UNIVERSITI PUTRA MALAYSIA

HEAVY METALS ACCUMULATION ON BLACK TILAPIA SP. EXPOSED TO MUNICIPAL SOLID WASTE LANDFILL LEACHATE AND THE HEALTH RISK ASSESSMENT

UMI RAIHANA BINTI ABDUL RAHMAN

FPSK(m) 2016 71

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UMI RAIHANA BINTI ABDUL RAHMAN

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

September 2016

Dedicated to my family

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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September 2016

Chairman : Sharifah Norkhadijah Syed Ismail, PhD
Faculty : Medicine and Health Sciences

Uncontrolled production and discharge of untreated landfill leachate poses environmental pollution. The hazardous contaminants such as heavy metals is pass through food chain via fish bioaccumulation and end up in human bodies. Tilapia is a type of fish that can adapt to a wide range of pollutants in various water conditions and are resistant to disease. Tilapia has high market demand for its edible nature and it is also vulnerable to leachate contamination in Malaysia. **Objective:** To assess level of heavy metals accumulation in Tilapia sp. exposed to municipal solid waste landfill leachate which were young and old leachate and the health risk associated via Tilapia consumption. **Methodology:** Landfill leachate from a young and old landfill were tested for physicochemical characteristic and heavy metals (copper, cadmium, lead, nickel, arsenic). Young leachate is leachate from a young landfill with less than five years old whereas old leachate is leachate from an old landfill, a landfill with more than 10 years of age. Ten Tilapia fish were exposed to leachate at different concentrations (2% to 20% v/v) for 96 hours to measure the level of heavy metal accumulations in the fish muscle and gills. Fish samples were digested using acid digestion method and heavy metals were determined using ICP-OES. Bio-concentration factor (BCF) of heavy metals in the fish muscle and gills were calculated. Health Risk Assessment was calculated to determine the safety for human consumption through Hazard Quotient (HQ), Hazard Index (HI) and Lifetime Cancer Risk (LCR). **Results:** Fish exposure to old leachate produces high heavy metal accumulations rate in fish compared to the young leachate. Cu, Pb and Ni were highly accumulated in the gills compared to the muscle. The highest Cu was detected in the fish gills at 6% v/v leachate concentration (22.72 ± 0.60 mg/kg) followed by fish muscle at 8% v/v leachate concentration (18.30 ± 0.36 mg/kg) in fish exposed to old leachate. The highest Ni was detected in the fish gills at 8% v/v leachate concentration (1.66 ± 0.021 mg/kg) and 4% v/v leachate concentration (1.34 ± 0.033 mg/kg) compared to fish muscle at 8% v/v leachate concentration (1.32 ± 0.024 mg/kg) in fish exposed to old leachate. Pb was the highest at 8% v/v of old leachate in fish gills (0.50 ± 0.011 mg/kg). Cd was commonly detected in fish gills and muscle with the highest concentration detected at 8% v/v leachate concentration (0.14 ± 0.01 mg/kg). High heavy metals accumulation on fish occur at 6% and 8% v/v of leachate concentration. The highest BCF was determined for Cu in gills with the value of 2186.67 at 2% v/v and 4544 at 6% v/v of old leachate. There was a non-carcinogenic risk of the exposure to combination of metals (Cu, Cd, Pb and Ni) due to fish consumption in fish expose to young and old leachate (HI > 1) and carcinogenic health risk of the exposure to Cd (LCR > 1 x 10^{-4}) via Tilapia consumption. **Conclusion**: The accumulation rate of heavy metals were higher in fish gills exposed to old leachate. There is a possibility of health risk from heavy metals exposure of municipal waste landfill leachate via fish consumption.

