CHAPTER ONE

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INTRODUCTION

1.1 Definition

Currently most of the global environmental debate is a mixture of worry for the safety and the ecological stability of the Planet Earth as a whole. Environmental studies were carried out to review and promote the development of environmental criteria and standards in relation to developmental and technological progress. Although much of the recent concern for the problems facing the global environment has focused mainly on global warming and climatic change, there is also increasing evidence about the accelerated environmental contamination. Environmental contamination represents a major threat to the ecosystem and consequently to human life.

A healthy ecosystem is the one that provides continuous flow of current benefits and also maintains the capacity to respond to future needs and values. In other words it must maintain both system structure and function in a sustainable manner. The natural ecosystem is subjected to different anthropogenic stresses that exert their influence, alter the flow of material and affecting the health and sustainability of the ecosystem (Vereijken, 1992). Chemical pollution is one of the major types of stresses influencing the ecosystem health. Human societies not only exploit the resources from the environment but also export waste and pollution back to it; human activities inevitably and increasingly introduce material and energy into the ecosystem. When that material or energy endangers or is liable to endanger man's health, his well being or his resources, directly or indirectly, it is called a pollutant (Douglas 1983). Pollution is the contamination of soil, water or the atmosphere by harmful substance and a substance may be considered a pollutant simply because it is in the wrong place, at the wrong time, and in the wrong quantity (Holdgate, 1979). Environmental pollution has become a major political and health issue and pollution of one sort or another occurs throughout human societies and the effects of any given pollutant are frequently the same wherever they are felt. Pesticides and insecticides can build up and damage the soil. Sewage and waste from factories and oil from tankers that pollute rivers and oceans; Contaminated liquid may leach from the waste and pollute ground water. Smoke from chimneys and fumes from cars that pollute the air (Dix 1981). The present situation results principally from the unbridled application of technology in industrialized countries. Developing countries, however, are already encountering the same problems and increasingly have to deal with the same pollution consequence (Badri, 1986). During this century both population growth and rapid industrialization have combined to poison the atmosphere; contaminate lakes, rivers, erode and pollute the soil and destroy many forms of life in the developed countries.

There are many reasons for concern about environmental pollution since soil, air and water contamination is spreading, and its danger is everywhere. Pollutants can affect man with direct effects such as acute effects from exposure to a toxic pollutant reaching man through air, water, soil or food. The long-term effects due to prolonged exposure to a pollutant at levels lower than those giving rise to overt toxic effects; synergistic interaction between pollutants or between a pollutant and malnutrition or disease; genetic effects that are manifested in future generations. Indirect effects on man may result from reduction of the food supply or deterioration of the environment.

Such effects include: damage to plants and animals; disruption of ecological cycles such that a previously harmless species becomes a pest; damage to the human habitat (air pollutants that destroy forests and corrode buildings; water pollutants that destroy the recreational value of inland waters; and alteration of the global climate.

1.2 Heavy metals and the environment

Heavy metals in the environment continue to receive increasing attention due to the growing scientific and public awareness of their environmental polluting role. Heavy metals released into the environment exert a broad range of toxic effect, metals such as cadmium are carcinogenic, other metals such as lead and mercury possess a wide spectrum of toxicity that includes neurotic, hepatic, nephrotoxic, or mutagenic effects (Schumacher et al., 1997). Studies on pollution of heavy metals in the urban environment become prominent due to the high input levels of such metals in the environment from the spreading of sewage sludge, fertilizer industry, and waste landfilling.

1.3 Sources of heavy metal pollution

The processes by which heavy metals are channeled to the environment are both natural and anthropogenic, the natural sources are mainly geological in nature being part of the earth forming material. Through the different terrestrial processes metals become parted from the earth matrices to incorporated with various components of the soil masses, from there they find their pathways to other environmental sinks. Mining activities are the major sources of heavy metals inputs in the environment. Other significant anthropogenic contributors of heavy metals in the environment are industries, transportation, agricultural chemicals and the human inputs of domestic, industrial or agricultural wastes.

