MANGROVE SEDIMENT QUALITY INDEX IN MATANG MANGROVE FOREST RESERVE, PERAK, MALAYSIA

By

AHMAD MUSTAPHA BIN MOHAMAD PAZI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Doctor of Philosophy

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December 2020

Chairman : Associate Professor Seca Gandaseca, PhD
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Mangrove forests have an integral role in the protection of ecosystem, hydrological and sedimentation regulatory functions. In addition, mangrove sediment can trap pollutants discharged through domestic, industrial and agricultural activities. Therefore, it is essential to assess sediment quality in the presence/absence of heavy metals that are toxic to most living organisms. Hence this study aims to develop a mangrove sediment quality index (MSQi) in Matang Mangrove Forest Reserve, Perak Peninsular Malaysia. The specific objectives of this study are: (i) to develop Mangrove Sediment Quality Index at Matang Mangrove Forest Reserve, (ii) to compare selected MSQi parameters between mangrove environment factors and (iii) to validate Mangrove Sediment Quality Index at Setiu Wetland, Terengganu and Kukup Island, Johor. The sampling areas were selected that relied on distinct levels of mangrove disturbance (highly disturbed, moderately disturbed and least disturbed). At 1.5 meter depth, sediments were sampled into five segments (0-15, 15-30, 30-50, 50-100 and 100-150 cm). A Total of 19 variables (Sand, Silt, Clay, EC, pH Water, N, P, K, Ca, Mg, Mn, Fe, Pb, Zn, Cu, Cd, Cr, Ni and Na) were analysed to determined sediment physico-chemical properties using the standard method of soil analysis. In developing MSQi, Principal Component Analysis (PCA) was used to find 4 important parameters then the MSQi modelling was developed using Microsoft excel to classify the level of mangrove sediment as I=Very Bad, II=Bad, III=Moderate, IV=Good and V=Excellent. According to the results of this study, the nutrient and heavy metal content came out to be within permissible range. Four parameters (Pb, Zn, Cr and Ni) were chosen by PCA to be included in MSQi. The MSQi result showed that Tiram Laut River, during the dry season, was moderately polluted under class III. During the wet season, MSQi of Tiram Laut River was less polluted under class IV. Tinggi River, during dry season, was under class III and moderately polluted, except at seaward at sediment depth of 30-50 and 50-100 cm it was under class IV with low pollution. On the other hand, during the wet season, Tinggi River was moderately to low polluted. Lastly, Sepetang River during dry season was found under class III with moderate pollution and with low pollution during the wet season. In term of MSQI validation results showed Ular River and Setiu River at Wetland Setiu Terengganu shows that season plays an important role in balancing the sediment pollutions. During dry season most of the areas are polluted, whereas during wet season the area becomes less. In case of mangrove

zones and sediment depths, different results have been obtained for MSQi. Landward zone was more polluted than other zones except at Kukup Island where, seaward zone had more pollution during dry season and then changed to slightly polluted. Sediment depths can also influence pollution levels, which was observed in this study. As a conclusion of this study, MSQi development can be a benchmark and guideline in assessing sediment pollution in the mangrove ecosystem of Malaysia.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

Indeks Kualiti Sedimen Paya Bakau Di Hutan Simpan Paya Bakau Matang, Perak, Malaysia

