Chapter 6

DISCUSSION

6.1 PRECISION AND ACCURACY OF ANALYTICAL METHOD

Pb and Zn concentration in soil

Several mineral acids (HCl, HNO_3, $HClO_4$, H_2SO_4) and their mixtures have been used for the dissolution and extraction of elements from soils. They do not dissolve silicates or silica completely but are strong enough to dissolve the heavy metals not bound to silicate phases. Most heavy metal pollutants fall in this category (Alloway, 1995).

The most widely adopted method for heavy metal analysis in soil is probably the aqua regia (HCl : HNO_3; 3 : 1) procedure, which has been chosen by the commission of European Community Bureau of Reference (BCR) for analysis of their certified reference soil and sludge. AAS is currently in wide use for the determination of most metals. In this research, Pb and Zn in soil were determined using AAS with aqua regia digestion.

By duplicating the analysis of 10 % of the total samples of both soil and plant tissue, the coefficients of variation (CV) of the analytical method were determined as shown in Table 5.1. For soil samples the mean CV has reached 5.8 and 6.2 for Pb and Zn, respectively; and for plant samples CV is equal to 9.8 for Pb and 7.6 for Zn. There are some sources of random errors occurring during analysis such as unreproducible efficiency of extraction by aqua regia, weighing, sample homogenization, dilution, making up a volume, precision of standard solutions etc. The wide range of heavy

Table 6.1 summarizes the proportions of samples containing various levels of Pb and Zn. Almost 50 % of samples have a level of Pb and Zn less than 100 ppm. 13.2% of samples contain more than 1,000 ppm Pb and 15.7% contain more than 1,000 ppm Zn.

Table 6.1 Proportions of levels of Pb and Zn in soil

Range (ppm)	Level ranking	Pb		Zn	
		No. of samples	% of total samples	No. of samples	% of total samples
< 100	background	20	52.6	19	50.0
100 to 250	slightly high	4	10.5	5	13.2
250 to 500	medium high	7	18.4	6	15.8
500 to 1,000	very high	2	5.3	3	7.8
> 1,000	extremely high	5	13.2	5	13.2

Average abundances of Pb and Zn in soil and crust, as listed in Table 2.1, are 10 ppm and 50 ppm, respectively. The results obtained in this study are much higher due to the fact that the earth's crust is not homogeneous. Thus the "average abundances" of heavy metals are very general levels. In reality those abundances drastically change from one region to another. In the study area, where a wide range of Pb and Zn level was found, nevertheless more than 50 % of samples have values lower than 100 ppm. Bearing this in mind, it is highly recommended that 100 ppm be taken as the threshold and values less than 100 ppm should be allocated to the regional geochemical background level. This assumption is used from hereafter.

A control sample, for comparison with the mean Pb and Zn content in soil of the study area, was taken from Doi Pui, where the ecosystem is similar to that of the study site at Mae Taeng in the terms of topography, degree of forest cover and distance from any busy road as well as from any industrial plant. The mean background levels in the study area are 47.7 ppm for Pb and 71.5 ppm for Zn as illustrated in Table 6.2. The results for the sample from Doi Pui reveal that soil in Doi Pui has a lower Pb level (28.1ppm) but a higher Zn (86.2 ppm) level (Table 5.5). This determination is compared only with the set of background level samples. These data and the comparison show that it is very necessary to determine the geochemical background level of heavy metal in soil on a national scale. Such information was not yet available during the literature search. Once more the value so-called "average abundance" of an element in soil is only a general value which approximates the specific value in a particular region.

About 1/5 of the study area has Pb and Zn levels over the threshold trigger concentrations (UK) (Table 2.3) or over the intervention values (Netherlands) (Table 2.4). According to their criteria, this area poses hazards to human health.

The soil samples were classified into 5 categories as shown in Table 6.1 based on the analytical results. This classification was used in GIS for creating a map for risk assessment.

There are two reasons why the Pb and Zn levels might be high in the study area. Firstly, high levels might have been caused by past mining activities such as excavation, hand sorting, transportation and etc. Secondly, they might represent a geochemical anomaly or "naturally contaminated" area. The ore body itself is a geochemical anomaly. The surrounding areas may have high levels of Pb and Zn as a result of geochemical processes in the past. But without argument there is a part of the study area which has high levels of Pb and Zn resulting from past mining activities. Many mine waste heaps were observed in area under the mine entrance. They are sources for Pb and Zn redistribution into the environment by weathering processes.

6.3 GIS FOR ASSESSMENT OF Pb AND Zn DISTRIBUTION IN STUDY AREA

The sampling sites with Pb and Zn levels exceeding 100 ppm are all located at the mine or in close proximity to the mine. As shown on Figures 5.1 and 5.2, the content of Pb as well as Zn is extremely high on the west side of the mine. The Pb and Zn anomalies extend only 0.5 km to the west of the mine. The stream acts as a boundary between the areas of very high (red), medium high (purple) levels of Pb and Zn and the area with background level (green). This situation can be explained in that the stream is an end point of Pb and Zn distribution from the source of Pb and Zn contamination. Heavy metal once it reaches the stream, can only be redistributed along the stream. It can not cross over to the other side of the stream.

