UNIVERSITI PUTRA MALAYSIA

BEHAVIOUR AND FATE OF HEAVY METALS AT AIR HITAM SANITARY LANDFILL, PUCHONG, SELANGOR

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By

KEEREN A/L SUNDARA RAJOO

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

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Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the Degree of Doctor of Philosophy

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April 2018

Chairman: Prof. Ahmad Ismail, PhD.
Faculty: Science

In this modern age, pollutants can come in many forms, but one of the most devastating type of pollutants are heavy metals. Heavy metals pose a major environmental problem as they are not biodegradable and will persist for extended periods of time. One of the biggest sources of heavy metal pollution is from the disposal of solid waste, which is usually by storing them at landfills. There is the possibility of heavy metal accumulation in the soils and also the leachate contaminating other ecosystems, and for flora and fauna to uptake these heavy metals. Besides landfills, atmospheric deposition is also a common source of heavy metal pollution. Thus, there is a need to evaluate the impact of heavy metals from both these sources. This study was undertaken with the following objectives; To compare the soil heavy metal concentrations according to the various phases of Air Hitam Sanitary Landfill, to determine the heavy metal concentrations in plants, invertebrates, landfill leachates and river at Air Hitam Sanitary Landfill, to compare atmospheric deposition and top soil heavy metal concentrations at Air Hitam Sanitary Landfill and Seri Kembangan, to compare the heavy metal speciation between Air Hitam Sanitary Landfill leachate sediments with Rasau River sediments and to evaluate the potential of heavy metal pollution at Air Hitam Sanitary Landfill. The study was conducted at Air Hitam Sanitary Landfill (AHSL), located near the Air Hitam Forest Reserve in Mukim Petaling, Daerah Petaling, Puchong, Selangor (longitude 101° 39’ 55’’ E and latitude 03° 0’ 10’’ N). Samples were collected from various aspects related to the landfill sites. Acid digestion was used to determine the concentration of heavy metal in all the samples collected. After digestion, the total concentrations of Cd, Fe, Zn, Cu, Pb, As and Cr was determined using the Atomic Absorption Spectrometer (AAS). Soil, plant, invertebrate and atmospheric deposition sampling was conducted at Phase 1-5 of Air Hitam Sanitary Landfill. Soil sampling was conducted in all three phases. These phases ceased operating at different periods, with Phase 1-5 ceasing operation the earliest while Phase 7 being the last to stop operating. Leachate sampling was conducted at the leachate collection ponds, which are Pond 1, Pond 2 and Pond 3. The leachate from all landfill phases is collected in Pond 1 and then undergoes aeration treatment at Pond 2 and Pond 3. River sampling was also conducted at the nearby river where treated leachate is disposed into. Appropriate statistical analyses was conducted using SPSS to analyze the research data. The heavy metal concentrations were lower in phases that ceased operating earlier, meaning Phase 7 had the highest

concentration of heavy metals. This could be attributed to heavy metals being leached out from the later phases. The aeration treatment of the landfill leachate was successful in reducing Cu and Pb concentrations, however Zn and Cr concentrations remained unchanged. Fe concentrations decreased in Pond 2 but then increased in Pond 3. As and Cd concentrations were found to increase in the final stages of leachate treatment. This could be because the leachate pool's sludge wasn't removed from the three leachate collection pools, and the concentration for most of the heavy metals in these leachate sediments were significantly high. Hence, aeration treatment solely is not sufficient in removing heavy metals from AHSL leachate, and a sludge removal system needs to be in place. Besides that, atmospheric deposition could also be contributing to the heavy metal concentrations within these leachate pools, as evident by the high heavy metal concentrations in the road dusts of Seri Kembangan. Another notable but worrying finding when comparing the speciation of landfill sediments with river sediments, was that the speciation composition of Cd, Cu and Pb for Station 7 onwards was similar to that of the leachate sediment, but this trend wasn't exhibited for Station 1 to Station 6. This is a sign that there is a possibility that landfill leachate is infiltrating the stream at this point, most likely due to damaged landfill liners not being able to contain the leachate efficiently. Besides that, it is also possible that atmospheric deposition was influencing the spike in heavy metal concentrations from Station 7 onwards. This finding was further substantiated when determining the pollution potential of the heavy metal concentrations in the river. Rasau River's heavy metal concentrations exceeded several international guidelines, indicating that the river heavy metal concentration was a serious pollution potential. This is especially true for Cd and Cu; the concentrations were categorized under Class V according to the National Water Quality Standards for Malaysia, meaning that the river water couldn't be used for anything. This research concluded that releasing the treated leachate into a nearby river is compromising long-term environmental quality. There also needs to be improvements to the leachate treatment system. Primarily, the leachate sludge needs to be removed. The treated leachate should also be channeled through a constructed wetland to allow phytoremediation to further treat the leachate. Atmospheric deposition was also a cause for concern at this area, thus the exact source of this pollution needs to be determined so that the harms can be mitigated.

