HEAVY METAL CONTAMINATION IN SEDIMENTS AND SURFACE WATER

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DEDICATION

This thesis is dedicated to my wife, who sacrificed the most during my absence for the completion of my Master of Engineering (Geotechnics). Thanks for the support and words of encouragement during my post graduate study.

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ABSTRACT

This study was conducted to determine the level of heavy metal concentration in sediment and surface water in the Ringlet Lakes, Cameron Highlands and the results obtained were compared with the Dutch Soil Remediation Intervention Value, 2000 (the New Dutch List) and National Water Quality Standards for Malaysia, Class IIB (Recreational use with body contact) for sediment samples and surface water samples respectively. Total of 9 sampling stations were established, 2 samples (April 2018 and July 2018) for each stations for sediments samples and 5 samples (May 2018, June 2018, July 2018, August 2018 and September 2018) for each stations for surface water samples. The parameters that were determined for sediment samples consist of Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni) and Zinc (Zn). Whereas the parameters for surface water samples consist of includes Arsenic (As), Cadmium (Cd), Chromium Hexavalent (Cr^{6+}), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni) and Zinc (Zn). Results for sediments samples shown that all heavy metals concentration did not exceed the Dutch Soil Remediation Intervention Value, 2000 (the New Dutch List). However, Copper (Cu) and Mercury (Hg) exceeded the National Water Quality Standards for Malaysia, Class IIB (Recreational use with body contact). No Cadmium (Cd) was found in all sediment samples and the present of Cadmium (Cd) and Chromium Hexavalent (Cr^{6+}) in surface water samples are non-detectable. Ringlet Lakes considered to be contaminated due to the concentration of Copper (Cu) and Mercury (Hg) in surface water exceeded the recommended value for most samples. It is recommended that periodic monitoring to be conducted and to determine the sources of the contamination to avoid further contamination in the area.

ABSTRAK

Kajian ini dilakukan untuk mengkaji tahap kepekatan pencemaran logam berat pada sedimen dan air di Tasik Ringlet, Cameron Highlands dan keputusan yang diperoleh dibandingkan dengan Dutch Soil Remediation Intervention Value, 2000 (the New Dutch List) untuk sampel sedimen dan Standard Kualiti Air Kebangsaan, Kelas IIB (kegunaan rekreasi) untuk sampel air. Terdapat 9 stesen sampel, 2 sampel bagi setiap stesen untuk sediment (April 2018 dan Julai 2018) dan 5 sampel bagi setiap sampel bagi air (Mei 2018, Jun 2018, Julai 2018, Ogos 2018 dan September 2018). Parameter yang dikaji bagi sampel sediment adalah Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni) dan Zinc (Zn). Parameter untuk sampel sedimen pula adalah Arsenic (As), Cadmium (Cd), Chromium Hexavalent (Cr^{6+}), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni) dan Zinc (Zn). Keputusan kepekatan logam berat pada sampel sedimen menunjukkan bahawa tiada kepekatan logam berat yang melepasi Dutch Soil Remediation Intervention Value, 2000 (the New Dutch List). Walaubagaimanapun, Copper (Cu) dan Mercury (Hg) melepasi had Standard Kualiti Air Kebangsaan, Kelas IIB (kegunaan rekreasi). Tiada Cadmium (Cd) yang dijumpai di dalam semua sampel sedimen. Cadmium (Cd) dan Chromium Hexavalent (Cr^{6+}) tidak dapat dikesan pada semua sampel air. Tasik Ringlet boleh dikategorikan sebagai tercemar kerana kepekatan Copper (Cu) dan Mercury (Hg) lebih daripada had yang disarankan. Adalah digalakkan untuk melakukan pantauan yang berkala untuk kepekatan logam berat di Tasik Ringlet dan mencari sumber pencemaran bagi mengelakkan pencemaran yang lebih teruk.

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LIST OF ABBREVIATIONS

APHA	-	American Public Health Association
EQA	-	Environmental Quality Act
INWQS	-	Interim National Water Quality Standard
USEPA	-	United States Environmental Protection Agency
Pb	-	Lead
Cr	-	Chromium
As	-	Arsenic
Zn	-	Zinc
Cd	-	Cadmium
Cu	-	Copper
Hg	-	Mercury
Ni	-	Nickel
Cr^{6+}	-	Chromium Hexavalent

LIST OF SYMBOLS

g	-	Gram
kg	-	Kilogram
µg	-	Microgram
mg	-	Milligram
L	-	Litre
N	-	North
E	-	East

CHAPTER 1

INTRODUCTION

1.1 Introduction

Malaysia currently undergoing rapid economic growth which leads to various development throughout the nation mainly on industrial and agricultural developments. The rapid developments are directly and indirectly affecting our environment such as the water quality, soil, groundwater, flora and fauna, ambient air, noise and many more. Government of Malaysia leads by the Department of Environment have issued a guideline in which to control pollution for every development. An Environmental Impact Assessment Guideline is one of the guideline published by the Department of Environment Malaysia as one of the control measure to minimise pollution and to monitor the pollutant released to the environment in accordance to the Environmental Quality Act (EQA) 1974.

