6. DISCUSSION

6.1. Trace elements in soils

In spite of changes in the element composition of rocks and minerals during weathering and soil formation processes, the total trace element content of soils usually reflects quite clearly the composition of the materials from which they have been derived (Sillanpaa, 1972). Table 6.1 shows the relationship between the concentration of a trace element in a soil and in its parent material, however, it is not always close enough for satisfactory quantitative estimation of the former from the latter. The relative variations of the total content of trace elements in different soils are much wider than those of major nutrient elements. Besides the mineralogical composition of the parent material, the total amounts of trace elements present in soils depends on the type and intensity of weathering and on climatic and other factors operating during the process of soil formation. The major rock components of the earth's crust are igneous rocks, sedimentary, and metamorphic rocks, and soil derived by weathering from these rocks.

Although wide variations occur in the trace element composition of individual soils and rocks, it is evident that, the differences between the average contents of igneous and sediment rocks and soil are not great. Soil samples collected from Mae Moh have high concentrations of trace elements, but most of the samples had concentrations of trace elements lower than tolerance limit. Table 6.2 shows the average trace element composition of rocks, coals, and soils compared with soil analysis in this study. Concentration range for chromium from 1 to 32.3 ppm, copper from 3.45 to 45.8, for lead less than 55 ppm as compared to tolerance limit for these elements in soil 100 ppm. Concentration of arsenic is high in Mae Moh coal, very high in Mae Moh fly ash and quite high in soil samples of this study. Concentration of arsenic in coal, fly ash and soil are 45-50, 213, 1-50 ppm respectively

Table 6.1 Natural content of metals in rocks

Type of rock	Cd	Mn	Ni	Co	Zn	Cu	Cr	Pb	Hg	Fe	Al
					mg/kg					mg/g	
Ultrabasic rock	0.X	1600	2000	150	50	10	1600	1	0.0X		
Basalt	0.1	1500	130	50	100	90	170	6	0.09	90	90
Granit Ca-rich	0.1	500	15	7	60	30	20	15	0.08	30	80
Granite Ca-poor	0.1	500	5	1	40	10	4	20	0.08	15	70
Syenit	0.1	400	5	1	130	5	2	10	0.0X	40	90
Shale	0.3	900	70	20	100	50	90	20	0.4	50	80
Sandstone	0.0X	X0	2	0.3	15	X	30	7	0.03	10	25
Limestone	0.04	1000	20	0.1	20	4	10	10	0.04	4	4
River sand	0.1							10		1-2	6

X: < 0.1
Source: Turekian and Wedepohl (1961)

Table 6.2 Concentrations of trace elements in coal, rocks, and soil

Element	Coals				Rocks[a]		Soil			
	USA[a]	Australia[a]	Europe[a]	Mae Moh[b]	Igneous	Sedimentary	Typical[a]	Range[a]	Tolerant limit[c]	This study[d]
As	15	3	6.3	45.5	2	1-3	6	0.1-40	1-30	
Cr	15	6	26.4	23.01	100	10-100	10	2-100	100	1-32.3
Cu	19	15	41		55	5-45	20	2-100	100	3.45-45.8
Mn	100	150	80		1000	50-1100	850	100-4000		
Ni	15	15	47	27.61	75	2-70	40	10-1000	50	1-31.6
Pb	16	10			12.5	5-20	10	2-200	100	<55
Zn	39	<100	70		70	10-100	50	10-300	300	12.7-70.8

Sources: a: from Straughan *et al.*,(1978)
b: from Fyfe *et al.*,(1993)
c: from Klarschlammverordnung von 1982
d: present study

A study in Mae Moh soil characteristics carried out by Institute Environmental Research, Chulalongkorn University (1981) showed that trace elements in Mae Moh area are quite high, however, there was no report how high it is. The concentrations of trace elements in this study are vary from site to site due to many factors, including soil organic matter, pH, bedrock, texture, natural changes in soil properties, distance from the power plant, wind direction, etc., which will be discussed as follow.