Keywords: Heavy metals, landfill leachate, Tilapia, bio-accumulation, Health Risk Assessment.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

PENGUMPULAN LOGAM BERAT DALAM TILAPIA HITAM YANG DIDEDAHKAN KEPADA AIR LARUT RESAP TAPAK PELUPUSAN SISA PEPEJAL DAN PENILAIAN RISIKO KESIHATAN

Oleh

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Penghasilan yang tidak terkawal dan pembebasan air larut resap yang tidak dirawat boleh mengakibatkan pencemaran alam sekitar. Bahan cemar berbahaya seperti logam berat telah dipindahkan melalui rantaian makanan, berkumpul di dalam ikan dan akhirnya terkumpul di dalam tubuh manusia. Tilapia merupakan sejenis ikan yang boleh menyesuaikan diri dengan pelbagai bahan pencemar dalam pelbagai keadaan air serta tahan penyakit. Tilapia mempunyai permintaan pasaran yang tinggi untuk dimakan namun ia juga terdedah kepada pencemaran air larut resap di Malaysia. **Objektif:** Untuk menilai tahap pengumpulan logam berat dalam Tilapia sp. yang terdedah kepada air larut resap tapak pelupusan sampah sisa pepejal dan risiko kesihatan yang berkaitan melalui pemakanan Tilapia. **Metodologi:** Air larut resap dari tapak pelupusan muda dan lama telah diuji untuk ciri fiziko-kimia dan logam berat (kuprum, cadmium, plumbum, nikel, arsenic). Air larut resap muda didapati daripada tapak pelupusan sampah muda yang berumur kurang daripada lima tahun manakala air larut resap lama didapati daripada tapak pelupusan sampah lama yang berumur lebih daripada sepuluh tahun. Sepuluh ekor ikan Tilapia didedahkan kepada air larut resap pada kepekatan yang berbeza (2% kepada 20% v / v) selama 96 jam untuk mengukur tahap pengumpulan logam berat dalam otot dan insang ikan. Sampel ikan dicerna menggunakan kaedah penghadaman asid dan logam berat ditentukan dengan menggunakan ICP-OES. Faktor Bio-kepekatan (BCF) logam berat dalam otot dan insang ikan dikira. Penilaian Risiko Kesihatan (HRA) telah dikira untuk menentukan tahap keselamatan untuk pemakanan manusia dengan menggunakan *Hazard Quotient* (HQ), *Hazard Index* (HI) dan *Lifetime Cancer Risk* (LCR). **Hasil kajian:** Pendedahan kepada air larut resap lama menghasilkan kadar pengumpulan yang tinggi di dalam ikan berbanding air larut resap muda. Pengumpulan Cu, Pb dan Ni lebih tinggi di dalam insang berbanding otot. Cu yang tinggi dijumpai dalam insang ikan pada kepekatan 6% v/v (22.72 ± 0.60 mg/ kg) berbanding otot ikan pada kepekatan 8% v/v (18.30 ± 0.36 mg / kg). Ni paling tinggi dikesan dalam insang ikan pada kepekatan 8% v/v (1.66 ± 0.021 mg / kg) dan 4% v/v (1.34 ± 0.033 mg / kg) berbanding otot ikan pada kepekatan 8% v/v (1.32 ± 0.024 mg/ kg). Pb tertinggi pada kepekatan 8% v/v dalam insang ikan

(0.50 ± 0.011 mg/ kg). Cd dijumpai dalam insang ikan dan otot ikan dengan kepekatan tertinggi dikesan pada kepekatan 8% v/v (0.14 ± 0.01 mg / kg). Pengumpulan logam berat yang tinggi berlaku pada kepekatan 6% v/v dan 8% v/v air larut resap. Faktor bio-akumulasi tertinggi bagi Cu adalah di dalam insang dengan nilai 2186.67 pada kepekatan 2% v/v dan 4544 pada kepekatan 6% v/v air larut resap lama. Terdapat risiko bukan karsinogen daripada pendedahan kepada kombinasi logam berat (Cu, Cd, Pb dan Ni) melaui pemakanan ikan (HI > 1) dan risiko kesihatan karsinogenik pendedahan kepada Cd (LCR> 1 x 10-4) melalui penggunaan Tilapia. **Kesimpulan:** Kadar pengumpulan logam berat adalah lebih tinggi pada insang ikan dan terdedah kepada air larut resap lama. Terdapat kemungkinan risiko kesihatan daripada pendedahan logam berat dari tapak pelupusan sampah sisa pepejal melalui penggunaan ikan.

