CHAPTER 1: GENERAL INTRODUCTION

Matang Mangrove Forest Reserve, Perak

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1.0 Mangrove

Mangroves are a group of coastal plants with similar adaptations that exceed a half meter in height and grow primarily in the intertidal zone (Duke, 1992). Mangroves are found in warm humid climates usually between 25°N and 25°S latitude. They exist as low shrubs in harsh conditions and can attain over 40 m in height under favourable conditions. They are viviparous and possess a variety of adaptations that allow them to survive in saline habitats, salty water, and reduced soils. Mangroves have a competitive advantage over other plants in saltwater areas. They can survive in fresh water environments, but they are poor competitors there. Mangroves remove excessive salt by either excreting salts or by excluding salts. Mangroves also have special aeration structures that include above ground prop roots or pneumatophores to accommodate the lack of gaseous exchange in the stagnant muck, typical of their habitat.

Mangroves are highly productive and play an essential role as a major primary producer within estuarine systems. Mangrove systems serve as habitant and nursery area for many juvenile fish and crustaceans, which have both direct and indirect socio-economics importance. They also provide erosion mitigation and stabilization for adjacent coastal landforms (Harty, 1997).

In Malaysia, mangroves occur primarily in the States of Perak, Selangor and Johor in the Peninsular Malaysia, along the east coast of Sabah, and in the northern and southwestern Sarawak. Mangroves are great economic importance, supporting commercial fish and prawn fisheries, sustainable exploitation for timber, protecting the coastline from erosion and providing over 50 different products of use to local inhabitants. Malaysian mangroves support variety of endangered species of wildlife such as proboscis monkey *Nasalis larvatus,* estuarine crocodile *Crocodylus porosu*s as well as many other highly specialized species whose survival depends on the existence of the mangrove ecosystems.

Despite their importance, mangrove ecosystems have been exploited and subjected to inappropriate management practices in terms of land reclamation and unsustainable forestry, as well as agricultural and aquaculture initiatives (Eong, 1995). As a result of their closeness to urban development, they have experienced significant direct contaminant input. Among the major pollutants from an anthropogenic input are heavy metals (MacFarlane, 2002).

Enhancement of metals in mangrove environments arises from urban and agricultural runoff, industrial effluents, boating and recreational use of waterbodies, chemical spills and sewage treatment plants. The metal pollutants most commonly entering estuarine systems through industrial sources are Cu, Pb and Zn (Mills, 1995). These metals therefore occur in high concentrations in many estuaries, with concentrations reaching up to 1,000 µg/g Cu, 1,000 µg/g Pb and 2,000 µg/g Zn in contaminated sediments (Irvine and Birch, 1998).

1.1 Matang Mangrove Forest Reserve

The Department of Forestry has reviewed the Management Plan for the Matang Mangroves once every ten years. In 2004, it has been reported that 7,360 hectares, about 18% of the total forest area is reserved as total protection and no logging is permitted in this "unproductive forest" which is a legal definition which means that no amount of timber extraction is allowed (Azahar *et al*., 2004). A total productive forest area of 29,794 hectares (74%) and restrictive productive forest of 2,892 hectares (7%) has sustainable production of timber outputs, mainly for the production of charcoal and construction poles. *R. apiculata* is the preferred timber for charcoal production. Construction poles are other plant product or by-product and *Bruguiera* poles are equally as acceptable as *Rhizophora* poles. The current management plans are based on a 30-year rotation with two thinnings between 10-15 year and 20-25 year. About 1,000 hectares of forest (3 % of total productive forest) are felled annually in small lots (179 tonnes/ha). Roughly, one half of these lots clear-felled sites are allowed to generate naturally, the remainder are manually replanted (Alongi *et al*., 1998).

The waterways of MMFR make up a total surface area of 8,653 hectares with a mean water depth of 5 metres (Sasekumar *et al*., 1994). These waterways form the important sites for fish cage aquaculture (Alongi et al., 2003). The mudflats in this area are important culture beds for cockles (*Anadara granosa*), other marine fauna, especially fish and prawns and baited trap catching of mud crabs (*Scylla serrata*). Furthermore, they also provide refueling and roosting sites for large numbers of migratory birds.

