Chapter 1

INTRODUCTION

In the past two decades there has been an increasing public awareness of the hazards that originate from the contamination of the environment by toxic substances. Heavy metals can be considered as toxic substances in the natural environment due to their cumulative toxicity.

The primary source of heavy metals in environment is from naturally occurring geochemical materials. Although this occurrence may be enhanced by human activity, this activity is not itself the source of heavy metal, rather it is the cause of an elevated occurrence. Relatively low levels of heavy metals occur naturally in the environment and some are essential for plant and animal growth (Latimer, 1996). When emission of heavy metals into the atmosphere resulting from human activity, exceeds natural processes it can cause severe damage to ecology, plants, animals and lastly to human health.

It is generally conceded that mining can cause soil pollution (Timsit, 1992). Any industrial process that makes use of materials containing appreciable quantities of heavy metals can be expected to represent a source of metal to the environment (whether via gaseous, particulate, soluble or solid forms). It should be readily apparent that the mining, smelting and refining industries will be of prime interest in this context. The mining activities of the Pb-Zn exploitation process spread into the soil as well as the surrounding environment, a considerable amount of Pb, Zn and other associated metals such as Cu, Ag, Sb etc. The major pathway of heavy metal contamination affecting plants, animals and man is from polluted soil. Lead, zinc, cadmium and mercury can be readily accumulated in soils, particularly in surface soil and become immediately accessible to plant roots (Shu and Bradshaw, 1995). Lead is of acute concern on the global scale, because of its prominent showing in all the enrichment factors and transfer rate considered.

One of the most important scientific ecological targets is monitoring strategy (Muller, 1994). Environmental monitoring creates the base for an empirical, systematic description of the environment (Prochazkova, 1995). The general objectives of environmental monitoring are to recognize environmental pollution problems as early as possible, to analyze the type, source, and path of contamination and to develop recommendations to solve the problem before serious effects become manifest.

Soils are one of the most important media for environmental monitoring and risk assessment. Status and changes of pollutant concentrations and other soil parameters in the different soil horizons of a site are valuable indicators of environmental quality, change, and ecosystem integrity.

Mining activity in a Pb-Zn mine can cause soil contamination by heavy metals. Due to the aim to secure sustainable development of the environment, thus enabling the welfare of the human population, the monitoring program on heavy metal contents (Pb, Zn) in soil of areas surrounding the abandoned mine in Ban Muang Kut, Mae Taeng district, Chiang Mai province, has exceptionally important meaning. The data will be a good baseline for further environmental risk assessment as well as for creating a suitable, effective environmental management plan for the above-mentioned area.

1.1. DEFINITION AND USE OF TERMS

Heavy metal

Heavy metal or trace metals is a large group of trace elements which are both industrially and biologically important. Although not completely satisfactory from a chemical point of view, "heavy metals" is the most widely recognized and used term for the large group of elements with an atomic density greater than 6 g/cm^3 (Alloway, 1995).

The other name that has been used for this group of elements is "toxic metal". This name is even less appropriate because all trace elements are toxic to living organisms when they present in excess. For example, Co, Cr, Cu, Mn, Mo and Zn are toxic at high concentration but they are essential for the normal healthy growth of either plants, animals or both in small but critical concentrations.

Lead, copper and zinc are heavy metals that have been extensively mined, and whose environmental levels have been strongly influenced by man. All are rather toxic to living organisms and may be regarded as pollutants. In spite of this, traces of copper and zinc are essential for their life. Like molybdenum, cobalt and iron, they function as co-factors for certain enzyme systems. Traces of these elements in the soil are essential for normal plant growth. A poison at relatively high concentration can turn out to be an essential co-factor at lower concentration (Walker, 1975).

The term "heavy metal" is often used with emphasis on the pollution and toxicity aspects rather than as a collective name for a group of elements of considerable economic and environmental importance (Alloway, 1995)

A newer term which is being increasingly used with reference to the harmful properties of these metals is "potentially toxic element" and this seems to be gained acceptance (Alloway, 1995). During the writing of this thesis the term "heavy metals" is used to mean potentially toxic elements.