Battery industry is among the significant sources of heavy metal in the environment and the battery waste disposal is a great environmental challenge since almost all kind of batteries contain high concentrations of at least two of the hazardous heavy metals cadmium, Copper, Lead, Manganese, Mercury, Nickel, and zinc. (Alloway 1995, Brady and Weil 1999)

1.4 Soil contamination

Soil is the basic component of terrestrial ecosystems, both natural and agricultural being essential for the sustaining of plants and for the degradation and recycling of dead biomass. The soil in physical terms is merely the unconsolidated material on the earth surface, and it is the host of life-supporting processes in testimony to the marvels of the natural environment as well as the main part of the hydrological cycle. Soils can affect human health adversely in several ways since all human food, plant and animal products, derives directly or indirectly from the soil (Singh and Steinnes 1993 and Brady and Weil 1999). The ecosystem health and the sustenance of future generations demands that our soil resources be protected against long term insidious poisoning by heavy metals released from the industrial wastes.

The chemical properties of soils largely depend on the chemical make-up of the materials from which they were formed and the nature of the processes of formation. The use of soils for various purposes may change their chemical characteristics through the application of fertilizers, pesticides, or through pollution from waste disposal or industrial contamination. Some of the activities that cause soil and ground water pollution include irrigation and drainage, application of fertilizers, agricultural chemicals, bio-solids, chemical waste and human induced contamination (Singh and Steinnes, 1993 and Alloway 1995).

There may be areas with naturally occurring mineralization. These occur where soils have formed on mineral rich or mineralized rocks with high concentrations of heavy metals such as arsenic. Soils that contain such high concentrations of metals occur in areas characterized by the presence of metalliferous mines (Kim, 1993). The landfilling of domestic and industrial wastes also lead to soil pollution with heavy metals in various ways. Although heavy metals are ubiquitous in the soil parent material, the major anthropogenic source of such metals in the soil environment are mining and metalliferous, agricultural chemicals, sewage sludge, fuel combustion, waste disposal and military training (Kim and Thornton 1993). The atmosphere is also an important medium for metals from various sources to find their way to the soil. Soils are often contaminated for up to hundred kilometers away from the site of emission (Tiller 1989). Soil pollution caused by heavy metals exceeding permitted levels is estimated to affect large areas of the total arable soils worldwide.

Heavy metals contamination of soil is common at many hazardous waste sites in many industrialized countries. The major industrial heavy metals pollutants of soils are cadmium, cobalt, manganese, copper, molybdenum, nickel, lead, zinc, tin, and boron) (Alloway and Ayres 1993). Soil contamination with such metals has a direct impact on animal and human health through the quality of food and water. Metals contaminant tends to be persistent and largely irreversible and their available levels remaining much the same after several years.

Metal contamination of soils represent a significant environmental challenge due to the widespread industrial usage of various toxic metals, the persistence of metals in the environment, the established toxicity of various heavy metals and the potential pathways for metal dissemination in the environment. The increasing public awareness of soil and ground water pollution by industrial and agricultural chemicals has created an increased attention on the issue of solute movement through soil (Alloway and Ayres 1993). Generally soils have varied ranges of storage capacity for pollutants and contaminants depending on their chemical composition.

1.5 Factors affecting the fate of heavy metals in soils

The fate of heavy metal particles in the soil environment is important because they tend to be reactive, mobile, and highly toxic (Rose et al., 1979). It is fortunate that the soil added plants do not readily absorb metals or readily leached from the soil, however their immobility means their accumulation in the soil and prolong hazard to the human food chain. There are many soil processes that affect the accommodation and release of such pollutants in the soil environment (Brady and Weil 1999). The heavy metals dumped in the soil from mine sites or factories can form soluble salts and therefore may contaminate waterways and ground water, some remain in the soil forever and the soil will always be intoxicated and noxious to future generation who do not know its history. The movement and recycling of heavy metals within the soil depends not only on soil structure and on the content of the clay fraction and organic matter in the soil but also on chemical and microbiological factors (Alloway 1995).