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

PENILAIAN DAN TAKDIR LOGAM BERAT DI TAPAK PELUPUSAN SANITARI AIR HITAM, PUCHONG, SELANGOR

Oleh

KEEREN A/L SUNDARA RAJOO

April 2018

Pengerusi: Prof. Ahmad Ismail, PhD.
Fakulti: Sains

Bahan pencemar boleh wujud dalam pelbagai bentuk dan berbahaya kepada manusia dan ekosistem. Salah satu jenis pencemar yang amat berbahaya adalah logam berat. Ini adalah kerana logam berat tidak boleh terbiodegradasi dan akan wujud untuk jangka masa yang sangat lama. Salah satu sumber pencemaran logam berat adalah tapak pelupusan sampah. Di tapak perlupusan sampah, logam berat boleh tertumpu di tanah, flora, fauna dan juga di air larut resap, dan ini dapat menjejaskan ekosistem persekitaran. Selain tapak pelupusan, pemendapan atmosfera juga merupakan salah satu sumber pencemaran logam berat. Untuk memahami potensi pencemaran logam berat, kita perlulah menilai impak logam berat dari kedua-dua sumber ini. Kajian ini dijalankan dengan objektif berikut; Untuk membandingkan kepekatan logam berat tanah di fasa-fasa Tapak Pelupusan Sanitari Air Hitam, untuk menentukan kepekatan logam berat dalam tumbuh-tumbuhan, invertebrata, air larut resap dan sungai di Tapak Pelupusan Sanitari Air Hitam, untuk membandingkan kepekatan logam berat di pemendapan atmosfera di Tapak Pelupusan Sanitari Air Hitam dan Seri Kembangan, untuk membandingkan spesi logam berat di antara mendapan air larut resap Tapak Pelupusan Sanitari Air Hitam dengan sedimen Sungai Rasau dan untuk menilai potensi pencemaran logam berat di Tapak Pelupusan Sanitari Air Hitam. Kajian ini telah dijalankan di Tapak Pelupusan Sanitari Air Hitam (AHSL), yang terletak berhampiran dengan Hutan Simpan Air Hitam, Mukim Petaling, Daerah Petaling, Puchong, Selangor (longitud 101 ° 39 E dan latitud '55' '03 ° 0' 10 " N). Sampel ekologi telah diambil dari pelbagai aspek yang berkaitan dengan tapak pelupusan. Asid penghadaman telah dijalankkan untuk mengetahui kepekatan logam berat dalam kesemua sampel yang telah diambil. Selepas penghadaman, jumlah kepekatan Cd, Fe, Zn, Cu, Pb, As dan Cr telah ditentukan dengan menggunakan Spektrometer Serapan Atom (AAS). Pensampelan tumbuhan, artropod dan pemendapan atmosfera telah dijalankan di Fasa 1-5 Tapak Pelupusan Sanitari Air Hitam. Pensampelan air larut resap telah dijalankan di kolam pengumpulan air larut lesapan, iaitu Kolam 1, Kolam 2 dan Kolam 3. Di Tapak Pelupusan Sanitari Air Hitam, air larut resap dar semua fasa akan dikumpulkan di Kolam 1, dan akan disalurkan ke Kolam 2 dan seterusnya Kolam 3. Rawatan pengudaraan dijalankkan di Kolam 2 dan Kolam 3. Pensampelan air sungai telah dijalankan di Sungai Rasau, iaitu sungai dimana air larut resap yang telah dirawat akan dilupuskan. Analisis statistik telah dijalankkan menggunakan SPSS. Rawatan pengudaraan untuk air larut resap

