Table VII-1-27 Correlation coefficient matrix by method II (4th survey)

	AG	AL
AG	1.000000	
AL	0.196727	1.000000

	AG	AL	AS	BA	BR	CA	CE	CL	CO
AS	-0.079872	0.540092	1.000000						
BA	0.028110	0.328971	0.080579	1.000000					
BR	0.072660	0.626479	0.153315	0.013519	1.000000				
CA	-0.034872	0.179376	0.145924	0.745768	-0.068744	1.000000			
CE	0.271517	0.650966	0.416434	0.505686	0.427951	0.506327	1.000000		
CL	0.005865	-0.308540	-0.268706	-0.083426	-0.518405	0.084657	-0.207472	1.000000	
CO	-0.008020	0.099002	-0.062834	0.883261	-0.104730	0.876673	0.437465	0.015370	1.000000
CR	0.007012	0.481256	0.555111	0.800655	0.081641	0.824360	0.666321	-0.173357	0.767351
CS	0.096642	0.769113	0.559357	0.366623	0.359013	0.471854	0.819817	-0.316296	0.338993
CU	-0.155778	0.093474	0.332095	-0.024840	0.036958	0.012906	0.236944	-0.182002	-0.062962
FE	0.109840	0.951581	0.649173	0.315731	0.551778	0.273254	0.823499	-0.254607	0.079142
HF	0.118415	0.617535	0.287531	0.839157	0.243123	0.752753	0.815382	-0.160743	0.761594
K	-0.055940	0.249540	0.471689	0.470853	-0.101154	0.371895	0.329280	-0.066895	0.356561
LA	0.228966	0.652929	0.368431	0.394053	0.306925	0.374253	0.838142	-0.329560	0.326691
LU	0.259279	0.745820	0.386299	0.001081	0.436127	0.019246	0.773526	-0.287513	-0.061764
MN	-0.004496	0.602725	0.736578	0.459579	0.195155	0.678279	0.633217	-0.095204	0.329981
NA	0.133932	-0.409419	-0.476280	-0.159610	-0.468965	-0.078971	-0.367701	0.871975	-0.022651
NI	-0.119566	-0.000515	-0.066066	0.785154	-0.184801	0.768659	0.317976	-0.052842	0.946267
SB	-0.106856	0.123460	-0.002607	-0.123927	0.076518	0.016875	0.197025	0.147014	-0.077792
SC	0.188437	0.992066	0.553545	0.340231	0.610356	0.191947	0.811235	-0.276535	0.097917
SE	-0.065179	0.361629	0.536763	0.236985	-0.037778	0.327513	0.461608	0.095543	0.170738
SM	0.195839	0.662755	0.413465	0.468419	0.524011	0.418151	0.957405	-0.208395	0.371926
TH	0.110426	0.635292	0.425551	0.180767	0.526116	0.169765	0.864101	-0.310194	0.058339
TI	0.099766	0.866248	0.537244	0.487939	0.549370	0.323968	0.739946	-0.236206	0.270375
V	-0.086696	0.153320	0.677348	-0.059823	-0.062223	0.243680	0.097232	-0.076839	-0.075706
W	-0.075301	0.030144	0.075771	0.869928	-0.217120	0.864977	0.361737	0.051989	0.943186
ZN	-0.136567	0.199565	0.633067	0.025197	0.024907	0.403194	0.204265	0.055597	-0.022310
CDK	0.132669	0.585094	0.478180	0.493095	0.094152	0.522705	0.648848	-0.060703	0.342403
PBK	0.110996	0.682541	0.243034	-0.026456	0.947654	-0.089422	0.483857	-0.483183	-0.163128
SK	-0.084958	0.129436	0.448716	0.319093	-0.115284	0.768373	0.281763	0.165529	0.400396
SIK	0.217854	0.991362	0.548664	0.378970	0.597265	0.250089	0.888893	-0.272247	0.164610
CLI	0.056071	-0.251113	-0.226238	-0.088866	-0.457529	0.150277	-0.143553	0.965714	0.038167
NO3I	0.010260	0.205343	0.524779	0.157571	-0.099824	0.648636	0.429258	0.207776	0.295754
SO4I	-0.129465	0.082862	0.519640	0.271927	-0.170676	0.718952	0.232320	0.135944	0.348081
TPH	0.149522	0.872479	0.488705	0.274533	0.812285	0.244711	0.805555	-0.405307	0.136977

	CR	CS	CU	FE	HF	K	LA	LU	MN
CR	1.000000								
CS	0.617887	1.000000							
CU	0.188567	0.099625	1.000000						
FE	0.553326	0.749296	0.231682	1.000000					
HF	0.648802	0.662814	0.158302	0.632367	1.000000				
K	0.564112	0.448970	0.013671	0.271503	0.421911	1.000000			
LA	0.527521	0.690696	0.575364	0.651741	0.727877	0.232118	1.000000		
LU	0.197238	0.760384	0.198791	0.673887	0.425451	0.247534	0.729251	1.000000	
MN	0.609293	0.605432	0.287421	0.782050	0.653422	0.454840	0.458389	0.304894	1.000000
NA	-0.365137	-0.366175	-0.463852	-0.467602	-0.291546	-0.165787	-0.466468	-0.302850	-0.411828
NI	0.701478	0.315690	-0.103700	-0.037593	0.644423	0.389494	0.232046	-0.088905	0.223920
SB	-0.029317	-0.063666	0.243020	0.158029	-0.084525	-0.202917	-0.005551	0.038572	0.094051
SC	0.492983	0.747424	0.021159	0.948725	0.601772	0.264660	0.569634	0.686814	0.628305
SE	0.459438	0.280422	0.112558	0.465514	0.297187	0.316422	0.207647	0.241840	0.564193
SM	0.599046	0.821710	0.268049	0.813215	0.764168	0.366704	0.810478	0.782264	0.566523
TH	0.351795	0.730670	0.408633	0.833334	0.580139	0.112655	0.858192	0.862785	0.491938
TI	0.638631	0.654681	0.034669	0.859145	0.624921	0.385325	0.466711	0.442512	0.676501
V	0.901075	0.175519	0.179965	0.354480	0.061623	0.160573	0.001339	-0.025190	0.676772

	CR	CS	CU	FE	HF	K	LA	LU	MN
W	0.601044	0.246379	0.059060	0.075162	0.739515	0.394727	0.295051	-0.160610	0.425098
ZN	0.448721	0.272166	0.377942	0.470834	0.207262	0.267057	0.133723	0.027778	0.820909
CDK	0.628032	0.665184	0.112431	0.684018	0.670426	0.490186	0.525344	0.435760	0.716763
PBK	0.094642	0.413563	0.097221	0.638707	0.278486	-0.165281	0.460836	0.532964	0.269549
SK	0.643265	0.408925	0.085096	0.349852	0.437735	0.338991	0.118711	-0.012673	0.796679
SIK	0.545490	0.777102	0.119867	0.953515	0.674462	0.307281	0.682476	0.750363	0.650477
CLI	-0.107139	-0.241609	-0.193896	-0.189434	-0.135400	-0.094694	-0.324783	-0.256166	-0.006423
NO3I	0.579355	0.411402	0.273641	0.411297	0.410130	0.171852	0.322831	0.181746	0.751781
SO4I	0.630042	0.380460	0.153952	0.318733	0.379318	0.360790	0.106916	-0.041318	0.791433
TPH	0.483865	0.688646	0.150914	0.853519	0.592326	0.229818	0.670236	0.677820	0.592221

	NA	NI	SB	SC	SE	SM	TH	TI	V
NA	1.000000								
NI	-0.019314	1.000000							
SB	-0.150248	-0.142973	1.000000						
SC	-0.372353	-0.001807	0.105630	1.000000					
SE	-0.248283	0.060930	0.574572	0.380949	1.000000				
SM	-0.357014	0.251349	0.250407	0.823825	0.417245	1.000000			
TH	-0.470948	-0.036307	0.186349	0.768608	0.376176	0.843595	1.000000		
TI	-0.380614	0.163256	0.191656	0.911163	0.363445	0.771483	0.567917	1.000000	
V	-0.261674	-0.037866	-0.065182	0.194333	0.316392	-0.032396	0.090978	0.230203	1.000000
W	-0.078376	0.653117	-0.072013	0.036591	0.291407	0.290209	0.007265	0.212639	0.039251
ZN	-0.303962	-0.107434	0.163268	0.231414	0.426454	0.165014	0.190516	0.293258	0.747270
CDK	-0.234246	0.292244	-0.024865	0.583824	0.360045	0.591826	0.551999	0.569112	0.445594
PBK	-0.472635	-0.243534	0.059583	0.657454	-0.026003	0.542290	0.636588	0.523705	0.017713
SK	-0.069352	0.336265	-0.052637	0.172163	0.324150	0.192426	0.095682	0.244001	0.670058
SIK	-0.400534	0.053906	0.143348	0.982732	0.430505	0.894506	0.833997	0.894067	0.157789
CLI	0.812636	-0.045744	0.225028	-0.212049	0.136597	-0.151139	-0.297215	-0.141748	-0.016585
NO3I	-0.118549	0.187512	0.208446	0.205250	0.601062	0.316208	0.324273	0.200823	0.606700
SO4I	-0.127618	0.267690	-0.032829	0.122493	0.366946	0.148192	0.068515	0.202931	0.698048
TPH	-0.527784	0.010114	0.128749	0.848720	0.364065	0.824878	0.792905	0.794314	0.176981

	W	ZN	CDK	PBK	SK	SIK	CLI	NO3I	SO4I
W	1.000000								
ZN	0.149166	1.000000							
CDK	0.329183	0.450935	1.000000						
PBK	-0.256658	0.084990	0.172546	1.000000					
SK	0.486762	0.831877	0.552420	-0.073399	1.000000				
SIK	0.106610	0.239726	0.595887	0.650220	0.181531	1.000000			
CLI	0.058020	0.143528	-0.050959	-0.422971	0.248235	-0.208392	1.000000		
NO3I	0.411627	0.784217	0.457024	0.007881	0.839530	0.270571	0.296217	1.000000	
SO4I	0.473190	0.869555	0.518659	-0.124386	0.985847	0.133701	0.215425	0.852611	1.000000
TPH	0.074967	0.278589	0.499526	0.826662	0.183572	0.880147	-0.319072	0.295827	0.145605

	TPH
TPH	1.000000

Table VII-1-28 Factor loading by method II (4th survey)

Principal component	1	2	3	4	5	6	7
AG	0.108741	-0.177177	-0.146855	0.334257	-0.218571	0.322648	0.203488
AL	0.859839	-0.413058	-0.021238	0.185622	-0.135381	-0.081635	-0.082518
AS	0.648355	0.015890	0.515647	-0.221426	-0.112585	0.092505	-0.338862
BA	0.554096	0.459094	-0.594251	-0.068113	-0.035582	-0.157449	-0.084901
BR	0.458743	-0.648849	-0.063743	-0.125652	-0.122066	-0.355013	0.347555
CA	0.578945	0.716289	-0.226696	-0.000266	0.048201	-0.086759	0.236963
CE	0.917245	-0.120663	-0.192622	0.220323	0.143832	0.104778	0.029046
CL	-0.504227	0.450045	0.152522	0.777417	0.028795	0.035648	0.013249
CO	0.425055	0.626280	-0.623643	-0.042712	0.083170	-0.101346	0.095845
CR	0.807905	0.493180	-0.160195	-0.162105	-0.017301	-0.071643	-0.062024
CS	0.850483	-0.076651	-0.084364	0.034203	-0.135327	0.242143	-0.031874
CU	0.266497	-0.066298	0.258757	-0.295359	0.668446	0.331828	0.054168
FE	0.908112	-0.263817	0.194069	0.123079	-0.081927	-0.066554	-0.022313
HF	0.834064	0.252405	-0.415778	0.018530	0.026611	0.052585	0.107625
K	0.453905	0.324907	-0.095341	-0.110690	-0.245857	0.192249	-0.582643
LA	0.761181	-0.208126	-0.218689	-0.039473	0.318064	0.417791	0.130285
LU	0.647176	-0.498034	-0.029589	0.204689	0.046492	0.414495	-0.063467
MN	0.848536	0.319696	0.362319	-0.056827	-0.075903	-0.074145	0.019018
NA	-0.513878	0.299592	-0.096909	0.707062	-0.246151	0.120315	0.063458
NI	0.316772	0.617509	-0.629266	-0.160160	0.024444	-0.047600	-0.005898
SB	0.104280	-0.088833	0.236216	0.318922	0.671915	-0.468473	-0.141520
SC	0.845548	-0.369605	0.007421	0.198261	-0.217673	-0.142536	-0.097570
SE	0.511418	0.197912	0.305693	0.223736	0.348735	-0.272757	-0.405981
SM	0.886842	-0.215285	-0.211623	0.233180	0.161521	0.047631	-0.028072
TH	0.791661	-0.427558	0.015056	0.118130	0.247300	0.213497	0.068635
TI	0.824798	-0.166998	-0.046868	0.124091	-0.198942	-0.333107	-0.166669
V	0.348825	0.309906	0.691931	-0.258349	-0.238386	0.014496	0.013100
W	0.412872	0.727883	-0.456591	-0.118873	0.152669	-0.091408	0.026345
ZN	0.472618	0.370634	0.736532	-0.122776	0.008483	-0.039259	0.130587
CDK	0.752392	0.205928	0.067839	0.082544	-0.181723	0.201356	-0.087299
PBK	0.513121	-0.667201	0.032425	-0.076010	-0.090293	-0.242240	0.391732
SK	0.502352	0.679425	0.395020	-0.040797	-0.163142	0.017019	0.260205
SIK	0.893725	-0.343197	-0.032986	0.206993	-0.098123	-0.070905	-0.083393
CLI	-0.230810	0.457109	0.206136	0.794590	0.022060	-0.038952	0.080580
NO3I	0.547487	0.515348	0.481653	0.120235	0.195296	0.085391	0.240514
SO4I	0.473232	0.685785	0.462888	-0.109576	-0.106565	0.040566	0.184002
TPM	0.842277	-0.399550	0.007107	0.024066	-0.055460	-0.171044	0.139700
VP	15.158072	6.688804	4.128308	2.671354	1.787252	1.514170	1.341193
PERCENT	41.0%	18.1%	11.2%	7.2%	4.8%	4.1%	3.6%
CUM PCT	41.0%	59.0%	70.2%	77.4%	82.3%	86.3%	90.0%