Oleh

AHMAD MUSTAPHA MOHAMAD PAZI

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Hutan paya bakau mempunyai peranan penting dalam melindungi fungsi pengawalan ekosistem, hidrologi dan sedimentasi. Selain itu, sedimen bakau dapat memerangkap bahan pencemaran yang dihasilkan oleh aktiviti domestik, industri dan pertanian. Oleh itu, adalah penting untuk menilai kualiti sedimen kehadiran / ketiadaan logam berat yang beracun bagi kebanyakan organisma hidup. Oleh itu kajian ini bertujuan untuk membangunkan indeks kualiti sedimen bakau (MSQi) di Hutan Simpan Paya Bakau, Perak Semenanjung Malaysia. Objektif khusus kajian ini adalah: (i) untuk membangunkan Indeks Kualiti Sedimen Paya Bakau di Hutan Simpan Matang, (ii) untuk membandingkan parameter MSQi terpilih antara faktor persekitaran bakau dan (iii) untuk mengesahkan Indeks Kualiti Sedimen Paya Bakau di Setiu Wetland, Terengganu dan Pulau Kukup, Johor. Kawasan pensampelan yang dipilih bergantung kepada tahap gangguan bakau yang berbeza (sangat terganggu, sederhana terganggu dan paling sedikit terganggu). Pada kedalaman 1.5 meter, sedimen diambil pada lima segmen (0-15, 15-30, 30-50, 50-100 dan 100-150 cm). Sebanyak 19 pemboleh ubah (Pasir, Lompong, Tanah Liat, EC, pH Air, N, P, K, Ca, Mg, Mn, Fe, Pb, Zn, Cu, Cd, Cr, Ni dan Na) telah dianalisis bagi mendapatkan sifat fiziko-kimia sedimen dengan menggunakan kaedah standard analisis tanah. Dalam membangunkan MSQi, Analisis Komponen Utama (PCA) digunakan untuk mencari 4 parameter penting maka pemodelan MSQi dikembangkan menggunakan Microsoft Excel untuk mengklasifikasikan tahap sedimen bakau sebagai I = Sangat Teruk, II = Teruk, III = Sederhana, IV = Baik dan V = Cemerlang. Berdasarkan hasil kajian ini, kandungan nutrien dan logam berat berada dalam lingkungan yang dibenarkan. Empat parameter (Pb, Zn, Cr dan Ni) dipilih oleh PCA untuk dimasukkan ke dalam MSQi. Hasil MSQi menunjukkan bahawa Sungai Tiram Laut, pada musim kemarau, tercemar secara sederhana di bawah kelas III. Semasa musim hujan, MSQi Sungai Tiram Laut kurang tercemar di bawah kelas IV. Sungai Tinggi, pada musim kemarau, berada di bawah kelas III dan tercemar sederhana, kecuali di tepi laut pada kedalaman sedimen 30-50 dan 50-100 cm ia berada di bawah kelas IV dengan pencemaran rendah. Sebaliknya, semasa musim hujan, Sungai Tinggi mengalami pencemaran sederhana hingga rendah. Terakhir, Sungai Sepetang pada musim kemarau dijumpai di bawah kelas III dengan pencemaran sederhana dan dengan pencemaran

rendah pada musim hujan. Dari segi hasil pengesahan MSQI menunjukkan Sungai Ular dan Sungai Setiu di Wetland Setiu Terengganu menunjukkan bahawa musim memainkan peranan penting dalam menyeimbangkan pencemaran sedimen. Pada musim kemarau kebanyakan kawasan tercemar, sedangkan pada musim hujan kawasan menjadi kurang. Sekiranya zon bakau dan kedalaman sedimen, hasil yang berbeza telah diperoleh untuk MSQi. Zon darat lebih tercemar daripada zon lain kecuali di Pulau Kukup di mana, zon laut lebih banyak pencemaran pada musim kemarau dan kemudian berubah menjadi sedikit tercemar. Kedalaman sedimen juga dapat mempengaruhi tahap pencemaran, yang diperhatikan dalam kajian ini. Sebagai kesimpulan dari kajian ini, pembanggunan MSQi dapat menjadi penanda aras dan garis panduan dalam menilai pencemaran sedimen di ekosistem bakau Malaysia.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement of the Degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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’	minute
”	second
º	degree
ºC	degree celsius
%	percentage
N	north
E	east
cm	centimetre
g	gram
Ca	calcium
Cd	cadmium
Cr	chromium
Cu	copper
Fe	iron
GPS	global positioning system
H_2SO_4	sulfuric acid
ha	hectare
HCl	hydrochloric acid
HNO_3	nitric acid
K	potassium
KCl	potassium chloride
km	kilometre
L	litre
M	mole

m	meter
mg	milligram
Mg	Magnesium
mg/kg	milligram per kilogram
mL	millilitre
Mn	manganese
MSQi	mangrove sediment quality index
Na	sodium
Na	sodium
NaOH	sodium hydroxide
Ni	nickel
Pb	lead
ppm	parts per million
rpm	revolution per minute
SAS	statistical analysis system
Sp	species
SPSS	statistical package social science
TN	total nitrogen
TP	total phosphorus
Zn	zinc

