CHAPTER 8 AIR QUALITY INVESTIGATION

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The JICA Study Team conducted a survey of air quality and meteorology in the area surrounding the Sohar mine area. This investigation included the following elements:

- Collecting ambient air quality data in the field using sulfur dioxide analyzer, high-volume air sampler and dustfall sampling jar to measure sulfur dioxide (SO_2), Total Suspended Particulates (TSP), suspended particulate matter less than 10 microns in diameter (PM_{10}) and dustfall;
- Collecting meteorological data near the site of OMCO plant;
- Gathering stack emission gas data of OMCO plant;
- Gathering historical ambient SO_2 data measured by OMCO;
- Selection of air dispersion model to predict SO_2 concentrations in the areas surrounding the Sohar mine area.

Each of the elements of the air quality and meteorology is described in the following sections.

8.1 Ambient Air Quality Monitoring

The main objective of the ambient air quality monitoring was as follows:

- To evaluate ambient air quality level in the areas surrounding the Sohar mine area;
- To evaluate the effect of OMCO on ambient air quality;
- To validate air dispersion modeling.

Monitoring parameter, station, equipment, duration and analysis method are summarized in Table 8.1.

8.1.1 Monitoring Parameters

Four parameters, consisting of SO_2, TSP, PM_{10} and dust fall were monitored.

8.1.2 Monitoring Stations

Ambient air quality monitoring stations were selected based on the topography, meteorology, population, existing emissions sources, sensitive receptors, obstructions, accessibility, vandalism, existing monitoring locations and existing air quality data. Finally, 12 stations for SO_2, TSP and PM_{10} and 14 stations for dustfall were selected respectively. These monitoring stations are shown in Figure 8.1.

Table 8.1 Summary of Ambient Air Quality Monitoring Method

Parameter	Number of Point	Equipment	Duration	Analysis Method
SO_2	12	UV fluorescent sulfur dioxide analyzer	Continuous 24 hours	· Direct reading of data measured by SO_2 UV fluorescent analyzer
TSP	12	High-volume air sampler	Continuous 24 hours	· Measuring of net weight gain of TSP collected on the filter by weighing of the filter before and after sampling · Caluculation of total mass per unit by dividing net weight gain by sampled air volume
PM_{10}	12	High-volume air sampler with sizing device	Continuous 24 hours	· Measuring of net weight gain of PM_{10} collected on the filter by weighing of the filter before and after sampling · Caluculation of total mass per unit by dividing net weight gain by sampled air volume
Dustfall	14	Dustfall sampling jar mounted on the top of 4 m height of steel pole	Continuous 30 days	· Weighing of total mass · Chemical analysis (atomic absorption spectrometry) of heavy metal concentration of Hg, Cd, Cr, As, Pb, Cu, Mn, Fe, Ni, Sn, Zn, Cl^-, and SO_4^{2-}

8.1.3 Monitoring Equipment

The following equipment was used for the monitoring of each parameter.

- SO_2 : UV fluorescent sulfur dioxide analyzer;
- TSP : High-volume air sampler;
- PM_{10} : High-volume air sampler with sizing device;
- Dustfall : Dustfall sampling jar mounted on the top of 4 m height of steel pole

8.1.4 Monitoring Duration

The following duration was applied for each parameter.

- SO_2 : continuous 24 hours;

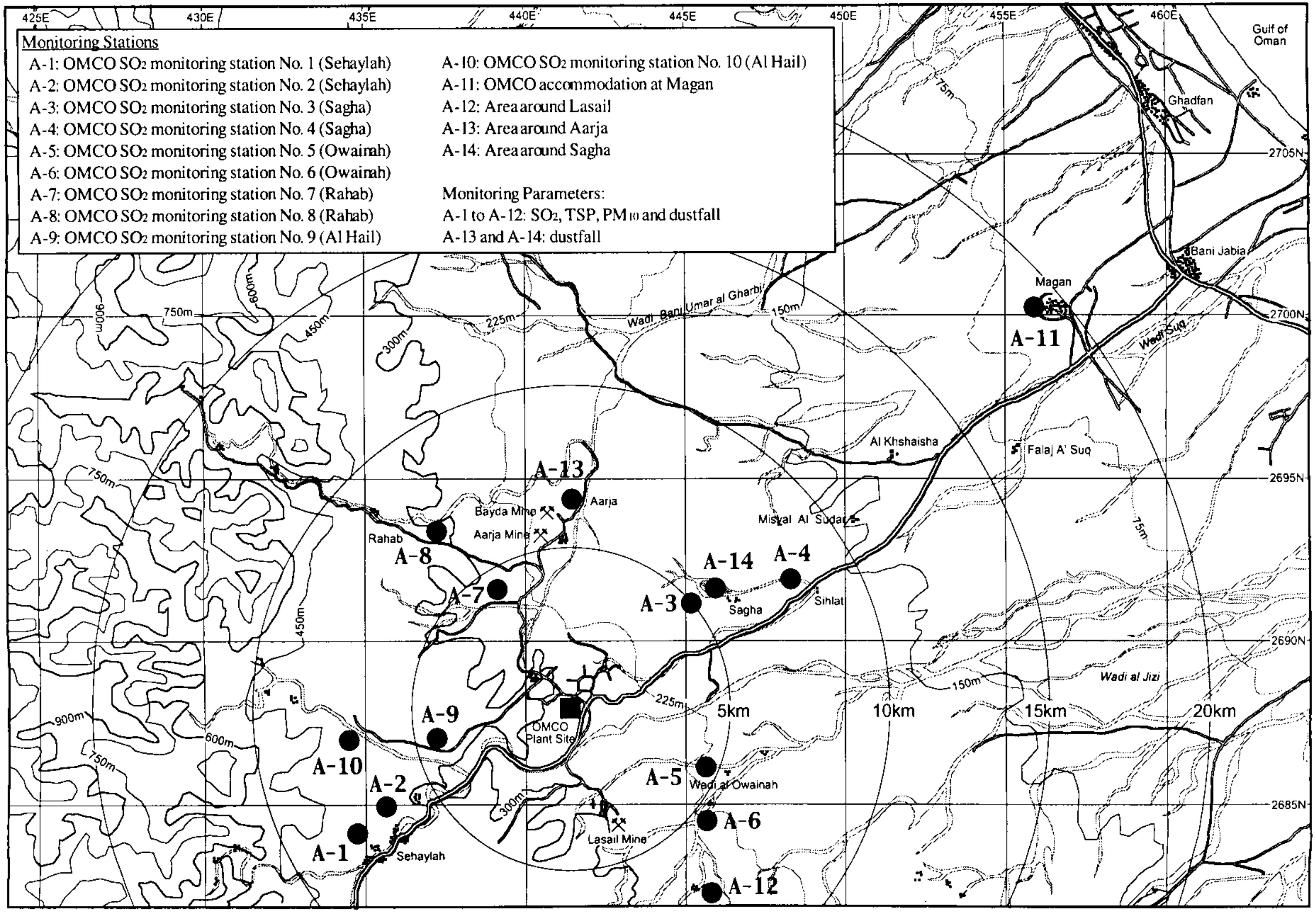


Figure 8.1 Ambient Air Quality Monitoring Point

- TSP : Continuous 24 hours;
- PM_{10} : Continuous 24 hours;
- Dustfall : Continuous 30 days.

8.1.5 Analysis Method

The following methods of analysis were applied for each parameter.

- SO_2: Direct reading of data measured by SO_2 UV fluorescent analyzer;
- TSP: Net weight gain of TSP collected on the filter was measured by weighing of the filter before and after sampling. The net weight gain was divided by sampled air volume to calculate the total mass per unit;
- PM_{10}: Net weight gain of PM_{10} collected on the filter was measured by weighing of the filter before and after sampling. The net weight gain was divided by sampled air volume to calculate the total mass per unit;
- Dustfall: Weighing of total mass and chemical analysis of heavy metal concentration of Hg, Cd, Cr, As, Pb, Cu, Mn, Fe, Ni, Sn, Zn, Cl, and SO_4.

8.1.6 Monitoring Result

The monitoring result of SO_2, TSP and PM_{10} and comparison with standards are summarized in Table 8.2. The monitoring result of dustfall and comparison with standards are summarized in Table 8.3 and Figure 8.2.

(1) SO_2

a. Summer Season

The 1-hour average SO_2 concentrations varied from 0.001 ppm (3 $\mu g/m^3$) to 0.465 ppm (1,291 $\mu g/m^3$). The maximum concentration of 0.465 ppm was measured at point of A-2. The 24-hr average SO_2 concentrations were in the range of 0.012 ppm (33 $\mu g/m^3$) to 0.111ppm (309$\mu g/m^3$). The maximum concentration of 0.111ppm was measured at point of A-2.

The ambient air quality standard for SO_2 applied to OMCO is EEC standard for 24-hour average concentration of 120 $\mu g/m^3$. The 24-hour average SO_2 concentration of A-1, A-2, A-9 and A-10 exceeded EEC standard. If the measured SO_2 concentrations are compared with other established SO_2 standard of Japan (1-hour average: 0.1 ppm and 24-hour average: 0.04 ppm), US (24-hour average: 0.14 ppm) and WHO (24-hour average: 125 $\mu g/m^3$), the status of compliance with these standards is as follows:

Table 8.2 Monitoring Results of SO_2, TSP, and PM10and Comparison with Standards (1)

Summer Season

1) SO_2 Monitoring Result and Comparison with Standards

Monitoring Point No.	Time																								24 h Average		Comparison with Standards (24 h avarage value)			
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	(ppm)	(μg/m³)	Applied to OMCO (EEC) (120 μg/m³)	US (0.14 ppm)	Japan (0.04 ppm)	WHO (125 μg/m³)
A-1	0.066	0.074	0.063	0.071	0.041	0.034	0.054	0.058	0.075	**0.289**	0.080	0.080	0.033	0.032	0.044	0.061	0.026	0.056	0.053	0.029	0.027	0.090	0.071	0.097	**0.067**	**185**	×	○	×	×
A-2	0.040	0.057	0.068	0.069	**0.154**	0.066	**0.293**	**0.313**	0.082	**0.330**	**0.465**	**0.388**	0.031	0.012	0.009	0.029	0.024	0.021	0.031	0.043	0.019	0.052	0.028	0.048	**0.111**	**309**	×	○	×	×
A-3	0.024	0.026	0.015	0.012	0.013	0.013	0.013	0.012	0.013	0.012	0.010	0.013	0.013	0.012	0.015	0.012	0.013	0.011	0.012	0.012	0.014	0.012	0.012	0.016	0.014	38	○	○	○	○
A-4	0.013	0.017	0.017	0.014	0.014	0.011	0.013	0.019	0.016	0.005	0.001	0.002	0.003	0.008	0.006	0.005	0.012	0.010	0.020	0.013	0.015	0.020	0.018	0.017	0.012	33	○	○	○	○
A-5	0.013	0.013	0.013	0.012	0.013	0.013	0.013	0.010	0.011	0.014	0.011	0.009	0.016	0.013	0.013	0.010	0.012	0.016	0.013	0.014	0.010	0.009	0.011	0.013	0.012	34	○	○	○	○
A-6	0.014	0.010	0.012	0.024	0.018	0.012	0.011	0.011	0.009	0.012	0.010	0.012	0.012	0.014	0.015	0.009	0.007	0.011	0.010	0.010	0.011	0.012	0.010	0.012	0.012	33	○	○	○	○
A-7	0.010	0.009	0.009	0.015	0.010	0.007	0.011	**0.146**	0.053	0.014	0.011	0.009	0.011	0.010	0.011	0.010	0.014	0.010	0.009	0.013	0.011	0.009	0.010	0.028	0.019	52	○	○	○	○
A-8	0.016	0.016	0.018	0.014	0.015	0.014	0.015	0.011	0.029	0.047	0.051	0.025	0.023	0.019	0.020	0.016	0.020	0.014	0.015	0.016	0.017	0.041	0.027	0.019	0.022	60	○	○	○	○
A-9	0.040	0.031	0.023	0.022	0.020	0.024	0.078	0.041	0.018	0.024	0.048	0.028	0.079	**0.142**	**0.144**	0.018	0.045	**0.189**	0.030	0.042	0.053	0.042	0.037	0.042	**0.053**	**145**	×	○	×	×
A-10	0.037	0.040	0.038	0.037	0.042	0.048	0.068	0.076	**0.288**	**0.133**	**0.125**	0.065	0.065	0.073	0.086	0.024	**0.261**	0.047	0.034	0.037	0.045	0.047	0.040	0.036	**0.075**	**205**	×	○	×	×
A-11	0.015	0.012	0.012	0.009	0.010	0.010	0.006	0.009	0.011	0.010	0.010	0.011	0.011	0.009	0.012	0.008	0.011	0.008	0.018	0.015	0.020	0.020	0.014	0.016	0.012	33	○	○	○	○
A-12	0.019	0.020	0.018	0.021	0.019	0.019	0.019	0.019	0.020	0.017	0.018	0.016	0.018	0.014	0.008	0.010	0.016	0.010	0.015	0.016	0.016	0.016	0.016	0.018	0.017	46	○	○	○	○
	0	0	0	0	1	0	1	2	1	3	2	1	0	1	1	0	1	1	0	0	0	0	0	0	0.035	98				
	Comparison with Standard (1 h avarage value, number of exceedances of Japan standard (0.1ppm))																								Average					

2) TSP Monitoring Result and Comparison with Standard

Monitoring Station No.	TSP value (μg/m³)	Comparison with Standards EU limit (300 μg/m³)
A-1	**308**	×
A-2	264	○
A-3	175	○
A-4	198	○
A-5	195	○
A-6	173	○
A-7	209	○
A-8	200	○
A-9	**304**	×
A-10	**332**	×
A-11	213	○
A-12	222	○
Average	233	
Maximum	332	(A-10)
Minimum	173	(A-6)

3) PM_{10} Monitoring Result and Comparison with Standards

Monitoring Station No.	PM_{10} value (μg/m³)	Comparison with Standards	
		US (150 μg/m³)	Japan (100 μg/m³)
A-1	**197**	×	×
A-2	**174**	×	×
A-3	81	○	○
A-4	49	○	○
A-5	87	○	○
A-6	68	○	○
A-7	97	○	○
A-8	94	○	○
A-9	**198**	×	×
A-10	**205**	×	×
A-11	65	○	○
A-12	97	○	○
Average	118		
Maximum	205	(A-10)	
Minimum	49	(A-4)	

4)The Ratio of PM_{10} to TSP

Monitoring Station No.	TSP value (μg/m³)	PM_{10} value (μg/m³)	PM10/TSP (%)
A-1	**308**	**197**	64%
A-2	264	**174**	66%
A-3	175	81	46%
A-4	198	49	25%
A-5	195	87	45%
A-6	173	68	39%
A-7	209	97	47%
A-8	200	94	47%
A-9	**304**	**198**	65%
A-10	**332**	**205**	62%
A-11	213	65	31%
A-12	222	97	44%
Average			48%
Maximum	(A-2)		66%
Minimum	(A-4)		25%

*Legend: ×=exceeding standard ○=achiving standard

Table 8.2 Monitoring Results of SO_2, TSP, and PM10and Comparison with Standards (2)