Table VII-1-29 Score of principal component by method II (4th survey)

Principal component	1	2	3	4	5	6	7
MP01	-0.8497	-0.1178	-0.1744	-0.1547	-0.2526	-0.4466	0.4196
MP02	-0.9298	0.1183	-0.3498	0.2559	-0.6544	0.3341	0.1145
MP03	-0.2286	-0.4406	-0.4771	1.1555	-0.7980	1.4155	0.5189
MP04	-0.1265	0.5719	1.2033	-1.0954	-0.6123	-0.1311	-0.2164
MP05	0.5946	1.9566	2.6132	-0.0470	-0.8628	0.2426	1.4331
MP06	-0.2385	0.6650	0.7188	-0.2576	0.4427	-0.2712	-1.2912
MP07	2.8408	-1.6762	0.0299	0.8616	-1.9352	-1.0639	-0.3545
MP08	0.7556	0.3947	0.7920	-1.0340	0.9998	0.2750	-0.7608
MP09	0.7640	-0.6203	0.1401	-0.8596	0.2296	1.3406	-1.6636
MP10	-0.8155	-0.5954	-0.6702	-2.0949	0.0800	-0.0916	-0.4170
MP11	1.1294	-1.1464	0.1382	0.1421	2.2041	1.9214	1.1483
MP12	-0.4359	0.2692	-0.2344	0.7910	-0.4514	0.4975	-0.9141
MP13	-0.4876	-0.9158	-0.3500	-1.0285	-0.4256	-1.5417	1.1720
MP14	-0.5611	-0.2217	-0.3441	0.6298	-0.1010	0.8151	0.8566
MP15	-1.1645	0.3850	-0.1491	1.8967	-0.1984	0.5587	-0.1429
MP16	-0.0532	-0.1511	0.6647	1.7074	2.3486	-2.2650	-0.7547
MP17	-0.3360	-0.9245	-0.2999	-0.7825	0.5062	-0.4691	1.6992
MP18	-0.7004	-0.0326	-0.5437	-0.1431	-0.6920	0.1267	-1.7314
MP19	-0.7425	-0.1901	0.0428	0.2739	-0.2245	-0.8313	0.4237
MP20	1.5853	2.6717	-2.7501	-0.2166	0.3973	-0.4154	0.4606
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

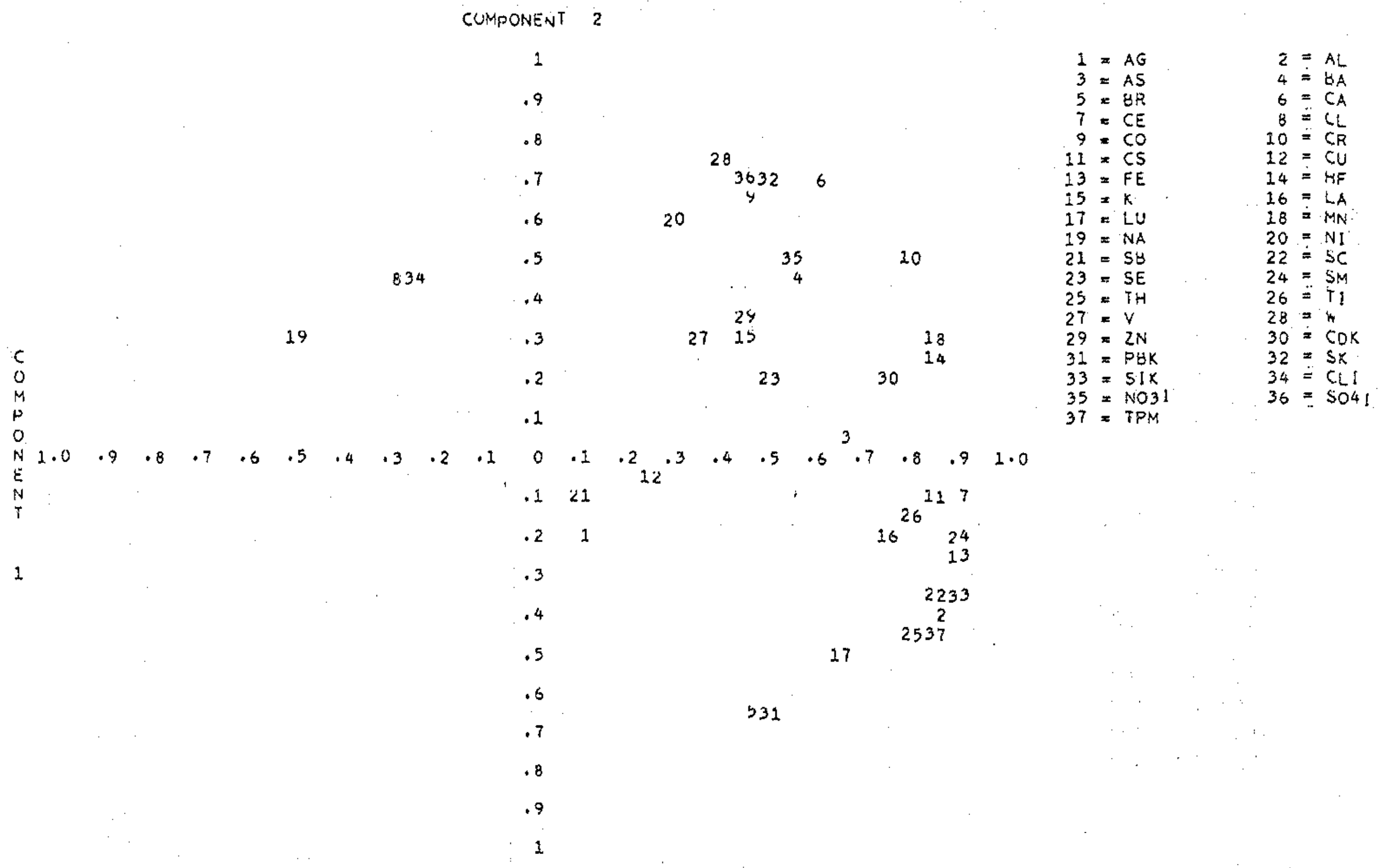
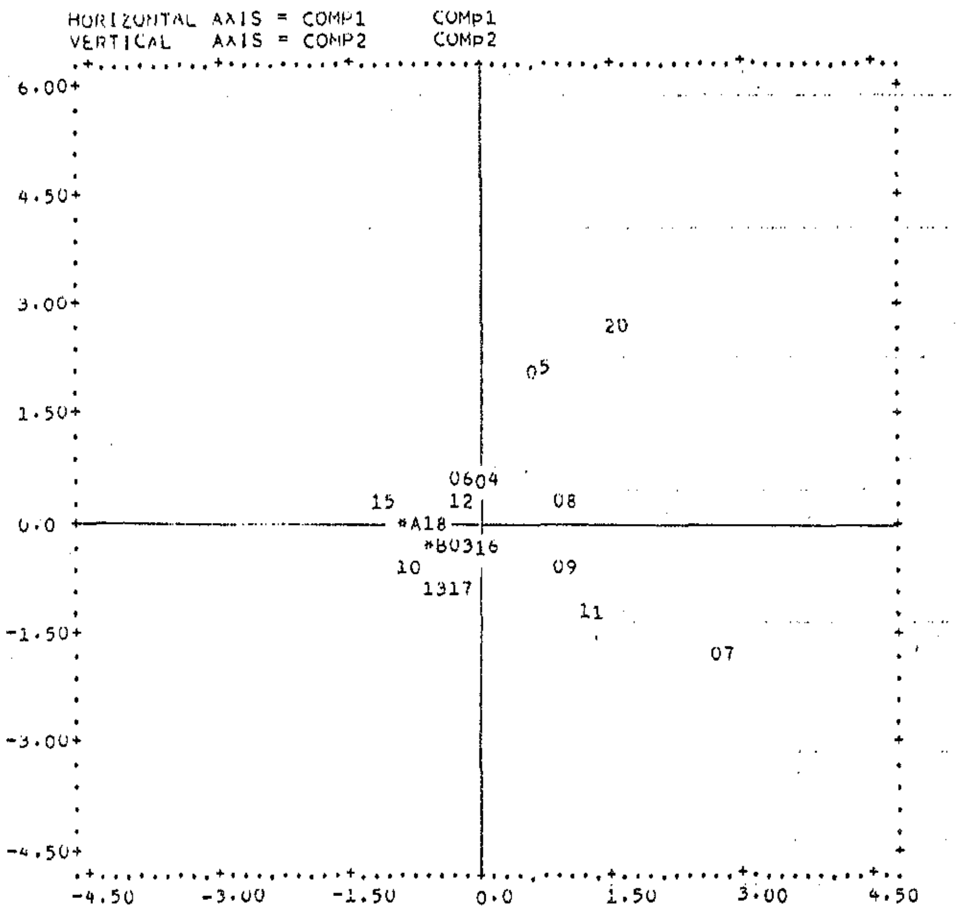


Fig. VII-1-15 Distribution of factor loading by method II (4th survey)



03 = MP03
04 = MP04
05 = MP05
06 = MP06
07 = MP07
08 = MP08
09 = MP09
10 = MP10
11 = MP11
12 = MP12
13 = MP13

15 = MP15
16 = MP16
17 = MP17
18 = MP18

20 = MP20

*A = MP01, MP02
*B = MP14, MP19

Fig. VII-1-16 Distribution of scores by method II (4th survey)

From these results, we estimated the contributions of emission sources on the chemical components concentrations at each monitoring station.

(1) 1st short term field survey

Table VII-1-30 shows the results of principal component analysis. In the 1st principal component, the loading factors of Al, Ca, Ce, Fe, Mn, Sc, Sm, Th, Ti, Si and TPM are high. And as the scores at MP4, 5, 7 and 17 are high, the contributions of soil, steel mills and cement are high in these stations. In the 2nd principal component, the loading factors of Cl and V have large positive value and those of Pb and Br have large negative value. Thus at MP5, the contribution of petroleum combustion is greater than that of exhaust gas from car. On the other hand, at MP7, 11 and 17, that of exhaust gas from car is greater. In the 3rd and 4th principal components, loading factors are small, and so clear tendency cannot be seen.

