UNIVERSITI PUTRA MALAYSIA

DISTRIBUTION AND ACCUMULATION OF HEAVY METALS IN FISH IN CAGE SYSTEM IN LINGGI ESTUARY, MALAYSIA

SHAHRIZAD YUSOF.

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By

SHAHRIZAD YUSOF

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

June 2005

DEDICATION

To my late father, Yusof bin Alang. May Allah showers him with His love.

And

To my mother, Hamizah binti Dollah,
brothers and sisters.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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June 2005

Chairman: Associate Professor Ahmad Ismail, PhD

Faculty: Science

Kuala Linggi is developing into potential aquaculture area in the west coast of Peninsular Malaysia but this area is facing ecological pressures. In Malaysia, data on heavy metals in aquaculture area and the cultured organisms are lacking. This study is aimed to evaluate the metal levels in fish cage ecosystem and to investigate the exposure route of metals to the cultured fish. Samples of three different sizes of cultured Nile tilapia (*Oreochromis niloticus*), river sediment, cage sediment, river water and periphyton were analysed for Cu, Zn, Cd and Pb content using atomic absorption spectrophotometer. The cultured fish Hg content was also determined using mercury analyser. Heavy metals (Cu, Zn, Cd, Pb and Hg) are present in the aquaculture area in Linggi Estuary. Concentrations of Cu and Zn in the Linggi River water in the estuary are below the standards outlined by the Malaysian Department of Environment, but Cd and Pb concentrations are above the standards. Sediment Cu and Zn concentrations are at safe levels but Cd and Pb concentrations are above threshold levels. Sediment Cu and Zn are due to anthropogenic origin while large percentage of Cd and Pb in the sediment occurs naturally. There is a similar trend of Cu, Zn, Cd and Pb accumulation in three components of the aquaculture area environment, the periphyton, the cage sediment and the river sediment. This reflects close relationship of these components in cycling of the heavy metals. These three components, plus the commercial fish feed contribute heavy metals to the cultured fish. Different metals accumulate in different organs of the cultured fish. Copper is concentrated in the liver, Zn in the bone, Pb in the operculum, Cd in the gills and Hg in the kidney. Copper, Zn, Cd and Pb were also found to accumulate with age of fish. With respect to Cu, Zn and Hg, the fish cultured in Linggi Estuary is safe for consumption but their Cd and Pb levels are above the permissible level set by the Malaysian Government. Elevated levels of these of non-essential elements may pose threats to human health through consumption of the fish. These results indicate that some measures should be taken to prevent the contamination of the estuarine environment for human and animal health.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

TABURAN DAN PENGUMPULAN LOGAM BERAT DALAM IKAN SISTEM SANGKAR DI KUALA LINGGI, MALAYSIA

Oleh

SHAHRIZAD YUSOF

Jun 2005

Pengerusi: **Profesor Madya Ahmad Ismail, PhD**

Fakulti: **Sains**

Kuala Linggi sedang berkembang menjadi kawasan akuakultur yang berpotensi di pantai barat Semenanjung Malaysia tetapi kawasan ini menghadapi tekanan ekologi. Di Malaysia data tentang logam berat di kawasan akuakultur dan organisma yang dikultur adalah sangat kurang. Kajian ini bertujuan untuk menilai tahap logam berat di ekosistem sangkar ikan dan untuk menyiasat punca logam berat yang terdapat dalam ikan yang dikultur di Kuala Linggi. Kandungan Cu, Zn, Cd dan Pb bagi sampel ikan tilapia merah dengan tiga saiz yang berbeza, sedimen sungai, sedimen sangkar ikan, air sungai dan perifiton telah dianalisis dengan menggunakan spektrofotometer penyerapan atom. Kandungan Hg dalam ikan juga ditentukan dengan menggunakan penganalisis merkuri. Didapati bahawa terdapat kehadiran logam berat (Cu, Zn, Cd, Pb dan Hg) di kawasan akuakultur di Kuala Linggi. Kandungan Cu dan Zn dalam air sungai di kawasan tersebut adalah di bawah tahap piawaian yang ditetapkan oleh Jabatan Alam Sekitar Malaysia, tetapi kandungan Cd dan Pb adalah melebihi tahap piawaian tersebut.

