IV. RESULTS AND DISCUSSION

The results of this study were depicted into four parts as follows:

1. Lignite
2. Laterite soil
3. Low volume airborne particulates
4. High volume airborne particulates

4.1 Lignite

Lignite sampling were performed in August, October and December, 1983. The average content of the heavy metals in lignite samples is tabulated in Table 3. Comparing to the previous reports, it was seen that the results were slightly different from the data obtained by the EGAT and were quite different from those obtained by Chulalongkorn University[35] (see Table 4). Owing to the variation of sampling dates, the heavy metal contents in lignite varied. This sampling period (August-December, 1983) was closer to EGAT sampling period (September, 1982 - October, 1983) than the other, so the same lignite layer may be suspected. It can be assumed that the heavy metal contents found in the lignite in the future may also vary. From this analytical data, it was obvious that although the average contents of the heavy metals were so small (in $\mu g/g$), they might create the air pollution problem in regarding to the combustion process by which some heavy metals were quite concentrated in the emitted fly ash.

4.2 Laterite soil

There are two types of roads in the Mae Moh Project area, asphalt and laterite roads. Most of the roads in the Project area are laterite type, and most of the sampling stations for airborne particulates are located nearby the laterite roads as shown in Figure 9. In the dry season, the laterite road can generate the fugitive dust which is blown

Table 3 The average content of the heavy metals in lignite

Sampling Period	Concentration* : ug/g					
	Cd	Cu	Pb	Mn	Ni	Zn
August	0.30±0.05	6.21±0.40	1.25±0.02	38.05±3.12	38.76±3.50	8.51±0.92
October	0.25±0.04	4.53±0.31	2.10±0.03	21.63±2.16	29.80±6.00	3.45±0.08
December	0.20±0.02	5.94±0.33	1.41±0.01	29.21±3.42	35.71±1.62	10.05±0.21
Average	0.25±0.05	5.56±0.90	1.59±0.45	29.63±8.22	34.75±4.55	7.34±3.45

* average ± mean deviation of 3 samples

Table 4 The heavy metal contents in lignite compared to the previous studies

Heavy Metal Species	Concentration : ug/g		
	This Study	Previous Studies	
		EGAT[18]	CU[35]
Ni	34.75	11.3	515
Cu	5.56	4.8	15
Cd	0.25	0.5	Trace
Pb	1.59	5.0	Trace
Mn	29.63	-	-
Zn	7.34	-	-

EGAT: Electricity Generating Authority of Thailand

CU : Institue of Environmental Research, Chulalongkorn University

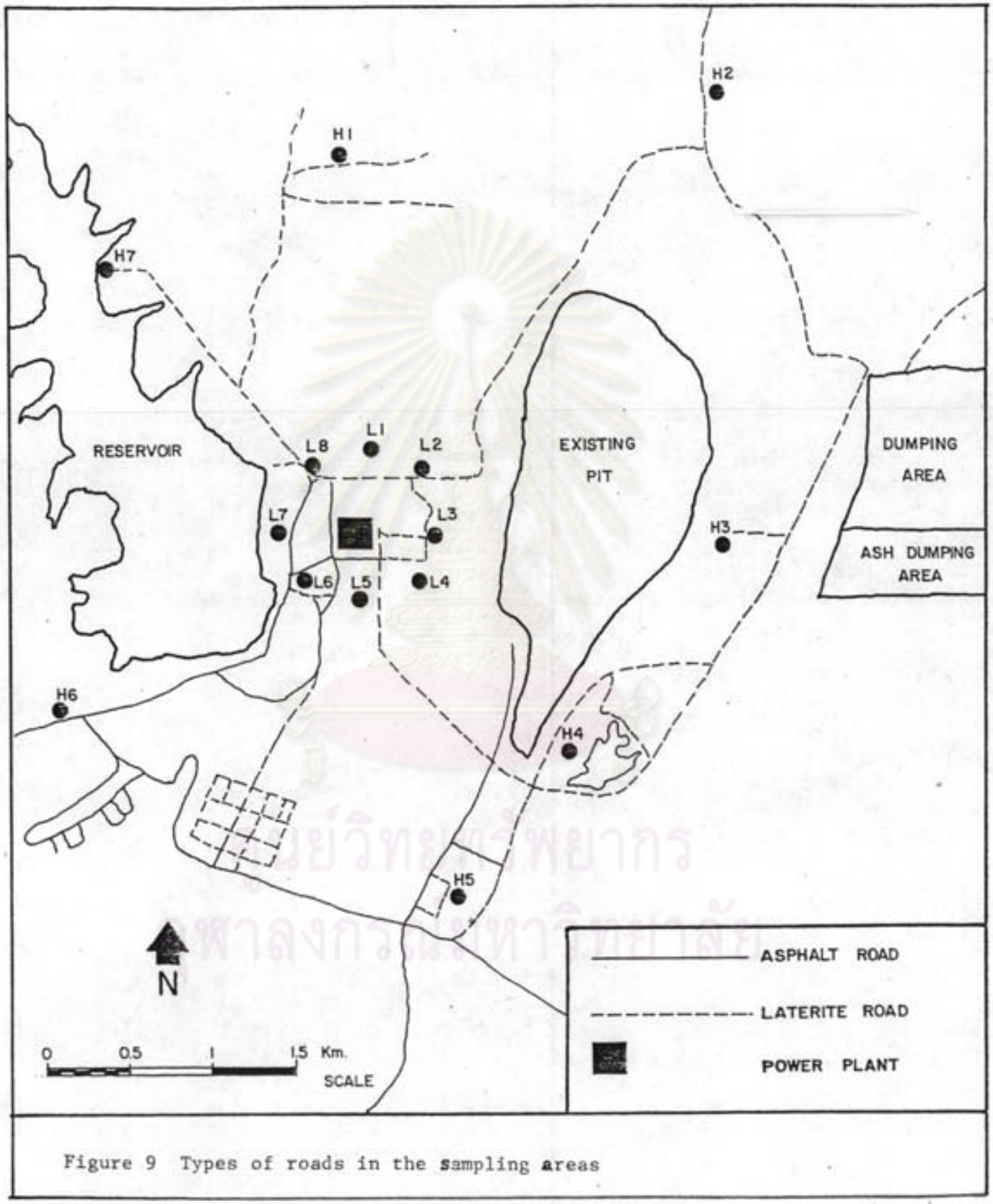

Figure 9 Types of roads in the sampling areas

by wind to the atmosphere. Thus, the laterite road is one of the sources for the airborne particulates in ambient air and also one of the emission sources of the heavy metals.

The laterite soils were sampled in December, 1983 at station L1-L8 and H1-H8. Three soil samples were collected at each station and a total of 48 samples were obtained. The average content of each heavy metal is tabulated in Tables 5 and 6. From the tables it can be seen that the concentration of manganese in the laterite soil of every station was higher than that of nickel, zinc, copper, lead and cadmium. In the lithosphere, manganese was the major element while the others were the traces[9]. Also the results showed that at all stations, the little contents of cadmium did not significantly differ. The results obtained in Table 5 showed that at Station No. L1-L5, the contents of the heavy metals except cadmium did not markedly vary. Moreover, these results were higher than the values at Stations No. L6, L7 and L8. The reason for such results was that Stations No. L1-L5 were located in the vicinity of the laterite roads where the ash dump truck passed by, and the dump ash can spill and accumulate in the soil around these areas. Similarly, the data tabulated in Table 6 showed that Stations No. H3, H4 and H5 where the ash dump truck passed by, were also found the heavy metal contents in the higher levels than the remained stations. Thus, it can be concluded that the increasing content of the heavy metals in the soil was resulted from the ash disposal. In addition, it was remarkable that the maximum contents of copper (40.9 μg/g), manganese (4737.0 μg/g), nickel (134.8 μg/g) and zinc (63.4 μg/g) were detected at Station No. H8 where is closer to the marine sedimentary rock, Doi Pha Hom, than theother stations. When the weathering process occurred, more heavy metals which associated with the parent material were deposited in the soil, and the nearest area to the rock would have higher heavy metal concentration.

Compared to the previous study[35], it was seen that the contents of the heavy metals in the laterite soil did not significantly differ as shown in Table 7. Because of the different sampling location, some variation of the heavy metal contents can be expected.

Table 5 The average content of each heavy metal in laterite soil at Station No. L1 through L8

Station	Concentration : μg/g *					
	Cd	Cu	Pb	Mn	Ni	Zn
L1	0.9±0.2	27.5±5.1	16.6±10.6	1,065.4±193.1	87.3±19.1	46.9±3.5
L2	0.8±0.1	26.9±1.4	18.8±8.1	984.2±78.6	89.4±6.4	45.9±7.8
L3	0.8±0.1	25.4±2.3	15.7±8.7	792.3±92.8	75.0±16.5	56.5±39.2
L4	0.7±0.1	27.0±4.7	23.5±4.3	653.8±176.6	72.4±11.4	48.3±2.8
L5	0.9±0.2	30.9±7.3	18.4±7.1	625.0±80.9	73.9±10.1	37.9±3.6
L6	0.7±0.1	22.9±1.0	18.4±7.8	322.9±37.0	52.7±12.7	31.0±6.6
L7	0.9±0.1	20.2±7.4	18.8±8.5	372.1±40.1	32.1±8.5	33.3±19.8
L8	0.7±0.0	22.1±4.4	16.7±4.5	461.4±75.9	21.0±1.4	34.5±19.6

* average ± mean deviation of 3 samples

Table 6 The average content of each heavy metal in laterite soil at Station No. H1 through H8

Station	Concentration : µg/g*					
	Cd	Cu	Pb	Mn	Ni	Zn
H1	1.0±0.3	24.8±3.1	16.9±5.3	190.8±13.5	56.7±5.8	41.8±4.2
H2	0.7±0.0	22.9±0.4	22.7±3.4	488.5±92.3	56.2±3.6	36.6±6.7
H3	0.7±0.0	34.0±3.0	29.9±10.1	718.5±60.4	75.0±14.6	69.5±39.2
H4	0.9±0.3	28.1±1.6	28.4±7.4	582.9±106.7	82.3±14.1	53.3±9.5
H5	0.9±0.3	36.0±5.4	17.6±7.1	695.4±211.9	59.6±9.4	38.9±6.0
H6	0.7±0.0	21.6±5.7	12.9±4.2	462.4±72.3	52.6±8.1	38.0±15.7
H7	0.8±0.0	18.5±4.2	13.8±5.0	187.6±49.2	33.2±9.8	27.8±6.1
H8	0.7±0.1	40.9±4.6	10.7±0.2	4,737.0±148.4	134.8±10.2	63.4±5.3

* average ± mean deviation of 3 samples

Table 7 The heavy metal contents in laterite soil compared to the previous study.

Heavy metal Species	Concentration, ug/g	
	This study	Previous study CU [35]
Ni	21.0-134.8	49-105
Cd	0.7-1.0	0.60-1.25
Cu	18.5-40.9	19-24
Pb	10.7-29.9	10-19.4

CU : Institute of Environmental Research, Chulalongkorn University

4.3 Low volume airborne partiuclates

The samplings of the low volume airborne particulates were performed in August and December, 1983 at Station No. L1-L8. At each station, four samples were collected within two days, two samples in the morning and the other two in the afternoon. A total of 64 samples were obtained. The range and average content of total particulate matters in ambient air at each station are tabulated in Table 8, and the histogram of the average content of the total particulate matters is shown in Figure 10.

In August, the Project area was directly affected by the South (S), South-Southeast (SSE) and South-Southwest (SSW) prevailing winds due to the southwest monsoon season (see Figure 30). The sampling Stations No. L1, L2 and L3 were located downwind from lignite emission sources (the lignite stockpiles and the crushing unit), and the Stations No. L4, L5, L6, L7 and L8 were upwind from the emission sources. The decreasing order of the total particulate matter contents tabulated in Table 9 showed that the contents of total particulate matters at the downwind stations were higher than those of the upwind stations, except Station No. L4. The total particulate matter contents of 3.95 mg/m^3 was detected at Station No. L4 (upwind station), and was higher than the value of 2.46 mg/m^3 at Station No. L1 (downwind station). Since the Station No. L4 was located nearby the laterite road where the heavier traffic volume was observed, the higher content of the particulates was found.

In December, the Project area was directly affected by the North-West (NW) and the North-Northwest (NNW) prevailing winds due to the northeast monsoon season (see Figure 32). The sampling Stations No. L4 and L5 were located downwind from the lignite emission sources (the lignite stockpiles and the crushing unit), and the remained stations were upwind from the emission sources. As a result obtained in August, it showed that the contents of total particulate matters in the downwind stations were also higher than the upwind stations, except Stations No.

Table 8 The range and average content of particulate matters at each station

Station	August		December	
	Range mg/m^3	Average* mg/m^3	Range mg/m^3	Average* mg/m^3
L1	n-4.46	2.46±0.67	3.07-4.94	3.70±0.88
L2	0.59-9.62	7.92±6.48	16.95±22.02	20.54±2.41
L3	6.80-10.78	9.21±1.72	6.29-12.21	8.84±2.58
L4	2.18-6.15	3.95±1.70	1.74-18.60	10.95±6.97
L5	n-1.69	1.38±0.29	1.10-7.75	4.38±2.72
L6	0.71-2.11	1.23±0.61	1.75-5.63	3.14±1.76
L7	0.91-1.52	1.19±0.26	1.12-4.21	2.45±1.30
L8	1.09-2.09	1.67±0.50	4.65-7.99	5.92±1.66

n non-detectable

* average ± mean deviation of 4 samples

Table 9 The decreasing order of total particulate matter contents in ambient air at Stations No. L1-L8 in August

Rank of Particulate Content	Sampling Station	Total Particulate Matters mg/m^3	Remarks
1	L3	9.21	- nearest to the emission sources - downwind from the emission sources - nearby the laterite road
2	L2	7.92	- downwind from the emission sources - nearby the laterite road
3	L4	3.95	- upwind from the emission sources - nearby the laterite road which the ash dump truck passed by
4	L1	2.46	- downwind from the emission sources - nearby the laterite road
5	L8	1.67	- upwind from the emission sources - nearby the laterite road with slightly traffic volume
6	L5	1.38	- upwind from the emission sources - nearby the laterite road with slightly traffic volume
7	L6	1.23	- upwind from the emission sources
8	L7	1.19	- upwind from the emission sources

L2, L3 and L8 (see Table 10). These stations were located nearby the laterite roads where the heavier traffic volume were observed: the particulate matter content of 20.54 mg/m^3 at Station No. L2 (upwind station) was higher than that of 10.95 mg/m^3 at Station No. L4 (downwind station), the contents of 8.84 mg/m^3 at Statin No. L3 and that of 5.98 mg/m^3 at Station No. L8 where were located upwind from the emission sources, were higher than that of 4.38 mg/m^3 at Station No. L5 (downwind station).

From Figure 10, it was seen that at Station L3 the contents of the total particulate matters in August and December did not markedly differ, since this station was nearest to the lignite emission sources where most of the dust came. Apart from Station No. L3, the result at the remaining stations showed that most of the particulate contents in August were approximately two times lower than those in December. Since the higher temperature of ambient air in August was recorded, the better dispersion of the pollutants in ambient air was occurred. Additionally, the particulates was removed from the air by wet deposition in the rainy season, and the laterite road was very wet and it cannot generate the particulates. Thus, the low content of the particulates in the rainy season was found. From the above discussion, it may be concluded that the total particulate matter contents in ambient air were influenced by meteorological factor such as wind direction, wind speed, precipitations, ambient air temperature and humidity. Moreover, the sampling location, topography etc. have an influence on the content of the particulates.

The range and average content of the heavy metal in the low volume airborne airborne particulate matters are tabulated in Tables 11-13. The concentrations of cadmium, nickel and zinc in the particulate matters were non-detectable at all sampling stations.