Winter Season

1) SO_2 Monitoring Result and Comparison with Standards

Monitoring Point No.	Time																								24 h Average		Comparison with Standards (24 h avarage value)			
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	(ppm)	($\mu g/m^3$)	Applied to OMCO (EEC) (120 $\mu g/m^3$)	US (0.14 ppm)	Japan (0.04 ppm)	WHO (125 $\mu g/m^3$)
A-1	0.024	0.023	0.023	0.021	0.020	0.022	0.024	0.022	0.023	0.027	0.029	0.026	0.028	0.031	0.030	0.032	0.049	0.023	0.026	0.024	0.028	0.025	0.023	0.025	0.026	75	○	○	○	○
A-2	0.023	0.026	0.025	0.024	0.022	0.021	0.021	0.021	0.021	0.021	0.022	0.022	0.021	0.021	0.022	0.023	0.024	0.024	0.028	0.028	0.027	0.026	0.025	0.024	0.023	67	○	○	○	○
A-3	0.026	0.027	0.027	0.015	0.021	0.026	0.027	0.034	0.039	0.030	0.026	0.027	0.010	0.009	0.007	0.007	0.008	0.019	0.024	0.026	0.030	0.029	0.029	0.028	0.023	66	○	○	○	○
A-4	0.013	0.014	0.009	0.007	0.006	0.007	0.007	0.006	0.008	0.005	0.008	0.005	0.003	0.004	0.002	0.002	0.002	0.003	0.008	0.009	0.007	0.008	0.006	0.012	0.007	19	○	○	○	○
A-5	0.008	0.005	0.042	0.017	0.014	0.015	0.014	0.013	0.020	0.008	0.005	0.005	0.004	0.002	0.008	0.005	0.006	0.004	0.004	0.004	0.004	0.005	0.004	0.002	0.009	26	○	○	○	○
A-6	0.019	0.017	0.018	0.033	0.031	0.029	0.025	0.029	0.034	0.017	0.014	0.014	0.018	0.017	0.020	0.010	0.011	0.012	0.011	0.015	0.018	0.018	0.020	0.021	0.020	56	○	○	○	○
A-7	0.007	0.010	0.007	0.008	0.007	0.006	0.007	0.006	0.006	0.017	0.011	0.009	0.008	0.009	0.008	0.008	0.007	0.007	0.006	0.010	0.007	0.008	0.006	0.007	0.008	23	○	○	○	○
A-8	0.034	0.034	0.029	0.032	0.053	0.044	0.032	**0.105**	0.090	0.029	0.026	0.026	0.026	0.026	0.024	0.024	0.022	0.023	0.025	0.027	0.030	0.030	0.063	0.050	0.038	108	○	○	○	○
A-9	0.034	0.029	0.034	0.045	0.037	0.030	0.031	0.028	0.034	0.062	0.041	**0.104**	0.029	0.038	0.040	0.061	**0.111**	0.052	0.063	**0.835**	0.039	0.031	0.030	0.036	0.078	225	×	○	×	×
A-10	0.071	0.026	0.028	-	**0.147**	0.057	**0.150**	**0.189**	0.069	0.026	0.024	0.026	0.030	0.046	0.059	0.048	0.043	0.042	0.042	0.039	0.032	0.028	0.025	0.058	0.057	163	×	○	×	×
A-11	0.003	0.001	0.002	0.003	0.003	0.001	0.003	0.001	0.001	**0.147**	0.012	0.005	0.005	0.002	0.002	0.005	0.003	0.004	0.003	0.002	0.006	0.002	0.006	0.005	0.009	27	○	○	○	○
A-12	0.010	0.007	0.006	0.009	0.007	0.006	0.010	0.007	0.007	0.003	0.005	0.005	0.005	0.005	0.004	0.004	0.009	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.007	20	○	○	○	○
	0	0	0	0	1	0	1	2	0	1	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0.025	73				
	Comparison with Standard (1 h avarage value, number of exceedances of Japan standard (0.1ppm))																								Average					

2) TSP Monitoring Result and Comparison with Standard

Monitoring Station No.	TSP value ($\mu g/m^3$)	Comparison with Standards EU limit (300 $\mu g/m^3$)
A-1	96	○
A-2	83	○
A-3	62	○
A-4	49	○
A-5	77	○
A-6	128	○
A-7	113	○
A-8	268	○
A-9	289	○
A-10	208	○
A-11	123	○
A-12	94	○
Average	133	
Maximum	289	(A-9)
Minimum	49	(A-4)

3) PM_{10} Monitoring Result and Comparison with Standards

Monitoring Station No.	PM_{10} value ($\mu g/m^3$)	Comparison with Standards US (150 $\mu g/m^3$)	Japan (100 $\mu g/m^3$)
A-1	58	○	○
A-2	38	○	○
A-3	43	○	○
A-4	33	○	○
A-5	51	○	○
A-6	85	○	○
A-7	54	○	○
A-8	203	×	×
A-9	188	×	×
A-10	138	○	×
A-11	72	○	○
A-12	52	○	○
Average	85		
Maximum	203	(A-8)	
Minimum	33	(A-4)	

4) The Ratio of PM_{10} to TSP

Monitoring Station No.	TSP value ($\mu g/m^3$)	PM_{10} value ($\mu g/m^3$)	PM10/TSP (%)
A-1	96	58	60%
A-2	83	38	45%
A-3	62	43	70%
A-4	49	33	68%
A-5	77	51	66%
A-6	128	85	66%
A-7	113	54	48%
A-8	268	203	76%
A-9	289	188	65%
A-10	208	138	66%
A-11	123	72	58%
A-12	94	52	56%
Average			62%
Maximum	(A-8)		76%
Minimum	(A-2)		45%

*Legend: ×=exceeding standard ○=achiving standard

Table 8.3 Monitoring and Chemical Analysis Results of Dustfall (1)

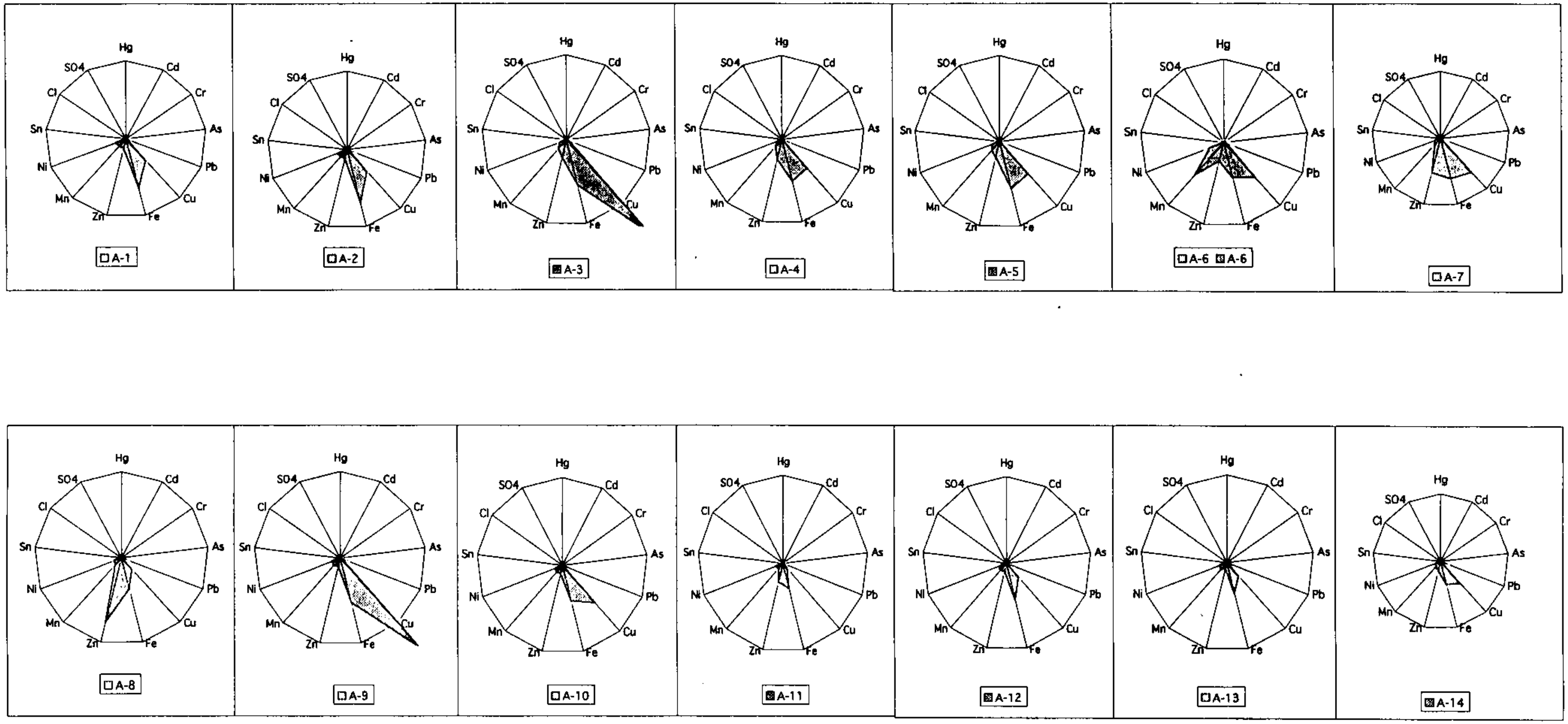
Summer Season

Monitoring Point No.	Amount of Dustfall (ton/km²/30days)	Heavy Metal Concentration (mg/kg)											Ion (g/kg)	
		Hg	Cd	Cr	As	Pb	Cu	Mn	Fe	Ni	Sn	Zn	Cl^-	SO_4^{2-}
A-1	0.69	1.6	3.8	231	4.5	152	2,617	875	45,380	951	53	867	135	22
A-2	0.42	1.6	3.1	200	6.3	188	2,656	825	48,880	919	50	825	126	19
A-3	0.67	2.0	3.9	271	7.5	314	10,160	969	38,430	561	43	1,494	119	18
A-4	0.62	2.1	4.3	149	7.2	85	3,212	813	36,170	460	43	1,711	121	18
A-5	0.98	1.3	2.7	137	5.6	81	3,505	960	39,810	591	24	1,355	110	16
A-6	0.82	5.3	17.0	68	93.2	339	3,932	3,627	30,150	1,203	17	1,644	99	15
A-7	1.25	1.2	2.1	199	8.9	106	4,702	863	42,960	626	13	3,681	99	15
A-8	2.90	0.4	0.9	142	3.9	73	1,267	746	26,160	608	9	5,417	129	20
A-9	0.96	1.2	2.8	88	11.6	165	9,650	769	37,440	713	14	661	12	18
A-10	1.64	0.5	1.6	82	7.1	96	4,032	744	29,280	661	13	680	141	22
A-11	2.10	0.5	1.3	74	6.0	63	574	583	21,060	613	4	1,536	19	29
A-12	2.12	0.5	1.2	83	6.1	99	1,564	770	31,020	670	1	714	149	22
A-13	2.12	0.4	1.2	77	6.3	62	1,468	779	25,910	604	1	486	160	24
A-14	1.45	0.6	1.8	87	9.5	73	3,106	752	24,900	596	2	989	128	19
Average	1.34	1.4	3.4	135	13.1	135	3,746	1,005	34,111	698	21	1,576	111	20
Maximum	2.90	5.3	17.0	271	93.2	339	10,160	3,627	48,880	1,203	53	5,417	160	29
Minimum	0.42	0.4	0.9	68	3.9	62	574	583	21,060	460	1	486	12	15

Table 8.3 Monitoring and Chemical Analysis Results of Dustfall (2)

Winter Season

Monitoring Point No.	Amount of Dustfall (ton/km²/30days)	Heavy Metal Concentration (mg/kg)											Ion (g/kg)	
		Hg	Cd	Cr	As	Pb	Cu	Mn	Fe	Ni	Sn	Zn	Cl^-	SO_4^{2-}
A-1	1.01	1.9	4.2	248	5.1	138	2,413	692	32,395	622	41	1,134	89	21
A-2	1.53	2.6	2.0	263	8.2	141	1,948	818	40,138	813	40	1,418	35	26
A-3	0.81	2.5	3.1	242	7.1	273	8,854	842	43,628	582	37	1,113	89	17
A-4	1.89	1.2	6.7	139	6.7	68	3,684	685	40,868	508	37	1,852	95	19
A-5	2.49	2.1	4.8	141	6.0	77	4,087	843	37,622	485	30	1,624	106	19
A-6	2.19	5.8	2.4	152	7.1	85	4,132	914	39,564	524	34	1,588	71	22
A-7	1.58	2.6	3.3	213	9.3	98	4,618	924	40,453	589	21	2,937	118	18
A-8	1.28	4.9	1.2	148	4.7	80	2,008	805	31,227	660	14	3,617	106	20
A-9	0.68	4.1	2.6	102	10.3	148	7,853	582	32,934	842	20	489	26	17
A-10	0.44	3.5	2.0	90	5.8	68	4,421	810	30,118	707	18	543	89	20
A-11	2.87	3.0	5.9	81	4.2	43	1,004	622	27,431	585	9	2,007	118	19
A-12	1.05	3.1	1.9	78	6.7	79	2,010	593	28,693	612	5	585	106	22
A-13	1.43	3.4	2.1	70	6.1	74	1,623	825	29,418	693	6	564	142	21
A-14	0.52	3.2	2.0	98	8.3	88	2,934	768	27,742	714	9	1,428	71	20
Average	1.41	3.1	3.2	148	6.8	104	3,685	766	34,445	638	23	1,493	90	20
Maximum	2.87	5.8	6.7	263	10.3	273	8,854	924	43,628	842	41	3,617	142	26
Minimum	0.44	1.2	1.2	70	4.2	43	1,004	582	27,431	485	5	489	26	17



Summer Season

Figure 8.2 Chemical Analysis Results of Dustfall (1)