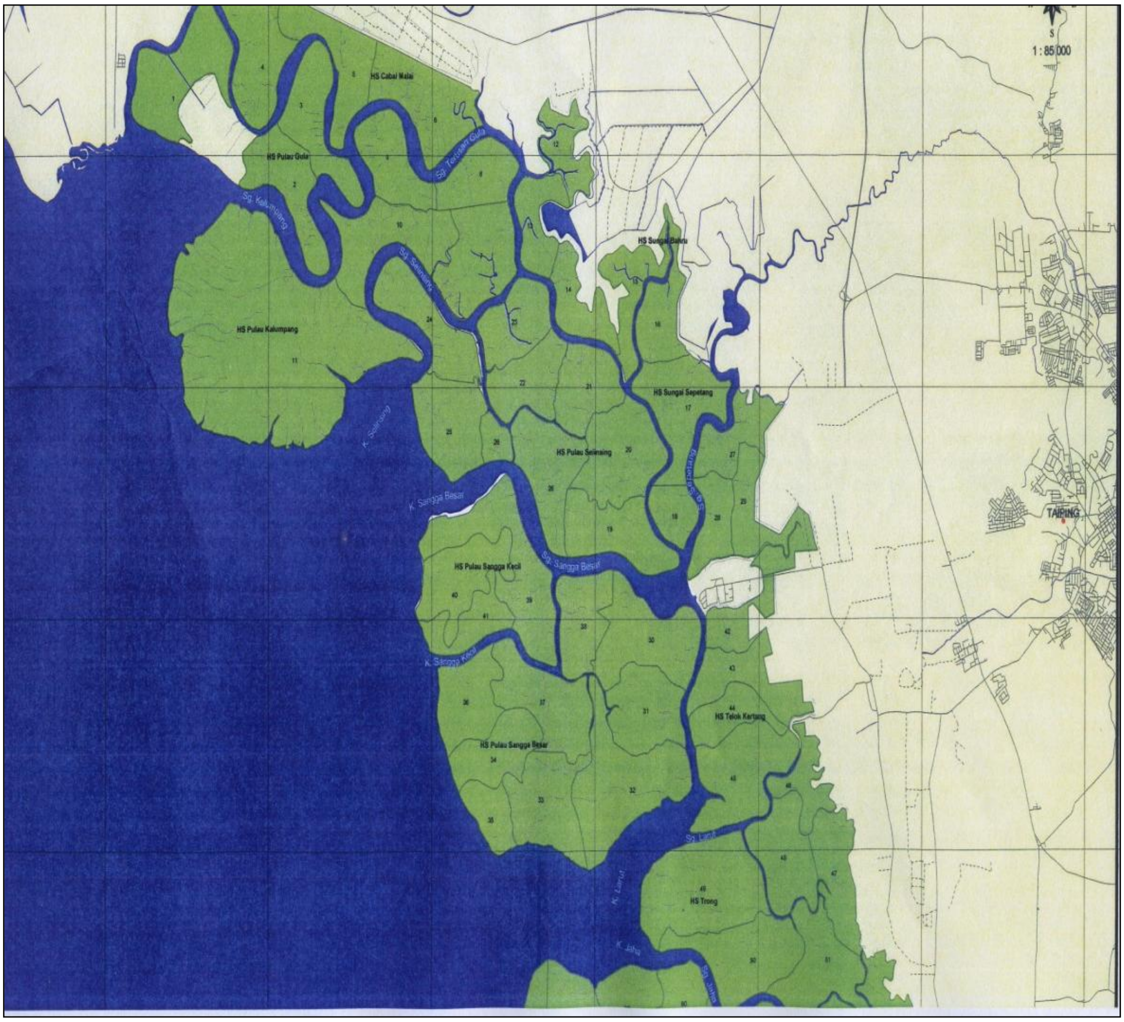

Figure 1.1: Matang Forest Reserve at the river-mouth of Sepetang River

(Source: Kuala Sepetang Master Plan 2007)

1.2 Importance of Mangrove to Prawns

Landings of prawns in Malaysia in the 1970s, adjusted to the area of intertidal substrate were recalculated as 202 kg ha^{-1} which highlights the productivity of the waters of western peninsular Malaysia. It has been reported that the major contribution of Perak to the prawn fishery of western peninsular Malaysia for total landings is about 50% and those of white prawns is about 35% (Loneragan *et al*., 2005). The largest landing centre in Perak (Kuala Sepetang) is situated in the Larut Matang mangrove forest reserve, which has the largest area of mangroves in peninsular Malaysia (Gan, 1995). The total prawn landings from Perak, taken from only 270 km of coastline, are similar in magnitude to those for the whole of Australia which is about 25, 000 metric tonnes (Preston *et al*., 1997). Likewise, the landings of white prawns from Perak are about 50–60% of the annual banana prawn catch recorded in the Australia's Northern Prawn Fishery with over 6,000 km coastline (3000 to 4000 metric tonnes, Somers and Wang, 1997).