berjaya mengurangkan kepekatan Cu dan Pb, bagaimanapun kepekatan Zn dan Cr tidak berubah. Kepekatan Fe menurun pada Kolam 2 tetapi meningkat semula di Kolam 3. Kepekatan As dan Cd didapati meningkat di peringkat akhir rawatan air larut resap, kemungkinan kerana logam-logam ini terkumpul di kolam terakhir kerana enapcemar kolam air larut resap tidak dikeluarkan semasa rawatan air larut resap. Kajian juga mendapati bahawa kandungan logam berat di sedimen larut resapan adalah sangat tinggi. Oleh itu, rawatan pengudaraan sahaja tidak mencukupi untuk mengeluarkan logam berat daripada air larut resap AHSL, dan satu sistem penyingkiran enapcemar perlu juga dijalankan untuk mengurankan kandungan logam berat di air larut resap. Di samping itu, pemendapan atmosfera juga boleh menyumbang kepada kepekatan logam berat di kolam air larut resap, kerana kajian ini juga telah mendapati bahawa kandungan logam berat yang tinggi di habuk jalan Seri Kembanagan. Salah satu pertemuan yang membimbangkan adalah penspesiesan Cd, Cu dan Pb di Stesen 7 Sungai Rasau dan seterusnya adalah seakan-akan air larut resap, tetapi tidak serupa di Stesen 1 ke Stesen 6. Ini adalah kerana terdapat kemungkinan bahawa air larut resap sedang menyusup ke sungai pada kawasan Stesen 7. Ini mungkin kerana terdapat kerosakan liner tapak pelupusan, yang menyebabkan air larut resap tidak dapat ditakung dengan sempurna. Kepekatan logam berat Sungai Rasau melebihi beberapa garis panduan antarabangsa, menunjukkan bahawa kepekatan logam berat di sungai ini berpotensi untuk menyumbang kepada pencemaran yang serius. Kepekatan Cd dan Cu di Sungai Rasau, dikategorikan di Kelas V mengikut Piawaian Kualiti Air Negara untuk Malaysia, bermaksud bahawa air sungai in langsung tidak dapat digunakan. Kajian ini mendapati bahawa perlepasan air larut resap ke Sungai Rasau dapat menyumbang kepada penjejasan kualiti alam sekitar. Tapak Pelupusan Sanitari Air Hitam perlulah memperbaiki sistem rawatan air larut resapnya, terutamanya enapcemar larut lesap perlulah dikeluarkan. Larutan air larut resap yang dirawat juga boleh disalurkan melalui tanah yang dibina khas untuk rawatan phytoremediasi. Sumber pemendapan atmosfera juga perlu dikenal pasti untuk mengurangkan impaknya kepada Tapak Pelupusan Sanitari Air Hitam.

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I certify that a Thesis Examination Committee has met on 17 April 2018 to conduct the final examination of Keeren a/l Sundara Rajoo on his thesis entitled "Behaviour and Fate of Heavy Metals at Air Hitam Sanitary Landfill, Puchong, Selangor" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

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

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
AAS	Atomic absorption spectrometer
ABC	Action plan for a beautiful and clean Malaysia
AHSL	Air Hitam Sanitary Landfill
BCF	Bioconcentration Factor
DOE	Malaysian Department of Environment
EPA	United States Environmental Protection Agency
JPSPN	Jabatan Pengurusan Sisa Pepejal Negara
LCPCMP	Landfill closure and post closure maintenance plan
MENGO	Malaysian Environmental Non-Governmental Organization
MIGHT	Malaysia industry government group for high technology
MSW	Municipal solid waste
NA	Not available
ND	Not detectable
QA/QC	Quality assurance / Quality control
SK	Seri Kembangan
SPSS	Statistical Package for Social Sciences
SRM	Standard Reference Material
TF	Translocation Factor

CHAPTER 1

INTRODUCTION

1.1 General Background

Rapid urbanization and unprecedented technological advancements has led to the improvement of the standard of living of both developed and developing countries. However, alongside the benefits are unavoidable harms. One of the biggest downsides of rapid development has been the growth of pollution, leading to ecological degradation and also the compromise of human wellbeing (Ismail and Manaf, 2013). Pollutants come in many forms, but one of the most devastating type of pollutants are heavy metals.

Heavy metals have been used in various fields for thousands of years, for instance lead (Pb) has been used for the past 5000 years as building materials, pigments for glazing ceramics and water pipes (Lide, 1992). The ancient Romans used mercury (Hg) as a remedy for teething pain, and western countries utilized it as a remedy for syphilis till late 1800s (Jarup, 2003). The usage of heavy metals grew exponentially ever since the industrial revolution, causing widespread heavy metal pollution to this very day (Achary *et al*., 2017).