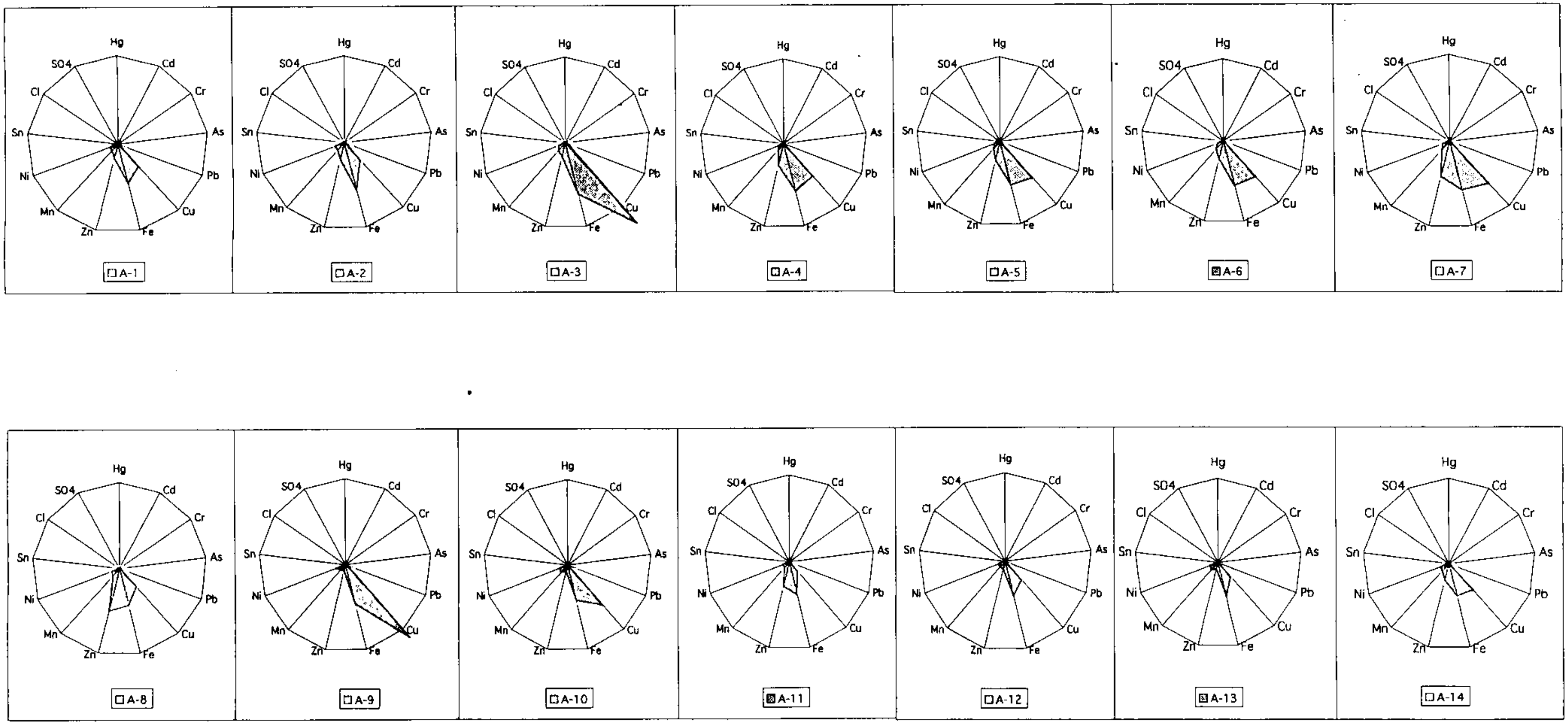


Figure 8.2 Chemical Analysis Results of Dustfall (2)

- 1-hour average concentrations: 15 data measured at A-1, A-2, A-7, A-9 and A-10 exceeded Japan's standard;
- 24-hour average concentrations: 4 data measured at A-1, A-2, A-9 and A-10 exceeded Japan's standard and WHO, however, all 24-hour average concentrations were below US standard.

b. Winter Season

The 1-hour average SO_2 concentrations varied from 0.001 ppm (3 $\mu g/m^3$) to 0.835 ppm (2,404 $\mu g/m^3$). The maximum concentration of 0.835 ppm measured at point of A-9. The 24-hour average SO_2 concentrations were in the range of 0.007 ppm (19 $\mu g/m^3$) to 0.078 ppm (225 $\mu g/m^3$). The maximum concentration of 0.078 ppm was measured at point of A-9.

The ambient air quality standard for SO_2 applied to OMCO is EEC standard for 24-hour average concentration of 120 $\mu g/m^3$. The 24-hour average SO_2 concentration of A-9 and A-10 exceeded EEC standard. If the measured SO_2 concentrations are compared with other established SO_2 standard of Japan (1-hour average: 0.1 ppm and 24-hour average: 0.04 ppm), US (24-hour average: 0.14 ppm) and WHO (24-hour average: 125$\mu g/m^3$), the status of compliance with these standards is as follows:

- 1-hour average concentrations: 8 data measured at A-8, A-9, A-10 and A-11 exceeded Japan's standard;
- 24-hour average concentrations: 2 data measured at A-9 and A-10 exceeded Japan's standard and WHO, however, all 24-hour average concentrations were below US standard.
- 24-hour average concentrations: 4 data measured at A-1, A-2, A-9 and A-10 exceeded standard of Japan and WHO, however, all 24-hour average concentrations were below US standard.

(2) TSP

a. Summer Season

The 24-hour average TSP concentrations varied from 173 to 332 $\mu g/m^3$. The highest concentration of 332 $\mu g/m^3$ was measured at A-10. Oman's ambient air quality standard for TSP has not been stipulated. If the measured TSP concentrations are compared with EU 24-hour average limit concentration of 300 $\mu g/m^3$, TSP measured at A-1, A-9 and A-10 exceed the limit.

b. Winter Season

The 24-hr average TSP concentrations varied from 49 to 289 $\mu g/m^3$. The highest concentration of 289 $\mu g/m^3$ was measured at A-9. Oman's ambient air quality standard for TSP has not been stipulated. If the measured TSP concentrations are compared with EU 24-hour average limit concentration of 300 $\mu g/m^3$, all of measured TSP concentrations are below the limit.

(3) PM_{10}

a. Summer Season

The 24-hr average PM_{10} concentrations varied from 49 μg/m^3 to 205 μg/m^3. The highest concentration of 205 μg/m^3 was measured at A-10. Oman's ambient air quality standard for PM_{10} has not been stipulated. If the measured PM_{10} concentrations are compared with 24-hour average standard of Japan (100 μg/m^3) and US (150 μg/m^3), the status of compliance with these standards is as follows:

- Comparison with Japan's standard: Data measured at A-1, A-2, A-9 and A-10 exceeded the standard;
- Comparison with US standard: Data measured at A-1, A-2, A-9 and A-10 exceeded the standard.

All points with the ratio of PM_{10} to TSP over 60 % exceeded the US standard for PM_{10}, while the ratio of other points was under 50 %.

b. Winter Season

The 24-hour average PM_{10} concentrations varied from 33 to 203 μg/m^3. The highest concentration of 203 μg/m^3 was measured at A-8. Oman's ambient air quality standard for PM_{10} has not been stipulated. If the measured PM_{10} concentrations are compared with 24-hour average standard of Japan (100 μg/m^3) and US (150 μg/m^3), the status of compliance with these standards is as follows:

- Comparison with Japan's standard: Data measured at A-8, A-9 and A-10 exceeded the standard;
- Comparison with US standard: Data measured at A-8 and A-9 exceeded the standard.

The ratio of PM_{10} to TSP of all points except for A-2 and A-7 exceeded 50 %.

(4) Dustfall

a. Summer Season

Measured dustfall masses varied from 0.42 t/km^2/30days to 2.90 t/km^2/30days. The maximum value of 2.90 t/km^2/30days was measured at A-8. British Columbia of Canada establishes the following dustfall standards for mining and smelting industries.

- Maximum desirable standards : 1.7 mg/dm^2/day (5.1 t/km^2/30days);
- Maximum acceptable standards: 2.9 mg/dm^2/day (8.7 t/km^2/30days).

If measured dustfall masses are compared with the above British Columbia standards all measured values are well below the standards. Heavy metals, SO_4 and Cl concentrations in the collected dustfall samples were analyzed chemically and the results are shown in Table 8.3 and Figure 8.2. The concentration decrease with distance from the OMCO plant site and monitoring points located in the predominant wind direction (A-1, A-2, A-3, and A-9) show relatively high concentrations.

b. Winter Season

Measured dustfall masses varied from 0.44 $t/km^2/30days$ to 2.87 $t/km^2/30days$. The maximum value of 2.87 $t/km^2/30days$ was measured at A-11. If measured dustfall masses are compared with the British Columbia standards, all measured values are well below the standards. Heavy metals, SO_4 and Cl concentrations in the collected dustfall were analyzed chemically and the results are shown in Table 8.3 and Figure 8.2. The concentration decrease with distance from the OMCO plant site and monitoring points located in the predominant wind direction (A-1, A-2, A-3, and A-9) show relatively high concentrations.

(5) Existing Ambient Air Quality Conditions

Emissions from existing sources largely affect the ambient air quality of the surrounding area. Emitted air pollutants are dispersed by wind direction, wind speed, temperature (which contributes to plume rise), and the turbulence of the lower atmosphere. The affected area of emissions from a 100 m-height stack height is generally limited to 10 km downwind from a source. Within a 20km-radius of OMCO plant in which ambient air quality monitoring points are deployed, the OMCO plant is the only emission source. Based on the monitoring results described above, the ambient air quality in the area surrounding the Sohar Mine site is affected by emissions from the OMCO plant.

The existing ambient air quality conditions are summarized as follows:

- The SO_2 concentrations at four monitoring points located downwind of the OMCO plant exceeded EEC SO_2 standard applied to OMCO plant (24-hour average concentration of 120 $\mu g/m^3$) and exceeded SO_2 Japan's standard (1-hour average: 0.1 ppm and 24-hour average: 0.04 ppm) and WHO (24-hour average: 125 $\mu g/m^3$) if compared with these standards. However, the concentrations were below the US standard (24-hour average: 0.14 ppm).
- The TSP concentrations at monitoring points located downwind of OMCO's plant were higher than other points. The TSP concentrations at three points exceeded 24-hour average EU limit of 300 $\mu g/m^3$ if compared with this standard.
- The PM_{10} concentrations at monitoring points located downwind of OMCO's plant were higher than other points. The PM_{10} concentrations at four points exceeded Japan's 24-hour average standard (100 $\mu g/m^3$) and the US standard (150 $\mu g/m^3$), if compared with these standards.
- SO_2 background concentrations are considered to be in the range of 27 to 33 $\mu g/m^3$ based on the

monitoring data at control point A-11.

- SO_2 concentrations at A-2, A-3, A-4 and A-5 are similar to the concentrations of A-11 that are considered to be background concentrations that are representative of the area surrounding the Sohar Mine sites. These points were not considered to be affected by the SO_2 emissions from OMCO plant.
- There are sensitive receptors, such as residences near points A-1 and A-2 where SO_2 concentrations exceeded the SO_2 standard. SO_2 emissions from OMCO's plant might affect to the resident people. However, based only on monitoring once in each summer and winter season, it is difficult to conclude whether the SO_2 emissions from OMCO's plant effects the resident people.
- The principal constituents of the particulate matter emitted from copper smelting are copper and iron oxides. Other heavy metals including arsenic, antimony, cadmium, lead, mercury and zinc are also present. The principal constituents of heavy metal in the collected dustfall samples at all monitoring points are copper and iron. Other heavy metals emitted from copper smelting are also contained in the collected dustfall. There is a decreasing tendency for the concentrations of heavy metals at each monitoring point in proportion to the distance from OMCO's plant. Emitted particulate and fugitive dust from OMCO's plant are considered to be scattered over a large area. Concentrations of copper and iron that are the principal constituents of the particulate matter emitted from the copper smelter are higher than other heavy metals. These results are considered to be associated with the OMCO plant operation.
- Ambient air quality standards are classified into three categories in terms of objectives: desirable, acceptable, and tolerable. The desirable levels are the long-term goal for air quality and provide a basis for an anti-degradation policy for unpolluted parts of the country. The acceptable levels are designed to protect the soil, water, vegetation, materials, animals, visibility, personal comfort, and well-being. The tolerable levels define time-based concentrations of air contaminants that, due to a diminishing margin of safety, require appropriate action to be taken without delay to protect the health of the general population.

8.2 Meteorological Monitoring

The main objective of the meteorological monitoring was as follows:

- To evaluate dispersion characteristics of the atmosphere;
- To evaluate relationship between ambient air quality and meteorological conditions;
- To make input data.

Monitoring parameter, station, instrument and duration of air dispersion model are summarized in Table 8.4.

Table 8.4 Summary of Meteorological Monitoring Method

Parameter	Number of Point	Instrument	Duration
Wind Speed	1	cup anemometer	9 months
Wind Direction	1	wind vane	9 months
Rainfall	1	tipping bucket rain gauge	9 months
Solar Radiation	1	pyranometer	9 months
Air Temperature	1	resistance temperature detector	9 months
Relative Humidity	1	polymer resistor sensor	9 months

8.2.1 Monitoring Parameters

The following 6 parameters have been monitored:

- Wind speed;
- Wind direction;
- Rainfall;
- Solar radiation;
- Air temperature;
- Relative humidity.

8.2.2 Monitoring Stations

Based on the consideration of topography, obstruction, existing meteorological stations, existing emission source, accessibility and vandalism, one meteorological monitoring station was selected as shown in Figure 8.3.

8.2.3 Monitoring Instrument

The following instruments were used for the monitoring of each parameter.

- Wind speed: cup anemometer;
- Wind direction: wind vane;
- Rainfall: tipping bucket rain gauge;
- Solar radiation: dynamometer;
- Air temperature: resistance temperature detector;
- Relative humidity: polymer resistor sensor.

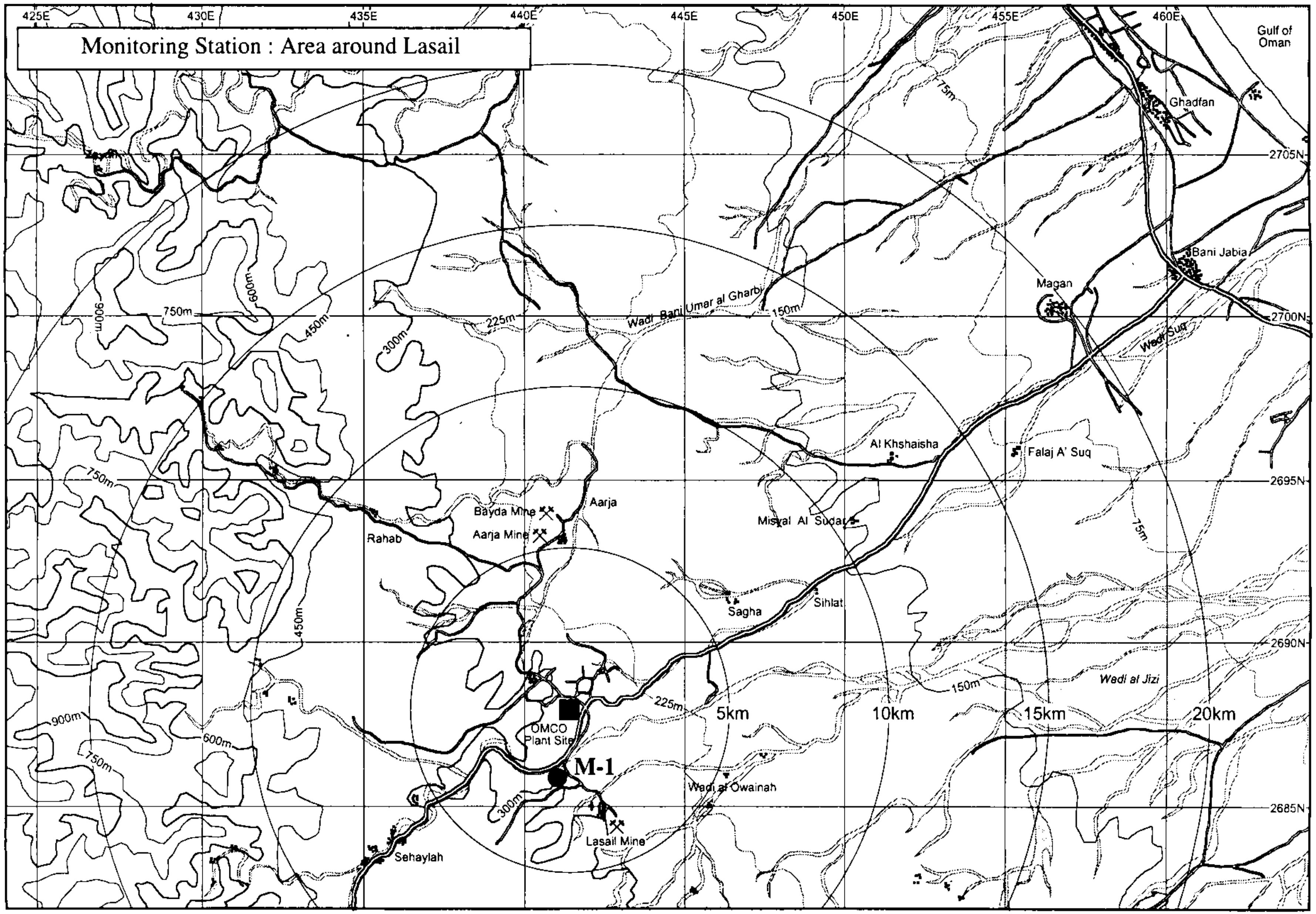


Figure 8.3 Meteorological Monitoring Point

8.2.4 Monitoring Duration

Meteorological monitoring is supposed to be performed for 9 months from June 2000.