Table VII-1-30 Results of method II (1st survey)

Principal component	1	2	3	4
Eigen value	15.93	5.11	3.20	2.39
Contribution rate	43.1%	13.8%	8.6%	6.5%
Factor loading	⊕ Al, Ca, Ce, Fe, Mn, Sc, Sm, Th, Ti, Si, TPM ⊖ Na	⊕ Cl, Ni, V, Cl^-, NO_3^-, SO_4^{2-} ⊖ Pb, Br	⊕ Sb, Zn ⊖ Ba	⊕ W ⊖ K
Score	⊕ MP4, MP5, MP7, MP17 ⊖ MP2, MP18,	⊕ MP5 ⊖ MP7, MP11, MP17	⊕ MP12, MP14, MP17 ⊖ MP4, MP20	⊕ MP1, MP14, MP15, MP20 ⊖ MP5, MP17
Explanation of the component	⊕ Side strongly affected by soil and steel mills	⊕ Side strongly affected by petroleum combustion and secondary particle		

(2) 2nd short term field survey

Table VII-1-31 shows the results of principal component analysis in 2nd survey. In the 1st principal components, the loading factor of Ca, Sc and Si show high value. At MP7 and 19 which show high scores, the contributions of soil are high. And as the loading factor of As also show high value, the contributions of anthropogenic sources are high. As the loading factors and scores are small in the 2nd to 5th components, we can't identify the emission source of chemical components in the stations.

Table VII-1-31 Results of method II (2nd survey)

Principal component	1	2	3	4	5
Eigen value	16.02	5.49	3.09	2.81	2.30
Contribution rate	43.3%	14.8%	8.4%	7.6%	6.2%
Factor loading	⊕ As, Ca, Ce, Cr, Fe, La, Sc, Sm, S, Si, SO_4^{2-} ⊖ Na	⊕ Ni, Zn ⊖ Al, Cs	⊕ Na ⊖ Pb	⊕ Br, Pb ⊖ NO_3^-	⊕ Na, Cl, K ⊖ Cu
Score	⊕ MP7, MP19 ⊖ MP3, MP18	⊕ MP1, MP15, MP19 ⊖ MP7, MP8, MP11	⊕ MP8, MP9 ⊖ MP7, MP12, MP13, MP16	⊕ MP7, MP19 ⊖ MP12, MP15, MP16	⊕ MP4, MP5, MP9 ⊖ MP6, MP10, MP17
Explanation of the component	⊕ Side strongly affected by soil and steel mills				

(3) 3rd short term field survey

Table VII-1-32 shows the results of principal components analysis in 3rd survey. In the 1st principal component, the loading factors of TPM and Fe show high value, and TPM concentrations at MP5, 6, 7 and 9 are high. From this, the contributions of steel mills etc. may be high in these stations. And at MP2, 10 and 15, the reverse tendency can be seen. In the 2nd principal component, the loading factors of Na and Cl (originated in sea-salt particle) show positive large values and that of Al (originated in soil) shows a negative large value. From this facts the contribution of sea-salt particle is greater than that of soil and exhaust gas from car at MP4 and 5.

On the other hand, the contributions of sea-salt particle at MP7 and 9 may be greater than those of soil and exhaust gas. In the 3rd to 5th principal components, the loading factors and scores are small. So we can't identify the emission sources.

Table VII-1-32 Results of method II (3rd survey)

Principal component	1	2	3	4	5
Eigen value	13.39	7.10	3.04	2.67	2.20
Contribution rate	36.2%	19.2%	8.2%	7.2%	5.9%
Factor loading	⊕ Co, Fe, Sm, S, SO_4^{2-}, TPM	⊕ Cl, Na ⊖ Al, Br, Th	⊕ Sb ⊖ Na, Cl, Cl^-	⊕ La ⊖ V, Br, Pb	⊕ Ag, V ⊖ Ni
Score	⊕ MP5, MP6, MP7, MP9 ⊖ MP2, MP10, MP15	⊕ MP4, MP5 ⊖ MP7, MP9	⊕ MP5, MP13, MP16 ⊖ MP1, MP7, MP12, MP15	⊕ MP6, MP20 ⊖ MP4, MP7, MP13	⊕ MP1, MP4, MP14, MP16 ⊖ MP5, MP12
Explanation of the component	⊕ Side strongly affected by soil and steel mills	⊕ Side strongly affected by sea-salt particle			

(4) 4th short term field survey

Table VII-1-33 shows the results of principal component analysis in 4th survey. In the 1st principal component, the loading factors of TPM, Al, Sc and Si are large, and TPM concentrations at MP7, 11 and 20 are high. Thus the contributions of soil at MP7, 11 and 20 may be high. And MP15, the contribution of sea-salt particle is higher than that of soil. In the 2nd principal component, the loading factor of Ca, Co and Ni show positive large values and those of Pb and Br show negative large value. And at MP7 and 11, the scores show negative value, so the contributions of winded up dust from roads are greater than those of exhaust gas from car. In the 3rd principal component, the loading factor of V is relatively high and the scores at MP4 and 5 show positive values. Thus at these stations, the contributions of petroleum combustion may be high.

Table VII-1-33 Results of method II (4th survey)

Principal component	1	2	3	4
Eigen value	15.16	6.69	4.13	2.67
Contribution rate	41.0%	18.1%	11.2%	7.2%
Factor loading	⊕ Al, Ce, Cr, Cs, Fe, Hf, Mn, Sc, Sm, Ti, Si, TPM ⊖ Cl, Na	⊕ Ca, Co, Ni, W, S, SO_4^{2-} ⊖ Br, Pb	⊕ V, Zn ⊖ Co, Ni	⊕ Cl, Na, Cl^-
Score	⊕ MP7, MP11, MP20 ⊖ MP15	⊕ MP5, MP20 ⊖ MP7, MP11	⊕ MP4, MP5 ⊖ MP20	⊕ MP3, MP15, MP16 ⊖ MP4, MP8, MP10, MP13
Explanation of the component	⊕ Side strongly affected by soil and TPM	⊖ Side not so much affected by car	⊕ Side strongly affected by petroleum combustion	⊕ Side strongly affected by sea-salt particle

CHAPTER 2 ESTIMATION OF CONTRIBUTION RATES OF EMISSION SOURCES ON PARTICULATE MATTERS BY CMB METHOD

In this chapter, using chemical components concentrations measured in the short term field surveys, we estimated how each emission source contributes to particulate concentrations of each station. Here, we used CMB method in this estimation. many estimations by CMB method have been proposed. So we examined several methods and performed the estimation by the best method.

VII-2-1 Outline of CMB (Chemical Mass Balance) Method

CMB method is the technique that estimates the contributions of emission sources on the chemical components concentrations at the receptor sites using the data measured at emission sources and receptor sites. Recently, this method has been paid attention with the progression of analysis technique. But in this method, the contributions of same kinds of emission sources can't be distinguished and the estimations are confined to monitoring stations and the estimations in figure can't be done.

VII-2-1-1 Basic equation

The basic equation of CMB method is defined as follow.

$$C_i = \sum_{j=1}^{m} F_{ij} \cdot \alpha_{ij} \cdot S_j \qquad \text{Equation VII-2-1}$$

where;

- C_i: The concentration of component (i) in suspended particulate matter at one receptor site
- F_{ij}: The proportion of component (i) concentration emitted from the source (j)
- S_j: The concentration of dust emitted from emission source (j)
- m: Number of emission sources under consideration
- α_{ij}: Conversion rate of component (i) from the source (j)

In generally, the value of α_{ij} is assumed to be 1, then Equation VII-2-2 is written as follow:

$$C_i = \sum_{j=1}^{m} F_{ij} \cdot S_j \qquad \text{Equation VII-2-2}$$

CMB method is the technique by which S_j is estimated using the known values - F_{ij} and C_i.

When we measure the component concentrations - C_i (i = 1, 2, ... n), following simultaneous equation can be derived from Equation VII-2-2.

$$\left.\begin{array}{l} C_1 = F_{11} \cdot S_1 + F_{12} \cdot S_2 + \dots + F_{1m} \cdot Sm \\ C_2 = F_{21} \cdot S_1 + F_{22} \cdot S_2 + \dots + F_{2m} \cdot Sm \\ \\ C_n = F_{n1} \cdot S_1 + F_{n2} \cdot S_2 + \dots + F_{nm} \cdot Sm \end{array}\right\} \qquad \text{Equation VII-2-3}$$

where:

m: Number of emission sources

n: Number of receptor sites

Now we express Equation VII-2-3 in matrix, then

$$\mathbf{C} = \mathbf{F} \cdot \mathbf{S} \qquad \text{Equation VII-2-4}$$

is obtained.

$$\text{where} \quad n \geqq m \qquad \text{Equation VII-2-5}$$

The methods of solution on Equation VII-2-2 have been variously proposed. Some of them are as follows:

(1) Simultaneous equation method
(2) Least-squares method
(3) Weighted least-squares method
(4) Effective variance method
(5) Ridge regression method

VII-2-1-2 CMB method using simultaneous equation

IF number of C_i and F_{ij} equal to that of emission sources in Equation VII-2-2, we can get the unique solution. So in this method we select marker elements whose number equals to number of emission sources and obtain the simultaneous equation. (Equation VII-2-2) Solving this equation, we estimate the contributions on the concentrations at receptor sites from emission sources.

When n equals to m, matrix $\mathbf{F}$ becomes square matrix. Multiplying both sides of Equation VII-2-4 by $\mathbf{F}^{-1}$ (inverse matrix), we can get $\mathbf{S}$.

$$\mathbf{S} = \mathbf{F}^{-1} \cdot \mathbf{C} \qquad \text{Equation VII-2-6}$$

VII-2-1-3 CMB method using least-squares method

If n (number of receptors) is greater than m (number of emission sources), Equation VII-2-2 generally has solutions $\mathbf{S}$. In this method, we select $\hat{\mathbf{S}}$ (the presumed value of $\mathbf{S}$) which makes the residual of $\mathbf{C}$ and $\hat{\mathbf{C}}$($\hat{\mathbf{C}} = \mathbf{F} \cdot \hat{\mathbf{S}}$) minimum. When we define the residual vector $\mathbf{E} = \hat{\mathbf{C}} - \mathbf{C}$, sum of squares about residual ε^2 is expressed by following equation.

$$\begin{aligned} \varepsilon^2 &= \mathbf{E}^t \cdot \mathbf{E} = (\hat{\mathbf{C}} - \mathbf{C})^t \ (\hat{\mathbf{C}} - \mathbf{C}) \\ &= (\mathbf{F} \cdot \hat{\mathbf{S}} - \mathbf{C})^t \cdot (\mathbf{F} \cdot \hat{\mathbf{S}} - \mathbf{C}) \end{aligned} \qquad \text{Equation VII-2-7}$$

where
$(\hat{\mathbf{C}} - \mathbf{C})^t$ is the transposed matrix of $(\hat{\mathbf{C}} - \mathbf{C})$

The condition which makes ε^2 minimum is as follows:

$$\frac{\partial \epsilon^2}{\partial \mathbf{S}} = 0$$

$$\frac{\partial \epsilon^2}{\partial \mathbf{S}} = 2\mathbf{F}^t \cdot (\mathbf{F} \cdot \hat{\mathbf{S}} - \mathbf{C}) = 0 \qquad \text{Equation VII-2-8}$$

We transform Equation VII-2-8, then following equation is obtained.

$$\hat{\mathbf{S}} = (\mathbf{F}^t \cdot \mathbf{F})^{-1} \cdot \mathbf{F}^t \cdot \mathbf{C} \qquad \text{Equation VII-2-9}$$

VII-2-1-4 CMB method using weighted least-squares method

Generally in least-squares method, the whole data are treated equally. But it is usually that accuracies of the data are different each other. So we weight the more accurate data more weight and weight the less accurate data less weight.

Such technique is called the weighted least-squares method. In this case, we adopted the inverse of standard error (the standard deviation of accidental error) as the weight.