The landings of prawns in Perak for 1998, 2004 and 2005 were 19,779, 24,850 and 14,165 metric tonnes, respectively. The landing data represented 35%, 54% and 51% of the total landings of prawns in the West coast of Peninsular Malaysia for 1998, 2004 and 2005, respectively. The decrease in landings of prawns in 2005 as compared to 2004 was due mainly to the Tsunami effect during December 2004. However, the overall percentage of landings in Perak /West coast of the Peninsular Malaysia remained above 50%. The common species of prawns are *Metapenaeus lysianassa*, *Penaeus merguiensis* and *Parapenaeopsis sculptilis*. Most of these species are also available in the Matang mangrove forest (Chong, 2004).

1.3 Cockles Production in Matang Mangrove Forest

The mud flats adjacent of the Matang Mangrove Forest are suitable cultural areas for cockle production. The soft flocculent mud of at least 45-75 cm thick and salinity level of 18-30 ppt are ideal for cockle culture. In 2005, there were 237 culturists, operating on 5,220.8 ha of mud-flats in Perak. At least half of culturists operated in the Matang Mangrove Forest and about 63% of cockle producing mud-flats in Perak. Kuala Sangga is the most important cockle production area, occupying at least 30% cockle producing area in Perak. The total production of cockles in Matang was 32,612 and 28,342 tonnes in 2004 and 2005, respectively. The Matang Mangrove Forest Reserve produces about 50% of the total cockles in Malaysia. The production in 2006 was also low (24,671 metric tonnes) as the supply of cockle seeds/spat may be limited. Matang produces only 5-10 % of the cockle seeds/spat and most of the cockles seeds are supplied from the State of Selangor. The drop of cockle production in 2005 was due to Tsunami effect. Many of cockle spat were slow to grow to adult (marketable) size of about 25mm long and died off before reaching adult size. Furthermore, the supply of cockle seeds was not available. Nevertheless, the total wholesale value of cockles in 2005 was estimated at RM 30 millions.

1.4 Heavy Metals

Heavy metals have been used by human in many different areas for thousands of years. This use influences their potential for health effects in at least two major ways, firstly by environmental transport that is by human or anthropogenic contributions to air, water, soil and food and secondly by altering the speciation or biochemical forms of the element (Beijer *et.al.*, 1986). Although several adverse health effects of heavy metals have been known for long time, the exposure to these elements continues.

The term heavy metal includes both essential and non-essential trace metals, which may be toxic to the organisms depending on their own properties, availability (chemical speciation), and concentration levels. Heavy metals (Ag, As, Cd, Cu, Cr, Hg, Ni, Pb, and Zn) can be present in the aquatic system in both dissolved forms (which can cause toxic effects on a wide diversity of organisms, including vertebrates) and particulate ones (including adsorbed on sediments, suspended particulate matter or colloids, in transitional complexes, and Fe/Mn hydroxides nets, linked to organic matter and carbonates.).

Metal toxicity usually arised from metal forming complexes with organic compounds. The metallo-organic molecules lose their ability to function properly, often causing the affected cell malfunction. Metals commonly bind to biological compound containing oxygen, nitrogen and sulphur and deactivate certain enzyme systems. Large excess of metals ion can affect the membrane and mitochondrial function. In most cases metal toxicity causes general weakness and malaise.

Heavy metals are introduced into the environment through various routes, such as smelting processes, fuel combustion, and industrialization. These activities cause air pollution and associated atmospheric deposition of contaminated dust. Solid and liquid wastes emanating from the industrial activities contain toxic chemicals such as chromium salts, sulphides and other substances including heavy toxic trace metals (Tariq *et al*., 2006). Other important potential anthropogenic sources of heavy metals include sewage sludge, phosphate fertilizers, manure and deposition of contaminated river sediments. Cu, Pb, Zn, and Cd are the most common contaminants in the aquatic environment, and their levels in water, sediment, and organisms are usually monitored.

Water bodies contaminated by heavy metals may lead to bioaccumulation in the food chain of an estuarine environment. Contaminants are transported from it sources through river system and deposited downstream. Estuary is a potential sink of pollutants since most of the pollutants could be mixed and became solid and bottom sediment through sedimentation, (Morisey *et al*., 2003).