8.2.5 Monitoring Result

The monitoring result for each parameter during July 2000 is summarized in Table 8.5 (refer to Appendix-8). The wind rose in July 2000 is shown in Figure 8.4.

(1) Wind Speed

The average monthly wind speed of 3.0 m/sec was generally weak or moderate. The maximum wind speed was 11.8 m/sec. Wind speed records over 5 m/sec occupied 17 % of the total record from June 2000 to February 2001. It seems that the wind speed had a daily variation pattern, such as, relatively strong wind speed over 5 m/sec occurred during certain time period of a day between 1 and 3 PM.

(2) Wind Direction

The prevailing wind directions were from east (E), east-northeast (ENE), and northeast (NE), which were wind directions blowing from the sea. It seems that the wind direction also had daily variation pattern, such as, east northeastern and eastern wind appeared from morning to evening and west southwestern and western wind appeared at midnight.

(3) Rainfall

The total rainfall was 15.9 mm from June 2000 to February 2001.

(4) Solar Radiation

Solar radiation had daily variation pattern according to the presence/absence and angle of sun. The maximum daily solar radiation was around 800~1,000 W/m^2 in summer season and around 600~800 W/m^2 in winter season.

(5) Air Temperature

The monthly average air temperature from June 2000 to February 2001 was 26.7 ^{o}C, ranging from 9.4 to 44.1 ^{o}C. Air temperature record over 40^{o}C was occupied 3 % of the total record from June 2000 to February 2001.

Table 8.5 Meteorological Monitoring Result of Each Parameter from June 2000 to February 2001

	Wind speed (m/s)	Wind direction (degrees)	Rainfall (mm)	Solar radiation (watts/m^3)	Temperature (℃)	Relative humidity (%)
Min.	0.4	—	—	—	9.4	11.0
Max.	11.8	ENE	—	978	44.1	100.0
Ave.	3.0	—	—	—	26.7	50.8
Total	—	—	15.9	—	—	—

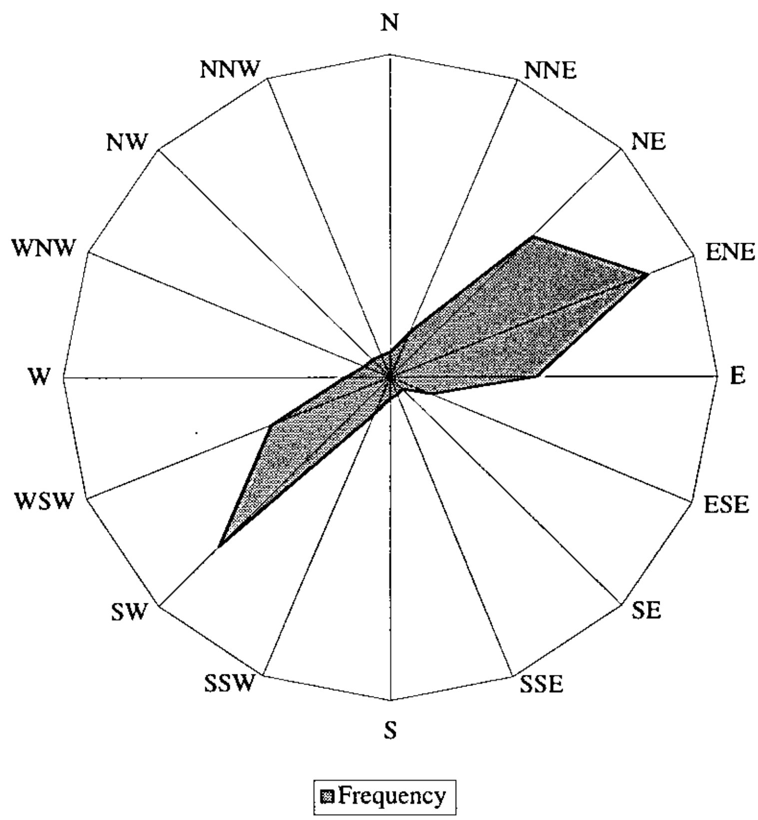


Figure 8.4 Wind Rose from June 2000 to February 2001

(6) Relative Humidity

The relative humidity was comparably high from night to morning ranging from 60 to 100 %. Low humidity ranging from 10 to 50 % appeared in the afternoon.

8.3 Data Collection of Stack Emission Gas of OMCO Plant

Emission gas data from stack are required for air dispersion modeling. OMCO provided the following data:

- Physical stack height (m): 100.85 m;
- Stack exit inner diameter (m): 1.872 m;
- Stack gas emission rate (m/sec): 18.8 m/sec;
- Stack gas exit temperature (K): 523 K;
- SO_2 emission rate (g/sec): 1,226 g/sec.

8.4 Data Collection of Existing Ambient SO_2 Measured by OMCO

OMCO has been conducting ambient SO_2 monitoring at 10 monitoring stations. OMCO provided SO_2 monitoring data of last 5 years at 8 monitoring stations.

The ambient air quality standard for SO_2 adopted by OMCO is EEC standard of 120 $\mu g/m^3$ for 24-hour average concentration. The SO_2 data of last 5 years exceeded EEC standard twice, such as, at A-2 of 131 $\mu g/m^3$ on March 23 to 24 1998, and at A-9 of 127 $\mu g/m^3$ on March 17 to 18 2000. These two values were recorded both in March 1998 at monitoring stations SW from OMCO plant.

8.5 Air Dispersion Modeling Analysis

This section describes the air dispersion modeling that was performed to assess the impacts on ambient air quality of SO_2 resulting from normal operation of OMCO's plant. The analyses were conducted to compare the predicted SO_2 concentrations with applicable ambient air quality standards for SO_2.

The following sections describe the selection of an appropriate model, the methodology of the modeling approach, the data used as input to the model (meteorology, source, and receptor parameters), and the modeling results.

8.5.1 Model Selection

Air pollutants emitted from a source are transported by the wind and dispersed by turbulent diffusion in the atmosphere. The behavior of the plume varies according to the atmospheric conditions, such as, wind velocity, turbulence intensity, thermal stability, and terrain conditions. There are several kinds of models that can be used to simulate the behavior of air pollutants:

- Gaussian plume models;
- Numerical models;
- Physical models.

(1) Gaussian Plume Models

Gaussian plume models are the most widely used techniques for estimating the impact of air pollutants. Gaussian plume models are usually less expensive to operate and easier to construct. In a Gaussian dispersion model, pollutant concentrations are assumed to be distributed normally (i.e., Gaussian distribution curve) about the centerline of the plume, a relationship that has been observed to occur for releases of gases and small particles from many types of sources. The plume travels with a uniform wind velocity downwind from the source. Its dimensions perpendicular to the wind direction are described by dispersion coefficients as a function of downwind distance from the source. The Gaussian plume model is based on the following assumptions:

- Steady-state conditions, which imply that all variables and parameters are constant in time;
- Homogeneous flow, which implies no spatial variability in the meteorological parameters;
- The coordinate system is directed with its x-axis into direction of the flow, the lateral and vertical components of the time averaged wind vector are set to zero.

(2) Numerical Models

Numerical models are based on the pollutant advection and dispersion theory. Pollutant concentration is predicted by solving the governing equations along with initial and boundary conditions, which describe the pollutant advection and dispersion in the atmosphere.

Various numerical techniques are used to solve the basic equation because the basic equation cannot be solved analytically. One of the biggest problems with numerical models is requiring many ambient air quality data and meteorological data as a function of time at multi-locations to calibrate the model to existing condition. The output quality of numerical models is dependent on input data quality. The cost of simulation by using numerical models is relatively high due to requirement of much data and computer time. Numerical models may be more appropriate than Gaussian models for area source, urban applications that involve reactive pollutants, but they require much more extensive input databases and resources and, therefore, are not as widely applied.

(3) Physical Models

Dispersion of air pollutants is predicted by using a wind tunnel in which analogous scaled physical model is placed. Wind tunnel tests are generally performed by releasing known quantities of tracer gas (such as ammonia gas) from the emission source in the wind tunnel and measuring the resultant ambient concentrations. The pollutant concentrations measured in the wind tunnel are converted to equivalent atmospheric concentrations through the use of appropriate scaling relationships. The most significant problem in physical models is that of ensuring scaling (or similarity) between conditions in the model and in realistic atmosphere, for example, modeling of emission buoyancy and momentum effects. It usually takes a long time to make a scale model. A wind tunnel test is a complex process requiring a high level of technical expertise, as well as access to the necessary facilities. The costs of a wind tunnel test are rather high. Nevertheless, physical modeling may be useful for complex flow situations, such as building, terrain or stack downwash conditions, plume impact on elevated terrain, diffusion in an urban environment, or diffusion in complex terrain. It is particularly applicable to such situations for a source or group of sources in a geographic area limited to a few square kilometers.

Key characteristics of each model including terrain (flat, complex), land use (urban, rural), reliability, reproducibility, applicability, complexity of environmental conditions, required data, required hardware were considered to select an appropriate model. Based on widespread acceptability, validated experience on real data, availability of input data, easy running on personal computer and versatility, the U.S. Environmental Protection Agency approved model of Industrial Source Complex Short Term version 3 (ISCST3) was selected to perform the air dispersion modeling. The ISCST3 model is a straight line, steady state Gaussian dispersion model used to predict ground level concentrations over terrain at or below plume height, within approximately 20 km from a source. The model uses hourly meteorological data to calculate average ground level concentrations over various time periods, ranging from one hour to one year. ISCST3 has been used in a number of projects, including power plant, gas processing plant, crude oil refinery, LNG and mining.

The key characteristics of the each model are summarized in Table 8.6.

Table 8.6 Comparison of Characteristics between Simulation Models

Type of Model	Terrain		Land Use		Pollutant			Emission Source			Downwash/ Downdraft	Time Scale	
	Flat	Complex	Urban	Rural	SOx	NOx	Particulate	Point	Line	Area		Short Term	Long Term
Gaussian Plume Model	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Numerical Model	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Physical Model	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No

Type of Model	Required Hardware	Inversion Layer	Simulation Area		Flexibility to case study	Required Time	Applied Project	Cost	Model Calibration	Simulation Result	Selected Model
			Near Field	Far Field							
Gaussian Plume Model	Computer	Yes	Yes	Yes	Yes	Short	Industry, Mining, Road	Low	Short Time	Two/Three Dimensions	ISCST3*
Numerical Model	Computer	Yes	Yes	Yes	No	Long	Industry, Road, Facility Design	High	Time Consuming	Two/Three Dimensions	
Physical Model	Wind Tunnel	No	Yes	No	No	Long	Industry, Road, Facility Design	High	Time Consuming	Two Dimensions	

* Industrial Source Complex Short Term Version 3, USEPA approved Model

8.5.2 Air dispersion Modeling

The basic equation used for ISCST3 model of the continuous point source is the standard Gaussian plume model equation expressed by:

$$C=\frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right)\left\{ \exp\left[-\frac{1}{2}\frac{(z-He)^2}{\sigma_z^2}\right] + \exp\left[-\frac{1}{2}\frac{(z+He)^2}{\sigma_z^2}\right]\right\}$$

Where,

C: pollutant concentration (µg/m^3)

Q: pollutant emission rate from the source (g/sec)

u: mean horizontal wind speed (m/sec)

He: effective stack height (m)

σ_y, σ_z: horizontal and vertical dispersion coefficient as a function of downwind distance, respectively (m)

Data required for input to the ISCST3 model include source characteristics (stack height and inner diameter, emission rate of pollutant, exit gas temperature and exit gas velocity), the locations of sources, hourly wind speed, wind direction, atmospheric stability and mixing height and the locations of the selected receptors.

8.5.3 Model Validation

The ISCST3 selected model for use in this study was validated based on the comparison of the predicted SO_2 concentrations with the field monitoring results of SO_2. SO_2 ground-level concentrations at twelve monitoring points (A-1 to A-12) for summer and winter seasons were predicted by using ISCST3, emission data of OMCO and site meteorological data at M-1. The predicted SO_2 concentrations showed good agreement with field monitoring results as shown in Figure 8.5. The ISCST3 can be used to predict SO_2 ground-level concentrations.

8.5.4 Meteorological Data

Atmospheric dispersion is a function of wind speed, duration and direction of wind, atmospheric stability, and mixing height. ISCST3 requires sequential hourly meteorological data of wind speed, wind direction, ambient temperature, atmospheric stability and mixing height. The ISCST3 uses six atmospheric stability categories, known as the Pasquill-Gifford stability classes. These stability classes range from extremely unstable, to neutral, to stable conditions as follows:

- A : Extremely Unstable Conditions;
- B : Moderately Unstable Conditions;
- C : Slightly Unstable Conditions;
- D: Neutral Conditions;
- E: Slightly Stable Conditions;
- F: Moderately Stable Conditions.

Unstable conditions are primarily associated with daytime heating, which results in enhanced turbulence levels. Stable conditions are associated primarily with nighttime cooling which results in suppressed turbulence levels. Neutral conditions are primarily associated with high wind speeds.

Wind blowing over the surface of the earth develops a turbulent, well-mixed layer. This layer is referred to, as the mixing layer and the top of this layer is the mixing height. Air pollutant emitted into this layer can be trapped below the mixing height. Thus, the properties of the mixing layer determine how serious air pollution is in a given region.