Kata kunci: Logam berat, air larut resap, Tilapia, bio- pengumpulan, Penilaian Risiko Kesihatan .

ACKNOWLEDGEMENT

First and foremost I am grateful and would like to express my sincere gratitude to my supervisor, Dr. Sharifah Norkhadijah Syed Ismail, for her invaluable guidance, continuous encouragement and constant support for me to complete this research. I am really appreciated her patient and willingness to share her knowledge and experience throughout my study life. Without her advice and assistance it would be hard for me to complete this study. I would like to express my warm thanks to my co-supervisors, Dr. Emilia Zainal Abidin and Dr. Sarva Mangala Praveena for their support, encouragement and guidance throughout my study. I really appreciate all the time they spent in proofreading my journal papers and thesis.

Special thanks with love to my parents, Mr. Abdul Rahman bin Mohd and Mrs. Roseazian binti Akil who raised me up with love and patience. I am really thankful for your sacrifice, patience, and understanding for all this time. Even you are not besides me anymore, your love will be in my heart forever. Thanks to my little brother, Muhamad Tarmizi bin Abdul Rahman, my uncle, Zolkifli bin Akil, my aunties, Samsiah binti Akil and Rubiah binti Akil and all my family members who always support me during my hard time, always love, support and care for me and my brother.

Lastly, Thanks to my friends, Aini Syuhaida, Siti Zulaikha, Nurul Husna, Siti Rahmah, Dora Esphylin, Aida Soraya, Nurul Ain, Siti Aminah, Nur Hamizah, Aini Dzaki, Akmal Liyana, Nurul Liyana, Nadirah, Farah Idayu, Ain Saipudin, Farahain Khairuddin, Dayana Hazwani, Farrah Atiqah, Hamizah and Khairul Anuar for your support and encouragement, and willingness to share knowledge and experiences.

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

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

ADD	Average Daily Dose
Cu	Copper
Cd	Cadmium
Ni	Nickel
Pb	Lead
HQ	Hazard Quotient
HI	Hazard Index
LCR	Lifetime Cancer Risk
RfD	Reference Dose
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
USEPA	United State Environmental Protection Agency

CHAPTER 1

INTRODUCTION

1.1 Introduction

Landfilling is the most common waste disposal method in the world. Rapid urbanization and economy growth leads to the continuity of waste generation (Syed Ismail and Abd. Manaf, 2013) and landfilling is the only way of disposing all kind of solid waste materials and this method poses the simplest and cheapest method to dispose solid waste compared to other method such as incineration (Mohd Masirin et al., 2008). It is the common method of waste disposal especially in low and middle income countries (Syed Ismail and Abd. Manaf, 2013). According to Abd Manaf et al., (2009), the average amount of municipal solid waste (MSW) produced in Malaysia was 0.5-0.8 kg/ person/ day in 2003 and increased to 1.7 kg/ person/ day in major cities. In 2012, overall waste generation in urban and rural area was 33,130 metric tonnes per day with 1.17 kg/ capita/ day (National Solid Waste Management Department, 2013)

Landfills in Malaysia are classified into five levels from Level 0 to Level 4. Level 0 is an open dumping site, Level 1 to 3 is classified as non-sanitary landfill while Level 4 is a sanitary landfill. Non sanitary landfill does not equipped with a lining underlying the surface of the dumping sites. Level 1 landfill is a controlled tipping landfill more or less like a dumping site with soil covering. Level 2 landfill is a controlled tipping landfill with a bund and leachate collection pond while Level 3 is a landfill with leachate recirculation system. Level 4 landfill is equipped with lining on the surface and proper leachate treatment system (Fauziah and Agamuthu, 2012; Suratman et al., 2011). Landfill received various types of waste from food waste, plastics, paper, mixed organic compounds, wood and other type of waste such as industrial or electric and electronic waste (Tarmudi et al., 2009; Budhiarta et al., 2012).