At the north, east and south-east (SE) parts of the area, the levels are high for both elements, especially at the SE part. Unlike the case of Pb distribution, the Zn level was found to be higher than the Pb level, especially in the SE corner of Figure 5.2. The brown red color indicates the value between 500 and 1,000 ppm of Zn at that corner. On the west side of the mine, the areas with extremely high levels of Pb and Zn almost coincide, but on the east side of mine, the distribution is a bit different with the extremely high levels of Zn in the SE and of Pb in the NE. Another difference between Pb and Zn levels is shown in the north-west (NW) part of the study area. In that area, the blue color indicates that the level of Zn is in the range of from 100 to 250 ppm, whereas the Pb level found at the same part is in a lower range of less than 100 ppm. The same situation occurs in the NE corner of the Figures 5.1 and 5.2.

Generally, it can be seen from the Figure 5.1 and 5.2 that Zn levels mainly are higher than Pb levels in the study area and the area on the east side of the mine has higher levels of Pb and Zn than the area on the west side. But a part of the study area on the west side is the most heavily polluted by heavy metal, having extremely high levels. Except in the SE direction, the concentrations of Pb and Zn decrease with increasing distances from the mine.

6.4 Pb AND Zn DISTRIBUTION BETWEEN DIFFERENT SOIL DEPTHS

Metal contamination in soil can occur by a variety of processes but as a generalization, it can be stated that in the areas of aerial contamination the metal profile in soil tends to show highest concentrations and contents in the upper layers of the soil profile. Areas in which contamination has resulted from past mining contamination tend to show disturbed profiles according to the past historical record of contamination and disturbance, while mineralized areas often show higher metal concentrations in both upper and lower levels of the soil profile (Martin and Coughtrey, 1982).

For easy investigation of Pb and Zn distribution in the study area, the samples were divided into two sets. The first set consists of samples with background level and the second set, comprising the rest of the samples, is called the set of high Pb and Zn level samples.

In this study, for the set of samples with background level, the concentration of Pb and Zn is the highest in the bottom soil (50 - 60 cm). This result is expressed in Figure 6.1 and 6.3. A statistical test confirmed the highest concentration in the bottom layer with a 95 % confidence level for both Pb and Zn (Table 6.2). The bottom sampling depth probably reaches the soil illuvial horizon according to observation during sampling, so in the terms of soil profiles, the illuvial horizon of sites with background level has a higher level of Pb and Zn than upper horizons.

For sites with high Pb and Zn levels, the concentration of the metals in each layer is shown in Figures 6.2 and 6.4. No tendency of Pb and Zn distribution was identified for these samples as can be seen in the figures and as was confirmed by a statistical test. There is no significant difference between three layers with confidence level ≥ 95 % (Table 6.3). The soil profile of heavy metal is disturbed in these sites.

Table 6.2 The mean Pb and Zn content (ppm) at different depths of background level samples

Element	Metal metal content (ppm) at			
	Surface depth	Middle depth	Bottom depth	Mean
Pb	40.8 **a***	48.4 **a***	53.8 **b***	47.7
Zn	62.3 **a***	68.6 **a***	83.5 **b***	71.5

** There is a statistically significant difference (P<0.05) between any two values (for the same element) if they have different letters affixed.*

Table 6.3 The mean Pb and Zn content (ppm) at different depths of high concentration samples.

Element	Metal content (ppm) at			
	Surface depth	Middle depth	Bottom depth	Mean
Pb	10.1×10^2 **a***	12.7×10^2 **a***	15.0×10^2 **a***	12.7×10^2
Zn	10.8×10^2 **a** *	11.9×10^2 **a***	12.7×10^2 **a***	11.8×10^2

** There is a statistically significant difference (P<0.05) between any two values (for the same element) if they have different letters affixed.*

The tendency of top soil enrichment of heavy metals was not found in the study area either in background or high level samples. Higher concentration of the metal in the top soil usually indicates aerial deposition as stated by Martin and Coughtrey (1982) and many other authors. At the study area there is no evident source of aerial contamination. The area is a remote forest, far from any industrial estates or busy roads.

During this thesis work, samples were taken according to metric depth but not horizon. Variation of metal concentration with depth in soil can be of considerable significance, especially if some impression is given not only of the absolute distribution with depth but also of the relationship with the various soil horizons.

In comparison to sites associated with aerial fallout, those associated with past or present mining activities can be expected to exhibit very different metal distribution characteristics. There are no common characteristics of profile distribution of Pb and

Zn at these sites. The reasons for these differences are complex. There may be several interrelated causes of the variation of heavy metal level in soil such as chemical leaching, precipitation and adsorption into soil organic matter, or it may be the result of the excessive disturbance of soils that may occur during mineral extraction.