When we perform measurements of concentration Ci in k times, the value of Ci can be obtained as following equation:

$$C_i = \frac{1}{k} \sum_{\alpha=1}^{k} C_{i\alpha} \qquad \text{Equation VII-2-10}$$

σ_i (the standard deviation of Ci) and Si (standard error) are defined as follows:

$$\sigma_i = \sqrt{\sum_{\alpha=1}^{k} (C_{i\alpha} - C_i)^2 / (k-1)} \qquad \text{Equation VII-2-11}$$

$$S_i = \frac{\sigma_i}{\sqrt{k}} = \sqrt{\sum_{\alpha=1}^{k} (C_{i\alpha} - C_i)^2 / \; k(k-1)} \qquad \text{Equation VII-2-12}$$

Thus, the basic Equation VII-2-2 is modified.

$$\frac{C_i}{S_i} = \frac{1}{S_i} \sum_{j=1}^{m} F_{ij} \cdot S_j = \sum_{j=1}^{m} \frac{F_{ij}}{S_i} \cdot S_j \qquad \text{Equation VII-2-13}$$

Here we define the weight matrix **W** as following:

$$\mathbf{W} = \left\{ W_{ij}^2 \right\}$$

$$W_{ij} = \begin{Bmatrix} \frac{1}{Si} & (i = j) \\ 0 & (i = j) \end{Bmatrix} \qquad \text{Equation VII-2-14}$$

Using Equation VII-2-14, Equation VII-2-13 is expressed by matrix.

$$\mathbf{W}^{1/2} \cdot \mathbf{C} = \mathbf{W}^{1/2} \cdot \mathbf{F} \cdot \mathbf{S} \qquad \text{Equation VII-2-15}$$

Then we can obtain the estimated value $\hat{\mathbf{S}}$

$$\hat{\mathbf{S}} = \left\{ (\mathbf{W}^{1/2} \cdot \mathbf{F})^t \cdot (\mathbf{W}^{1/2} \cdot \mathbf{F}) \right\}^{-1} \cdot (\mathbf{W}^{1/2} \cdot \mathbf{F})^t \cdot \mathbf{W}^{1/2} \cdot \mathbf{C}$$

$$= (\mathbf{F}^t \cdot \mathbf{W} \cdot \mathbf{F})^{-1} \cdot \mathbf{F}^t \cdot \mathbf{W} \cdot \mathbf{C} \qquad \text{Equation VII-2-16}$$

VII-2-2 Examination of CMB Method

Table VII-2-1 shows the average concentrations in twenty stations and four seasons. In using these data, we calculated the contribution rates of each emission source on the concentrations at receptor sites by three methods (simultaneous equation method, least-squares method and weighted least-squares method). And we examined the results by these methods.

Table VII-2-1 Average concentrations of chemical components

Analysis	Component	Unit	Average
Instrument neutron activation analysis	Ag	ng/m^3	0.3900
	Al		2142.2998
	As		6.3213
	Ba		30.3187
	Br		98.6375
	Ca		1981.6250
	Cd		18.7750
	Ce		1.8435
	Cl		3420.3750
	Co		0.5661
	Cr		6.2368
	Cs		0.1140
	Cu		67.4125
	Fe		1042.8125
	Hf		0.1270
	K		725.0000
	La		0.8014
	Lu		0.0127
	Mn		22.3243
	Na		1494.6250
	Ni		11.4512
	Sb		2.8761
	Sc		0.2622
	Se		1.1089
	Sm		0.1138
	Th		0.4917
	Ti		110.7125
	V		19.2483
	W		1.7425
	Zn		91.9187
X-ray fluorescence analysis	Cd	ng/m^3	3.5200
	Pb		234.4500
	S		1447.7500
	Si		9950.6250
Ion chromatography	Cl^-	ng/m^3	2326.6250
	NO_3^-		1075.5125
	SO_4^{--}		3062.5000
TPM	TPM	$\mu g/m^3$	66.6046

VII-2-2-1 Species of emission sources and marker elements

We considered the emission sources of particulate matters as soil, sea-salt particle, gasoline automobile, petroleum combustion, steel mills, refuse combustion and cement. And marker elements of these emission sources are shown in Table VII-2-2.

In simultaneous equation method, we adopted seven elements as shown in Table VII-2-2. In other two methods, other several elements (Cr, Sc, Ti, Fe and Br) were added as marker elements. When data was under measurable limit, we used 50% of the value.

Table VII-2-2 Emission source and marker element

Emission source	Marker element
Soil	Al
Sea-salt particle	Na
Gasoline automobile	Pb
Petroleum combustion	V
Steel mill	Mn
Refuse combustion	Zn
Cement	Ca

VII-2-2-2 Emission source matrix

We set elements concentrations in particulate matters in each emission sources as shown in Table VII-2-3. These values were decided as follows:

Soil : We sampled three kinds of surface soil in Singapore and measured chemical components. Average of these data were adopted, and the data was adopted half of the value in the case of the value under measurable limit.

Sea-salt particle : Used the data by Mizobata(*)

Gasoline automobile : Used the data by Kowalczyk(**) and Mizobata

Petroleum combustion : Used average of data measured in eight facilities of Japan and U.S.A.

Steel mill	:	Used the data by Mizobata(*)
Refuse combustion	:	Used the average data of Mizobata(*) and Kowalczyk(**)
Cement	:	Used the data by Friedlander(***)

(*) Mizohata, Mamuro (1980), Journal of Japan Society of Air Pollution, Vol. 15, No. 5, P198-206

(**) Kowalczyk (1978), Atmospheric Environment, Vol. 12, P1143-1153

(***) Friedlander (1973), Environmental Science and Technology, Vol. 7, No. 3, P235-240

Table VII-2-3 The matrix about the component concentrations in emission sources

(ppm)

	Soil	Sea-salt particle	Gasoline automovile	Petroleum combustion	Steel mill	Refuse combustion	Cement
Al	120000	0.3	1500	2100	10000	7638	24000
Na	1700	304200	270	45000	14000	91382	4000
Pb	69	0.087	149000	510	14000	39651	0
V	77	0.058	2.4	10000	130	25.5	0
Mn	39	0.058	36	240	22000	446.5	0
Zn	29	0.029	2235	1800	52000	59150	0
Ca	1200	12000	7450	8200	45000	11961	460000
Cr	43	0.001	16	890	3200	614.215	0
Sc	14	0.001	0.23	0.09	1.3	0.73765	0
Ti	4100	0.029	0	740	1000	1373	1440
Fe	33000	0.29	7450	28000	157000	5592	10900
Br	13	1900	56620	8.5	140	1015	0
Ag	1.8	0.087	0	0	54	150	0
As	66	0.029	0	23	100	167.3	0
Ba	320	0.86	1937	920	0	463	0
Ce	75	0.012	0	0	69	91	0
Cl	1100	550500	14900	920	34000	212070	0
Co	0.93	0.014	1.8	31	44	13	0
Cs	3.1	0.029	0	0	0	12	0
Cu	200	0.017	190	3600	3700	2400	0
K	17000	11000	1200	850	13000	200000	5300
La	43	0.009	0	0	9.8	5.28	0
Lu	0.44	0	0	0	0	0	0
Ni	38	0.014	39	7700	2900	119.99	0
Sb	6.1	0.014	2.1	6.9	90	1113	0
Se	2.6	0.12	0	48	51	28.613	0
Sm	6.5	0	0	7.6	0.21	0.49	0
Th	23	0.020	0	0	0	1.3845	0
W	5.6	0.003	0	0	47	0	0
Cd	0.9	0.002	0	240	250	827	0
S	210	26000	0	96000	48000	130000	0

VII-2-2-3 The weights used in weighted least-squares method

When we estimate the contributions rates of emission sources by weighted least-squares method, we must know the error variance of each chemical component concentration. In the recent studies, someone used unique error variances (Watson (1984)*), but Scheff (1984)** decide them using the results of repeated analysis on samples. And Kowalczyk (1982)*** considered the variance of analysis error by instrument neutron activation analysis and the value of filter blank. In this investigation, Industrial Pollution Control Association of Japan determined the measurement errors of each component as shown in Table VII-2-4. Then we calculated the weights with the equation $S_i = C_i \cdot g_i$. Here, C_i is the concentration of component i and g_i is the measurement error of component i.

Table VII-2-4 Measurement error of the components

Element	g_i (%)
Al	5.8
Na	10.1
Pb	11.0
V	5.8
Mn	10.1
Zn	7.4
Ca	16.6
Cr	10.1
Sc	9.6
Ti	39.4
Fe	11.4
Br	27.0

Note:

g_i: measurement error

* J. G. Watson et al, (1984); Atmos. Env. 18, 7, 1347-1355

** P. A. Scheff et al, (1984); Environ. Sci Technol. 18, 923-931

*** G. S. Kowalczyk et al, (1982); Environ. Sci. Technol. 16, 79-90

VII-2-3 Results of Examinations

We estimated the contributions of emission sources by three methods. The results are shown in Table VII-2-5 to VII-2-7. From the results, there were not clear difference among three methods.

The emission source which shows the highest contribution is soil and its contribution rate is about 25%. And then sea-salt particles' contribution and cement's contribution are high in order. The contributions of natural emission sources are higher than those of anthropogenic emission sources. The sum of contribution rates of estimated emission sources is 45%. The remaining contribution (55%) is considered from diesel car and secondary particles and etc. But these emission sources cannot be distinguished.

Table VII-2-5 Results of analysis using simultaneous equations

Component		Calculated ($\mu g/m^3$)	Observed ($\mu g/m^3$)	Contribution (%)
Soil		16.889		25.4
Sea salt		4.276		6.4
Gasoline automobile		1.309		2.0
Fuel oil combustion		1.781		2.7
Iron and steel Ind.		0.950		1.4
Refuse combustion		0.607		0.9
Cement		3.991		6.0
Total		29.802	66.605	44.7
Element		Calculated (ng/m^3)	Observed (ng/m^3)	Calculated / Observed
Marker elements	Al	2142.299	2142.300	1.00
	Na	1494.624	1494.625	1.00
	Pb	234.450	234.450	1.00
	V	19.248	19.248	1.00
	Mn	22.324	22.324	1.00
	Zn	91.919	91.919	1.00
	Ca	1981.625	1981.625	1.00
Remaining elements	Cr	5.746	6.237	0.92
	Sc	0.239	0.262	0.91
	Ti	78.092	110.712	0.71
	Fe	813.041	1042.812	0.78
	Br	83.215	98.637	0.84
	Ag	0.173	0.390	0.44 --
	As	1.352	6.321	0.21 ---
	Ba	9.862	30.319	0.33 --
	Ce	1.388	1.844	0.75
	Cl	2554.567	3420.375	0.75
	Co	0.123	0.566	0.22 ---
	Cs	0.060	0.114	0.52 -
	Cu	15.009	67.413	0.22 ---
	K	492.055	725.000	0.68 -
	La	0.739	0.801	0.92
	Lu	0.007	0.013	0.59 -
	Ni	17.232	11.451	1.50 +
	Sb	0.879	2.876	0.31 --
	Se	0.196	1.109	0.18 ---
	Sm	0.124	0.114	1.09
	Th	0.389	0.492	0.79
	W	0.139	1.743	0.08 ---
	Cd	1.182	3.520	0.34 --
	S	410.126	1447.750	0.28 --
Total		10472.383	12967.324	0.81

(Calculated/observed)
≧4.0 → +++
≧2.0 → ++
≧1.5 → +
≦0.7 → -
≦0.5 → --
≦0.25 → ---

Table VII-2-6 Results of analysis using least-squares

Component		Calculated (μg/m³)	Observed (μg/m³)	Contribution (%)
Soil		16.877		25.3
Sea salt		4.402		6.6
Gasoline automobile		1.511		2.3
Fuel oil combustion		2.930		4.4
Iron and steel Ind.		2.227		3.3
Refuse combustion		-0.571		-0.9
Cement		3.869		5.8
Total		31.247	66.605	46.9
Element		Calculated (ng/m³)	Observed (ng/m³)	Calculated / Observed
Marker elements	Al	2144.451	2142.300	1.00
	Na	1494.651	1494.625	1.00
	Pb	236.414	234.450	1.01
	V	30.882	19.248	1.60 +
	Mn	50.152	22.324	2.25 ++
	Zn	91.200	91.919	0.99
	Ca	1981.706	1981.625	1.00
	Cr	10.135	6.237	1.63 +
	Sc	0.239	0.262	0.91
	Ti	78.380	110.712	0.71
	Fe	1038.934	1042.812	1.00
	Br	93.920	98.637	0.95
Remaining elements	Ag	0.065	0.390	0.17 ---
	As	1.309	6.321	0.21 ---
	Ba	10.764	30.319	0.36 --
	Ce	1.368	1.844	0.74
	Cl	2421.941	3420.375	0.71
	Co	0.200	0.566	0.35 --
	Cs	0.046	0.114	0.40 --
	Cu	21.083	67.413	0.31 --
	K	274.937	725.000	0.38 --
	La	0.745	0.801	0.93
	Lu	0.007	0.013	0.58 -
	Ni	29.655	11.451	2.59 ++
	Sb	-0.308	2.876	-0.11 ---
	Se	0.282	1.109	0.25 --
	Sm	0.132	0.114	1.16
	Th	0.387	0.492	0.79
	W	0.199	1.743	0.11 ---
	Cd	0.803	3.520	0.23 ---
	S	432.020	1447.750	0.30 --
	Total	10446.656	12967.324	0.81