The average contents of lead were non-detectable at all sampling stations, except Stations No. L3 and L4 where the contents of 0.19 μg/m^3 and 0.09 μg/m^3 were found, respectively (see Table 11). Since these stations were located nearby the laterite roads where the ash dump trucks

Table 10 The decreasing order of total particulate matter contents in ambient air at Stations No. L1-L8 in December

Rank of Particulate Content	Sampling Station	Total Particulate Matters mg/m^3	Remarks
1	L2	20.54	- Upwind from the emission sources - Nearby the laterite road with heaviest traffic volume
2	L4	10.95	- Downwind from the emission sources - Nearby the laterite road
3	L3	8.84	- Upwind from the emission sources - Nearby the laterite road
4	L8	5.92	- Upwind from the emission sources - Nearby the laterite road
5	L5	4.38	- Downwind from the emission sources - Nearby the laterite road
6	L1	3.70	- Upwind from the emission sources
7	L6	3.14	- Upwind from the emission sources
8	L7	2.45	- Upwind from the emission sources

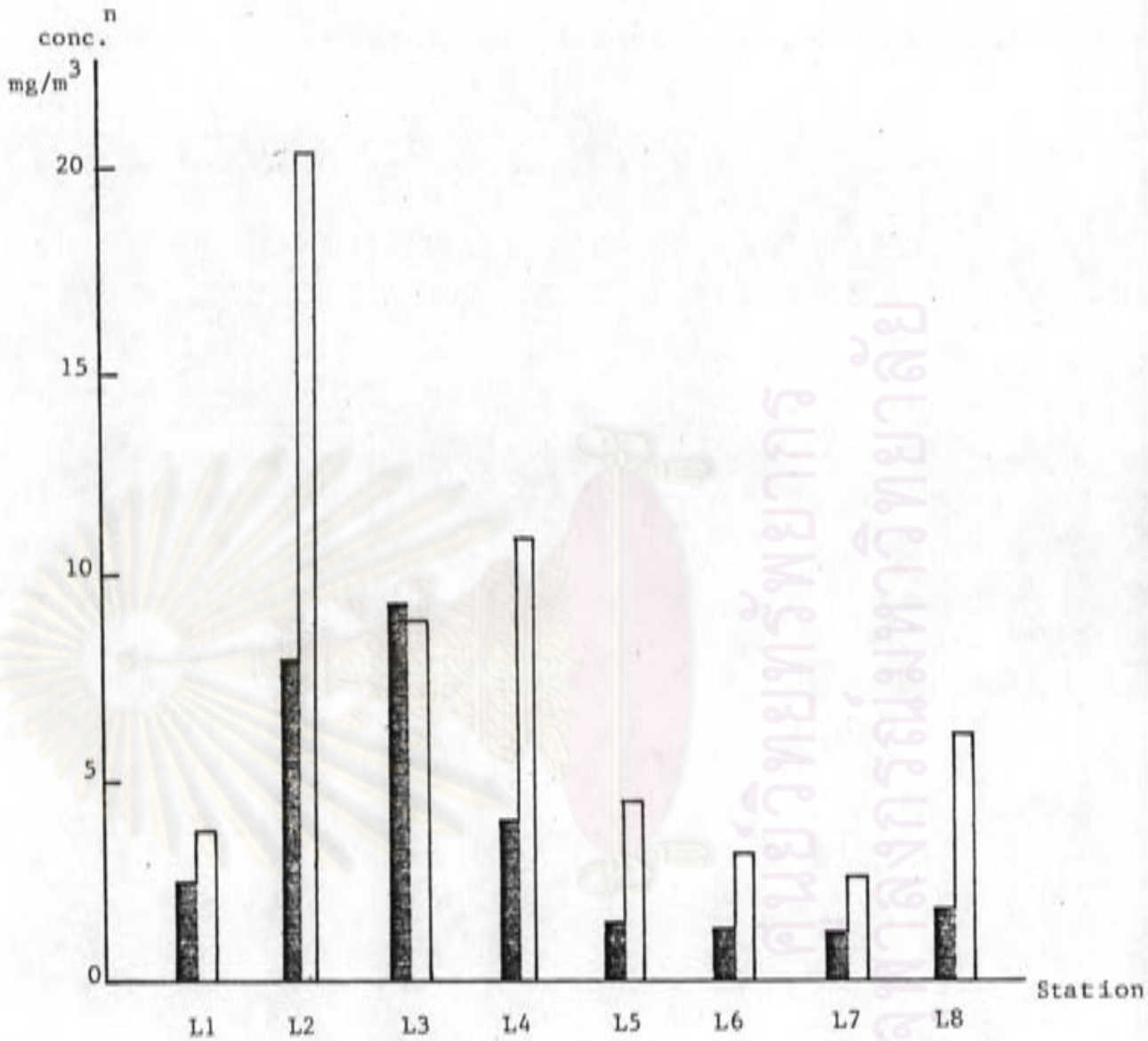

Figure 10 The Histogram of the Average content of total particulate matters collected by Low Volume Air Sampler at each station in August ■ and in December □

Table 11 The range and average content of lead in the low-volume airborne particulates at each station.

Station	August		December	
	Range $\mu g/m^3$	Average * $\mu g/m^3$	Rang $\mu g/m^3$	Average * $\mu g/m^3$
L1	n	n	n	n
L2	n	n	n	n
L3	n	n	n-0.45	0.19±0.23
L4	n	n	n-0.36	0.09±0.18
L5	n	n	n	n
L6	n	n	n	n
L7	n	n	n	n
L8	n	n	n	n

n non-detectable

* average ± mean deviation of 4 samples

passed by, the dump ash could spill into the atmosphere. As this was a small sources of lead, it was non-detectable in August (rainy season). Similarly to lead, the higher contents of copper, 0.20 $\mu g/m^3$ and 0.29 $\mu g/m^3$, were also detected at Stations No. L4 and L5, respectively. It can be seen that these results supported the above discussion. From Tables 12 and 13, at all stations studied, the average contents of copper, 0.10-0.34 $\mu g/m^3$, and manganese, 0.33-2.92 $\mu g/m^3$, in December were higher than the values of non-detectable -0.29 $\mu g/m^3$ of copper and non-detectable -1.23 $\mu g/m^3$ of manganese in August. The higher concentrations of total particulate matters were found, the higher concentrations of copper and manganese were detected as shown in Tables 14 and 15. Thus, it can be concluded that the heavy metal contents tended to increase with the particulate matter contents. Moreover, the ratios of each heavy metal to the particulate matters were not markedly different from the contents of those metal species in the laterite soil as shown in Figures 11 and 12.

From the above discussion, it can be concluded that most of the heavy metals in ambient air in the distance of 0.5 km around the plant were derived from the laterite road, the lignite stockpiles, the crushing unit and the ash disposal.

The Labour Department of the Ministry of Interior Notification and the Occupational Safety and Health Administration (OSHA) regulations of 0.1 mg/m^3 for cadmium, 0.1 mg/m^3 for copper, 0.2 mg/m^3 (Labour Department) and 0.05 mg/m^3 (OSHA) for lead, 5 mg/m^3 for manganese, 1 mg/m^3 for nickel, 5 mg/m^3 for zinc and 15 mg/m^3 for total particulate matters, were applied in light of the particulate matters and airborne heavy metal impact assessments [72] (see Table 16). Comparing to the detected levels, it was noticeable that the quantity of the heavy metal at very station were very much below both allowable limits. From both standard viewpoints such heavy metal results in ambient air can not cause any deterioration to human healths.

4.2 High volume airborne particulates

Total suspended particulates (TSP) were collected at the level of about 1 m above the ground via High Volume Air Sampler at Stations No. H1-

Table 12 The range and average content of copper associated with low-volume airborne particulates at each station

Station	August		December	
	Range $\mu g/m^3$	Average * $\mu g/m^3$	Range $\mu g/m^3$	Average * $\mu g/m^3$
L1	n-0.43	0.11±0.22	0.11-0.19	0.14±0.04
L2	0.14-0.19	0.17±0.02	0.15-0.52	0.34±0.16
L3	0.23-0.36	0.29±0.06	0.13-0.24	0.20±0.05
L4	n-0.29	0.16±0.12	0.15-0.35	0.26±0.09
L5	0.04-0.09	0.07±0.02	0.22-0.39	0.29±0.07
L6	n	n	0.06±0.20	0.13±0.06
L7	n-0.08	0.05±0.03	0.07-0.20	0.10±0.09
L8	0.04-0.09	0.06±0.02	0.07-0.22	0.15±0.08

n non-detectable

* average ± mean deviation of 4 samples

Table 13 The range and average content of manganese in the low-volume airborne particulates at each station

Station	August		December	
	Range ug/m^3	Average * ug/m^3	Range ug/m^3	Average * ug/m^3
L1	n-0.86	0.22±0.43	n-3.99	1.00±1.99
L2	n-0.83	0.21±0.42	0.15-6.54	2.92±2.74
L3	n-4.90	1.23±2.45	n-4.12	1.47±1.82
L4	n	n	n-4.31	1.24±2.06
L5	n-1.30	0.54±0.65	n-4.11	1.09±1.27
L6	n	n	n-0.62	0.16±0.31
L7	n-0.46	0.12±0.23	n-1.32	0.33±0.66

n non-detectable

* average ± mean deviation of 4 samples

Table 14 The average content of total particulate matters and heavy metals at each station in August

Station	Particulate Matters mg/m^3	Heavy metal content*: ug/m^3					
		Cd	Cu	Pb	Mn	Ni	Zn
L1	2.46±0.67	n	0.11±0.22	n	0.22±0.43	n	n
L2	7.92±6.48	n	0.17±0.02	n	0.21±0.42	n	n
L3	9.21±1.72	n	0.29±0.06	n	1.23±2.45	n	n
L4	3.95±1.70	n	0.16±0.12	n	n	n	n
L5	1.38±0.29	n	0.07±0.02	n	0.54±0.65	n	n
L6	1.23±0.61	n	n	n	n	n	n
L7	1.19±0.26	n	0.05±0.03	n	n	n	n
L8	1.67±0.50	n	0.06±0.02	n	0.12±0.23	n	n

n non-detectable

* average ± mean deviation of 4 samples

Table 15 The average contents of total particulate matters and heavy metals at each station in December

Station	Particulate Matters mg/m^3	Heavy Metal Content *: $\mu g/m^3$					
		Cd	Cu	Pb	Mn	Ni	Zn
L1	3.70±0.88	n	0.14±0.04	n	1.00±1.99	n	n
L2	20.54±2.41	n	0.34±0.16	n	2.92±2.74	n	n
L3	8.84±2.58	n	0.20±0.03	0.19±0.23	1.47±1.82	n	n
L4	10.95±6.97	n	0.26±0.09	0.09±0.18	1.24±2.06	n	n
L5	4.38±2.72	n	0.29±0.07	n	1.09±1.27	n	n
L6	3.14±1.76	n	0.13±0.06	n	0.16±0.31	n	n
L7	2.45±1.30	n	0.10±0.09	n	1.10±1.28	n	n
L8	5.92±1.66	n	0.15±0.08	n	0.33±0.66	n	n

n non-detectable

* average ± mean deviation of 4 samples

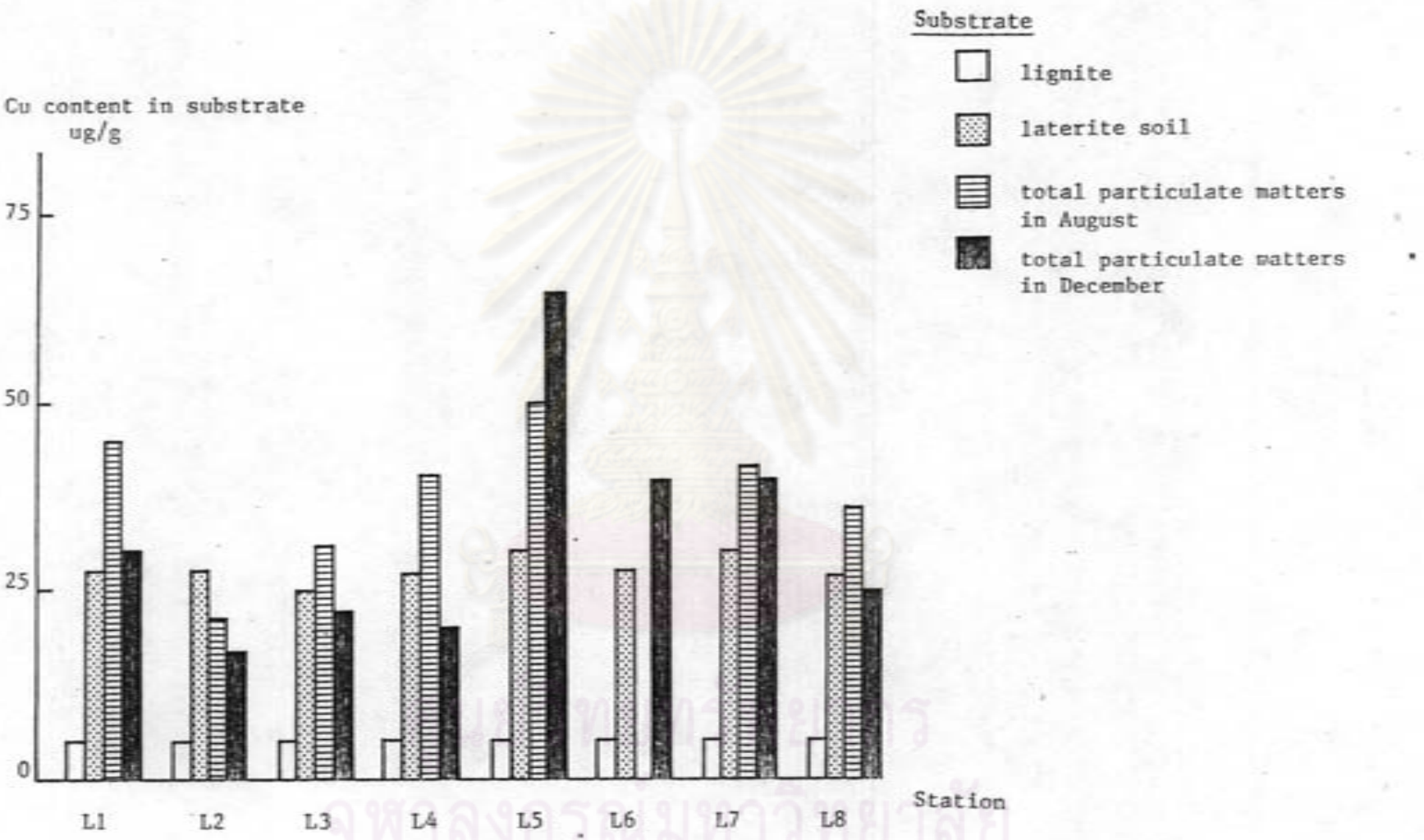

Figure 11 Comparison of copper content in lignite, copper content in laterite soil and copper content in total particulate matters at Stations L1 to L8 in August and December