CHAPTER 1

INTRODUCTION

1.1 General Background

Mangroves have an estimated are of around 15.2 million hectares, of which most are found in Statistic for Asia (Hectare of mangrove) (FAO, 2007). In Malaysia, mangroves are found on all coasts with 58.6% in Sabah, 24.4% in Sarawak and 17% in Peninsular Malaysia (Kanniah *et al.,* 2015). Malaysia has a total of 107,802 ha of mangrove forests of which 82,091 ha are gazetted as Permanent Reserved Forests (Jusoff and Taha, 2008).

Mangroves provide various economic and ecological services such as tourism, recreation, boating, fishing (Spalding and Parrett, 2019) and bird watching (Othman *et al.,* 2004). Between 1980 and 1990, most of the mangrove forest reserves in Malaysia decreased by 12% due to deforestation, land conversion to agriculture, shrimp farming, urban development and industrial development (FAO, 2007; Ibrahim *et al.,* 2015; Kanniah *et al.,* 2015). Due to these activities, mangroves have suffered from pollution, decline in water quality, reduction of biodiversity, destruction of habitat for fish and crustaceans (Ibrahim *et al.,* 2015).

Mangroves are under threat of the accumulation of pollutants which are transported through runoff from rivers and streams (Kruitwagen *et al.,* 2008; Maiti and Chowdhury, 2013). Metals are trapped in mangrove sediments through the formation of complexes with sulphides, particulate organic carbon, or iron oxyhydroxides (Zhang *et al.,* 2014). The distribution, behaviour and accumulation of these imported chemicals in the ecosystem are primarily defined by the hydrology of mangroves, geochemical properties of sediments and the class of pollutants (Kruitwagen *et al.,* 2008). The properties of the mangrove sediments provide optimal conditions for binding for a number of these pollutants. For instance, hydrophobic organic pollutants adsorb to the extensive surface area provided by fine particulate sediments of estuaries and mangroves (Chen and Hur, 2015).

Matang Mangrove Forest Reserve (MMFR) Perak comprises of more than 40 000 ha and the largest mangrove forest in Peninsular Malaysia. This forest lies on the North West coast of Peninsular Malaysia and occupies 51.5 km of coastline in the state of Perak, from Kuala Gula in the north to Bagan Panchor in the south (Azahar *et al.,* 2003). According to FAO, (2007) MMFR has been reported as sustainably managed since the start of this century. It is one of the very few examples of a successful sustainable management of a tropical forest ecosystem in the world. In addition to that MMFR provides employment for 2,400 people in the timber industry with a revenue of US$ 6 million per year. Further there is an associated fishing industry in the area which employs about 10,000 people with an annual revenue of USD 12-30 million.

Despite the timber extraction for charcoal production, MMFR provides protection for migratory birds, local forest birds (Othman *et al.,* 2004), commercial and non-commercial fishers and shrimp industry (Chong, 2007), cockle culture (Awang-Hazmi *et al.,* 2007) and fish cage culture (Alongi *et al.,* 2003). Moreover, this forest also provides the opportunity for bird watching activities (Ahmad, 2009) and natural defence against strong wind and tsunami (Tanaka *et al.,* 2007).

Along the coast of MMFR, mangrove stands are found at the river mouth, estuaries and island. Mostly anthropogenic pollutants are filtered from the river and accumulate in the sediments. Due to the capacity of mangrove sediments to trap chemicals, it can serve as an indicator of level of pollution in coastal and mangrove areas. Due to pollution protecting sediment is one of the critical issues in to improve water quality and prevent bioaccumulation of pollutants in the food chain.