6.2. Difference in element concentrations between two different depths.

Most of the trace elements are naturally present as contaminants in the particulate fraction. Fuel combustion from stationary sources is responsible for nearly one-third of atmospheric particulate pollutants and industrial processes are second to stationary fuel combustion and also account for nearly one-third of the total. (Stoker and Seager, 1972). Contamination of soil from air pollution can often be significant since many trace elements tend to remain near the soil surface after deposition. Trace element contamination of the soil surface resulting from atmospheric pollution from an industrial source can lead to accumulation of toxic elements in the surface horizon. If the surface soil is substantially polluted by atmospheric deposition, the surface few centimeters and especially surface organic layers may contain high total concentration of heavy metals compared with the original background contents of materials at greater depth. Especially in forest soil the organic surface layers often show an enrichment of heavy metals as a result of the air filtering effect of the forest vegetation as well as littering and decomposed of plant leaves which contain high concentration by absorbing from the soil. Thus, the content of lead and other heavy metals in the organic surface layers of forest soils can be taken partly as an indication of the degree of atmospheric deposition. But also a translocation of metals from subsurface horizons to organic surface layer by metal uptake of the plant roots, transport to the overground parts of the plants and accumulation of organic material on the soil surface may cause an increase

of metal contents in the organic layers (Bruemmer *et al*, 1986). The non-significant difference of concentration between two depths for major and trace elements can be explained since there is not much pollution in the area consequently there is no change of concentration with soil depth. The other possibility is there is too narrow a depth range which does not show any change in concentration. All samples were collected from surface layers therefore, there is not much difference in the soil composition. On the other hand, soil erosion by heavy rain and run off in the mountainous areas could put some pollutants into aquatic ecosystems. Soil erosion consists of two main kinds of processes that closely follow one another; firstly rain-splash or rain drop erosion which involves the impact of rain drops on the ground and the detachment and ejection splashing of soil particles, and secondly, run-off erosion which transports the detached particles through overland flow. All metals deposition can be washed out from surface soil by these erosions methods. Animals and microorganisms are also responsible for transfer and mix up metals contents between different layers.

6.3. Trace element concentration- distance relationship.

Figures 6.1. and 6.2 show concentrations of trace elements and arsenic in the study area. The ranges of concentrations of Al, Ca, Mg and Fe found in fly ash and bottom ash were within the ranges of their concentrations in soil (Mattigod *et al.*, 1990). Therefore, there was no effect from the power plant on soil major elements concentration. However, concentration of trace elements in fly ash are much higher those in soil (Hart *et al.*, Ratanasthien *et al.*, 1991, Page *et al.*, 1979). Trend in soil data of this study shows no distance-concentration relationship. Normally, concentration of pollutants exhibits a reverse correlation with distances from the source of pollution. However, in some cases the changes in trace elements in soil reflects natural changes in trace element content and even increasing in concentration with increasing distance from the power plant. Concentration of lead at most of the study

sites were low, according to low lead content in coal and fly ash. Lead concentration in soil at sites 6, 7, and 8 are higher than the other sites due to heavy traffic on Lampang-Ngao road. General, concentration of trace elements in soil didn't show any correlation with distances. However, there is relationship between concentration with wind direction and topography of the area. Sites 11, 13, 14, and 16 are located southwest direction from the power plant show the low levels trace elements content in soil. Sites 9, 10 and 12 in the south and southeast direction also show low trace element level. Soil samples from site 4 and 5 in the north and northeast direction behind high mountain contain low trace elements levels except sample taken from gully of site 5 which locates near pineapple fields. This sample maybe affected by pollution from agriculture activities e.g. pesticides and fertilizers and run-off. There is trend trace element contents higher in soil northern of the power plant. It is due to the wind direction, wind turbulence and topography of the area. Sites 1, 2, 3, 6, 7, 8, 15, 17 and 18 show high levels in copper, chromium, lead, nikel and zinc. There are many factors which affect pollution patterns such as stack height, wind direction and turbulence, topography of the area, and vegetation.