Kandungan Cu dan Zn yang dalam sedimen sungai adalah pada tahap selamat tetapi kandungan Cd dan Pb melebihi aras ambang. Kuprum dan Zn yang terdapat dalam sedimen berasal dari aktiviti manusia manakala sebahagian besar Cd dan Pb hadir secara semula jadi. Terdapat corak pengumpulan Cu, Zn, Cd dan Pb yang sama dalam tiga komponen persekitaran akuakultur tersebut iaitu perifiton, sedimen sungai dan sedimen sangkar ikan. Keadaan ini menggambarkan hubungan rapat komponen-komponen ini dalam pengitaran logam-logam berat. Ketiga-tiga komponen ini dan juga makanan komersial yang diberikan kepada ikan didapati telah menyumbang kepada kehadiran logam berat dalam ikan yang dikultur. Logam yang berbeza didapati berkumpul dalam organ yang berbeza. Kuprum berkumpul di hati, Zn di tulang, Cd di insang, Pb di operculum dan Hg di ginjal. Pengumpulan Cu, Zn, Cd dan Pb meningkat dengan umur ikan. Berdasarkan kandungan Cu, Zn dan Hg, ikan yang dikultur di Kuala Linggi adalah selamat untuk dimakan tetapi kandungan Cd dan Pb melebihi aras yang dibenarkan oleh Akta Makanan Malaysia. Aras yang tinggi bagi elemen tidak perlu ini boleh mengancam kesihatan manusia melalui pengambilan ikan yang dikultur di kawasan yang dikaji. Langkah-langkah tertentu perlu diambil bagi menghalang pencemaran kawasan tersebut demi kesihatan manusia dan hidupan lain.

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I certify that an Examination Committee met on 27th June 2005 to conduct the final examination of Shahrizad Yusof on her Master of Science thesis entitled "Distribution and Accumulation of Heavy Metals in Fish in Cage System in Linggi Estuary, Malaysia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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Date: 08 SEP 2005

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare it has not been previously or concurrently submitted to any other degree at UPM or other institutions.

SHAHRIZAD YUSOF

Date: 12 AUGUST 2005

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LIST OF ABBREVIATIONS

μgg^{-1}	microgram per gram
μgL^{-1}	microgram per litre
mgL^{-1}	milligram per litre
$HClO_4$	perchloric acid
HNO_3	nitric acid
ppb	parts per billion
tf	transfer factor
w.w	wet weight

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CHAPTER I

INTRODUCTION

The increasing human population, the need for new food supply, the increasing demand for quality fish protein, the impacts of global climate change together with over fishing of capture-based fisheries and pollution had increased the importance of aquaculture. Starting from an insignificant total production, inland and marine aquaculture production grew by about 5 percent per year between 1950 and 1969 and by about 8 percent per year during the 1970s and 1980s, and it has increased further to 10 percent per year since 1990 (FAO, 2000). The future needs for fish products and other supplies from aquatic organisms cannot be met without a substantial increase in aquaculture production since the harvest of most important stocks are already close to or past the limits of sustainable exploitation (Bentsen and Olesen, 2002). Aquaculture is rapidly expanding in developing countries and is generally regarded as an efficient means for increasing protein production and generating income (Balarin, 1988). Many countries have identified a future shortfall in the supply of fishery products and support aquaculture development. In 1997, Asian countries produced 91% of the global aquaculture production (Prein, 2002) using a wide range of integrated agriculture-aquaculture systems. Aquaculture is seen not only as having greater development potential than capture fisheries, but also as an important tool for increasing food security.

In Malaysia, aquaculture sector will become the main player to increase the production of fish to fulfil the country's needs and for export (MOA, 1999). Aquaculture development can be seen by the formation of big aquaculture estates. Freshwater and brackish water aquaculture are being developed and are expected to contribute significantly to increase production as a whole. Land, lakes, embarkments, ponds, pools, rivers and coastal areas will be utilised for the production of fishes, prawns, crabs and cockles. One of the objectives of the Department of Fisheries is to speed up the growth of aquaculture. A total of 29 630 hectares has been identified as potential areas for aquaculture project in 2000 (DOF, 2001). Aquaculture will be encouraged and supported with adequate incentives, infrastructure and programmes.