1.5 Metal Speciation and Toxicity

The term heavy metal is applied to the group of metals and semimetals that have been associated with contamination and potential toxicity or ecotoxicity. It usually refers to common metals such as copper, lead or zinc. Still, the term is only loosely defined and there is no single authoritative definition. Some define a heavy metal as a metal with an atomic mass greater than that of sodium, whereas others define it as a metal with a density above 3.5-6g cm^{-3}. As mentioned before, the term also applies to semi metals such as arsenic, presumably because of the hidden assumption that heaviness and toxicity are in some way identical.

1.5.1 Copper

Copper, is a member of the IB group in the periodic table, occurs naturally in sandstone and in minerals such as malachite and chalcopyrite. It is a reddish brown metal that binds strongly to organic matter and clay minerals, thus decreasing its mobility. However, the organic matter can be degraded through anaerobic or aerobic means, releasing the copper in its monovalent or divalent states, respectively (Cameron, 1992). Copper compounds are used in agriculture to treat mildew and other plant diseases. Copper is widely used in the food industry as preservatives, additives, or coloring agent; in preservatives of wood, leather and fabrics (Roncero *et al.*, 1992).

Copper is absorbed by the small intestinal epithelial cells by specific copper transporters or other nonspecific metal ion transporters on the brush-border surface. Once copper is absorbed, it is transferred to the liver. Liver, brain and kidney tissues contain higher amounts of copper per unit weight than muscle and other body tissues.

The acquired copper deficiency in adults is rare, with most cases of deficiency premature and normal-term infants. The deficiency can lead to osteoporosis, osteoarthritis and rheumatoid arthritis, cardiovascular disease, chronic conditions involving bone, connective tissue, heart and blood vessel and possibly colon cancer. Other copper deficiency symptoms include anaemia, neutropenia, hypopigmentation and abnormalities in skeletal and immune system functions. Even a mild copper deficiency, which affects a much larger percentage of the population can impair health in many ways.

1.5.2 Zinc

Zinc is a bluish-white metal which dissolves readily in strong acids. In nature it occurs as a sulphide, oxide, or carbonate. Zinc ligands are soluble in neutral and acidic solutions, so that zinc is readily transported in most natural waters. Zinc oxide, the compound most commonly used in industry, has a low solubility in most solvents. Zinc bioavailability and toxicity to aquatic organisms are highest under conditions of low pH, low alkalinity, low dissolved oxygen, and high temperatures. Soluble chemical species of zinc are the most bioavailable and most toxic.

Zinc toxicity to aquatic organisms depends on the physical and chemical forms of zinc, the toxicity of each form and the degree of interconversion among them. Fish is relatively unaffected by suspended zinc, but many aquatic invertebrates and some fishes may be adversely affected if they ingest enough zinc-containing particulates. Zinc toxicosis affects freshwater fishes by destruction of gill epithelium which may result in tissue hypoxia.

Zinc is an essential trace nutrient and forms part of many enzymes needed for growth and development and DNA synthesis. Zinc metalloenzymes play an important role in many aspects of cellular metabolism, including DNA replication, repair and transcription protein synthesis, and energy metabolism. In humans and animals, long-term exposure to excess levels of zinc may result in copper deficiency, reduced immune function, anaemia and damage to the liver, pancreas, and kidneys (ATSDR, 2006).

1.5.3 Cadmium

Cadmium can form complexes with other ions and compounds. The four main species are cadmium halides, cadmium sulphide, cadmium oxide and organocadmium compounds. Cadmium is used primarily in metal plating and the manufacture of pigments, batteries and plastics The main anthropogenic sources of cadmium are ore mines, metallurgical industries and sewage sludges.

Various forms of cadmium ions and compounds can be found in freshwater and seawater. The inorganic speciation of cadmium in water has similarities to that of lead, but is simplified in that the free cation exists at relatively low pH values. Hence, it is a major component of freshwater, and a significant component of seawater. The pH of freshwater usually varies from 5-7 whereas that of seawater is 8.0. Under oxidizing conditions cadmium is present in the hydrated cation form. Hence, under normal environmental conditions the major species of cadmium in fresh to weakly saline water is the hydrated Cd^{2+} ion. Under reducing conditions, the soluble species of cadmium is probably bisulphide ion.

Cadmium can be transported to soil and water through wet or dry deposition. Cadmium in water comes from contaminated agricultural soils, mining wastes, mine waters and the industrial use of cadmium. An important source is municipal sewage effluents and sludges, including those of domestic origin. Cadmium enters the sea and ocean from the air mainly in particulate form and, to a lesser extent, dissolved in rain and snow. The transport of cadmium from freshwater to the sea occurs either in particulate or soluble form. It depends on the state of the river, its mineralization and the sources of pollution, as well as on unidentified local factors.