Raising the height (H) of the stacks will reduce the concentration within distances D <10 H. In some cases, it creates pollution problem in areas located far away from the pollution source. Wind turbulence is one of the factors influencing the distribution of air pollutants. When the wind is strong, the diffusion is rapid and maximum concentration at ground level will be reached at D >10 H but the magnitude of maximum concentration will be lower. With weak turbulence, the pollutants drift away so that maximum concentration occurs at D < 10 H, but the concentration will increase (Summer, 1963). The height of power generating units 1-3 stack is 100 m while that of units 4-12 is 150 m. This disperses pollutants to a large area far from power plant. Wind direction and wind turbulence change with the monsoon seasons, therefore, the maximum concentration of pollutants also occurs in different distances

from the power plant. Moreover, polluting particles and dust from dumping sites, mining activities, and transport of coal and ash are adding pollution and changing this pattern. The tailings, depending on the local composition of the lignite and sediments, also contain heavy metals such as Pb, Zn, Cu, and Cd. Thermal inversion frequently occurs in the area, especially during the cool season is another reason which reduces difference in concentration between sites. The dense fog, calm atmosphere and highly toxic fumes from the plant may combine to make a chamber. There may be hardly any air movement and conditions can be quiescent and stable for a few days at a time. Thermal inversions create built-up pollution affecting the health of people and animals, as well as spreading pollution over the valley, which causes damage to crops. On the other hand, it has also been observed that the mountains and vegetation may play an important role as a green filter especially in area with more forest. Calculations to estimate element enrichment in surrounding area (Figure 6.3) shows that if the electric precipitators could trap 99 percent of particles and release only 1 percent or less than that of fly ash produced, trace elements pollution would be negligible. Calculation shows there is less than 6 ppm of arsenic, chromium, cobalts, nikel added to soil in the area after 18 years the power plant operates.

No concentration-distance relationship indicates small input of trace element from the power plant to the surrounding soil.

6.4. Arsenic content in soil samples

From figure 6.2 it is obvious that concentration of arsenic in soil samples is much higher at sites (sites 3, 4, 7, 8, 9, 17 and 18) which situated north of the power plant. It maybe relates to wind prevailing throughout the year with north direction much longer period than this of south direction. Topography of the area also seems to affect in arsenic content in soil.

Arsenic is a toxic, highly volatile element. The concentration of As is quite high in some study sites. The reason for this is that Mae Moh lignite and fly ash contain high concentrations of As (Ratanasthien *et al.*, 1991). Chadwick and Lindmand (1982) evaluated the reported values on concentrations of trace elements in coal found that concentrations of trace elements from different coals often display considerable variability. Generally, trace element content decreased with increasing hardness of coal. Trace element content of coal is known to vary considerably between regions. Reports also show that As almost always has higher content in low grade coal deposits like lignite. In the case of As, lignite deposits in Czechoslovakia contain from 900 to 1500 μg/g, and serious As contamination has arisen in the vicinity of the power plants which consumes this coal. As can be accumulated in fine ash particles (Fyfe *et al.*,1993) which can be dispersed a very far distance. This may be the reason for having high As content in soil samples at Mae Moh. Another recent work of ERA students in studying air pollution problems in Mae Moh showed high concentrations of As in dust deposited on the surface of bamboo leaves collected from 5 sites namely Mae Chang, Dumping area, Mae Kham reservoir, Ban Tha Si and Ban Huay Luang . Result of As analysis of dust samples using graphite furnace AAS at Saarbrucken, Germany is shows in Figure 6.4 (Peveling, 1994). Soil and dust samples at site 3 (Dumping area) contain high arsenic content since this site locates near dumping site, near old units 1-3 and also near units 4-12. Moreover, high mountain (Doi Chang) of the site traps pollutant particles and keep them in the site.

However, due to some technical problems, lack of experience and graphite furnace, arsenic analysis in this study is not successful as it is expected. It was not until last moment analysis got first reliable results and calibration curves. Method of digestion of soil samples, reaction time, expensive platinum crucibles and Teflon reaction bottle all affected in arsenic analysis. To study about arsenic contamination from the power plan, more detailly study is needed.

