrove reserve (Ibharim et al., 2015). Matang Forest is a well-managed and sustainable forest system that delivers a consistent output of renewable ecosystem biodiversity and richness, despite not being a Ramsar site (Goessens et al., 2014). Currently, Malaysia has seven Ramsar sites: four in Peninsular Malaysia, two in Sabah, and one in Sarawak. Tanjung Piai, Sungai Pulai, and Pulau Kukup are three Ramsar sites in the state of Johor. Sarawak Kuching Wetlands National Park's Mangrove Forest Reserve, with roughly 6,600 hectares of mangrove forest, is located in Sarawak. Lower Kinabatangan Segama Wetlands, Malaysia's largest Ramsar site, is made up of three protected forest reserve: Kulamba Wildlife Reserve, Trusan Kinabatangan Forest Reserve, and Kuala Maruap and Kuala Segama Forest Reserve.

Mangrove loss in Malaysia was caused by the conversion of mangrove forests to oil palm farms, which accounted for around 38% of total mangrove loss (Richards and Friess, 2016). Between 1990 and 2010, roughly 1,282 hectares (or about one percent) of mangrove were lost per year in Peninsular Malaysia. (Hamdan et al., 2012). Matang Mangrove Forest, which is well-known for its environmentally friendly forest management, is vulnerable to pollution from industrial regions upstream (Otero et al., 2018). Mangrove forests at Tanjung Piai, Pulau Kukup, and Sungai Pulai, which are mostly spread along the coastal areas and rivers, are threatened by development and over-exploitation, which exacerbates sediment erosion (Hasmadi et al., 2011). The Marudu Bay Mangrove in Sabah is concerned about over-exploitation of precious marine resources and mangrove plants, as well as pollution from a nearby oil palm plantation (Zakaria & Rajpar, 2015). Sabah Biodiversity Centre listed logging, sediment erosion, loss of species, habitat loss, and oil palm plantation and mills as factors that could potentially compromise the integrity of the Lower Kinabatangan-Segama Wetlands as a Ramsar Site (Romañach et al., 2018). The Kuching Wetlands National Park is under risk of environmental degradation due to untreated solid and liquid wastes, land-clearing activities, and a nearby stone quarrying industry because it is located downstream of a high population density and development region (Choo et al., 2015).

About 90% from approximately 364,168 ha of Permanent Forest reserve in Sabah are still largely intact and most of these areas are under the stewardship of the Sabah Forestry Department (Lohuji & Tangah, 2019). Mangroves in Sabah are distributed abundantly in most of the coastal areas but it might not be secure for the long term as there is a growing pressure for increased timber production and land conversation of mangrove as inland natural forests are rapidly diminishing (Tangah et al., 2019). After Sabah, Sarawak has the second-largest mangrove coverage in Malaysia. When compared to other Malaysia states, Sarawak's mangrove forest is the least affected (Ashton & Macintosh, 2002). Mangrove forest in Sarawak mainly has been harvested for charcoal, woodchips and firewood (Chong, 2006). It is also the natural habitat for the proboscis monkey in which they feed on the mangroves leaves and various forms of marine life also thrive in the mangrove forest in Sarawak.

2.3 Benefits of mangrove

Mangroves are providers not only to the nature but also to people as communities depend on mangroves for protection, food and income. The importance of mangrove forest has often been unappreciated and leading to extensive mangrove loss and degradation (Gilbert & Janssen, 1998). Mangrove forest are productive ecosystems and not only have diverse variety of wildlife, but also give benefits to the community and coastal protection (Ashton et al., 1999). Mangrove forests are a productive ecosystem and has complex functions, such as biological functions (nursery ground, spawning ground as well as a source of genetic and germplasm), physical functions and socio-economic functions (Walters et al. 2008).

2.3.1 Biodiversity in mangrove ecosystem

Biodiversity refers to the diversity of living organisms found in all habitats, including terrestrial, marine, and other aquatic ecosystems, which encompasses diversity between species, within species, and across ecosystems. (Dencer et al., 2018). Due to the presence of both terrestrial and aquatic species and their adaptability to a wide range of harsh environmental conditions such as high temperatures, extreme tides, strong winds, anaerobic sediments, and high salinity that fluctuated frequently, the mangrove ecosystem is rich in genetic diversity (Kerry et al., 2017). In Malaysia, mangrove forests are among the most important types of forest. Malaysia mangrove forest has 104 mangrove species, of which 38 are exclusive mangrove species, 57 non-exclusive species and 9 associate species (Ahmad et al., 2018).

The diversity of other life forms can be much greater, with abundant mollusks, arthropods, birds and fish as mangroves provides nursery habitat for many commercial fish and shellfish which contributes to the local abundance of seafood (Mahmood et al., 2005). Coastal birds such as little blue herons, brown pelicans, and great egrets use mangrove as nesting sites (Cheadle, 2020). For part of their seasonal migrations, many birds rely on mangroves. Even dead mangroves play an important role as it provides roosting areas for bird species. Furthermore, mangrove roots are nature's strongest protection against soil erosion and typhoons, and they help to maintain a healthy fish population in the sea by providing a safe sanctuary for nursing fish (Newsome et al., 2012).

Aside from that, mangrove plant diversity varies consistently across continental or inter-island regions, showing the importance of distance from diversification centres, dispersal capabilities, ocean current directions, and the viability of propagules prior to roots (Kerry et al., 2017). Mangroves do not refer to a single taxonomic group of species, and they are not all related, but they are all adapted to surviving in moist, loose soil, saline habitat, and tidal submergence on a regular basis. All halophytic or salt resistant tropical tree and shrub species, comprising around 12 families and over 50 species, are included in one description (Giri et al., 2011). According to Middleton (2018), most mangroves grow on muddy soils, although they can also thrive in peat, corral rock and sand. The following are the main types of mangrove forest zones in Peninsular Malaysia, based on the dominating species that create practically pure stands from the beachfront to the hinterland: (i) *Avicennia-Sonneratia* type (on pioneer shore), (ii) *Bruguiera cylindrical* type, (iii) *Bruguiera parv*iflora type, (iv) *Rhizophora* type and (v) *Bruguiera gymnorhiza* type (on landward margin).

2.3.2 Natural coastal defense

Mangroves are the first line of defense for coastal communities. Many tropical and subtropical regions mangroves stabilize shorelines by reducing waves and storm surges, and serve as a first line of defense against erosion and flooding (Menéndez et al., 2020). Roots, canopy and trunk dissipates waves and storm surge, and the aerial roots of a mangrove forest retain sediments, reducing erosion and stabilizing the sediment on intertidal areas (Mcivor et al., 2012). Every coastlines waves and currents create change, sometimes resulting in land loss and erosion. Mangrove vegetation reduces wave energy and slows the flow of water over the soil surface, lowering the water's ability to dislodge particles while also allowing suspended sediments to settle out of the water, resulting in enhances sediment deposition (Das & Crepin, 2013).

When mangroves are gone, sediment transport patterns can shift dramatically. Sediments and mud that were formerly stable or even slowly growing up may begin to disintegrate, and land eventually dissolved into the sea. This can be seen in coastal areas where mangroves have been converted to aquaculture or agriculture, such as the beaches of the Gulf of Thailnd, northern Java, and Guyana, where the coasts are retreating at rates of several meters per year (Moris et al., 2018). Mangroves may help to lessen the loss of life and property damage caused by storms, cyclones, and even tsunamis by minimizing the effects of waves, storm surges, and high winds (Friess, 2017). The canopy of mangroves serves to absorb wave energy when massive storm surges impact the leaves and branches. The intricate root and branch network of mangroves can trap even large moving objects, minimizing rubbish migration (Morris et al., 2019).

2.3.3 Benefits to the local community

apart from providing ecosystem services such as refuge and sanctuary for flora and wildlife, as well as a barrier to considerably lessen the height and power of tsunami waves, the mangrove forest is also a valuable natural resource that provides products and services to the community (Jusoff, 2008). Furthermore, the mangrove forest is a key source of fishing resources, and the communities that love within the mangrove forests rely on them for their livelihood. Local populations have relied on mangrove forests for edible plants and medicinal herbs for a variety of medical purposes, such as the bark of *Rhizophora*, which is used to treat diarrhea, stop bleeding, and repair fractures (Abdullah et al., 2014). Mangroves provide various production functions to the community, such as food, wood, fuel, and non-timber forest products, in addition to protecting the shorelines from erosion. As a result of these various functions, people are concentrating on the coastal area, with nearly half (44%) of the world's total population living within 150 kilometers of the coastline (Sarmin et al., 2018).

Mangroves forests produce a wide range of items that can assist local people earn more money. Shrimps, fish, crabs, and other species have a lot of habitat in mangrove forests because they supply a lot of food and are good for species breeding. Mojiol et al (2016), has done a survey on the contribution of mangrove forest to the monthly income to residence live near mangrove forest in Kudat, Sabah. According to Table 2.3, it is the list of mangrove forest product that villagers will sold or for their own used and the average monthly income collected were RM 485.

Table 2.1: List and types of mangrove forest products collected by the villagers (Mojiol et al., 2016)

No.	Local name	Scientific name	Uses
1	Black crab	*Scylla sarrata*	Sale and own use
2	Cat fish	*Plotosus* sp.	Sale and own use
3	Seashell	*Polymedusa expansa*	Sale and own use
4	Snail	*Cerithidea obtuse*	Sale and own use
5	Mullet fish	*Valamugil seheli*	Sale and own use

2.3.4 Carbon storage

Mangrove forests are thought to be the most productive ecosystems in terms of biomass, particularly below ground (Kainuma et al., 2013). A study that has been done by Donato et al. (2013) showed that mangroves are among the most carbon-dense forests in tropics, with an average of 1,023 MgC/ha, indicating that they play an important role in carbon storage. In the Indo-Pacific, mangroves store there to four times more carbon than temperate, tropical upland, and boreal forests (Siikamaki et al., 2012).

2.4 Mangroves threats in Malaysia

Mangroves forest provide a very important ecosystem to both human life and the diversity of life that inhabits it, unfortunately not many are aware of the importance of mangrove ecosystem thus leading to the threat of its extinction (Spalding et al., 2010). Mangroves in Malaysia today are becoming increasingly threatened by various unhealthy human activities, such as agriculture, coastal resort development, widespread logging, pollution and reclamation of land for aquaculture (Abd Rahman & Asmawi, 2016). Shrimp farming and aquaculture, recreational and tourism applications, water disposal, and development sites for urban and industrial uses are all significantly reliant on coastal and marine ecosystems (Adeel & Pomeroy, 2002). As the world's population grows, the potential impact of coastal and marine ecosystem degradation on communities, food security, human health, local economy, and biodiversity protection will multiply (Lee et al., 2019). Some of these human-related activities may exacerbate disease and pest consequences (Kathiresan, 2002). Mangrove forests are one of the most threatened environments on the planet, decreasing at an alarming rate and with little public awareness.

2.4.1 Urban development and population growth

Structures like as hotels, marinas, desalination plants, coal-fired power plants, and cruise ship docks have been built along the coast, bringing with them challenges such as changed hydrology, pollution and erosion. As the river passes through the mangroves and is obstructed or rerouted, temperature, salinity, sedimentation, and filtration change, affecting aquatic species such as commercial and sustenance fish species for coastal people (FAO, 2007). The coasts of removing the functioning and protective mangrove systems should be carefully balanced against the advantages of any coastal development project (Spalding et al., 1997).

With an increase of urban development and population growth, organic deposit from the trash or waste might increase (Thiel et al., 2018). People frequently leave rubbish and debris into the water from boats or offshore facilities such as oil rigs (Abd Rahman & Asmawi, 2016). Anything that gets into the ocean, from glass bottles to aluminium cans to medical waste, and the majority of it is plastic (Dias, 2016). Plastics do not biodegrade quickly as it were designed to decompose in a landfill or compost pile when heated (Thiel et al., 2018). Plastic will emit compounds as it gets smaller and smaller, and one of those molecules could be bisphenol A (BPA) (Baulch & Perry, 2014). Bisphenol A can interfere with animals' reproductive systems and exposed fish produce fewer healthy offspring (Cho, 2005). The activities in coastal areas has the potential to disturb and human activities have changed the quality of the marine due to the presence of marine debris (Hetherington et al., 2005). However, the role of mangrove forests as marine litter traps is mainly unexplored.

According to Sheavly & Register (2007), the most common types and sources of marine debris, such as food wrappers, cigarettes, and beverage containers, have been discovered all over the world. Land-based sources account for up to 80% of global marine pollution, according to th Union Nations Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP). Additional resources of debris include boats and ships in the water, as well as fishing piers and offshore drilling rigs and platforms (Laist & Liffmann, 2000). Litter and debris from our streets enter rivers and streams via sewers and storm drains, and is carried from beach parking lots and dumped on beaches by beachgoers (Sheavly & Register, 2007). Trash and litter can travel great distance before being deposited on shorelines or laying on the bottom of the ocean, bay, or riverbed, making it difficult to determine the source of the debris (Martins & Sobral, 2011).

2.4.2 Mangrove forest deforestation

Over the years, illegal logging in mangrove coasts have contributed to the thinning of the mangrove belts and erosion has often progressed up to the coastal bunds or levees (Tan et al., 2007). Mangrove forest destruction includes the direct use of mangrove timbers and leaf products, exploitation of the wetland environment, and conversion for coastal constructions. Mangroves have been deforested for lumber and fuel, with very little success in replanting, while new hydrology-based methods may be more hopeful (Lewis & Gilmore, 2007). Deforestation caused by logging, wood harvesting, and over-extraction of forest products not only reduces mangrove acreage but also changes forest structure and composition, affecting the mangrove forest's many ecosystem services (Rasquinha & Mishra, 2020). Mangroves will be functionally extinct in less than a century if current practices are not corrected, as these fragile and distinctive ecosystems are being lost at such a rapid rate (Duke et al., 2007). Without mangroves, the plant would be devoid of storm-protecting bioshields, most fisheries, and many birds and other animals (Valiela & Bowen, 2001).

Changes in mangrove forest composition and structure have been shown to produce sediment layer disturbances, which release a significant quantity of greenhouse gases such as CO_2, CH_4, and N_2O (Lovelock et al, 2011). Mangrove forest carbon out welling processes may be impacted by deforestation (Mackenzie et al., 2016). Deforestation also exposes top sediment layers to harsh weathering processes, resulting in increased decomposition and reduced carbon sequestration due to the loss of aboveground biomass (Lovelock et al, 2011; Aheto et al., 2016). Deforestation has a number of ecological consequences, including gap formation, changes in canopy microclimate, sediment erosion, changes in hydrologic and biogeochemical cycles, and the loss of associated flora and fauna (Bruijnzeel, 2004).

From the deforestation, woody debris may be the disturbances to mangrove forest, but despite the fact that it could be a vital component of mangrove ecosystems (Krauss et al., 2003). Slow decomposition of woody debris has led to conjecture that coarse woody debris can help a forest ecosystem's long-term persistence and supply of nutrients (Harmon & Hua 1991). In tropical mangrove forests, woody debris can last for years, serving as a possible source of fuel, promoting sediment pedogenesis, providing nursery beds for germinating seeds, and providing habitat for heterotropic groups (Allen et al., 2000).

2.4.3 Agriculture and aquaculture

The growth of the agricultural sector in the 1960s resulted in a surge in demand for land in the coastal plains to plant cash crops, with one of the most viable alternatives being the conversion of mangrove forest area to arable land for agriculture (Chong, 2006). Then, an extensive tract of coastal mangroves was cleared for planting coconut, rice, oil palm and cocoa during the last four decades (Sasekumar, 2002). Apart from agriculture, mangrove forests are ideal locations for shrimp farming and other types of mariculture due to their proximity to the sea. Mangrove environments are nutrient-rich and are part of broader wetland systems, which makes mangroves are attractive as agriculture regions (Ellison, 2008). Hundreds of thousands of hectares of mangrove forests have been removed, and the hydrology has been changed in order to increase commercial shrimp and other species production and develop agriculture crops, causing these delicate tidal regimes to be disrupted and the balance between salt and fresh water to be lost (FAO, 2007). Other than that, the aquaculture usually used specific diets that often contains chemical to feed the shrimps and other species in the artificial ponds can cause eutrophication. Toxins can disrupt adjacent marine environments by reducing oxygen levels and changing species distributions because they penetrate the food chain and harm nearby species (Ashton, 2008).

Most of the coastal areas were contaminated by man-made goods including polystyrene blocks, polyethylene bags, food wrapper, footwear, rope and fishing net might be cause from the aquaculture and agricultural near to mangrove areas (Posadas et al., 2021). Dumping sites, inadequate waste management, beach littering behavior, and marine activities such as shipping, fishing and aquaculture can all contribute to the release of this debris (Vegter et al., 2014). Mangrove trees grow on the intertidal fringe and have a partially emerging root system, providing an excellent filter that reduces wave energy and turbulence, as well as pneumatophores and prop roots, and may trap things carried by current (Norris et al., 2017).

2.5 Source of organic deposit accumulation on mangrove

Organic deposit has been discharged into the coastal or marine environment as marine litter which is human-created waste. This included any manufactured, anthropogenic or processed solid material disposed, discharged or abandoned in the environment on the shore, into the sea or brought indirectly to the sea by winds, rivers, waves, or sewage. The sources of organic deposit are originated from various sources, and it enters the ocean in multitude ways such as illegal dumping of domestic and industrial waste, manufacturing sites, dump sites that are poorly managed or under-resourced, as well as shore-based solid waste disposal and processing facilities. Table 2.2 summarizes some of organic deposit that have been previously reported.

Table 2.2: Source of organic deposit in Malaysia

Location	Activity	Source	Finding	Reference
Pasir Pandak, Santubong, Sarawak	Urbanization, Fishing	Plastic, Wood	Types of deposit collected at this public beach are plastic bottle, food wrappers, cardboard cartons, woods, cigarette lighters, and colour plastic bottle. Total of deposit collected at Pasit Pandak is 1,120 item/km.	(Mobilik at al., 2014)
Teluk Kemang, Negeri Sembilan	Recreational, Fishing	Plastics, Paper	Percentage of deposit found on the beach are, 64% (plastics), 18% (paper), 16% (polystyrene) and 2% (others). The 2% of deposit that represent others categories are food waste, wood and aluminum.	(Khairunnisa et al., 2012)
Pulau Payar, Kedah	Marine parks	Organic waste, Food waste, Plastic bag, Garden waste	An average of 150 items/m^2 were collected from beaches in Pulau Payar.	(Fauziah et al., 2019)
Pasir Panjang, Negeri Sembilan	Aquaculture	Fishing net, Rubber, Plastic, Textile	Two units of deposit were found for every 2 m^2 Abundance of huge and heavy abandoned net from fishing activities left on the beach. Other deposit found are rubber, plastic, glass and textile.	(Khairunnisa et al., 2012)

Table 2.2, continued

Kuala Perlis, Perlis	Commercialization, Agriculture, Fishing	Plastics, Fabric, Wood, Rubber	The highest amount of plastic deposit collected with weight of 53.15 kg/m^2. All deposits were collected at three points along the shoreline stretching 30 m in lengths and 5m in width.	(Odli et al., 2020)
Port Dickson, Negeri Sembilan	Recreational, Shipping, Coastal Zone construction	Plastic, Cigarette butts, Foamed fragments, Food Wrappers	Total mass of deposit collected over eight weeks of study at four beaches at Port Dickson is 169.8 kg.	(Yi & Kannan, 2016)
Tanjung Piai, Johor	Shipping	Sawdust, Oil	This sawdust believed to originated from material used to clean ships. 7,000 mangrove seedlings were killed as this fresh form of deposit were acidic. It has ability to absorb oil and heavy metals which made it toxic to plant. However, upon degradation and decomposition, it turns into neutral state.	(Wan Rasidah et al., 2015; Mazlina, 2012; Syed, 2012)
Batu Pahat, Johor	Recreational, Fishing, Tourism	Plastics, Glass, Wood, Rubber, Paper	Total of 2,634 of deposit collected along two beaches at Batu Pahat within two months of investigation. Percentage of deposit collected are 80% (plastics), 13% (paper), wood (2%) and others (3%)	(Kadir et al., 2015)

2.6 Physical and chemical properties of mangrove sediment

2.6.1 Physical properties of mangrove sediment

Marine alluvium is carried as sediments and deposited by rivers and the sea in mangrove sediments. Sand, silt, and clay in various proportions make up sediments, while a mixture of silt and clay, both abundant in organic matter, is referred as mud. Sandy or clayey forms of topsoil are loosely produced. Mangrove forests are often confined and protected settings with low-energy waterways, which favour clay particle deposition; nonetheless, sediments with greater sand particles have also been found (Ferreira et al., 2010). Sand, silt and clay percentages were used to classify sediments, and clay loam was defined as sediments with fewer than 35 percent, 40 percent, and 45 percent of sand, silt, and clay particles, respectively. Sandy clay loam sediment texture has 53 percent sand particles, while silt loam sediment texture has 45 percent sand particles (Hossain et al., 2012). It is crucial to figure out the physical properties of the sediment texture to get a better understanding of its potential to retain sediment nutrients (Sofawi et al., 2017). Silt and clay have a higher ability to trap nutrients compare to sand (Nguyen et al., 2013).

2.6.2 pH of mangrove sediment

Mangrove sediments have been found to be either acidic or alkaline in various investigations of tropical mangrove ecosystems. Sediment pH ranged from 2.87 to 6.40 in some investigations, whereas pH levels beyond 7.0 ranged from 7.4 to 8.22 in orders (Rambok et al., 2010; Das et al., 2012). The availability of metals in the sediment is influenced by pH. There is a larger release of hydrogen ions (H^+) in acidic sediment, and metal cations competing with these H^+ might produce desorption in the sediment solution and probable absorption by plant roots (Garcia et al., 2002).

Due to its influence on many other sediment properties and processes affecting plant growth, pH can be considered a crucial variable. Some of the most essential activities that are affected by pH are microorganism activity, nutrient solubility, and availability. Most micronutrients, for example, are more accessible to plants in acid sediments than in neutral-alkaline sediments, encouraging plant development in general (Loncaric et al., 2008). While the availability of most macronutrients is increased in alkaline sediments, the availability of phosphorous and micronutrients is often reduced, and their lower levels might negatively affect plant growth (Gentili et al., 2018). pH has an impact on a variety of plant traits like biomass, height, flower size, and pollen production (Jiang et al., 2017).

2.6.3 Nitrogen in mangrove sediment

Nitrogen (N), phosphorous (P), and potassium (K) are the three most important nutrients for plant growth. Plants rely on significant mounts for their growth and survival, these main nutrients are frequently the first lacking from sediment. One of the most significant limiting elements impacting the development of mangrove vegetation is nitrogen (Rosca et al., 2009). Mangrove productivity relies on sediment ammonification, nitrification, and dissimilatory reduction to ammonium for accessible nitrogen (Alongi, 2018). The amount of nitrogen deposited in sediment is linked to climate via biotic processes such as vegetation productivity and decomposition of organic matter (Ray et al., 2014). Nitrogen fixation, dry deposition input, rainfall input and inorganic nitrogen losses due to leaching are all factors that influence nitrogen storage fluctuation (Reef et al., 2016).

Biological N fixation, in which atmospheric nitrogen (N_2) is converted to ammonia (NH_3^+) by microorganisms that possess the nitrogennase enzyme complex, is one of the main mechanisms of N entering mangrove habitats (Alongi 2009). Other than that, plant can obtain nitrogen by N mineralization, a microbial-mediated process in which organic nitrogen is transformed to inorganic forms, which includes the processes of ammonium synthesis (ammonification) and NH_4^+ oxidation (nitrification) to produce NO_2 and NO_3 (Silver et al., 2000).

Many intertidal mangrove ecosystems have benthic microbial mats, which can contribute significantly to the mangrove's nitrogen cycle, especially when the mat is dominated by nitrogen-fixing cyanobacteria (Lee & Joye, 2006). Foliar uptake of nitrogen in the form of ammonia from the atmosphere or precipitation has been suggested as a potentially essential source of nitrogen for mangroves, especially in situations that favour ammonia volatilization, such as flooded sediments rich in organic matter, warm and acidic conditions (Fogel et al., 2008).