There are many contaminants that can enter the environment specifically on water pollution and soil pollution. For examples for soil, it can be contaminated due to several activities such as industrial, mining, disposal of high metal wastes, sewage, pesticides, irrigation, coal combustion, spillage of chemicals, and others. Most heavy metals found in contaminated areas are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn) cadmium (Cd), copper (Cu), mercury (Hg) and nickel (Ni) (R. A. Wuana, 2011).

There are many potential risk and hazard caused by heavy metal contamination. Human can be directly consumed heavy metals by eating contaminated food, contaminated water, contaminated animals, inhaling polluted air, and others (G. A. Engwa *et al.*, 2019). Heavy metals may cause serious health effects to human if consumed higher than the recommended value. For example, consuming high level of cadmium (Cd) may decreased learning ability, demonstrate decreased in attention level

and memory, damage nerve function, exposure to breast cancer, prostate cancer, pancreatic cancer, lung cancer and others.

1.2 Problem Background

The proposed area of study is Ringlet Lakes, Cameron Highlands, Pahang. Based on Figure 1.1, Ringlet Lakes located at 15km from Tanah Rata, Cameron Highlands.

Figure 1.1 Ringlet Lakes

There are several rivers surrounding the Ringlet which directly effecting the surface water quality and sediment quality in Ringlet Lakes which are Bertam river, Kilat

river, Khazanah river and Jasin/Jasik river. Ringlet lakes is one of reservoir that was handled by Tenaga Nasional Berhad for electricity generation under Cameron Highlands Hydroelectric Power Stations.

1.3 Problem Statement

Most of the contamination and pollution will concentrated at the Ringlet Lakes as it is surrounded by several rivers. Activities near the streams and rivers have the potential to cause soil and water pollution resulted from surface runoff and soil erosion. High quantities of sediment which mostly carry micronutrients and contaminants such as suspended solid, oil and grease, ammoniacal nitrogen, phenol, heavy metals, Aldrin, Dieldrin, Endosulfan, Endrin and E Coli will be transferred to the lakes especially during raining events. Pollution due to erosion and sedimentation can cause physical, chemical and biological impacts to water.

Rapid development and uncontrolled clearing of land for housing, hotels, road construction, agricultures in the area have resulted in serious degradation of land, severe silt accumulation, contamination and other. Activities such as agricultures may cause serious pollution because the usage of pesticides, fertilizers and soil erosion by surface runoff. Other activities like construction, roads and commercial area contribute to vehicles fumes, oil and grease, sewage, disposal of wastes and other. Hence, it is important to carry out monitoring to monitor the level of contaminant entered the water body.

1.4 Research Goal

1.4.1 Research Objectives

To monitor the level of contaminants in the project area, this research aims to document the concentration of heavy metals at Ringlet Lakes Cameron Highlands, Pahang. The key objectives of this research are :-

(a) To determine the level of heavy metal concentration in sediment and surface water in the Ringlet Lakes, Cameron Highlands.

(b) To carry out comparison between the heavy metal concentration results with the Dutch Soil Remediation Intervention Value, 2000 (the New Dutch List) and National Water Quality Standards for Malaysia, Class IIB (Recreational use with body contact) for sediment samples and surface water samples respectively.

1.5 Scope of Study

Two (2) type of sampling will be conducted to determine the heavy metals concentration which are sediment sampling and surface water sampling. The sampling station for both sediment samples and surface water samples will be same. However, the frequency of sampling for sediment are lower than surface water due generally, the rate of sedimentation is much lower than surface water runoff.

There are nine (9) sampling stations for sediments samples which are R1, R2, R3, R4, R5, R6, R7, R8 and R9. Sediment samples were taken two (2) times which was in April 2018 and July 2018. The list of parameters for sediment sampling includes Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni) and Zinc (Zn). Results obtained are compared with the Dutch Soil

Remediation Intervention Value, 2000 (the New Dutch List) for soil and sediment which indicate the acceptable levels of heavy metals in sediments.