(Calculated/observed)
≧4.0 → +++
≧2.0 → ++
≧1.5 → +
≦0.7 → -
≦0.5 → --
≦0.25 → ---

Table VII-2-7 Results of analysis using weighted least-squares

Component	Calculated ($\mu g/m^3$)	Observed ($\mu g/m^3$)	Contribution (%)
Soil	17.470		26.2
Sea salt	4.290		6.4
Gasoline automobile	1.349		2.0
Fuel oil combustion	1.787		2.7
Iron and steel Ind.	0.997		1.5
Refuse combustion	0.566		0.8
Cement	4.020		6.0
Total	30.478	66.605	45.8

Element		Calculated (ng/m^3)	Observed (ng/m^3)	Calculated / Observed	
Marker elements	Al	2212.881	2142.300	1.03	
	Na	1497.104	1494.625	1.00	
	Pb	239.543	234.450	1.02	
	V	19.364	19.248	1.01	
	Mn	23.355	22.324	1.05	
	Zn	92.033	91.919	1.00	
	Ca	1997.834	1981.625	1.01	
	Cr	5.901	6.237	0.95	
	Sc	0.247	0.262	0.94	
	Ti	80.509	110.712	0.73	
	Fe	840.083	1042.812	0.81	
	Br	85.503	98.637	0.87	
Remaining elements	Ag	0.170	0.390	0.44	--
	As	1.389	6.321	0.22	---
	Ba	10.114	30.319	0.33	--
	Ce	1.431	1.844	0.78	
	Cl	2556.233	3420.375	0.75	
	Co	0.125	0.566	0.22	---
	Cs	0.061	0.114	0.54	-
	Cu	15.230	67.413	0.23	---
	K	494.682	725.000	0.68	-
	La	0.764	0.801	0.95	
	Lu	0.008	0.013	0.61	-
	Ni	17.437	11.451	1.52	+
	Sb	0.841	2.876	0.29	--
	Se	0.199	1.109	0.18	---
	Sm	0.128	0.114	1.12	
	Th	0.403	0.492	0.82	
	W	0.145	1.743	0.08	---
	Cd	1.162	3.520	0.33	--
	S	408.142	1447.750	0.28	--
Total		10603.016	12967.324	0.82	

(Calculated/observed) ≧4.0 → +++
≧2.0 → ++
≧1.5 → +
≦0.7 → -
≦0.5 → --
≦0.25 → ---

VII-2-4 Estimation of Contribution Rates of Each Emission Sources on the Concentration of Particulate Matters at the Monitoring Stations

Estimation of contribution rates were performed by weighted least-squares method. These results are shown in Table VII-2-8 to VII-2-11. The contribution rates of emission sources are as follows:

(1) Soil

1st survey : 42.8% (MP20) to 12.6% (MP8)
2nd survey : 51.7% (MP15) to 5.4% (MP3)
3rd survey : 44.5% (MP7) to 0% (MP1)
4th survey : 62.6% (MP7) to 5.7% (MP5)

(2) Sea-salt particle

1st survey : 28.1% (MP15) to 0% (MP13)
2nd survey : 10.1% (MP4) to 0.3% (MP11)
3rd survey : 32.6% (MP15) to 2.3% (MP9)
4th survey : 25.7% (MP15) to 1.6% (MP7)

(3) Gasoline automobile

1st survey : 7.0% (MP12) to 0% (MP14)
2nd survey : 6.7% (MP13) to 0.3% (MP8)
3rd survey : 11.4% (MP13) to 0% (MP5)
4th survey : 3.0% (MP13) to 0% (MP6)

(4) Petroleum combustion

1st survey : 11.1% (MP13) to 0.2% (MP15, 18, 19)
2nd survey : 13.1% (MP15) to 1.5% (MP7)
3rd survey : 7.5% (MP4) to 0.1% (MP12)
4th survey : 6.4% (MP4) to 0.1% (MP12)

(5) Steel mill

1st survey : 1.7% (MP14) to 0% (MP10)
2nd survey : 14.2% (MP19) to 0.2% (MP3)
3rd survey : 5.5% (MP4, 5) to 0.1% (MP15)
4th survey : 2.8% (MP5) to 0.1% (MP2, 15)

(6) Refuse combustion

1st survey : 3.1% (MP14) to 0% (MP4)
2nd survey : 7.5% (MP19) to 0% (MP20)
3rd survey : 5.4% (MP5) to 0% (MP1)
4th survey : 3.2% (MP5) to 0% (MP20)

(6) Cement

1st survey : 8.5% (MP4) to 0.6% (MP11)
2nd survey : 35.7% (MP19) to 1.4% (MP5)
3rd survey : 20.0% (MP5) to 0.1% (MP9)
4th survey : 32.8% (MP20) to 0.4% (MP15)

The characteristics of the contribution rates are as follows:

(1) Soil

The contribution rate of soil is highest. The rate varies by station and by seasons. This may be due to its broad spreading in the objective area and the effects of soil are not uniform by station. And the seasonal variations of its rate may be affected by the meteorological conditions.

(2) Sea-salt particle

The contribution rate of sea-salt particle is next to that of soil. It has large seasonal and spatial variations. These variations depend on the distances between monitoring stations and the sea, wind direction and wind velocity.

(3) Other emission sources

The contribution rates of other emission sources (gasoline automobiles, petroleum combustion, steel mill, refuse combustion and cement) vary widely by stations. This may depend on the location of emission source and station.

As shown in above, the contributions of natural emission sources are greater than those of anthropogenic sources.

Table VII-2-8 Percentage contributions using weighted least-squares (1st survey)

(%)

Component	MP 1	MP 2	MP 3	MP 4	MP 5
Soil	42.5	15.1	15.1	34.2	22.3
Sea salt	6.5	11.7	4.9	2.7	6.6
Gasoline automobile	0.5	2.5	2.2	0.1	0.8
Fuel oil combustion	4.2	4.3	8.7	5.3	6.7
Iron and steel Ind.	1.4	0.3	0.7	0.9	0.6
Refuse combustion	0.1	1.7	1.4	-0.2	0.5
Cement	5.3	3.6	4.7	8.5	4.6
Total	60.5	39.2	37.6	51.4	42.1

Component	MP 6	MP 7	MP 8	MP 9	MP10
Soil	17.6	40.9	12.6	15.5	28.7
Sea salt	2.1	1.0	18.6	16.3	13.9
Gasoline automobile	0.7	2.4	3.0	2.6	0.2
Fuel oil combustion	4.2	2.2	1.9	4.0	0.9
Iron and steel Ind.	0.9	0.8	0.2	0.3	-0.2
Refuse combustion	2.1	1.1	0.6	0.6	1.1
Cement	4.0	2.8	3.9	2.7	6.0
Total	31.7	51.2	40.7	42.0	50.5

Component	MP11	MP12	MP13	MP14	MP15
Soil	38.3	15.9	17.6	17.7	22.6
Sea salt	-0.1	4.9	-1.3	3.9	28.1
Gasoline automobile	3.1	7.0	1.4	-0.7	1.4
Fuel oil combustion	1.5	0.9	11.1	1.5	0.2
Iron and steel Ind.	0.9	1.6	0.7	1.7	0.1
Refuse combustion	1.9	2.7	1.4	3.1	0.8
Cement	0.6	7.8	3.9	7.1	7.0
Total	46.3	40.9	34.9	34.2	60.2

Component	MP16	MP17	MP18	MP19	MP20
Soil	13.4	29.1	22.7	36.5	42.8
Sea salt	8.9	0.5	9.1	14.0	15.1
Gasoline automobile	1.4	6.0	1.9	3.3	1.5
Fuel oil combustion	6.2	0.7	0.2	0.2	0.3
Iron and steel Ind.	0.9	1.0	0.9	0.9	1.1
Refuse combustion	0.4	1.5	0.3	0.4	0.0
Cement	2.2	4.1	4.6	4.6	5.5
Total	33.4	43.1	39.8	59.8	66.2

Table VII-2-9 Percentage contributions using weighted least-squares (2nd survey)

(%)

Component	MP 1	MP 2	MP 3	MP 4	MP 5
Soil	18.6	41.5	5.4	14.4	11.8
Sea salt	2.1	8.9	7.3	10.1	8.1
Gasoline automobile	1.6	6.3	1.2	2.5	1.7
Fuel oil combustion	7.5	7.2	1.7	2.3	2.2
Iron and steel Ind.	1.6	1.5	0.2	0.5	0.4
Refuse combustion	2.3	0.7	0.4	0.5	0.5
Cement	8.1	21.2	1.5	4.1	1.4
Total	41.9	87.2	17.7	34.3	26.0

Component	MP 6	MP 7	MP 8	MP 9	MP10
Soil	47.6	41.1	38.7	33.2	29.9
Sea salt	2.3	0.6	6.4	5.7	9.0
Gasoline automobile	1.2	2.1	0.3	0.6	1.5
Fuel oil combustion	2.7	1.5	2.2	1.8	5.3
Iron and steel Ind.	1.0	2.1	1.6	1.2	1.2
Refuse combustion	0.7	0.2	0.3	1.1	2.0
Cement	5.3	10.7	3.5	3.3	5.8
Total	60.7	58.3	53.1	46.9	54.7

Component	MP11	MP12	MP13	MP14	MP15
Soil	44.7	28.1	21.7	19.6	51.7
Sea salt	0.3	2.3	1.2	3.5	4.0
Gasoline automobile	1.4	2.5	6.7	4.3	3.5
Fuel oil combustion	2.6	5.0	3.7	4.8	13.1
Iron and steel Ind.	0.9	3.0	1.2	1.4	4.7
Refuse combustion	1.0	4.8	1.2	1.1	4.2
Cement	3.9	10.9	4.2	4.9	11.7
Total	54.8	56.6	39.8	39.5	92.8

Component	MP16	MP17	MP18	MP19	MP20
Soil	34.6	26.9	10.2	23.6	14.7
Sea salt	3.2	4.1	7.0	4.1	5.3
Gasoline automobile	1.4	4.6	3.3	1.5	2.7
Fuel oil combustion	2.5	3.1	2.2	10.6	4.8
Iron and steel Ind.	1.8	1.0	0.4	14.2	0.9
Refuse combustion	1.1	0.7	0.3	7.5	0.0
Cement	4.3	5.9	1.9	35.7	6.8
Total	48.9	46.2	25.2	97.2	35.2

Table VII-2-10 Percentage contributions using weighted least-squares (3rd survey)

(%)

Component	MP 1	MP 2	MP 3	MP 4	MP 5
Soil	-1.7	9.1	17.7	9.3	11.7
Sea salt	16.7	21.1	16.9	13.7	13.5
Gasoline automobile	1.7	1.6	1.1	0.9	-0.1
Fuel oil combustion	4.1	3.0	5.0	7.5	4.3
Iron and steel Ind.	1.8	0.5	1.6	5.5	5.5
Refuse combustion	-0.5	0.2	-0.2	1.3	5.4
Cement	7.7	4.0	11.3	12.9	20.0
Total	29.7	39.5	53.4	51.1	60.3

Component	MP 6	MP 7	MP 8	MP 9	MP10
Soil	23.2	44.5	34.3	29.1	17.1
Sea salt	7.6	4.2	3.3	2.3	6.1
Gasoline automobile	0.5	3.5	1.3	1.7	1.9
Fuel oil combustion	2.1	1.7	1.5	2.1	2.7
Iron and steel Ind.	3.5	1.7	0.9	1.5	0.7
Refuse combustion	3.5	0.1	2.5	0.6	0.5
Cement	17.4	3.6	0.9	0.1	3.8
Total	57.7	59.3	44.8	37.4	32.7

Component	MP11	MP12	MP13	MP14	MP15
Soil	21.3	21.5	14.3	24.7	3.3
Sea salt	3.3	14.1	5.8	13.9	32.6
Gasoline automobile	2.8	2.0	11.4	4.2	0.6
Fuel oil combustion	1.8	0.1	4.2	1.5	1.6
Iron and steel Ind.	1.1	1.8	0.4	1.3	0.1
Refuse combustion	1.5	0.3	0.9	0.3	0.1
Cement	4.2	7.2	0.3	7.1	1.4
Total	36.1	46.9	37.3	53.0	39.6