2.6.4 Sediment organic carbon

Organic matter and organic carbon contents of the mangrove sediments are widely varied in different mangrove forest of the world (Hossain et al., 2012). However, if the value of organic carbon were less than one per cent, it indicates the poor nutritional conditions of the sediments of the mangrove forests (Rambok et al., 2010). Organic carbon in marine sediments is an important part of global carbon cycle, and its degradation has an impact on a variety of processes, including inorganic carbon recycling and nutrient recycling (LaRowe et al.,2020). Organic carbon in sediments is also is large component of organic matter in sediments, and it is important because it serves as the foundation of sediment fertility, providing nutrients for plant growth, promoting the structure, and acting as a buffer against hazardous compounds (Alongi, 2014). The majority of mangrove carbon is retained in sediment and a large pool of belowground dead roots, which serve in the conservation and recycling of nutrients beneath the forest. (Alongi et al., 2003).

Mangroves are highly productive, fixing and storing significant amounts of carbon (Duarte & Cebrian, 1996). Due to low decay rates caused by waterlogging, mangrove forests can store more carbon in their substrate than any other ecosystem on the plant (Kristensen et al., 2008). Mangrove forest have large amounts of carbon vested belowground compared with terrestrial forest because of dead roots serve as a nutrient conserving mechanism (Page et al., 2011). Even though mangrove ecosystems are rich in carbon, they are in a paradox and often nutrient poor (Reef et al., 2010). Litters from trees such as leaves, twigs, propagules and subsurface root growth provide significant input of organic carbon to mangrove sediments (Cannicci et al., 2008).

Mangroves can store up to four times more magnesium per hectare than other systems like saltmarshes and seagrass meadows, even mangroves cover fewer than 1% of the world's coastal areas (Alongi, 2014). The majority of the carbon sequestered in mangrove sediments comes from autochthonous organic matter, which accounts for roughly one-third of the net output of mangrove plants (Sanders et al., 2016). Within mangrove forests that receive substantial loads of nutrients, such as from aquaculture ponds and home effluents, carbon buildup can approach 1,000 g $m^{-2}yr^{-1}$ (Bournazel et al., 2015). Mangroves are important ecosystems for extracting carbon from the water column and the atmosphere and storing it in their sediments because of this significant accumulation capacity (Breithaupt et al., 2012).

2.6.5 Available phosphorous in sediment

Phosphorus is an important macronutrient for growth and development (Koralage et al., 2015). After nitrogen, phosphorous is the second most limiting nutrient, and it can impede plant growth and development as well as crop output. Phosphorous in excess in sediment can be harmful to the ecology because it can enter freshwater bodies via surface runoff and trigger an algal bloom, reducing water quality. The phosphorous cycle is unique from the nitrogen cycle because phosphorus does not exist in a gaseous state (Li et al.,2020).

Phosphorous in sediment found in two forms, namely inorganic and organic. The total sediment phosphorous were the total of these two forms. Despite the fact that overall soil phosphorous levels are normally high, ranging from 224 to 6,725 kg per ha, 80% of this phosphorous is immobile and unavailable to plant (Ye et al., 2018). About 30 to 65 percent of total soil phosphorous is in organic forms that are unavailable to plants, with the remaining 35 to 70 percent in inorganic forms (Ye et al., 2018). Microorganisms in sediment play an important role in digesting and converting organic forms of phosphorus into plant-available forms (Hassan et al., 2013). Inorganic phosphorous forms include plant accessible phosphorus, sorption phosphorous, and mineral phosphorous, while organic phosphorous forms include dead animal or plant remains and sediment microorganisms (Cabugao et al., 2017)

Mineralization, dissolutions, weathering, and desorption influence phosphorus availability in the sediment for plant uptake, whereas immobilization, precipitation, runoff, adsorption, and erosion reduce phosphorous availability (Hou et al., 2018). Organic matter, clay concentration, sediment pH, sediment mineralogy, and other parameters such as moisture, temperature, and sediment aeration, which all alter the rate of phosphorous mineralization from organic matter decomposition, all influenced phosphorous availability in sediment (Penn & Camberato, 2019).

Organic matter mineralization releases plant-available forms of phosphorous into sediments, where the organic molecules compete with phosphate adsorbed on sediment surfaces, reducing phosphorous retention (Maguire et al., 2001). Clay particles have a large surface area per unit volume, they can quickly absorb phosphorous, sediment with a higher clay concentration has a higher phosphorous retention capacity (Richardson & Simpson., 2011). Between 6 and 7 is the ideal sediment pH for maximum phosphorus availability (Helfenstein et al., 2020). Aluminum and iron in acidic sediments make very strong connections with phosphate, whereas calcium is the major cation at high pH, and phosphate tends to precipitate with calcium (Rana et al., 2020).

2.6.6 Cation exchange capacity (CEC)

Jones (1982) defined cations exchange capacity (CEC) as the capacity of a sediments to store cations or the total number of exchangeable cations that a sediment can absorb (Brady et al., 2008). Cations are positively charged such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), sodium (Na^{+}), zinc (Zn^{2+}) and aluminum (Al^{3+}). The negatively charged clay and organic matter particles in the sediment hold these cations in place through electrostatic forces, in which the negative sediment particles attract the positive cations. The cations on the CEC of sediment particles are easily exchangeable with other cations and as a result, they are accessible to plants. As a result, a sediment's CEC represents the entire quantity of exchangeable cations it can absorb. The cation exchange capacity (CEC) of sediments varies between mangrove forests around the world, indicating the existence of a large amount of organic materials and implying that the sediments could serve as a large cation sink (Moreno & Calderon, 2011).

Calcium, magnesium and potassium are the most abundant cations needed by plants. CEC is important because it provides a reservoir of nutrients to replace nutrients lost from sediment water by plant uptake. Cations in the sediments water that are leached below root zones by excess irrigation or rainfall water are replaced by cations formerly bound to the CEC. Clay sediments, in particular, have a high CEC and can hold water, whereas sandy sediments have a low CEC have a low ability to hold water. Other than clay, pH of the sediment is significant for CEC because as the pH increase (become less acidic), the amount of negative charges on the colloids increase, resulting an increase in CEC.

2.6.7 Exchangeable calcium (Ca), Magnesium (Mg) and Potassium (K)

Calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), sodium (Na^{+}) and aluminium (Al^{3+}) are the five most abundant exchangeable cations in sediment. Collotds, which are negatively charged clay and humus particles, hold cations. Colloids may hold large amounts of cations and act as a nutrition storage facility for plant roots. Other cations in the sediment water will replace them on the colloid, as plant roots take up cations. In terms of cation exchange capacity (CEC), the stronger the negative charge of the colloid, the more it can store and exchange cations.

2.6.8 Heavy metals in mangrove sediments

Sediments play an important role in the metal contamination assessment and monitoring are widely used as environmental indicators, and the ability to track contamination sources and monitor contamination in sediments is generally acknowledged

(Islam, 2010). Essential heavy metals sich as Znand Cu play a key part in biochemical and physiological processes of both plants and sediments, but at excessive quantities, they could be hazardous to mangrove environments (Laurna et al., 2019). Sediments are a mixture of several mineral species that serve as an essential sink for a variety of pollutants in aquatic systems, including heavy metals, and can help with heavy metals contamination assessment (Yunus et al., 2020). Mangrove sediments often acts as sinks for heavy metals because of their enormous potential to hold heavy metals from fresh water, tidal water, and storm water run-off (Tam & Wong, 2000). Several mangrove ecosystems near urban areas have been contaminated by urban and industrial run-off, which contains significant levels of heavy metals in the form of dissolved particulates or particles (Defew et al., 2005). Furthermore, heavy metals adsorption and resorption in sediments is influenced by sediment parameters such as pH, CEC, organic matter, clay content, salinity, and the presence of other metals (Tam & Wong, 1996). Table 2.4 shows the distribution of heavy metals in Peninsular Malaysia.

Table 2.3: Distribution of heavy metal (mg kg^{-1}) (Cd, Cu, Pb and Zn) in Peninsular Malaysia Coastal

Heavy metal location	Cd	Cu	Pb	Zn	Hg	As	Cr	Ni	Reference
Malaysia Coast	4.35	18.42	8.67	196.07	-	-	-	4.99	Hossen et al., 2015
Peninsular Malaysia	0.16	9.59	12.21	49.82	-	6.13	41.48	23.86	Zulkifli et al, 2010
Mangrove Peninsular	1.56	17.15	98.97	100.96	2.90	41.43	40.92	-	Cheng & Yap, 2015
Strait of Johor	0.30	57.84	52.52	210.45	-	27.30	55.50	18.31	Zulkifli et al., 2010
South West Malaysia	-	25.60	0.07	-	4.64	18.00	-	-	Kamaruzzaman et al., 2011
South China Coastal	-	24.21	32.70	-	-	-	-	-	Kamaruzzaman & Ong, 2009
Northern Peninsular	1.64	-	-	258.50	-	-	-	40.00	Yap & Pang, 2011

Table 2.3, continued

Bayan Lepas, Penang	1.70	56.03	35.45	-	-	-	37.96	51.50	Khodami et al., 2016
Port Klang	0.810	118.34	128.98	492.39	-	475.26	388.84	74.56	Tavakoly Sany et al., 2013
East Coast Peninsular	0.25	9.30	37.40	44.30	0.10	14.90	46.40	20.10	Rezaee Ebrahim et al., 2011
Tanjung Piai, Johor	1.31	5.02	8.18	15.90	-	5.21	-	-	Wan Rasidah et al., 2015

2.6.9 Fractionation of heavy metals

Metals in sediment pose a problem because they can be transported by water or plants, which regulate their reactivity and thus their mobility and bioavailability (Liang et al., 2014). Although the total quantity of heavy metals can be used as a worldwide indicator of heavy metal contamination, it lacks information on heavy metal toxicity and bioavailability (Li et al., 2007). Research into different heavy metal fractions can help in understanding the bioavailability, mobility, and sources of heavy metals in sediments (Zhang et al., 2005). Metal pollution in sediments can cause substantial environmental issues and can severely harm aquatic ecosystems (Charkhabi et al., 2005). Some heavy metals that have been sediment-bound may be remobilized and released back into the water when environmental factors such as cations exchange capacity, pH, nutritional status, and redox potential change, posing a risk to living species (Chai et al., 2014).

Metals can be bound to various compartments adsorbed onto clay surfaces such as manganese and iron oxyhydroxides, complexed with organic materials, or in the form of a lattice of primary minerals such as silicates in aquatic sediments (Tessier et al., 1979). Heavy metals in sediments are ususally fractionated using a sequential extraction process (Li et al., 2007). The European Community Bureau of Reference (BCR) devised a three-step sequential extraction process, which is high interlaboratory reproducibility and ideal for analysis of polluted sediment samples (Pueyo et al., 2003). A sequential extraction process gives precise information on the origin, speciation, mobility, and bioavailability of metals in various environments (Block, 1994).

CHAPTER 3: METHODOLOGY

3.1 Characteristic of organic deposits

3.1.1 Sampling site

The samples of organic deposits were collected at three different mangrove forests which located in Pulau Ketam, Perlis, Pantai Kelanang, Selangor and Tanjung Piai, Johor. The chemical composition such as pH value, organic carbon, nitrogen and the heavy metals content were tested in the laboratory.

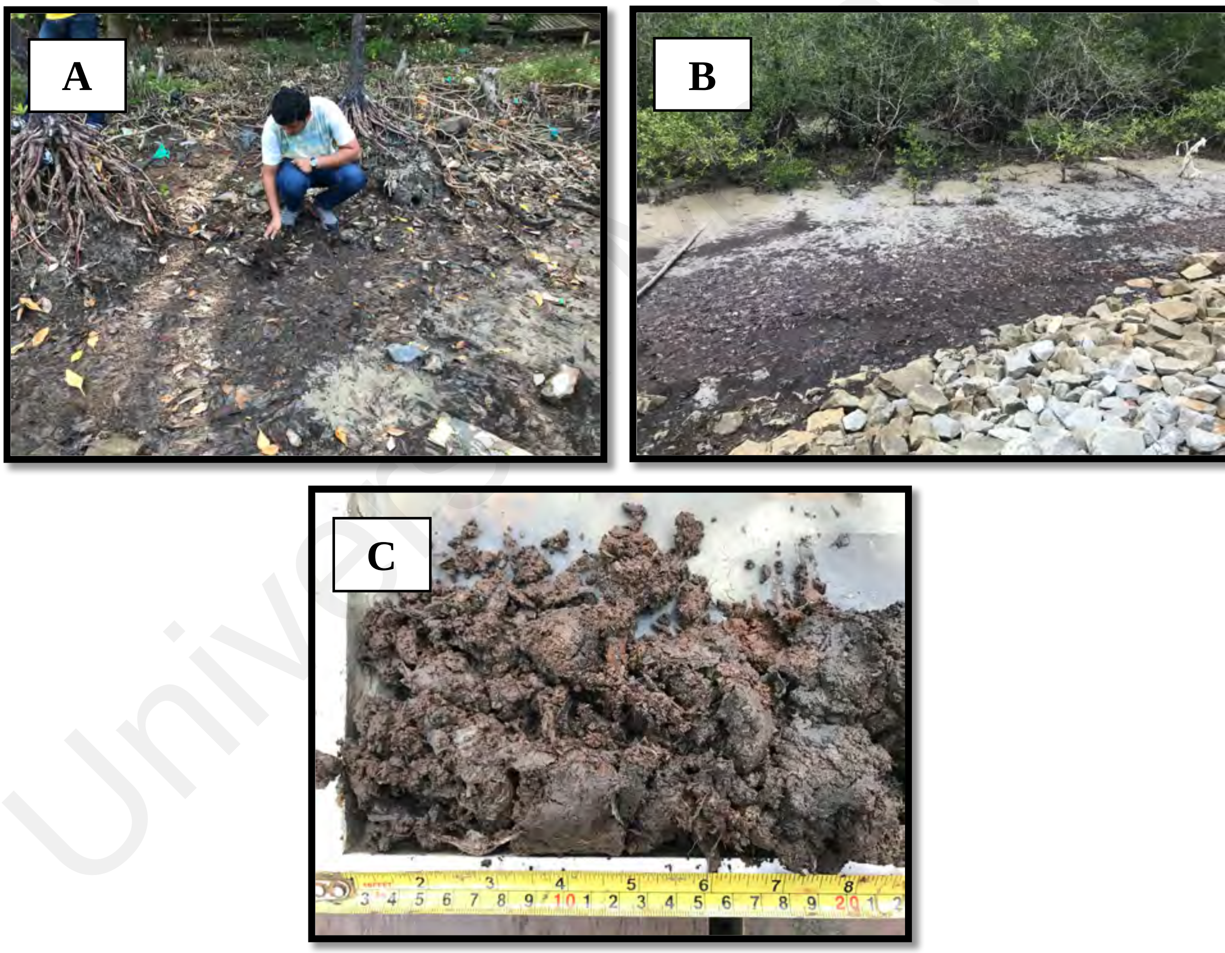

Figure 3.1: Organic deposits at three different location. (A) Pulau Ketam, Perlis (B) Pantai Kelanang, Selangor (C) Tanjung Piai, Johor

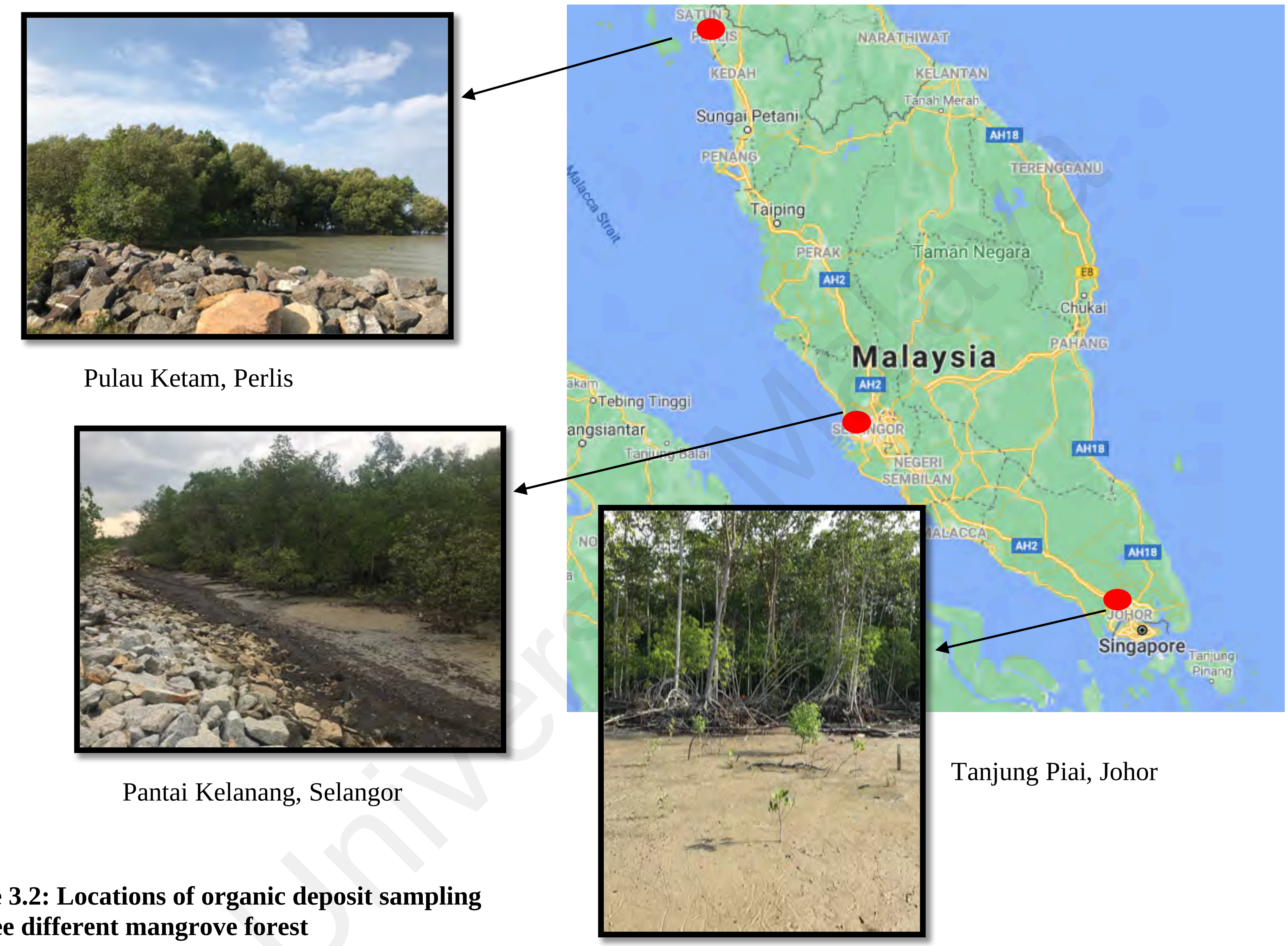

Figure 3.2: Locations of organic deposit sampling at three different mangrove forest

The organic deposit was collected at these three different locations due to the presence of the organic deposit at the mangrove area. The activities around these three location were almost the same as the mangrove area were located near to the shipping and recreational activities.

3.1.2 Chemical composition of organic deposit

3.1.2.1 Wet pH of organic deposit

Ten gram of fresh organic deposit were used and add with 25 millilitres of distilled water. Placed on the orbital shaker for one hour of shaking. The pH meter was used to take the reading.

3.1.2.2 Dry pH of organic deposit

Organic deposit samples were dried in the oven at 60 °C to constant weight (48 to 72 hours), and ground in an agate mortar. Then ten grams of dried organic deposit were weight and 25 millilitres of distilled water. Placed on the orbital shaker for one hour and the pH value were taken using the pH meter.

3.1.2.2 Nitrogen content in organic deposit

Total nitrogen in sediment was be determined by using the modified Kjeldahl method (Bremner and Mulvaney, 1982). Preparation for sodium hydroxide (NaoH) 30%: 300 g of sodium hydroxide (NaOH) was dissolved in 200 mL of distilled water and produced up to one litre in a volumetric flask as the reagent for distillation. Thirty grams of boric acid was dissolved in distilled water and diluted to one litre in volumetric flask for the preparation 3% of boric acid. In 100 mL ethyl alcohol, dissolve 0.10 g methyl red and 0.05 g methylene blue as the indicator for this analysis.

Following that, 0.01 N of HCl were prepared with 0.83mL of concentrated HCl was pipette in 400 mL distilled water and was make up to one litre in volumetric flask. The digestion steps for nitrogen content are 0.5 g of organic deposit inserted into a digestion tube and added with 1 g of catalyst (mixture of sodium sulphate and selenium). This then be mixed with 2.5 mL of concentrated sulphuric acid and digested the sample at 350°C for two hours or until the sample colour change to yellow colour. 12 mL of sodium hydroxide were added into the digestion tube together with sample. 10 mL of 3% boric acid was added into conical flask followed by two or three drops of indicator. After the distillate has been collected, titrate with 0.01 N HCl until the colour changed from green to pink for end point.

3.1.2.3 Organic carbon content in organic deposit

The total organic carbon was determined using the Wakley and Black (1934) method, with the first steps consisting of reagent preparation. 1 N potassium dichromate ($K_2Cr_2O_7$) was diluted in a one litre volumetric flask, and 132 g of ferrous ammonium sulphate (FAS) was made by dissolving it in distilled water and then adding 50 mL concentrated sulphuric acid (H_2SO_4). The solution was allowed to cool before being diluted to one litre. In a dropping bottle, two grams of diphenylamine were dissolved in 100 mL concentrated H_2SO_4.

0.05 g sample were added with 10 mL potassium dichromate solution, 20 mL concentrated sulphuric acid and 3 mL phosphoric acid. Leave for 1 hour before 120 mL distilled water was added. 15 to 20 drops of indicator solution were added. Titrate with FAS until the colour changes from blue to purple to green. To restore excess dichromate, one mL of potassium dichromate solution was added, and the titration was completed by adding FAS solution drop by drop until the last trace of blue colour was seen. After that, recorded the titration readings.

3.1.2.4 Heavy metals content in organic deposit

The heavy metals content in the organic deposits were extracted using dilute nitric acid. The organic matter is destroyed through dry ashing process. The elements are determined using the Agilent 725 ICP-OES. A crucible containing 0.5 g of organic deposit sample was weighed and heated in a furnace at 500 °C for five to six hours. In each crucible, three drops of pure water were added, followed by two mL of concentrated hydrochloric acid (HCl). The crucible was then put on the sand bath until the HCl solution was completely dry. Pipette ten mL of 20% nitric acid into the crucible and heat for 30 minutes to an hour on the sand bath, until roughly three to four mL of nitric acid remained inside the crucible. The samples were filtered into a volumetric flask of 25 mL, the crucible was rinsed, and the solution was brought up to volume. Agilent 725 ICP-OES was used to determine the heavy metals content.

3.2 Field study

3.2.1 Study area in Tanjung Piai mangrove forest

Johor National Park (JNP) of Tanjung Piai is a wetland national park located in the district of Pontian, Johor, Malaysia and this national park consists of the coastal mangrove forests as its main natural resources ecosystem (Sidi et al., 2018). According to Tan et al., (2012), Johor state holds 28.7% of mangrove forests in Peninsular Malaysia (27,733 ha), and it is the home of three Ramsar sites which make-up 60% of Malaysia’s wetland. Tanjung Piai National Park have been declared as a globally important place for wetland conservation under the RAMSAR Convention 1971 in 2003 due to its value and its scarcity as a wetland in Malaysia (Husin et al., 2016). Tanjung Piai National Park located 1° 16' 04.2" north latitude and 103° 30' 30.2" east latitude in Johor is the most Southern tip of Peninsular

Malaysia which made up mostly of mangrove and mudflats. This national park is strategically located between Malaysia, Singapore and Indonesia. The heart of this national park is the southernmost tip of Mainland Asia that located at this national park. Geographically, this is the important place for geographical value due to it was the location point of The Southern Most Tip of Mainland Asia and it also has a geographically value that attracts both local and foreign visitors to reach the tip (Sidi et al., 2018). Tanjung Piai national park is 526 hectares in size and consists of an eight-kilometre stretch of coastal mangrove and mudflats (Johor Parks, 2018). The forest structure of Tanjung Piai mangrove forest were a Bruguiera-Rhizophora mangrove forest type (Razali et al., 2019).