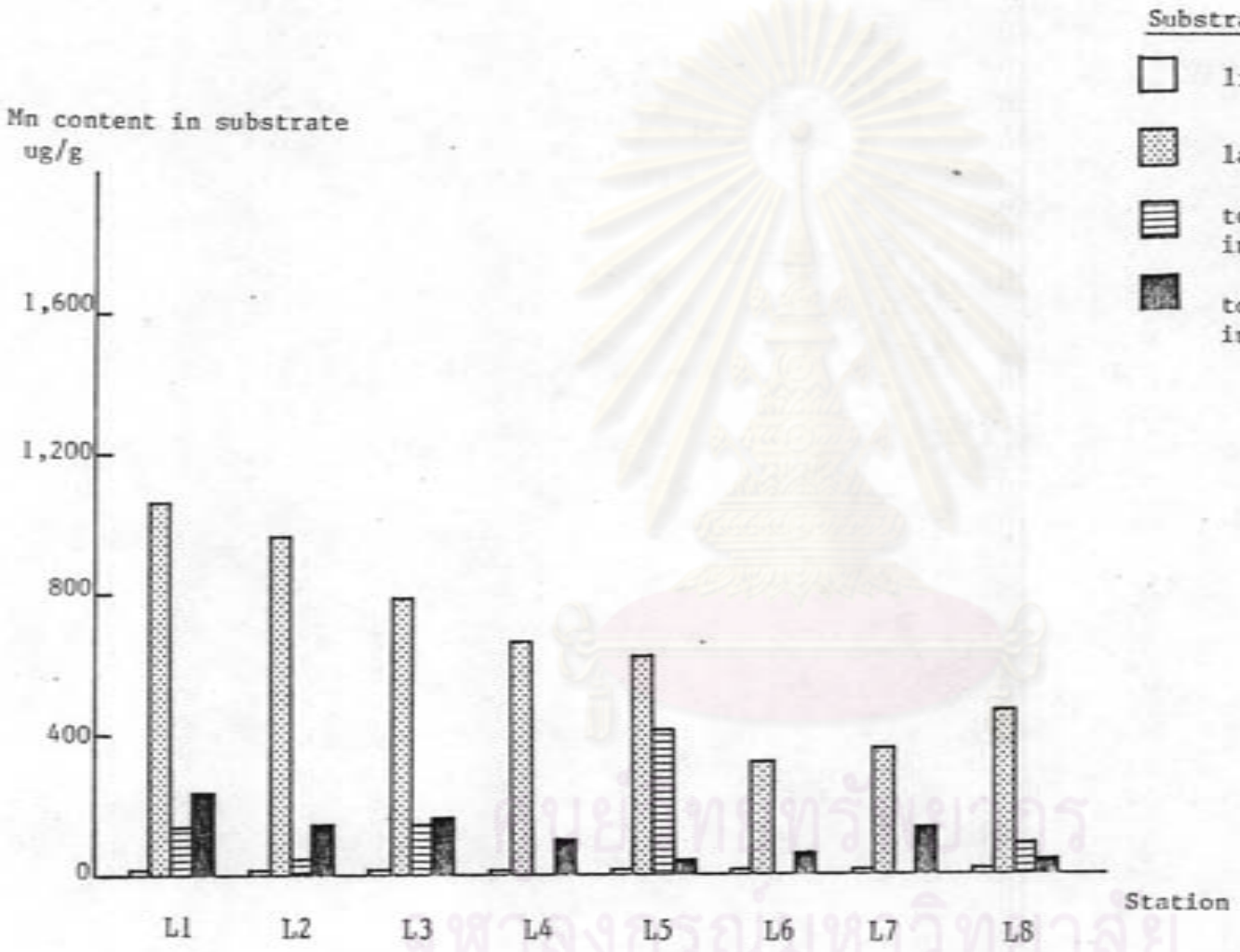

Figure 12 Comparison of manganese content in lignite, nangamese content in laterite soil and manganese content in total particulates matters at Stations L1 to L8 in August and December

Table 16 Hierarchy of industrial regulation for total particulate matters and some airborne heavy metals in working area[72,77]

Pollutant Species	Industrial Regulation Value: mg/m^3	
	OSHA*	Labour Department**
Cd and its compounds	0.1	0.1
Cu and its compounds	0.1	0.1
Pb and its compounds	0.05	0.2
Mn and its compounds	5	5
Ni and its compounds	1	1
Zn and its compounds	5	5
Total particulate matters	15	15

* OSHA : Occupational Safety and Health Administration

** Labour Department of the Ministry of Interior Notification

H8 in August, October and December, 1983. The sampler was set at each station for four days, so it can collect four daily samples. A total of 92 samples were obtained. The range and average content of the TSP in ambient air at each station are tabulated in Table 17, and the histogram of the average content is illustrated in Figure 13.

In August, the project area was directly affected by the S, SSE and SSW prevailing winds. The observation showed that the Plant, laterite road and ash disposal were main sources of the TSP in the rainy season, since the mining activities were shut down. The sampling Stations No.H1,H2 and H7 were located downwind from the Plant, and the other stations were upwind. The decreasing order of the TSP contents is shown in Table 18. It can be seen that the highest TSP content of 101.11 $\mu g/m^3$ was detected at Station No. H5 (upwind station) where was located in the vicinity of the heavier traffic area occuring from the constructing activities of the Power Plant Units 4 and 5. The low TSP contents of 98.76 $\mu g/m^3$ and 59.49 $\mu g/m^3$ were found at Stations No. H4 and H5 (upwind stations), respectively. Such results was occurred from the dump truck activities, since these stations were nearby the laterite roads where the ash and overburden dump trucks passed by. Although these stations were close to the existing mine pit, the low TSP contents were found owing to the shut-down mining activities in the rainy season. It can be concluded that in August most of the TSP resulted from the constructions and the laterite roads. At the other stations, i.e. Stations No. H2, H8, H6, H1 and H7, very low TSP contents of 46.87 $\mu g/m^3$ 44.34 $\mu g/m^3$, 42.44 $\mu g/m^3$, 20.61 $\mu g/m^3$ and 5.47 $\mu g/m^3$ were detected, respectively because the fact that they were not in the areas of ash dump truck passed by. In addition, the laterite roads were sufficiently wet that the TSP could not generate.

In October, the meteorological factors that influenced on the TSP contents were similar to those of in August except wind direction. The Project area was directly affected by the NW and NNW prevailing winds. The sampling Stations No. H3, H4 and H5 were located downwind from the Plant whereas the remaining stations were upwind. The decreasing order of the TSP contents is illustrated in Table 19. Comparison with the results

Table 17 The range and average content of total suspended particulates in ambient air at each station

Sampling Station	August		October		December	
	Range $\mu g/m^3$	Average* $\mu g/m^3$	Range $\mu g/m^3$	Average* $\mu g/m^3$	Range $\mu g/m^3$	Average* $\mu g/m^3$
H1	16.93-24.52	20.61±3.49	40.96-74.16	54.03±14.20	25.21-107.70	61.21±41.50
H2	19.23-94.29	46.87±32.77	74.34-183.48	136.23±45.56	214.45-463.24	299.15±117.14
H3	73.99-138.13	98.76±28.86	41.39-200.45	119.92±84.40	809.83-1,620.08	1,114.71±353.19
H4	44.86-80.62	59.49±15.33	34.46-183.85	96.39±63.71	458.44-957.91	651.86±216.43
H5	92.37-120.17	101.11±12.82	90.01-254.06	150.98±71.34	75.89-155.51	123.61±34.38
H6	36.95-52.62	42.44±6.96	15.45-22.92	19.07±3.77	34.77-71.18	45.09±19.40
H7	1.48-10.59	5.47±3.79	2.08-7.33	5.31±2.52	-	-
H8	28.30-56.05	44.34±12.50	49.34-95.50	72.73±24.33	23.54-54.20	32.50±14.57

* average ± mean deviation of 4 samples

- No sample was collected since the road to the station was too muddy.

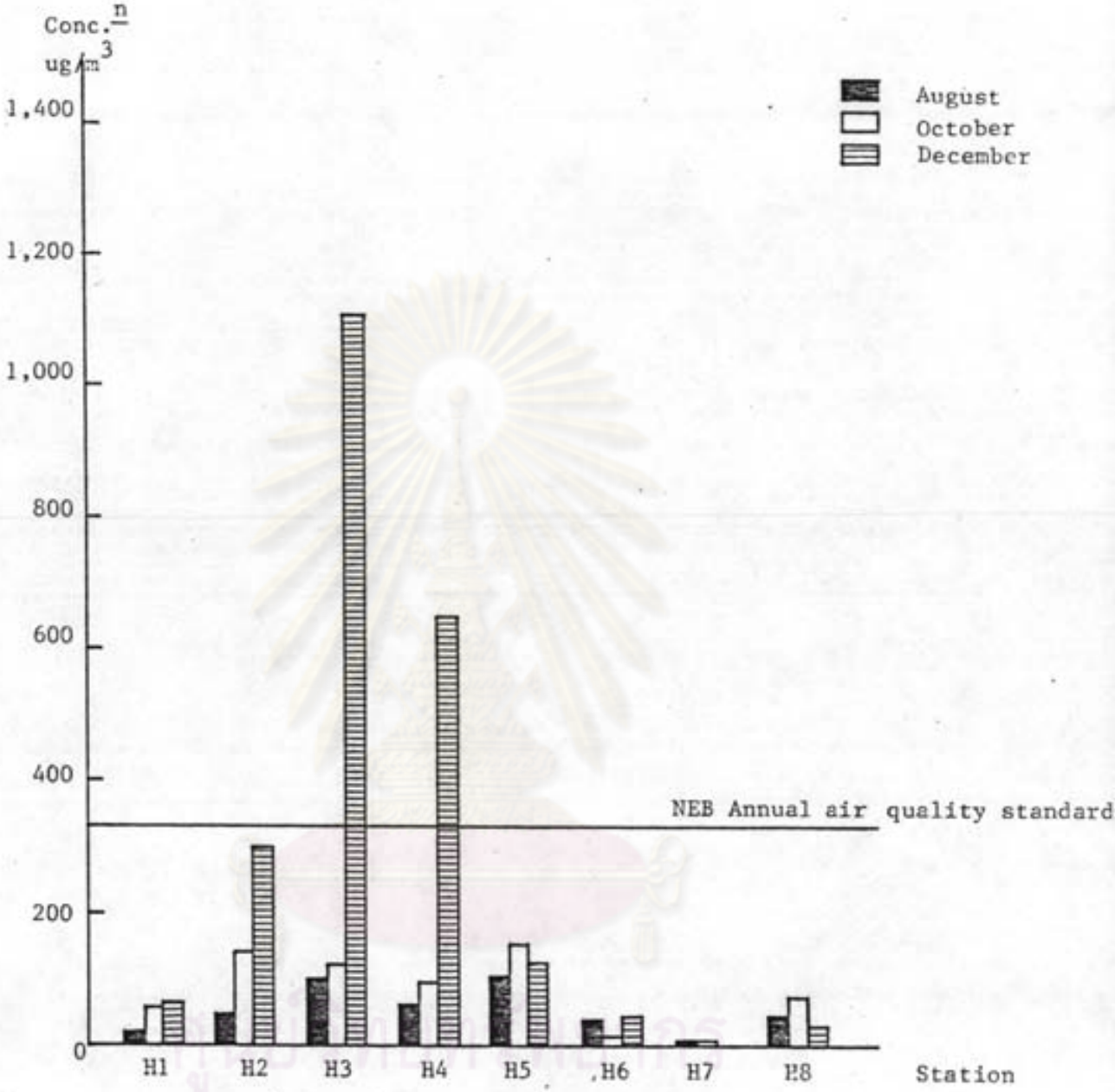

Figure 13 The histogram of total suspended particulates in ambient air at each station

Table 18 The decreasing order of the TSP contents in ambient air at Stations No. H1-H8 in August

Rank of TSP Content	Sampling Station	TSP ug/m^3	Remarks
1	H5	101.11	- nearby the laterite road - upwind from the plant
2	H3	98.76	- nearby the laterite road, existing mine pit and dumping area - upwind from the plant
3	H4	59.49	- nearby the laterite road - upwind from the plant
4	H2	46.87	- nearby the laterite road - downwind from the sources
5	H8	44.34	- upwind from the plant - nearby the laterite road with slightly low traffic volume
6	H6	42.44	- upwind from the plant - nearby the asphalt road with high traffic volume
7	H1	20.61	- downwind from the plant - nearby the laterite road with very low traffic volume - in the forest
8	H7	5.47	- downwind from the plant - nearby Huai Luang Research - in the forest

Table 19 The decreasing order of the TSP contents in ambient air at Stations No. H1-H8 in October

Rank of TSP Content	Sampling Station	TSP ug/m^3	Remarks
1	H5	150.98	- downwind from the plant - nearby the laterite and asphalt roads
2	H2	136.23	- upwind from the plant - nearby the laterite road
3	H3	119.92	- downwind from the plant - nearby the mine pit, dumping area and laterite road
4	H4	96.39	- downwind from the plant - nearby the laterite road
5	H8	72.73	- upwind from the plant - nearby the laterite and asphalt roads
6	H1	54.03	- upwind from the plant - in the forest
7	H6	19.07	- upwind from the plant - nearby the asphalt road
8	H7	5.31	- upwind from the plant - nearby the reservoir

in August, it was seen that the results just varied although the different wind direction showed some pattern of effect. It can conclude that the season in terms of rainfall was more influence on the TSP contents in Mae Moh ambient air than the other factors.

In December, the Project area was also directly affected by the NW and NNW prevailing winds, likewise in October. The decreasing order of the TSP contents are tabulated in Table 20. From the Table it can be seen that the highest TSP content of 1,114.71 $\mu g/m^3$ were found at Station No. H3 where was located nearby the dumping area and laterite road where the dump trucks heavily passed by. Moreover, it was downwind from the existing mine pit, and was in a position that was directly affected by the prevailing winds. The 2nd rank of TSP content, 651.81 $\mu g/m^3$, was found at Station No. H4 where was in the southeast of the pit, the southwest of the dumping area and nearby the laterite road leading to the dumping area (see Figure 9). It was in a position that was also directly affected by the NW and NNW prevailing winds. The 3rd rank of TSP content, 299.15 $\mu g/m^3$, was at Station No. H2 where was nearby the laterite road leading to Ban Moh Luang (see Figure 9). Such high TSP contents can probably be attributed to the fugitive dust raised from the laterite road where the heaviest traffic volume was observed. The 4th rank of TSP content, 123.61 $\mu g/m^3$ was at Station No. H5 where was in the same direction as Station No. L4 from the emission sources. Since it was in the longer distance from the sources than Station No. H4, the lower TSP content was found. It was concluded that the TSP contents seemed to diminish with the distance from the emission sources. The slightly low TSP content of 61.21 $\mu g/m^3$ was at Station No. H1 where was in the forest and upwind from the emission sources. The very low TSP contents of 45.09 $\mu g/m^3$ and 32.50 $\mu g/m^3$ were detected at Station No. H6 and H8, respectively. Station No. H6 was located nearby the asphalt road where the heavier traffic volume was observed, whereas Station No. H8 was nearby the laterite road with slightly low traffic volume. The above analytical results corresponded to the monthly rainfall (see Table 27). The higher TSP contents occurred in the dry month whereas the lower contents occurred

Table 20 The decreasing order of the TSP contents in ambient air at Stations No. H1-H8 in December

Rank of TSP Content	Sampling Station	TSP $\mu g/m^3$	Remarks
1	H3	1,114.71	- nearby the laterite road - downwind from the emission sources
2	H4	651.86	- nearby the laterite road - downwind from the emission sources
3	H2	299.15	- nearby the laterite road - upwind from the emission sources
4	H5	123.61	- nearby the laterite and asphalt roads - downwind from the emission sources
5	H1	61.21	- nearby the laterite road - in the forest - upwind from the emission sources
6	H6	45.09	- nearby the asphalt road with high traffic volume - upwind from the emission sources
7	H8	32.50	- nearby the laterite road with slightly low traffic volume - nearby the asphalt road - upwind from the emission sources

in the rainy months as shown in Figure 13. Since the TSP were eventually removed by the precipitation in rainfall and the laterite roads could not generate the dust because the roads were very wet in the rainy season.

The reported results showed that very high TSP contents were found in the areas which were in the vicinity of the existing mine pit, dumping areas and laterite roads where the heavy traffic volume was observed, particularly in the dry season. Apart from these areas, lower TSP contents were found.

Comparison with the National Environment Board (NEB) annual air quality standard of 330 ug/m^3 for 24 hours, it was seen that at all stations, the TSP contents detected in three months, were below the NEB standard, except Stations No. H3 and H4 (only in December) as illustrated in Figure 13. Such exceeding levels of the TSP will cause some deterioration effects, but the serious problem was prevented by using safety equipment, safety mask and air conditioned car etc. Moreover, these sites were quite remoted from the residential areas.

The range and average content of each heavy metal in the TSP which collected via High Volume Air Sampler are tabulated in Tables 21-26.

From Table 21, cadmium contents in ambient air at all sampling stations ranged from non-detectable to 5.4 ng/m^3. It was seen that the cadmium contents were very low in the unit of ng/m^3, and the values during three-month period varied from station to station owing to the different sampling sites and dates. Since there was no major source of cadmium in the Mae Moh Basin, i.e. very little cadmium contents were found in lignite and laterite soil, (see Tables 3 to 5), the air pollution resulting from hazardous cadmium should not occur.

The range and average content of copper in the TSP in ambient air at each station in August, October and December are tabulated in Table 22.