Landfill leachate occurs when water percolates the landfill, leach through the waste, and carry along contaminants compound in the landfill (Mohd Zin et al., 2012). Abdul Aziz et al., (2004) stated that production of leachate is because of the moisture that enter the landfill, extract the contaminants and discharged from the landfill in liquid phase when the moisture produced is sufficient to initiate a liquid flow. Landfill has many types of waste, which all the soluble contaminants in the waste will be leached out as leachate with contaminants that might be hazardous to the environment and human.

Landfill leachate is one of the environmental concern as it is toxic to the environment. Figure 1.1 shows the situation of landfill leachate in a landfill. Mor et al., (2006) indicated that area near landfills have a potential of being contaminated especially the groundwater contamination. Without proper leachate management system in landfill, leachate it may leach out and pollute the nearest water sources. Leachate can migrate more than 100 m from the landfill which leads to surface water pollution such as river and lake (Bortolotto et al., 2009). The toxicity of landfill leachate can spread to aquatic food chain as well as to human. Landfill leachate has complex contaminants composition consists of metals, ammonia, organic compounds and other toxicants (Olivero-Verbel et al., 2008; Pivato and Gaspari 2006). Heavy metal is one of the hazardous substances detected in the landfill leachate (Slack et al., 2005). Products that being used at home contain hazardous substances such as paints, vehicle maintenance product, waste that contain mercury, pharmaceuticals product, and batteries (Slack et al., 2005). Heavy metals pollution in the aquatic food chain can cause severe health effects via food consumption to human (Sivaperumal et al., 2007; Ozuni et al., 2010).

Figure 1.1: Landfill leachate situation in a landfill.

Organisms can be affected by the landfill leachate toxicity due to the toxic and genotoxic possibility in the landfill leachate from various concentration of organic and inorganic compounds (Bortolotto et al., 2009).

Heavy metals in leachate can cause toxicity and accumulate in aquatic organisms (Fauziah et al., 2013; Saei-Dehkordi and Fallah, 2011). Certain environmental condition may help in the accumulation of heavy metals in the environment that may lead to other potential hazards to human as the contaminants are being passed through the food chain (Sivaperumal et al., 2007). These organisms have the abilities to accumulate metals for a long period. The accumulation of metals in these organisms depend on the uptake and excretion rate mechanism of each organism. The degree of accumulation by the organisms depend on the available metals in the environment and the lipid distribution in the organisms' body or tissue (Phillips and Rainbow, 2013).

Fish is an important food source in many natural food chain (Taweel et al., 2013). It has been recognized as a good accumulator for organic pollutants (i.e.: acids and aldehydes) and inorganic pollutants (i.e.: heavy metals, Mg and Ca) (Eneji et al., 2011). This is because fish is located at the higher level of the food chain, where it acts as a predator for small fish and other small aquatic living. Therefore, it can accumulate and contain high metals from the water or from other living organisms (Yilmaz et al., 2007). Besides, the uptake mechanism of pollutants in fish occur through the gills epithelia and being pass through other organs (Jezierska and Witeska, 2006). The level of pollutants accumulation in fish is depends on their uptake and elimination rates (Sivaperumal et al., 2007). Fish bioassay is one of the common methods used to test the toxicity of landfill leachate discharge to the water sources. Heavy metals accumulated in fish may enhance and interrupt the benefits of omega-3 and protein in fish (Taweel et al., 2013). The toxicity level of leachate discharge to the aquatic environment can be measured using fish as the biological indicator.

Human is potential of being affected by toxic elements via fish as it is a type of protein consumed daily. Heavy metals being taken up through different organs in fish such as gills, muscles and liver at different concentration (Sivaperumal et al., 2007). Fish may accumulate large amount of heavy metals from polluted water by ion-exchange of dissolved metals across lipophilic membranes and absorption on tissues and membrane surface (Ismail and Mat Saleh, 2012). Heavy metals in fish may lead to many human threatening disorders and may cause fatality if it is accumulated in the organs such as kidney and liver for a long time (Saei-Dehkordi and Fallah, 2011).

Tilapia *sp.* is one of the edible fish and has high market demand in Malaysia as well as its vulnerability to leachate contamination (Emenike et al., 2011). Tilapia *sp.* is also one of the most common and eatable fish in Malaysia (Emenike et al., 2011) and in other countries (Eneji et al., 2011).