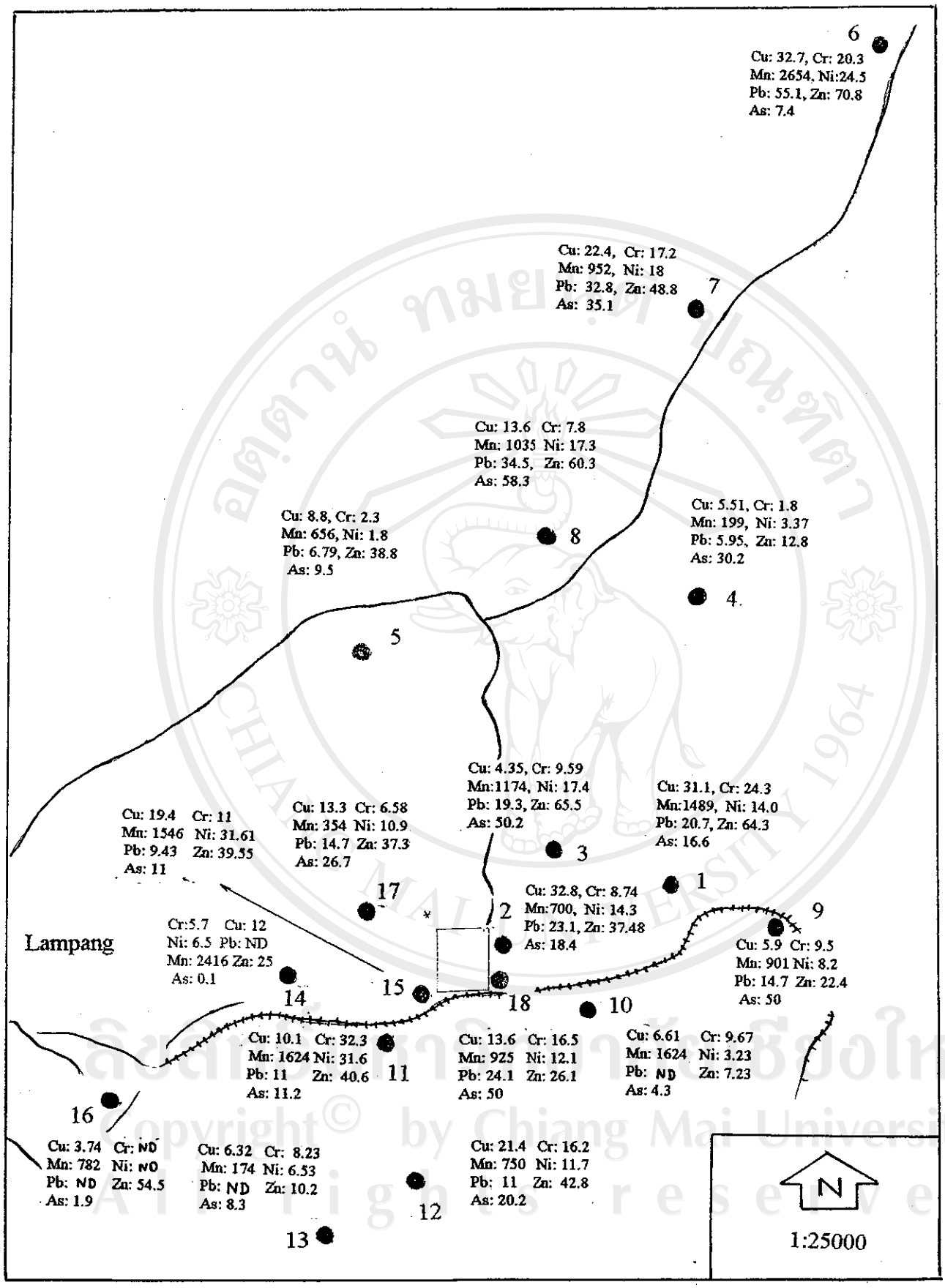


Figure 6.1 Concentration of trace element at 18 study sites