Table 21 The range and average content of cadmium in the TSP at each station

Sampling Station	August		October		December	
	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3
H1	n-1.8	0.8±0.9	0.1-0.5	0.3±0.2	0.2-0.8	0.5±0.3
H2	n	n	0.2-0.7	0.5±0.3	0.5-0.6	0.5±0.1
H3	0.4-5.4	3.1±2.3	0.5-1.0	0.7±0.3	1.4-1.7	1.6±0.3
H4	n	n	n-0.7	0.4±0.3	1.3-2.5	1.8±0.6
H5	n-1.3	0.9±0.6	n-1.4	0.9±0.8	n-1.7	0.7±0.8
H6	n-2.9	1.9±2.1	n	n	n-1.1	0.6±0.5
H7	n	n	n-0.2	0.1±0.2	-	-
H8	n-1.3	0.6±0.7	n-1.0	0.6±0.5	n-0.7	0.2±0.4

n non-detectable

* average ± mean deviation of 4 samples

- No sample was collected since the road to the station was too muddy.

Table 22 The range and average content of copper in the TSP at each station

Sampling Station	August		October		December	
	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3
H1	n-11.8	3.5±5.6	11.3-29.8	18.0±8.2	12.1-25.0	18.9±7.1
H2	15.3-57.9	30.8±19.2	9.5-26.6	16.9±7.3	35.2-108.3	55.7±35.2
H3	14.9-58.8	33.9±19.8	11.2-26.5	17.7±7.7	58.6-118.9	89.5±24.6
H4	5.9-35.6	23.3±13.6	23.7-103.9	58.8±34.1	110.6-323.3	235.5±104.0
H5	16.3-42.2	30.4±11.6	22.4-40.4	30.0±7.6	10.7-192.7	61.6±87.6
H6	11.0-15.8	13.6±2.2	6.8-12.4	8.2±3.9	10.7-25.0	15.8±6.5
H7	0.9-9.6	5.3±4.6	n-4.4	2.2±2.1	-	-
H8	n-31.4	15.2±13.0	12.8-17.6	14.8±2.4	21.5-74.0	39.5±23.9

n non-detectable

* average ± mean deviation of 4 samples

- No sample was collected since the road to the station was too muddy

In August, the high copper contents of 33.9 ng/m^3, 30.8 ng/m^3, 30.4 ng/m^3 and 23.3 ng/m^3 were detected at Stations No. H3, H2, H5 and H4, respectively (see Table 22). This was because Stations No. H2, H4 and H5 were located nearby the laterite roads where the ash dump trucks passed by. Some dump ash could spill into the atmosphere. In addition, whenever the heavy trucks passed by, the highly remained copper in the soil at these stations which occurred from the accumulation of the spilled ash could also be dispersed and suspended in the ambient air. At Station No. H2 (downwind station from the plant), it was in a position that was affected by the S, SSW and SSE prevailing winds, and was nearby the laterite road consisting of copper. Thus, some copper could be generated into the ambient air. For Stations No. H8 and H6 where were located upwind from the plant, the copper contents of 15.2 ng/m^3 and 13.6 ng/m^3 were detected, respectively. It was remarkable that even Stations No. H7 and H1 were downwind from the plant, the low copper contents of 5.3 ng/m^3 and 3.5 ng/m^3 were found, respectively. These corresponded to no other emission source located around except the plant, so the copper contents in ambient air of these stations were lower than the others.

In October, the high copper contents in ambient air, 58.8 ng/m^3 and 30.0 ng/m^3, were found at Stations No. H4 and H5, respectively, since both stations were located downwind from the plant, and were nearby the laterite roads where the ash dump trucks passed by. The copper contents of 18.0 ng/m^3, 17.7 ng/m^3, 16.9 ng/m^3 and 14.8 ng/m^3 were detected in ambient air at Stations No. H1, H3, H2 and H8 (upwind stations from the plant), respectively. However, these stations were nearby the laterite roads, some copper in the laterite soil could be generated into the atmosphere. The low contents of copper in ambient air, 8.2 ng/m^3 and 2.2 ng/m^3, were found at Stations No. H6 and H7, respectively, since both stations were upwind from the plant and were not located nearby the laterite roads.

In December, the similar pattern of the distribution of copper content in ambient air as in October was notified. At Station No. H4, the highest copper content, 235.5 ng/m^3, was observed and those of Stations No. H3, H5, H2, H8, H1 and H6 were 89.5 ng/m^3, 61.6 ng/m^3, 55.7 ng/m^3, 39.5 ng/m^3, 18.9 ng/m^3 and 15.8 ng/m^3, respectively. The explanation of such results was that Stations No. H4 and H5 (downwind station from the plant) and Station No. H3 (upwind station from the plant) were nearby the laterite road where the ash dump trucks passed by, so the high copper contents were found. The copper contents in ambient air, 55.7 ng/m^3 and 39.5 ng/m^3, were found at Stations No. H2 and H8, since both stations were upwind from the plant, but they were nearby the laterite road where the copper came from. The low contents were detected at Stations No. H1 and H6 where were upwind from the plant and were in a long distance from the laterite roads.

The histogram of the average contents of copper in the TSP during three-month period at each station is illustrated in Figure 14. It was seen that the copper contents in ambient air at all stations in December were much higher than those in August and October. Owing to the high rainfall in August and October, copper in the TSP was removed from the ambient air. The relationship between the copper content and the TSP content in the ambient air as shown in Figure 15 illustrated that copper content tended to increase with the TSP content but no exact proportion was obtained, since the distribution of both was depended upon the meteorological factors which were very variable.

Figure 16 showed the comparison of copper content in lignite, copper content in laterite soil and copper content in TSP in ambient air in August, October and December at Stations No. H1 to H8 in the unit of μg/g. It could be totally concluded that the content ratios of copper to TSP in ambient air was higher than the sum of copper contents in lignite and in laterite soil at every station in each month. This meant that copper in ambient air was emitted not only from lignite and laterite soil, but also emitted from fly ash and dump ash.

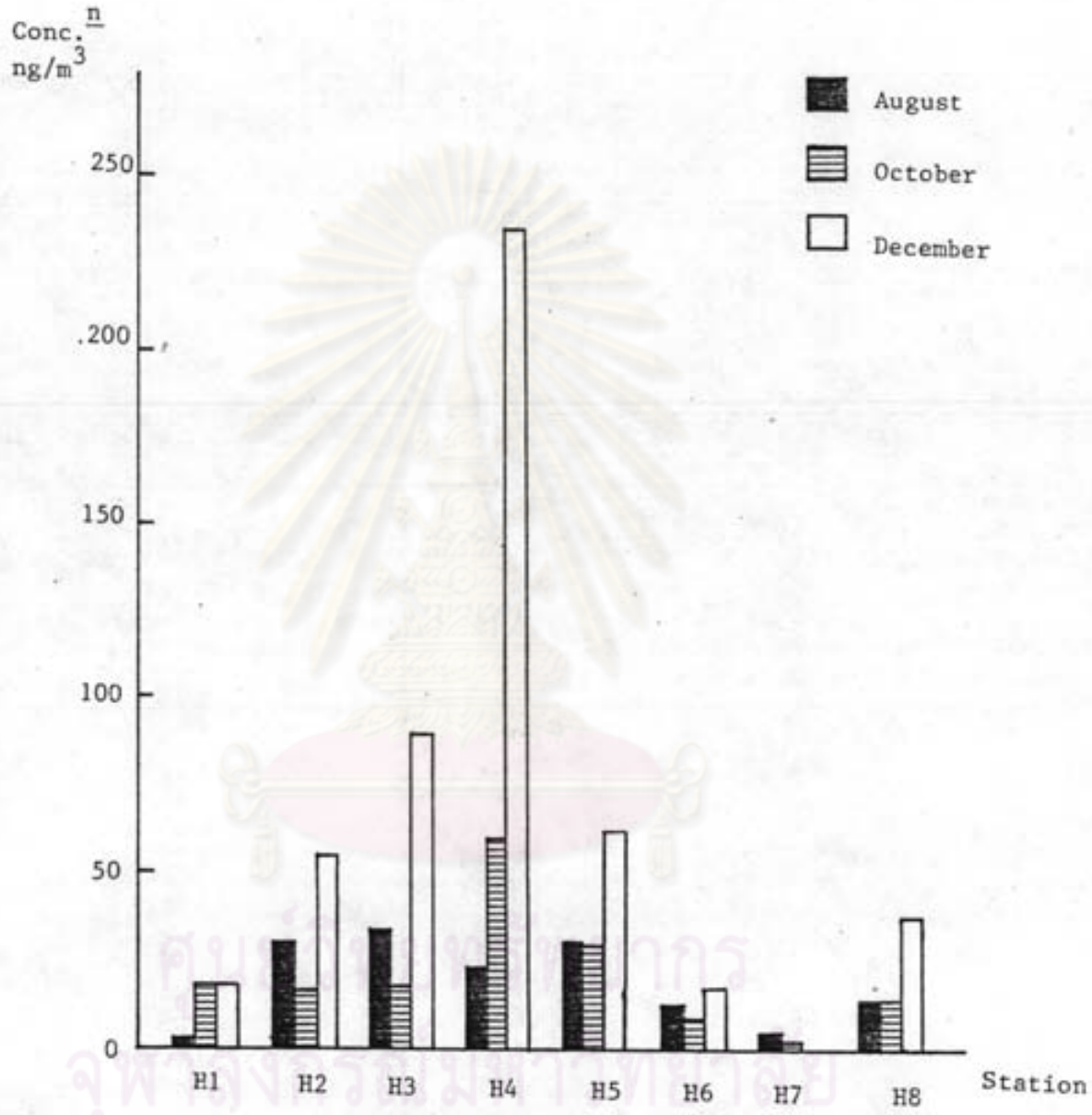

Figure 14 The histogram of the average content of copper in the TSP at each station in August, October and December

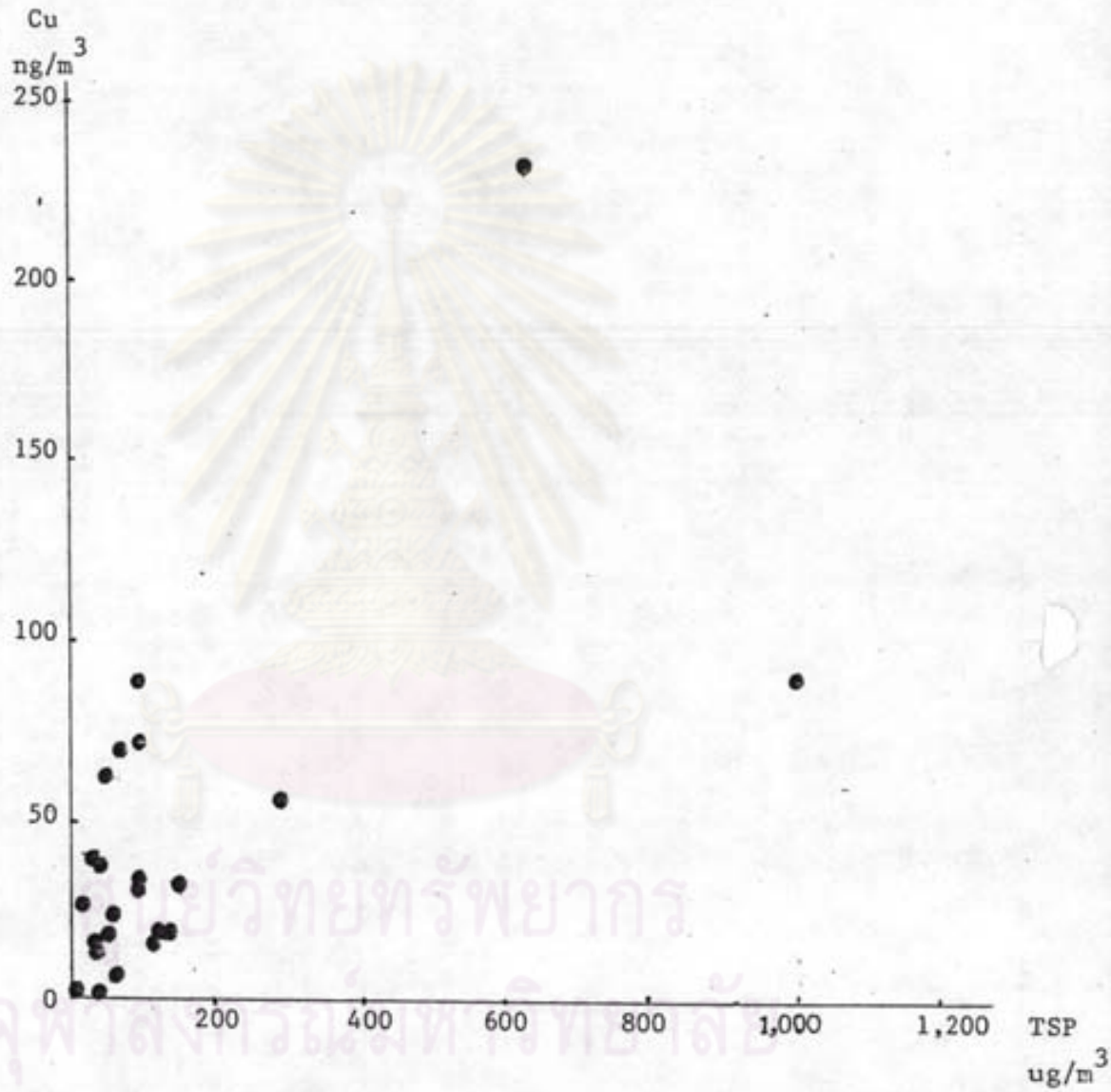

Figure 15 The relationship between copper content and TSP content in the ambient air

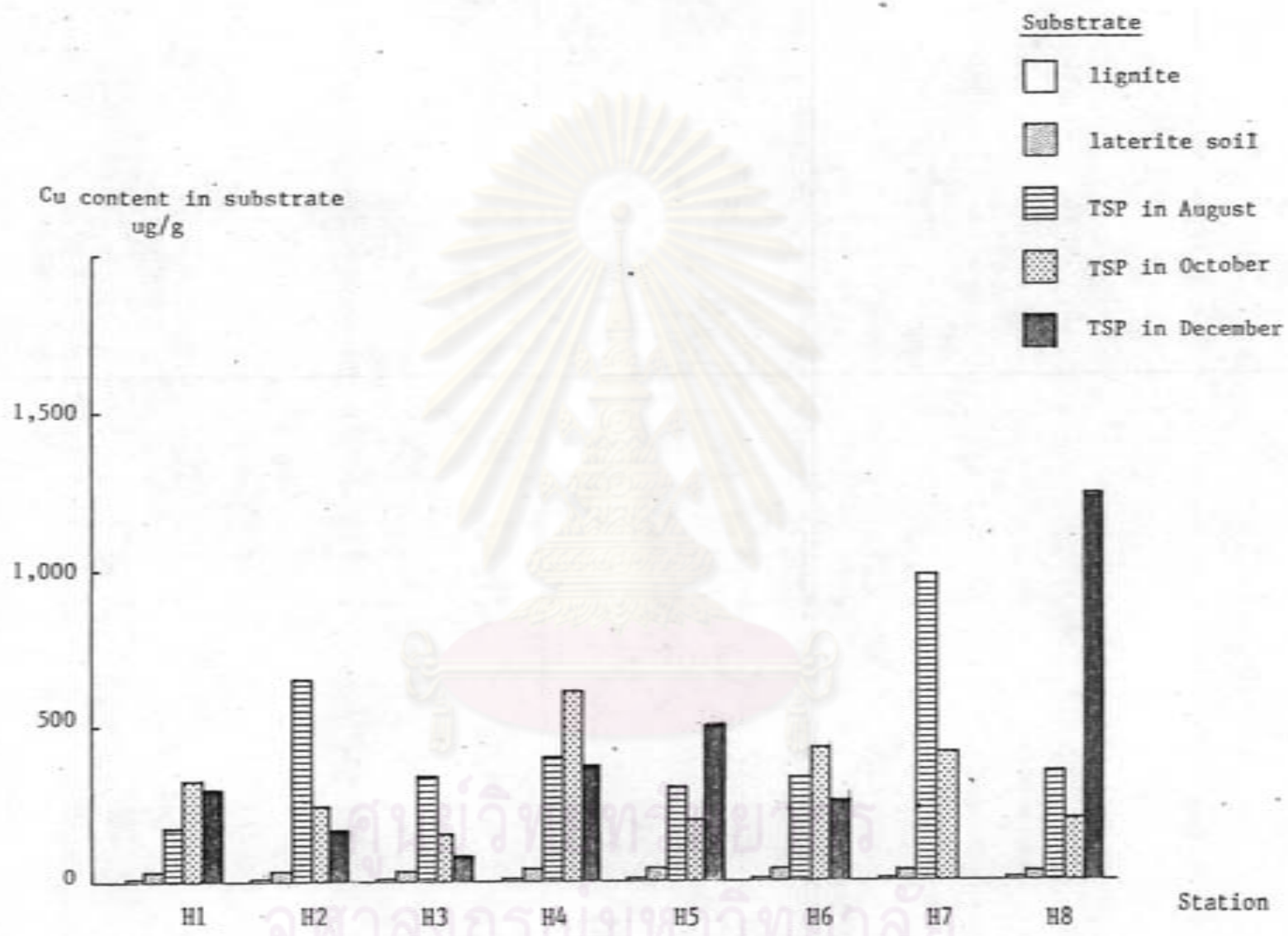

Figure 16 Comparison of copper content in lignite, copper content in laterite soil and copper content in TSP at Stations H1 to H8 in August, October and December