Some heavy metals, such as zinc, are needed in small amounts by living organisms. However, these heavy metals at high concentrations can become highly toxic to living organisms (Reichman, 2002). Certain heavy metals, such as arsenic and cadmium, can pose a serious threat to human health even when present in small concentrations (Zhou and Wong, 2001). The harms that heavy metals can cause to humans are numerous, from genomic instability (Zhou and Wong, 2001) to causing endocrine disruption (Reichman, 2002). The biggest concern about heavy metals at sanitary landfills is that it will remain in the environment for very long periods, since they are not biodegradable and thus cannot be degraded naturally (Rosazlin *et al*., 2007). These metals persist indefinitely and cause pollution of air, water and soils (Jarup, 2003).

One of the biggest source of heavy metal pollution is municipal solid waste (MSW). The ever expanding industrialization and population bloom has caused a huge increase in the volume of MSW. This increasing amount of waste poses a major threat to both the environment and to human beings, even for countries with adequate treatment facilities, as the disposal or storage of these various waste products usually results in toxic pollutants (Ismail and Manaf, 2013). These contaminants can be hazardous to both the environment and living organisms. MSW is disposed of in numerous ways, from burning to disposing it at sea (Lau, 2004). However, the most common disposal method is by using sanitary landfills (Ismail and Manaf, 2013).

Although sanitary landfills are essential in waste disposals, it can also be a major source of environmental degradation due to the toxic nature of the solid waste being stored at these facilities (Ismail and Manaf, 2013). Solid waste contains high amounts of contaminants, hence sanitary landfills can serve as the breeding grounds for widespread ecological contamination that threaten human wellbeing (Nummelin *et al*., 2007). Countless researches have been focused on the pollution potential of sanitary landfills, most of it focusing on persistent organic pollutants (POPs) (Hassan *et al*., 2000). POPs are organic compounds that do not experience degradation, either chemically or biologically. POPs can occur naturally, but are mostly produced due to anthropogenic activities. POPs are known to accumulate in the environment, especially at landfill sites (Ismail and Manaf, 2013). POPs have caused an array of health complications to human beings, prompting most developed countries to band its usage since the 1980s. Although Malaysia has banned POPs since the late 1990s, there are still high concentrations of POPs in the environment. This is because some POPs are still used in Malaysia, while some are created unintentionally as by-products (National Poison Center, 1988). Besides that, due to their non-degrading nature, POPs remains in the environment for decades. POPs accumulate at dump sites and landfill sites, the chemicals are then washed by rain in the soil and will eventually end up in streams and rivers (Ling, 2008). Pesticides too have been found to be a common source of POPs, often contaminating water sources (Polidoro *et al*., 2017). Studies in Malaysia have found POPs in breast milk to be comparable to that of the former Soviet Union, and much higher than developed nations (Ling, 2008). Ling (2008) attributed pesticides and landfills as the source of POPs contamination in breast milk in Malaysia. Besides POPs, as mentioned before, heavy metals are also a very common ecological contaminant at sanitary landfill sites (Cossu, 2008).

As water, either through rainfall or groundwater, seep through solid domestic wastes that had been deposited in a landfill, it dissolves organic and inorganic components and decomposition products (Hassan *et al*., 2000). These dissolved components create a polluted liquid known as leachate. Leachate, which was initially defined as hazardous wastewater (Slater *et al.,* 1983), is commonly attributed as a major source of environmental pollution in developing countries. These include surface and groundwater pollution from leachate formation and the production of volatile gases. Hence, the disposal of landfill leachates is recognized as one of the most difficult tasks associated with the operation of landfills (ABSMaterials, 2014). The composition of leachate is dependent on the MSW, but landfill leachates often contain high levels of chemical oxygen demand, biochemical oxygen demand and ammoniacal nitrogen, in addition to high concentrations of metals such Iron (Fe), Manganese (Mn), Calcium (Ca) and sometimes Zinc (Zn) (Cossu, 2008). Pollutants present in MSW and the products of decomposition can be leached by water, hence causing serious water and environmental pollution.

Besides landfill leachate, there is also the possibility of heavy metals from landfills being transferred to surface soils. Studies have found that there is potential for heavy metals within the landfills to reemerge to the surface of landfills. This happens when landfill leachate is stagnant within the landfill, causing it to be pushed to the surface where it can transport heavy metals to the surface environment (Fujimori and Takigami, 2014; Liu et al., 2012). A research conducted at an electronic waste dumpsite at Manila found that heavy metals such as Cu, Zn and Pb were transported to the surface soil environment (Fujimori and Takigami, 2014). Fujimori and Takigami (2014) concluded that it was because the dumpsite leachate was not leached out of the environment thus ended up resurfacing, contaminating the surface soil with the dumpsite's heavy metals. However, there is also evidence of landfill leachate resurfacing despite a leachate collection system being present. This has been evident at Shanghai Laogang Landfill, where Zn and Cr concentrations of the surface soil was similar to that of the landfill's leachate, although the landfill had a leachate drainage and collection system (Liu et al., 2012).