1.2 Problem Statement

Improper leachate management in landfill is one of the potential pollutant of rivers and groundwater because these leachate will be accidentally discharged into the river or groundwater sources without prior treatment. Untreated leachate discharge will contaminate the nearby water resources (Mohd Masirin et al., 2008). The common pathway for leachate to the environment is from the bottom of the landfill through the unsaturated soil layers to the groundwater and from groundwater through hydraulic connections to surface water (Syed Ismail and Abd. Manaf, 2013).

Current leachate management in landfill in Malaysia depending on the landfill level. In level 2 landfill, leachate is being collected in the leachate pond whereas in level 3 landfill, leachate is being collected in leachate pond with the addition of leachate recirculation system. Besides, in level 4 or sanitary landfill, leachate treatment facilities including the aerators and proper lining material were added to the landfill management system to prevent the leachate from penetrate the ground (Ministry of Housing and Local Government, 2004). Generally, for a proper leachate management, some common elements should be included such as a low permeability lining system to minimize leachate penetration to the ground as well as leachate drainage and control system to ensure the maintenance of a low head of leachate above the liner and to allow efficient leachate recirculation (Mohd Masirin et al., 2008).

The Ministry of Housing and Local Government, Malaysia has produced a technical guideline for Sanitary Landfill, Design and Operation (a revised draft, 2004) which highlights the details in term of the design of leachate collection facility in the landfill. Elements that were highlighted in the guideline including the component of leachate collection facility, the design and the loading conditions (Ministry of Housing and Local Government, 2004). However, this is only applied to sanitary landfill.

The current leachate management system in sanitary landfill is effective since it was designed with a proper leachate treatment pond and proper lining material. However, for non-sanitary landfill, the leachate management system is inadequate and need to be improved. This includes the design of the landfill, the site location, and the size of the disposal sites (Abd Manaf et al., 2009). For a better leachate management system, a landfill must be designed as sanitary landfills with a leachate treatment system, a gas ventilation system, and waste reduction facilities for treatment prior to disposal (Abd Manaf et al., 2009).

The problem of landfill leachate management is almost the same in most developing Asian countries because landfilling is the most common method used for waste disposal. However, in developed Asian countries such as Japan and South Korea, this problem may not be significant as their main method of waste disposal is incineration (Syed Ismail and Abd. Manaf, 2013). In most of these countries (i.e. South Korea and Japan), the MSW management system is focusing on waste reduction, recycling, and waste thermal treatment thus reduce their dependence on landfilling (Idris et al., 2004). It is similar to most European countries such as Denmark and Germany, where incineration and recycling is the main waste disposal method with strong restrictions of certain waste being dumped on the landfill (Syed Ismail and Abd. Manaf, 2013). Thus, untreated leachate discharge is not the main environmental problem in these countries.

Landfill leachate contains many type of pollutants in which some of the compounds is a threat to the environment and human (Oman and Junestedt, 2008). Some hazardous compounds found in landfill leachate are pesticides (i.e.: Bentazone), heavy metals (i.e.: Cd, Cu and Ni), ammonium, aromatic compounds (i.e.: naphthalene and pyrene), phenols (i.e.: Bisphenol A and dichlorophenol) and halogenated compounds (i.e.: Dichloromethane) (Oman and Junestedt 2008). Heavy metals can become highly toxic at high concentrations (Eneji et al., 2011; Ozuni et al., 2010). It can dispersed through water sources, suspended solids and sediments during its mobilization (Eneji et al., 2011; Ozuni et al., 2010).

The main pathway of human exposure to heavy metals was through food consumption (Yap et al., 2015). In 2003, Malaysian consume fish about 51.4 kg per year with the average increment of about 1.6% yearly since the year 2000 (Ibrahim et al., 2014). Tilapia was one of the famous freshwater fish eaten by Malaysian. This is due to its cheap price and easy to find in the market.