The range and average content of lead in the TSP in ambient air at each station in August, October and December are tabulated in Table 23. From the Table, it was seen that lead contents in ambient air markedly differed from each station and each month as the following:

In August, the highest lead content of 185.5 ng/m^3 was found at Station No. H3, since this station was located nearby the laterite road where the ash dump trucks passed by. The contents of 76.4 ng/m^3, 66.1 ng/m^3 and 47.9 ng/m^3 were found at Stations No. H6, H5 and H8, respectively, since stations No. H6 and H8 were nearby the asphalt road leading to the Mae Moh Project area; Station No. H5 was nearby the asphalt road leading to the Power Plant Units 4 and 5 which were under construction. All these roads were observed that the heavy traffic volume occurred. Not only the motor vehicles but also the dump ash were considered to increase the lead content in Mae Moh ambient air, since there were some amount of lead found in dump ash (see Table 2); and Stations No. H3 and H5 where closed to the ash dump trucks passed by showed the higher lead contents in ambient air than the other stations. The low lead contents of 23.4 ng/m^3, 19.6 ng/m^3, 14.2 ng/m^3 and 12.6 ng/m^3 were found at Stations No. H2, H1, H4 and H7, respectively. This was because Station No. H2 was nearby the laterite road leading to Ban Moh Luang; Station No. H4 was nearby the road where only a few of ash dump trucks passed by whereas Stations No. H1 and H7 were located in the forest without any traffic load. These stations were located in the vicinity areas of low traffic volume. Although Stations No. H1 and H7 were downwind from the plant, the slightly low contents of lead were detected. Thus, the main emission source of lead should not be the Plant.

In October, the high lead contents were also found at Stations No. H3, H2, H6, H4, H5 and H8, since these stations were located in the heavy traffic area; and Stations No. H3, H4 and H5 were nearby the ash dump road. Additionally, Stations No. H4 and H5 were downwind from the

Table 23 The range and average content of lead in the TSP at each station

Sampling Station	August		October		December	
	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3
H1	0.8-49.7	19.6±23.3	n-58.0	32.6±27.8	17.6-41.1	27.8±12.2
H2	15.5-28.8	23.4±5.6	130.0-222.8	162.3±40.0	22.5-28.7	25.1±2.6
H3	16.5-452.2	185.5±207.4	202.1-249.3	226.6±25.5	136.3-160.0	150.2±11.5
H4	0.3-31.9	14.2±16.3	17.4-75.3	45.1±24.7	49.7-90.8	64.9±17.9
H5	2.5-91.6	66.1±42.6	21.7-53.9	30.5±14.0	40.8-241.1	115.9±89.0
H6	53.2-101.5	76.4±22.8	40.9-57.6	52.3±7.8	61.2-166.8	106.3±46.0
H7	0.2-27.7	12.6±14.4	4.2-18.2	13.8±5.2	-	-
H8	n-79.8	47.9±33.9	23.5-61.1	37.8±18.01	38.8-74.9	52.7±15.6

n non-dectectable

* average ± mean divation of 4 samples

- No sample was collected since the road to the station was too muddy

plant, and were in a position that was affected by the NW and NNW prevailing winds. The low lead contents were detected at Stations No. H1 and H7 where were located in the forest.

In December, at Station No. H3, the lead content was higher than those of Stations No. H5, H6, H4, H8, H2 and H1. Owing to the same distribution patterns of lead in October, such results should be explained as these occurred in October.

Figure 17 illustrated the histogram of the average content of lead associated with the TSP at each station during three-month period. It was seen that at each station, the lead content varied a bit due to the difference of traffic load Additionally, lead contents in December were usually higher than those in August and October (see Figure 17), except Stations No. H2 and H3, since the traffic volume in the areas of both stations were uncertainly fluctuated. Thus, lead content depended upon the traffic load more than seasonal effect. However, the lead content in the ambient air increased as the TSP increased. The actual relationship between lead content and TSP content in Mae Moh ambient air is illustrated in Figure 18. The trend of this relationship can be divided into 2 types consisting of line 1 and line 2. The line 1 was found in the sampling areas of heavy traffic volume whereas the other line was in the areas where were nearby the laterite road, dumping area and existing mine pit. Thus, the proportionality of lead to TSP in ambient air in Mae Moh Basin varied, depending on the types of emission sources.

Figure 19 showed the comparison of lead content in lignite, leads content in laterite soil and lead content in TSP in ambient air in August, October and December at Stations H1 to H8 in the unit of µg/g. Similarly to copper, it could be totally concluded that the content ratios of lead to TSP was also higher than the sum of lead contents in lignite and in laterite soil. This meant that lead in ambient air was emitted not only from lignite and laterite soil but also from the other sources such as motor vehicles, bottom ash and fly ash.

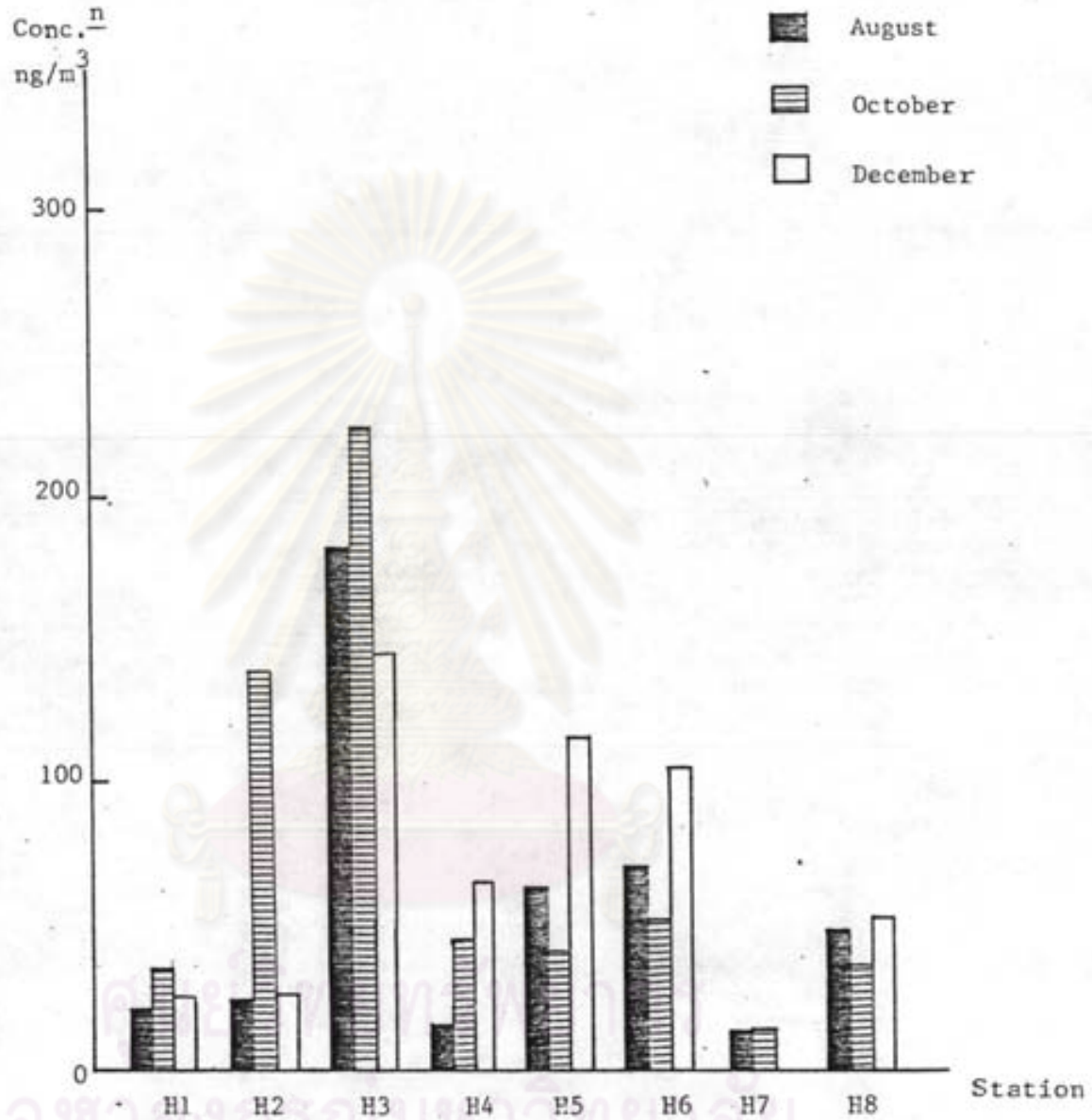

Figure 17 The histogram of the average content of lead in the TSP at each station in August, October and December

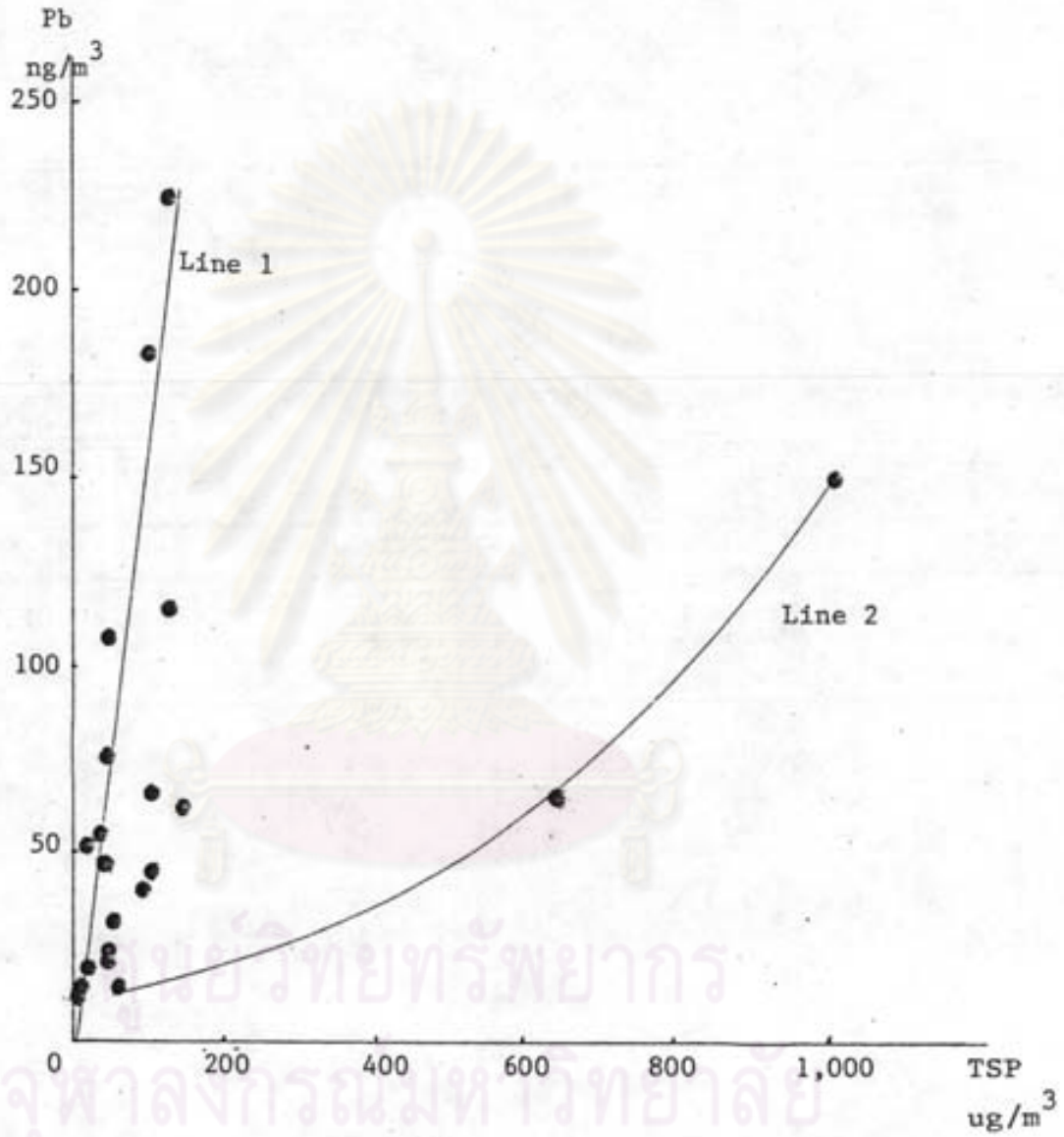

Figure 18 The relationship between lead content and TSP content in the ambient air

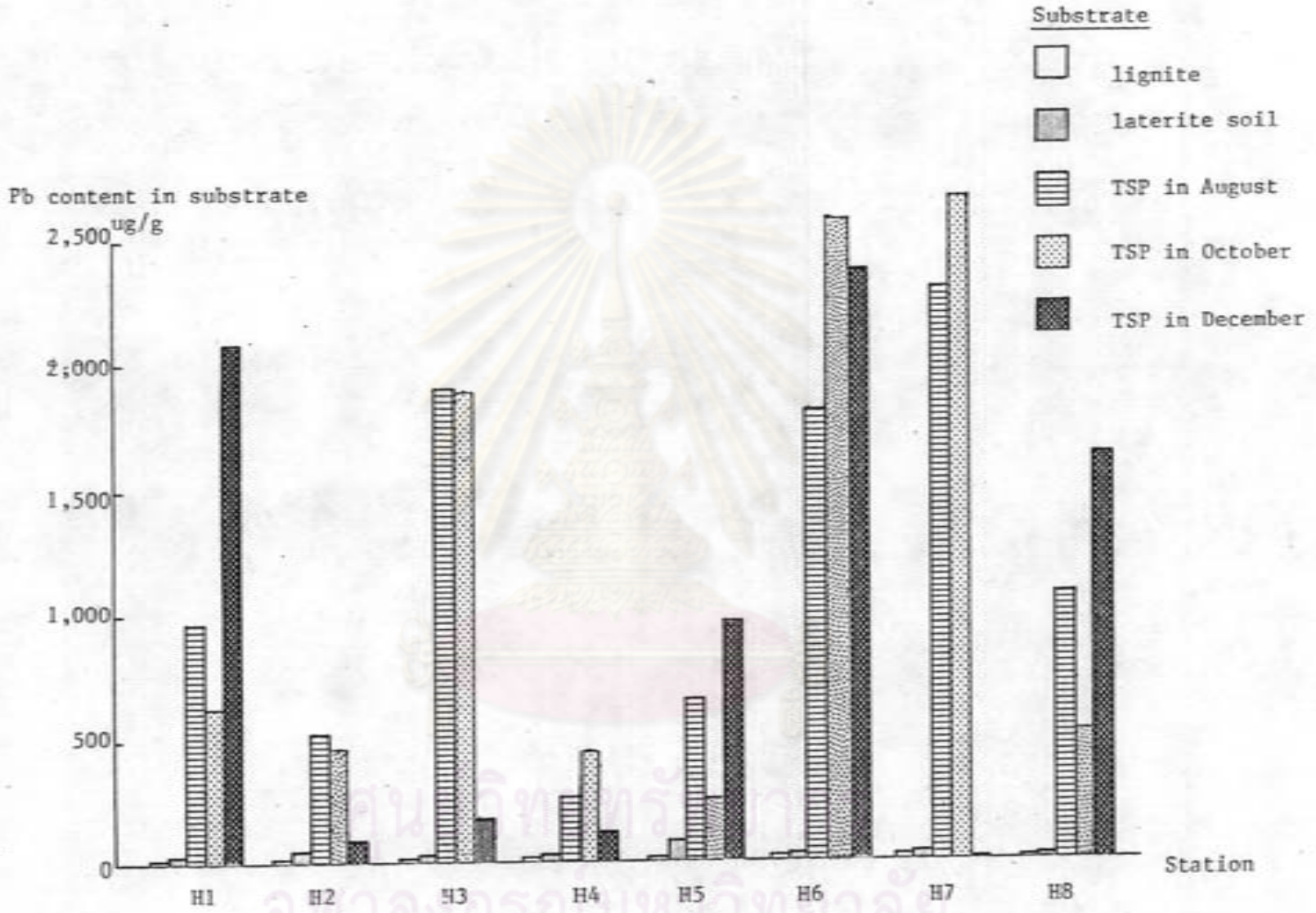

Figure 19 Comparison of lead content in lignite, lead content in laterite soil and lead content in TSP at Stations H1 to H8 in August, October and December

The above results showed that the high lead contents were significantly found in the sampling areas of the heavy traffic volume. It could be concluded that most of lead in Mae Moh ambient air was mainly derived from lead additives in motor fuels. However, slightly high lead content was detected at the areas where were downwind from the plant, and/or were nearby the ash transported road.