3.2.2 Threats at Tanjung Piai mangrove forest

Tanjung Piai is vulnerable to serious coastal erosion on the east side of the headland, and as a result, there has been a significant loss of protective mangrove coastlines has been observed over the past 20 years (Jensen et al, 2016). Since the opening of the Tanjung Pelepas port, increased shipping traffic in the Johor Straits has had a disastrous effect on the coastal mangrove in Tanjung Piai (Chong, 2006). Ibrahim et al., (2007) reported that in 2006 alone, more than sixty-five thousand ships passing through the Strait of Malacca and with such high traffic of ships. With such heavy ship traffic, severe accidents have occurred multiple times in recent decades, polluting the sea with hazardous and noxious subsrances (HNS) and oil, endangering biodiversity in the sea and coastal mangroves, and harming the local community’s income and livelihood (Ahmad et al., 2019).

Emerging threats to mangrove ecosystems from marine transportation and ports could be sourced from spills of oil and ballast water, leaks, docks and harbours in the form of solid waste, sludge, chemicals and paints as well as domestic waste from the activities of the ports and ships. Mangrove vegetation is very sensitive to oil pollution and it is very easy to affected and will soon die if the environment is contaminated by oil (Aboudha & Cairo, 2001). In July 2012, Kosmo's newspaper reported that Tanjung Piai National Park was facing the problem of oil spills and marine debris that contained organic deposit which had killed approximately 7,000 mangrove trees that had been planted in the mangrove forest. On the same year, Berita Harian had also reported about this organic deposit in September where this problem had change the natural habitat of the Tanjung Piai mangrove forest. It also mentioned in the news article that the organic deposit turned to toxic materials as they absorb the oil during ship cleaning process. This organic deposit was not only acidic but also have high heavy metal contents which has tendency to cause the decaying of mangrove roots and slowly kills the mangrove tree (Wan Rasidah et al., 2015). Shipping traffic in the Malacca Straits had an impact on Tanjung Piai, resulting in pollution and sediment erosion (Mustafar et al., 2019). Furthermore, pollution was caused by ship waste dumping, and the waves produced by the large ships will bring greater erosion to the Tanjung Piai mudflats (Awang et al., 2014).

3.2.3 Design of study

Table below (Table 3.1) shows the sampling sites for *Rhizophora* spp. growth performance that had been established in Tanjung Piai mangrove forest:

Table 3.1: The description of each plot

Plot	Description
T1	Site without organic deposit material • There is no organic material present at this plot • 25 meters from shoreline
T2	Site with new organic deposit material • The presence of organic deposit on of the sediment • 40 meters from shoreline
T3	Site with decomposed organic deposit material • The organic deposit material mixed in the sediment • 90 meters from shoreline
T4	Site with decomposed organic deposit material • The organic deposit material mixed in the sediment • 150 meters from shoreline

Sediment sampling at T1 were divided into two groups which are;

1. T1F: Sampling site facing sea

2. T1B: Sampling site facing mangrove forest

Figure 3.3: The locations of each plots at Tanjung Piai mangrove forest

3.3 *Rhizophora* spp. growth in Tanjung Piai mangrove forest

The growth of *Rhizophora* spp. seedlings were measured at different localities based on the presence and extent of organic deposit. Three dominant species of *Rhizophora* spp. in Tanjung Piai mangrove forest have been selected; i. *Rhizophora stylosa* ii. *Rhizophora apiculata* and iii. *Rhizophora mucronata*. The *Rhizophora* spp. These species were identified with the help of officers from Tanjung Piai National Park and tagged accordingly based on the species. Each study plot was set up with 3 set of 10 m x 10 m. The shoot height from the tip of each seedling to the soil was measured every three months within duration of one year research. First data collection for the *Rhizophora* spp. growth analysis were done in June 2016 until June 2017.

3.4 Survival rate of *Rhizophora* sp. at study plot in Tanjung Piai mangrove forest

Each *Rhizophora* spp. that have been tagged for the growth analysis within the study plot were recorded for the survival rate analysis at each plot. The number of surviving mangrove seedlings of each mangrove species was counted every three months from June 2017 until June 2017. The total of survival *Rhizophora* tree at each month were divided with total of *Rhizophora* tree at Month 1 and multiple with 100% to get the percentage of survival. The data for survival rate were separated according to its species; i. *Rhizophora stylosa* ii. *Rhizophora apiculata* and iii. *Rhizophora mucronata*.

3.5 *Rhizophora* spp. leaves sampling

Leaves sampling were collected and placed in separated container according to the three species of *Rhizophora* spp. Random leaf position were collected (upper, middle and basal leaves). The treatments were replicated three times. Samples were dried in the oven at 60 °C to constant weight (48 to 72 hours), and ground in an agate mortar.

3.5.1 Nitrogen content in *Rhizophora* spp. leaves

Refer the section 3.1.2.2 for Nitrogen determination.

3.5.2 Heavy metals content in *Rhizophora* spp. leaves

Refer section 3.1.2.4 for heavy metal determination.

3.6 Sediment sampling and analysis

3.6.1 Sediment profiling at Tanjung Piai mangrove forest

Sediment profiles were taken down to 120 cm by using auger boring method. Continuous series of sediment samples is taken which makes it possible to assemble a core showing the sediment horizons. The auger was drilled into the soil to a depth of 15 to 20 cm and then pulled up carefully to keep the soil in place. The sediment samples were place on a plastic sheet. Then sediment drilling is continued and the successive sections were placed one after the other to assemble a core that showing the sediment horizons. Each layers of the sediments were analysed based on its colour, texture, structure and thickness. The colours of the sediments were determined by using Munsell soil chart.

3.6.2 Sediment sampling for chemical and physical analysis

Sediments samples were taken at two depths: from 0 to 10 cm and 10 to 30 cm for sediment composite using the sediment Augers. All sediment samples were dried in the oven at temperature not exceeding 40°C. Once the sediments were completely dried, they were ground and sieved.

3.6.3 Sediment texture at Tanjung Piai mangrove forest

The sediment texture was determined by using the pipette method. The reagent used were 35 % or 33 % hydrogen peroxide, ammonia solution and dispersing agent by diluting eight grams of sodium carbonate and sodium hexametaphospate in 1 litre distilled water.

On day one, 20 g of sediment samples was weighed and place in 600mL beaker. Distilled water were added to wet the sediment sample. The sample was kept overnight with nine mL of ammonia solution and nine mL of H_2O_2. On the second day, the sediment from the side beaker was rinsed with distilled water until it reached a volume of 300 mL. Nine millimetre of ammonia solution and nine millimetres of H_2O_2 were added and the sample was left for two to three hours on sand bath before repeating the process again and the sample was left overnight.

25 mL dispersing agent and distilled water were added the next day till the volume reached 300 mL. The sample was stirred for about 15 minutes. Then the mixture was transferred and the excess sample in the beaker has been washed with tap water into a cylinder. The volume of the cylinder was made up to one litre with tap water and then the sample was then left overnight. The cylinder was then corked and inverted before being shaken for one minutes. 20mL of suspension was pipette into the metal dish from a depth of

10 cm below the surface. Then dried in the oven at 105°C and weighted for mixture of silt and clay after it is completely dried. The cylinder's remaining solution was left for 6 hours. A total of 20 mL of suspension was pipette from a depth of 10 cm below the surface, transferred to a metal dish, and oven dried at 105°C. Then, weighted for clay after the suspension is completely dried. The cylinder's supernatant liquid was decanted away, leaving the sand particles. The sand particles in the cylinder were washed with tap water before being moved into a metal dish after all of the silt and clay particles had been removed completely during the rinsing process. Clay, sand, and silt percentages were calculated. By sieving the sand using 125 to 250 μm sieves, the percentage of coarse and fine sand was determined.

3.6.4 pH value in sediment at Tanjung Piai mangrove forest

Refer section 3.1.2.1 for pH analysis.

3.6.5 Nitrogen content in sediment at Tanjung Piai mangrove forest

Refer section 3.1.2.2 for nitrogen content.

3.6.6 Total organic carbon in sediment at Tanjung Piai mangrove forest

Refer section 3.1.2.3 for total organic carbon.

3.6.7 Available phosphorous in sediment at Tanjung Piai mangrove forest

The Bray and Kurtz No.2 extraction solution was used to determine this analysis (Bray and Kurtz, 1945). The extraction reagent was made by dissolving 18.3 g of 1 N NH_4F in distilled water, diluting it to 500 mL, and storing it in a paraffin bottle. For 1 N HCl stock solution, 40.4 mL concentrated HCl was diluted in distilled water and made up to 500 mL

100 mL of 1 N HCl and 30 mL of 1 N NH_4F were combined to make one litre of extracting solution with pH of 1.8.

Reagent for colorimetric determination was prepared with in 20 mL distilled water, 25 g of ammonium molybdate was dissolved. After that, 800 mL of distilled water was added to 280 mL of concentrated H_2SO_4. Both solutions were cooled to room temperature. While stirring, ammonium molybdate solutions was added to H2SO4 solution. Then a 0.8 M boric acid solution was created by dissolving 49.4 g of boric acid in distilled water and diluted to one litre. 1 g of stannous chloride was dissolved in 10mL concentrated HCl for stannous chloride also called as tough reagent. 40 mL of the solution was diluted in a 10 mL beaker with distilled water and then filtered before use it.

The procedure for sample extraction were two grams of sediment were weighed into a test tube, and 20 millilitres of extraction solution were pipette into the test tube. Then shake the sample using horizontal shake for one minute. Filter the filtrate and collect it in a test tube. The sample was left for around 15 minutes, or until the entire solution had been filtered. 10 mL of the sample was then pipette into a 100 mL round bottomed flask. After adding 7.5 mL of boric acid, 2 mL of tough reagent was added. Following that, 0.5 mL of indicator was added. Shake for 15 minutes to allow the reaction to take place. Agilent Cary 60 UV-Visible spectrophotometry was used to examine the analysis.

3.6.8 Cations Exchange Capacity (CEC) in sediment at Tanjung Piai mangrove forest

Sediment exchangeable bases ($K^=$, $Ca^{2+}$and Mg^{2+}) and CEC was determined by leaching with 1 N ammonium acetate (pH 7) and 1N potassium sulphate. First, the reagent preparation of 1 M ammonium acetate solution was prepared with dilute 77.08 g of ammonium acetate in one litre volumetric flask with pH of 7.0. Then 17.426 g of potassium sulphate was dilute in two litre volumetric flask for 0.01 M potassium sulphate preparation.

Ten grams of sediment were weighted and leached for 5 to 6 hours in 100 mL of 1 M ammonium acetate. The leachate was collected in 1 100 mL volumetric flask, and the volume was filled up with 1 M ammonium acetate until it reached 100 mL. Then the leachate was analysed by Agilent 725 ICP – OES for exchangeable Ca, Mg and K. The sediment sample were washed with 96% ethanol. The sediment sample was then leached with 100 mL of 0.1 M potassium sulphate, and the collected leachate was tested for CEC using a flow analyzer.

3.6.9 Heavy metals content in sediment at Tanjung Piai mangrove forest

The heavy metals concentration of Cd, Cu, Fe, Mn, Pb, and Zn has been determined by using the Agilent 725 ICP – OES and method adopted from Aqua Regia. 0.5 g of sediment sample was weighted into a digestion tube. The digestion tube was filled with 2 mL hydrochloric acid and 1 mL nitric acid. After that, the sample was heated at 110°C in the digestion block until only around 1 mL of acid remained. After the sample has been cooled down for overnight. In the digestion tube, 10 mL of 1.2% nitric acid was added and heated at 80°C for 30 minutes before being left overnight. 20 mL distilled water was added to the digestion tube, and the liquid was mixed with a vortex mixer. It was then filtered and made up to volume in a 100 mL volumetric flask. Agilent 725 ICP-OES was used to determine the heavy metal content.

3.6.10 Fractionation of heavy metals in sediment at Tanjung Piai mangrove forest

The Community Bureau of Reference (BCR method), which is a modified sequential extraction procedure proposed by the Standards, Measurement and Testing Programme (formerly BCR) of the European Commission reference, was adopted. The extraction of each extraction step has been analysed with Agilent 725 ICP-OES. The extraction included four stages:

1. Acid soluble and exchangeable fraction (F1)

One gram of sample was sonicated for seven minutes at 22 ± 5 °C in a 100 mL centrifuge tube with 40 mL of 0.11 M acetic acid. The mixture was then centrifuged at 3000 g for 20 minutes. For analysis, the extract was separated. The residue was then sonicated for five minutes with 20 mL of deionized water before been centrifuged for 20 minutes at 3000 g. The water was discarded.

2. Reducible fraction, bound to Fe/Mn oxides (F2)

The residue from the first step was added with 40 mL of fresh 0.5 M hydroxylamine hydrochloride solution, pH 1.5, and sonicated for seven minutes at temperature 22 ± 5 °C. the mixture was then centrifuged at 3000 g for 20 minutes. For the reducible fraction analysis, the extract was separated. Similarly to the first stage, the residue was washed with deionized water.

3. Oxidizable fraction, bound to organic matter (F3)

Residue from the second step was added with 20 mL of 30% hydrogen peroxide and sonicated for two minutes at temperature 22 ± 5 °C. Then, reduced the volume of H_2O_2 around 1 mL using water bath. The moist residue was added with 50 mL of 1 M ammonium acetate and sonicated for 6 minutes at 22 ± 5 °C. The mixture was then centrifuged at 3000 g for 20 minutes. For analysis, the extract was separated. Similarly to the previous processes, the residue was washed with deionized water.

4. Residual fraction (F4)

The third-step residue was extracted with concentrated HNO_3 with addition of 30% H_2O_2. It was heated for 30 minutes at 80°C before being left overnight. 20 mL distilled water was added to the mixture, which was then mixed using vortex mixture. It was then filtered and made up to volume in a 100 mL volumetric flask. The fractionation of heavy metals at each step content was determined by Agilent 725 ICP-OES.

3.7 Statistical analysis

IBM SPSS version 24 was used to analyse the statistical data (IBM Inc., Armonk, NY, USA). The data was given as mean ± standard deviation of the mean. One-way analysis of variance (ANOVA) and Tukey's Test were used to find the mean difference of data between the variables. When $P \leq 0.05$ was used, the differences were considered statistically significant, and different letters in the same column or row were used to indicate them. In bivariate correlations, Pearson's correlation coefficient was used to calculate correlation between data.

CHAPTER 4: RESULTS

4.1 Characteristic of organic deposit

Table 4.1 shows the wet pH, dry pH, total organic carbon and total nitrogen for three different locations of organic deposit sample. The wet pH of the organic material at Pantai Kelanang was neutral with 7.52 and the dry pH were 7.52. Both of this pH values were at natural pH range. The organic deposit sample at Tanjung Piai, both wet and dry pH were the lowest among these three locations which is 6.52 and 6.39 respectively. While for the Pulau Ketam, the wet pH is 6.55 and dry pH is 7.05. The wet and dry pH were not significantly different at all sampling locations.

4.1.1 Chemical composition

Table 4.1: Organic deposit wet pH, dry pH, total organic carbon and total nitrogen (± standard error) at three different locations.

Location	Wet pH	Dry pH	Total Organic Carbon (%)	Total Nitrogen (%)
Tanjung Piai	6.51±0.25a	6.39±0.27a	21.71±0.78c	0.91±0.07a
Pulau Ketam	6.55±0.13a	7.05±0.05a	32.59±0.03b	0.55±0.02b
Pantai Kelanang	7.52±0.12a	7.52±0.10a	65.53±0.25a	0.47±0.03b

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

The highest total organic carbon was detected in organic deposit from Pantai Kelanang sample with 65.53%, followed by Pulau Ketam with 32.59% and Tanjung Piai 18.38%. Total organic carbon was significantly different at all locations. Meanwhile for total nitrogen, the highest value is 0.91% for the Tanjung Piai organic deposit sample. Organic deposit from Pulau Ketam with 0.55% and 0.47% for Pantai Kelanang. The total nitrogen in organic deposit from Tanjung Piai was significantly different from Pulau Ketam and Pantai Kelanang.

4.1.2 Heavy metals content

Table 4.2 shows the heavy metal contained in the organic deposit samples from Tanjung Piai, Pulau Ketam and Pantai Kelanang. The heavy metals of this study was compared with European countries (EU) and United Sates (USA) for the limit set for bio-waste and previous study done by Wan Rasidah et al., in year 2015 for the organic deposit found in Tanjung Piai, Johor.

For the current study in Tanjung Piai, the concentration of Pb and Zn in the organic deposit were the higher than previous study and other locations of sampling. The concentration of Zn were seven times more than the previous study but still below the EU and USA limit range. Pb concentration were higher at bit from previous study with 82.41 mg kg^{-1} but it exceeds the limit range of EU and USA. Even though, the Cd value were the lower than the previous study but it exceeded the value for bio-waste compost limits by the EU and USA. For Cu concentration from Tanjung Piai, the concentration was a bit low which is 21.50 compared to the previous study with reading of 27.6 mg kg^{-1}. Fe and Mn concentration for organic deposit from Tanjung Piai were the second highest with 2.61 mg kg^{-1} and 0.053 mg kg^{-1} respectively.

Organic composite samples from Pantai Kelanang, Klang, has the highest concentration of Mn. For Cd, Cu, Pb, Fe and Zn, the concentration was the lowest compared to the organic deposit from Tanjung Piai and Pulau Ketam. Even though the concentration of Cd were the lowest among others, but the concentration of Cd for this sample were exceeded the EU and USA limit range for bio-waste compost. However, the concentration value for Cu, Pb and Zn are much lower compare to the limit range by EU and USA. The value of Pb from Pantai Kelanang samples were 12 times lower compared to the Pb concentration in organic deposit from Tanjung Piai.

Table 4.2: Comparison of heavy metal contained in organic deposit with previous study in Tanjung Piai, EU, USA bio-waste compost limits

Heavy metal	EU limit range[a]	USA limit range[b]	Previous study[c] Tanjung Piai	Tanjung Piai[d] (Current study)	Pulau Ketam[e]	Pantai Kelanang[f]
				mg kg^{-1}		
Cd	0.15	1.9	5.02	2.45±0.30b	4.38±0.09a	2.02±0.08b
Cu	12	75	27.6	21.50±0.10a	13.71±0.11b	0.70±0.01c
Fe	-	-	-	2.61±0.30b	4.49±0.38a	1.85±0.15c
Mn	-	-	-	0.053±0.01b	0.035±0.00c	0.10±0.00a
Pb	49.6	47	67.2	82.41±0.52a	46.68±0.81b	6.39±0.16c
Zn	183	198	17.5	133.12±1.53a	39.23±0.16b	21.40±0.47c

Means ± standard error of mean value followed by different letters in row are significantly different using repeated measures ANOVA
[ab]Limits set for bio-waste compost applied in European countries and United States (Amlinger et al., 2004)
[c]Results of heavy metal content in organic deposit from previous study in Tanjung Piai
[def]Mean of heavy metal content in organic deposit from the study

The concentration value for Cd and Fe were the highest at Pulau Ketam with 4.38 mg kg^{-1} and 4.49 mg kg^{-1} respectively. Only concentration of Cd exceeded the EU and USA limit range and Cu only exceeded the EU limit range for bio-waste compost. The concentration of Pb and Zn were not exceeded both limit range same as organic deposit from Pantai Kelanang which made only samples from Tanjung Piai exceeded the ranges.

4.2 Effect of organic deposit on *Rhizphora* spp.

4.2.1 Height increment of *Rhizophora* spp. growth analysis in Tanjung Piai mangrove forest

Figure 4.1 shows the total mean plant increment of *Rhizophora* spp. according to its species at all four-study plot within one year duration. Lowest mean increment recorded for all three species were at T1. *R.mucronata* at T1 has the lowest mean increment after one year of study.

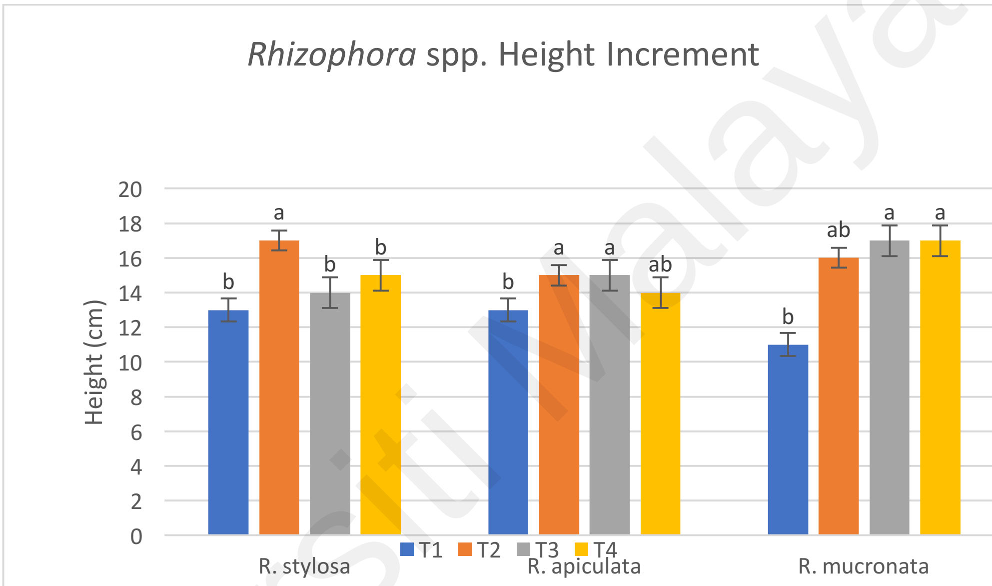

Figure 4.1: Total mean of plant height increment (with standard error) of *Rhizophora* spp. from Month 3 to Month 12; T1 = site without organic deposit; T2 = site with fresh organic deposit; T3 = site with decomposed organic deposit; T4 = site with decomposed organic deposit

However, *R.mucronata* at T3 and T4 has the highest increment with 17 cm. *R.stylosa* recorded highest mean of increment at T2 with 17 cm. While the highest increment for *R.apicuata* is at T2 and T3 with 15 cm.

Figure 4.2 shows the plant growth performance for *Rhizophora* spp. for different treatment in one year of study. At T1, slow increment shown for *R.mucronata* compare to *R.apicutala* and *R.stylosa*. However, *R.stylosa* start to slow growth during Month 6 to Month 12. During first six month, highest increment for *R.apicutala* and *R.stylosa* at T2, then start to slow growing at Month 9 to Month 12. The increment of *R.apiculata* and *R.mucronata* during Month 9 to Month 12 were only increasing by 2 to 3 cm at T2.