Once on the surface soil, heavy metals can be accumulated by some organisms, by both flora and fauna. Studies have been conducted on such organisms, and some are even used as bioindicators of heavy metals (Nummelin et al., 2007). Therefore, there is a possibility for organisms existing at landfill sites to accumulate heavy metals in their bodies, especially if the landfill leachate resurfaces (Fujimori and Takigami, 2014). These organisms carry the risk of contaminating the food chain, and thus pose a threat to human health. All these factors indicate that heavy metal accumulation at landfills pose a major threat to the ecosystem and humans. However, there is also possibility for surface soils at landfill sites to have higher heavy metal concentrations due to atmospheric deposition (Liu et al., 2012). Thus, it is important to conduct atmospheric deposition sampling alongside surface soil sampling to determine whether the two are correlated.

Atmospheric deposition is also a common source of heavy metal pollution. Although natural air fluxes of heavy metals occur, anthropogenic activities can significantly contribute to heavy metal particles in the air. Despite heavy metal air pollution being more prevalent in industrial areas, research has found that major cities and even urban areas experiencing toxic levels of this pollution (Qiu *et al*., 2016). This is mainly due to heavy vehicular activities, and also sometimes small industrial activities taking place in these locations (Alahmr *et al*., 2012). There are various factors that contribute to the intensity of atmospheric deposition pollution, ranging from distance to the type of pollution source (Alahmr *et al*., 2012).

We selected the Air Hitam Sanitary Landfill (AHSL) to be the focus of our research as to determine the pollution potential and fate of heavy metals in a Malaysian urban setting. This sanitary landfill is one of the most advanced landfill in Peninsular Malaysia, being the first engineered sanitary landfill in Malaysia equipped with several amenities (Hassan *et al.*, 2006). AHSL was designated for the disposal of non-scheduled waste, including domestic/household waste, commercial and light industrial waste, market waste, street cleaning waste and food waste (Hatfield, 2009). AHSL had undergone a risk assessment for persistent organic pollutants and dioxins once AHSL had undergone closure, but no assessment had been conducted for heavy metal contamination. Besides the MSW stored within the landfill being a source for heavy metal soil and water pollution, AHSL is also vulnerable to heavy metal air pollution as it is located at Seri Kembangan, a highly urbanized area. Seri Kembangan, formerly known as Serdang New Village or sometimes referred to as Serdang, is a vibrant city that is home to shopping complexes, schools and small industries (Bin, 2011). As urban areas and major cities can also experience toxic levels of heavy metal atmospheric deposition pollution (Qiu *et al*., 2016), AHSL could be susceptible to atmospheric deposition. As no study had been conducted on the contamination potential of heavy metals at AHSL, the potential threat to humans is still unknown and could be very hazardous to the residents of Seri Kembangan.

1.2 Problem statement

When it comes to assessing potential pollution of landfill sites, focus is usually placed upon persistent organic pollutants. Rosazlin *et al*. (2007) said that heavy metal contamination is rarely focused upon, especially in developing countries like Malaysia. The biggest concern about heavy metals at sanitary landfills is that they are unaffected during degradation of organic waste, meaning that heavy metals remain in the environment for very long periods. These metals can also be transformed to different oxidation states and complexes, meaning that they can become bioavailable; which means that there is the potential for flora and fauna in the surrounding areas of a landfill site to uptake these heavy metals and also be absorbed by groundwater (Rosazlin *et al*., 2007). The most common way for heavy metal at sanitary landfills to be spread to other ecosystems is via landfill leachate. Thus, heavy metals at sanitary landfills can not only contaminate our food chains, but also our drinking water.

Therefore, heavy metal accumulation at landfill site need to be extensively studied in order to better understand and address this growing threat to human wellbeing. This can only be achieved by evaluating the heavy metal concentrations of various abiotic and biotic factors of the sanitary landfill, to determine where the heavy metals transfer to. It is only by determining the nature and concentration patterns of these heavy metals, would we be able to understand the true extent of the pollution potential of heavy metals in Malaysia due to sanitary landfills. There is also a need to study how heavy metals behave after closure of landfills. As heavy metals do not remain stagnant in landfills, we need to study to determine how these heavy metals affect nearby ecosystems. This is especially important these days as most modern landfills are situated in urbanised areas to reduce the need for transportation of the solid waste to landfill sites (Fauziah and Agamuthu, 2010). Special emphasis needs to be placed on aquatic ecosystems, as leachates remains the biggest source of pollution from landfills (Hassan *et al*., 2000).

