ASSESSMENT OF LEAD AND ARSENIC IN SOILS FROM PADDY FIELDS

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF BIOTECHNOLOGY (HONOURS)

FACULTY OF HEALTH AND LIFE SCIENCES INTI INTERNATIONAL UNIVERSITY PUTRA NILAI, MALAYSIA

MAY 2017

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ACKNOWLEDGEMENT

I would like to thank my supervisor, Dr. Cheng Wan Hee for his patience, advice, motivation and constructive criticism throughout the entire process in the completion of the final year project. His advices greatly assisted me in completing my work efficiently. I am indebted to him for sharing his expertise, and valuable guidance and encouragement which enabled me to complete my lab works and thesis writing on time.

I would also like to express my sincere thanks to Dr. Wong Kok Kee and Dr. Geeta a/p Selvarajah for their guidance during the entire venture.

Besides that, I am grateful to Nasfath Rahman who helped me out in collecting the soil samples. Without them, I would not have done this well. Not forgetting the Faculty of Health and Life Sciences (FHLS) for the permission of using the necessary facilities such as the chemicals, equipment and instruments in the laboratories which were the source of results for this project. Also to the laboratory technicians, Ms. Quah Hui Hsien and Mr. Ng Peng Wah for their commitments.

Last but not least, I also thank my parents for the unceasing support, attention, and encouragement. I am also grateful to my partner who supported me throughout this venture. I also place on record, my sense of gratitude to one and all, who directly or indirectly, have lent their hand in this venture.

ABSTRACT

There are major environmental and health concerns associated with heavy metal contamination in the soil as they are regarded as poisonous trace elements in the environment. The current study examines the concentration of lead (Pb) and arsenic (As) in the paddy field soils which were collected from Bahau, Negeri Sembilan and Sekinchan, Selangor. The total metal concentrations were determined by treating the soil with aqua-regia method as well as sequential extraction technique (SET) to distinguish the origin of heavy metal. The metals EFLE, acid reducible, oxidizable and resistant fractions concentration were determined using inductively coupled plasma mass spectrometry (ICP-MS). Overall both sites were extremely contaminated by both Pb and As exceeded the permissible limit with the highest value of 5900.00 µg/g dw and 6038.38 µg/g dw when compared with standards of China and Germany. The Pb was found highest at the acid reducible fraction indicating that Fe-Mn concentration is the contributing factor for the fixation of Pb to the soil surface and making them not bioavailable to plants, whereby As was always found in low level compared to Pb in all fractions. Factors such as soil pH, texture, target elements and organic matter content affect the metals bioavailability and their existence in soil. Hence, the metals bioavailability was studied by carrying out the pH analysis and organic matter content of the soil. Soils of Sekinchan showed an alkaline pH 7.05 and Bahau acidic pH of 5.02. Organic matter was higher at Sekinchan fields 124% compared to Bahau which was 88%.

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LIST OF ABBREVIATIONS

°C	Degree Celsius
μg/g DW	Microgram per gram dry weight
Pb	Lead
Pb^{2+}	Lead (II) ion
As	Arsenic
EFLE	Easily or freely leachable and exchangeable
Fe	Iron
G	Gram
H_20_2	Hydrogen peroxide
PI	Pollution index
HNO_3	Nitric acid
Hg	Mercury
M	Molar
Cm	Centimetre
ng/g	Nano gram Per gram
μm	Micrometre
Mg	Milligrams
mL	Millilitre
Mn	Manganese
ICP-MS	Inductively coupled mass spectrometry
DMA	Dimethyl arsenic
Rpm	Revolutions per minute
SET	Sequential extraction technique
MMA	Monomethyl arsenic
AR	Acid reducible
MAC	Maximum allowable concentration

CHAPTER 1

INTRODUCTION

Rice has been the most important crop and a staple food in many countries including Malaysia, which provides a major source of nutrition for human survival (Herman, Murchie, & Warsi, 2015). The rice has been a major contribution to the financial income of many Asian countries as shown in the statistics, 50 % per annum is contributed to countries economy (Fahmi, Abu Samah, & Abdullah, 2013). Henceforth, numerous experiments were carried out to create a good quality paddy and to expand its yield due to increase demand in food. Due to consistent climate changes some part of the paddy soil are prone to metal contamination (Sow et al., 2013).