Understanding the physical, chemical, and the biological properties of the soil is necessary for assessing the extent of land contamination and also necessary for the rehabilitation and reclamation of such metal contaminated soils (Badri 1986). Metals are differing in their tendency to adhere to soil particles. A range of physiochemical processes that dictate their availability and mobility in the soil system governs the behavior and fate of metals. Metal speciation is defined as the identification and quantification of the different and defined forms, species or phases in which an element occurs (Tack and Verloo 1995). The growing awareness of the strong dependence of the toxicity of heavy metals upon their chemical forms led to an increasing interest in the quality and quantity determination of specific metal species. Chemical speciation has therefore become an important topic of present-day analytical research.

Knowledge of chemical speciation of heavy metals in soils is essential to understand their chemical, biological interactions and transport mechanisms. Metal bioavailability is the degree to which metal is available for the biotransformation processes. It is believed that the primary factor limiting the bioavailability of a contaminant in the subsurface environment is their association with the solid subsurface, thus factors influencing their bioavailability are focused primarily around the physical, chemical and electrostatic sorption with the subsurface. The readily soluble fraction of a contaminant is generally considered to be bioavailable. Many evidences indicate that the bioavailability and up take of many heavy metals to plant much more related to their chemical form rather than to their total concentration (Winistorfer, 1995). In the soil solution phase, the chemical forms of a metal determine its bioavailability and chemical reactivity while the binding forms in the soil solid phase related to the intensity of metal release into the solution phase.

The length of time soils are exposed to contaminant is defined as residence time or aging and it is important factor determining the fate of metal contaminants in the environment (Daniel and Sparks 1999). To protect human and ecosystem health from overexposure there must exist accurate risk assessment and models that accurately predict the fate of heavy metals in the environment. For these task to be accomplished the above-mentioned factors must be taken in consideration.

1.6 Prediction of the heavy metals pollution of soils

In order to control or reduce potential environmental consequences of soil pollution with heavy metals, it is necessary to understand the forms of combination of such metals and their chemistry in the soil and to focus on the means of prediction of such metals, their speciation, mobility and residual fraction.

There are many methods that have been adopted to predict heavy metals pollution of soils. These include measuring the degree of soil pollution, prediction of uptake by means of soil analysis, prediction of uptake by means of plant analysis and the measurement of the background levels of heavy metals in soil (Tiller, 1989). The determination of total content of heavy metals in the soil environment is clearly important. However, the quantification of their bioavailable and residual fractions are equally if not more important as they are the fractions, that determine the actual effective risk of metals as contaminants (Schumacher et al., 1997).

Several chemical speciation and fractionation methods for heavy metals analysis in soils have been developed and applied which are primarily intended to understand the particular environmental behavior of metals, present in a variety of forms and matrices. Techniques used include chemical extractions, ion exchange, filtration, centrifugation, sieving and selective solvent extraction (Tack and Verloo1995).

1.7 Heavy metals in Malaysian soils

The enhanced urbanization and industrialization progress in Malaysia led to an increased usage of metals and consequently an increased metal out put in the environment (Ahmed (1995). It is fortunate enough that there is a physical separation of the industrial areas from the residential areas and the centers of urban growth. Based on Dean et al., (1972) listing of the industries designated with the source of heavy metals pollution, in Malaysia there are almost all the heavy metals related industries. Studies of heavy metals status in Malaysian soils indicated that high concentrations of such metals are dominant in urban soils, landfill sites and the roadsides of the highways. (Ahmed (1995); Ahmed et al., (1995); Badri et al., (1995). Although considerable research work has been done on the concentration of heavy metals in Malaysian soils little is known about the chemical distribution of heavy metal cations dumped in to the soil as wastes or chemical by product.

1.8 Objectives of the present work

The aims of the present research is to understand heavy metal limits for polluted soils and to generate reliable data on the soil chemical pollution by heavy metals of particular interest are the types that can be found in industrial wastes. The research also geared to examine how the physical and chemical properties of soil influence the persistence and the availability of heavy metals in the soil system and to outline a prediction model for estimating the speciation and bioavailability of heavy metals in soil environment. The study will investigate the effect of metal amendment level and residence time on the portioning of the added metals between the soil solid and solution phases, identifying and quantifying the different chemical forms and their uptake by plants. Aiming that the integration of these aspects will provide a better understanding of the long-term effects of wastes containing high levels of heavy metals to improve the environmental management practices involved in their disposal.