Pollution and contamination

" Pollution" is, in some ways, a term easier to define than " heavy metal", but it is commonly confused or used interchangeably with the term "contamination". One widely accepted interpretation of the term "pollution" and "contamination" states that pollution is

"The introduction by man into the environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structures or amenity , or interference with legitimate uses of the environment"(Alloway, 1995)

Other definitions use the term "contamination" where the anthropogenic inputs do not appear to cause obvious harmful effects and "pollution" is applied only to situation where toxicity has occurred. However, this is unsatisfactory because the effects of the *contamination* may not be fully understood at the time. In practice, the terms *contamination* and *pollution* are frequently used interchangeably. For soil, there is a fairly widely adopted convention to use the term "contamination" for any situation in which elevated concentration of a substance occurs (Alloway, 1995)

1.2 GEOCHEMICAL ANOMALY, NATURAL CONTAMINATION

By definition, an anomaly is a deviation from the norm. An ore deposit is a relatively rare or abnormal phenomenon in a geochemical pattern. A ore deposit is itself a geochemical anomaly.

The threshold is the concentration of an indicator element above which a sample is considered anomalous. In the simplest case, the threshold is the upper limit of normal background fluctuation; any higher value is anomalous, and lower values are considered background.

The anomalies of heavy metals in soil are most closely related to ore (Arthur; 1979). The heavy metal content deposited in soil resulted from the dispersion of chemical elements that took place at the same time that the host rock was being formed and the weathering process that took place after deposition of the rocks (Bockris, 1977). The concept of pollution is strongly linked to the background levels of the natural environment. Geochemical exploration is by definition based on the fact that high metal contents in soil and streambeds are related to the presence of metallic ores. In such cases, even if the soils are effectively "naturally contaminated", no pollution exists in terms of human activities. Thus pollution can only be defined in relation to its natural environment, which requires at the very least a thorough knowledge of the regional geochemical background. Consequently it is difficult to extrapolate such data from one site to another; each site has its own level of "zero contamination" that must be taken into account for pollution studies (Timsit, 1992)

When trace elements have abnormally low or high level concentration, adverse effects on animals and plants in the area can be recognized, and the region is said to be a biochemical province. Examples of such areas are the seleniferous soils of the western United States, and the areas of iodine deficiency in Switzerland and other countries.

1.3 SOURCE OF HEAVY METAL IN THE ENVIRONMENT

It is apparent that the primary source of heavy metals in the environment is from naturally occurring geochemical materials (Martin and Coughtrey, 1982). Ore minerals containing high concentration occur and these constitute the main commercial source of the particular metals (Alloway, 1995). Although heavy metals are ubiquitous in soil parent materials the major anthropogenic sources of metal in soils and the environment are

i) Metalliferous mining and smelting;
ii) Agricultural and horticultural materials;
iii) Sewage sludge;
iv) Fossil fuel combustion;
v) Metallurgical industries;
vi) Industrial activities: electronics, chemicals;
vii) Waste disposal;
viii) Other sources such as : sports shooting and fishing etc.

It may be argued that, in causing pollution, humans are only redistributing elements which are already present in the earth's crust, because after all, no element can be created or destroyed. However what man is really doing is extracting a metal that is present in high concentration in very localized areas and redistributing it throughout the whole world to an extent which can cause adverse effects upon the environment. A classical case of this is the mining of the locally abundant but environmentally rare element lead, and dispersing it universally via heavy industry and the internal combustion engine.

1.4 HEAVY METAL UPTAKE BY PLANTS

The factors affecting the amounts of metal absorbed by plants are those controlling:

i) the concentrations and speciation of the metal in the soil solution;

ii) the movement of the metal from the bulk soil to the root surface;

iii) the transport of the metal from the root surface into the root, and

iv) its translocation from the root to the shoot.

Plant uptake of mobile ions present in the soil solution is largely determined by the total quantity of this ion in the soil but, in the case of strongly adsorbed ions, absorption is more dependent upon the amount of root produced.

Absorption of metals by plant roots can occur through both passive (non-metabolic) and active (metabolic) processes. Passive uptake involves diffusion of ions in the soil solution into the endodermis. On the other hand, active uptake takes place against a concentration gradient so it requires metabolic energy and can therefore be inhibited by toxins. The mechanisms appear to differ between metals; for instance Pb uptake is generally considered to be passive while that of Cu, Mo and Zn, is thought to be either active metabolic uptake, or a combination of both active and passive uptake. Relative differences in the uptake of metal ions between plant species and cultivars are genetically controlled and can be due to various factors, including :

surface area of the root, root cation exchange capacity, root exudates and the rate of evapotranspiration.