The range and average content of manganese associated with TSP in the ambient air at each station in August, October and December are tabulated in Table 24.

In August, the highest manganese content of 95.0 ng/m^3 was detected at Station No. H3 where was located nearby the ash and overburden dumping areas, and laterite road where the laterite soil contained a lot of manganese (see Table 6). The manganese contents of 76.5 ng/m^3 was detected at Station No. H8, and of 74.3 ng/m^3 was at Station No. H5 since both stations were in the areas of the laterite soil containing with high manganese as shown in Table 6. Station No. H8 was located in the area where the highest manganese content in the soil was found. It was expected that the high manganese containing in the soil could contribute some manganese in the ambient air. At the other stations, the slightly low contents of manganese obtained because these stations were far away from the laterite road with heavy traffic load, thus manganese (associated with the TSP) distribution could not reach.

Similarly to August, the results of manganese content in the ambient air in October and December are as the following:

In October, the highest of manganese content of 214.4 ng/m^3 were found at Station No. H5. The manganese contents of 151.8 ng/m^3, 110.1 ng/m^3 and 104.5 ng/m^3 were detected at Stations No. H2, H8 and H3 whereas the low manganese contents of 31.2 ng/m^3, 19.0 ng/m^3 13.2 ng/m^3 and 3.1 ng/m^3 were detected at Stations No. H4, H6, H1 and H7, respectively.

In December, at Station No. H3 the manganese contents of 871.1 ng/m^3 was higher than those of 644.5 ng/m^3 (Station No. H2), 602.0 ng/m^3

Table 24 The range and average content of manganese in the TSP at each station

Sampling Station	August		October		December	
	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3
H1	0.3-22.2	7.9±10.3	5.1-26.5	13.2±9.4	33.2-134.1	81.8±54.9
H2	14.9-59.8	37.5±19.4	123.1-209.2	151.8±57.3	468.2-1,038.5	644.5±265.5
H3	67.9-112.0	95.0±20.8	28.1-169.7	104.5±66.9	728.6-1,023.4	871.1±121.4
H4	2.5-63.9	21.4±28.8	7.8-57.1	31.2±20.9	289.3-1,347.1	602.0±504.5
H5	51.9-91.6	74.3±16.5	163.8-280.8	214.4±54.8	33.2-157.2	91.5±50.9
H6	17.7-80.7	42.7±27.4	15.9-20.7	19.0±2.2	33.9-83.3	52.4±21.8
H7	n-7.7	2.6±3.6	0.7-7.5	3.1±4.21	-	-
H8	n-123.4	76.5±58.5	67.4-150.1	110.1±50.0	68.3-177.7	103.5±50.2

n non-detectable

* average ± mean deviation of 4 samples

- No sample was collected since the road to the station was too muddy

(Station No. H4), 103.5 ng/m^3 (Station No. H8), 91.5 ng/m^3 (Station No. H5), 81.8 ng/m^3 (Station No. H1) and 52.4 ng/m^3 (Station No. H6).

The above results showed that the high manganese contents in Mae Moh ambient air were in the areas where were nearby the laterite roads with heavy traffic load for example: Stations No. H2, H3, H4, H5 and H8, and the laterite soil of these areas contained a lot of manganese that is one of major elements in the soil[9]. Especially in the dry month, the laterite road was so dry that very high particulates containing with manganese were generated and suspended in the atmosphere. These particulates and manganese were removed from the atmosphere due to the high rainfall in rainy months. Thus, in the dry months. Thus, in the dry month (in December), the manganese in ambient air was ususally higher than those in the rainy month (in August and October) as shown in Figure 20. Comparison between manganese content and TSP content in ambient air showed that the manganese increased with TSP content as illustrated in Figure 21. However, the exact proportionality was not obtained due to the fluctuation of factors which influenced upon both contents.

From the literature[9, 32, 55], manganese is one of the elements that was more concentrated in bottom ash than in emitted fly ash. During three-month period, the high manganese contents of 95.0-871.1 ng/m^3 and 21.4-602.0 ng/m^3 were obtained in Mae Moh ambient air at Stations No. H3 and H4 respectively. These stations were in the area of ash dump trucks passed by. From this study and the literatures, it could be expected that such high airborne manganese content found was emitted not only from manganese containing in soil particulates but also from manganese concentrating in the dump ash (bottom ash).

Figure 22 showed the comparison of manganese content in lignite, manganese content in laterite soil and manganese content in TSP in August, October and December in the unit of μg/g. It was seen that the content of manganese in lignite can be negligible when it was compared to the

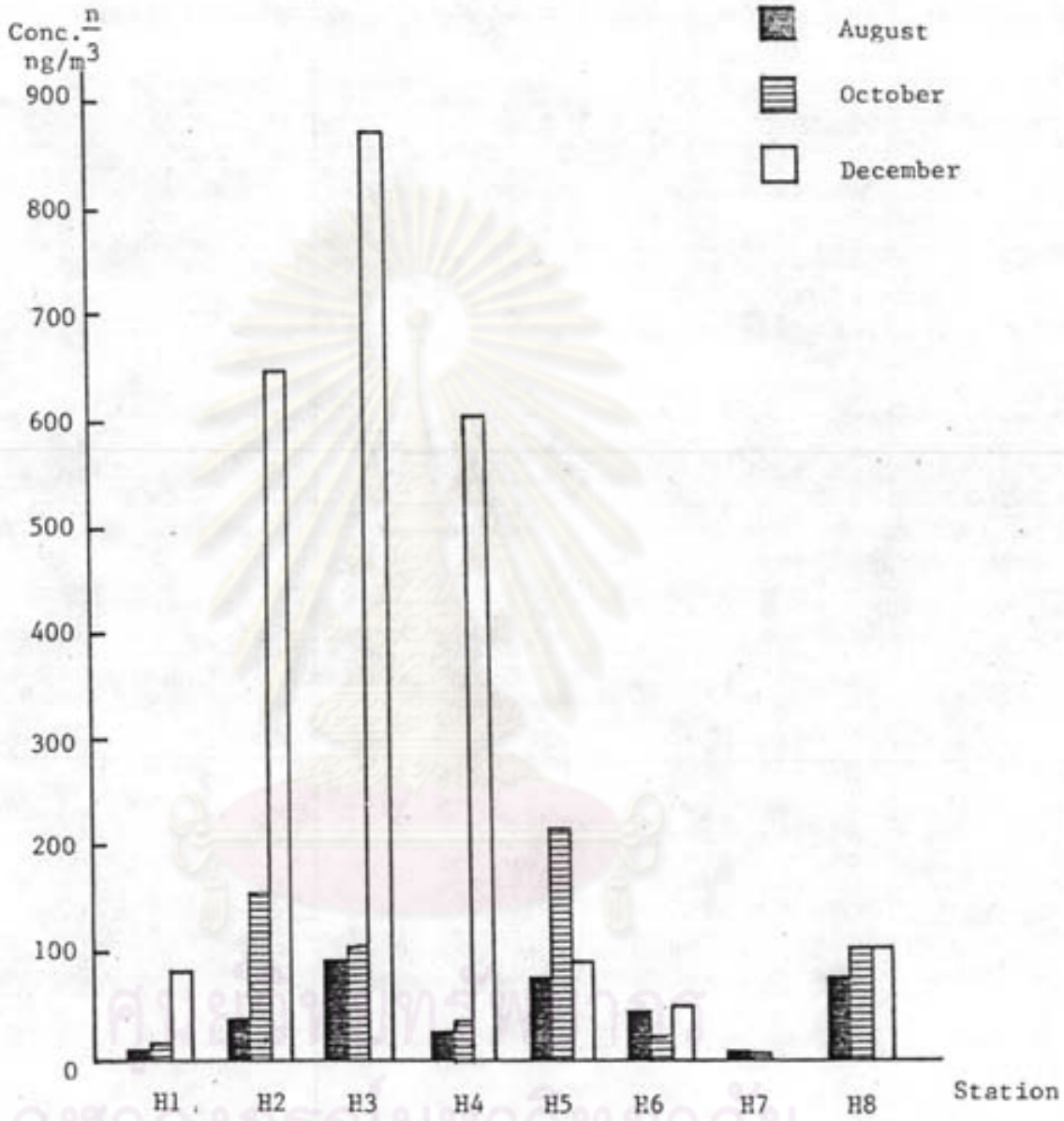

Figure 20 The histogram of the average content of manganese in the TSP at each station in August, October and December

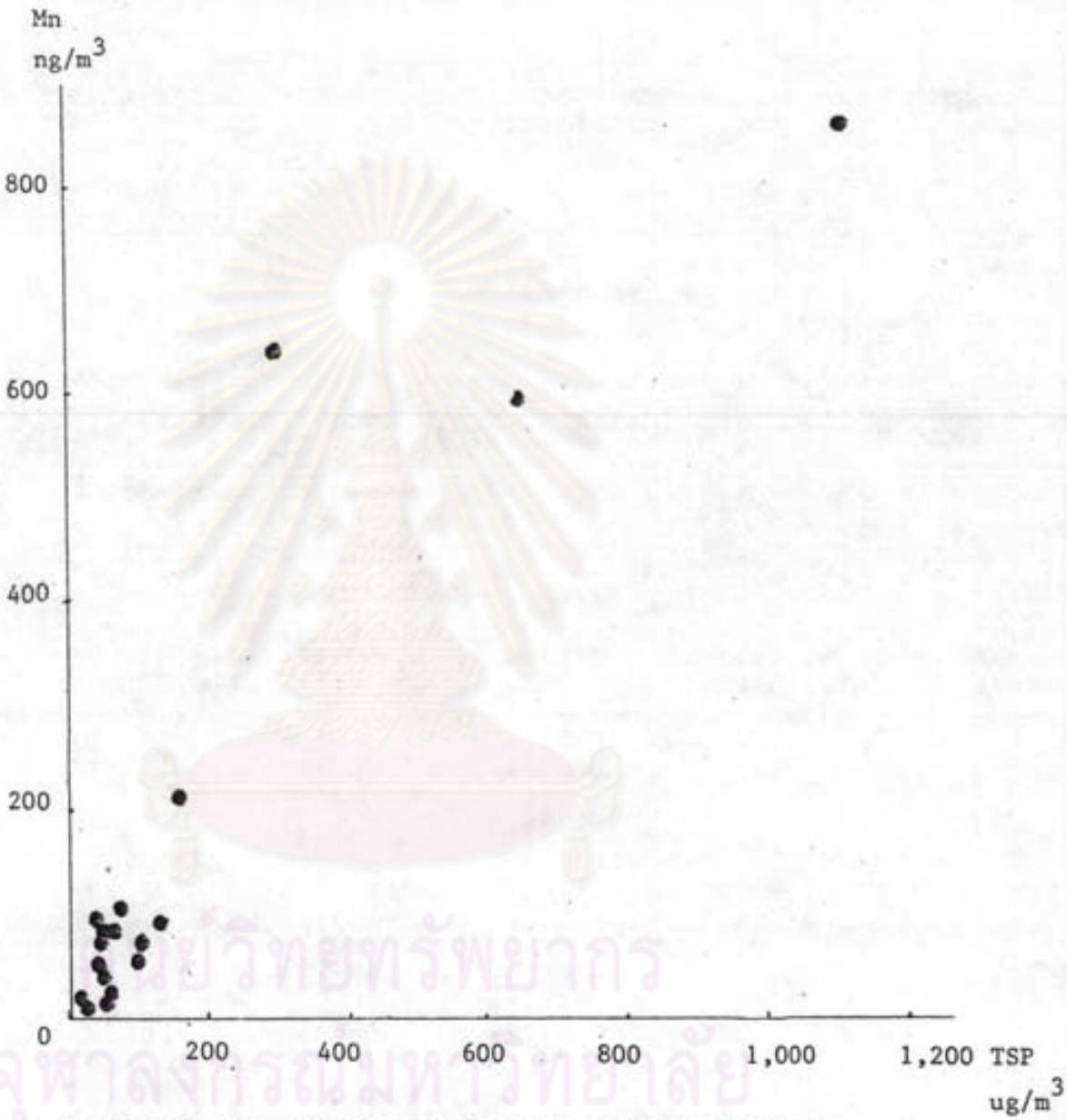

Figure 21 The relationship between manganese content and TSP content in the ambient air

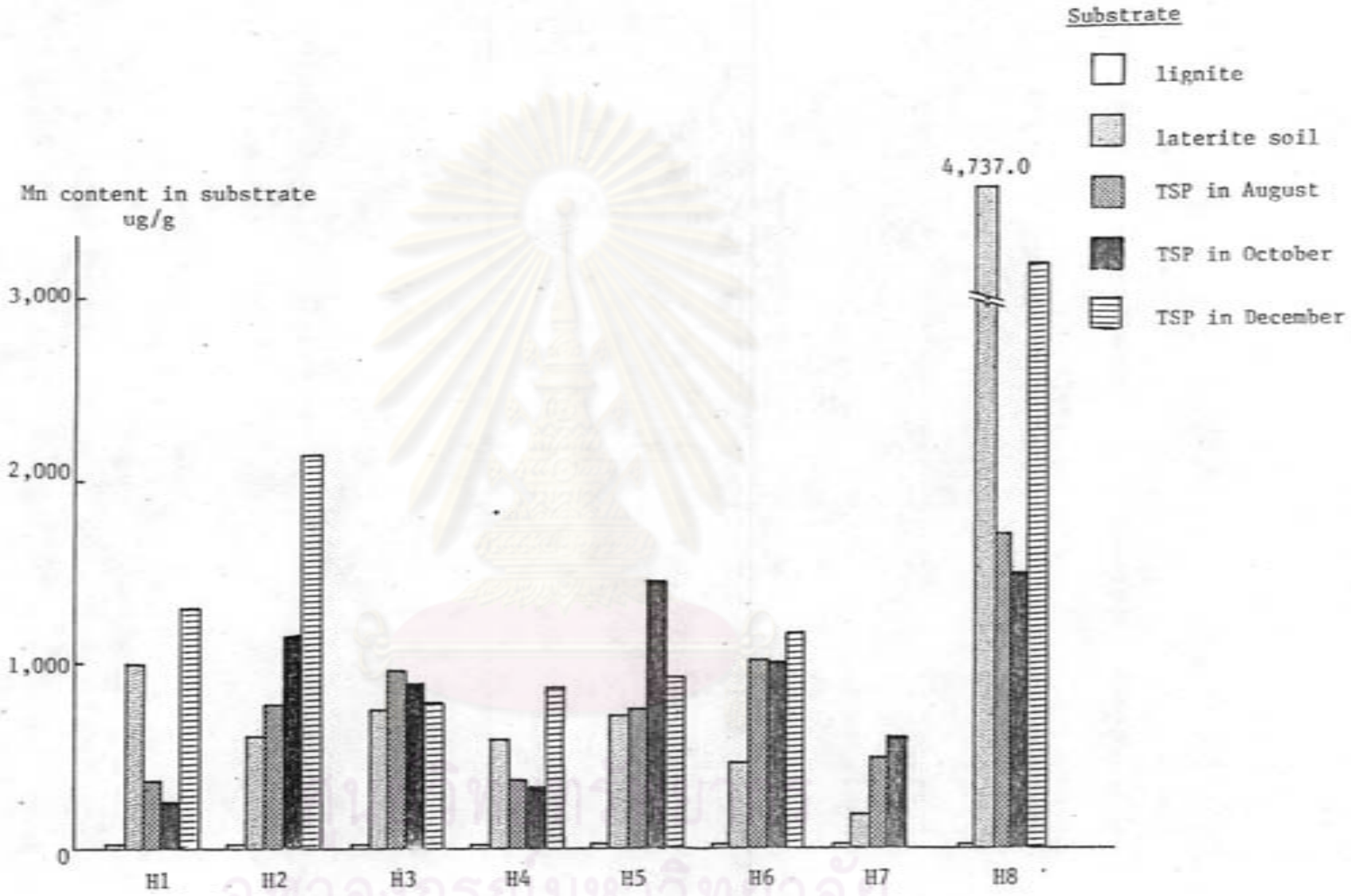

Figure 22 Comparison of manganese content in lignite, manganese content in laterite soil and manganese content in TSP at Stations H1 to H8 in August, October and December

content of manganese in laterite soil. Therefore most of airborne manganese content should mainly come from the laterite soil. The other emission sources such as fly ash and bottom ash were minor sources.