The coefficient of variation between three depths at each same sampling site was calculated. There is a strong variation between them indicating that they are significantly different from one another. But even though samples were collected at three depths, all samples from a particular site usually fall in the same rank shown in Table 6.1. Exceptions are sites 6, 30, 33 for Pb values and sites 24, 31 for Zn values. It is easily noticed that at these sites, the CVs among depths are higher than 40 %. Some of the samples with extremely high levels of heavy metal, have CV higher than 40 % but are still in the same rank because there is no upon limit to the highest rank.

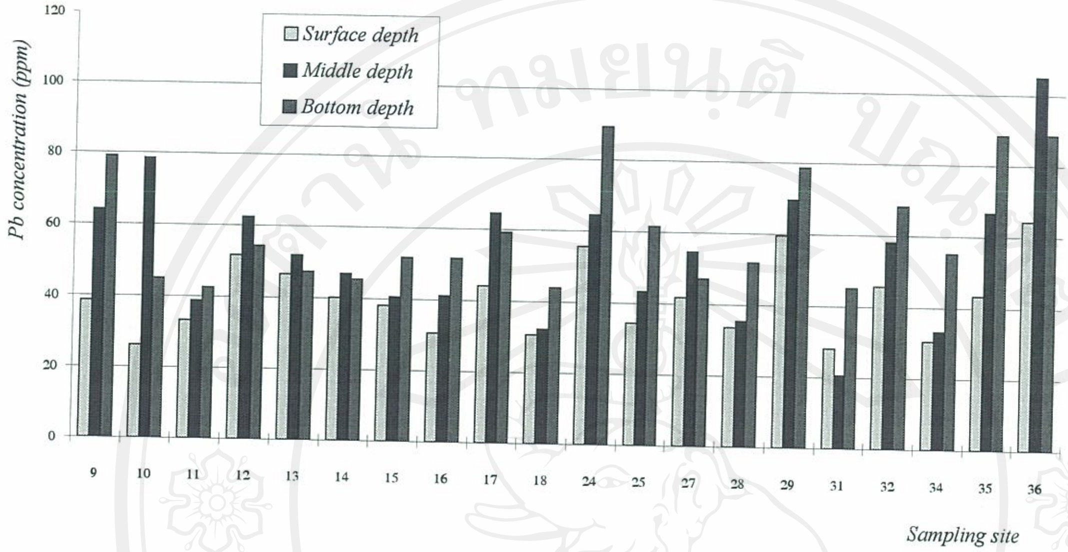

Figure 6.1. Pb distribution in three depths of background level samples.