Kloke et al. (1994) gave the general order to the transfer coefficients for most of the biologically important heavy metals which are shown in Table 1.1. The transfer coefficient is the metal concentration in plant tissue above ground divided by the total metal concentration in the soil. Although numerous soil and plant factors can affect the accumulation of metals in plants, the values given are intended as a guide to the order of magnitude of the transfer coefficients and not precise values.

Table 1.1. Soil-plant transfer coefficients of heavy metals

Element	Soil-plant transfer coefficient
Cd	1 - 10
As	0.01 - 0.1
Zn	1 - 10
Pb	0.01 - 0.1
Ni	0.1 - 1.0

Martin and Coughtrey (1982) described three categories of plants based on their response to the increase of heavy metal concentration in soil, i.e., accumulators, indicators and excluders.

Accumulators: are defined as plants in which metals are concentrated in above ground parts from low or high soil concentrations.

Indicators: are the plants in which the uptake and the transport of heavy metals to the aerial part are regulated so that plant concentrations reflect soil concentrations.

Excluders: are the plants in which the concentration of heavy metal in the shoot remains low or constant over a wide range of soil concentrations, until the control mechanism breaks down and unrestricted transport occurs which is usually deleterious to the plant.

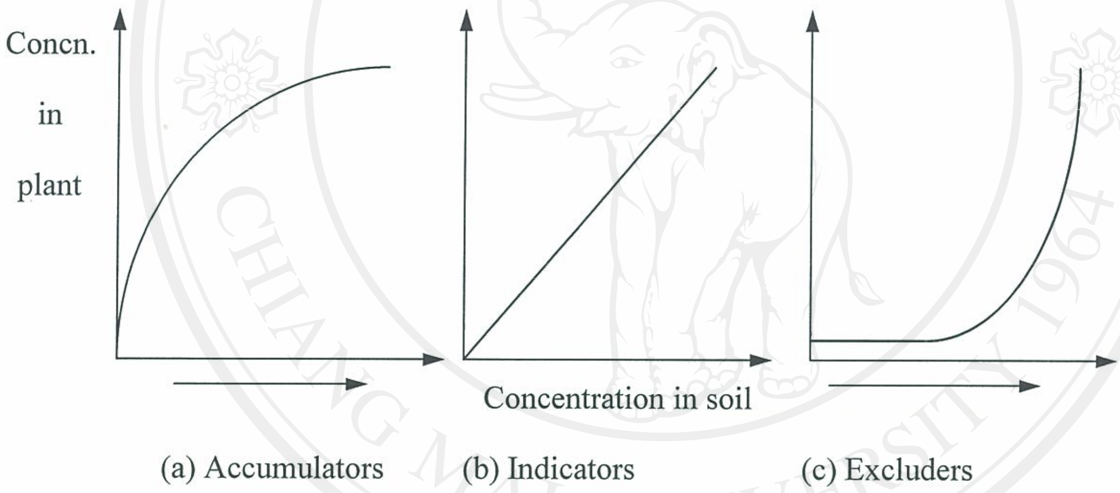

Figure 1.1. Patterns of uptake of heavy metals by plants

A number of authors have advocated the use of biological monitoring to assess and understand the status of and trend within natural ecosystems. The attention on the use of biological materials for indicating and monitoring heavy metals is important because the use of biological monitors will be a better indication of the degree of pollution received by the system than physical monitoring methods.

1.5 THE PURPOSE OF STUDY

The overall purpose of this study is to monitor the Pb and Zn levels in soil in the surrounding area of an abandoned mineral mine in Ban Muang Kut, Mae Taeng district, Chiang Mai province. Especially it aims to:

- Investigate the distribution of these heavy metals in soil at different depths (0-10 cm; 20-30 cm; 50-60 cm) and different distances from the mine.

- Map the distribution of the above-mentioned heavy metals in soil of the study site.

- Use GIS as a tool for assessment of the risk of heavy metal contamination in the study area.

- Investigate plant-soil relationships of heavy metals and the potential for using plants as bioindicators of soil contamination by heavy metals.