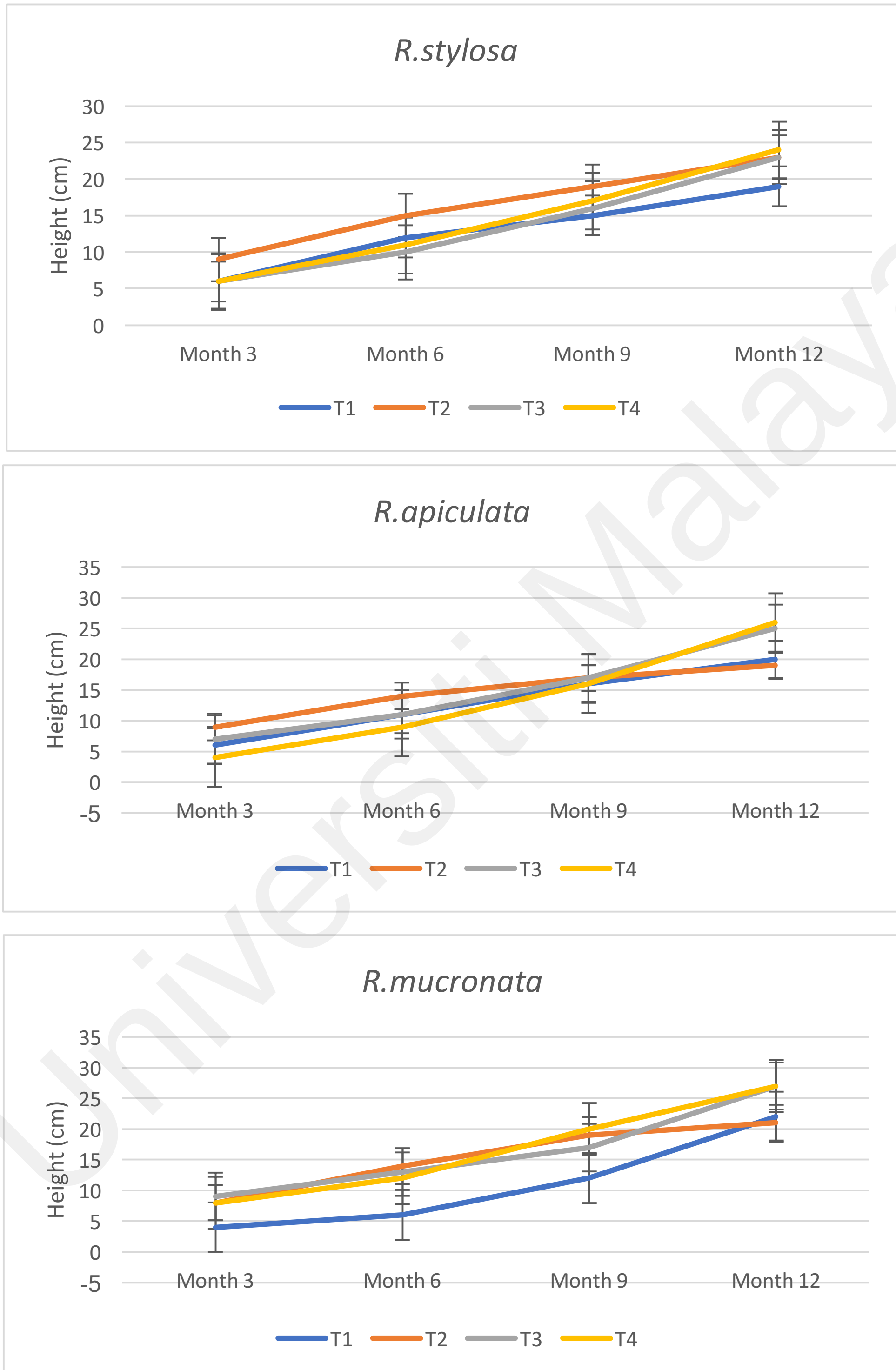

Figure 4.2: Plant growth performance (mean plant height with standard error) of *Rhizophora* spp. for different treatment from Month 3 to Month 12; T1 = site without organic deposit; T2 = site with fresh organic deposit; T3 = site with decomposed organic deposit; T4 = site with decomposed organic deposit

4.2.2 Survival of *Rhizophora* spp. at each study site in Tanjung Piai mangrove forest

Figure 4.3 shows the percentage of survival for *Rhizophora* spp. seedlings at four study plots for 12 month durations according to its species. The percentage of survival at T4 for all species were more than 80% after 12 months. The second highest of survival for all species is at T3 with range of 84% to 75%. While the lowest percentage of survival is at T2 with range of 73% to 47% after 12 months. At T1, all species have percentage of survival more than 75% after one year. *R.stylosa* at T4 and *R.mucronata* at T3 have 100% of survival at first three month.

The species with lowest survival after 12 months is *R.stylosa* at T2 with 47%. The percentage considerably decrease from 100% to 77% at Month 3 the continuously dropped until 47%. Highest percentage of survival for *R.stylosa* is at T1 and T4 with 81% and 82% respectively. Among of these species, *R.mucronata* has the highest percentage of survival at all study plot. The highest survival of *R.mucronata* is at T3 and T4 with 84%. *R.apicula*ta survival percentage at T4 is 81% and 78% at T3.

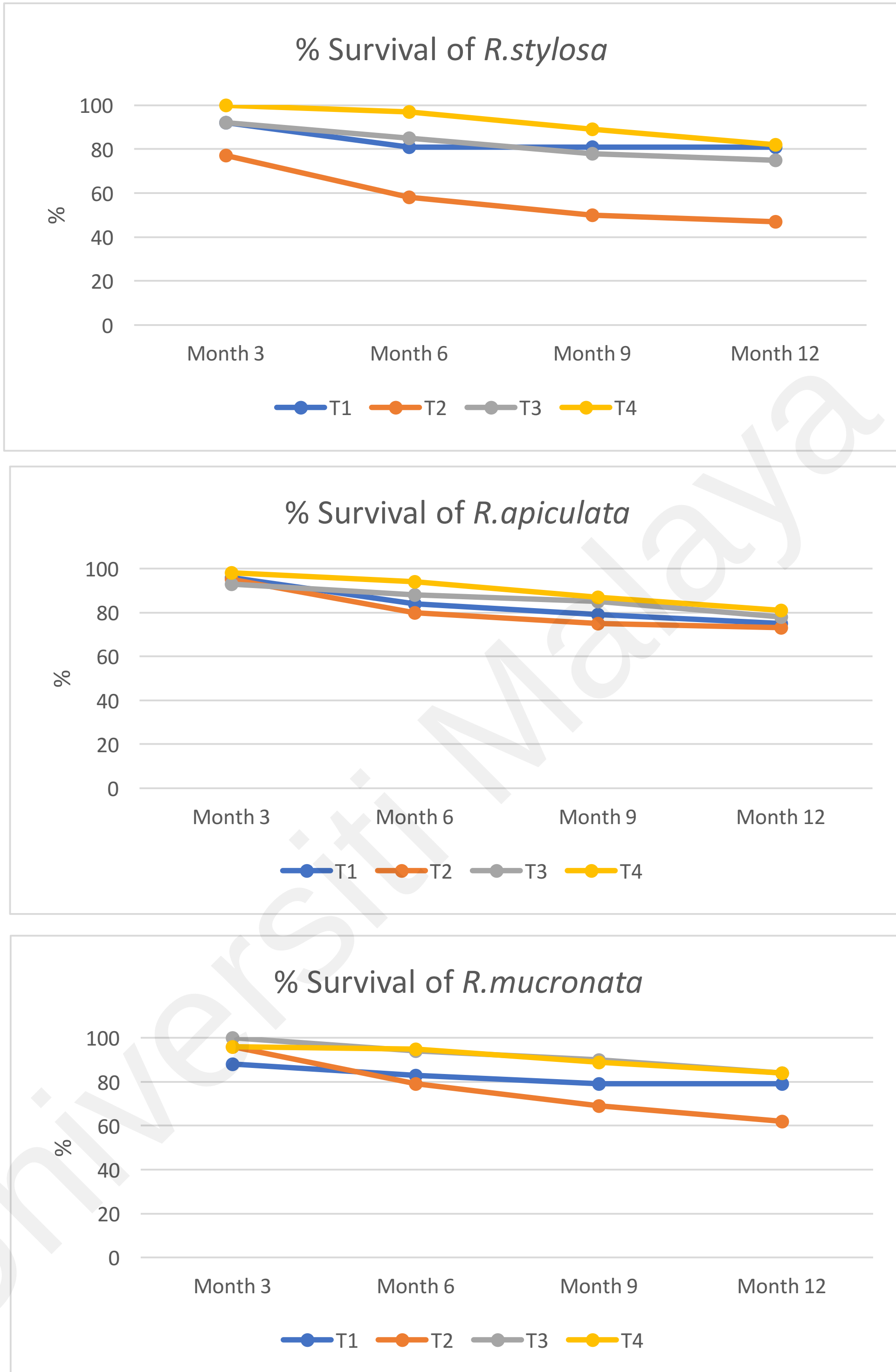

Figure 4.3: Percentage survival of *Rhizophora spp.* from Month 3 to Month 12; T1 = site without organic deposit; T2 = site with fresh organic deposit; T3 = site with decomposed organic deposit; T4 = site with decomposed organic deposit

4.2.3 Nitrogen content in *Rhizophora* spp. leaves

Total nitrogen in *Rhizophora* leaf for each species were shown in Table 4.3. There are significant different ($p>0.05$) in mean total percentage of total nitrogen in site T2 for all three species of *Rhizophora* studied, compared to other three other study sites. All study plots recorded similar percentage of total nitrogen which range from 1.09% to 1.45% except in T2 which range from 0.57% to 0.83%.

Table 4.3: Total nitrogen in *Rhizophora* spp. leaves

Site	*Rhizophora stylosa*	*Rhizophora apiculata*	*Rhizophora mucronata*
T1	1.15%± 0.07a	1.19% ± 0.09ab	1.23% ± 0.03a
T2	0.57% ± 0.22b	0.71% ± 0.11b	0.83% ± 0.07b
T3	1.11% ± 0.09a	1.22% ± 0.23ab	1.15% ± 0.05a
T4	1.11% ± 0.11a	1.45% ± 0.45a	1.09% ± 0.07a

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.2.4 Heavy metals content in *Rhizophora* spp. leaves

Heavy metals accumulation was detected in the leaves of three mangrove species for this study. Table 4.4 shows concentration of heavy metals in plant leaves of *Rhizophora stylosa*, *Rhizophora apiculata* and *Rhizophora mucronata* in four study plots in Tanjung Piai mangrove forest. The average concentration of heavy metals in the leaves from the highest to the lowest are: Mn>Fe>Pb>Cu>Zn>Cd.

The highest concentration found in the *Rhizophora* spp. leaves is Mn with 657.60 mg kg^{-1} in *Rhizophora apiculata* leaves at T1. The Mn concentration for *Rhizohora stylosa* and *Rhizophora mucronata* at T1 also were the highest among the four-study plot with 489.87 mg kg^{-1}and 374.12 mg kg^{-1} respectively. Others with reading of Mn concentration more than 200 mg kg^{-1} are *R. stylosa* at T2, *R. apiculata* at T4 and *R. mucronata* at T3.

Second highest concentration of heavy metals in *Rhizophora* spp. leaves is Fe with 469.99 mg kg^{-1}in *R. mucronata* at T3, 303.05 at T4 and 226.84 at T1. *R. stylosa* in T3 and T4 also have high concentration of Fe with 346.59 mg kg^{-1} and 350.00 mg kg^{-1} followed by T1 with 283.57 mg kg^{-1}. *R. apiculata* leaves samples at T1, T3 and T4 also recorded Fe concentration with more than 200 mg kg^{-1}. All *Rhizophora* spp. leaves at T2 have the Fe concentration below than 200 mg kg^{-1} but more than 100 mg kg^{-1}.

However, for Pb concentration, the highest reading was found in *Rhizophora* spp. leaves at T2. *R. mucronata* with 2.92 mg kg^{-1}, *R. apiculata* with 2.83 mg kg^{-1} and *R. stylosa* with 2.22 mg kg^{-1}. All Pb concentrations were above 1 mg kg^{-1} except for *R. stylosa* at T1 with 0.73 mg kg^{-1}. Next is Cu concentration, where the highest concentration was found in *R. stylosa* at T4 with 2.64 mg kg^{-1} followed by *R. mucronata* at T3 and T4 also *R. apiculata* at T3 with 1.51, 1.49 and 1.63 mg kg^{-1}, respectively. The lowest Cu concentration is in *R. mucronata* at T1 with 0.06 mg kg^{-1} and not detectable at T1 for both *R. stylosa* and *R. mucronata* and T2 for *R. mucronata*.

The Zn concentrations were only measurable at T1 for *R. apiculata* and *R. mucronata* and others were not detectable. The concentration for *R. apiculata* is 0.62 mg $kg^{-1}$and only 0.05 mg kg^{-1} detected for *R. mucronata*. Same as Cd concentration, most of the *Rhizophora* spp. leaves were not detectable for this study but only found in *R. stylosa* at T3 and T4 with concentration less than 1 mg kg^{-1}. Heavy metal concentration of Cu, Fe, Mn, Pb and Zn were found to be significantly different ($p<0.05$) between *Rhizophora stylosa* species over the study plots, while the concentration of Cd was not significantly different. In *Rhizophora apiculata*, the concentration of Cu, Fe, Mn, Pb and Zn were found to be significantly different

($p<0.05$) between each treatment plots. Next for *Rhizophora mucronata*, the heavy metals except for Cd were found to be significantly different over treatment plots in Tanjung Piai mangrove forest.

Table 4.4: Heavy metal content in *Rhizophora* spp. leaves

Site	mg kg^{-1}					
	Cd	Cu	Fe	Mn	Pb	Zn
			Rhizophora stylosa			
T1	nd	nd	283.57±2.79b	489.87±2.28a	0.73±0.09c	nd
T2	nd	0.48±0.05b	164.79±2.43c	207.19±1.06b	2.22±0.04a	nd
T3	0.05±0.01b	0.43±0.02b	346.59±5.48a	196.17±0.94b	1.63±0.07b	nd
T4	0.53±0.03a	2.64±0.13a	350.00±1.50a	162.43±6.18c	1.56±0.04b	nd
			Rhizophora apiculata			
T1	nd	nd	216.08±2.17c	657.60±2.98a	1.30±0.04d	0.62±0.04a
T2	nd	0.39±0.33b	176.25±1.04d	186.66±2.33c	2.83±0.07a	nd
T3	nd	1.63±0.14a	276.71±1.68a	189.53±1.514c	2.29±0.04b	nd
T4	nd	0.75±0.07b	248.19±0.93b	248.28±2.09b	1.73±0.04c	nd
			Rhizophora mucronata			
T1	nd	0.06±0.01b	226.84±2.56c	374.13±0.85a	1.57±0.29b	0.05±0.35a
T2	nd	nd	135.36±1.59d	167.91±1.74c	2.92±0.10a	nd
T3	nd	1.51±0.06a	469.99±3.99a	224.93±1.97b	1.17±1.14b	nd
T4	nd	1.49±0.08a	303.05±1.23b	163.10±2.05d	1.20±0.05b	nd

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA
Note: nd = not detectable

4.3 Physio-chemical properties and fractionation of heavy metals content of mangrove sediment at different localities in Tanjung Piai mangrove forest

4.3.1 Sediment profile

Tables 4.5 to 4.9 were the sediment profile for site T1F, T1B, T2, T3 and T4 with the sediment depth and horizon for each depth. The description for each depth was described together with the colour code for the sediments according to the Munsell colour system based on three properties of colour: Hue, Chroma and Value.

Table 4.5 shows the sediment profile for T1F which is the site without organic deposit in Tanjung Piai mangrove forest. The location of T1F is near the coastline and facing the sea. There is no presence of any organic deposits from depth 0 to 120 cm. The structure of 0 to 5 cm is very massive and 5 to 120 cm, the structure is considered massive as it has little or no structure.

Next is the sediment profile for T1B as shown in Table 4.6 and has similar massive structure like T1F from 0 to 120 cm. At 36 to 45 cm the layer was dominant with shell layer and decreased by depth. Compared to T1F, shell was found at depth of 110 to 120 cm. Meanwhile, at T2 the fresh organic material was observed on the top layer of the sediment. At 9 to 30 cm, organic material was found together with decomposed wood and it decrease by depth. the soil structure was not massive at 65 to 120 cm.

T3 were located slightly landward compared to T1 and T2. The horizon of the sediment also not same as T1 and T2 where it is BC horizon. Decomposed organic deposit with sapric layer was found at 0 to 10 cm at T3. The organic deposit layer was mix with clay and probably pyrite at 10 to 25 cm. At this depth the soil layer was dominant with dark brown colour sediment. The water table measured at sampling time was 20 cm. However, the sediment structure changed to massive as it decreased with depth.

Similar with T3, the horizon for T4 is BC and the organic deposit mix with sapric material were found at 0 to 10 cm. From 10 to 24 cm, the organic deposit was mixed with hemic material. Hemic material was defined as material that has rubbed fiber content while sapric is highly decomposed organic material.

Table 4.5: Sediment profile for site T1F

	Horizon	Description
0 cm	C	Vey massive and sediment layer consists of liquid mud Surface have different colour: 1. Pale green (Gley 1 6/5g) 2. Greenish grey (Gley 1 5/10y)
5 cm		Massive Greenish green (Gley 1 4/5g)
60 cm		Massive + few sapric material Greenish green (Gley 1 4/5g)
92 cm		Massive + increasing sapric material Greenish green (Gley 1 4/5g)
110 cm		Massive + shell Greenish green (Gley 1 4/5g)
120 cm		

Table 4.6: Sediment profile for site T1B

Depth	Horizon	Description
0 cm	C	Massive Top surface with yellowish brown (10YR 5/4) colour Very dark greenish green (Gley 1 3/5Y)
7 cm		Massive with black layer Dark bluish grey (Gley 2 4/10B)
36 cm		Shell layer dominant, decrease by depth
45 cm		Sapric layer Very dark brown (10YR 2/2)
70 cm		Massive Greenish grey (Gley 1 5/5G)
95 cm		Slight massive + few organic material Dark greenish (Gley 1 4/10G)

Table 4.7: Sediment profile for site T2

	Horizon	Description
0 cm	C	Fresh organic deposit Massive Dark greenish grey (Gley 1 4/5 GY)
9 cm		Massive Organic deposit + few decompose wood 1. Very dark brown (10YR 2/2) 2. Greenish green (Gley 5/5 G)
30 cm		Pyrite at 30 cm to 35 cm Massive + few fine roots Greenish grey (Gley 1 5/10GY)
65 cm		Not massive Greenish grey (Gley 1 5/10GY)
120 cm		

Table 4.8: Sediment profile for site T3

Depth	Horizon	Description
0 cm	BC	Organic deposit + sapric Very dark greyish brown (10YR 3/2)
10 cm		Clay + organic deposit Mix with pyrite Dominant colour; Dark brown (10YR 3/3) Pyrite; Black (Gley 1 2/5N) Water table at depth 20 cm
25 cm		Massive to slightly massive Few roots, organic deposit decrease with depth 1. Dark greenish grey (Gley 1 4/10GY) 2. Dark greyish brown (10YR 4/2)
68 cm		Massive Few fine roots + few fiber Greenish grey (Gley 1 5/5G)
96 cm		Massive Greenish grey (Gley 1 6/5G)
120 cm		

Table 4.9: Sediment profile for site T4

Depth	Horizon	Description
0 cm	BC	Organic deposit + sapric Very dark greyish brown (10 YR 3/2)
10 cm		Organic deposit + hemic Very dark brown (10 YR 2/2)
24 cm		Organic deposit + clay Dark grey (10 YR 4/1)
40 cm		Organic deposit + clay Dark greenish grey (Gley 1 4/10GY)
70 cm		Few organic deposit + clay Sticky and massive Greenish grey (Gley 1 5/5/G) Organic deposit decrease by depth
120 cm		

4.3.2 Sediment texture at study plot in Tanjung Piai mangrove forest

Table 4.10 show the percentage of sand, silt and clay with their textural classes for each plot at Tanjung Piai mangrove forest. The textural class were according to the United States Soil Classification System (USDA) textural soil classification. Sand were separated to subdivided of coarse sand with diameter range of 1.0 to 0.5 mm and fine sand, 0.25 to 0.10 mm.

Percentage of sand was higher at T1F, T1B and T2 compare to T3 and T4 at both depths. However, the percentage of clay was higher at T3 and T4 compared to T1F, T1B and T2. Highest percentage of clay at depth 0 to 10 cm with 50% is at T3 and at 10 to 30 cm is at T3 and T4 with 48%. The highest percentage of silt for both depths is at T1B with 30% at 0 to 10 cm and 32% at 10 to 30 cm.

The textural class for each plot were determined from the percentage of sand, silt and clay. Textural class for T1F and T2 for both depths, 0 to 10 cm and 10 to 30 cm is sandy clay loam. For T1B, both of the depths is clay loam. While for T3 and T4, both depths are classified as clay.

Table 4.10: Sediment texture for 0 to 10 cm and 10 to 30 cm

Site	Sediment depth (cm)	Texture (%)				Textural class
		Coarse sand	Fine sand	Silt	Clay	
T1F	0 – 10	2	46	28	27	Sandy clay loam
	10 – 30	1	51	27	24	Sandy clay loam
T1B	0 – 10	1	40	30	34	Clay loam
	10 – 30	1	38	32	34	Clay loam
T2	0 – 10	15	54	8	24	Sandy clay loam
	10 – 30	14	52	10	25	Sandy clay loam
T3	0 – 10	19	10	21	50	Clay
	10 – 30	17	12	24	48	Clay
T4	0 – 10	23	9	21	47	Clay
	10 – 30	19	10	24	48	Clay

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.3 pH of sediment in Tanjung Piai mangrove forest

Table 4.11 shows the pH of sediments from the study plots for 12 month durations. For both sediment depths, 0 to 10 cm and 10 to 30 cm shows almost similar pattern which the pH value increasing from Month 1 to Month 6 and then decreased from Month 6 to Month 12. The pH range for T3 and T4 at 0 to 10 cm is 4.78 to 6.68, while at 10 to 30 cm is 5.04 to 6.82, respectively, which are below 7. The other 3 plots, pH value was more than 7 for both sediment depths, 0 to10 cm and 10 to 30 cm.

Table 4.11: pH of the sediments at each site for 12 month durations

Site	pH				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 – 10 cm				
T1F	7.78±0.13a	7.69±0.14a	7.99±0.15a	7.92±0.02a	7.76±0.04a
T1B	7.88±0.06a	7.71±0.05a	7.83±0.04a	7.79±0.08a	7.89±0.05a
T2	7.72±0.46a	7.79±0.46a	7.86±0.21a	7.72±0.02a	7.91±0.07a
T3	4.78±0.16b	5.14±0.35b	5.85±0.06c	5.61±0.16c	5.18±0.27b
T4	5.19±0.48b	5.41±1.05b	6.68±0.47b	6.43±0.51b	5.23±0.32b
	Sediment depth 10 – 30 cm				
T1F	7.82±0.04a	7.82±0.06a	7.83±0.10a	7.89±0.02a	7.74±0.01a
T1B	7.86±0.12a	7.68±0.02a	7.82±0.02a	7.93±0.03a	7.86±0.11a
T2	7.66±0.08a	7.80±0.53a	7.87±0.12a	8.05±0.25a	7.60±0.17a
T3	5.12±0.26b	5.93±0.21c	6.18±0.29c	5.55±0.22c	5.55±0.17b
T4	5.63±0.08b	6.82±0.29b	6.53±0.34b	6.12±0.63b	5.04±0.20b

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.4 Nitrogen content in sediment at Tanjung Piai mangrove forest

The percentage of nitrogen in sediments of all studied plots was shown in Table 4.12. At depth 0 to 10 cm, the highest percentage of N is at T3 with 0.81% and followed by T4 with 0.71% in M1. The lowest percentage were recorded at T2 and T1F with 0.09% in M3 and M6 respectively. At T3 and T4, the percentage of N were decreased from M1 to M6, then the percentage of N was increased in M9 and then it decreased in M12. As for T2, percentage of N were decrease from 0.17% to 0.09% at M3, then it increased until M9 and decreased to 0.08% in M12. For 10 to 30 cm, the highest percentage of N is 0.77% at T3 in M1. Same as fo 0 to 10 cm, the percentage of nitrogen at T3 were decrease until M6 then increased to 0.61% in M9 then decreased to 0.39% in M12. The range of N percentage for T1F, T1B and T2 at 10 to 30 cm for the 12 month durations is 0.11% to 0.19%.