There are nine (9) sampling stations for surface samples which are R1 R2, R3, R4, R5, R6, R7, R8 and R9. Sediment samples were taken five (5) times which was in May 2018, June 2018, July 2018, August 2018 and September 2018. The list of parameters for sediment sampling includes Arsenic (As), Cadmium (Cd), Chromium Hexavalent (Cr^{6+}), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni) and Zinc (Zn). Results obtained were compared with the National Water Quality Standards for Malaysia, Class IIB (Recreational use with body contact).

REFERENCES

Ahmad Luqman Bin Halit (2017) Heavy Metals Accumulation Along the Estuary of Sungai Tampok and Sungai Sanglang. Bachelor of Degree Thesis, Universiti Teknologi Malaysia

Alan B. Jones and Darell G. Slotton (1996) 'Mercury Effects, Sources and Control Measures', 1-13

Alwievie Flories Alip (2018) *Heavy Metals Contamination in Sediment Along Downstream of the Johor Strait*. Bachelor of Degree Thesis, Universiti Teknologi Malaysia

Chao Su, LiQin Jiang and WenJun Zhang (2014) 'A Review on Heavy Metal Contamination in the Soil Worldwide: Situation, Impact and Remediation Techniques', *Environmental Skeptics and Critics* 3(2), 24-38

Charles T. Driscoll, Young-Ji Han, Celia Y. Chen, David C. Evers, Kathleen Fallon Lambert, Thomas M. Holsen, Neil C. Kamman and Ronald K. Munson (2019) 'Mercury Contamination in Forest and Freshwater Ecosystems in the Northeastern United States', *Bioscience* 57(1), 1-23

Godwill Azeh Engwa, Paschaline Udoka Ferdinand, Friday Nweke Nwalo and Marian N. Unachukwu 'Mechanism and Health Effects of Heavy Metal Toxicity in Humans', *Poisoning in the Modern World – New Tricks for an Old Dog?*, 9-16
doi: http://dx.doi.org/10.5772/intechopen.82511

H.B. Bradl (2005) Heavy Metals in the Environment. United Kingdom: Elsevier Academic Press.

Helena Oliviera (2012) 'Chromium as an Environmental Pollutant : Insights on Induced Plant Toxicity', *Journal of Botany*, 1-5
doi: 10.1155/2012/375843

Jakir Hussain, Ikbal Husain, Mohammed Arif and Nidhi Gupta (2017) 'Studies on Heavy Metal Contamination in Godavari River Basin', Appl Water Sci 2017(7), 4539-4548
doi: 10.1007/s13201-017-0607-4

Jeff Sires (2017) 'A Review of Potential Zinc and Copper Pollution Sources in the Kenai River Watershed', *Kenai Watershed Forum*, 8-19

John Emsley (2011) 'Nature's Building Blocks: An A-Z Guide to the Elements', Oxford University Press, New York, 2nd Edition, 2011

K.K. Dasm S.N. Das and S.A. Dhundasi (2008) 'Nickel, its Adverse Health Effects & Oxidative Stress', *Indian J Med Res 128* pp 412-425

Malaysia (1974) Environmental Quality Act 1974, *National Water Quality Standard for Malaysia*. EQR 2006

Mihai Andrei (2019) 'The types of rock : igneous, metamorphic and sedimentary
doi: https://zmescience.com/category/other/science-abc/types-of-rock/

Netherlands (1994) *Circular on intervention value for soil remediation*. Netherlands Government Gazette 1995, 95

Ravindra Singh, Narendra Kumar Ahirwar, Jagrati Tiwari and Jyotsana Pathak (2018) 'Review on Sources and Effect of Heavy Metal in Soil : Its Bioremediation', International Journal of Research in Applied, Natural and Social Science. Maidenhead: Impact Journals

Raymond A. Wuana and Felix E. Okieiman (2011) 'Heavy Metals in Contaminated Soils : A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation', *International Scholarly Research Network*, 2011(402647), 1-7.
doi: 10.5402/2011/402647

Robin A. Bernhoft (2013) ‘Cadmium Toxicity and Treatment’, The Scientific World Journal, 1-3
doi: 10.1155/2013/394652

Shiv Shankar, Uma Shanker and Shikha (2014) ‘Arsenic Contamination of Groundwater : A Review of Sources, Prevalence, Health Risks, and Strategies for Mitigation’ 1-10
doi: http://dx.doi.or/10.1155/2014/304524

Vynavi A/P Thanapalasingam (2005) Pollution Status of the Sungai Skudai River System Through Heavy Metals. Master Thesis, Universiti Teknologi Malaysia