Component	MP16	MP17	MP18	MP19	MP20
Soil	22.7	22.9	29.8	17.1	30.5
Sea salt	3.8	6.8	7.3	9.2	4.5
Gasoline automobile	4.3	5.3	2.7	1.2	2.1
Fuel oil combustion	2.7	2.1	0.7	0.8	0.4
Iron and steel Ind.	2.1	0.8	0.6	0.9	1.5
Refuse combustion	0.2	0.9	0.7	0.1	-0.2
Cement	5.0	1.4	4.1	3.7	12.1
Total	40.7	40.3	45.9	32.9	51.0

Table VII-2-11 Percentage contributions using weighted least-squares (4th survey)

(%)

Component	MP 1	MP 2	MP 3	MP 4	MP 5
Soil	11.4	9.6	19.7	8.2	5.7
Sea salt	12.8	19.0	8.1	5.9	6.1
Gasoline automobile	2.5	0.9	1.1	0.8	-0.1
Fuel oil combustion	1.6	1.6	0.6	6.4	5.0
Iron and steel Ind.	0.6	0.1	0.4	1.5	2.8
Refuse combustion	0.3	0.5	0.1	0.9	3.2
Cement	2.8	1.8	2.4	6.3	24.2
Total	31.9	33.5	32.5	30.0	46.8

Component	MP 6	MP 7	MP 8	MP 9	MP10
Soil	17.0	62.6	29.3	31.8	14.0
Sea salt	9.7	1.6	2.6	3.5	7.2
Gasoline automobile	-0.3	2.0	0.8	1.2	1.3
Fuel oil combustion	3.2	0.6	2.2	0.8	1.2
Iron and steel Ind.	1.5	1.0	2.0	0.7	0.4
Refuse combustion	1.0	-0.1	1.3	0.4	0.3
Cement	6.3	3.5	3.7	1.2	1.0
Total	38.4	71.3	41.9	39.5	25.5

Component	MP11	MP12	MP13	MP14	MP15
Soil	27.5	21.5	6.6	18.5	8.6
Sea salt	2.9	15.6	4.2	12.2	25.7
Gasoline automobile	1.8	0.9	3.0	1.8	0.2
Fuel oil combustion	0.5	0.1	0.3	0.6	0.7
Iron and steel Ind.	0.6	1.3	0.2	0.6	0.1
Refuse combustion	0.4	0.8	0.2	0.4	0.3
Cement	4.9	6.8	1.2	3.2	0.4
Total	38.6	47.1	15.7	37.2	36.0

Component	MP16	MP17	MP18	MP19	MP20
Soil	28.2	15.7	8.1	8.3	18.6
Sea salt	6.4	5.1	9.6	7.1	5.7
Gasoline automobile	0.9	2.3	0.1	1.3	0.3
Fuel oil combustion	0.3	0.3	0.4	0.5	0.4
Iron and steel Ind.	0.8	0.4	0.2	0.3	1.7
Refuse combustion	1.0	0.8	0.6	0.6	-0.5
Cement	5.7	1.4	1.1	1.7	32.8
Total	43.2	25.9	20.1	19.8	59.1

ANNEX

ANNEX I

SCOPE OF WORK

FOR

THE STUDY OF ENVIRONMENTAL EFFECTS

OF COAL FIRING POWER STATIONS

AND INTEGRATED STEEL MILL

DECEMBER 1980

This Scope of Work is agreed by the following two authorities concerned;

The Jurong Town Corporation,
Government of the Republic of Singapore.

Japan International Cooperation Agency,
the Official Agency responsible for the implementation of technical cooperation programmes of the Government of Japan.

To confirm the aforementioned, the Scope of Work is herewith attached and signed by the responsible personnel of the said authorities concerned.

Date: 19th December 1980

Issued at: Singapore

For the Jurong Town Corporation,
Government of the Republic of Singapore.

YING YOK HANG
PRINCIPAL DIRECTOR (TECHNICAL)
JURONG TOWN CORPORATION
GOVERNMENT OF THE REPUBLIC OF SINGAPORE

For Japan International Cooperation Agency,
the Government of Japan.

ICHIRO KIKUSHIMA
LEADER OF THE JAPANESE PRELIMINARY SURVEY TEAM
DEPUTY DIRECTOR
ENVIRONMENTAL PROTECTION GUIDANCE DIVISION
INDUSTRIAL LOCATION & ENVIRONMENTAL PROTECTION BUREAU
MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY

IN THE PRESENCE OF:-

LIM SAK LAN
SENIOR DIRECTOR, ENGINEERING
JURONG TOWN CORPORATION

AKIHIRO MITARI
HEAD, INDUSTRY DIVISION
MINING & INDUSTRIAL PLANNING AND SURVEY DEPARTMENT
JAPAN INTERNATIONAL COOPERATION AGENCY

(1)

1. Introduction

In response to the request of the Government of the Republic of Singapore, the Government of Japan has agreed to extend the technical assistance to conduct the study on the environmental effects of coal firing power stations and the integrated steel mill which will be sited in the new industrial estates of the Republic of Singapore, which assistance is given in accordance with the laws and regulations in force in Japan.

The study will be carried out through The Japan International Cooperation Agency (hereinafter referred to as JICA), which is the official agency responsible for the implementation of technical cooperation programmes of the Government of Japan, in close cooperation with the Government of the Republic of Singapore and authorities concerned.

2. Objectives

The objectives of the study are:-

(1) To conduct the field survey in terms of air and water qualities within and at surrounding areas of Pulau Seraya, Jurong, Pulau Tekong, where the proposed coal firing power stations and the integrated steel mill are to be sited.

(2) To conduct the simulation study by computers based on the data obtained from the above said field survey and to assess the estimated pollution loads when these plants are in operation.

3. Scope of the study

3-1 Survey Areas

(A) Pulau Seraya, the proposed site of the coal firing power station and its surrounding areas.

(B) Pulau Tekong, the proposed site of the coal firing power station and the integrated steel mill, and its surrounding areas.

(C) Other areas mutually agreed to be surveyed.

3-2 Survey Plan

(A) Air Quality Survey

i) Long Term Measurement

a) Sulphur dioxide (SO_2) concentration

b) Wind directions and velocity at ground surface

c) Net radiation

d) Temperature

Notes: Period of measurement - 1 year

ii) Short Term Measurement

a) Vertical profile of wind directions and velocity

Notes: Period of measurement - two days each at two stations.

iii) Simulation - Simulation of sulfur dioxide (SO_2)

(B) Water Quality Survey

i) Measurement

a) Current directions and velocity

b) Chemical Oxygen Demand (COD)

c) Water temperature and salinity

Notes: Period of measurement - 2 weeks per measuring point for the above (a), once per measuring point for the above (b) and (c), and 1.5 months in total including preparation works.

ii) Simulation - Simulation of COD and temperature

4. Time Schedule

As shown in ANNEX I (Subject to change)

5. Report

5-1 Interim Report

i) 30 copies

ii) The interim report will be submitted in English to the Government of the Republic of Singapore within 5 months after the completion of the simulation for water quality survey.

iii) The interim report will contain the results of the water quality survey and refer to the progress of air quality survey.

iv) The Government of the Republic of Singapore will provide the comments to JICA through the Embassy of Japan within 1 month after receipt of the interim report.

5-2 Draft Final Report

i) 30 copies

ii) The draft final report will be submitted in English within 4 months after the completion of the simulation for air quality survey.

iii) The Government of the Republic of Singapore will provide the comments to JICA through the Embassy of Japan within 1 month after receipt of the draft final report.

5-3 Final Report

i) 50 copies together with 50 copies of abstracts.

ii) The final report will be submitted in English within 2 months after receipt of the comments of the draft final report.

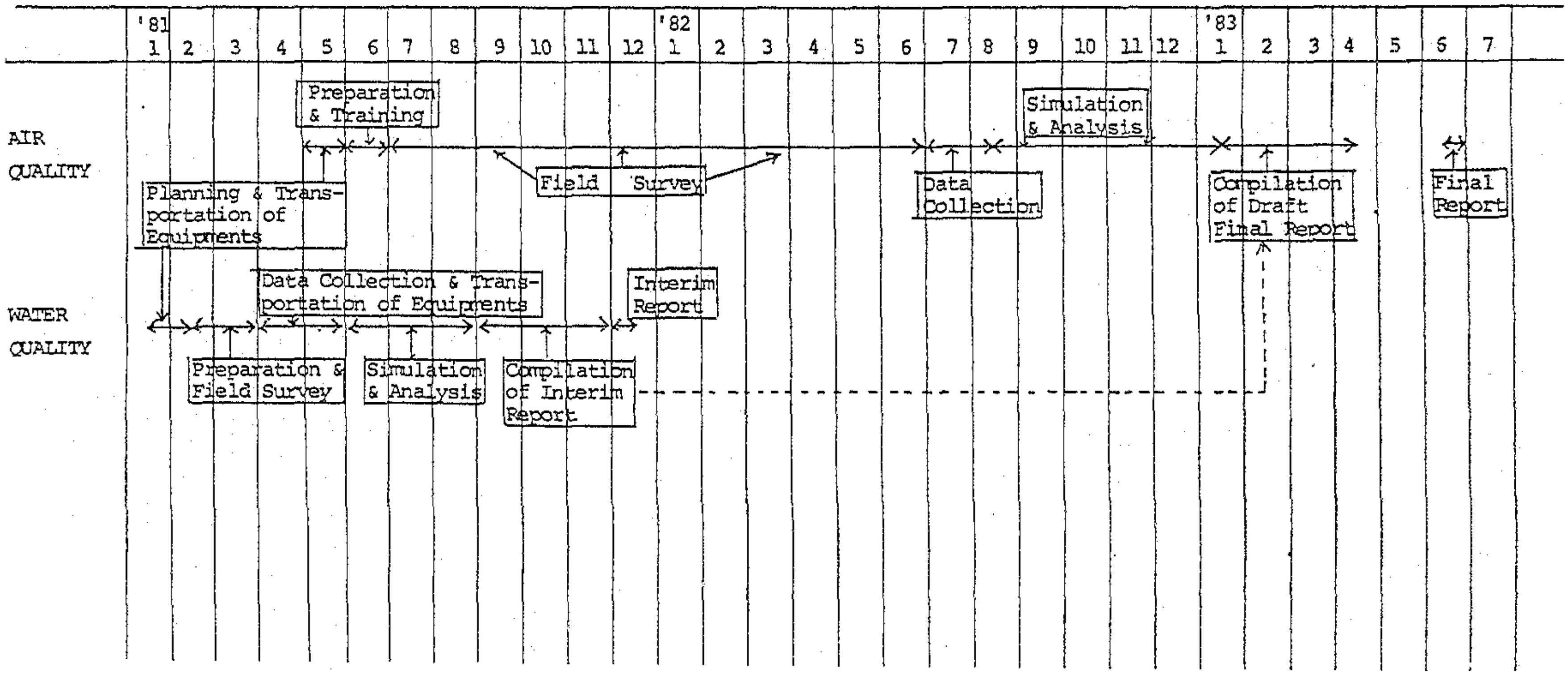
6. Contribution of the Government of the Republic of Singapore

1. The Government of the Republic of Singapore will assign a qualified counterpart to be responsible for liaison and cooperation with the team conducting the survey. (hereinafter referred to as Survey Team)
2. The Government of the Republic of Singapore will provide the Survey Team with the necessary and available information and data.
3. The Government of the Republic of Singapore will make arrangements for the Survey Team to visit the authorities concerned.
4 The Government of the Republic of Singapore will provide the Survey Team with an office, sites for monitoring stations, laboratory testing facilities, storage space, temporary site office, transportation and boats as are necessary for the survey (ANNEX II)
5. The Government of the Republic of Singapore will exempt the Survey Team from taxes and duties on machinery, equipments and materials brought in Singapore by the Survey Team.
6. The Government of the Republic of Singapore will exempt the members of the Survey Team from any tax, including import and export duties imposed on the members' personal effects.
7. The Government of the Republic of Singapore will make an effort to ensure the securities of machinery, equipments and materials brought in Singappre by the Survey Team.

7. Contribution of the Government of Japan

1. The Government of Japan, through JICA, will provide a Survey Team who will conduct the field survey and simulation according to the Time Schedule (ANNEX I)
2. The Government of Japan will conduct during the stay of the Survey Team in the Republic of Singapore the training course for the Singapore counterparts to further their skills in operating and maintaining the necessary measuring machinery and equipments for the period of the field survey.