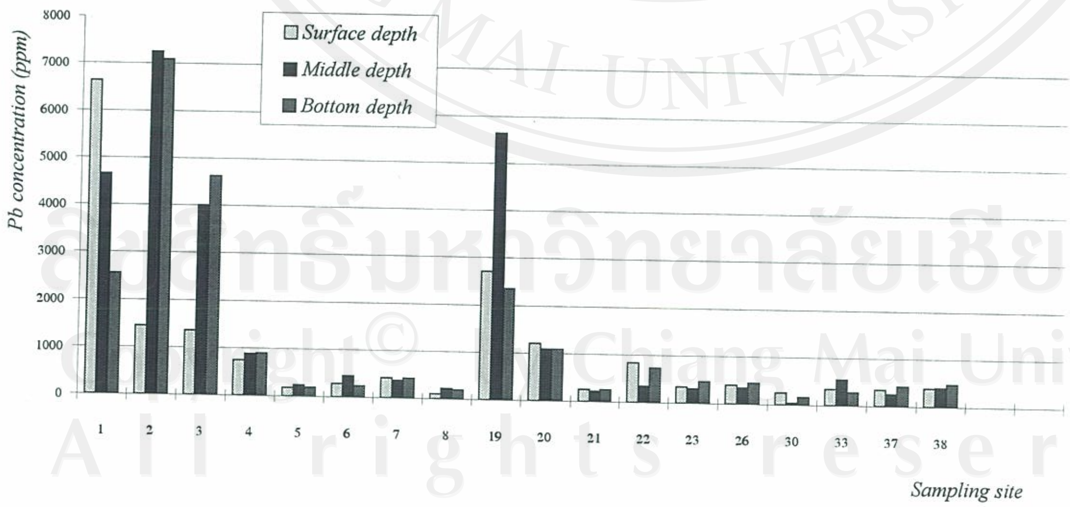

Figure 6.2. Pb distribution in three depths of high level samples

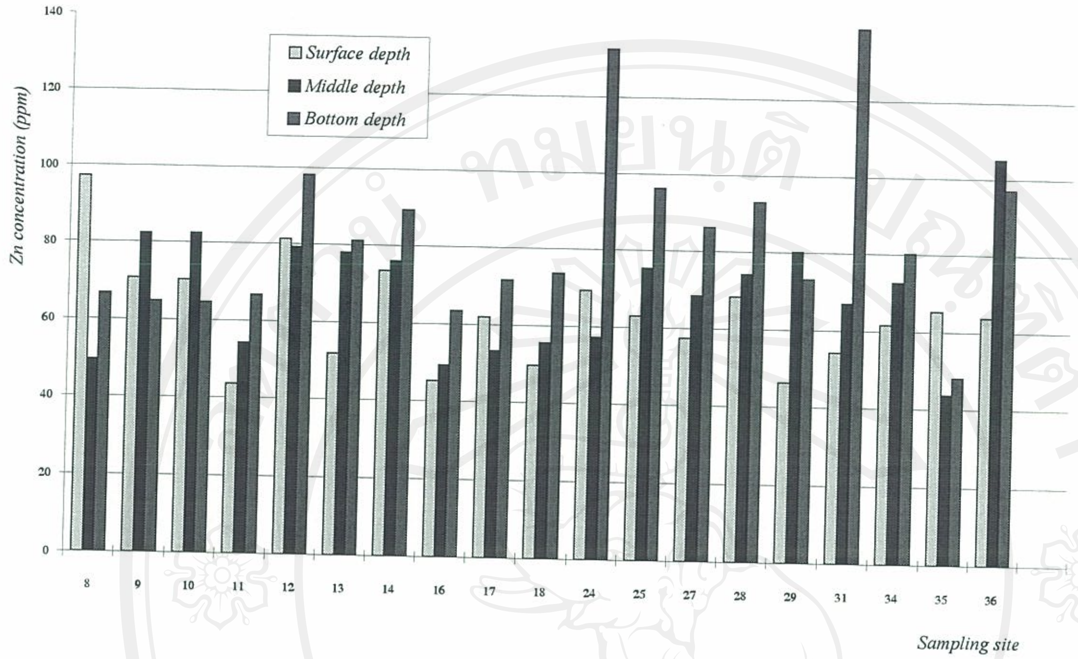

Figure 6.3. Zn distribution in three depths of background level samples.

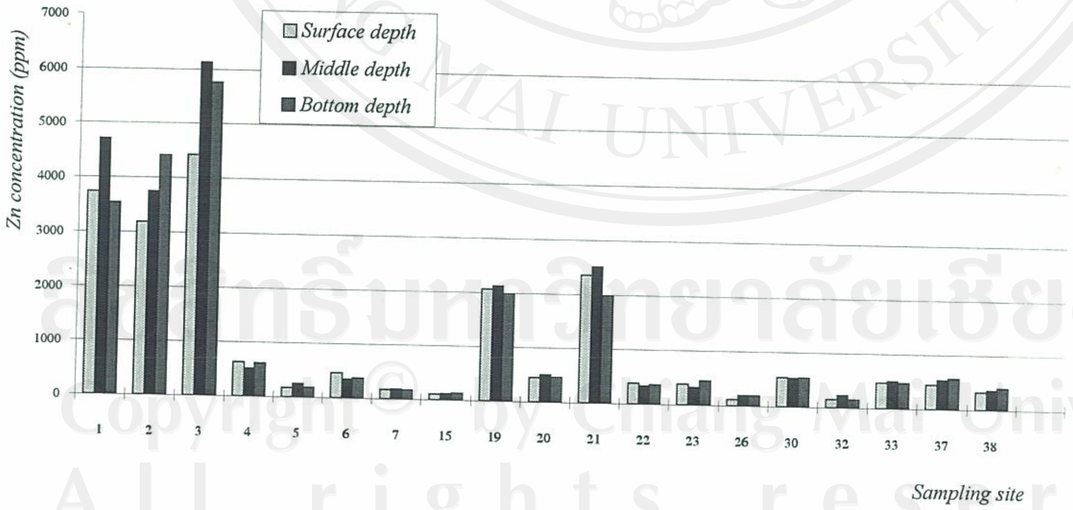

Figure 6.4. Zn distribution in three depths of high level samples.

6.5 THE CHANGE OF Pb AND Zn CONCENTRATION WITH DISTANCE FROM THE SOURCE OF CONTAMINATION

The mean concentrations of Pb and Zn were calculated from values from 8 squares. In each of three lines (also called transects), significant differences of Pb and Zn content were observed as listed in Table 5.6 and as was confirmed by ANOVA statistical test. The mean concentration of Pb changes from 943 ppm at the source line to 418 ppm at the second and 100 ppm at the last line. The mean Zn concentration changes from 3,650 ppm to 1,500 and 108 ppm in the same order of line.