Fish is at the top of the aquatic food chain that can accumulate large high organic and inorganic pollutants in environment (Obasohan, 2008; Ismail and Mat Saleh, 2012; Johnson et al., 2004; Thomas et al., 2009; Eneji et al., 2011). Fish can accumulate heavy metals in their tissues through gills, skin or ingestion of the contaminated water and food in the aquatic environment (Ismail and Mat Saleh, 2012). Heavy metals accumulation in fish will cause direct threat to human health as this aquatic organism is the mains source of protein in our food chain (Obasohan, 2008).

Many studies have determined heavy metals pollution in water from leachate discharge. However, limited studies have done so far to explore the accumulation of heavy metals in leachate to the muscle and gills of Tilapia *sp*. one of the type of fish that can adapt to a wide range of pollutant and water condition (Luna, 2012). Previous study by Ismail and Mat Saleh, (2012) was done on Tilapia sp. collected in different location of the lake located near to sewage treatment plant, paint factory and waste dumping area. Cu was presence below the detection limit in the Tilapia samples. Similar to Taweel et al., (2013), he also did a study on heavy metals exposure (Cu, Cd, Pb and Ni) to *Oreochromis sp.* fish. What made the present study is different as compared to the previous one is the experiment was conducted in the laboratory under control environment where temperature, photoperiod, feeding and leachate concentrations were controlled. This is to understand the purely relationship between the exposure to the leachate and the accumulation in the fish without interfere of other environmental conditions.

Therefore, this study was aimed to determine the level of heavy metals accumulation in the muscle and gills of Tilapia sp. exposed to municipal solid waste landfill leachate at different volume and the health risk of particular consumption of the contaminated fish to human. Fish sample was exposed to different age of leachate in this study at different volume from 2% to 20% v/v to explore the level of heavy metals accumulation. Muscle and gill of the fish was the sample in this study because these fish part have the ability to accumulate high pollutant and may produce high toxicity even in small amount of pollutants (Thomas et al., 2009). Raw landfill leachate was used in the heavy metals accumulation experiment in this study to imitate the volume of pollutant concentration by dilution factor discharge into the aquatic environment from the point source.

Tilapia *sp.* is mainly freshwater fish, live in ponds, river, lakes and some in brackish water. It is a fast growing species, suitable for commercial and can reach its maximum size in five to six months. There are three common types' of commercial species of Tilapia which are Nile Tilapia (*Oreochromis niloticus*), Blue Tilapia (*Oreochromis aureus*) and the breed of Nile and Blue Tilapia called Mozambique Tilapia (*Oreochromis mossambicus*). Tilapia is a type of fish that can adapt to a wide range of pollutants in various water conditions (Luna, 2012). Tilapia has high market demand for its edible nature and it is also vulnerable to leachate contamination in Malaysia (Umi Raihana et al., 2014). The main advantage of tilapia is it relatively low cost of production in high scale tilapia seedling; mainly it is being used for fry and seed, and the quality of its flesh (Fagbenro and Akinduyite, 2011). Furthermore, tilapia is more resistant to disease compared to other fish species either in original extensive or semi-intensive culture systems (Diana, 2009).

The health risk from heavy metals exposure through fish consumption was highlighted in this study. Fish contaminated with heavy metals can disturb human body systems such as cardiovascular system, endocrine system, respiratory system, immune system, as well as reproductive system (Al-Bakheet et al., 2013). It can cause health problems such as stroke, heart disease, kidney failure and others (Agarwal et al., 2011; Baun and Christensen, 2004). This study explain the possible risk of fish contamination and human effects from the leachate discharge to the river or lake.

1.3 Study Justification

Uncontrolled leachate in landfill pose serious environmental hazard. Accidentally discharge, heavy rainfall, disaster (flood) may discharge the leachate to the nearest surface water and groundwater. For example, there is a reported case where the existing leachate treatment system and related facilities to waste disposal in Ampar Tenang landfill is currently not functioning effectively and it may cause contamination to the nearby river which is Sungai Labu (Mohd Masirin et al., 2008). Ismail, (2011) also have observed the flowing of leachate from the landfill site in Sedu, Ampar Tenang and Sg Kembong, flowing to the nearest river of Langat, Labu and Kembong. Aquatic organisms such as fish are the one who may receive the hazardous effect. Heavy metals are being a concern in this study because of its hazardous effect even it is present in small amount. Heavy metals accumulation in fish can have serious consequences in human. The contaminated fish has potential of affecting human health. The long-term effect will spread via consumption of fish as food. Sivaperumal et al., (2007) stated that heavy metals are one of the toxic contaminants may affect human health via food. This study is worth to provide baseline information of the health risk from heavy metals accumulation in the fish.