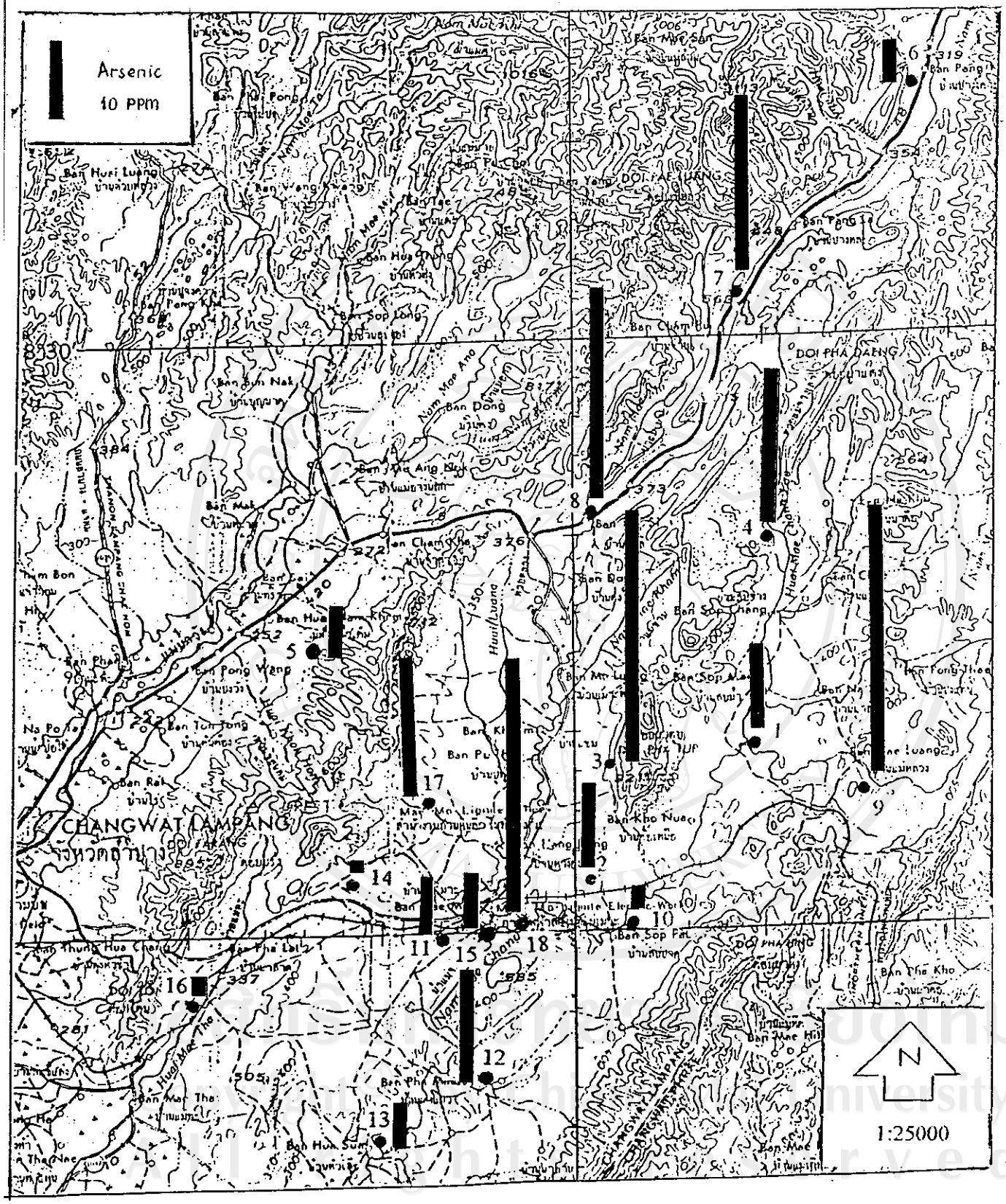
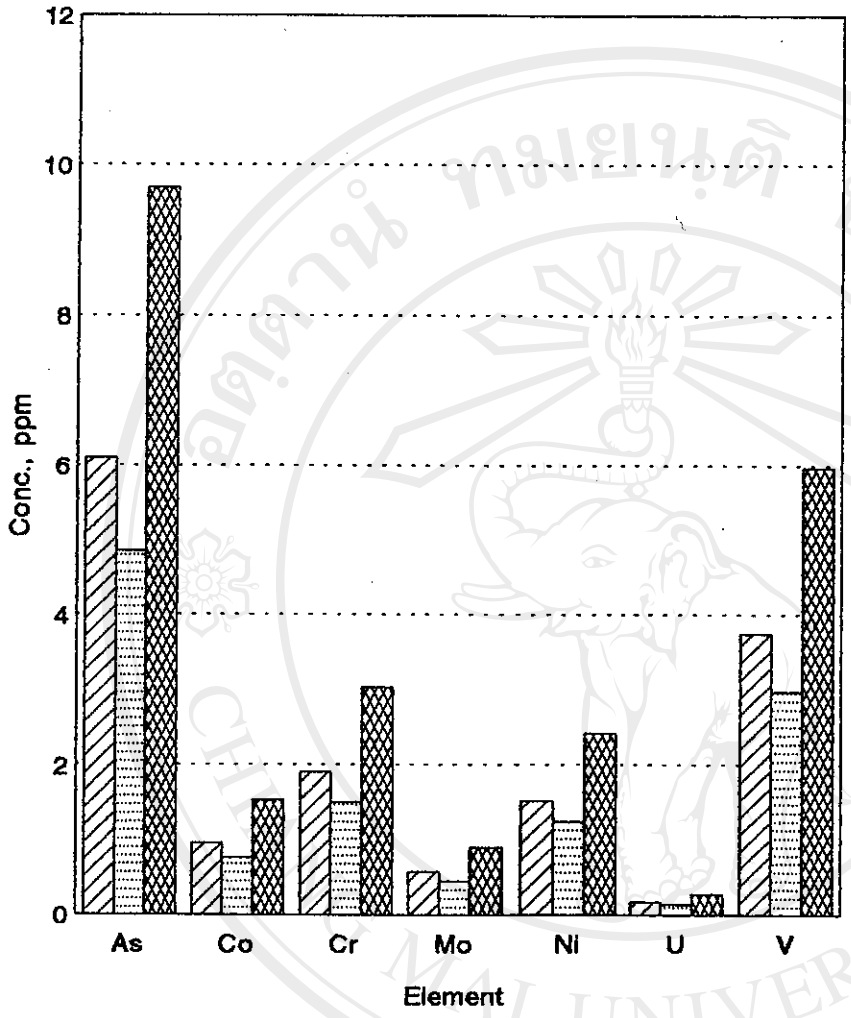