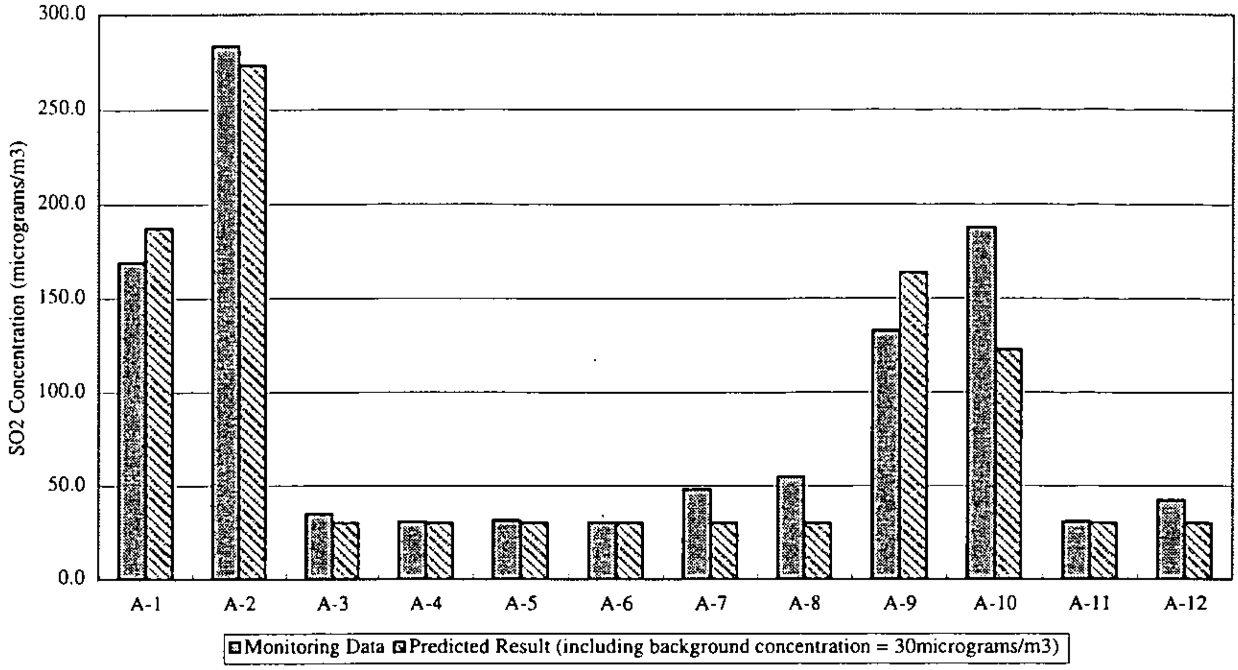


Figure 8.5 Comparison between Field Monitoring Results and Predicted Results (1)

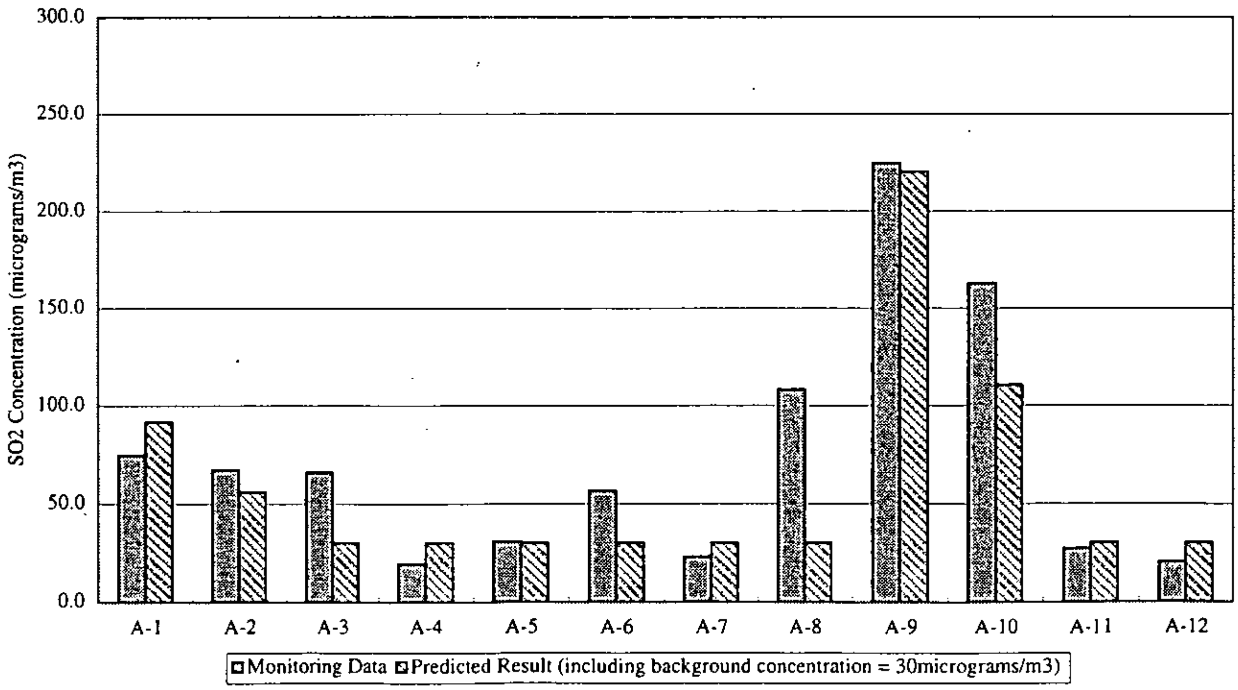


Figure 8.5 Comparison between Field Monitoring Results and Predicted Results (2)

The following meteorological data of 1999 measured at the nearest meteorological station from the OMCO plant site were used in the dispersion analysis as it provided the most readily and reasonably available meteorological data set for the ISCST3 model.

- Surface meteorological data at Majis;
- Upper air data at the Abu Dhabi Airport;
- Surface meteorological data at the Abu Dhabi Airport.

The nearest upper air meteorological station is located at Seeb airport and Abu Dhabi airport. The frequency of measurement is once per day at the Seeb Airport, and twice per day at the Abu Dhabi airport. Therefore, twice-daily upper air data measured at the Abu Dhabi airport was used for the ISCST3 modeling. Surface observations consist of hourly measurements of wind direction, wind speed and cloud cover. Twice-daily radio-sonde measurement data at the Abu Dhabi airport were used to estimate a mixing height.

These surface and upper air data were processed into a format suitable for ISCST3 dispersion modeling by USEPA program PCRAMMET, which is a meteorological processor, used for preparing data for ISCST3. PCRAMMET utilizes the Turner Classification Scheme to estimate the atmospheric stability developed by Pasquill-Gifford. Using the surface observations of wind speed and cloud cover combined with an estimate of solar insolation based on solar altitude, a stability class category is assigned for each hour of meteorological surface data. The twice-daily mixing height values are interpolated to obtain hourly mixing height values. Hourly output data from PCRAMMET were used for meteorological data input to ISCST3.

8.5.5 Receptor Grid

The modeling area 20 km x 20 km was divided into a rectangular grid system composed of 500 m by 500 m grid cells, and individual receptor points were also placed at the residential area. The receptor grid consists of 1,600 receptor points covering the 20 km x 20 km of the modeling area. The discrete receptors were also place at 10 points considered as sensitive receptors.

8.5.6 Modeling Case

Current operation case was simulated. The following SO_2 emission data of current operation required for ISCST3 was prepared based on the analysis of process flow diagrams and mass balance data provided by OMCO.

- Physical stack height (m) : 100.85 m;
- Stack exit inner diameter : 1.872 m;

- Stack gas exit velocity : 18.8 m/sec;
- Stack gas exit temperature : 523 K;
- SO_2 emission rate : 38,682 t/year (1999).

8.5.7 Predicted Results

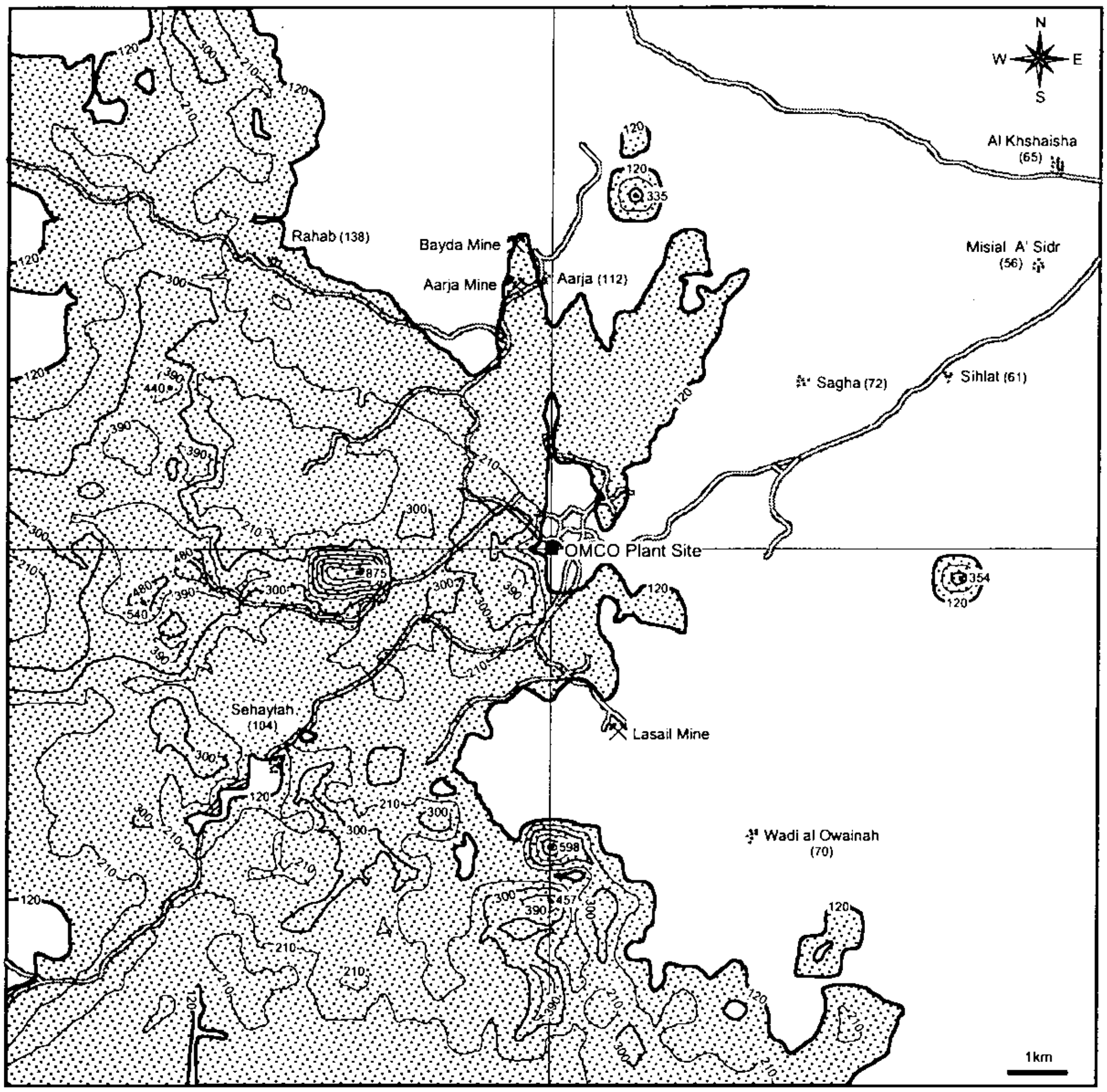
Figures 8.6 and 8.7 summarize the predicted results over 20km x 20km area for the current OMCO plant operation case. The Figures indicate:

- Maximum 24-hour average ground-level SO_2 concentrations;
- Annual average ground-level SO_2 concentrations.

Predicted concentrations at the sensitive receptors (residential areas) are shown in Table 8.7.

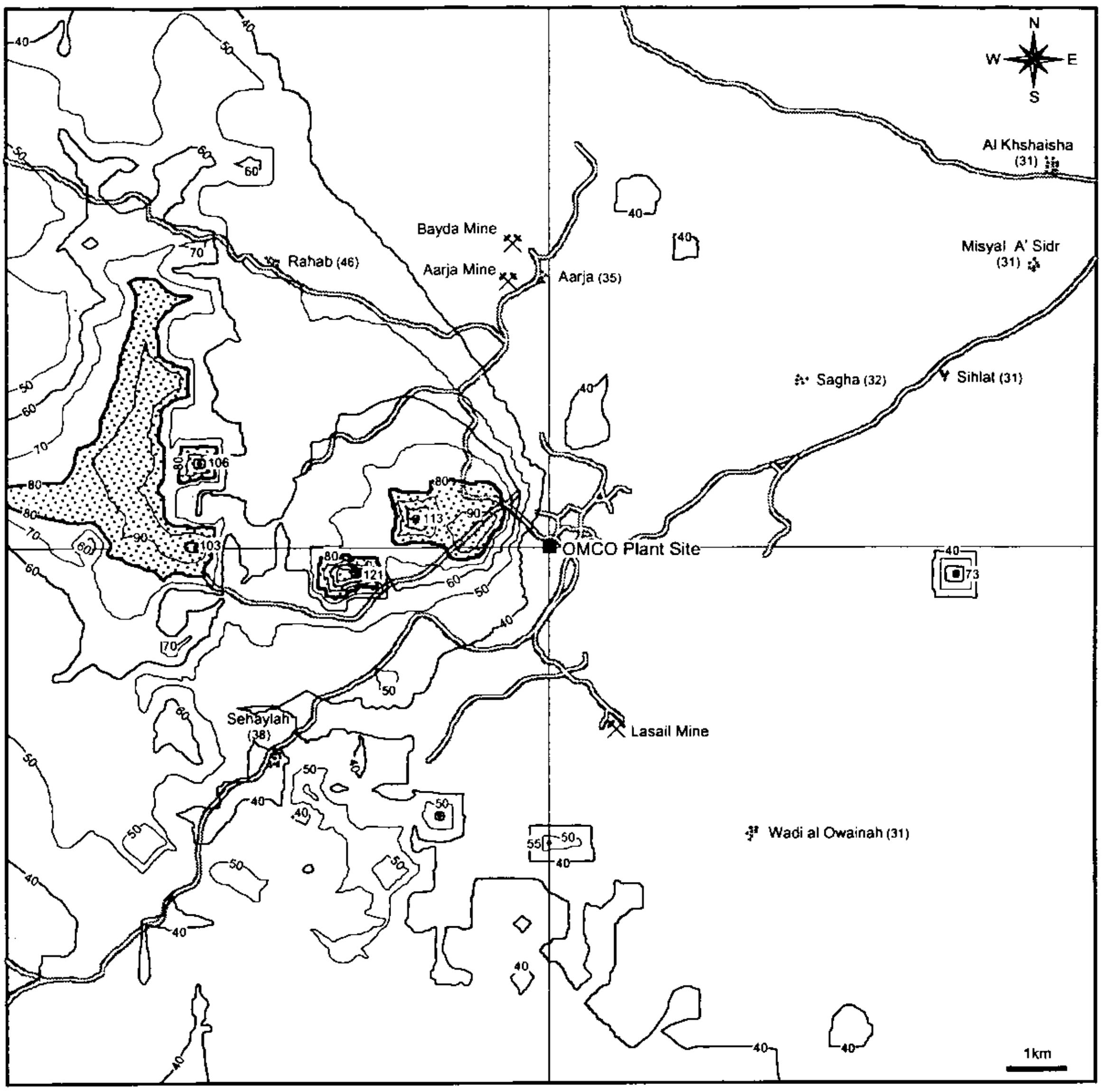
The predicted results of ground-level SO_2 concentration show that SO_2 disperses westerly downwind area of OMCO plant. The areas with hachure marks in the figures indicate the areas exceed the applicable standards for SO_2 (24-hour average: 120 $\mu g/m^3$, annual average: 80 $\mu g/m^3$). The predicted maximum concentration was 875 $\mu g/m^3$ for 24-hour average and 121 $\mu g/m^3$ for annual average. Both of maximum concentrations occur in the same area located approximately 3.5 km west of OMCO plant.