The range and average content of nickel in the TSP in ambient air at each station in August, October and December are tabulated in Table 25. The results of nickel content in ambient air at all stations were as the following:

In August, the decreasing order of nickel content in ambient air was 22.4 ng/m^3, 20.4 ng/m^3, 15.3 ng/m^3, 14.1 ng/m^3, 14.0 ng/m^3, 13.9 ng/m^3, 9.0 ng/m^3 and 5.5 ng/m^3 at Stations No. H3, H5, H1, H6, H2, H4, and H7, respectively.

In October, at Station No. H4 and H5, the high nickel contents of 81.0 ng/m^3 and 80.5 ng/m^3 were found. The slightly low contents of 25.7 ng/m^3, 18.6 ng/m^3, 16.5 ng/m^3 and 15.7 ng/m^3 were detected at Stations No. H3, H2, H8 and H1, respectively. At Station No. H6, the very low content of 5.6 ng/m^3 was found whereas the lowest content of 2.2 ng/m^3 was at Station No. H7.

In December, it was similarly to October, the high nickel contents of 67.3 ng/m^3, 58.9 ng/m^3 and 40.0 ng/m^3 were detected at Stations No. H3, H4 and H5 whereas the low contents were obtained at Station No. H6, H2, H8 and H1 as 29.8 ng/m^3, 23.0 ng/m^3, 20.7 ng/m^3 and 15.7 ng/m^3, respectively.

Comparison of such results to the airborne copper contents in Table 22, it was seen that the distribution patterns of both nickel and copper contents were the semilar. Thus, the same explanation of both heavy metal should be expected. The high nickel contents were often found at Stations No. H3, H4 and H5 where were located downwind from the Plant, and were nearby the ash dump road and laterite road; the remaining stations where were located far away from the emission sources showed the low nickel content.

Table 25 The range and average content of nickel in the TSP at each station

Sampling Station	August		October		December	
	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3
H1	0.8-39.2	14.1±18.0	n-38.9	15.7±19.1	9.8-19.9	15.7±14.5
H2	12.6-15.4	13.9±1.2	13.9-26.7	18.6±5.73	11.2-32.6	23.0±9.1
H3	10.6-32.1	20.4±10.1	8.6-45.0	25.7±19.3	41.0-101.7	67.3±25.4
H4	0.4-25.4	9.0±11.8	52.5-96.1	81.0±20.0	46.5-68.8	58.9±11.2
H5	8.2-20.1	15.3±5.2	72.6-92.6	80.5±11.3	32.0-55.8	40.0±11.0
H6	1.6-20.8	14.0±8.7	n-8.6	5.6±3.9	24.0-37.4	29.8±6.6
H7	n-12.8	5.5±6.5	0.8-4.3	2.2±3.3	-	-
H8	13.3-29.1	22.4±6.7	1.5-24.8	16.5±7.6	10.7-24.6	20.7±6.7

n non-detectable

* average ± mean deviation of 4 samples

- No sample was collected since the road to the station was too muddy.

The histogram of the average content of nickel in the TSP at each station during three-month period as in Figure 23 showed that nickel content at most stations in December was higher than those in the other sampling months. The nickel content increased with the TSP but the exact relationship between each other could not find (see Figure 24), since the distribution of both were depended upon the meteorological factors which quite varied.

The nickel content in lignite, in laterite soil and in TSP were also compared as shown in Figure 25 likewise the other heavy metals. It was seen that the nickel content in TSP was higher than the sum of nickel content in lignite and in laterite soil. This indicated that nickel in ambient air was emitted not only from both lignite and laterite soil but also from the other sources which were already explained, such as emitted fly ash from the plant's exhaust and bottom ash from ash disposal.

The range and average content of zinc in the TSP at each station in August, October and December are tabulated in Table 26, and the histogram of the average zinc content at every station is illustrated in Figure 26. Comparison of airborne zinc content in Table 26 to airborne manganese content in Table 24; and the histogram of the average zinc content in Figure 26 to the histogram of the average manganese content in Figure 20, it was seen that the distributions of both heavy metals in ambient air during three-month period were the same, just the different content of both heavy metals was obtained. Corresponding to the occurrence of manganese and zinc in lithosphere as major and trace elements[9], the airbonre manganese content was higher than the airbonre zinc content. Moreover, the zinc content to TSP content at every station during three-month period was just higher than the zinc content in lignite and in laterite soil as shown in Figure 27, likewise manganese in Figure 21. So the same explanation for such results could be concluded that most of zinc in ambient TSP was mainly arised from the laterite soil. However, some zinc was also resulted from plant's exhaust and ash disposal

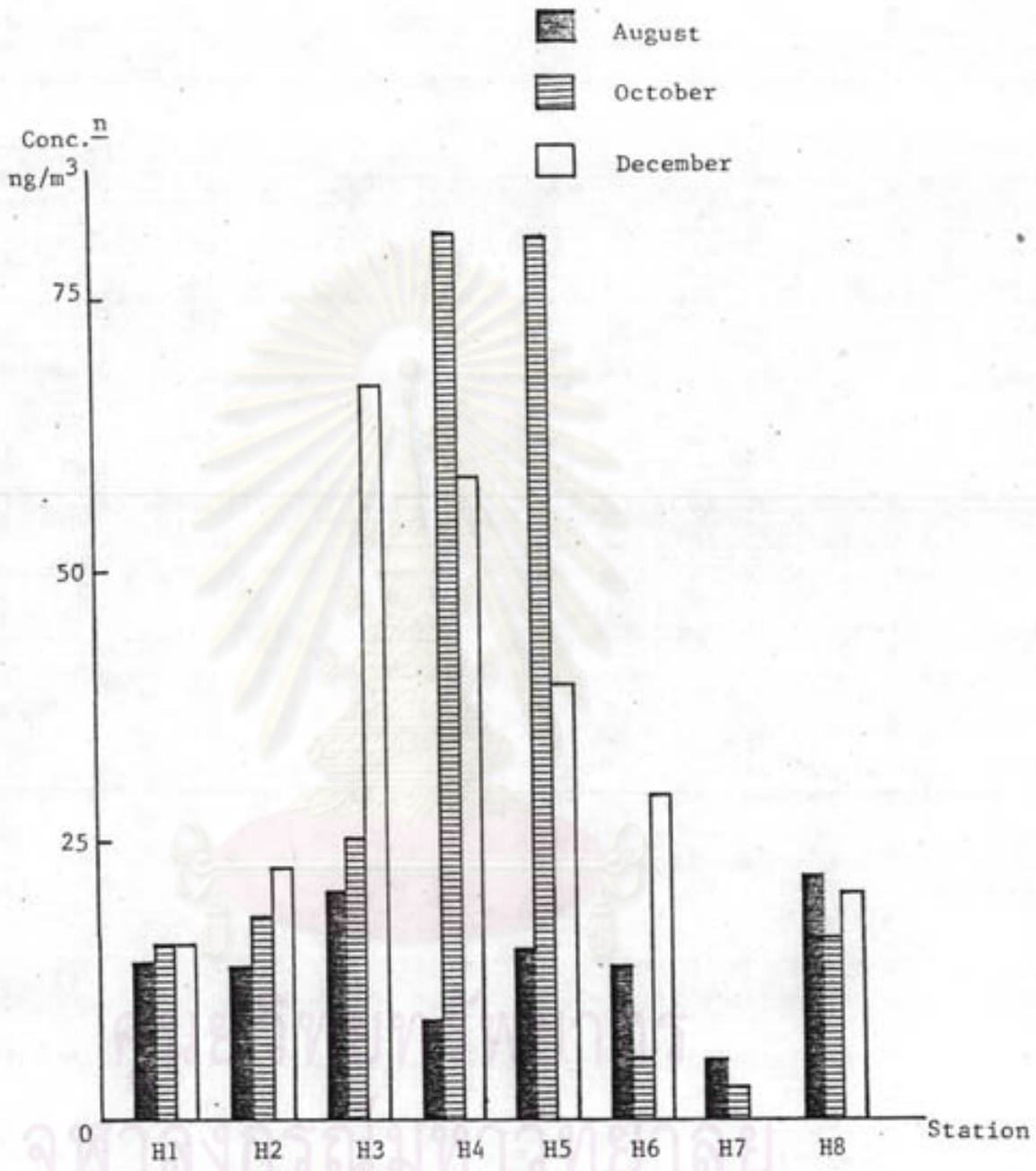

Figure 23 The histogram of the average content of nickel in the TSP at each station in August, October and December.

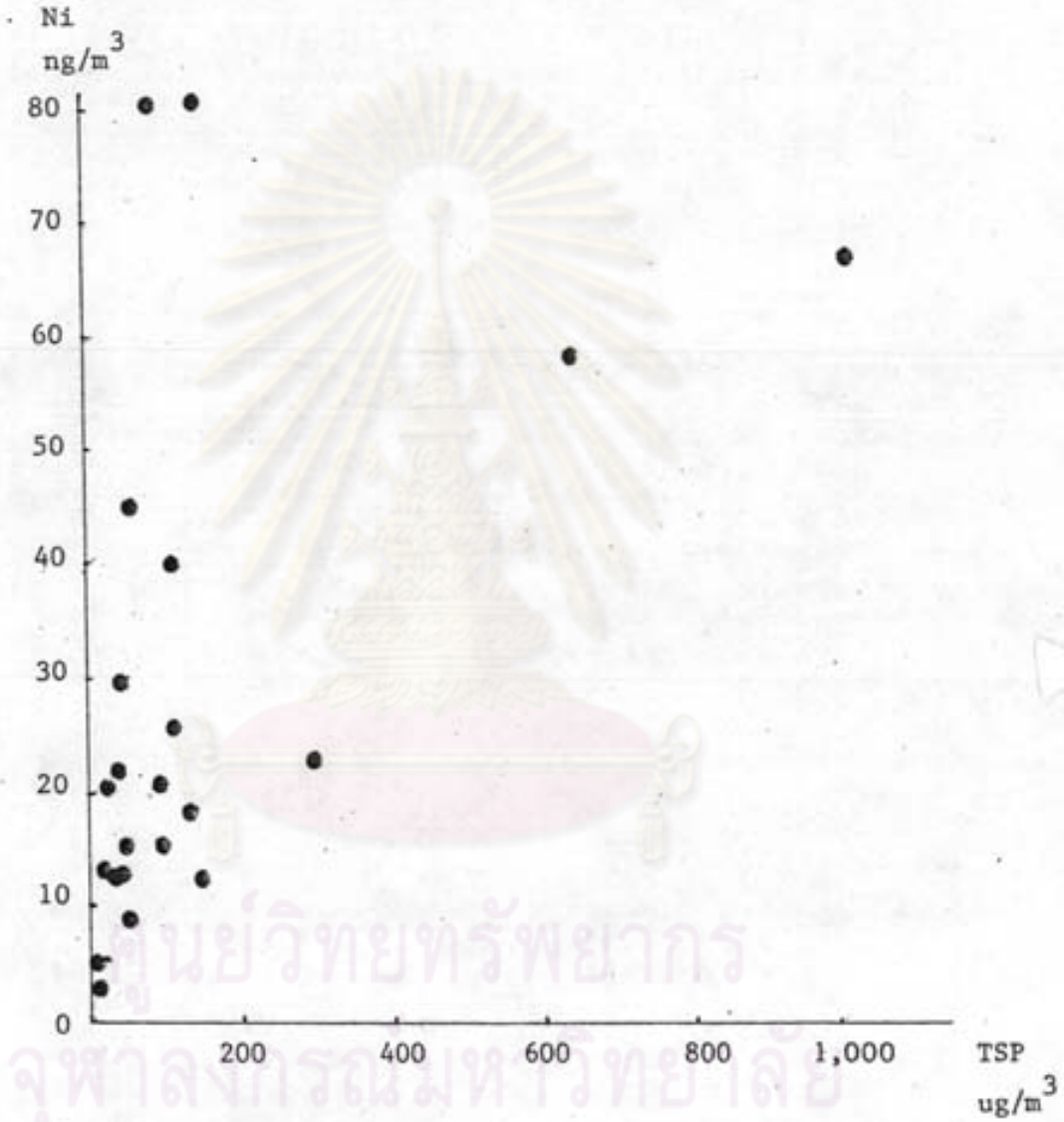

Figure 24 The relationship between nickel content and TSP content in the ambient air