Figure 6.2. Concentration of arsenic at 18 study sites



: Area of Mae Moh Basin

: Area around radius 10 km

: Area around radius 5 km

Figure 6.3. Estimated concentration enriched in surrounding area

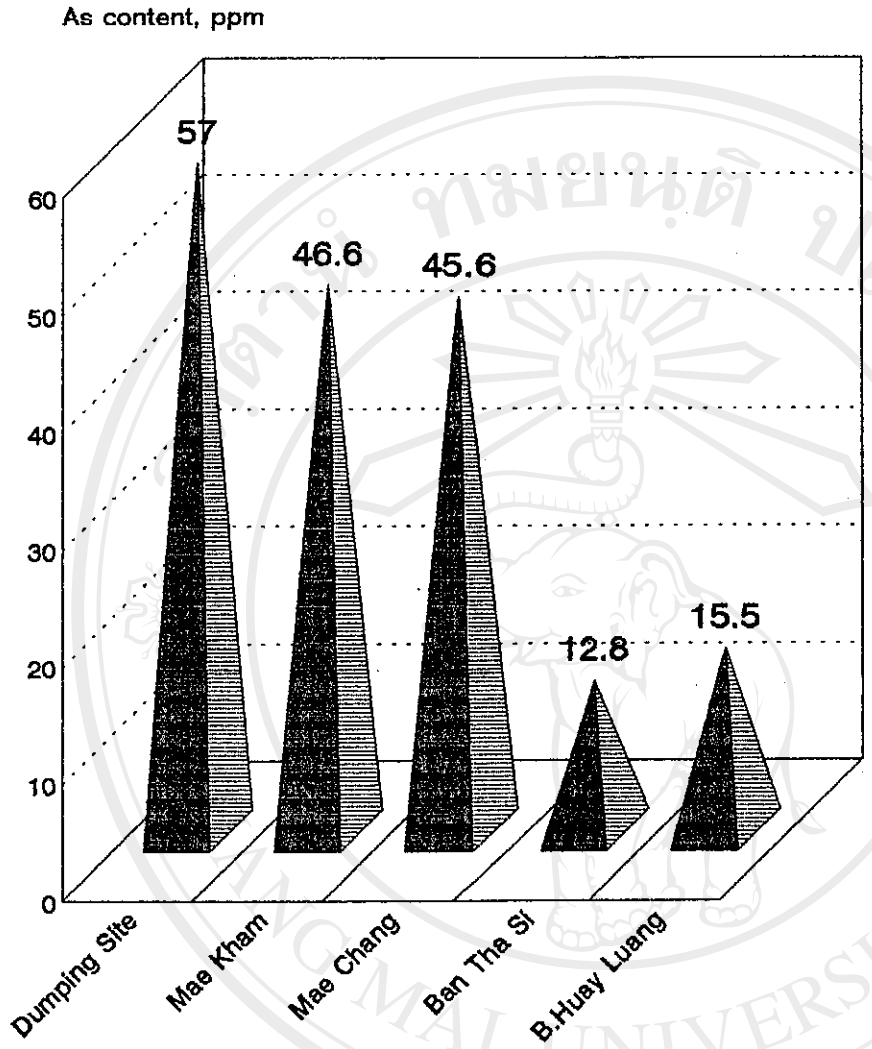


Figure 6.4. Concentration of arsenic in dust samples near Mae Moh area

Source: Peveling (1994)

6.5 Environmental risk assessment

Volatile elements generally are discharged from combustion sources as either gases or associated with conventional emission control technology and exhibiting relatively long atmospheric residence times. Gas-phase reactions with particles result in preferential concentration of volatile elements on particle surfaces, which may increase their effective bioavailability through solubilization reactions. Investigations on the effects of air pollutants on vegetation should be concerned with careful characterization and correlation of both pollutant dose and plant response. Several volatile elements in coal pose a potential hazard to the environment, but the large variability in the trace element content of soil may be masking the input of small quantities of trace elements from coal combustion, not detectable by conventional bulk analysis. Greater solubility of an element in fly ash compared to soil will increase its biological availability and potential for bio-accumulation, but also lead to greater mobility, resulting in rapid passage through the soil. Adverse effects on soil/litter processes may also result from the long-term deposition and accumulation of trace element around power plants. A possibility also exists that atmospheric deposition from coal combustion will ameliorate the deficiency of a particular essential trace element in the surrounding soil. The accumulation of trace elements by terrestrial vegetation growing around ash disposal ponds or on fly ash landfill has been examined recently. Elseewi *et al.*, (1981) pointed out the existence of a substantial fraction of boron in fly ash which is soluble in water. The solubility of this fraction is apparently enhanced by weathering of fly ash in farmland soils. As a result, fly ash-amended soil are greatly enriched in soluble boron. The study indicated that plants grown on acid soils deficient in boron may benefit from small applications of fly ash to soil. The selenium content of fly ash grown samples was greater than the fly ash concentration itself, yet soil-grown plants contained lower levels than the substrate. Elseewi and Page (1984) applied fly ash to calcareous and acid soil and investigated the availability of Mo to crops in relation to the rate of fly ash