The predicted results indicate that emissions from OMCO plant contribute to exceed the SO_2 standards. Appropriate mitigation measures are required to reduce the emissions.



Unit: μ g/m^3
Interval between contour lines : 90 μ g/m^3
: area exceeded the standard

Figure 8.6 Isopleth Map of SO_2 24-Hour Maximum Concentration



Unit: μ g/m^3
Interval between contour lines : 10μ g/m^3
: area exceeded the standard

Figure 8.7 Isopleth Map of SO_2 Annual Average Concentration

Table 8.7 SO_2 Concentration Prediction Result in Sensitive Areas by ISCST3Air Dispersion Simulation Model

1. Annual Average Concentration

unit: μ g/m³

No.	Area Name	Direction and Distance from OMCO	Predicted Result	Comparison with Annual Standard (US; 80 μ g/m³)
1	Magan	NE 20km	30.9	○
2	Falaj A'Suq	ENE 15km	30.9	○
3	Al Khshaisha	NE 12km	31.3	○
4	Misial A'Sidr	ENE 11km	31.3	○
5	Sihlat	ENE 8km	31.3	○
6	Sagha	ENE 5km	32.3	○
7	Wadi al Owainah	SSE 5km	31.4	○
8	Aarja	N 5km	34.8	○
9	Rahab	NW 7km	45.8	○
10	Sehaylah	SW 7km	37.6	○

Legend: ○ = satisfy standard × = exceed standard

2. 24-hour Average Concentration

unit: μ g/m³

No.	Area Name	Direction and Distance from OMCO	Highest 24h Average Predicted Result	Highest 24h Average Concentration Predicted Date	Number of Days Exceeded 24h Average Standard (EEC; 120 μ g/m³)
1	Magan	NE 20km	52.8	24.Apr	0
2	Falaj A'Suq	ENE 15km	46.2	29.Oct	0
3	Al Khshaisha	NE 12km	65.0	24.Apr	0
4	Misial A'Sidr	ENE 11km	56.4	24.Apr	0
5	Sihlat	ENE 8km	61.2	29.Oct	0
6	Sagha	ENE 5km	71.8	24.Nov	0
7	Wadi al Owainah	SSE 5km	69.5	29.May	0
8	Aarja	N 5km	111.7	31.Jul	0
9	Rahab	NW 7km	138.3	21.Jul	1
10	Sehaylah	SW 7km	103.6	7.Feb	0

CHAPTER 9 INVESTIGATION ON EXPANSION PROGRAM FOR SMELTER AND REFINERY PLANT

CHAPTER 9 INVESTIGATION ON EXPANSION PROGRAM FOR SMELTER AND REFINERY PLANT

9.1 Investigation Result

It has been stated that plans for expanding the annual production of OMCO's smelter ranging from 40,000 to 100,000 t/year have been drafted. However, if the plant's production is increased, the concern exists that air pollution will be similarly increased. Therefore, the proposed expansion of the smelter and its potential impact on the environment were investigated during the Second site visit.

During the actual Second field investigation, OMCO did not disclose any concrete data related to the expansion plan and a clear explanation of any proposed plans was not given. Therefore, the JICA Team concluded there is no feasible plan for expansion of the plant at this time.

CHAPTER 10 ENVIRONMENTAL IMPACT INVESTIGATION

CHAPTER 10 ENVIRONMENTAL IMPACT INVESTIGATION

10.1 Methodology

The methodology used for an environmental impact survey consisted of personal interviews with local residents based on an environmental questionnaire concerning air pollution, water pollution, effects on health, and damage from pollution. The areas visited for interviews include Falaj A' Suq, Misyal A'Sidr, Sagha, Sihlat, Al Khshaisha, Wadi al Owainah, Eastern Sehaylah, Western Sehaylah, Rahab, Aarja and Falaj al Qabail. Interviews were conducted with 23 persons living within a radius of 23 km from the OMCO plant site as shown in Figure 10.1.

In addition to the personal interviews, a questionnaire was prepared for health and medical facilities to obtain information on disease and health impairment concerned with water pollution and air pollution in the Sohar mine area. The questionnaire was delivered to the Sohar Royal Hospital.

10.2 Interview Investigation Results

The results of the interviews with the local residents are summarized in Table 10.1.

The response from Sohar Royal Hospital to the questionnaire was as follows:

"I do not have enough information about this as this information could be available with the primary health care activity."

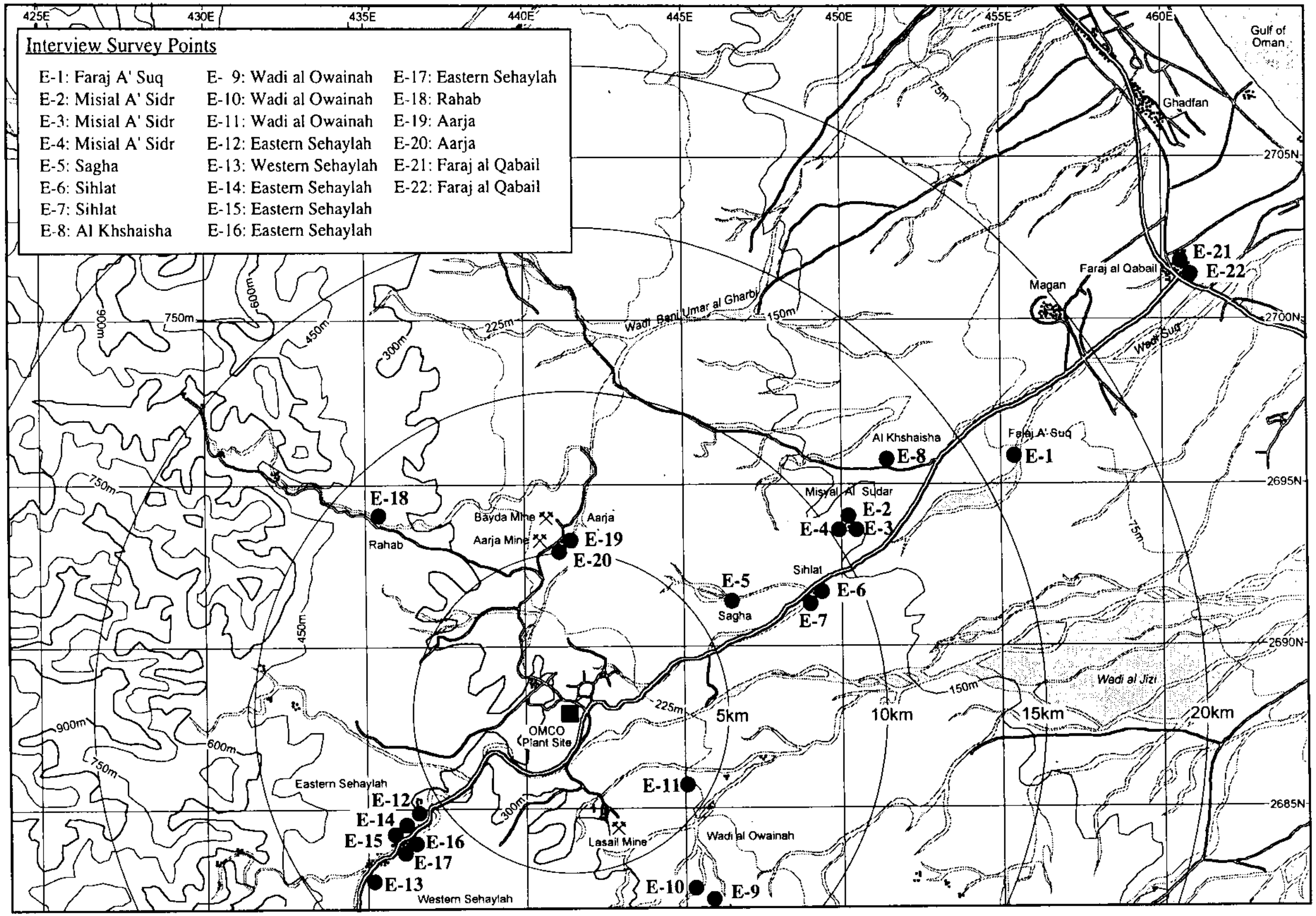


Figure 10.1 Interview Investigation Points

Table - 10.1 Results of Interview Investigation

Livestock	Various diseases have occurred in livestock. The names of diseases have not been identified	E-1
	Symptom of falling hair off goats is observed	E-1
	Livestock may be affected by grazing polluted grass	E-1, E-2
	The number of goats has been decreased by unknown causes	E-3, E-5
	The number of goats has been decreased by elimination of grass due to water shortages	E-9, E-13, E-11, E-14, E-19
	Animals died from drinking well water.	E-6
	Livestock may be affected by well water	E-7
	The number of goats has not been changed	E-10
Health	It seems that no effect on health has been observed.	E-1, E-4, E-7, E-13, E-14, E-15, E-17, E-20
	Children and women are suffering from coughing, asthma or allergy due to air emissions	E-12
	There is unconfirmed information that the neighborhood children are suffering from respiratory symptoms	E-16, E-18
	Children are suffering from coughing. Doctor told residents that the coughing is caused by air pollution	E-19
	A skin rash consisting of colored spots on the faces of children has been observed.	E-18
Water	Well water cannot be drunk because water is salty.	E-1, E-2, E-6, E-20
	Well water quality is good.	E-9, E-10, E-12, E-13, E-14, E-16
	Well water is not salty but turbidity is high	E-21
	Water quality in the Falaj became worse after the start of OMCO operations	E-21
Plant	Something like dust covers the surface of dates because of salty water, therefore these dates can be used only for livestock food	E-3, E-6, E-16, E-18
	Trees in the garden and farms have died	E-5
	Onion and henna died.	E-14
	Grass has died.	E-5
	Leaves of dates trees have become yellow after the start of OMCO operation	E-19
Air	Smoke is seen in the morning.	E-3, E-4, E-9, E-13
	Odor is detected and a cough is caused when smoke from OMCO reaches the area.	E-7
	Breathing is affected depending on the circumstances when a continuous smoke is seen.	E-10
	Emissions from oil factory in the Sohar Industrial Estate affect air quality.	E-21, E-22
Material	Basins made of cement are easily cracked because of salty water	E-4
Wildlife	Honey bees have disappeared, may be affected by emissions of OMCO. So honey has not been collected	E-7, E-9

CHAPTER 11 SOCIO-ECONOMIC INVESTIGATION

CHAPTER 11 SOCIO-ECONOMIC INVESTIGATION

11.1 National Economy

11.1.1 Background

Petroleum development is the major part of Oman's economy, including crude oil production, oil refining, and natural gas production. After petroleum, industrial activities, including construction, cement producing, and copper refining are the next most important parts of the economy, as shown in Table 11.1. As indicated in this figure, the largest component of Oman's economy is the oil industry, which accounted for almost 40 % of the total GDP as shown in Figure 11.1. The economic benefit from the petroleum industry is related to the movement of international crude oil prices and the agreement of oil production quotas by OPEC. The revenue from crude oil production accounts for almost 75 % of the government revenue, 75 % of the total export revenue, and 40 % of GDP.

On the other hand, agricultural production occupies only 4 % of GDP because the amount of arable land occupies less than 2 % of the whole land area of the nation. The number of employed people in the Agriculture sector (including the fishery industry) accounts for 40 % of the total employment in Oman. Dates, limes, bananas, vegetables, goats, etc. are produced for j subsistence. Most of the nation depends on the imported food products.

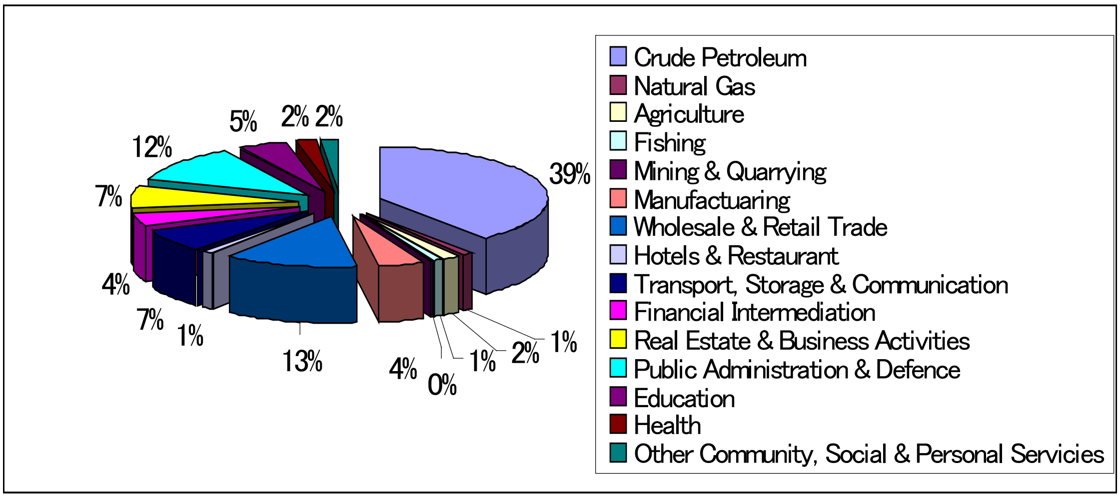


Figure 11.1 Composition of GDP

11.1.2 Past Trend of Economic Situation

The economy of Oman grew steadily from 1990 to 1998 with a growth rate of 4.5 % per annum under the constant price in 1988 as shown in Figure 11.2 and Table 11.1. However, in 1999 the gross domestic