Chronic cadmium intoxication may be a result of long-term exposure via inhalation of cadmium fumes or dust, or from pre-oral exposure to contaminated food or beverages. The critical organ is the kidney. Cadmium can cause a number of adverse effects on human and other organisms including death. Although high level exposures are rare, there is great concern regarding the effects of low-level, long-term exposure. Soluble cadmium compounds have greater toxicity than insoluble cadmium compounds because they are more readily absorbed by the body. However cadmium is metabolized by humans very slowly and even low doses can result in the accumulation of toxic levels if the exposure continues for a long period of time.

1.5.4 Chromium

Chromium is a group VIB compound from the periodic table, with an atomic number of 24 and atomic weight of 51.996 and density of 7.1g/ml. The two important forms are trivalent chromium and hexavalent chromium. Both hexavalent and trivalent chromium occur in natural waters, but it is difficult to model and predict their relative concentrations. The solubility of trivalent chromium varies with hardness and salinity.

Hexavalent chromium is very soluble, and relatively stable in air and pure water. It is reduced to trivalent chromium when it comes in contact with organic matter.

Almost all the hexavalent chromium in the environment arises from human activities, namely as metallurgical processes and manufacturing. Hexavalent chromium sources include the industrial oxidation and mined chromium deposits, metal plating and finishing industries, pigment production, cooling tower breakdowns and possibly the combustion of fossil fuels. The major industrial discharges of trivalent chromium are textile colouring, photographic applications, glass manufacturing and ceramics production. Various other industries such as paper production, fertilizer and steel manufacturing and petroleum refining may also be important sources.

Chromium enters the body by adsorption through both the gastrointestinal and respiratory tracts. Once chromium is absorbed into the organism, it is rapidly cleared from the blood stream and either excreted or taken up by tissues. The absorption of ingested chromium compounds can be estimated by measuring the amount of chromium excreted in the urine.

The harmful effects of chromium are associated with Cr (VI). It has been speculated that the biological effects of hexavalent chromium may be reduced to trivalent chromium which forms complexes with intracellular macromolecules. For aquatic organisms, hexavalent chromium is probably toxic because of its solubility and mobility. Exposure to chromium, particularly in the chrome production and chrome pigment industries, may lead to lung cancer. Skin irritation an also be induced by dermal exposure to chromium. Exposure to chromium has also been reported and resulted in kidney damage, birth defects and genetic mutations in humans and animals.

1.5.5 Lead

Lead is one of the most abundance and useful metals known to humans. Lead is a member group of 14 (IVA) of the periodic table and it is usually found combined with two or more other elements to form lead compound. Lead also exists in both organic and inorganic forms. Lead is rapidly dissolved by warm, diluted or moderately concentrated nitric acid. It is little affected by diluted hydrochloric acid and sulphuric acid. Organic acids such as acetic acid act as a solvent for metallic lead.

Lead enters the marine environment via industrial discharges, non-ferrous metal smelters, highway run-off and sewage effluent. Other pathways include wet deposition and dry deposition of atmospheric lead. Most anthropogenic inputs of lead originate resulted from mining, smelting and refining of lead and other metal ores.

The main route of exposure is food and air. Occupational exposures to lead occur for workers in the lead smelting industries, battery, manufacturing plants, plastics and printing industries. Lead may enter the body through intestines, ingestion, through the skin or by direct swallowing. The metal is absorbed into and transported by the blood stream to other tissues. Once absorbed, lead accumulates in high concentrations in bone, teeth, liver, lung, kidney, brain and spleen, and it goes through the blood brain barrier and the placenta (Goyer and Clarksom, 2001).

The most sensitive targets for lead toxicity are the developing nervous system, the haematological and cardiovascular systems and the kidney. The symptoms of lead poisoning are headache, abdominal pain and various symptoms related to the nervous system. Chronic lead toxicity in humans often develops dullness, irritability, vomiting, coma and death.

1.6 Research Objectives

The research objectives can be outlined as follows:

(i) To determine the heavy metal concentrations in water, tissue and sediment samples from Matang mangrove forest, Perak, Peninsular Malaysia.

(ii) To observe the trend of heavy metal pollution based on uptake and accumulation of aquatic organisms species.

(iii) To compare the result of heavy metal concentration in this study with the recommended level by the Marine Water Quality Standard (MWQS) for Malaysia.