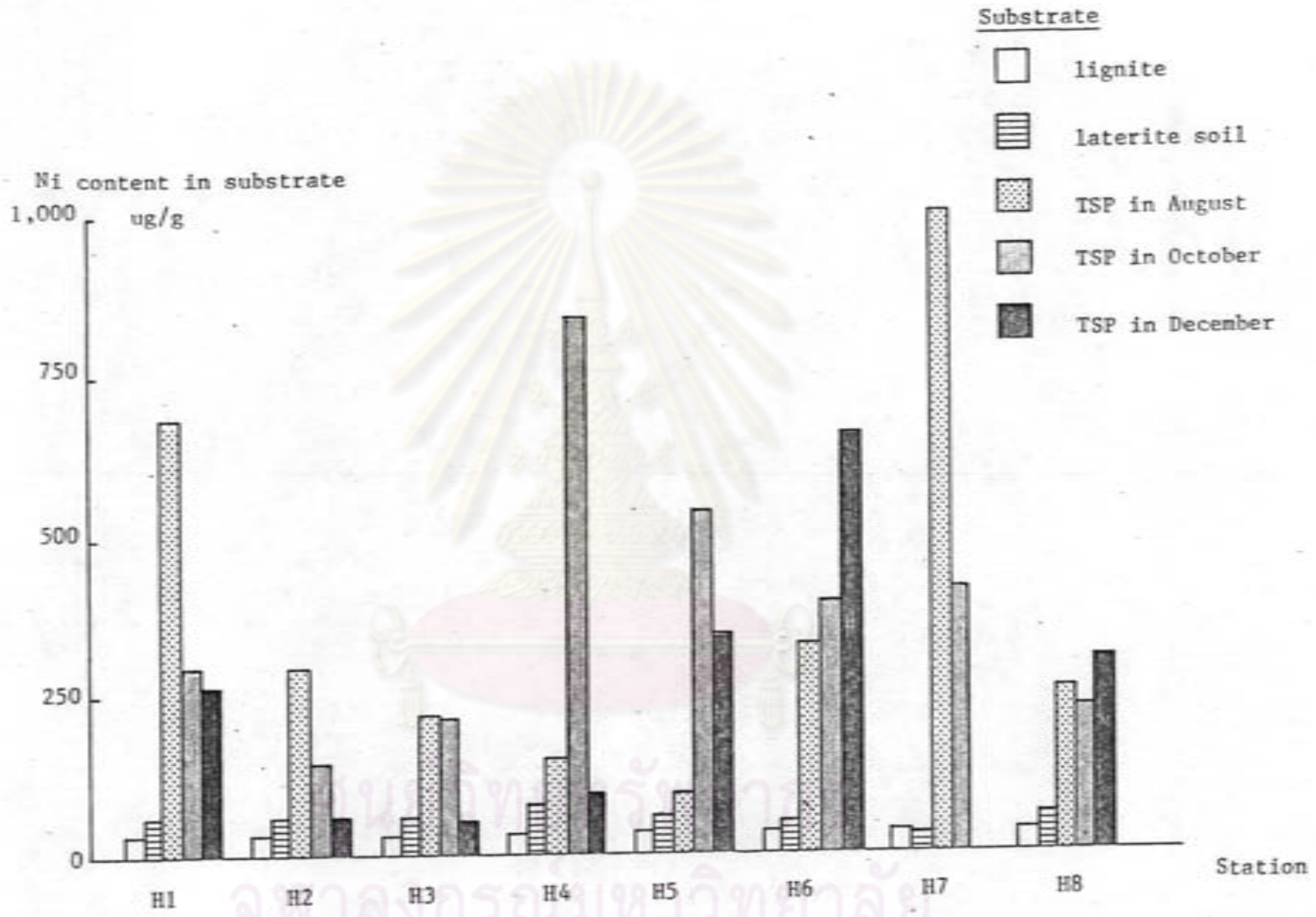

Figure 25 Comparison of nickel content in lignite, nickel content in laterite soil and nickel content in TSP at Stations H1 to H8 in August, October and December

Table 26 The range and average content of zinc in the TSP at each station

Sampling Station	August		October		December	
	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3	Range ng/m^3	Average* ng/m^3
H1	2.3-15.1	5.7±6.3	n-10.3	3.5±6.5	3.0-8.1	5.1±2.3
H2	0.9-7.5	5.2±3.1	12.8-30.1	19.6±8.1	10.5-74.0	27.1±32.3
H3	n-17.0	10.5±8.0	16.9-51.7	30.0±18.3	30.0-140.5	78.5±49.0
H4	0.5-4.7	2.8±1.9	15.4±32.4	23.4±5.0	28.4-108.3	53.4±38.1
H5	1.2-8.2	2.6±3.7	n-5.4	3.5±2.5	3.5-10.3	7.3±3.1
H6	1.8-9.7	3.5±4.3	0.8-7.3	3.5±2.7	9.1-23.4	14.1±7.3
H7	n-2.5	1.2±1.4	n-2.7	1.0±2.5	-	-
H8	1.1-15.6	8.4±7.9	1.8-17.7	12.9±8.2	n-7.5	4.3±3.2

n non-detectable

* average ± mean deviation of 4 samples

- No sample was collected since the road to the station was too muddy.

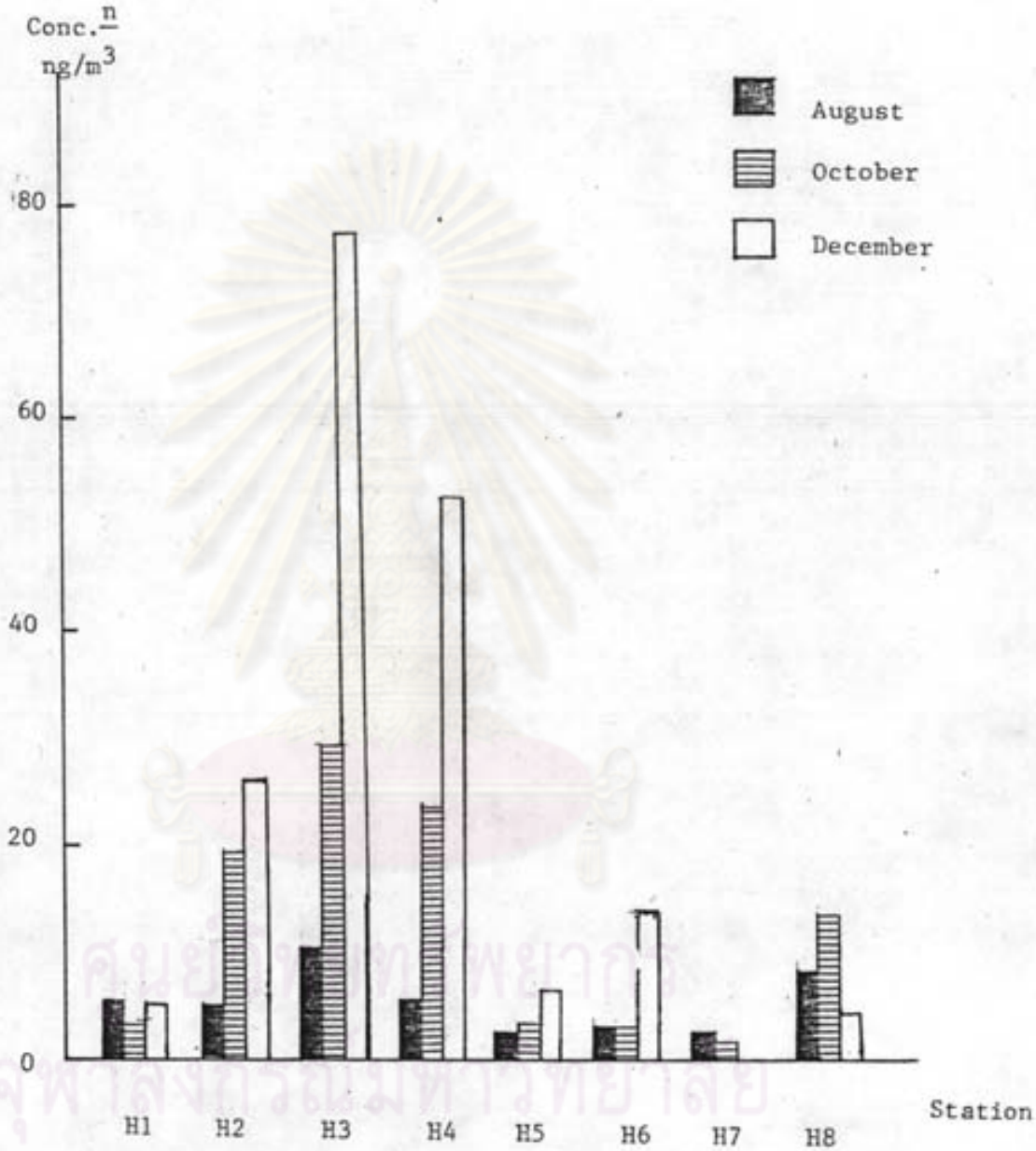

Figure 26 The histogram of the average contents of zinc in the TSP at each station in August, October and December

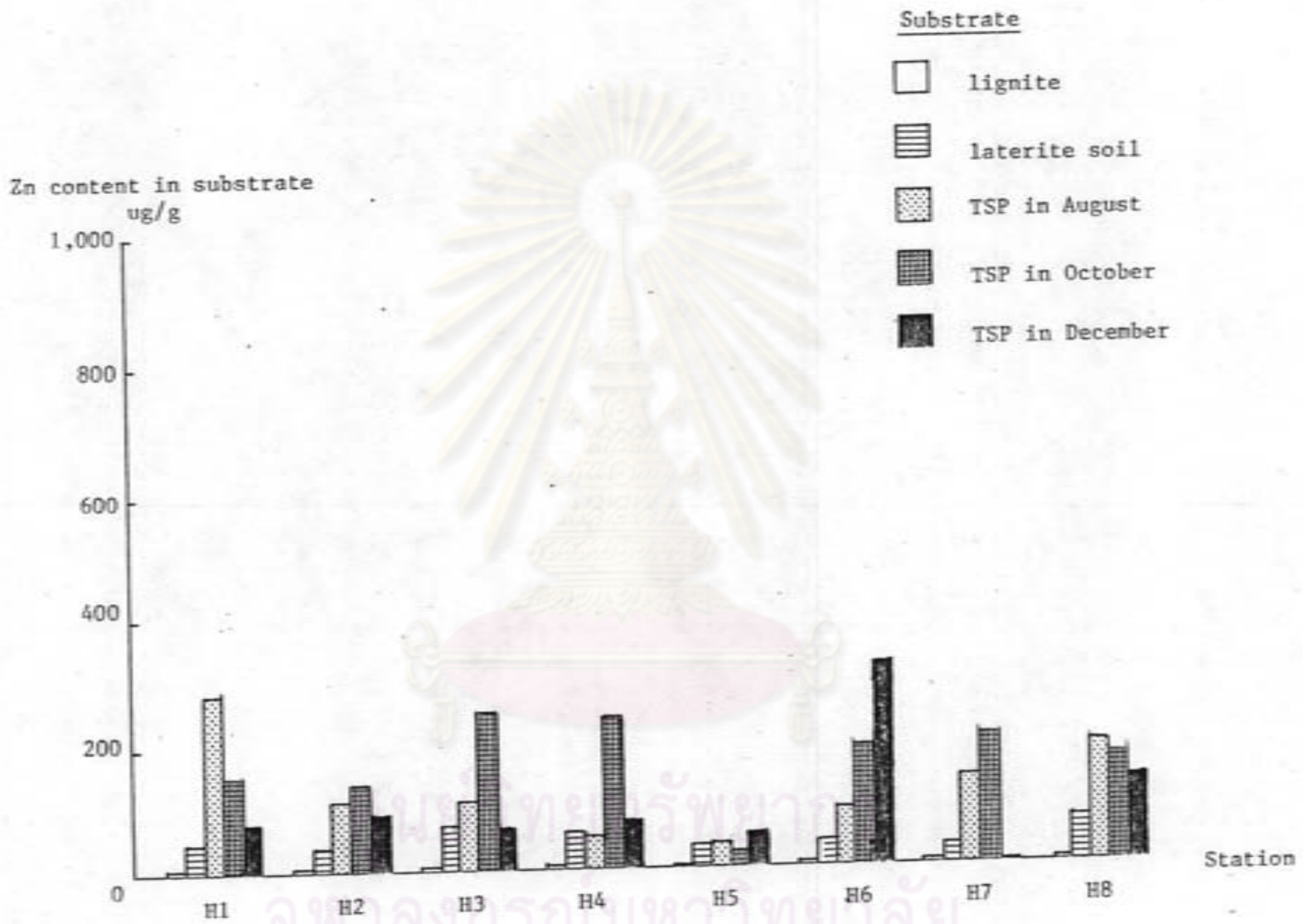

Figure 27 Comparison of zinc content in lignite, zinc content in laterite soil and zinc content in TSP at Stations H1 to H8 in August, October and December

due to the high content found in the area influenced by these activities. As the other heavy metal contents, the zinc content tended to increase with the TSP (see Figure 28) but this relationship did not exactly find due to the large fluctuation of the influenced factors.

As the overall discussion, although the analyzed heavy metals presented in Mae Moh ambient air were generally low, it was reasonable to suspect that such quantities of the heavy metal were mainly derived from the Mae Moh Project and its activities.

There was no current ambient air quality standards or guidelines available for the heavy metals, except lead. The NEB 24-hour ambient lead standard of 10 $\mu g/m^3$ and U.S. EPA quarterly standard of 1.5 $\mu g/m^3$ were applied in light of the heavy metal impact assessment[19]. As can be seen in Table 23, the lead contents in this sampling period (August, October and December, 1983) were much lower than both allowable standards. Thus, it could be concluded that the lead content in Mae Moh ambient air should not cause any deteriorated effects to human beings and the environments. The generally low content of the other heavy metals in Mae Moh ambient air were also found in ng level. Additionally, EGAT had prevented the air pollution problem by using high collection electrostatic precipitator, using water spray into the laterite road and using some safety equipments such as air conditioned truck, safety mask. Thus, it could be expected that the airborne heavy metals in the Mae Moh Basin should not cause any deteriorating effects to the human health.

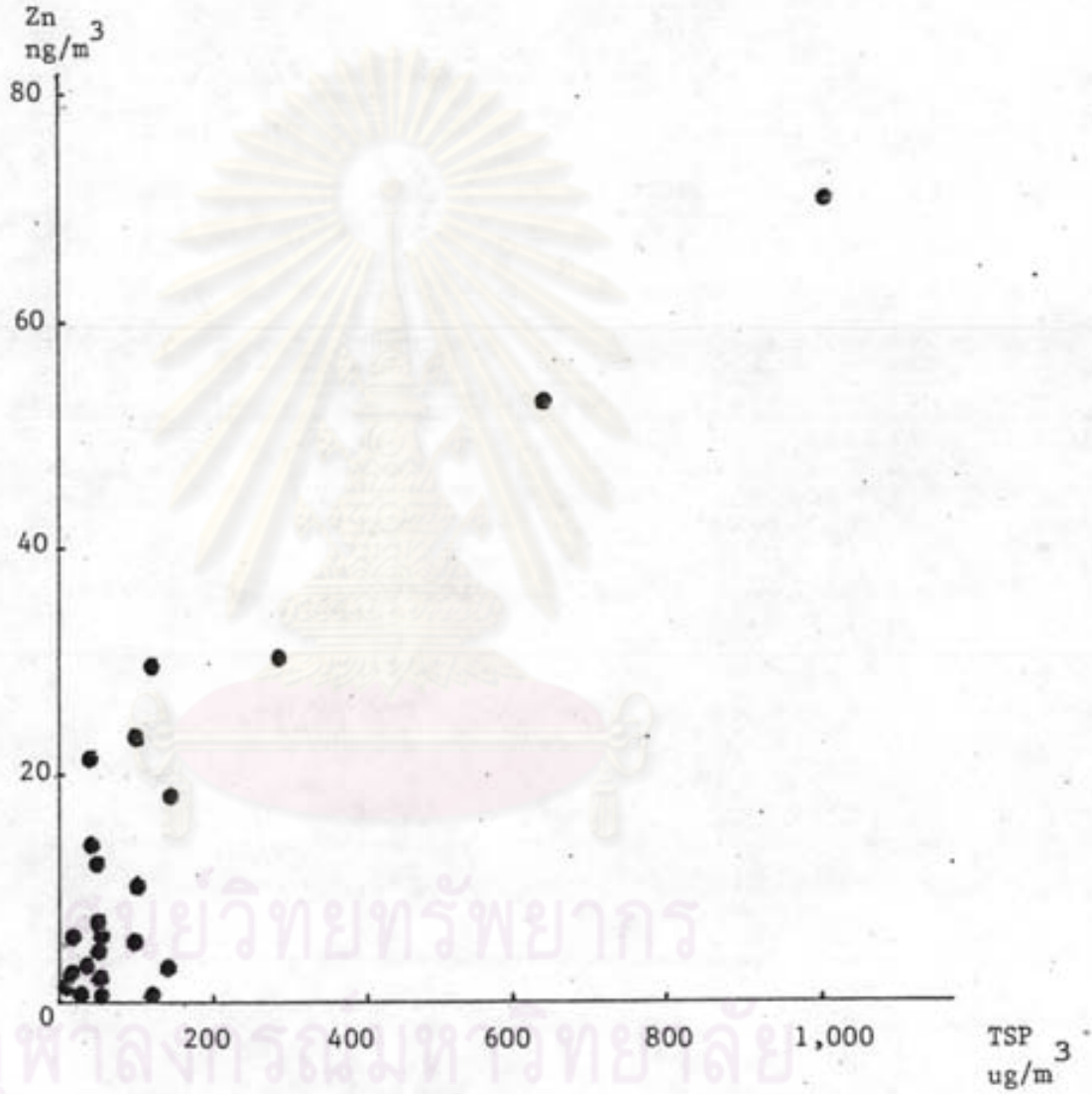

Figure 28 The relationship between zinc content and TSP content in the ambient air