1.4 Objectives and Hypotheses

The general objective of this research was to determine heavy metals (Cu, Cd, Pb, Ni, As) accumulation in *Tilapia sp*. exposed to different concentration of the young and old landfill leachate and the health risk it pose via human consumption.

Several research questions were answered in this study as follow:

1) What is the level of heavy metals concentration (Cu, Cd, Pb, Ni, As) and its physicochemical properties in young and old leachate from active landfill?

2) Is the level of physicochemical characteristics and heavy metals concentration within Malaysian and other countries standard values?

3) What is the level of heavy metals accumulation and bio-concentration factor (BCF) in the Tilapia *sp.* gills and muscle exposed to different concentrations of the young and old leachate?

4) What is level of health risk from the consumption of Tilapia *sp.* contaminated with the heavy metals from the young and old active leachate?

The specific objectives of this study as follow:

1) To compare the physicochemical properties and heavy metals (copper, cadmium, lead, nickel and arsenic) concentration in young and old leachate from active landfill.

2) To compare the physicochemical characteristics and heavy metals concentration of leachate to Malaysian and other countries standard values.

3) To compare the level of heavy metals accumulation in the Tilapia *sp.* gills and muscle exposed to the young and old leachate at different concentrations.

4) To compare the bio-concentration factor (BCF) in the Tilapia *sp.* gills and muscle exposed to the young and old leachate at different concentrations.

5) To determine the relationship between the heavy metals accumulation in Tilapia *sp.* with leachate concentration.

6) To calculate the health risk from the consumption of Tilapia *sp.* contaminated with the heavy metals from the young and old active leachate.

The hypotheses of this research are:

1) There is a significant difference of physicochemical properties and heavy metals concentration between the young and old leachate from active landfill.

2) There is a significant difference between physicochemical characteristics and heavy metals concentration of leachate is within the Malaysian and other countries standard values.

3) There is a significant difference of heavy metals accumulation level in the gills and muscle of the Tilapia *sp.*

4) There is a significant difference bio-concentration factor (BCF) in the gills and muscle of the Tilapia *sp.*

5) There is a significant relationship of heavy metals accumulation in the Tilapia *sp.* with the increase of leachate concentration.

1.5 The Conceptual Framework

Figure 1.2 shows the conceptual framework for this study. The main focus of this study was to determine the accumulation of heavy metals in fish exposed to leachate from young and old landfill as well as the health risk to human consumption. Both leachate samples were tested for their physicochemical characteristics and heavy metals (copper, cadmium, lead, nickel and arsenic) which represents carcinogenic and non-carcinogenic compound in the landfill leachate if the leachate were discharged into the river. Heavy metals were the focus in this study because of it can produce negative effect to human health even at low concentration. Tilapia fish was exposed to both leachate samples to determine the accumulation of heavy metals in fish muscle and gills. Tilapia was chosen in this study because of it is a hardy fish which can survive in a wide range of temperature and chemical pollutants (Froese et al., 2007). Heavy metals accumulated in the fish were used to calculate the Health Risk Assessment (HRA) for carcinogenic (LCR) and non-carcinogenic (HQ) risk for human consumption. The outcome of this study involved the implication of landfill leachate toxicity in human and fish if uncontrolled leachate is released to the environment without proper leachate treatment.