Heavy metal contamination has been a major issue in rural ecological reviews for quite a while causing a high level of As toxicity in agricultural areas (Tchounwou, Yedjou, Patlolla, & Sutton, 2014). Heavy metals from natural and anthropogenic activities gathered in soil making both soil and paddy prone to metal contamination. This accumulation of heavy metals brings detrimental effects to human health through respiration, consumption and dermal contact absorption of rice (Jiao et al.,2015). Henceforth, when these contaminants are utilized as harvest generation, there are chances that these metals' would offer damage to the entire ecosystem (Satpathy et al., 2014). Soil polluted with heavy metal antagonistically affects the plants and creatures existing in the environment by disrupting their ecosystem. When these toxic substantial metals move into sediments or up taken by widely varied vegetation, which may bring about extraordinary risk because of translocation and bioaccumulation (Kim, Kim, Lee, Lee, & Cook, 2001). Substantial metals arsenic, in soil causes food contamination, especially in rice cropping framework. (Huq, Joardar, Parvin, Correll, & Naidu, 2006). Shimbo et al. (2001) stated rice contamination has been recognized as one of the important element for Asian people.

There were reports that expressed that yield of paddy plants have the potential to absorb and gather heavy metals in their vacuoles (Satpathy et al., 2014). Lead and As are taken up by the plants at different rates, depending on the type of crop and the occurrence of absorption and accumulation of heavy metals. Crops absorb and accumulate metals at different rates with vast variance in uptake of metal and through the process of translocation (Payus et al., 2015). Plants absorb heavy metals from the top surface of 25 cm depth zone of the soil which is the root where it is mostly influenced by pollutants due to anthropogenic activities, a majority of them found mostly in cereal crop roots (Payus, Farhana, Talip, & Hsiang, 2015).

The pollutants to be studied are (lead) Pb and (Arsenic)As as this metal is found majorly in paddy soil of Asia (Shimbo et al., 2001). Therefore, the aim of this assessment is to find the environmental pollutants Pb and As concentration in soils of paddy cultivation around Sekinchan, Selangor as well as from Bahau, Negeri Sembilan. The second objectives of this research are to determine the Pb and As in each geochemical layer through sequential extraction technique and to analyze the soil pH, organic matter as it affects the bioavailability of heavy metal. The pollutants will be assessed based on the soil of paddy (Satpathy et al., 2014). The research on heavy metal bioavailability and mobility mineralogy dependant of Pb and As from both paddy cultivations will be carried out using the analytical methods (Al-Banoon, 2012). It enables data such as the mode of occurrence, transport of heavy metals mobilization, bioavailability and speciation of heavy metal to be determined (Soul et al., 2013).

CHAPTER 2

LITERATURE REVIEW

2.1 PADDY INDUSTRY

Rice is the staple and important food of Malaysia, which provides a stable income for the country growth (Fahmi et al., 2013).The year 2004, was known as the national year of paddy because paddy was the staple food for 50% of the world (Herman et al.,2015).In 2009, apart from being the main source of food, it also provides the livelihood to 172,000 paddy farmers in the country. The Paddy industry has always been massively regulated because of its economic, social-political importance (Nurul Nadia et al., 2012).

In 2007, the occurrence of staple food crisis affected many countries, especially Thailand and Vietnam major rice producers due to the occurrence of flood (Fahmi et al., 2013). As per the Food and Agriculture Organization (FAO), the rice paddy generation in 2012 was evaluated to be 724.5 million tons (FAO 2012). In the course of the most recent couple of decades, the utilization of rice has expanded quickly which has made it a profitable item. Specifically, in Asia where 92 % of the aggregate rice is delivered, rice is the staple sustenance that is eaten by most by far of the populace (Arunakumara, Walpola & Yoon, 2013).