The first line is located at about the 950 m elevation above sea level, the second line is at about 850 m and the third has an elevation ranging from 650 m to 700 m. The horizontal distances from the first to the second and the third line are 150 m and 400 m, respectively. The first line was taken as a source of Pb and Zn because of two reasons as follows:

- Firstly, it was located in close proximity to the mine (about 30 m from the mine), where many mine waste heaps were observed.

- Secondly, it was located at the highest elevation in comparison with other two lines, which were at the same site but at lower elevations. The Pb and Zn and other elements have high potential to move down because of height differences between these lines.

There are many factors which affect the movement or change of heavy metal in soil media, such as topography, climatic conditions, soil properties etc. Thus comparison of Pb and Zn levels between the three transects by taking representative samples from 8 squares is only a preliminary study of the real fate of Pb and Zn change with change in distance from the source. In order to discuss the change or dispersal of Pb and Zn in a designed study, it is necessary to assume that:

i) The three designed lines have similar topography and climatic conditions as well as soil properties;

ii) The Pb and Zn concentrations in the first line were considered as the source of contamination, i.e. they are the so-called 100 % source of contamination.

iii) The natural deposition of Pb and Zn is the same or almost the same with very low difference in the chosen study area. All of differences of heavy metal level in three lines are caused by movement of the elements only.

The contents of Pb and Zn found in the second and the third lines were recalculated as percentage of the contents in the source line. Thus, the pattern of change with distance down to the foot of the slope, is clarified.

As shown in Figure 6.5, the mean contents of Pb and Zn concentration at each line expressed as percentage of the contents at the first line, indicate that movement of Pb has a different tendency from that of Zn. The percentages of elements found along the lines indicate how much each element has moved. The greater the percentage found in the line, the more the amount of the element that has moved.

At the second line, 44 % of Pb was found in comparison with 100 % at the source, whereas the level of Zn was found to be 40.9 %. This indicates that Pb has moved down more than Zn. If the change is only due only to the movement of elements as assumed above, the interpretation that Pb was moved down in the term of distance more than Zn is possible. The contrast between the two elements is strongest at the last line where the amount of Zn is down to 2.9 % whereas the amount of Pb is 10.6 % confirming that Pb was found in higher percentage (compared with the source) than Zn at 400 m distance. Pb has moved or dispersed to a greater distance than Zn.

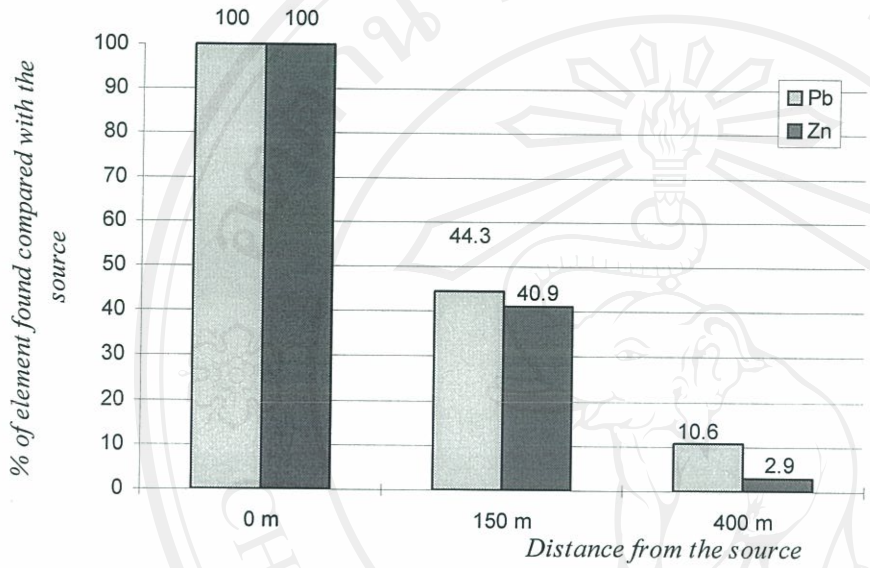

Figure 6.5. The change of Pb and Zn according to distances from the source

The percentages of 10.6 % for Pb and 2.9 % for Zn, are not very high at the final line. Horizontal distance from the first line to the third line is less than 500m, but the concentrations of Pb and Zn considerably decrease. 30 years after human exploitation of the ore deposit, the first line has a high level of Pb and extremely high level of Zn, whereas at the third line, 500m away from the first line, the mean ultimate concentration of both elements almost reaches the background level 100 ppm for Pb, and 108 ppm for Zn. That shows the low mobility of Pb and Zn in soil resulting in their persistence but low dispersal in the soil environment.

Although the source contains very high to extremely high levels of the potentially toxic elements Pb and Zn, as mapped in the Figure 5.4 the total area heavily affected by Pb and Zn extends for only 500 m to 1 km from the mine.