Table 4.12: Nitrogen content in sediments

Site	N (%)				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	0.18±0.13b	0.16±0.14c	0.09±0.15c	0.17±0.02c	0.19±0.04b
T1B	0.16±0.06b	0.20±0.05c	0.21±0.04b	0.17±0.08c	0.12±0.05b
T2	0.17±0.46b	0.09±0.46c	0.12±0.21b	0.14±0.02c	0.08±0.07b
T3	0.81±0.16a	0.81±0.35a	0.67±0.06a	0.78±016a	0.48±0.27a
T4	0.71±0.48a	0.66±1.05b	0.66±0.47a	0.70±0.51b	0.46±0.32b
	Sediment depth 10 to 30 cm				
T1F	0.18±0.04c	0.17±0.06c	0.11±0.10b	0.18±0.02b	0.19±0.01b
T1B	0.16±0.12c	0.19±0.02c	0.17±0.02b	0.19±0.03b	0.12±0.11c
T2	0.14±0.08c	0.14±0.53c	0.13±0.12b	0.18±0.25b	0.15±0.17bc
T3	0.77±0.26a	0.64±0.21a	0.56±0.29a	0.69±0.22a	0.43±0.17a
T4	0.55±0.08b	0.43±0.29b	0.54±0.34b	0.61±0.63a	0.39±0.20a

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.5 Total organic carbon in sediment at Tanjung Piai mangrove forest

Same as nitrogen, the percentage of carbon was the highest at T3 and T4 with 17.98% at T3 and 18.70% at T4 in M1 for sediment depth 0 to 10 cm. The pattern of C content in sediments for T3 and T4 is the percentage of C content decreased from M1 to M12. However, at T1F, percentage of C was increased from 1.76% in M1 to 6.88% in M12. For T1B, C percentage was increased from M1 (1.67%) to M3 (6.91%) then it decreased until M12 with 1.91% of C. Percentage of C in the sediments at T2 was decreased from M1 to M6 then it increased to 5.25% in M9 then decreased to 2.49% at M12.

For 10 to 30 cm sediment depth, the percentage of C was also high at T3 and T4. The pattern of the C concentrations in sediment were also the same as in 0 to 10 cm. The percentage of C decreased from M1 to M12. At T3, the highest C is 17.98 at M1 and it decreased to 10.38% in M12. The range of C for T2 is 3.19% to 10.38%. Meanwhile for T1F, the percentage of C increased from 1.86% to 7.61%, same pattern as 0 to 10 cm for T1F. Besides T1F that have same pattern of C percentage as 0 to 10 cm, T1B also increased from M1 to M3 then it decreased until M12. The highest C percentage for T1B is 6.78% in M3.

Table 4.13: Total organic carbon in sediments

Site	Total organic carbon (%)				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	1.76±0.13c	1.75±0.14d	1.63±0.15c	2.00±0.02d	6.88±0.04b
T1B	1.67±0.06c	6.91±0.05d	2.96±0.04b	1.99±0.08d	1.91±0.05c
T2	3.80±0.46b	2.50±0.46c	1.73±0.21bc	5.25±0.02c	2.49±0.07c
T3	16.52±0.16a	15.12±0.35a	14.97±0.06a	14.86±0.16a	11.20±0.27a
T4	16.77±0.48a	12.51±1.05b	13.94±0.47a	12.71±0.51b	10.16±0.32a
	Sediment depth 10 to 30 cm				
T1F	1.86±0.04c	1.59±0.06e	1.69±0.10c	2.25±0.02c	7.61±0.01b
T1B	1.73±0.12c	6.78±0.02c	2.36±0.02c	2.64±0.03c	2.21±0.11c
T2	3.60±0.08b	3.19±0.53d	5.49±0.12b	10.38±0.25b	5.86±0.17b
T3	17.98±0.26a	13.10±0.21b	13.73±0.29a	14.70±0.22a	10.38±0.17a
T4	18.70±0.08a	18.85±0.29a	14.54±0.34a	15.00±0.63a	9.74±0.20a

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.6 Available Phosphorous in sediment at Tanjung Piai mangrove forest

Table 4.14 shows the results of available phosphorous (Avail P) in sediments in Tanjung Piai mangrove forest. At both depths, 0 to 10 cm and 10 to 30 cm, T2 has the highest amount of available phosphorous. For depth 0 to 10 cm, M12 recorded the highest concentration with 23.03 mg kg^{-1} and 22.53 mg kg^{-1} in M9 for depth 10 to 30 cm. The lowest amount of available phosphorous is at T3 for both depths with 3.47 mg kg^{-1} for 0 to 10 cm and 4.30 mg kg^{-1} at 10 to 30 cm.

Available phosphorous in T2 shows and increment from M1 to M12 for both sediment depths. Compared to others site, the pattern of available phosphorous is fluctuate in values with slight increase and decrease for the 12 month durations. As for example, at depth 10 to 30 cm, the amount of available phosphorus is increased from M1 to M6 with 9.89 mg kg^{-1} then it decreased to 5.62 mg kg^{-1} and it increase to 13.63 mg kg^{-1} in month 12.

Table 4.14: Available P in sediments

Site	Available Phosphorous (mg kg^{-1})				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	7.19±0.47b	4.11±0.28c	6.55±0.35c	9.77±0.88b	9.45±0.32c
T1B	8.39±0.09b	3.57±0.35c	7.76±0.18b	11.16±0.63b	10.76±0.42b
T2	15.39±0.30a	15.57±0.30a	16.51±0.17a	21.00±0.88a	23.03±0.33a
T3	3.62±1.06c	3.51±0.31c	3.47±0.25d	4.42±0.46c	4.44±0.28d
T4	7.87±0.51b	8.21±0.65b	7.13±0.13bc	5.19±0.18c	11.84±0.75b

Sediment depth 10 to 30 cm					
T1F	6.23±1.02c	3.56±0.32d	8.47±0.38c	7.41±0.13c	8.49±0.37c
T1B	5.28±0.67c	5.19±0.27c	6.40±0.33d	9.40±0.59b	14.54±0.47b
T2	19.57±0.19a	18.83±0.13a	17.59±0.25a	22.53±0.36a	20.68±0.40a
T3	5.53±0.35c	5.26±0.88c	6.23±0.20d	6.75±0.57cd	4.30±0.40d
T4	8.71±0.37b	8.86±0.59b	9.89±0.10b	5.62±0.52d	13.63±0.70b

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.7 Cations exchange capacity (CEC) in sediment at Tanjung Piai mangrove forest

The cations exchange capacity (CEC) values of the study plots were shown in Table 4.16. The highest value of CEC is at T3, followed by T4 and T1B at both sediment depths. The highest value of CEC at depth of 0 to 10 cm is 66.70 $cmol_{(+)}\ kg^{-1}$ and 58.45 $cmol_{(+)}\ kg^{-1}$ at 10 to 30 cm in M3. The CEC value increase from M1 to M3 then it decreased until M12 for both depths. Similar to T3, at T4 also shows the same pattern which the value increase from M1 to M3 with 55.79 $cmol_{(+)}\ kg^{-1}$ at 0 to 10 cm and 57.14 $cmol_{(+)}\ kg^{-1}$ at 10 to 30 cm, then it decreased from M6 to M12. The amount of CEC for each of the study plot for the 12 month durations were different at each plots and depth plus the pattern also was not the same for each of the plots. At T1F and T2, the value increase from M1 to M9 then it decreased at M12 for both sediment depths. The range for CEC value at T1F is 11.65 $cmol_{(+)}\ kg^{-1}$ to 29.22 $cmol_{(+)}\ kg^{-1}$ while for T2 is 11.62 $cmol_{(+)}\ kg^{-1}$ to 29.38 $cmol_{(+)}\ kg^{-1}$. Meanwhile for T1B, CEC value drop from M1 to M6 then the value increase until M12.

Table 4.15: CEC values in sediments at study site in Tanjung Piai mangrove forest

Site	CEC ($cmol_{(+)}$ kg^{-1})				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	11.65±0.13c	25.74±0.14c	29.22±0.15c	28.42±0.02b	20.52±0.04d
T1B	27.17±0.06b	25.63±0.05c	12.04±0.04e	28.93±0.08b	27.64±0.05c
T2	12.73±0.46c	14.64±0.46d	23.62±0.21d	18.63±0.02c	11.62±0.07e
T3	40.63±0.16a	66.70±0.35a	39.59±0.06b	38.92±0.16a	36.30±0.27b
T4	30.20±0.48b	55.79±1.05b	50.54±0.47a	40.48±0.51a	44.21±0.32a
	Sediment depth 10 to 30 cm				
T1F	11.65±0.04c	24.98±0.06b	26.93±0.10b	29.16±0.02b	24.81±0.01d
T1B	27.17±0.12b	22.85±0.02b	9.68±0.02c	28.63±0.03b	30.15±0.11c
T2	12.73±0.08c	18.18±0.53c	19.99±0.12b	29.38±0.25b	11.85±0.17e
T3	40.63±0.26a	58.45±0.21a	43.35±0.29a	43.32±0.22a	38.57±0.17b
T4	30.20±0.08b	57.14±0.29a	43.64±0.34a	41.63±0.63a	44.68±0.20a

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.8 Exchangeable calcium in sediment at Tanjung Piai mangrove forest

The highest concentration of exchangeable calcium as shown in Table 4.16 is at T2 at both depths in M1. The concentration of exchangeable calcium was 27.36 $cmol_{(+)}\ kg^{-1}$ for 0 to 10 cm and 27.70 $cmol_{(+)}\ kg^{-1}$ for 10 to 30 cm. At 0 to 10 cm, the value of exchangeable calcium in T2 decrease along with the time of 12-month study while at 10 to 30 cm the concentration only slightly decrease from 27.70 $cmol_{(+)}\ kg^{-1}$ to 26.75 $cmol_{(+)}\ kg^{-1}$. Second highest concentration is at T1F and T1B. The range of exchangeable calcium concentration at both sites for 0 to 10 cm is 9.46 $cmol_{(+)}\ kg^{-1}$ to 16.62 $cmol_{(+)}\ kg^{-1}$ and at 10 to 30 cm is 10.42 $cmol_{(+)}\ kg^{-1}$ to 18.27 $cmol_{(+)}\ kg^{-1}$.

The lowest concentration of exchangeable calcium is at T3. For both sediment depths, at M3 recorded the lowest concentration of exchangeable calcium with 5.76 $cmol_{(+)}\ kg^{-1}$ at 0 to 10 cm and 5.49 $cmol_{(+)}\ kg^{-1}$ at 10 to 30 cm. While the highest is in M9 with 9.02 $cmol_{(+)}\ kg^{-1}$ and 8.70 $cmol_{(+)}\ kg^{-1}$ for 0 to 10 cm and 10 to 30 cm respectively. The concentration pattern for exchangeable calcium in T4 at both depths is the same where the concentration decreasing from M1 to M6 then it increased at M9 then it decreased back in M12. The highest concentration recorded for 0 to 10 cm in T4 is 8.50 $cmol_{(+)}\ kg^{-1}$ and 11.94 $cmol_{(+)}\ kg^{-1}$ at 10 to 30 cm.

Table 4.16: Exchangeable calcium values in sediments at study sites in Tanjung Piai mangrove forest

Site	Exchangeable calcium ($cmol_{(+)}$ kg^{-1})				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	13.96±0.53b	12.61±0.43b	12.54±0.27b	16.62±0.52b	9.49±0.28b
T1B	13.85±0.69b	12.02±0.12b	13.07±0.59b	13.21±0.78c	9.46±0.43b
T2	27.36±0.58a	25.22±0.24a	23.44±0.48a	18.74±0.73a	12.02±0.41a
T3	6.38±0.44d	5.76±0.11d	7.43±0.45c	9.02±0.43d	8.69±0.22bc
T4	8.25±0.12c	8.43±0.19c	7.01±0.81c	8.50±0.31d	7.92±0.82c
	Sediment depth 10 to 30 cm				
T1F	12.85±0.44c	12.26±0.15c	10.42±0.19b	18.27±0.20b	13.11±0.64c
T1B	16.76±0.70b	15.27±0.20b	10.68±0.56b	17.05±0.22c	16.37±0.30b
T2	27.70±0.14a	27.27±0.27a	26.89±0.48a	25.57±0.53a	26.75±0.40a
T3	6.27±0.31e	5.49±0.15e	7.49±0.10d	8.70±0.24e	7.37±0.19e
T4	10.06±0.53d	9.66±0.35d	8.78±0.32c	11.94±0.56d	10.24±0.20d

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.8 Exchangeable magnesium in sediment at Tanjung Piai mangrove forest

Table 4.17 shows the concentration of exchangeable magnesium for all study plots in Tanjung Piai mangrove forest. For exchangeable magnesium, the highest concentration is at T4 and the lowest was at plot T2, in contrast with exchangeable calcium result as in Table 4.17. At depth 0 to 10 cm the concentration of exchangeable magnesium at T4 were increase from M1 with 22.34 $cmol_{(+)}$ kg^{-1} to the highest concentration at M9 with 30.30 $cmol_{(+)}$ kg^{-1}

then decrease to 28.90 $cmol_{(+)}\ kg^{-1}$ in M12. For 10 to 30 cm at T4, the concentration had increased from M1 to M9 then it decreased in M12. Second highest concentration of exchangeable magnesium is at T3 with range of 15.61 $cmol_{(+)}\ kg^{-1}$ to 27.88 $cmol_{(+)}\ kg^{-1}$ at 0 to 10 cm and 18.46 $cmol_{(+)}\ kg^{-1}$ to 29.22 $cmol_{(+)}\ kg^{-1}$ at 10 to 30 cm.

For site T2 at depth of 0 to 10 cm, the concentration of exchangeable magnesium was decreasing from M1 to M12 while at 10 to 30 cm, the concentration is increasing from M1 to M12. The range of exchangeable magnesium at T1F and T1B at 0 to 10 cm depth was almost at same range from M1 to M12. At 10 to 30 cm, the concentration was only slightly different from M1 to M12 for both study sites.

Table 4.17: Exchangeable magnesium values in sediments at study site in Tanjung Piai mangrove forest

Site	Exchangeable magnesium ($cmol_{(+)}\ kg^{-1}$)				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	16.89±0.61c	16.38±0.14b	15.45±0.32c	16.72±0.20c	13.46±0.30d
T1B	15.08±0.31d	15.61±0.31c	15.97±0.18c	17.27±0.11c	16.36±0.29c
T2	18.58±0.20b	14.51±0.13d	16.36±0.38b	12.76±0.20d	10.70±0.28e
T3	16.42±0.37c	15.61±0.23c	15.58±0.34bc	23.74±0.23b	27.88±0.03b
T4	22.34±0.30a	21.47±0.11a	22.48±0.18a	30.30±0.20a	28.90±0.08a
	Sediment depth 10 to 30 cm				
T1F	16.59±0.61c	16.53±0.05d	16.71±0.24c	16.58±0.23e	16.25±0.35e
T1B	16.68±0.09c	15.68±0.16e	16.88±0.21c	17.60±0.25d	19.48±0.39d

T2	17.61±b0.24c	17.64±0.22c	17.72±0.02c	18.70±0.18c	24.63±0.29c
T3	18.46±0.42b	19.65±0.20b	21.5±0.53b	29.22±0.20b	27.72±0.31b
T4	23.11±0.60a	23.59±0.06a	23.19±0.76a	34.74±0.40a	32.38±0.09a

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.10 Exchangeable potassium in sediment at Tanjung Piai mangrove forest

Table 4.18 shows the results of exchangeable potassium at the study plots and it have lower range of concentration compare to exchangeable calcium and magnesium. The range for both depths of exchangeable potassium is from 0.96 $cmol_{(+)}\ kg^{-1}$ to 3.46 $cmol_{(+)}\ kg^{-1}$. The highest concentration of exchangeable magnesium is at T1F and T1B and the pattern of the concentration is increasing from M1 to M6 then it decreased until M12 for both plots and sediment depths. The highest concentration is 3.46 $cmol_{(+)}\ kg^{-1}$ at T1B in M6.

At T2, the concentration at 0 to 10 cm was decreased from M1 to M12 with small different between the months. For 10 to 30 cm, the highest concentration is 2.08 $cmol_{(+)}\ kg^{-1}$ at M9 then it decrease to 1.41 $cmol_{(+)}\ kg^{-1}$ in M12. At T3, the concentration range of exchangeable potassium is 0.96 $cmol_{(+)}\ kg^{-1}$ to 2.55 $cmol_{(+)}\ kg^{-1}$ at 0 to 10 cm and 1.25 $cmol_{(+)}\ kg^{-1}$ to 2.58 $cmol_{(+)}\ kg^{-1}$ for 10 to 30 cm. While at 0 to 10 cm T4 is 1.84 $cmol_{(+)}\ kg^{-1}$ to 2.58 $cmol_{(+)}\ kg^{-1}$ and 2.54 $cmol_{(+)}\ kg^{-1}$ to 3.39 $cmol_{(+)}\ kg^{-1}$ at 10 to 30 cm.

Table 4.18: Exchangeable potassium values in sediments at study site in Tanjung Piai mangrove forest

Site	Exchangeable potassium ($cmol_{(+)}\ kg^{-1}$)				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	1.98±0.04a	2.64±0.12a	3.19±0.03ab	2.94±0.06a	2.89±0.38a
T1B	1.78±0.03b	2.51±0.06a	3.41±0.30a	2.47±0.27b	2.62±0.28a
T2	1.75±0.01b	1.53±0.06c	1.42±0.20d	1.22±0.11c	1.24±0.42b
T3	0.96±0.03c	1.29±0.06d	2.55±0.66bc	2.20±0.15b	2.28±0.19a
T4	1.94±0.05a	1.84±0.05b	2.42±0.32c	2.58±0.36ab	2.29±0.05a
	Sediment depth 10 to 30 cm				
T1F	1.91±0.08b	2.86±0.11a	3.31±0.18a	2.94±0.37ab	2.85±0.13a
T1B	1.60±0.11bc	2.73±a0.11b	3.46±0.19a	3.25±0.23a	3.09±0.73a
T2	1.56±0.03c	1.51±0.06c	1.55±0.22c	2.08±0.32c	1.41±0.54c
T3	1.25±0.04c	1.64±0.05c	2.53±0.17b	2.58±0.28bc	2.38±0.69b
T4	2.76±0.27a	2.54±0.05b	3.39±0.29a	2.93±0.05ab	2.96±0.65a

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.11 Heavy metal content in sediment

Table 4.19 to Table 4.24 shows the result of heavy metals concentration in sediment at all study plot in Tanjung Piai mangrove forest in one year duration for both depths at 0 to 10 cm and 10 to 30 cm. The mean heavy metal concentration in the sediment decreased in order of Zn > Pb > Cu > Fe > Cd > Mn.

4.3.11.1 Cd concentration in sediment

The result of cadmium (Cd) concentration in the sediments for both sediment depths were shown in Table 4.20. The average concentration of Cd in the sediments for 0 to 10 cm followed the decreasing order of: T3 > T4 > T1B > T1F > T2 and at 10 to 30 cm followed the decreasing order of: T3 > T1B > T1F > T4 > T2. At both depths, 0 to 10 cm and 10 to 30 cm, T3 recorded the highest concentration of Cd while T2 the lowest concentration of Cd in the sediments. The range of Cd concentration at all plots is 1.28 mg kg^{-1} to 3.80 mg kg^{-1}.

4.3.11.2 Cu concentration in sediment

Table 4.20 show the concentration of Cu in the sediments in Tanjung Piai mangrove forest. The highest concentration recorded at T3 for both sediment depths, 0 to 10 cm and 10 to 30 cm. At 0 to 10 cm, the highest concentration is 26.01 mg kg^{-1} while at 10 to 30 cm is 23.69 mg kg^{-1}. The lowest concentration of Cu is at T2 with 4.10 mg kg^{-1} at 10 to 30 cm in M6.

Table 4.19: Cd content in sediments at each study plots

Site	Cd (mg kg^{-1})				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	1.96±0.98b	3.19±0.22ab	2.42±0.14a	2.72±0.31a	1.96±0.14abc
T1B	3.12±0.22a	2.44±0.26c	2.31±0.21a	2.36±0.07a	1.84±0.26bc
T2	1.67±0.28b	1.13±0.19d	1.26±0.18b	1.45±0.30b	1.36±0.28c
T3	3.46±0.28a	3.72±0.24a	2.64±0.13a	2.72±0.21a	2.55±0.05a
T4	3.38±0.42a	2.66±0.13bc	2.48±0.42a	2.58±0.63a	2.39±0.19ab
	Sediment depth 10 to 30 cm				

T1F	2.38±0.36b	3.43±0.32a	2.64±0.11a	2.42±0.24bc	1.63±0.06c
T1B	3.43±0.32a	3.59±0.21a	2.72±0.24a	2.65±0.16b	1.34±0.12c
T2	1.28±0.23c	2.79±0.18b	1.49±0.17b	1.65±0.42c	1.28±0.22c
T3	3.12±0.09a	3.22±a0.12b	2.48±0.37a	3.80±0.20a	3.31±0.20a
T4	2.14±0.37a	2.67±0.05c	2.16±a0.40b	2.49±0.37b	2.33±0.36b

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

Table 4.20: Cu concentration in sediments at each study plots

Site	Cu (mg kg^{-1})				
	Month 1	Month 3	Month 6	Month 9	Month 12
Sediment depth 0 to 10 cm					
T1F	12.44±0.49c	12.20±0.52c	12.54±0.28c	7.26±0.13d	9.44±0.36c
T1B	11.66±0.62cd	10.29±0.49d	12.32±0.20c	8.66±0.20c	9.54±0.24c
T2	10.11±0.72c	8.11±0.80d	8.30±0.81d	4.56±0.42d	7.32±0.38d
T3	24.43±1.36a	26.01±0.67a	21.75±0.64a	14.80±0.38a	20.31±0.22a
T4	16.84±0.16b	18.97±0.56b	19.12±0.53b	12.57±0.06b	18.48±0.22b
Sediment depth 10 to 30 cm					
T1F	12.37±0.30c	12.54±0.84c	7.35±0.28c	10.45±0.21c	8.44±0.34c
T1B	9.53±0.26d	12.32±0.28c	7.55±0.14c	11.04±0.13c	8.49±0.42c
T2	10.45±0.26cd	8.29±0.41d	4.10±0.40d	7.45±0.33d	7.69±0.36c
T3	23.69±0.67a	21.76±0.62a	16.95±0.17a	18.35±0.30a	22.56±0.34a
T4	18.61±0.59b	19.12±0.31b	12.97±0.45b	16.40±0.48b	18.85±0.12b

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.11.3 Fe concentration in sediment

The concentration of Fe in the sediments of all plots in Tanjung Piai mangrove forest were shown in Table 4.21. The highest concentration of Fe at depth 0 to 10 cm and 10 to 30 cm is at T3 with 5.15 mg kg^{-1} and 4.17 mg kg^{-1} respectively. During M6, M9 and M12, there is no significant different between plot T1F, T1B, T3 and T4 at depth 0 to 10 cm.

Table 4.21: Fe content in sediments at each study plots

Site	Fe (mg kg^{-1})				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	3.42±0.14c	2.91±0.05ab	2.03±0.10a	3.48±0.10a	2.97±0.02a
T1B	3.35±0.20c	2.18±0.24c	2.03±0.04a	3.07±0.05a	2.95±0.17a
T2	2.19±0.18d	1.39±0.46d	1.23±0.24b	1.39±0.22b	1.58±0.32b
T3	5.15±0.27a	3.46±0.09a	2.13±0.08a	3.53±0.29a	3.39±0.37a
T4	4.45±2.23b	2.36±b0.06c	2.01±0.23a	3.57±0.26a	3.06±0.06a
	Sediment depth 10 to 30 cm				
T1F	3.36±0.28bc	2.98±0.09a	2.13±0.10a	3.17±0.24b	2.72±0.20a
T1B	2.54±0.02cd	1.48±0.45d	2.26±0.02a	3.35±0.06b	2.69±0.19a
T2	2.38±0.32d	2.33±0.21b	1.30±0.12b	2.25±0.39c	1.44±0.46b
T3	4.42±0.35a	2.38±0.17ab	2.07±0.26a	4.71±0.23a	3.16±0.19a
T4	3.56±0.49bc	2.49±0.02bc	1.90±0.26a	3.18±0.36b	2.52±0.12a

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.11.4 Mn concentration in sediment

Concentration of Mn were the lowest concentration among other heavy metals studied in the sediments samples. The highest concentration of Mn is 0.13 mg kg^{-1} at T1F. The lowest concentration of Mn is at T3 and T4 with range of 0.01 to 0.02 at both depths.