Table 11.1 Past Trend of Gross Domestic Product (GDP) by Economic Activity

Economic Activity	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999[1]
1 - Total Petroleum Activities	2,144.4	1,825.1	1,952.0	1,782.3	1,814.8	2,020.0	2,464.9	2,443.6	1,672.6	2,365.8
1.1 Crude Petroleum	2,095.7	1,774.5	1,896.6	1,720.5	1,749.4	1,973.2	2,416.5	2,387.3	1,609.7	2,299.2
1.2 Natural Gas	48.7	50.6	55.4	61.8	65.4	46.8	48.4	56.3	62.9	66.6
2 - Total Non Petroleum Activities	2,407.0	2,588.9	2,880.6	3,071.0	3,220.0	3,368.5	3,497.9	3,758.8	3,859.7	3,751.2
2.1Agriculture & Fishing	116.2	114.8	111.7	115.0	125.8	147.3	147.1	159.5	153.3	157.5
A - Agriculture	88.1	92.7	85.1	88.2	94.9	95.1	100.7	106.7	102.4	105.2
B - Fishing	28.1	22.1	26.6	26.8	30.9	52.2	46.4	52.8	50.9	52.3
2.2 Industriy Activities	286.0	329.3	383.9	413.2	425.8	446.9	435.0	517.3	536.9	481.1
C - Mining & Quarrying	12.0	11.4	12.4	10.5	11.3	13.2	14.6	16.3	15.7	15.8
D - Manufactuaring	131.6	150.3	175.7	202.0	215.7	247.4	237.3	240.6	251.3	253.9
- Manufacturing of refined petroleum Products	14.8	14.3	21.2	39.0	38.6	54.8	39.4	33.6	36.4	31.5
- Other Manufacturing	116.8	136.0	154.5	163.0	177.1	192.6	197.9	207.0	214.9	222.4
E - Electricity & Water Supply	39.3	39.8	42.9	42.5	49.1	48.6	53.2	66.6	67.9	71.4
F - Building & Construction	103.1	127.8	152.9	158.2	149.7	137.7	129.9	193.8	202.0	140.0
2.3 Service Activities	2,004.8	2,144.8	2,385.0	2,542.8	2,668.4	2,774.3	2,915.8	3,082.0	3,169.5	3,112.6
G - Wholesale & Retail Trade	457.9	515.4	583.4	619.4	621.0	681.1	721.7	772.5	839.9	762.2
H - Hotels & Restaurant	35.6	35.6	37.8	41.9	43.6	46.9	54.2	53.1	52.2	53.6
I - Transport, Storage & Communication	203.9	243.4	267.7	287.0	311.7	332.9	363.9	417.9	449.1	436.4
J - Financial Intermediation	106.7	109.4	120.4	129.7	141.2	162.5	183.0	275.0	254.4	254.8
K - Real Estate & Business Activities	320.6	364.1	409.0	444.5	451.3	417.2	416.0	420.0	423.6	417.8
L - Public Administration & Defence	576.0	555.1	615.3	630.3	689.4	705.0	709.2	679.1	671.3	682.7
M - Education	149.4	157.1	174.8	195.5	209.4	221.3	253.2	253.1	261.8	279.8
N - Health	66.2	70.0	78.4	88.3	89.9	92.2	104.4	105.8	110.6	115.5
O - Other Community, Social & Personal Servicies	77.8	79.5	84.3	91.8	97.5	99.7	95.5	90.4	90.7	93.6
P - Private Household with Employed Person	10.7	15.2	13.9	14.4	13.4	15.5	14.7	15.1	15.9	16.2
Financial Intermediation Servicies Indirectly Measured	-91.0	-92.7	-92.6	-93.3	-109.0	-126.6	-136.1	-156.7	-178.1	-197.0
GDP at Producers Prices	4,460.4	4,321.3	4,740.0	4,760.0	4,925.8	5,261.9	5,826.7	6,045.7	5,354.2	5,920.0
Plus : Import Tax	32.6	39.5	47.8	43.6	41.5	45.3	47.6	43.8	61.7	80.3
GDP at Market Prices (Current Prices)	4,493.0	4,360.8	4,787.8	4,803.6	4,967.3	5,307.2	5,874.3	6,089.5	5,415.9	6,000.3
GDP at Market Prices (1988 Constant Prices)	3,599.0	3,816.3	4,140.5	4,394.9	4,563.9	4,784.3	4,922.8	5,226.9	5,368.2	5,315.7
1 - Total Petroleum Activities	1,407.6	1,441.8	1,508.2	1,588.1	1,644.5	1,724.6	1,803.5	1,858.6	1,866.0	1,873.8
2 - Total Non Petroleum Activities	22,425.0	2,415.5	2,663.8	2,839.2	2,969.8	3,127.5	3,193.8	3,462.5	3,598.9	3,535.7

Note : 1) Provisional

Source : Statistical Year Book August 2000 (Ministry of National Economy) product (GDP) dropped slightly by 0.1% for the first time during past 10 years, in spite of the significant development of GDP from 5,415.9 million R.O. in 1998 to 6,000.3 million R.O. in 1999 under the current price base by the increment of the international oil price and revival of economic activities in crises struck countries. However, higher oil export earnings improved the government's fiscal balance and reduced the external current account gap. The export of crude oil increased 1,379.2 million O.R. in 1998 to 2,070.3 million R.O. 1999 by 50.1 %. Therefore, the afore-mentioned rise in national output was mainly attributable to the higher contribution of the petroleum sector to GDP by 38.6 %.

On the other hand, non-petroleum sectors including agriculture and services contracted by 2.2 %. These are shown in Table 11.2, 11.3 and 11.4.

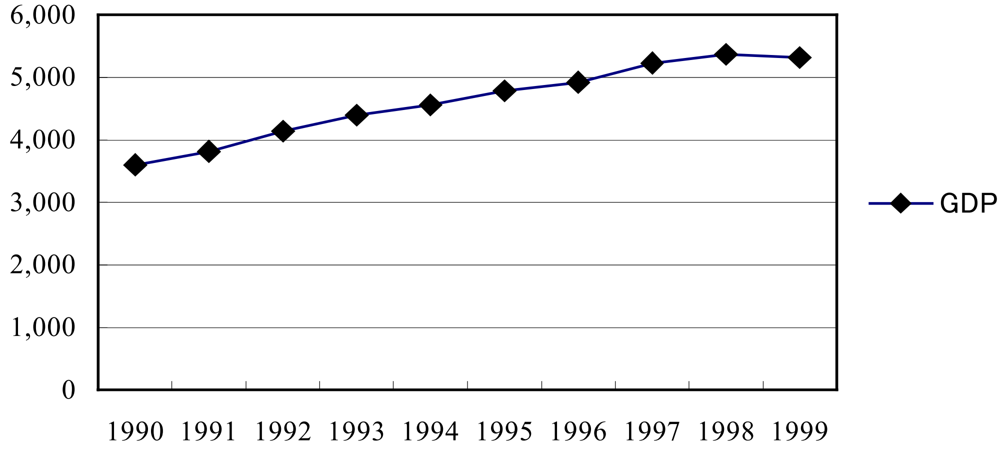


Figure 11.2 Past Trend of GDP

Table 11.2 Export and Import

Year	Export					Import	Balance
	Refined Oil	Crude Oil	Non Oil	Re-Export	Total		
1990	54.3	1,885.9	68.8	107.4	2,116.4	1,075.9	1,040.5
1991	54.6	1,575.1	79.1	165.1	1,873.9	1,279.1	594.8
1992	39.3	1,745.8	96.7	253.5	2,135.3	1,500.2	635.1
1993	27.2	1,594.9	122.5	320.3	2,064.9	1,651.8	413.1
1994	48.7	1,587.2	145.4	358.5	2,139.8	1,543.3	596.5
1995	41.1	1,800.9	182.0	321.9	2,345.9	1,683.6	662.3
1996	47.1	2,227.6	173.3	387.0	2,835.0	1,818.0	1,017.0
1997	52.5	2,181.4	203.3	506.8	2,944.0	1,995.8	948.2
1998	50.6	1,379.2	199.3	493.3	2,122.4	2,240.0	-117.6
1999	56.3	2,070.3	201.4	455.3	2,783.3	1,846.0	937.3

Table 11.3 Recorded Merchandise Import by Country

Country	1997		1998		1999	
	Value	%	Value	%	Value	%
1 U.A.E	468,043	24.2	550,766	25.2	505,314	28.1
2 Japan	319,581	16.5	343,780	15.7	273,697	15.2
3 United Kingdom	142,825	7.4	159,001	7.3	122,894	6.8
4 United States	155,128	8.0	153,522	7.0	115,318	6.4
5 Germany	102,667	5.3	107,150	4.9	70,760	3.9
6 France	55,821	2.9	122,035	5.6	63,464	3.5
7 India	66,049	3.4	63,689	2.9	62,004	3.5
8 Saudi Arabia	70,503	3.6	64,652	3.0	61,167	3.4
9 Netherlands	32,103	1.7	47,256	2.2	57,720	3.2
10 Italy	81,202	4.2	128,242	5.9	49,080	2.7
11 Australia	51,255	2.7	46,290	2.1	48,480	2.7
12 South Korea	45,725	2.4	41,310	1.9	37,909	2.1
13 Malaysia	30,502	1.6	23,849	1.1	22,737	1.3
14 China	19,305	1.0	52,902	2.4	20,247	1.1
15 Pakistan	19,731	1.0	19,985	0.9	19,980	1.1
Others	272,026	14.1	260,115	11.9	266,307	14.8
Total	1,932,466	100.0	2,184,544	100.0	1,797,078	100.0

Table 11.4 Merchandise Export and Re-Export by Country

Country	1997		1998		1999	
	Value	%	Value	%	Value	%
1U.A.E	286,422	40.3	286,884	41.4	276,104	42.0
2Iran	67,271	9.5	61,652	8.9	46,159	7.0
3Saudi Arabia	28,029	3.9	38,865	5.6	44,738	6.8
4Yemen	22,986	3.2	52,456	7.6	35,021	5.3
5United States	33,686	4.7	33,393	4.8	33,235	5.1
6United Kingdom	24,684	3.5	20,659	3.0	30,438	4.6
7Tanzania	26,137	3.7	24,290	3.5	29,696	4.5
8Zambia	10,586	1.5	9,339	1.3	16,133	2.5
9Kenia	12,454	1.8	13,706	2.0	14,224	2.2
10India	31,215	4.4	20,386	2.9	11,294	1.7
11Iraq	36	0.0	1,176	0.2	10,841	1.7
12Singapore	10,204	1.4	9,706	1.4	9,720	1.5
13Jordan	2,902	0.4	9,158	1.3	8,932	1.4
14Kueait	10,833	1.5	7,382	1.1	8,330	1.3
15Qatar	4,037	0.6	6,285	0.9	6,457	1.0
Others	138,590	19.5	97,249	14.0	75,435	11.5
Total	710072	100.0	692,586	100.0	656,757	100.0

11.2 Socio-economy in National Level

11.2.1 Population

As shown in Table 11.5, the total population of Oman is estimated 2,325,438 persons of which 1,729,312 persons are Omanis and 596,126 persons are foreign guest workers. The population increased with an average growth rate of 2.6 % per annum (the former 2.7 % and the latter 2.1 %) during the past 5 years (from 1994 to 1999). Looking at the growth rate, Muscat Prefecture in the Muscat Region showed the highest growth rate of 2.9 % of which the growth rate in the Omani's population was 3.3 %, compared to a growth rate of only 1.9 % for the foreign population.

Table 11.5 Population by Administrative Region

Governorate	Exp.		Omani		Total	
	Persons	Share (%)	Persons	Share (%)	Persons	Share (%)
Muscat	280,498	47.1	354,781	20.5	635,279	27.3
Al-Batinah	104,108	17.5	544,494	31.5	648,602	27.9
Musandam	6,959	1.2	26,006	1.5	32,965	1.4
Adh-Dhahirah	51,468	8.6	156,971	9.1	208,439	9.0
Ad-Dkhlivah	34,173	5.7	230,527	13.3	264,700	11.4
Ash-Sharqivah	43,954	7.4	253,975	14.7	297,929	12.8
Al-Wusta	3,909	0.7	15,859	0.9	19,768	0.9
Dhofar	71,057	11.9	146,699	8.5	217,756	9.4
Total	596,126	100.0	1,729,312	100.0	2,325,438	100.0

In Sohar Prefecture, the total population is 104,169 persons (Omani 82,182 persons and foreigner 21,987 persons), which accounts for 16.1 % of the Al-Batinah Region (Omani 15.1 % and foreigner 21.1 %). The growth rate during the same period was 2.5 % (Omani 2.5 % and foreigner 2.3 %), a little lower than the national average. Table 11.6 shows the population by region in Al-Batinah.

11.2.2 Employment

The total number of employed people in 1999 was 1,114,902 persons, which slightly decreased from 1,164,716 persons in 1998. A sharp drop of employment in the private sector caused this decrease. The share of the private sector was 85.2 % in 1999, which also decreased from 87.8 % in 1998. Table 11.7 shows the number of employment in Oman.

11.3 Socio-economy in Sohar Region

Socio-economic data in the Sohar area are very scarce. Statistical facts and finding in Sohar Wilayat are as follows:

Table 11.6 Population by Al Batinah Region

Region	Exp.		Omani		Total	
	Persons	Share (%)	Persons	Share (%)	Persons	Share (%)
Sohar	21,987	21.1	82,182	15.1	104,169	16.1
Al rustaq	8,033	7.7	63,252	11.6	71,285	11.0
Shinas	7,570	7.3	43,345	8.0	50,915	7.8
Liwa	3,613	3.5	22,437	4.1	26,050	4.0
Saham	12,028	11.6	74,055	13.6	86,083	13.3
Al khaburah	6,611	6.4	40,231	7.4	46,842	7.2
As Suwayq	14,802	14.2	82,881	15.2	97,683	15.1
Nakhal	1,455	1.4	13,594	2.5	15,049	2.3
Wadi Al maawil	1,295	1.2	10,693	2.0	11,988	1.8
Al Awabi	891	0.9	9,036	1.7	9,927	1.5
Al Musanah	7,910	7.6	46,741	8.6	54,651	8.4
Barka	17,913	17.2	56,047	10.3	73,960	11.4
Total	104,108	100.0	544,494	100.0	648,602	100.0

Table 11.7 Employment by Administrative Region

Administrative region	1998					1999				
	Government			Private	Total	Government			Private	Total
	Omani	Foreigner	total			Omani	Foreigner	Total		
Muscat	17,277	5,769	23,046	258,214	281,260	17,717	5,455	23,172	242,727	265,899
Al-Batinah	11,264	5,795	17,059	86,870	103,929	12,421	5,350	17,771	79,766	97,537
Musandam	1,156	590	1,746	4,935	6,681	1,240	555	1,795	4,870	6,665
Adh-Dhahirah	4,451	2,282	6,733	39,776	46,509	4,935	1,866	6,801	37,222	44,023
Ad-Dakhlyah	6,221	2,663	8,884	22,452	31,336	6,957	2,338	9,295	22,389	31,684
Ash-Sharqiyah	7,791	2,800	10,591	39,074	49,665	8,480	2,619	11,099	38,819	49,918
Al-Wusta	486	394	880	0	880	486	437	923	0	923
Dhofar	7,059	4,817	11,876	50,222	62,098	7,367	4,511	11,878	48,924	60,802
Total	55,705	25,110	80,815	501,543	582,358	59,603	23,131	82,743	474,717	557,451
Abroad	153	0	0	0	0	171	0	0	0	0
No. of Departed	0	0	0	19,016	0	0	0	0	0	0
Grand Total	111,563	50,220	161,630	1,022,102	1,164,716	119,377	46,262	165,468	949,434	1,114,902
Growth Rate								1,024	0,929	0,957

(1) Summary

Sohar Region is the biggest area in the Governorate of Al-Batinah and the center of its regional politics and economy. This center faces the Gulf of Oman and now a new port is under construction for the purpose of developing the regional economy. Since this area is very close to the capital city of Muscat (only 3 hours by car), the economy is expected to develop further in the future. The following data summarize this area.

- Area : 1,728 km^2
- Length of coast : 45 km
- Distance from Muscat : 235 km
- Number of Villages : 99 villages
- Number of Mosque : 399 mosques

(2) Agriculture and Fisheries

Most of this area is desert. However, near the wells or along wadis, agriculture has been developed due to a good irrigation system. Among the agricultural activities, cultivating fruits such as dates is the dominant activity. Other than fruit, many goats are raised. Near coastal areas fishing is the main activity. The following is the situation of agriculture and fishery;

- Irrigated (Planted area) : 16,180 Acres
- Fodder (Planted area) : 3,445 Acres
- Fruit trees : 775,850
- Number of cattle : 5,175
- Number of sheep : 10,670
- Number of goats : 38,870
- Number of camels : 734
- Number of birds and pets : 18,180
- Number of bee hives : 116
- Number of fishermen : 1,410
- Number of fishing boats : 650

(3) Education

There are 38 schools in Sohar Prefecture, where 27,834 students are studying. The number of teachers is 864 teachers. The number of students per teacher is 37.3 for primary school, 33.7 for preparatory school, and 54.5 for secondary school. In addition, there are 4 kindergartens, where 842 pupils are learning.