It can be seen from Table 5.6, that the standard deviations on contents of Pb and Zn at each line are high. CV at the third line reached the value of 69.3 % for Pb and the value of 43.3 % was reached in the case of Zn at the second line, indicating that the concentration along the study lines is considerably variable. This situation makes a comparison of the study less reliable and conclusive than it might be. In the other hand, the movement of metals in soil media is due to the mass movement of soil (solifluction) and also is due to their movement in soil solution *in vitro* (hydromorphic). All of the evidences shows that the movement of Pb and Zn as well as that of all other heavy metals, is very complex. But the obtained results can be used as a start towards further understanding of heavy metal behavior in soil.

6.6 SOIL pH and SOIL ORGANIC MATTER

The soil reaction is the pre-eminent factor controlling the chemical behavior of metals and many other important processes in soil. However, the pH concept is not as precise for soil as it is for solution *in vitro* because of the heterogeneity of soil, the relatively small proportion of solution present in the pores of the solid and the adsorption of H^+ ions onto solid phases. Soil pH was measured in the laboratory after letting samples dry in open air. Soil pH values of the study area range in value from 5.8 to 7.6. For easier expression they were divided into three groups: of less than 6, from 6 to 7 and more than 7 and then displayed in the map, as shown in Figure 5.3.

It was found that 26 of 38 sampling sites have pH values in the range from 6 to 7, whereas site 4, 8, 9, 12 and 21 have pH of lower than 6 and the other 5 sites i.e. 25, 26, 36, 37 and 38 have pH of more than 7. No correlation was found between soil pH and Pb and Zn level, as shown in Table 5.8.

The main feature which distinguishes soil from decomposed rock is the presence of living organisms, organic debris and humus. All soil contains organic matters, although the amounts and types may vary considerably. Soil organic matter in the study area ranges from 5.9 % to 9.6 %, which is within the normal range of soil organic matter found in most literature. Slightly negative correlation between soil OM and Pb and Zn was found.

6.7 SOIL PLANT RELATIONSHIP FOR Pb AND Zn UPTAKE BY PLANTs

6.7.1 Lead and Zinc uptake by ground flora in non-contaminated soil

Besides the geochemical environment, the different biogeochemical cycles of elements in the forest and on the land also have an influence on the element contents of the plants. All of chosen plant species are ground flora. Two of them are herb (*Apluda, Microstegium*) and two of them are ferns (*Ligodium, Anisocampium*) and one is a fern ally (*Selaginella)*

The total quantity of lead and zinc in above ground plant tissues is shown in Table 5.11 which indicates that above ground tissues carry a lower amount than root tissues. Many authors conclude that heavy metal uptake by plants is mostly accumulated in the roots. In the case of *Apluda* the quantity of Pb in roots is 14.4 ppm, almost three times higher than that in its above ground tissue. Hereafter only the amount of Pb and Zn found in above ground plant tissue, simply called plant tissues, is considered.

Table 5.11 lists the Pb and Zn concentrations found in plant tissues and related soil samples. All of the samples were collected at sites where Pb and Zn occur at background level. The value of Pb in soil varies from 45.3 ppm to 53.8 ppm, and that of Zn from 40.8 to 67.4 ppm. These data can be used as reference levels of Pb and Zn in plants growing in non-contaminated soil. Plant samples taken from non-contaminated sites have Zn contents in the tissue higher than Pb. The concentrations of Pb in 5 species were found to be less than 10 ppm, except in the case of *Microstegium*, in which 40.2 ppm was found , whereas Zn concentrations were from 17.3 to 31.8 ppm. Accumulation of Zn in plants is higher than that of Pb which is the normal situation, because Zn is an essential element for plant growth, whereas Pb is considered to be a potential toxic element for plant growth.

The amount of Pb and Zn taken up by the five species is not conclusive about their uptake capability for Pb and Zn because that amount is highly correlated with the Pb and Zn levels in soil. Table 5.11 indicates that *Microstegium* has the highest Pb and Zn contents in comparison with the other selected species. *Microstegium* has the highest soil-plant transfer coefficient (K=0.888 for Pb and K=0.780 for Zn).

The K coefficients shown in Table 5.11 indicates that all of the plant species have a tendency to accumulate Pb and Zn from soil. Pb and Zn absorption and accumulation by plants varies widely between plant species. Generally, increases in soil element content cause the increases of the element in plant tissue content. Uptake rate of Pb by plants in this study decreased in the order *Microstegium, Anisocampium*

Selaginella, Ligodium, Apluda,. For the plant uptake of Zn the decreasing order is *Microstegium, Ligodium, Apluda, Selaginella, Anisocampium.*

6.7.2 Soil-plant relationship in contaminated and non-contaminated soil

The ferns have very short life cycles. Even though the species *Anisocampium,* or *Selaginella* seemed to be promising subjects for the study of soil plant relationships they were not available throughout the period of study. Therefore the soil-plant relationship study was intensively focused on two herb species namely *Apluda* and *Microstegium*. There were two advantages in doing this. Firstly, they are very abundant species growing abundantly not only in highly but also in less contaminated land. Secondly they have longer life cycles than ferns.