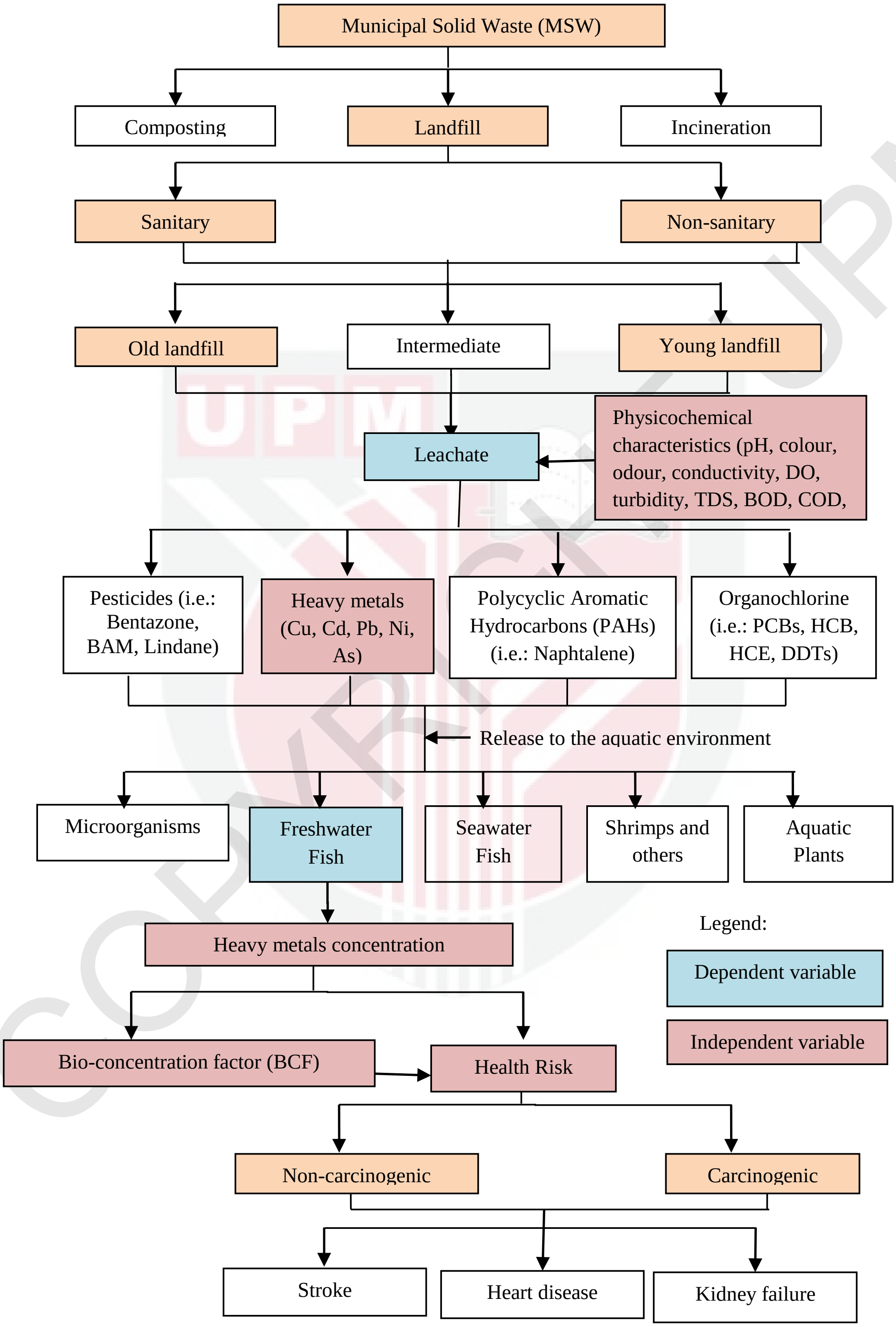

Figure 1.2: Summary of the Conceptual Framework

1.6 Thesis Structure

This thesis consists of five chapters. Chapter 1 introduce the topic of research, the research problem and the objectives of the research. Chapter 2 consist of a literature review of the study. Chapter 3 highlights the methodology that being used in this study. Chapter 4 described the findings and Chapter 5 discussed the results obtained from this study. This thesis was written following the format of answering the objectives highlighted in this research. Finally, Chapter 6 provides a conclusion of the research thesis which also includes the summary of research findings, the remaining research issues and recommendations for future research. The limitations and reflection of the study was included in this final chapter.

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