Table 4.22: Mn concentrations in sediments at each study plots

Site	Mn (mg kg^{-1})				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	0.08±0.01a	0.07±0.01a	0.04±0.01a	0.07±0.01a	0.06±0.01a
T1B	0.07±0.01a	0.07±0.00a	0.04±0.00a	0.05±0.01b	0.06±0.01b
T2	0.03±0.00b	0.03±0.01b	0.02±0.01b	0.02±0.00c	0.03±0.01b
T3	0.01±0.01c	0.01±0.00c	0.02±0.00b	0.01±0.01c	0.02±0.01b
T4	0.02±0.01b	0.01±0.1c	0.01±0.01b	0.01±0.01c	0.02±0.01b
	Sediment depth 10 to 30				
T1F	0.10±0.00a	0.13±0.01a	0.06±0.00a	0.06±0.01a	0.05±0.01a
T1B	0.06±0.01b	0.08±0.01b	0.05±0.01a	0.07±0.00a	0.05±0.01a
T2	0.03±0.01c	0.06±0.01b	0.02±0.01b	0.03±0.01b	0.03±0.01b
T3	0.01±0.01d	0.01±0.00c	0.01±0.00c	0.02±0.01b	0.01±0.01c
T4	0.01±0.01d	0.01±0.01b	0.01±0.00c	0.01±0.01b	0.02±0.01bc

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.11.5 Pb concentration in sediment

The concentration of Pb in the sediments was the second highest and as shown in Table 4.23. During M3, the concentration of Pb at all plots were the highest compare to other months on this study. The concentration was increase from M1 to M3 then decrease during M6. The highest concentration is 117.31 mg kg^{-1} at T3. The lowest concentration of Pb recorded was 16.16 mg kg^{-1} at T2.

Table 4.23: Pb concentration in sediments at each study plots

Site	Pb (mg kg^{-1})				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	25.64±2.61c	86.06±2.54b	26.29±1.70c	34.18±2.73b	26.44±1.62b
T1B	25.08±0.64c	64.56±3.97c	23.86±2.51cd	26.13±1.02c	26.52±1.86b
T2	26.12±1.08c	24.21±2.71d	13.86±3.52d	16.16±3.97d	17.64±3.27c
T3	69.23±3.89a	117.31±5.58a	51.24±6.82a	56.67±2.34a	21.23±0.75bc
T4	48.19±1.67b	78.69±5.05b	28.63±1.35b	34.8±2.91b	42.97±1.82a
	Sediment depth 10 to 30 cm				
T1F	30.03±1.19c	86.59±1.80ab	24.74±0.23b	26.25±1.05c	26.031.25ab
T1B	27.39±2.04c	44.18±3.12d	27.40±1.20b	26.83±1.37c	25.27±1.54b
T2	24.24±1.59c	65.46±3.56c	18.91±1.29c	23.54±1.77c	22.81±2.85b
T3	67.07±5.72a	88.54±3.39a	34.26±1.84a	59.36±1.18a	27.86±0.78a
T4	52.36±2.57b	78.39±3.23b	37.71±3.55a	45.28±1.64b	16.75±0.83c

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.11.6 Zn concentration in sediment

Table 4.24 show the concentration of Zn at all study plots. The highest concentration of Zn was at T1F and T1B while the lowest concentration is at T2. All plots have the highest concentration of Zn in M6 except for T2, where the highest concentration recorded in M3 for both depths, 0 to 10 cm and 10 to 30 cm.

Table 4.24: Zn concentration in sediments at each study plots

Site	Zn (mg kg^{-1})				
	Month 1	Month 3	Month 6	Month 9	Month 12
	Sediment depth 0 to 10 cm				
T1F	82.54±2.35a	87.45±0.44b	110.17±2.52a	94.88±3.67a	93.73±2.81a
T1B	86.24±1.18a	89.37±2.35b	112.35±0.52a	81.60±3.69b	96.18±2.68a
T2	44.01±2.52c	126.35±3.62a	82.24±1.88b	34.55±2.02d	53.02±0.74c
T3	43.63±1.65c	50.22±5.44d	97.63±5.34ab	67.07±2.90c	72.35±1.67b
T4	64.87±2.88b	64.88±2.49c	119.02±4.35a	72.42±4.24c	69.40±3.26b
	Sediment depth 10 to 30 cm				
T1F	88.43±1.97a	90.01±3.51a	115.86±3.23a	95.23±2.53a	94.98±0.83a
T1B	65.59±3.20b	88.84±5.01a	116.86±2.49a	88.29±0.78b	83.87±3.47b
T2	35.58±3.14d	73.31±1.07b	68.53±3.95c	47.00±0.21d	65.67±3.92c
T3	57.61±1.18bc	67.39±3.70b	124.65±0.69a	69.03±0.13c	76.36±3.47b
T4	52.93±4.90c	82.62±1.18a	91.26±3.83b	73.16±4.04c	56.72±1.74c

Means ± standard error of mean value followed by different letters in column are significantly different using repeated measures ANOVA

4.3.12 Fractionation of heavy metals

The average percentage of metals in the fractionation at each study sites are represented graphically in Figure 4.3 until Figure 4.14 at both depths; 0 to 10 cm and 10 to 30 cm. the heavy metal species include: Cd, Cu, Fe, Mn, Pb and Zn. The mobility of heavy metal can be determined by adding the residual fraction, oxidizable fraction and reducible fraction (F1 + F2 + F3) and availability of the heavy metals is the total of residual and oxidizable fraction (F1 + F2).

4.3.12.1 Fractionation of cadmium (Cd)

Figure 4.3 show the fractionation of Cd at 0 to 10 cm depth and Figure 4.4 at 10 to 30 cm at all study plots in Tanjung Piai mangrove forest. At both depths, 0 to 10 cm and 10 to 30 cm, fractionation of Cd was as following order:

Residual fraction > Oxidizable fraction > Reducible fraction > Acid soluble fraction

For 0 to 10 cm depth, the highest percentage of residual fraction (F4) is at T1B with 98.56%, followed by T1F with 86.94%. T4 recorded the lowest percentage of residual fraction with only 57.05%. For oxidizable fraction (F3), the highest percentage is at T3 (28.57%) and T4 (24.16%) while at other three plots the percentage of oxidizable fraction is below than 20%. At T4, the reducible fraction (F2) recorded with 18.79%, followed by T1F with 6.34%.

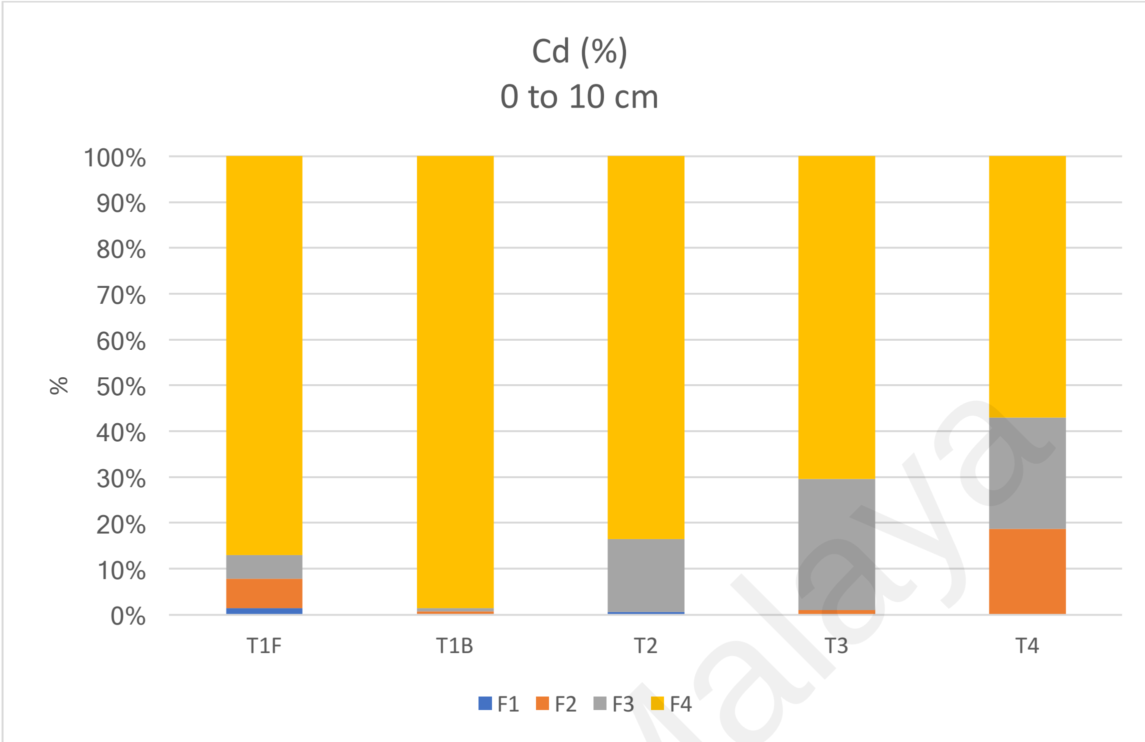

Figure 4.3: Fractionation of Cd at 0 to 10 cm at all study plot

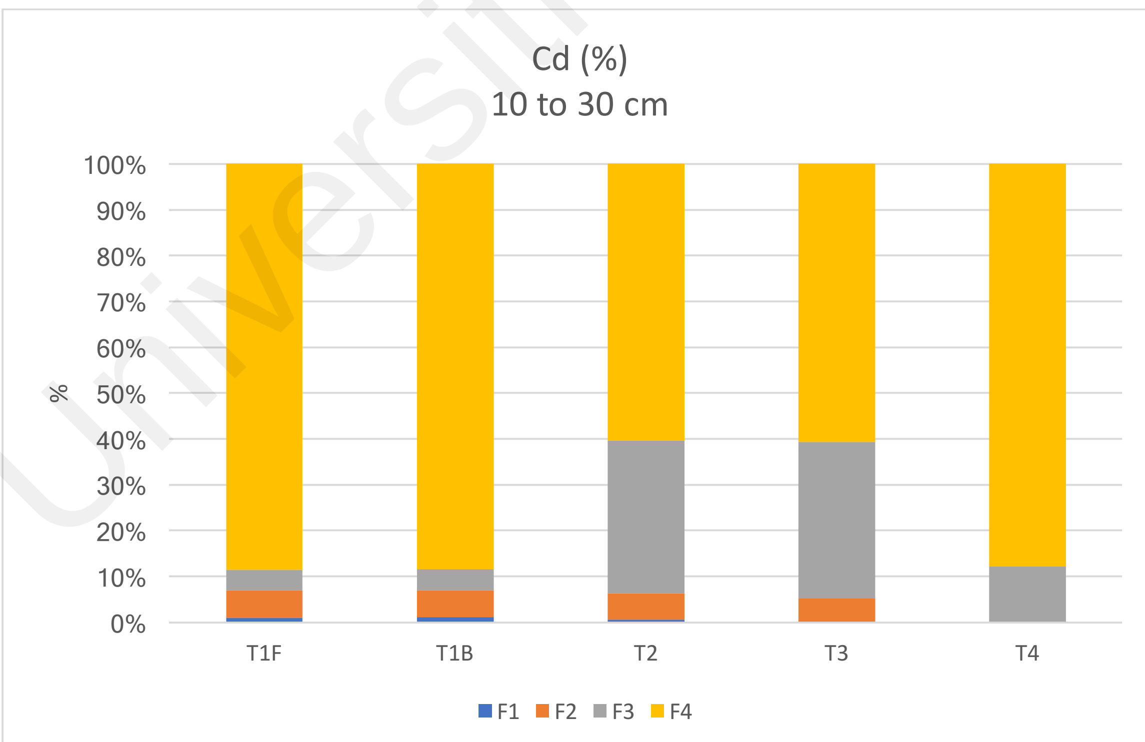

Figure 4.4: Fractionation of Cd at 10 to 30 cm at all study plot

The mobility and availability of Cd at 0 to 10 cm is decreasing by these following order:

T4 (42.95%) > T3 (29.59%) > T2 (16.46%) > T1F (13.05%) > T1B (1.44%)

While at 10 to 30 cm, the mobility and availability of Cd was as following:

T2 (39.65%) > T3 (39.38%) > T4 (12.21%) > T1B (11.62%) > T1F (11.54%)

The mobility and the availability of Cd were not same at both sediment depths. At T4, Cd was more mobile and available compare at 0 to 10 cm but less mobile and available at 10 to 30 cm. However, at T1F and T1B, at both sediment depths, the percentage of Cd mobility and availability was low compared to others.

At 10 to 30 cm depth, Cd percentage for residual fraction (T4) high at T1F, T1B and T4 with 88.46%, 88.37% and 87.79% respectively. For oxidizible fraction at this depth, T3 and T2 have high percentage with 34.20% and 33.33% respectively. Both acid soluble fraction (F1) and reducible fraction (F2) percentage were only below than 10%. The range for acid soluble fraction is in between 0.00% to 1.16% and for reducible fraction is 0.00% to 5.18%.

4.3.12.2 Fractionation of copper (Cu)

Figure 4.5 and figure 4.6 show the fractionation of Cu. At both depths fractionation of Cu was decreasing as following orders:

Residual fraction > Oxidizable fraction > Reducible fraction > Acid soluble fraction

Same as Cd, fractionation of Cd at 0 to 10 cm was high at residual fraction with 83.42% at T1F and 86.00% at T1B. The other three study plots, the residual fraction was below than 50%. However, at T2, oxidizable fraction was the highest with 69.52% followed by T4 with 52.06% and 48.62% at T3. At T1F and T1B, the oxidizable fraction was only

14.80% and 13.62% respectively. Percentage of acid soluble fraction and reducible fraction at all study site was less than 3%. The mobility and availability of Cu at 0 to 10 cm depth at each study plots were as the following order:

T2 (69.52%) > T4 (54.27%) > T3 (51.80%) > T1F (16.59%) > T1B (14.00%)

While at 10 to 30 cm, the mobility and availability of Cu was as the following order:

T3 (51.62%) > T2 (50.54%) > T4 (48.76%) > T1B (16.5%) > T1F (12.4%)

Residual fractionation at 10 to 30 cm was higher at T1F and T1B with 87.5% and 83.50% respectively. Residual fraction and oxidizable fraction at T2, T3 and T4 were almost at same percentage with 48.93% (F3) and 49.46% (F4) at T2, 49.60% (F3) and 48.38% (T4) at T3 and 46.88% (F3) and 51.24% (F4) at T4. The range for acid soluble and reducible fractionation at all study site is in between 0.57% to 2.17%.

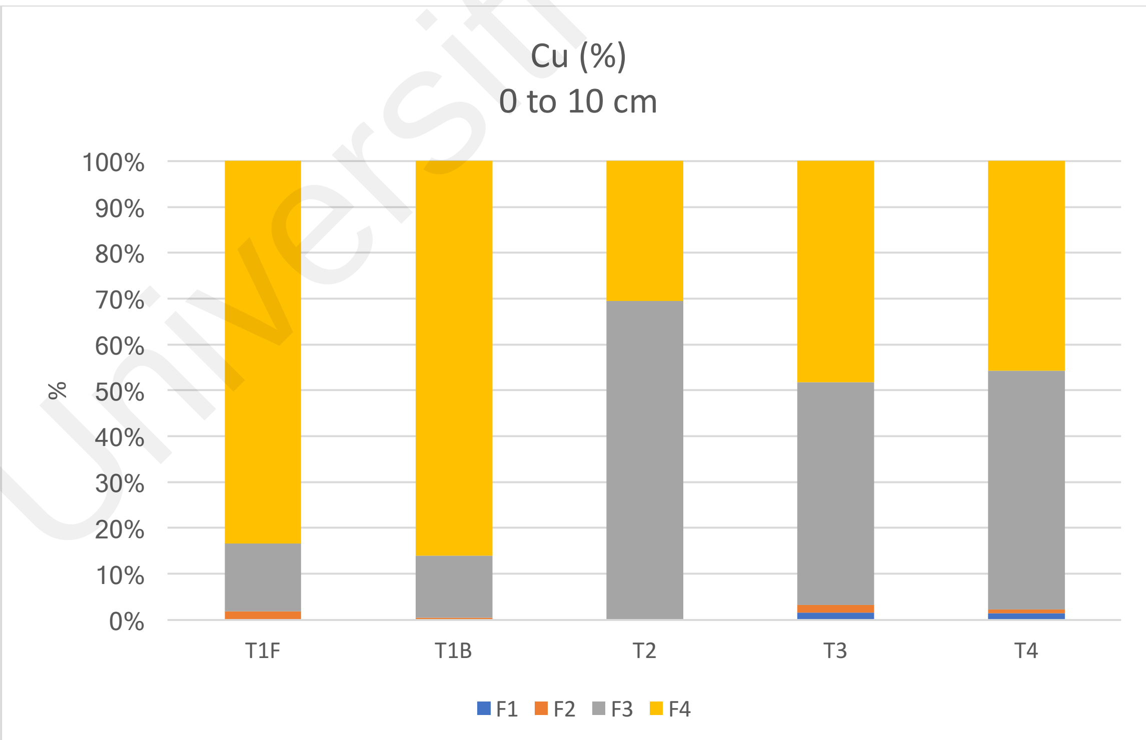

Figure 4.5: Fractionation of Cu at 0 to 10 cm at all study plot

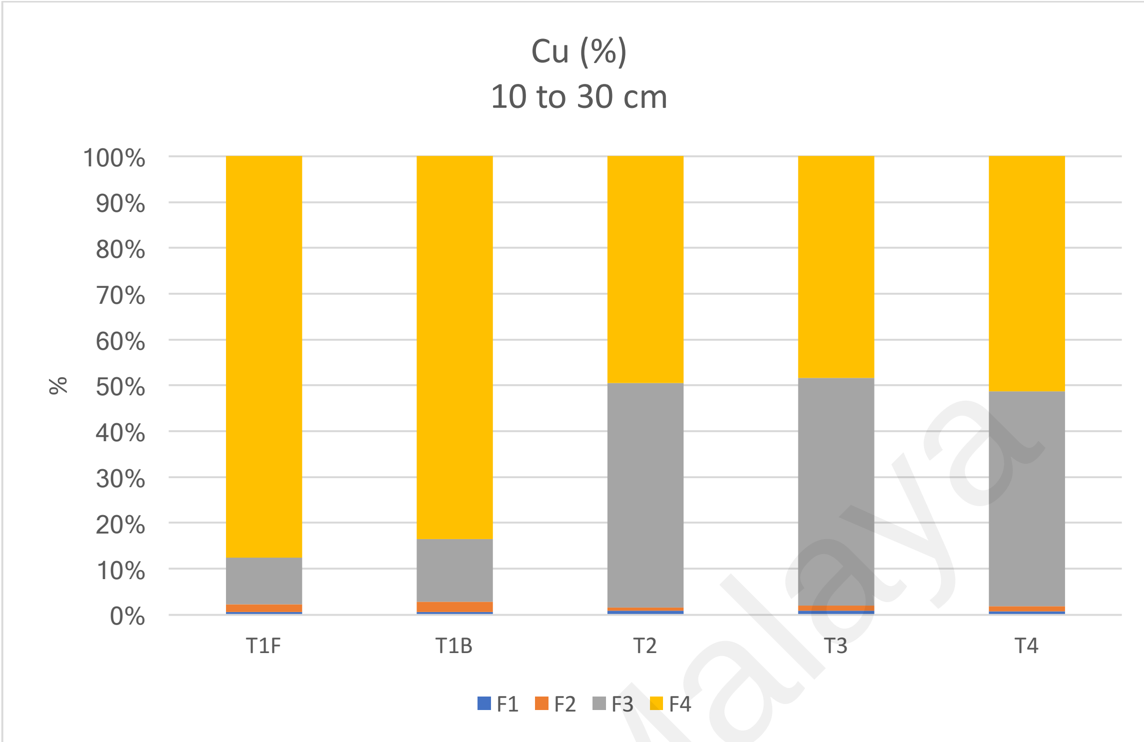

Figure 4.6: Fractionation of Cu at 10 to 30 cm at all study plot

4.3.12.3 Fractionation of iron (Fe)

Referring to Figure 4.7 and Figure 4.8, fractionation of Fe at both depths is decreasing as following order:

Acid soluble fraction > Residual fraction > Oxidizable fraction > Reducible fraction

At both depths, acid soluble and exchangeable fractionation (F1) was more than 95% with range of 97.24% to 98.74% at 0 to 10 cm and 96.54% to 97.77% at 10 to 30 cm. Therefore, mobility of Fe at all study sites were highly mobile at both depths. Others fractionation for Fe were below 3%. The mobility and toxicity of heavy metals in sediment depend largely on their type of binding forms. Exchangeable (F1) and bound to carbonates (F2) are considered to be bioavailable. Oxidisable fractions (F3) may be potentially bioavailable while the residual fraction is mainly not available to either plants or microorganisms.