Further study on the soil-plant relationship of heavy metals (simply called the soil-plant relationship) revealed that the amount of Pb and Zn found in plant tissues is a function of Pb and Zn amounts in soil. Figure 6.6 to 6.9 illustrate the tendency of these functions of the amount of Pb and Zn in soil.

The samples were taken in natural condition. It was difficult to take a plant samples in soil of expected Pb and Zn level. Two factors which limited the plant sampling were the availability of plants at chosen sampling sites and the unknown content of Pb and Zn where plants were growing. Pb and Zn contents were determined soon after taking samples back to the laboratory.

The data listed in Table 5.12 are plotted in Figures 6.6 to 6.9. A tentative conclusion can be drawn as each herb species has its own mechanism of metal uptake, or in other words, the differences in uptake of metals by plants are dependent on the plant species but not on the element itself.

Species *Apluda* is sensitive to the level of Pb and Zn in soil when this is lower than 5,000 ppm. The Pb and Zn content in plant tissue proportionally increases with the increase of metal level in soil as illustrated by Figure 6.6 and 6.8. When the Pb and Zn content in soil is higher than 5,000 ppm, the species Apluda shows a relatively stable Pb and Zn level in its tissue. In contrast with *Apluda*, the *Microstegium* species has stable Pb and Zn content in its tissue where the soil contents of Pb and Zn are less than 10,000 ppm. Where the content of Pb and Zn in soil is more than 10,000 ppm, the Pb or Zn content in plant tissues proportionally increases with increasing content in the soil (Figure 6.7 and 6.9)

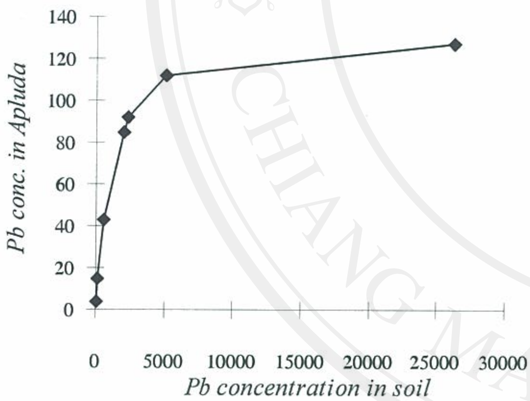

Figure 6.6. Soil-plant relationship of Pb (ppm) for *Apluda*

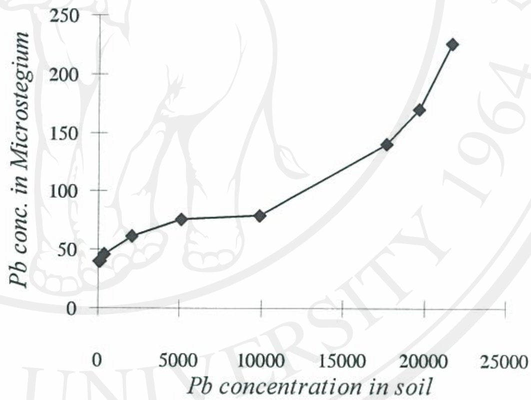

Figure 6.7. Soil-plant relationship of Pb (ppm) for *Microstegium*

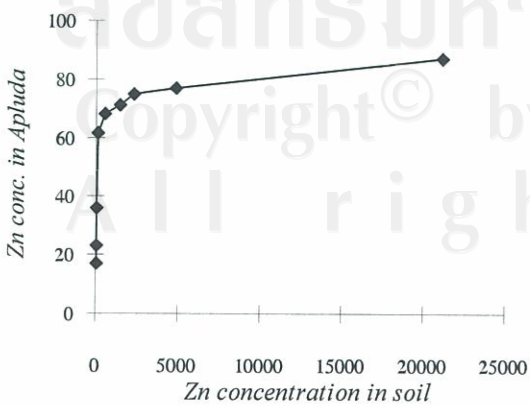

Figure 6.8. Soil-plant relationship of Zn (ppm) for *Apluda*

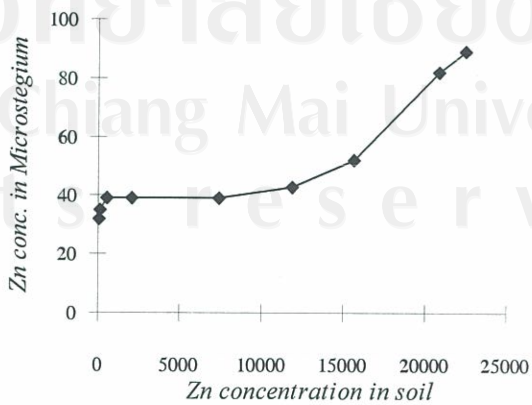

Figure 6.9. Soil-plant relationship of Zn (ppm) for *Microstegium*

Unlike Pb, Zn is a nutrient element for plants as well as for other living organisms. The amount Zn found in plant tissue is higher than that of Pb in the non-contaminated land. But as shown by Figures 6.6 to 6.9, when the concentrations of Pb and Zn reach extremely high levels, the Pb content in the studied plants is higher than the Zn content.