TIME SCHEDULE FOR THE STUDY OF ENVIRONMENTAL EFFECTS OF COAL FIRING POWER STATION AND INTEGRATED STEEL MILL IN THE REPUBLIC OF SINGAPORE



The Detailed Information on Provision of Facilities by the Government of The Republic of Singapore

[1] Air Quality Survey

1. Monitoring Stations
   About 7 monitoring stations are to be established in the surrounding areas of the proposed sites. The land or places for these monitoring stations should be provided.
2. Electricity Supply
   The electricity connection and supply for monitoring stations at mutually agreed sites should be provided by the Government of the Republic of Singapore.
3. The Facilities to Accomodate the Chemical Reagents
   The facilities for storage, preparation of chemical reagents and distilled water should be provided at Jurong Town Corporation's Laboratory or National University of Singapore's Laboratory.
4. The Government of the Republic of Singapore will provide necessary personnel for the daily operation and maintenance of the monitoring stations.

[2] Water Quality Survey

1. The Laboratory Testing Facilities for Chemical Analysis
   The laboratory testing facilities for chemical analysis of aqueous samples shall be provided at Jurong Town Corporation's Laboratory or National University of Singapore's Laboratory.
2. The Storage Space for the Measuring Equipments and Materials
   The storage space to be provided for the measuring equipments and materials shall be big enough for opening of the packages and adjusting the equipments.
3. The Small Boats for Survey
   The Survey Team will require 3 small boats for about 20 days in total. The Government of the Republic of Singapore will provide the Survey Team with such number of boats as are necessary for the survey.

(2)

[3] Handling of Measuring Equipments

All the measuring equipments necessary to conduct the field survey will be, in principle, brought in and out by the Survey Team. The Government of the Republic of Singapore is requested to provide facilities and arrangement on the followings:-

(a) Custom clearance including loading and unloading

(b) Inland transportation

(c) Packing and unpacking

ANNEX II

MINUTES OF MEETINGS

FOR

THE STUDY OF ENVIRONMENTAL EFFECTS

OF COAL FIRING POWER STATIONS

AND INTEGRATED STEEL MILL

DECEMBER 1980

MINUTES OF MEETINGS

FOR

THE STUDY OF ENVIRONMENTAL EFFECTS

OF COAL FIRING POWER STATIONS

AND INTEGRATED STEEL MILL

19TH DECEMBER 1980

CONFIRMED BY:

YING YOK HANG
PRINCIPAL DIRECTOR (TECHNICAL)
JURONG TOWN CORPORATION
GOVERNMENT OF THE REPUBLIC OF
SINGAPORE

菊島一郎

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PROTECTION BUREAU
MINISTRY OF INTERNATIONAL TRADE AND
INDUSTRY

MINUTES OF MEETINGS

The Japanese Preliminary Survey Team and the Singapore Counterpart had discussion on the Environment Effects of the Coal Firing Power Stations and Integrated Steel Mill and the following were mutually agreed upon.

Data of the Proposed Coal Firing Power Stations and the Integrated Steel Mill

(A) Coal Firing Power Station

i) The Japanese side requested for information on the proposed coal firing power station.

ii) After discussion with the Singapore side which included P.U.B., the assumptions given in Appendix A were agreed upon.

iii) It was indicated that one coal firing power station will be on Pulau Seraya and one on Pulau Tekong. (See Appendix D)

(B) Integrated Steel Mill

i) The Singapore side indicated that the proposed steel mill will use about eight million tons of iron ore per year and producing about one million tons of steel product by the direct reduction process using coal.

ii) The Japanese side requested for technical information similar to those in Appendix A.

iii) The Singapore side replied that it is not in a position to provide, except that the location will be in Pulau Tekong (See Appendix D). However, it will try to obtain the information requested by the Japanese side at the earliest possible date.

iv) It was mutually agreed that this matter will be further discussed and resolved when the next water quality survey team visits Singapore.

(C) Data on Emission Sources (Present & Future 1990)

(a) Air Quality

i) The Japanese side requested for emission data both present and future and suggested that if such data is not available then a survey be carried out to obtain the same.

ii) The Singapore side agreed to carry out such survey.

iii) The Japanese side indicated that these data shoul be made available by June 1982.

iv) The Singapore side agreed to the above.

(b) Water Quality

i) The Japanese side requested for effluent data present and future including industries located on the southern islands and suggested if such data is not available then a survey be carried out to obtain the same.

ii) The Singapore side agreed to carry out such survey.

iii) The Japanese side indicated that these data should be made available by May 1981.

iv) The Singapore side agreed to the above.

(c) Malaysian Development Plan (North of Straits of Johore)

i) The Japanese side requested information regarding industrial development plan immediately north of the Straits of Johore.

ii) The Singapore side replied that it is not in a position to do so.

iii) It was mutually agreed that effects of the Malaysian developments shall not be considered.

(D) Monitoring Points

Based on survey carried out by Japanese Preliminary Survey Team, the following monitoring points were agreed upon.

(a) Air Quality

i) SO_2, wind direction, wind velocity - 7 points

ii) Net radiation - 1 point

iii) Vertical distribution of temperature - 1 point

iv) Pilot balloon observation - 2 points

(b) Water Quality

i) Current direction, current velocity - 10 points (around the two proposed sites

ii) Water temperature, salinity, COD observation. - 30 points (around the two proposed sites

(c) Clearance from Competent Authorities

The Singapore side will arrange and obtain necessary clearance from the competent authorities to conduct the above surveys.

(3)

(E) Simulation Methods

i) The Japanese side stated that for SO_2 diffusion calculation, Plume Puff model will be adopted and predict a yearly concentration of SO_2.

ii) As for water temperature and COD diffusion calculation, FEM (Finite Element Method) will be adopted.

iii) The Singapore side agreed to the above methods.

(F) Evaluation on the Environmental Effects and Impacts

i) The Japanese side enquired about the environmental ambient standards of SO_2 and COD.

ii) The Singapore side replied that it has only the emission standard but not the ambient standard.

iii) The Japanese side stated that it will predict the levels of SO_2 and COD from the coal firing power stations and integrated steel mill.

iv) The Japanese side stated that it will also be able to predict the total levels of SO_2 and COD in the year 1990 if adequate datas on the emission are collected from the survey referred in para C.

v) It was mutually agreed that if no ambient standard is indicated by the Singapore side, the Japanese side will not be in a position to comment on the levels of SO_2 and COD and in any case further evaluation will have to be carried by the Singapore side.

(G) Maintenance of monitoring stations

i) The Japanese side requested the Singapore side to provide the necessary personnel for the daily operation and maintenance of the monitoring stations as indicated in Appendix 'B'.

ii) Singapore side agreed to provide the personnel required.

(H) Survey Schedule

i) The Japanese side mentioned that the schedule may need to be altered. Such alteration will be mutually discussed and agreed upon.

ii) The Singapore side agreed to the above.

5(I) Contributions

i) The Japanese side requested that land and sea transport for future survey team and equipments and their local counterparts be provided in accordance with schedule in Appendix 'C'.

ii) The Singapore side agreed to provide the same.

iii) At the commencement of the survey, the Japanese side will arrange for all the equipments to be delivered to Jurong Town Hall. The Singapore side will arrange for the transportation of the equipments from the Jurong Town Hall to the various monitoring stations and will be responsible for the setting up of the stations.

iv) On completion of survey, the Singapore side will arrange for transportation of all equipments from the monitoring stations back to Jurong Town Hall and the Japanese side will arrange to collect the same from Jurong Town Hall.

(J) Datas/Reports

i) The Singapore side requested that information supplied to the Japanese side shall be treated as confidential materials. Similarly the results and report of the study are to be treated also as confidential.

ii) The Japanese side agreed to the above.

Assumption on Coal Firing Power Station

Generated Output	350 MW x 2
Fuel	Coal Calorific Value 7,000 Kcal/kg Sulphur 1% (wt%) Consumption 154 x 10^4 t/year (operation rate 70%)
Stack	Gas Volume 182 x 10^4 Nm^3/h Gas Temperature 150°C (without desulfurization of flue gas) Gas Discharge Velocity 30 m/s Height 200m
Cooling Sea Water	Amount 29.4 m^3/s Temperature difference 7°C
Effulent	Volume 1,200 m^3/d COD 160 mg/l

NOTE:

The sites of stacks and outlets are as shown in Appendix D

ON THE MAINTENANCE OF MONITORING STATIONS

	Qualified Persons	Regular Persons
1 SO_2 Monitor	Once every 20 days:- a Absorption solution and chart sheet, ink should be refilled or replaced b Calibration of monitor should be conducted c Chart data for last 20 days should be sent to Japan through JICA, Singapore	Once per everyday he should check the monitoring station whether it is operating properly without any trouble or not
2 Wind Speed Meter	Same as above but no calibration required	Same as above
3 Net Solar Radiation Flux Meter and Air Thermometer	Same as No (2) above	Same as No (1) and (2) above

APPENDIX C

TIME SCHEDULE FOR FIELD SURVEY IN SINGAPORE (AIR QUALITY)

Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27			388		390		392		394	395
Travel & Official Visits																																					
Number of Persons	4	4																																			
1. Site Selection,																																					
N.of Person			4	4	4	4	4	4	4	4																											
2. To set equipments & Training																																					
N.of Person											4	4	4	4	4	4	4	4	4	4	4	4															
3. Surveillance & Pilot Balloon																																					
N.of Person																							4	4	4	4											
4. Observation																									(365)												
N.of Person																							(1)						(1)								
5. Travel to Japan																																					
N.of Person																											4										
6. Travel to S'pore																																					
N.of Person																													2								
7. Withdrawal of Equipments																																					
N.of Person																														2	2	2	2	2	2		
8. Travel to Japan																																					
N.of Person																																				2	2

TENTATIVE TIME SCHEDULE FOR FIELD SURVEY IN SINGAPORE (WATER QUALITY)

Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Travel & Official Visits																																								
Number of Persons	2	2																																						
1. Site Selection Jurong Area																																								
N. of person			2	2	2	2																																		
N.of ships				1																																				
2. Site Selection Tekong Area																																								
N.of person							2	2	2	2																														
N.of ships								1																																
3. Travel of Survey Team																																								
N.of person										6																														
4. Preparation																																								
N.of person											8	8	8	8	8																									
5. Setting of Equipments																																								
a) Jurong																																								
N.of person																8																								
N.of ships																2																								
b) Tekong																																								
N.of person																	8																							
N.of ships																	2																							
6. Observation & Withdrawal																		Observation														Withdrawal & Reserve								
N.of person																		8	8	8	8	8	8	4	4	4	4	4	4	4	4	4	4	4	4					
Local Employ																		(1)		(1)		(1)	(1)									(2)	(2)	(2)	(2)					
N.of ships																		3	2	3	2	(3)	(3)	2	2			2	2			2	2	(2)	(2)					
7. Travel to Japan																																								
N.of person																								4																

TENTATIVE TIME SCHEDULE FOR FIELD SURVEY IN SINGAPORE (WATER QUALITY)

(2)

Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
8. Packing of Equipments																																								
N.of person																																				4	4	4	4	
9. Travel to Japan																																								
N.of person																																								4

ANNEX III

MINUTES OF MEETING

ON

THE STUDY OF ENVIRONMENTAL EFFECTS

OF COAL FIRING POWER STATIONS

AND

INTEGRATED STEEL MILL

IN THE REPUBLIC OF SINGAPORE

AGREED AND CONFIRMED ON 6TH JUNE, 1983 IN SINGAPORE

LIM SAK LAN
SENIOR DIRECTOR, ENGINEERING
JURONG TOWN CORPORATION
GOVERNMENT OF THE REPUBLIC
OF SINGAPORE

KENJI IWAGUCHI
LEADER, PRELIMINARY SURVEY TEAM
JAPAN INTERNATIONAL COOPERATION
AGENCY

Based on the Scope of Work signed on 19 December 1980 (hereinafter referred to as "the Original S/W"), the JICA started to conduct the study in mid-February 1981. The water quality survey and simulation were completed in December 1981 and the final report was submitted on 4 February 1982. The air quality survey and simulation has been under way and the final report will be submitted at the end of July 1983.

In view of the critical impact of particulates and also to achieve a more comprehensive study, the Government of the Republic of Singapore, by the Note Verbal No. MFA/RE/453/82 dated 31 July 1982, further requested the Government of Japan to add the study on particulates (hereinafter referred to as "the Additional Study").

Accordingly, JICA sent a team headed by Mr Kenji Iwaguchi from 1 to 7 June 1983 to discuss the Scope of Work for the Additional Study.

As a result of discussions, JICA and JTC hereto agreed upon the following as "the supplement" to the Original S/W.