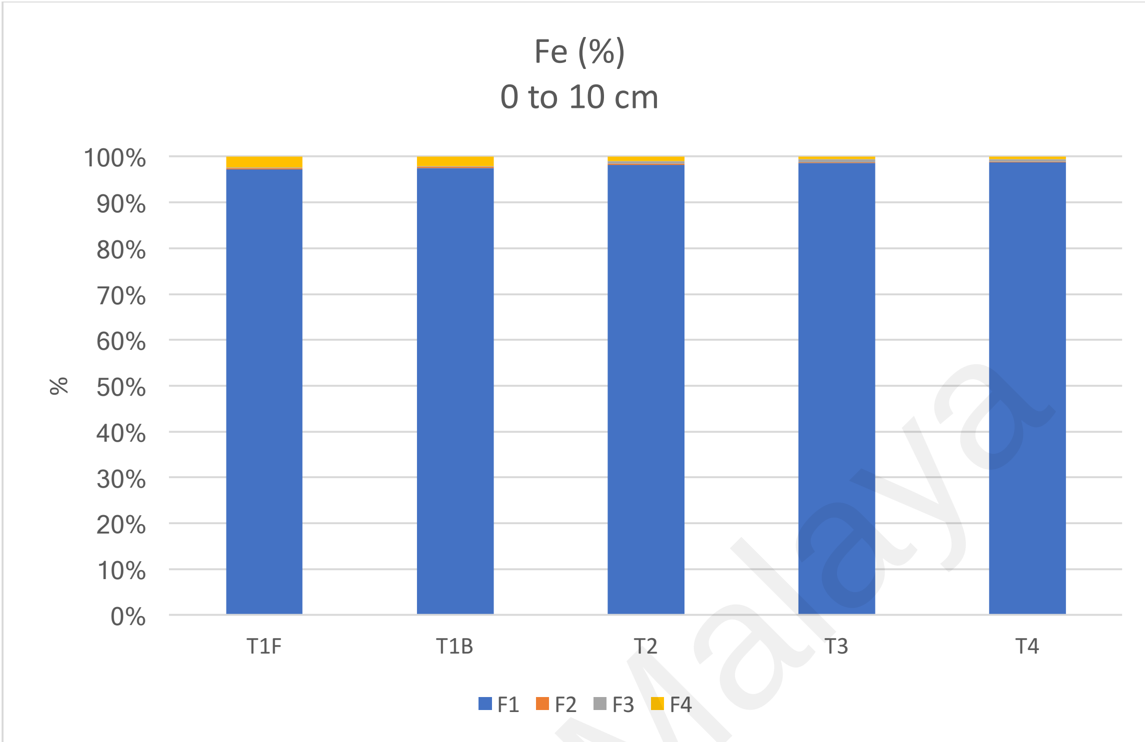

Figure 4.7: Fractionation of Fe at 0 to 10 cm at all study plot

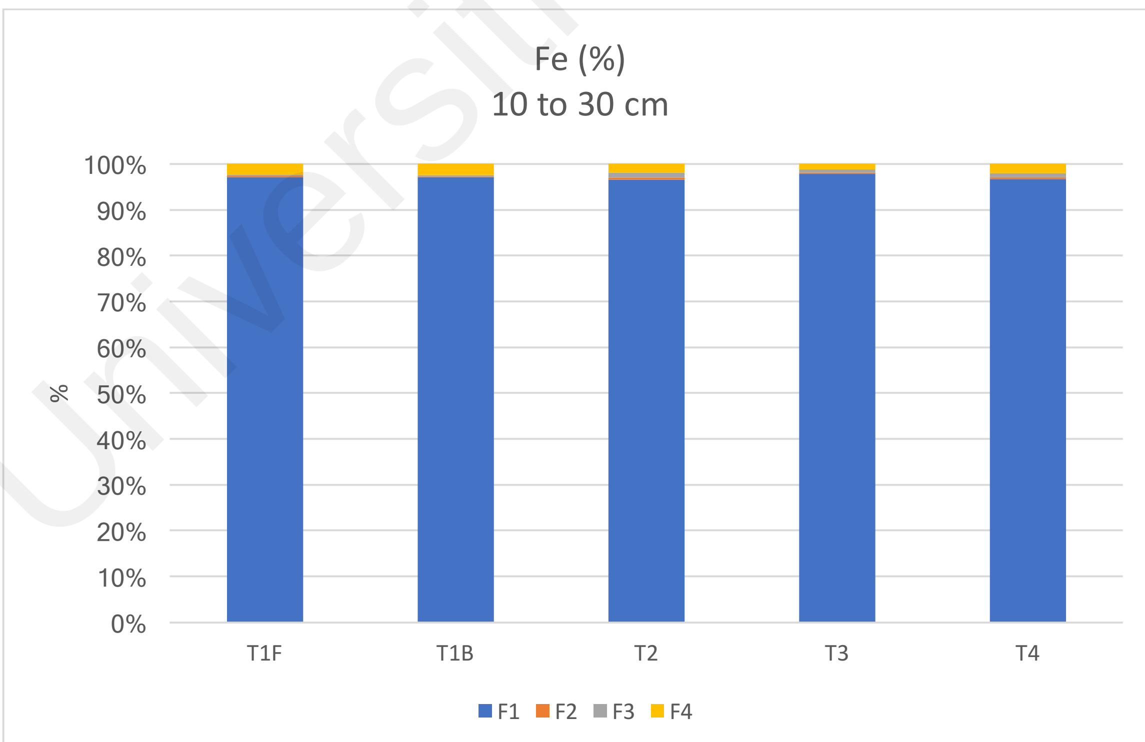

Figure 4.8: Fractionation of Fe at 10 to 30 cm at all study plot

4.3.12.4 Fractionation of manganese (Mn)

Figure 4.9 show the fractionation of Mn at 0 to 10 cm depth and Figure 4.10 at 10 to 30 cm at all study plot in Tanjung Piai mangrove forest. At depth, 0 to 10 cm fractionation of Mn was as following order:

Acid soluble fraction > Oxidizable fraction > Residual fraction > Reducible fraction

The highest percentage of acid soluble (F1) at 0 to 10 cm depth is at T2 with 66.03% followed by T1F with 61.97%. Reducible fraction (F2) at T3 and T4 were high with 28.96% and 30.94% respectively compare to other three sites where the range of residual fraction is 0.13% to 1.92%. Even the F2 fractionation is less than 2% at T1F, T1B and T2, availability of Mn were high as F1 fraction is high at these three sites. The mobility of Mn were as following order: T1F > T2 > T4 > T3 > T1B

At 10 to 30 cm, fractionation of Mn was as following order:

Oxidizable fraction > Reducible fraction > Acid soluble fraction > Residual fraction

Compare to 0 to 10 cm depth, reducible fraction (F2) at T1F, T1B and T2 were high at 10 to 30 cm. Mn at 10 to 30 cm were more available at T1F and T2 with percentage of availability more than 65%. The mobility of Mn are high at T2, T1B and T1F with 89%, 82% and 81% respectively.

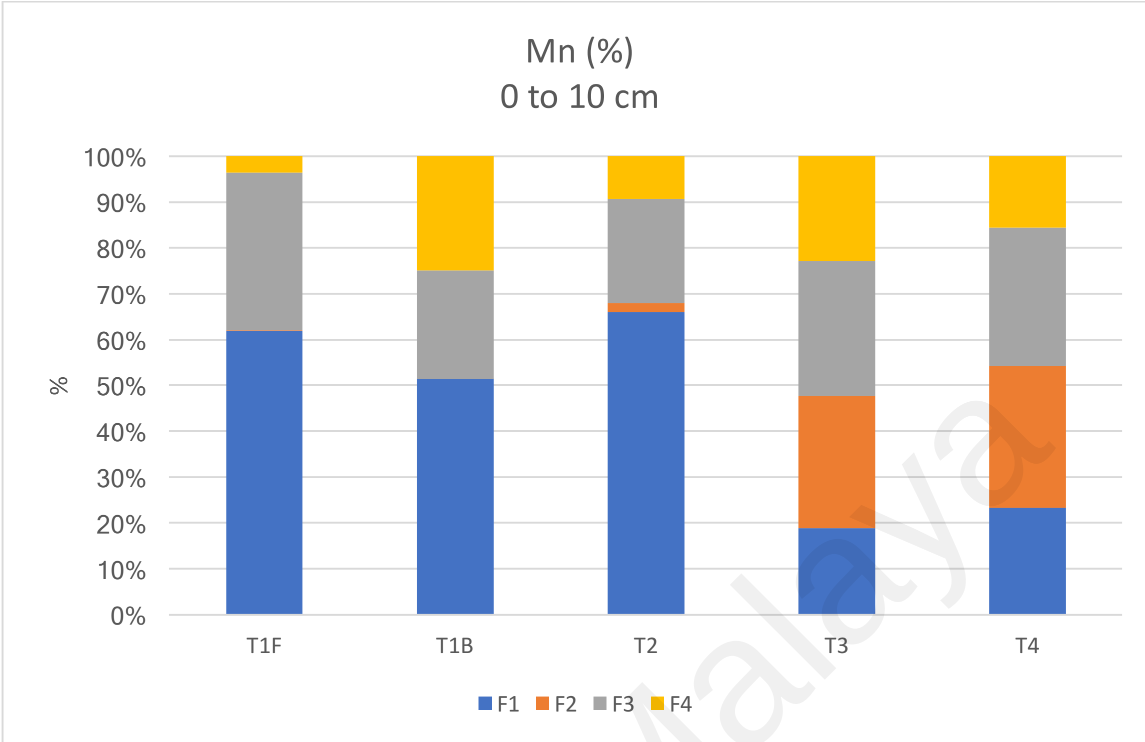

Figure 4.9: Fractionation of Mn at 0 10 10 cm at all study plot

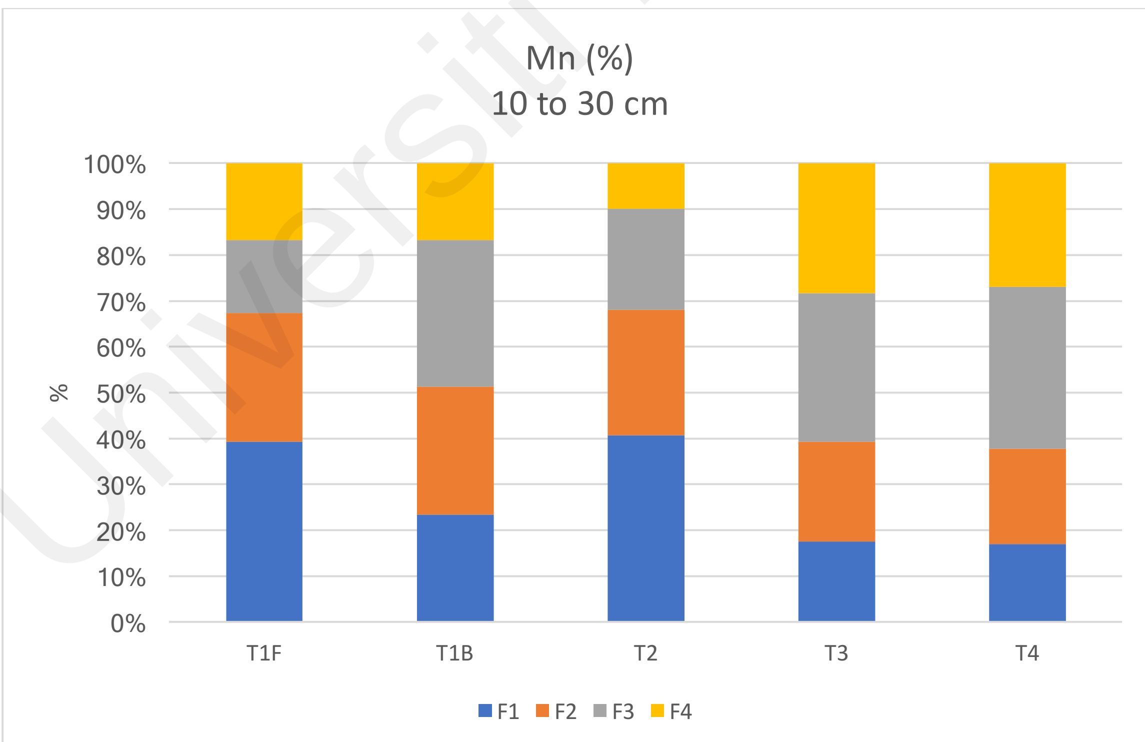

Figure 4.10: Fractionation of Mn at 10 to 30 cm at all study plot

4.3.12.5 Fractionation of lead (Pb)

Figure 4.11 show the fractionation of Pb at 0 to 10 cm depth and Figure 4.12 is the fractionation of Pb at 10 to 30 cm depth. At depth 0 to 10 cm, fractionation of Pb were decreasing as following order:

Residual fraction > Reducible fraction > Oxidizable fraction > Acid soluble fraction

While at 10 to 30 cm, the order for Pb fractionation is:

Residual fraction > Oxidizable fraction > Reducible fraction > Acid soluble fraction

At both depths, residual fraction (F4) were high compare to others fraction. The highest percentage of F4 at 0 to 10 cm is at T1F with 66.35%. Acid soluble fraction (F1) for Pb was low if compared to Mn and Fe. The range of F1 fraction at 0 to 10 cm is 0.24% to 8.95% only. The availability of Pb at 0 to 10 cm were low as the sum of acid soluble and reducible fraction at all four sites was below 38%. The mobility of Pb also can be considered as low as the total of three fraction (F1 + F2 + F3) were less than 50% except at T4 where the mobility of Pb is 61.43%.

The highest percentage of residual fraction at 10 to 30 cm is 70.96% at T1B followed by T1F with 60.31%. The availability of Pb at this depth were also low as their percentage of mobility were in range of 17.04% to 32.77%. The mobility of Pb were high at T3 and T4 with percentage of mobility 63.49% and 63.17% respectively. While at other three study site, the percentage of Pb mobility were less than 50%.

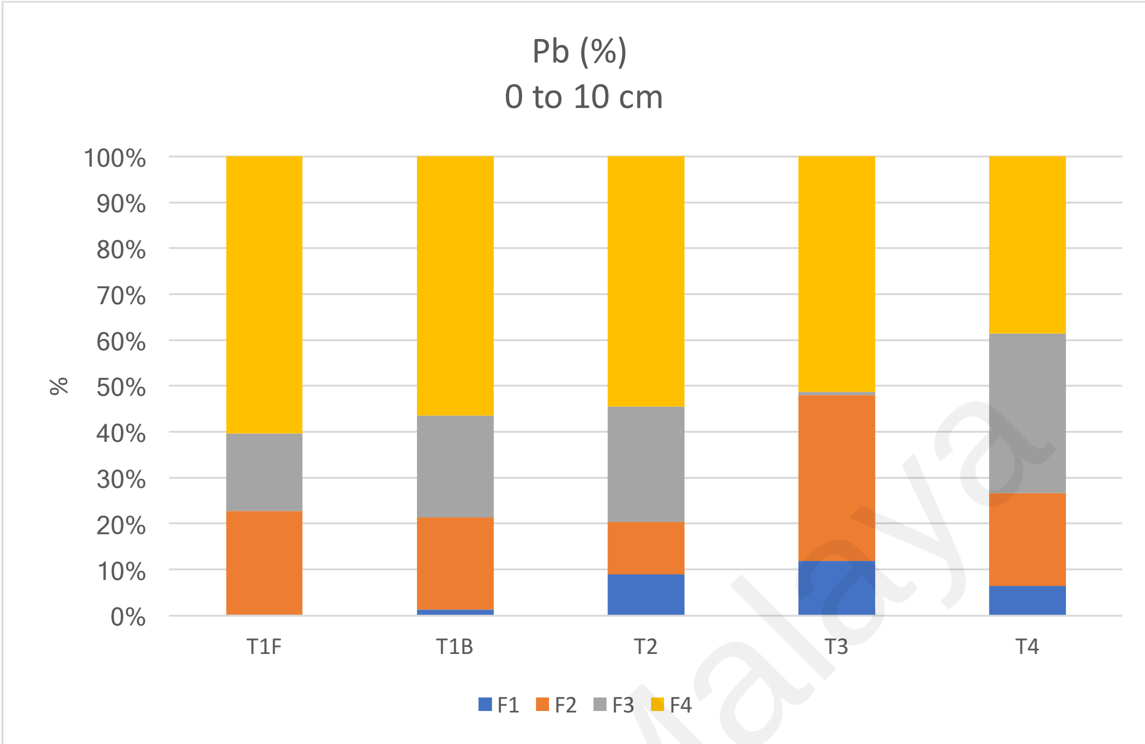

Figure 4.11: Fractionation of Pb at 0 to 10 cm at all study plot

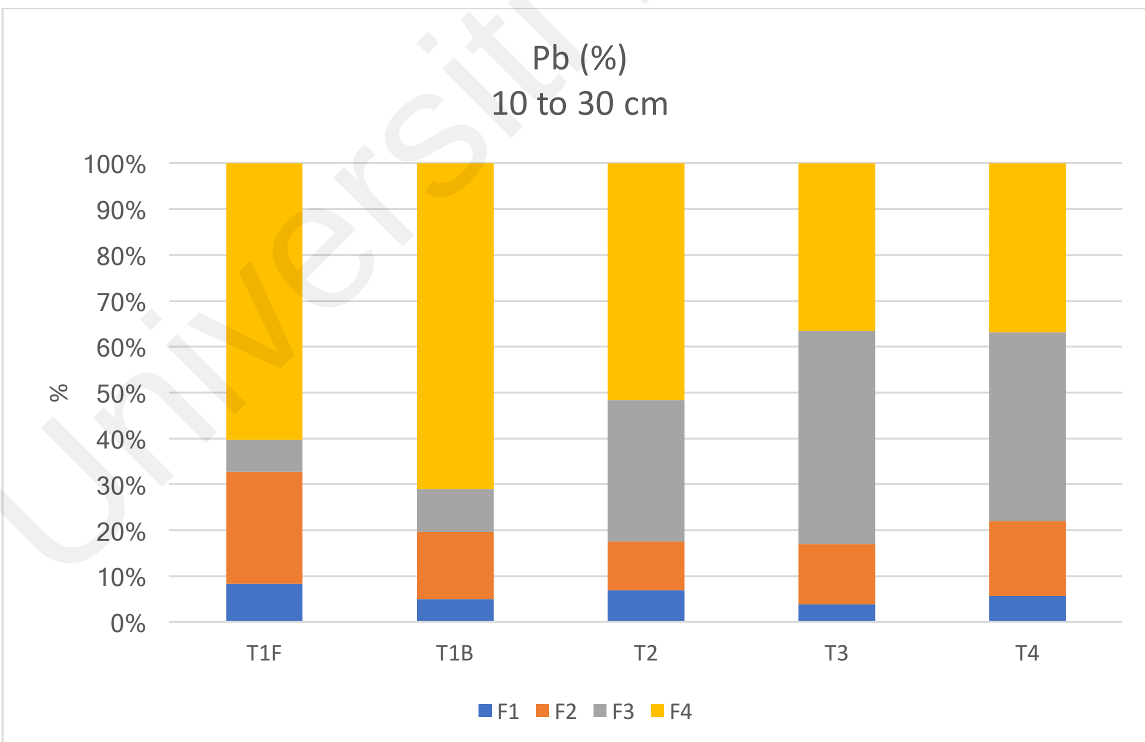

Figure 4.12: Fractionation of Pb at 10 to 30 cm at all study plot

4.3.12.6 Fractionation of zinc (Zn)

Fractionation of Zn at both depths was decreasing as following order:

Residual fraction > Oxidizable fraction > Reducible fraction >Acid soluble fraction

Figure 4.13 shows the fractionation of Zn at all study sites at 0 to 10 cm and Figure 4.14 is the fractionation of Zn at 10 to 30 cm. At both depths, study site T1F and T1B have the highest residual fraction (F4) with 65.81% and 60.62% at 0 to 10 cm, and 80.27% and 76.45% at 10 to 30 cm respectively. This also indicates that Zn is not highly available and mobile to the plant.

At T2, both depths record low fractionation of acid soluble with less than 10%. The residual fraction of 0 to10 cm at T2 were higher compare to 10 to 30 cm. It is also low in availability but easy to mobile as the mobility fraction for both depths are more than 50%. Next, oxidizable fraction at T3 was high at both depths and compare to other study site. With 32.66% at 0 to 10 cm and 32.98% at 10 to 30 cm. This also indicates that Zn at T3 was easy to mobile from sediment to the plant. T4 has the highest fraction of residual (F4) with 48.13% at 0 to 10 cm and 62.20% at 10 to 30 cm. The mobility of Zn at T4 is low at 10 to 30 cm but high at 0 to 10 cm. The availability of Zn at T3 and T4 at both depths was low as the sum of F1 and F2 and this study site were less than 40%. Even it is easy to mobile but it is not much available in the sediment.

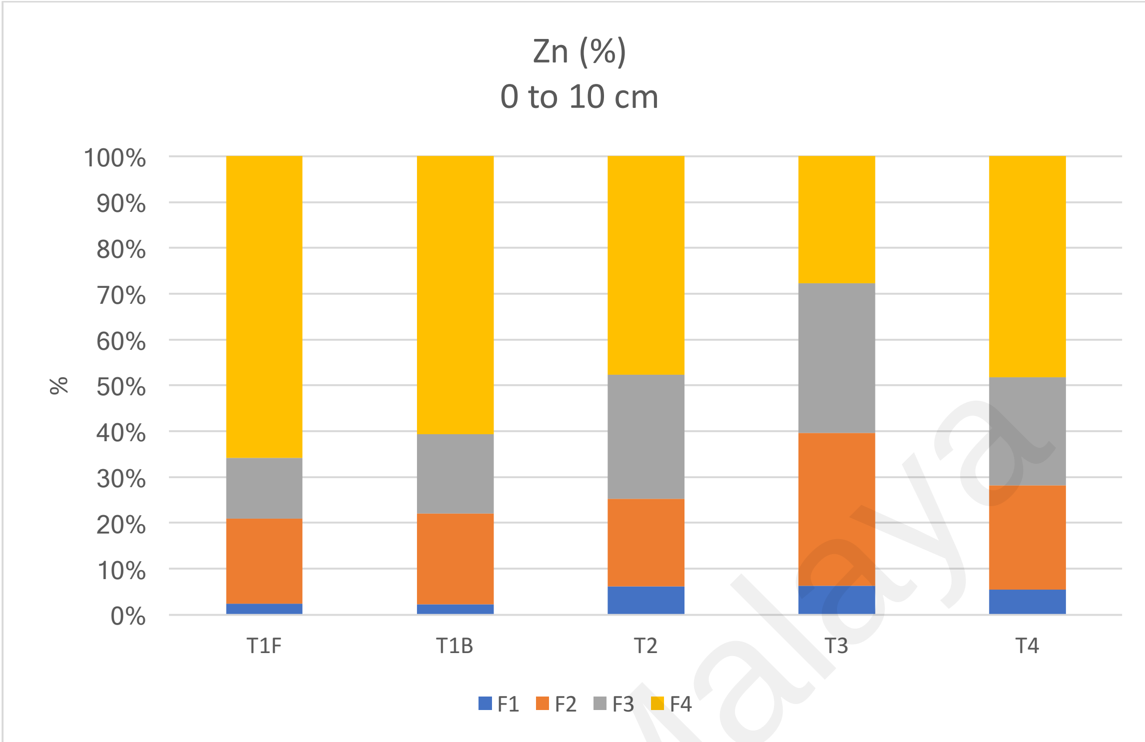

Figure 4.13: Fractionation of Zn at 0 to 10 cm at all study plot

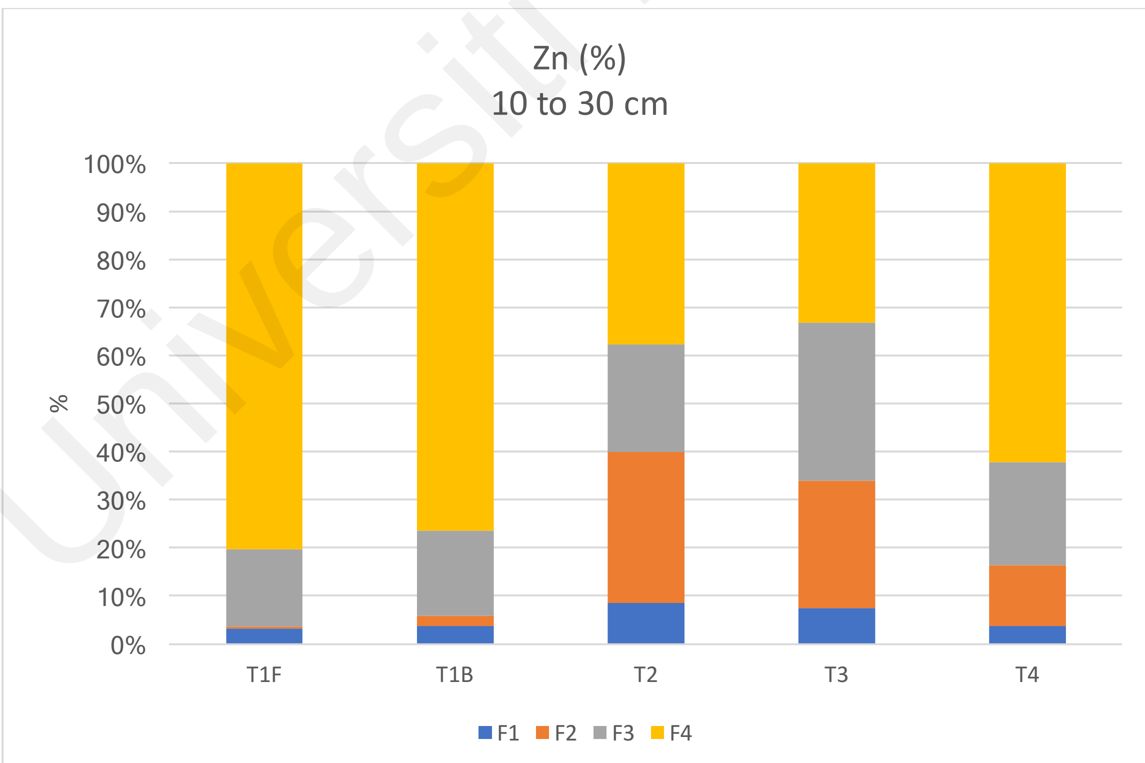

Figure 4.14: Fractionation of Zn at 10 to 30 cm at all study plot

4.4 Correlation study

4.4.1 Correlation between growth with sediment fertility

Table 4.25 shows the correlation between *Rhizophora* spp. growth with sediment properties. Positive correlation between growth with N, C, CEC, exchangeable magnesium and exchangeable potassium. Sediment pH show negative correlation and not significant for available phosphorous and exchangeable calcium.