As shown in Table 5.12, the soil-plant transfer coefficient of *Apluda* for Pb ranges from 0.005 to 0.097. These values are very low compared to those of *Microstegium*, where the K ranges from 0.007 to 0.888. The soil-plant transfer coefficient is very low when the soil content is very high, pointing out the uptake limit of plant species. The same tendency was observed in the case of Pb in *Microstegium*. The K value tends to be steady around 0.01 when the Pb in the soil is higher than 9,870 ppm.

In the case of Zn , K varies from 0.004 to 0.720 for *Apluda* and from 0.004 to 0.604 for *Microstegium*. The K value for Zn in *Microstegium* varies little, being in the range from 0.003 to 0.005 when the Zn content in soil is above 7,880 ppm showing that the concentration of Zn in plant tissue becomes increasingly proportional with increasing Zn level in soil.

For both elements, K value considerably decreases with increasing metal content in soil. The K value reaches value less than 0.01 indicating the limit of plant ability to take up metals in soil. There is no significant increase of metal content in plant tissue even when the content of metals in soil is more than 20,000 ppm, which is considerably high.

As explained and illustrated in Figure 1.1 by Martin and Coughtrey (1982), plants can be divided into three categories based on their responses to increasing heavy metal concentration in soil. *Apluda* can be considered as accumulator species in which the relationship between uptake and substrate concentration is curvilinear: Uptake levels off at high concentration. *Microstegium* is an excluder species in that metal concentrations in the plant tissue are maintained at a low and constant value over a range of soil concentration until some threshold value is exceeded, when uptake becomes unrestricted.

Zn is essential. Pb at earth crust average levels is not toxic to plants. High soil contents of metals in soil do result in stunted growth or death. The herb species, *Apluda* and *Microstegium* have evolved tolerance to very high soil Pb and Zn and can be used to revegetate contaminated land.

6.8 RISK ASSESSMENT

The Mae Taeng lead-zinc bearing ore deposit was exploited 30 years ago. The principal metals extracted were lead and zinc. The operation was carried out without taking consideration of development planning, pollution control and environmental legislation that present day mines have to contend with. Consequently there was none or very little control over the way that the mine was worked for their waste disposal arrangement and their eventual abandonment.

As at most other old mining areas, the Mae Taeng mine is a characteristically derelict and polluted site, with combination of the following features:

- Mine-waste heaps, which are unvegetated or have degraded forest cover and are heavily contaminated by heavy metals;

- Potential for contamination of water courses, arising from erosion of mine wastes during heavy rain;

- Surrounding land contaminated by water and wind-eroded spoil.

Some of crop production sites in the study area have no risk from contaminated soil but some of them are liable to very high risk. None of the crop production sites was located in the area contaminated by mining wastes. But a lot of them are located in the areas which have naturally high contents of Pb and Zn as found in this study. These are listed in the Table 6.4.

Table 6.4 Crop production fields in the study area (8/ 1997) and their risk values

Sampling site	Crop field	Risk value of Pb	Risk value of Zn
6	Maize field	3	3
7	Rice field	3	1
11	Maize field	1	1
12	Cassava field	1	1
15	Banana farm	1	2
17	Lychee farm	1	1
20	Maize field	5	3
28	Maize field	1	1
33	Banana farm	3	3
37	Rice field	3	4
38	Maize field	3	3

The Mae Taeng mine was quite small and was closed 30 years ago. It still has a few remains and has been naturally colonized with vegetation, blending with the surrounding landscape. The extent to which the old mine becomes an environmental problem depends on a combination of two factors:

- The site characteristics: the mine is located at the elevation of 1,000 m almost on the top of a mountain. The contents of Pb and Zn in its close proximity are extremely high. The persistence of those heavy metals is very high. Many downstream properties obtain water run-off from this contaminated land. This water supply is potentially contaminated with Pb and Zn and may be with other associated heavy metals.

- The surroundings: one residence of Lahu people was located 500 m far from the mine and other three hill tribe villages are located in its surroundings .Their rice fields, maize fields and other crops are situated in highly contaminated land. Local people and visitors are exposed to the high risk of heavy metals pollution of water and soil involved in food production.

Some of heavy metals such as copper and zinc are essential for man, animals and plants, whereas other elements, e.g. lead, cadmium and mercury show no positive effect at all. Their re-introduction to soil, which is used for food or feed production can therefore do nothing but harm. Some heavy metals can influence microbial activities in soil and thereby reduce the soil productivity. In high concentration all of these elements whether essential or not, are potentially toxic to plants and warm blooded animals and man.