application. It is concluded that in situations where soils are deficient in Mo, plants may benefit from small applications of fly ash to soil, but Mo concentrations in plants grown on fly ash- treated soil should always be carefully monitored. Elseewi *et al.*,(1978), Elseewi *et al.*,(1982), Page *et al.*, (1979), Phung *et al.*,(1979) pointed out that fly ash-treated soil increased in soil pH and electrical conductivity and in concentrations of Ca, Mg, Na, SO_4, and B of the saturation extract. There was no ill effects on the yield of some crops . Positive yield response to fly ash is, in most cases, attributed to increased availability of plant nutrients in treated soils. It is obvious that fly ash enrichment surrounding soil does not affect on vegetation and crops in the area. Soil in all sites with high pH decreases the mobility of most elements in soil and reduces the effects on toxic elements. pH dependence of the solution concentration of these elements shows that the mobility and availability of heavy metals is high at strongly to extremely acid soil condition (Brummer and Herms, 1986). Therefore, a high input of heavy metals, especially in strong acid soils, may lead to toxic environmental effects from the accumulated elements. Forests in the area are very degraded and have been destroyed by logging and burning. There is little evidence to say about the effects of power plant on the vegetation in the area except at site 3 which near the ash dumping area. Perera (1995) analyzed trace and major elements in plant samples collected from the study sites. Result shows *Eupatarium odoratum* and *Selaginella ostenfeldii* are accumulated high concentrations of most elements. However, there is no relationship between elements content in soil and those in plants. It can explained that not all total amount elements is available for plant. The uptake of elements by plant roots is restrictly to the liquid phase, the content of heavy metals in soil solutions is of primary importance not the total content. The total content of any trace element in the soil normally gives little indication of the availability of that element to plants. This depends on the extent to which the element becomes mobilized within the soil under the influence of a ranges of environmental factors (Jenkins and Wyn Jones, 1980). There is no relationship between