Kuala Linggi is one of the potential aquaculture area in the west coast of Peninsular Malaysia. Situated at the state border of Malacca and Negeri Sembilan, this estuary supports active fisheries and is developing into lucrative fish and mussel aquaculture areas. The Linggi River which drains into the Straits of Malacca is the main water source for Port Dickson and Seremban. Several species of fishes are being cultured in cages in the estuary. Red tilapia (*Oreochromis niloticus*) is the major species being cultured and is selected in this study for its commercial significance. At present, the estuary environment is being extensively modified by the construction of a fishery complex and a sanctuary (P.D. Sanctuary). With accelerating rate of development, this area will presumably be exploited and will face ecological pressures in the future. The constructions are being made at the expense of mangroves. This affects the nursery function of the mangrove area and the sustainable reproduction of fish stocks.

Shorelines have also been reclaimed and hardened and natural patterns of water flow are being altered. These physical changes are bound to alter water quality and may affect the quality of aquaculture product. Being situated along the Straits of Malacca, this estuary is subjected to a great variety of pollutants due to its location. The Straits of Malacca is a principle repository for agricultural, industrial and domestic waste originating from land-based activities, while shipping activities in the form of operational discharges as well as accidental discharges all contribute to the pollution load in the straits (Abdullah *et al.,* 1999). Heavy metals, primarily from the manufacturing sector, including cadmium, copper, lead, mercury and nickel, were reported to be present in the coastal waters of West Malaysia. Organic pollutants consisting domestic, palm oil and rubber, and animal husbandry wastes were outlined to be the main pollutants in the Linggi River basin (Nather Khan and Lim, 1991). In 1989, pig farms near the Linggi River and Langat River generated waste with an estimated 218 tonnes/day, or 46% of the total national pollution load (Chua *et al.*, 2000).

Problems of poor water quality affect most developed countries in the world. Detrimental effects of modern society to the environment keep on rising everyday. As aquatic environments are final collectors of all kinds of pollution (Moiseenko and Kudryavtseva, 2001), aquaculture faces the risks of negative environmental impacts such as pollution, landscape modification, or biodiversity change (Tovar *et al.*, 2000). This is enhanced by the fact that mangrove-dominated swamps and estuaries worldwide have long been regarded as convenient sites for the disposal of industrial and urban wastes (Edyvane, 1999). Many cases of elevated trace metal concentrations can be directly attributed to industrial and municipal waste discharges, especially in estuaries (Bryan and Langston, 1992). They receive a multitude of inputs from diffuse and point sources. Therefore there may be potential health risk from consumption of estuarine-cultured fish. Thus, the quality and safety of aquaculture product need to be monitored. Ecological understanding about the intimate link between the supporting environment and the aquaculture system is very important. Even though the Linggi River was categorised as moderately polluted by the Malaysian Department of Environment (DOE, 1999) the ecosystem health of Linggi Estuary is threatened if measures are not taken to minimise the source of pollution. If aquaculture development is to be ecologically sustainable, efforts must be directed towards methods that make use of the natural environment without severely or irreversibly degrading it (Berg *et al.*, 1996). A sustainable aquatic system must be economically viable, ecologically sound, and socially acceptable (El-Gayar and Leung, 2001).

Fish is considered to be an essential part of the diet in this region. Potential contamination of fish with heavy metals might be crucial for the exploitation of this resource. Bioaccumulation of heavy metals can provide a clear picture about the health of any aquatic ecosystem for sustainable production. The study of the presence of heavy metals in the environment is important because they play toxic roles in organisms especially when they are passed on to human beings through the consumption of foodstuffs. In Malaysia, data on heavy metals in aquaculture area and the organisms being cultured are lacking. There is a scarcity of data on certain elements of the aquatic environments most notably in terms of ecosystem health. Studies on heavy metal levels in fish mostly concentrate on levels of metals in muscle tissue only, without any broader picture of the accumulation processes and distribution of the metals among other tissues of the organism. Presently, no detailed studies exist on metal concentrations in commercial species of fish from the Linggi Estuary, despite the fact that this area is an important aquaculture area. Thus, the aims of this study are:

(i) to determine the levels of some heavy metals (copper, zinc, lead, cadmium and mercury) in water, sediment, algae and cultured fish from the fish cage system in Linggi Estuary

(ii) to evaluate heavy metals concentrations in different organs of tilapia cultured in the Linggi Estuary and thus to gain sight into the distribution and fate of metals in the fish

(iii) to investigate the exposure route of heavy metals to the fish

It is hoped that the data obtained could serve as a baseline to evaluate the metal levels in fish cage system. Information on this issue is important because potential contamination of fish with heavy metals might be detrimental to future exploitation of the Linggi Estuary for fish production.