2.2 HEAVY METALS

Heavy metals are naturally found in soil, which has five times greater density and atomic mass compared to water (Tchounwou et al., 2014). The anthropogenic activities such as smelting, mining, use of pesticides and fertilizers in paddy soil, changes in biochemical and physiological properties increase the metal concentration leading to toxic heavy metals (Chibuike & Obiora, 2014). The heavy metals As, Pb, Hg, and Cr, are listed as the key polluting element in paddy soil due to their poisonous ability, irreversible persistent and accumulation nature (Liu, 2016). The Pb and As, metalloid species is considered as a contaminant as it does provide any benefits to human or plant but be a threat to the environment and human by occurring where it is unwanted (Chibuike & Obiora, 2014 & Singh et al., 2011).

2.2.1 Sources of Heavy Metals

Heavy metals contamination can be either from natural or industrial sources that occur within the earth's crust. Natural processes such as rainfall, use of pesticides in vegetation. Anthropogenic activities such as smelting operation, mining, soil erosion and traffic emissions are certain elements heavy metal accumulation in the soil (Tchounwou, et al 2014). Other than that, there are also some natural components, include elements from parental rocks or the atmospheric deposition of particles, released from natural sources and human activities such as industrial effluents sewage and urban discharge activity which might cause heavy metal contaminations (Jaishankar, Tseten, Anbalagan, Mathew & Beeregowda, 2014). The accumulation of heavy metals in the paddy will easily lead to disastrous effect to human health through the food chain (Liu & Li, 2001).

Urban and suburban soil are largely influenced by heavy metals from various sources such as lattice structural components in soil, insoluble precipitates of organic, inorganic dissolved ions in soil and human activities such that where high level of pollutants are found at rural area due to wider application of anthropogenic activity (Dawaki, Dikko, Noma, ; Aliyu, 2013 & Chopra, Pathak, & Prasad, 2009). The frequent use of fertilizers and pesticides are major source of heavy metal contaminations, where phosphate fertilizer the major inorganic source of fertilizer that has been found in high level in agricultural soils of Malaysia (Zarcinas et al., 2004) that lead to soil toxicity as the soil sediments are prone to pile up the pollutant, since substantial metals in the soil are bound to the different stage sediments like, carbonates, sulfides, clay, minerals, Fe–Mn oxyhydrates and biological or organic components (Sow et al., 2013).

2.2.2 Bioavailability of Heavy Metals

The rate of heavy metal uptake depends on the sorption, desorption properties of soil, organic-inorganic ligands, biotic-abiotic factors and redox reaction. To be more specific, all these factors are influenced by pH, organic content, nutrients and microbes present in the soil (Violante, Cozzolino, Perelomov, Caporale, & Pigna, n.d.). Among all pH was regarded as the principle factor governing bioavailability as it increases and decreases metals solubility level (Rieuwerts et al., 2015).

The alkaline pH range was reported as the most suitable range for metals Pb and As to be bioavailable (Campbell et al., 1985). Henceforth low levels of organic will still greatly increase the sorption character by spreading widely on the surface of soil (Silveira et al.,2003). Enzymatic activities of sediment, germination of seed, bacterial bioassays, observing plant growth are few elements to be considered to the assess metals bioavailability (Pietrzykowski & Doorn, 2014). Besides that clay mineral and soil organic matter serve as the primary factor for metal solubility (Scientist, Jones, & Olson-rutz, 2017). High organic matter in the soil makes the soil more acidic, subsequently more bioavailable to plants. There were different reports on negative connections between bioavailability and pH of metals in soil yet positive relationships between bioavailability of metal and organic matter (Chibuike & Obiora, 2014; Zeng et al., 2011).