SUPPLEMENT

1 OBJECTIVES

The objectives of the study are:

1.1 to conduct the field survey for particulates in the Republic of Singapore

1.2 to conduct the simulation study by computers based on the data obtained from the above said field survey and to assess the estimated pollution loads when these plants are in operation.

2 SCOPE OF THE STUDY

2.1 Survey Area

The survey area of the study covers whole area in the Republic of Singapore

2.2 Establishment of monitoring stations (as shown in Annex I).

2.3 Survey Plan

2.3.1 Measurement of Particulates

i Quarterly measurement (every 3 months) of total particulate matters (TPM), suspended particulate matter (SPM) at 20 monitoring stations and particulate size distribution of SPM at 3 monitoring stations.

ii Through-year measurement of suspended particulate matter (SPM) at 3 key monitoring stations.

2.3.2 Measurement of other items at 7 monitoring stations

i Through-year measurement of SO_2 ambient concentration.

ii Through-year measurement of meteorological conditions.

2.3.3 Collection of relevant data on emission factors of the proposed plants.

2.3.4 Chemical analysis of particulate components.

2.3.5 Data anlysis, and numerical estimation of environmental impacts of the proposed plants.

3 TENTATIVE TIME SCHEDULE

The tentative time schedule is shown in Annex II.

4 REPORTS

4.1 <u>Draft Report</u>

4.1.1 30 copies

4.1.2 The draft final report will be submitted in English within three(3) months after the completion of the numerical calculation for particulates survey.

4.1.3 The Government of the Republic of Singapore will provide the comments to JICA through the Embassy of Japan within one(1) month after the presentation of the draft final report.

4.2 <u>Final Report</u>

4.2.1 50 copies together with 50 copies of abstracts.

4.2.2 The final report will be submitted within two(2) months after the receipt of the comments on the draft report.

5 ADDITIONAL CONTRIBUTION OF THE GOVERNMENT OF THE REPUBLIC OF SINGAPORE

5.1 Monitoring Stations

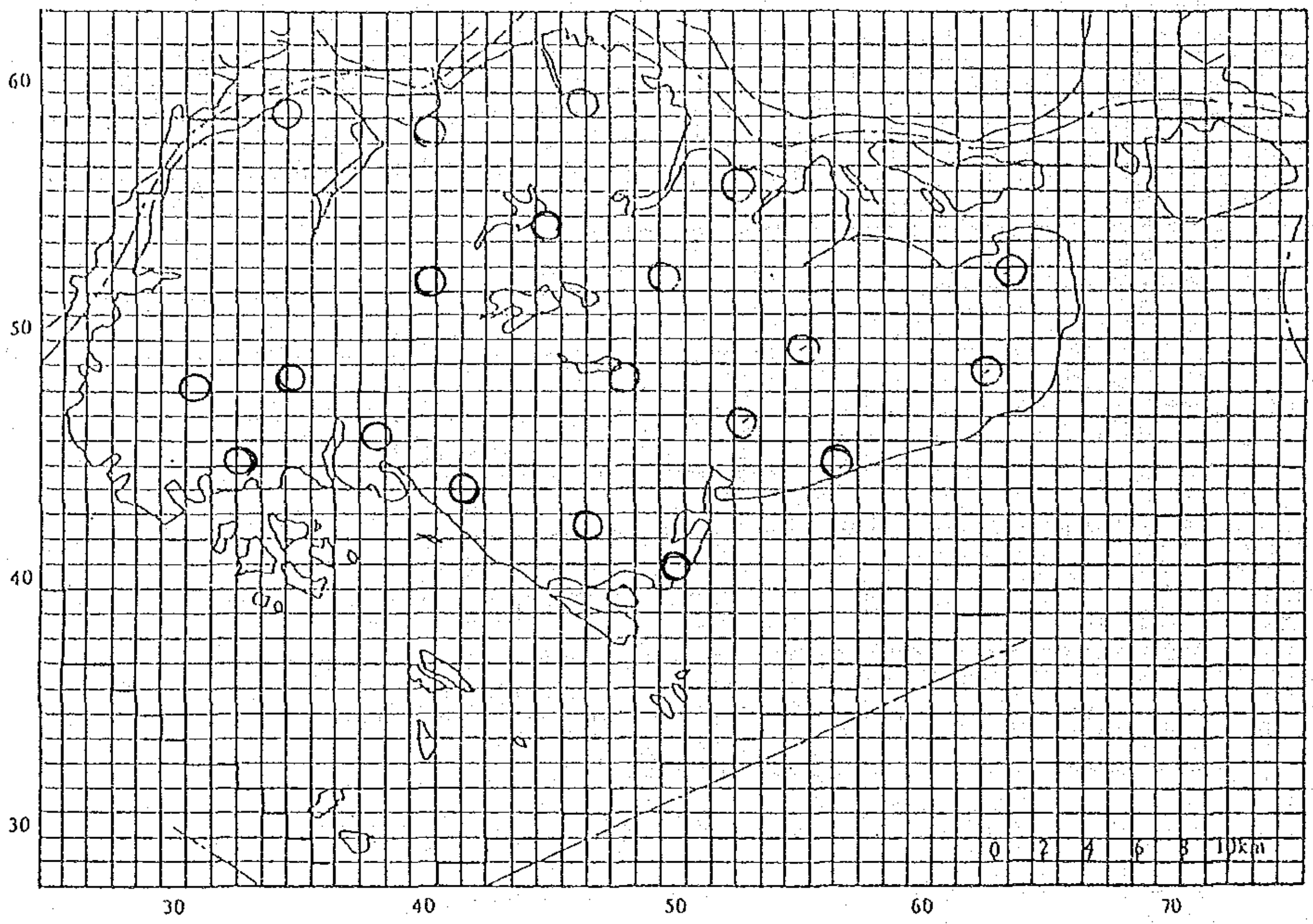
About 20 monitoring stations are to be established in the main island of the Republic of Singapore. The lands or places for these monitoring stations should be provided.

5.2 Electricity Supply

The electricity connection and supply for monitoring stations at mutually agreed sites should be provided by the Government of the Republic of Singapore.

5.3 The Government of the Republic of Singapore will provide necessary personnel for the daily operation and maintenance of the monitoring stations.

5.4 Measurement of SO_2 ambient concentration and meteorological conditions will be conducted by the Government of the Republic of Singapore during the same period with the through-year measurement of particulates by the survey team, and the data will be provided to the survey team.



Monitoring Points for Measurement of Particulates

Key Stations (3)

Installed with β ray analyser, Andersen sampler and high volume samplers

Principal Stations (9)

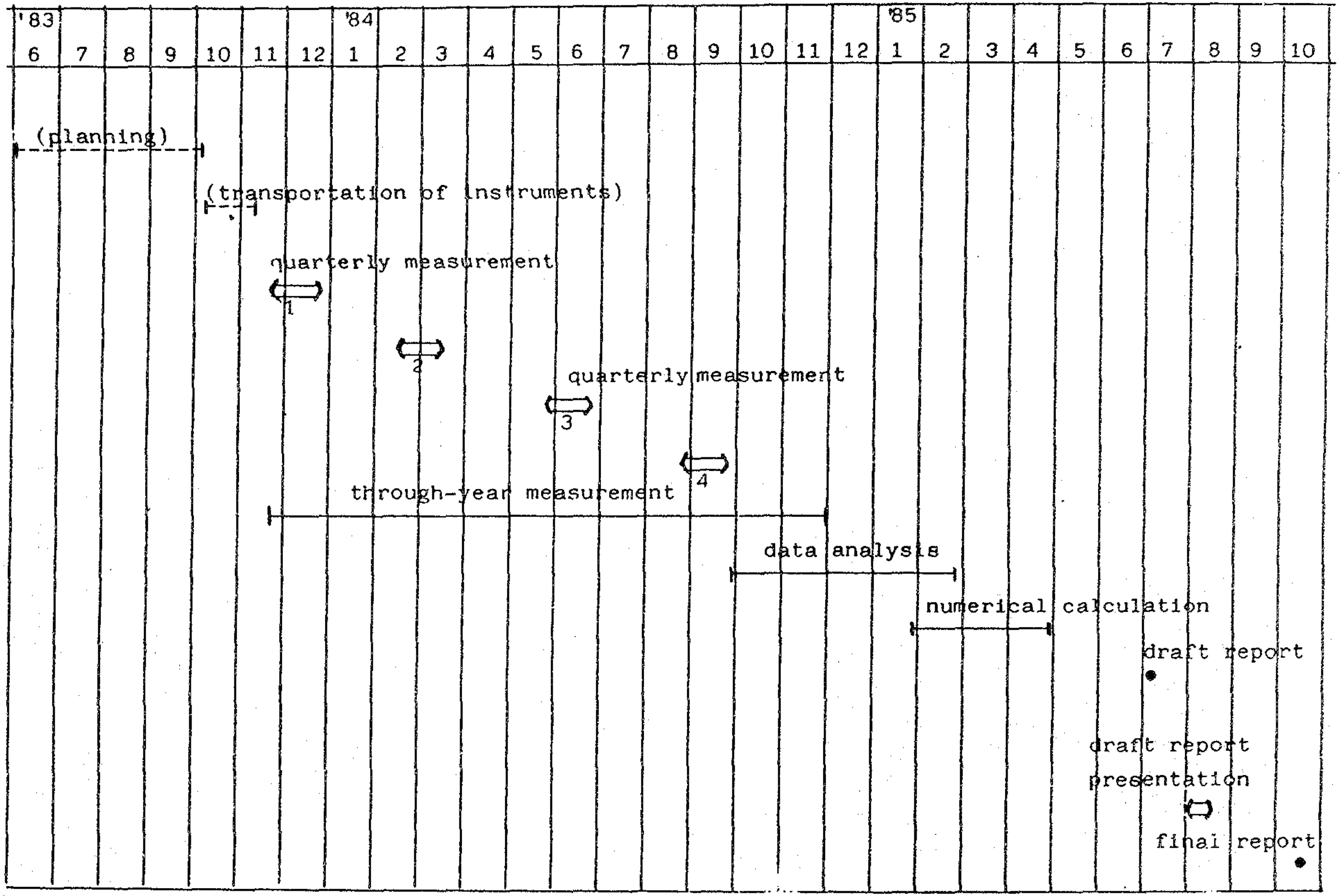
Installed with high volume samplers

Supplementary Stations (8)

Installed with high volume samplers

Annex II

TENTATIVE TIME SCHEDULE



ANNEX IV

MINUTES OF MEETING

ON

THE STUDY OF ENVIRONMENTAL EFFECTS

OF COAL FIRING POWER STATIONS

AND

INTEGRATED STEEL MILL

IN THE REPUBLIC OF SINGAPORE

AGREED AND CONFIRMED ON 27TH SEPTEMBER, 1984 IN SINGAPORE

YING YOK HANG PRINCIPAL DIRECTOR (TECHNICAL) JURONG TOWN CORPORATION GOVERNMENT OF THE REPUBLIC OF S'PORE	TAKESHI YAMADA MANAGING DIRECTOR, IPCAJ ON BEHALF OF THE JAPAN INTERNATIONAL COOPERATION AGENCY

Based on the Supplement to the Original Scope of Work signed on 6 June 1983, the Japanese Environmental Study Team had completed the field survey for particulates in the Republic of Singapore in September 1984.

To conduct the simulation study by computers based on the data obtained from the above said field survey and to assess the estimated pollution loads when these plants are in operation, it is hereby agreed that the assumptions to be made for the particulate emmisions are as follows:-

1 **Coal Firing Power Stations**

1.1 **Pulau Seraya**

Particulates emmision volume	-	130 kg/hr
Particulates concentration	-	0.05g/Nm^3-dry gas

1.2 **Pulau Tekong**

Particulates emmision volume	-	120 kg/hr
Particulates concentration	-	0.05g/Nm^3-dry gas

2 **Integrated Steel Mill**

2.1 **Grate Kiln**

Particulates emmision volume	-	900 kg/hr
Particulates concentration	-	0.18g/Nm^3-dry gas

2.2 **Electric Arc Furnance**

Particulates emmision volume	-	324 kg/hr
Particulates concentration	-	0.18g/Nm^3-dry gas

2.3 **Reheating Furnance**

Particulates emmision volume	-	6 kg/hr
Particulates concentration	-	0.18g/Nm^3-dry gas

It is further assumed that electrostatic precipitators and/or bag filters will be installed in the above items except 2.3 Reheating Furnance.

Id 3349c/202a

JICA