element content in plants and distances from the power plant. Heavy metals uptake by plants grown in polluted soil has been studied to a considerable extent. Studies show that elevated levels of heavy metals in soil may lead to uptake by plants, but high relationships between concentrations in soils and plants are not generally found (Kuboi *et al.*, 1986, Xian, 1988). More information is necessary about multiple ion activity ration and about antagonistic and synergistic effects of accompanying cation and anions in soil solutions in relation to uptake and physiological effects of heavy metals in plants.

Fly ash from coal-fired power generating plant which contains high concentration of B, Co, Cr, Cd, Mo, Ni, Pb, As and Se than normal found in soils. Fly ash could be used for amendment to agricultural soil as liming material (Phung *et al.*, 1976), used in concrete, building blocks and as road bed stabilizer in the construction industry, but most of that generated is disposed of in lagoons and landfill areas. The impact of fly ash on the environment when the fly ash is disposed and /recycled on agricultural lands is of growing interest to researcher. The phytotoxicity of trace elements, salt injury, and potential leaching of these constituents to the drainage or ground water are particular concern. More study about impact of fly ash and power plant on soil and ecosystems as well as trace and toxic element content in soil and plants around power plant -the pollution sources are needed to help reclamation area and decrease adverse impact.

CONCLUSION AND RECOMMENDATION

Chemical analysis of soil samples collected from 18 sites around Mae Moh Power Plant shows the variability of trace elements in soil. It reflects natural changes in soil trace elements. Trace element concentrations in Mae Moh soil are generally high, but most of the elements are lower than tolerance limits. Concentration of trace elements were various with the maximum concentration of : copper 32.8 ppm, chromium 32.3 ppm, nickel 31.6 ppm , lead 55.1 ppm, zinc 70.8 ppm and arsenic 50 ppm. On the other hand, soil high pH (6.5 to 7) consequently reduces mobilization of toxic compounds contained in the soil. There is not much difference in element concentration for two different depths soil due to soil erosion, run-off, and a narrow range of depths taken for analysis. Trends in element content in plant samples also given no relationships with distances from power plant sources of gaseous and particulate pollutants in the area. However, high arsenic concentration in soil samples at sites situated in the northern direction of the power plant shows correlation with wind direction and topography. Arsenic could be from rock, mineral, lignite and partly from airborn pollutants which dispersed with fly ash from the power plant. There is no evident effects of particulate matter with trace elements on terrestrial ecosystems. With limited time, technical problems, as well as the changing weather with a long rainy season of 1994 (from March to December), this study was limited. Dust samples deposited on bamboo and teak leaves were not analyzed for heavy metals and scanned for fly ash. Air pollution monitoring is necessary to have a comprehensive analysis of the causes, effects and distribution of pollutants. A vital step in the reduction of acute and potential health risks for man and animals in the area is the elimination of air pollution in cool season when thermal inversions frequently occur by reducing electricity production, improvement electric precipitators, using high quality lignite, etc. Long-term monitoring

is needed since new power plant units are planned. Analysis of agricultural soil and trace elements in vegetables and crop to assess risk for ecosystem as well as for the plant-animal-man food chain is necessary. Soil samples should be taken at different layer of soil profile from 0 to 120 cm and analyzed for extractable element concentrations since it relates to element availability for plants. Environmental risk assessment for aquatic ecosystems and ground water in the surrounding area is necessary to monitor mobility of potential toxic elements in the area, especially around dumping areas and villages. Analysis of particulate matter is highly recommended since its content could correlate with pollution from the power plant and scanning for fly ash is needed to find out the pollution dispersion pattern. Air pollution monitoring by checking concentration of sulfur dioxide and measuring pH of rain in different area around the power plant is also suggested to understand problems in the area and find out solution concerning development and environment .