Table 4.25: Correlation between *Rhizophora* spp. growth and sediment fertility

	Growth
pH	-.689**
Avail P.	ns
N	.682**
C	.761**
CEC	.792**
Exch Ca.	ns
Exch Mg.	.926**
Exch K.	.797**

*Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed); ns = not significant

4.4.2 Correlation between heavy metals concentration with sediment fertility

Correlation between heavy metals concentration and sediment fertility was shown in Table 4.28. Positive correlation between pH with Zn and Mn and other heavy metals shows negative correlation with pH value. None of the heavy metals have positive correlation with available P and not significant for Mn with available phosphorous. For correlation with nitrogen, only Mn is negatively correlated and not significant for Zn, while others have positive correlation with nitrogen.

As for carbon, only Zn and Mn is negatively correlated with carbon while the other four metals are positively correlated. Zn, Cd ad Fe was not correlated with any of CEC, exchangeable calcium (Exch Ca), exchangeable magnesium (Exch Mg) and exchangeable potassium (Exch K). Cu only positively correlated with exchangeable magnesium while Mn was negatively correlated with exchangeable magnesium and exchangeable potassium. Pb show positive correlation with CEC but negative correlation with exchangeable magnesium and exchangeable potassium.

Table 4.26: Correlation between heavy metal concentration with sediment fertility

	Pb	Zn	Cd	Cu	Fe	Mn
pH	-.307**	.189*	-.364**	-.734**	-.439**	.533**
Avail P.	-.395**	-.212**	-.356**	-.518**	-.435**	ns
N	.485**	ns	.459**	.820**	.512**	-.642**
C	.378**	-.198*	.413**	.767**	.402**	-.681**
CEC	.250**	ns	ns	ns	ns	ns
Exch Ca.	ns	ns	ns	ns	ns	ns
Exch Mg.	-.217**	ns	ns	.167*	ns	-.263**
Exch K.	-.351**	ns	ns	ns	ns	-.319**

*Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed); ns = not significant

CHAPTER 5: DISCUSSION

5.1 The chemical composition of organic material at three different locations

Table 4.1 shows the result of pH, total organic carbon and total nitrogen of organic deposit at three different locations. The pH value for both wet and dry for organic deposit from Tanjung Piai recorded the lowest value compared with the other two locations. However, this pH value was not as was acidic as it had been reported by Wan Rasidah (2015). The latter study with data measured at earlier phase reported that the wet pH for the organic deposit was 3.49 and dry pH was 3.08. The different pH between these two findings might be due to the decaying of organic deposit that produces H^+ which is responsible for acidity (Zhou et al., 2019). Furthermore, the burning of fossil fuel, destruction of forests and other human activities may have resulted in a release of a high level of CO_2 into the air. As more of CO_2 has been released, the amount of CO_2 dissolved into the ocean and forming an acid increases, then resulting in higher acidity (Sippo et al.,2016). According to the newspapers articles, in the year of 2012 it has been reported about the crisis faced by the Tanjung Piai mangrove this might be one of the reasons why the pH value of the organic deposit was acidic compared to this study.

For the percentage of organic carbon, organic deposit from Pantai Kelanang has the highest percentage with 65.53%, followed by Pulau Ketam with 32.59% and Tanjung Piai with 21.71%. The contribution of high organic carbon in Pantai Kelanang might possibly coming from the continuous deposits of organic deposits from terrestrial, urban runoff and variety waste from the residents as the sampling locations were located near to the village. Raw organic deposit has high concentration of carbon compared to decomposing organic deposit due to the large amount of carbon loss as it turns to humus (Han et al., 2020). The organic deposit collected at Tanjung Piai were not as raw as organic deposit collected at Pantai Kelanang, therefore the organic carbon between this two sampling sites were different. However, percentage of nitrogen were high at Tanjung Piai with 0.91% and the lowest nitrogen content in the organic deposit was in Pantai Kelanang with 0.47%. Commercial fertilizers, plant residue, sewage and animal manures can increase the percentage of nitrogen (Cai et al., 2020). Tanjung Piai mangrove forest located near to Pelabuhan Tanjung Pelepas, this might be one of the source of that contributed to the high percentage of nitrogen in the organic deposit sample.

Referring to Table 4.2, the heavy metals in organic deposit at Tanjung Piai, Johor have the highest concentration of Cu, Pb and Zn while Cd and Fe the highest in organic deposit sample from Pulau Ketam, Perlis. Various economic and shipping activities near to Tanjung Piai and Pualau Ketam might contributes the heavy metals content in the organic deposits. Heavy metals have a particular significant in ecotoxicology as they are highly persistent and have the potential to be toxic to living organisms if their concentration reaches above certain threshold bio-available levels (Zulkifli et al., 2010). The results of heavy metals contained in organic deposit as shown in Table 4.2 shows that concentration of Cd, Cu, and Pb at Tanjung Piai exceed limits set for bio-waste compost in European countries and United Stated of America. Some organic deposits have the ability to be an efficient absorbent material for oil such as activated carbon, chemical synthetic organic materials, porous material and oil absorption resin (Peng et al., 2016). Due to this ability, it can inevitably encounter some drawbacks including secondary pollution to the ocean (Duan et al., 2015).

Based on the heavy metals contained in the organic deposit, further study on the influence of the organic deposit on the growth of *Rhizophora* spp. and sediments chemical properties have been carried out in Tanjung Piai mangrove forest. The fractionation of heavy metals been also done to see the mobility and availability of the heavy metals from sediment to the plant intake.

5.2 The growth of *Rhizophora* spp. at mangrove forest in Tanjung Piai, Johor

Mangrove species are variously adapted to cope with coastal wetland environment which is highly dynamic and harsh. According to figure 4.1, study plots with the present of organic deposit shows the highest increment compared to the site without organic deposit. Decomposed organic deposit were present in plot T3 and T4 while at T2, new organic deposit was present on the top of the sediment layer and at 9 to 30 cm of the sediment layer (Table 4.7). At T4, the mean of height increment of the *Rhizophora* spp. is 19 cm and at T3 with 15 cm. The decomposed of organic compound in the soil layer at T3 and T4 might lead to an increase in nutrient availability thus enhance the sediment fertility (FAO, 2005). However, Wechakit (1990) reported that the mean heights increament of *Rhizophora* seedlings was 45 cm for one year old stands. The mean obtained for the highest mean increment in the present study which is at T4 is 19 cm and it was only half that of Wechakit's. Tree height for *Rhizophora apiculata* normally exceeds 100 cm in two years after propagules are planted (Matsui et al., 2008). The relatively small mean tree height was presumably because of poor growth of the plants. The highest growth has been recorded during M1 to M3 (Figure 4.1) where less rain was recorded during June (M1) to September (M3) compared to M6 to M9 which it is raining season in December (M6) to March (M9). Topographic factors such as duration and the frequency of tidal inundation, which subsequently affects the oxidation sates, nutrient availability of the sediment, salinity, resulting in complex patters of nutrients supply and demand that contributes to the variable structure of mangrove forests (Reef et al., 2010). The pattern of mangrove seedling might be driven by the seasonal change in light availability for the maximum growth rates at end of the dry season when rainfall was low and solar radiation likely high (Padilla et al., 2004). Besides of the present of organic deposit, proper zone for mangrove restoration also play an important role for the growth of *Rhizophora* spp. According to Basyuni et al., (2018), the study that has been done by them found that 96% growth rate of *R. mucronata* was in the landward zone and it had compared with other two zones which is seaward and middle zones. Referring to Table 1 on the description of each study plot, T3 and T4 were located more on landward compared to T1 which is located in seaward zone. The physical conditions were critical for the survival and growth of mangrove in the study plots. Proper zone for mangrove restoration also play an important role for the growth of *Rhizophora* spp. According to Basyuni et al., (2018), the study that have been done by them found that 96% growth rate of *R. mucronata* was in the landward and it was compared with other two zones which is seaward and middle zones. Referring to Table 1 on the description of each study plot, T3 and T4 were located more on landward compared to T1 which is located in seaward zone. The physical conditions were critical for the survival and growth of mangrove in the study plots. Decomposition of organic deposit in sediments also an important process as it break down into simplest components. As organic deposit decomposed, nutrients are released and available for plants to use to grow.

For the survival of *Rhizophora* spp. at all study plot, Plot T2 recorded the lowest percentage survival of *Rhizophora* spp. as the location for plot T2 were relatively at high disturbance and harsh environments compared to the other three study plots. During M6, the percentage drops from 93.33% to 74.67% because there was a few fallen trees and drift wood seen around the plot due to big tidal before collecting data in M6 and cause the high mortality of *Rhizophora* spp. seedling at T2. Thus, physical damage could be the cause for the low survival rate of seedlings at T2. The horizon of sediment profile at T2 (Table 4.7) is C horizon and massive structure of the sediment also contribute the factors that affecting the survival of *Rhizophora* spp. seedling during the big tidal. Some of the *Rhizophora* spp. seedling did not survive might be due to poor growth considered to result from sediment properties of the sediments at study sites. Some also did not survive due to the natural mortality such as change in nutrient availability, spikes in salinity often cause of natural runoffs and also due to leaf loss and the remaining leaves may not be able to photosynthesize at a level to support the tree (Sippo et al., 2018). There are some seedlings missing from the plot which might be caused by the wild animals and also the corporate social responsibility (CSR) activity done at the study site especially at site T2, T3 and T4. Other than that, site that appears more exposed to wave which is T1 and T2 in this study, the mechanical disturbance associated with wave exposed might to be one of the reasons the mean of mortality rate higher as it caused lower percentage of silt in the sediments (Padilla et al., 2004). Table 4.10 shows the silt percentage at T2 is the lowest compared to other study site for both sediment depths. Mechanical disturbance associated with water movement has been identified as one of the causes of mortality of established mangrove seedlings (Thampanya et al., 2002). Balke (2016) suggested considering the incorporation of geomorphic knowledge into site planning and design for restoration activity. By approaching with geomorphic site, ecological condition, salinity concentration and recommended species will increase successful restoration and survival of the trees (Basyuni et al., (2018).

Plants tend to allocate nutrients at leaves to secure growth and are able to use nutrients stored in woody stems to fulfill the needs of leaves when nutrients are limited (Leghari et al., 2016). Plant with sufficient nitrogen typically exhibit vigorous plant growth and development, produce rapid early growth, stimulates root growth and improves fruit quality (Zhang et al., 2018). Table 4.3 shows the nitrogen content in *Rhizophora* spp. leaves where there are no significant different ($p>0.05$) in mean total percentage of total nitrogen. Nitrogen availability in soil can fluctuate due to factors such as temperature, soil type, pH and precipitation (Tatsumi et al., 2019). Therefore, the preferred form in which nitrogen is taken up depends on plant adaptation to soil conditions (Gopalakrishnan et al., 2017). Nitrogen is not directly available to plants and it need to be converted to available forms such as urea by the microorganisms (Nordhaus et al., 2017). Majority of nitrogen in inorganic forms of NH_4^+ and $NO_3^-$was plant-available (Pradisty et al., 2021).

Heavy metals like iron, copper, vanadium, and manganese occur naturally in the environment and could serve as plant nutrients depending on their concentration. Some might be indirectly distributed from human activities and could be toxic even at low concentration such as mercury, lead, cadmium and chromium (Khosropour et al., 2019). Table 4.4 shows the concentration of heavy metals in *Rhizophora* spp. leaves and concentration of Mn were the highest compared to other heavy metals. Mn is a major contributor to various photosynthetic processes (Ariyanto et al., 2019). Mn deficiency in plants may cause lower numbers of chloroplasts, decrease in chlorophyll content, lower net photosynthetic efficiency and higher susceptibility to pathogen infections (Alejandro et al., 2017). Critical concentration of Mn deficiency is generally below 10 to 20 mg kg^{-1} (Alejandro et al., 2020). The result for Mn concentration in *Rhizophora* spp. leaves in Tanjung Piai mangrove forest were above the critical concentration for Mn deficiency. However, high concentration of Mn may cause toxicity to the plant. Toxic Mn concentration are highly dependent on plant species and genotype (Fernando and Lynch, 2015). Excessive Mn can prevent the uptake and translocation of essential elements such as Ca, Fe, P and Mg (Yamaji et al., 2013), cause decline in the photosynthetic rate (Lambers et al., 2015), and inhibit chlorophyll biosynthesis (Blamey et al., 2015).

Second highest metal found in *Rhizophora* spp. leaves after Mn is Fe. Same as Mn, Fe also involve in chlorophyll synthesis and the reason for the chlorosis (yellowing) appear at leaf surface is associated with Fe deficiency (Yoneyama, 2021). Deficiency of Fe uptake may be caused by competition by other cations in the soil, such as calcium and manganese (Kathpalia & Bhatla, 2018). In waterlogged soils condition, concentration of soluble iron may increase by several orders of magnitude because of low redox potential. Fe may be taken up in excessive quantities and it is potentially toxic and can promote the formation of reactive oxygen-based radicals, which are able to damage vital cellular constituents by lipid peroxidation (Mezzaroba et al., 2019). However according to Karimian et al. (2018), increase in the concentration of available Fe in acidic or flooded soils may result in excessive adsorption of Fe and often reaching levels of toxicity. Other than that, the present of organic matter like organic deposit can promote the availability of Fe, presumably through the supply of soluble complexing agents that interfere with fixation (Vardhan et al., 2019).

5.3 Physico–chemical properties and fractionation of heavy metals of mangrove sediments at different localities

Mangrove soil suitability is based of C horizon which is a marine clay parent material and one of the determining factors for the success of mangrove planting (Wan Rasidah et al., 2015). The deeper the C horizon in the soil profile, the firmer the soil, and thus the better for mangroves (Wan Rasidah et al., 2015). Both T3 and T4 have same textural class and similar particle size distribution for both sediment depths (Table 4.10). The textural class for T3 and T4 is clay which the percentage of clay is the highest compared to sand. High percentage of silt and clay can increase the mobility and availability of heavy metals. Clay is the main parameter which can control the concentration of heavy metals as it can absorb heavy metals from water and have an ability to retain the heavy metals in the sediment (Nduka and Orisakwe, 2011).

Soil pH can be an excellence indicator for a soil suitability for plant growth as it is significantly affect the nutrients uptake (Gondal et al., 2021). According to Pazi et al. (2016), soil pH decreases with increasing distance from the water edge and due to sulphur reducing bacteria and the presence of acidic clays and mangrove soils are generally neutral to slightly acidic. As shown in Table 4.11, the pH value of mangrove soils in Tanjung Piai were neutral to slightly acidic. Pazi et al., (2016) had done a study on comparing the soil chemical properties among the zonation between seaward, middleward and landward zones of mangrove forest. From his study, the pH of seaward zone was higher compared to middleward and landward zones as it might be affected by seawater than freshwater. Seawater is probably one of the factors in determining soil pH of mangrove forest (Islam et al., 2019). Same as the result from this study, soil pH at T1B and T1F which located at seaward zonation were higher compared to other study site.

Nitrogen in mangrove forest relies on nitrification, ammonification and dissimilatory reduction of ammonium (Alongi, 2018). The decomposition of organic deposit in soil at T3 and T4 has liberated nitrogen as ammonia and subsequently converted into soluble or nitrate form which is readily available and useable to the plant (Kida et al., 2019). At T1B and T1F which are located at seaward zone and easily flooded during tides might have he organic deposit being washed away.

The total organic carbon in the sediments are high at T3 and T4 at both depths which contributes to the growth performance of *Rhizophora* spp. at this study sites. Carbon is important to sediment productivity and function, and a main component of and contributor to healthy sediment conditions (Schlesinger & Andrews, 2000). Organic matter that present in the soil will lead to increase in total organic carbon levels in the sediment (Havlin et al, 2005). The contributions of carbon sources in mangrove forest may reflect either pure mangrove litter, organic materials that has been brought in by tides or rivers that deposited along with mangrove detritus, stage of decomposition or a variable contribution by other carbon sources (Kristenen et al., 2008). Organic carbon is important to chemical composition and biological productivity including fertility and nutrients holding capacity of the sediment. As carbon stores in sediment increase, it will reduce the risk of loss to other nutrients through erosion and leaching which will enhanced overall agricultural productivity (Schlesinger & Andrews, 2000) and it shows as in Table 4.16, the amount of CEC in T3 and T4 were the highest compare to plot T1F, T1B and T2. Majority of the nutrient pool of mangrove forest is stored in the sediment and not in the trees (Alongi et al., 2003). The decomposition of the organic matter facilitates nutrient availability and is a major source of nutrients in mangrove ecosystem (Milne et al., 2015). Among sediment properties, organic matter is likely to play a key role in promoting tree growth as it will improve sediment structure and facilitate root growth, and organic matter decomposition will provide nutrients to trees (Matsui et al., 2008). High level of carbon allocation to roots in many forests in conjunction with mangrove litter fall and low rates of decomposition imposed by anoxic sediments results in mangrove ecosystems being rich in organic matter (Komiyama et al., 2008). The concentration of organic carbon was more than 1%, therefore the nutrient conditions of the sediments at Tanjung Piai mangrove forest were not in poor nutritional conditions. If the value of organic carbon were less than one per cent, it indicates the poor nutritional conditions of the sediments of the mangrove forests (Rambok et al., 2010).

The concentration of available phosphorous at T2 were the highest among other study site. Concentration of available phosphorus were derived from several sources such as mineralization of organic phosphate, anthropogenic sources such as agricultural runoff and sewage effluent, natural weathering of phosphate minerals and solubilization of metal phosphate precipitates or phosphate absorbed onto clays (Venkiteshwaran et al., 2018). However, excessive amount of phosphorous will stimulates the growth of various microorganisms, eutrophication, clogging and ecosystem deterioration (Azam et al., 2019).

Other than sediment texture of clay contributes to the heavy metal concentration in sediment, sediment pH also had the greatest impact on the desorption and bioavailability of heavy metals due to its strong effects on solubility and speciation of heavy metals both in sediment as a whole and particularly in the sediment solution (Muhlbachova et al., 2005). Referring to the correlation between heavy metals and sediment pH in Table 4.26, only Zn and Mn have positive correlation with sediment pH while others show negative correlation with sediment pH.

The concentration of Zn was the highest among other heavy metals in the sediments (Table 4.24). Zn plays an important role in cellular metabolism and can be regulated by organisms in their body (Chaiyara et al., 2013). Zinc is one kind of heavy metals regarded as serious pollutant in aquatic ecosystem because of its environmental persistence, toxicity and ability to be incorporated into food chains (Kishe and Machiwa, 2003). Mangrove plants were also known to absorb and accumulate heavy metals in tissues and Zn mostly accumulated in mangrove roots, while lower accumulation in leaves and stems (Kumar et al., 2010). This explain why zinc was mostly not detectable in *Rhizophora* spp. leaves in Table 4.4.

The mobility and immobility of heavy metals along with their availability in sediment largely depend on their types of binding forms. The mobility and availability of the metals decrease in order of acid soluble fraction > reducible fraction > oxidizable fraction > residual forms (Zimmerman & Weindorf, 2010). The first two fractions, acid soluble and reducible fractions constitute a more available form of the metals. The last two fractions, oxidizable fraction and residual fraction form a less available pool (Alvarez et al., 2002). According to Rauret (1998), the concentration of the first three fractions (acid soluble + reducible + oxidizable) are mobile fractions.

Cd, Pb and Zn are mostly present in the residual fraction of all the samples. The abundance of Cd, Pb and Zn in residual phase but in other geochemical phases was low indicating that these metals was more stable in this environment than the other metals. Cu fraction is found more bound to the organic matter than other elements in T2 and T3. Copper can easily complex with organic matters because of high formation of organic – Cu compounds (Fagbote & Olanipekun, 2010). The high concentration of acid soluble Fe and Mn indicated that the metal exits in the reduced form (Tessier et al., 1979).

Fractional distribution of cadmium indicates that major portion is bound to residual fraction at all of the sites in Tanjung Piai mangrove forest. Only negligible amount (1.44% to 42.95%) of Cd released from non-residual fraction and 57.05% to 98.56% in residual fraction. The high concentration of metal present in inert phase (residual) being lattice and detrital origin which can be taken as natural sources (Singh et al., 2003).

Higher percentage of heavy metals in the non-residual fraction reflect a greater tendency to become bioavailable. The higher percentage of Fe and Mn in the bioavailable non-residual fraction indicated that their bioavailability and mobility in the sediments of Tanjung Piai mangrove forest were high. So, the potential hazards of Fe and Mn were larger than Cd, Pb and Zn which occurred mostly in the residual fraction. Heavy metal contamination can lead to increased heavy metal concentration in the non-residual fraction, reflecting the intensity of anthropogenic influence (McLaren et al., 2004). In this study, high mobility and greater availability of Fe and Mn indicate the environmental pollution and can pose a critical toxicity risk in plant production areas over time.

According to Table 4.4, the results of heavy metal content in *Rhizophora* spp. leaves show high concentration of Fe and Mn which support the fractionation result of Fe (Table 4.7 and Table 4.8) and Mn (Table 4.9 and Table 4.10) at each plot where their mobility percentage are high. Mobility and plant uptake of heavy metal proceed through the solution phase. The heavy metal uptake of plant depends not only on its activity in the solution, but also on the relation existing between solid-phase ions and solution ions (Violante et al., 2010). Significant amount of Mn was detected in the reducible fraction, which Mn exists as oxides and may be released if the sediment is subjected to more reducing conditions (Panda et al., 1995). According to Peng et al., (2004), considerable amount of Mn may be released into environment (reducible fraction) if conditions become more acidic and referring to the fractionations results, percentage of Mn in reducible fraction increase at T3 and T4 as the pH value of the sediments were more acidic compare to T1F, T1B and T2.

5.4 Correlation of sediment physico-chemical properties on the concentration of heavy metals and in sediment and plant

Sediment pH and organic matter are both important physical and chemical properties in sediment. Analyzing the correlation between them and the content of heavy metals in sediment can not only explain the migration and transformation rues of different forms of heavy metals, but also can be used for sediment remediation and land use in mangrove areas to provide a scientific basis (Li at al., 2009).

Table 4.26 shows that pH is positively correlated with Zn and Mn, indicating that as sediment pH increases, total of Zn and Mn will increase. Metals such as Fe, Cu and Zn are essential micronutrients to life in right concentrations, but in excess, these chemicals can be poisonous. According to Chen et al., (2011), when pH in water falls, metal solubility increases and the metal particles become more mobile. Unlike some organic pesticides, metals cannot be broken down into less harmful components in the environment.

The *Rhizophora* spp. growth were positively correlated with N, C, CEC, Exch Mg., and Exch K. Plant growth and development largely depend on the combination and concentration of mineral nutrients that are available in sediment. Nutrient deficiency may cause stunted growth of plant, death of plant tissue or yellowing of leaves caused by reduced production of chlorophyll that needed for photosynthesis (Schmidt et al., 2014).

CHAPTER 6: CONCLUSION AND RECOMMENDATION

The chemical composition of organic deposit at three different locations shows sample from Tanjung Piai have the highest concentration of nitrogen, Cu, Pb and Zn. The concentration of Pb and Cd in the organic deposit from Tanjung Piai exceeds level set for bio-waste in Europeans countries and United States. Heavy metal toxicity can damage and alter the functioning of organs in human body. Long-term expose of some heavy metals may cause cancer. As for mangrove stand, heavy metals can alter the composition and activity of soil microbial communities thus, adversely affects mangrove growth and genetic variation.

The growth performance and survival rate of *Rhizophora* spp. in Tanjung Piai, it is the highest at the study sites with present of composed organic deposit as it might lead to increase in nutrient availability thus enhance the sediment fertility. The percentage of nitrogen and carbon at study sites also shows higher percentage at study plot with decomposed organic deposit which is at T3 and T4. The fractionation of Fe and Mn indicates that this two metals the most mobile and the highest in availability for plant uptake. The growth of *Rhizophora* spp. in Tanjung Piai mangrove forest were positively correlated with N, C, CEC, Exch Mg. and Exch K.

Therefore, further study on ecological risk and human health risk assessment is recommended to evaluate the exposure to human and terrestrial animals that inhibited within the vicinity of the mangrove forest.

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