Besides that, there is also a need to determine the severity of heavy metal air pollution in urbanized areas of Malaysia. The best method to evaluate this is by conducting atmospheric deposition sampling at wide, open spaces, which makes sanitary landfills an ideal location for such studies (Alahmr *et al*., 2012).

Based on the findings of this research, we would be able to have a better understanding on the effect an engineered, adequately planned and managed sanitary landfill site has on the accumulation of heavy metals on the environment, and we would be able to better charter future strategies in solid waste management. We would also be able to evaluate the air pollution severity at Seri Kembangan, a highly urbanised area that experiences high traffic volumes and is also home to several light industries. This research will lead us to understand the nature of heavy metals in landfills post closure and also how vulnerable we are to atmospheric deposition pollution, which will lead to an overall better understanding of how to mitigate harms from heavy metals at sanitary landfills. This research would also serve as a foundation to understand how heavy metals behaved at Seri Kembangan, allowing us the opportunity to evaluate the potential threat of heavy metals in this highly urbanised location of Malaysia. Besides, researchers and legislators would be able to develop better strategies to prevent heavy metal pollution as the ecological characteristics of these heavy metals would be better understood.

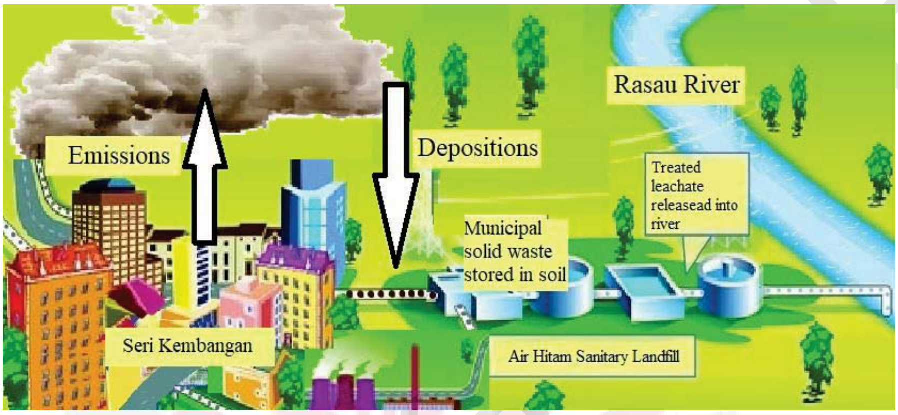

Figure 1.1: The various sources of heavy metals at Seri Kembangan.

As shown in Figure 1.1, heavy metal accumulation at Seri Kembangan is contributed by various sources. As Seri Kembangan is highly urbanised, vehicles and light industries in this area will contribute to heavy metal emissions that will eventually accumulate on various surfaces via atmospheric depositions. As landfills are wide open spaces, the surface soils of these landfills are very susceptible to atmospheric deposition pollution (Han *et al*., 2014). Besides the surface soil of Air Hitam Sanitary Landfill, the leachate collection ponds could also be vulnerable to atmospheric deposition as they are left exposed to the atmosphere. Besides that, as mentioned before, MSW is also a source of heavy metal accumulation. This means that the MSW stored at AHSL would also be a source of soil heavy metal pollution, which in turn could transfer the heavy metals to flora and fauna via bioaccumulation. Heavy metals at AHSL would also be transferred through leachate, which is collected and treated in leachate collection pools prior to being released into Rasau River. Thus, to determine the nature of heavy metals at Seri Kembangan, the heavy metal concentrations in the various abiotic and biotic factors need to be studied.

1.3 Objectives

The objectives of this study are:

1) To compare the soil heavy metal concentrations according to the various phases of Air Hitam Sanitary Landfill.
2) To determine the heavy metal concentrations in plants, invertebrates, landfill leachates and river at Air Hitam Sanitary Landfill.
3) To compare atmospheric deposition and top soil heavy metal concentrations at Air Hitam Sanitary Landfill and Seri Kembangan
4) To compare the heavy metal speciation between Air Hitam Sanitary Landfill leachate sediments with Rasau River sediments.
5) To evaluate the potential of heavy metal pollution at Air Hitam Sanitary Landfill.

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