The assessment of mangrove sediment quality indicates mangrove health in MMFR. To understand the dynamic of mangrove sediment, the basic knowledge of mangrove and sediment characteristics need to be understood. Thus, mangrove ecological factors such as wet/dry season, mangrove zonation and sediment depth need to be considered for mangrove sediment quality assessment. Therefore, the development of mangrove sediment quality index is projected to reflect the extent of influence from land conversion in MMFR and can act as a baseline to be used in other mangrove forest areas.

1.2 Problem Statement

There are many studies in assessing and monitoring sediment quality worldwide (Praveena *et al.,* 2007; Aris *et al.,* 2014; Mustapha *et al.,* 2017). In Malaysia, there is no appropriate index to assessing sediment quality in mangrove forest, specifically in assessing and monitoring mangrove sediment quality in mangrove forest. The methods currently being used are not appropriate since they do not integrate seasonal effects, zones and tidal effects (Mustapha *et al.,* 2017). Due to the complex interactions of above-mentioned factors in determining the quality of mangrove sediment, a comprehensive assessment of all integrating factors at the ecosystem level is needed to select appropriate indicators that could adequately reflect its real-time health status. However, not all factors can be included in establishing the Mangrove Sediment Quality Index. Thus, this study aims to develop mangrove sediment quality index with help of (seasons, mangrove zones and sediment depths) in MMFR, Malaysia.

1.3 Justification and Significance of the Study

Most of the mangrove near semi urban and urban areas in Malaysia are slightly polluted (Wang *et al.,* 2017). Several anthropogenic activities have continued to degrade the mangrove environment (Aris *et al.,* 2014). Some of the mangrove rivers in the areas being industrialized are heavily contaminated. They have lost their natural ecosystem due to rapid urbanisation and developmental activities around the area (Pauchard *et al.,* 2006). Mangroves provide a high proportion of the water for domestic, aquaculture,

agriculture, industrial and ecological needs in both landward and seaward areas (Hein, 2002). The relationship between forest, soil and water is a critical issue that must be given high priority. Although some of these occur naturally, with or without the presence of plantations, many adverse impacts are clearly due to poor forest management practices. This study will result in the development of an index in assessing mangrove sediment quality, provide useful information and understanding on mangrove sediment pollution.

1.4 Research Framework

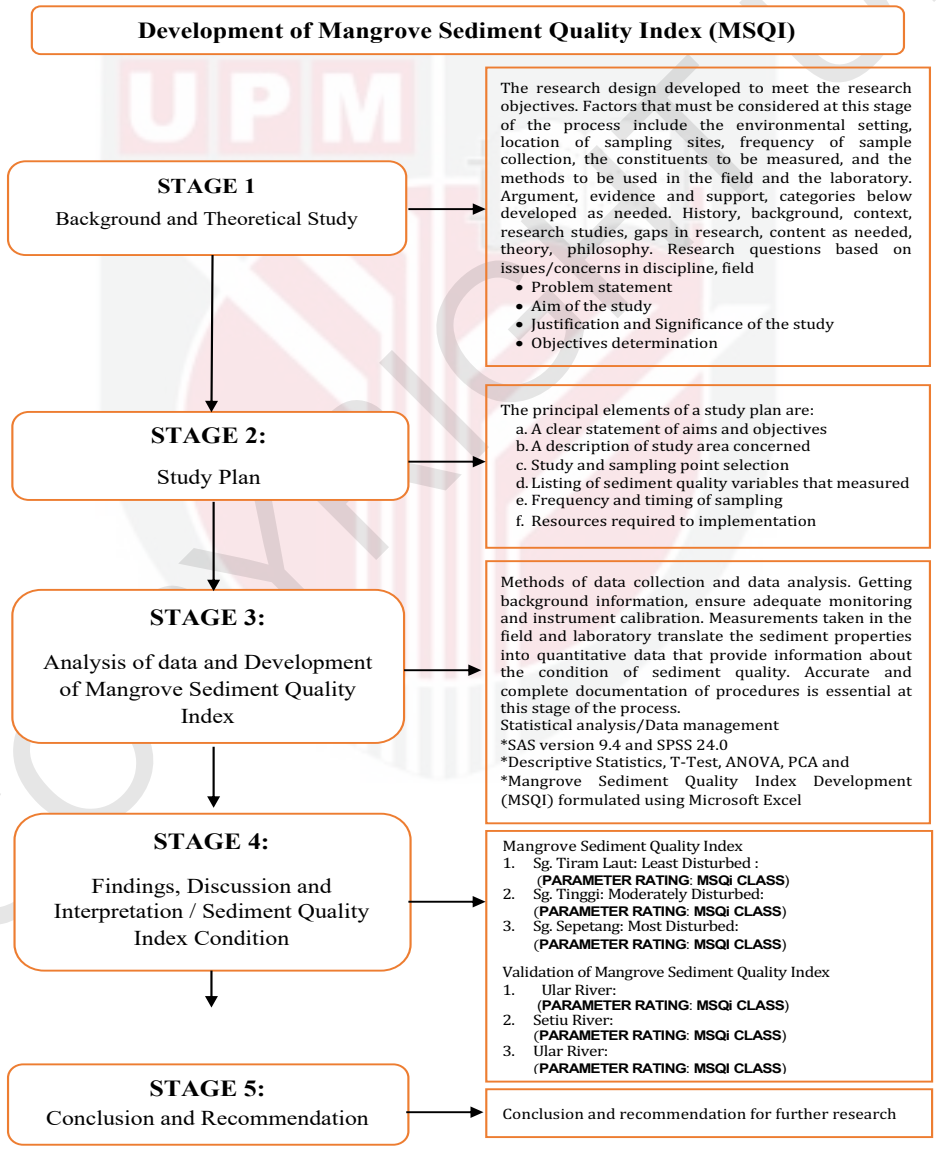

Figure 1.1: Research Framework

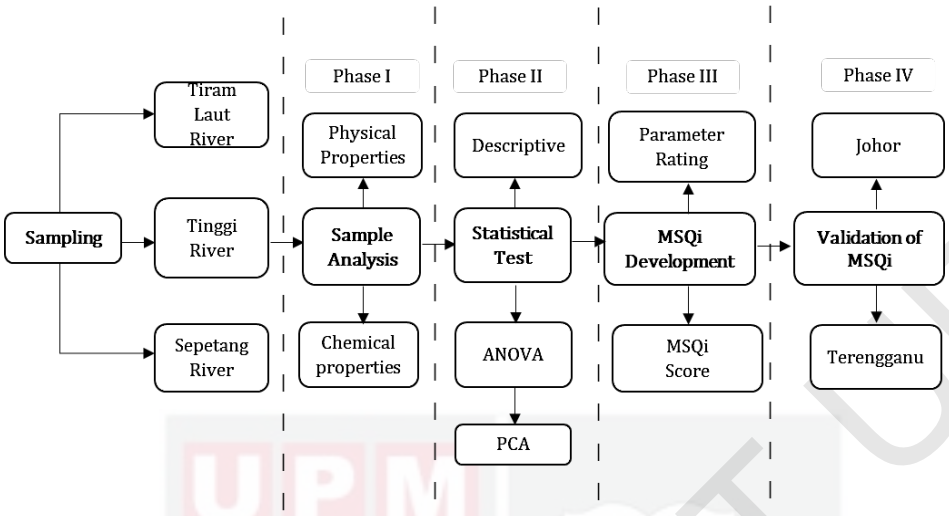

Figure 1.2: Sampling and Data Processing Framework

1.5 Objectives

The general objective of this study is to develop mangrove sediment quality index, and the specific objectives of this study are:

i. To develop the Mangrove Sediment Quality Index at Matang Mangrove Forest Reserve.

ii. To compare the selected MSQi Parameters between three different levels of disturbance (least disturbed, moderately disturbed and most disturbed) between mangrove environment factors (seasons, mangrove zones and sediment depths)

iii. To validate Mangrove Sediment Quality Index at Setiu Wetland, Terengganu and Kukup Island, Johor.

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