Number of School			
Primary	Preparatory	Secondary	Total
6	26	6	38

Omani Teacher				
Sex	Primary	Preparatory	Secondary	Total
Male	284	96	18	398
Female	241	131	76	448
Total	525	227	94	846

Number of Students			
Level	Male	Female	Total
Primary	8,199	6,865	15,064
Preparatory	4,195	3,450	7,645
Secondary	2,634	2,491	5,125
Total	15,028	12,806	27,834

(4) Health

The number of hospitals under the Ministry of Health in Sohar Prefecture is only 2 hospitals and the total number of beds 381 beds. In addition, there are 2 health centers, however, they do not have any beds. On the other hand, the number of private clinics is 74 (Dental: 12, Specialist: 9, General: 53) in the whole Al-Batinah Governorate. Considering that almost half of the hospitals under the Ministry of Health are concentrated in the Sohar area, more than half of the private clinics (about 30) are located in the Sohar Region.

11.4 Socio-economy in Objective Area

11.4.1 Population and the Number of Houses

The number of persons and houses located within the area considered to be negatively impacted by the mining pollution were estimated. The total number of persons and houses within this area is estimated at 24,308 persons and 4,055 houses through the site investigation. The results are shown in Table 11.8. The location of communities is shown in Figure 11.3.

Table 11.8 Population by Communities in Objective Area

Community	House	Population	Method
1. Faraj A' Souq	5	30	Counted
2. Kheshishet Al Milh	9	50	Counted
3. Misial A'sidr	14	100	Counted
4. Sihlat (Sagha)	7	50	Counted
5. A'Sahga	9	70	Counted
6. Aarja & Bayda	8	60	Counted
7. Wadi al-Owaynah	22	150	Counted
8. Suhaylah	45	360	Counted
9. Faraj al Qabail	868	5,208	Estimated
10. Majis	3,068	18,230	Estimated
Total	4,055	24,308	-

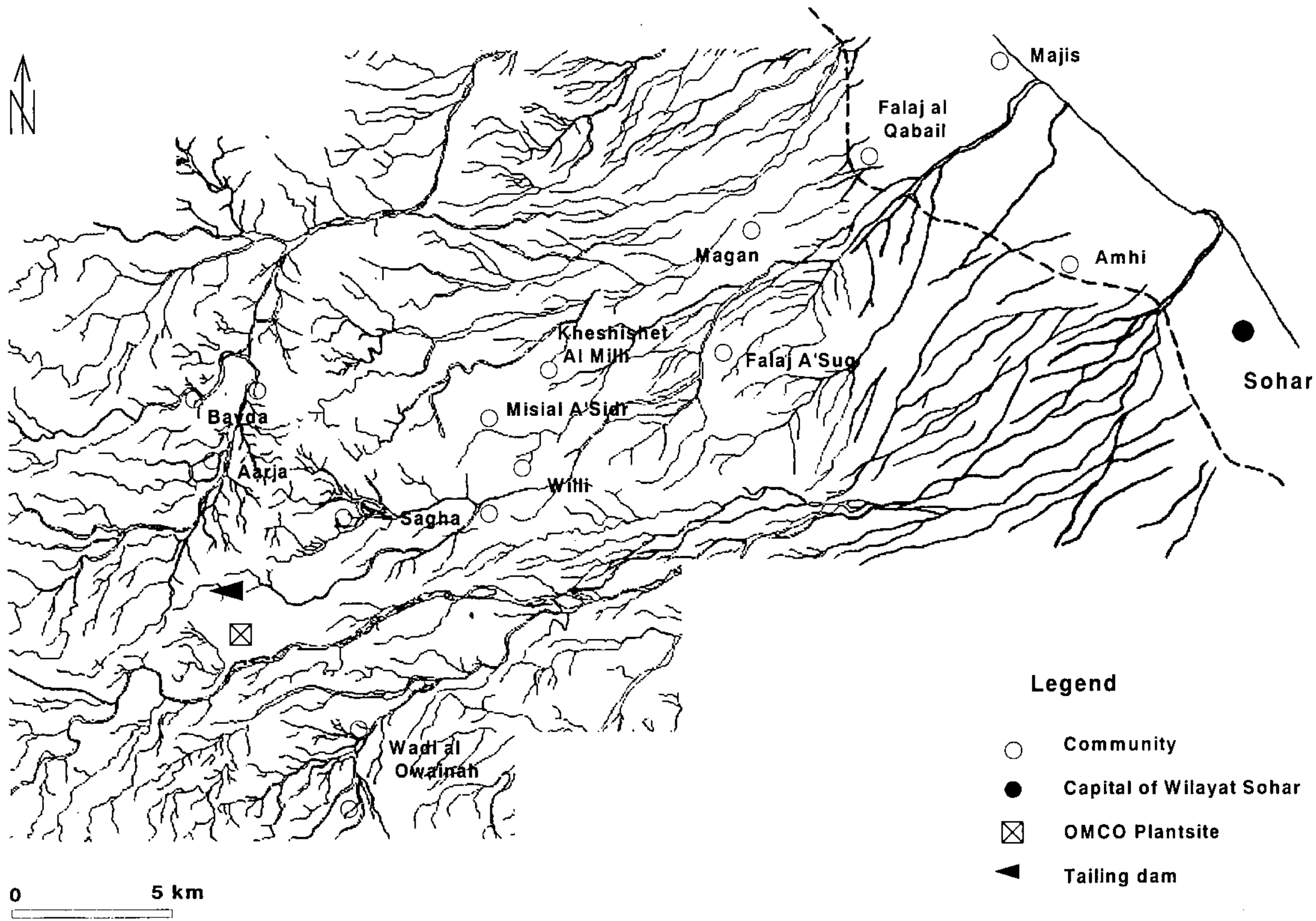


Figure 11.3 Location Map of Communities

11.4.2 Sohar Industrial Estate

The Public Establishment operates the Sohar Industrial Estate (PEIE) to encourage the private sector to contribute to industrialization in the Sohar area. The Estate is located near the industrial port and started its activities in November 1992. The total area of the estate is about 330 ha, however, at the moment only 130 ha has been developed. At present industries such as food industries, building materials, furniture, glass, leather & chemicals are operating. In the near future industries such as paper, foundry, spinning, electrical products and appliances are planned to operate.

Current operated or planned factories and company are shown in Table 11.9.

Table 11.9 Operated or Planned Factory and Company

Factory or Company	Number
Under Production	41
Under Trial Production	7
Under Construction	9
APPD. & Building Permit Issued	5
Land Allotted	12
Under Evaluation	9

11.4.3 Industrial Port

This new port is under construction now. The port will be completed by the end of 2001. The purpose of this port is to help export-oriented industries. Therefore, the location of this port is within 220 km of Dubai, E.A.U., etc. Near this port, the construction of oil refinery industries, aluminum refinery industries, hydrocarbon industries, etc. are planned.

11.5 Results of Interview Investigation

To select the most viable countermeasures, benefits occurring from these countermeasures should be estimated and compared with their costs. The following benefits are considered to be obtained after taking proposed countermeasures;

a. Valuing damages from groundwater contaminated salt or air pollution,
b. Estimating the displacement cost saving,
c. Estimating the value of existence for Al Ons Nature Reserve and as a part of the national land.

Among the above three items, item b is not mentioned here because it is an engineering matter. Therefore, the interview investigations for item and item c were conducted to obtain the basic data for estimating proposed countermeasures benefits. These interview investigations were conducted under the cooperation of MCI, Sohar Municipality, Sohar Development Office, Ministry of Water Resources, etc. These investigations and their investigation items are as follows;

- Household and Damage Investigation;
  - Contraction of diseases, medical treatment cost, cost of medicine
  - Damaged agricultural products and livestock
  - Contamination of drinking water
  - Others
- Willingness-to-pay investigation on Al Ons Nature Reserve; and
  - Checking familiarity of this Reserve
  - Willingness-to-pay to preserve for Al Ons Nature Reserve
  - Others
- Willingness-to-pay Investigation on Value of Existence.
  - Impression of the Sohar mine area
  - Problem of the Sohar mine area
  - Possibility of investment
  - Willingness-to-pay to eliminate the pollution from the Sohar mine area
  - Others

11.5.1 Household and Damage Investigation

The purpose of this investigation is to understand existing conditions of households and their damage from the negative impacts resulting from deteriorating water and air quality. About 42 households were interviewed. The followings are the major results of this investigation.

(1) Situation in Communities Except Majis and Falai al Qabail

a. Household Summary

- There are 8 communities around the Sohar mine with 119 families and 870 residents.
- Most people have lived in the area long before OMCO was established.
- Half of husbands do not have jobs at the moment.
- Four families get a small amount of money from the Ministry of Welfare.
- About one forth of households do not have the certificate of ownership for their land.
- The average area of land except farms is about 600 m^2 to 900 m^2.
- The average number of family members is 7.3 persons.
- About half of households have their farm, where they mainly plant dates, grass for animals.
- Almost all households have twenty to thirty goats. One of the households has one hundred goats. A few households have cows and/or Camels.
- In communities located in Falaj A'Souq, Khshishet Al Milh, Misial A'sidr, Sagha, and Aarja OMCO

supplies water at free.

- The land price ranges from 3,000 to 5,000 R.O. per 600 m^2. If including land, the price becomes four times.
- Children go to school by cars prepared by the Ministry of Education. Generally it takes 20~30 min.
- Ninety percent of households have cars, despite of few households with regular salary.
- Most of households pay the electricity fee of 20~30 R.O. per month.

b. Negative environmental Impact by Water Contamination and Air Pollution

- In Faraj A'Souq, Kheshishet, Misial A'sidr, Sagha, and Aarja, water is already salty.
- Symptoms such as hair falling off of goats are observed.
- Something a type of dust is deposited on the surface of dates because of salty water, therefore these dates can be used only for animal's food.
- Basins made from concrete, are easily cracked because of salty water.
- Trees in garden and farms have died.
- In Suhaylah, there is not any water problem, but air problem is serious. Some of the children and women are suffering from coughing, asthma or allergy.
- In Sagha, honeybees have disappeared. So honey has not been collected now.
- In Wadi al Owaynah there is a smoke smell depending on wind direction.

(2) Situation in Majis and Farai Al Qabail

- There are no environmental negative effects caused by OMCO operation.
- Groundwater already includes salt, so most of households are buying water.

(3) Situation in Sohar Sultanate Hospital

- Any disease caused from the groundwater contamination or air pollution in the Sohar mine area was not reported.

11.5.2 Interview Investigation on Al Ons Natural Reserves

This investigation was conducted for the purpose of estimating the value of the importance of Al Ons Natural Reserves. However, the Study Team was not allowed to get any information from the Ministry of Agriculture, which is in charge of the administration of the Reserves. Therefore, this interview investigation was not conducted during the next stage.

11.5.3 Interview Investigation on Value of Existence

This interview investigation was conducted for the following purpose; leaving the Sohar mine area as it is as a contaminated area is also one of the countermeasures. However, from the viewpoints of geopolitics and environmental quality, abandonment of any piece of national land cannot be considered. Rather it is natural to examine the possibility of future usage by eliminating the pollution. Therefore, the value of existence of the Sohar mine area was investigated through the interview to persons living outside of the Sohar mine area. The followings are major results of this investigation;

- About half of the interviewee do not the situation of the Sohar mine area.
- Almost all persons who visited Sohar mine area know the existing environmental negative effects.
- All persons who know the environmental problems in the Sohar mine area insist on the importance of eliminating pollution.
- Some persons think it needs a lot of money for eliminating pollution.
- About one third of the interviewees said they are not using any land in the Sohar mine area, but they may use it in the future.
- Some of persons think they do not use the land in the Sohar mine area, but others may use it.
- Their willingness-to-pay for improving the environmental condition in the Sohar mine area is considered to be reasonable.

CHAPTER 12 TECHNOLOGY TRANSFER

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12.1 Technology Transfer

As specified in the terms of reference, one of the purposes of the study is to transfer the mine pollution investigation and evaluation technology to counterparts in the Sultanate of Oman throughout the study.

Technology transfer was implemented through cooperative efforts during study, including the practice of on-site training, the explanation of the analysis results with the counterparts, counterpart study and training in Japan and so on, according to the plan which was shown in the inception report of the study.

Some of the problems experienced in implementing the technology transfer element of the study included a shortage of technical experts within MCI and MMEW and the differences in the social environments between Oman and Japan. In the end, however, the anticipated object of the study was achieved sufficiently and the study was completed with the sincere attitude and efforts of Omani and Japanese study teams.

The results of the counterpart study and training in Japan for technology transfer are shown in the Tables 12.1 and 126.2.

Table 12.1 Technical Transfer Program

Division	Item	Method	Time
1. General	Inception report Interim report Draft final report	Meeting Meeting Meeting	The 1st site investigation The 4th site investigation The 6th site investigation
2.Hydrology-geology	Execution & analysis of data collection Execution & analysis of hydrology-geology, core investigation Execution & analysis of soil investigation Execution & analysis of pollutant source Study& execution of simulation analysis on water contamination Study, planning, & determination on water contamination countermeasure	O JT* 1 O JT O JT O JT OJT meeting OJT, meeting	The 1st & 2nd site investigation The 2nd & 3rd site investigation The 2nd & 3rd site investigation The 2nd & 3rd site investigation The 4th & 5th site investigation The 4th & 5th site investigation
3. Smelter/atmosphere	Execution & analysis of data collection Execution & analysis of present situation of smelter Execution & analysis of air quality investigation Study& execution of simulation analysis on air pollution Study, planning, & determination on air pollution control countermeasure	O JT O JT O JT OJT, meeting OJT, meeting	The 1st & 2nd site investigation The 2nd & 3rd site investigation The 2nd & 3rd site investigation The 4th & 5th site investigation The 4th, 5th & 6th site investigation
4. Geochemical exploration	Execution & analysis of data collection Execution & analysis of soil investigation Execution & analysis of geochemical exploration	O JT O JT O JT	The 2nd site investigation The 2nd site investigation The 2nd site investigation
5. Geo physical exploration	Execution & analysis of precise gravity exploration Execution & analysis of electro-magnetic exploration Execution & analysis of survey work	O JT O JT O JT	The 2nd site investigation The 2nd site investigation The 2nd site investigation
6. Drilling	Execution & analysis of data collection Execution & analysis of drilling investigation Execution & analysis of survey work Execution & analysis of measurement of water level & water quality, & water sampling	O JT O JT O JT O JT	The 2nd & 3 rd site investigation The 2nd & 3 rd site investigation The 2nd & 3 rd site investigation The 2nd & 3 rd site investigation
7. Environment	Execution & analysis of data collection Hearing investigation technology, arrangement & analysis of data Execution & analysis of air & water quality investigation Execution & analysis of pollutant source Study& execution of simulation analysis on air pollution Study; & execution of simulation analysis on water contamination Study, planning & determination of air pollution control countermeasure Study, planning & determination of water contamination countermeasure	O JT O JT O JT O JT OJT, meeting OJT, meeting OJT, meeting OJT, meeting	The I st & 2nd site investigation The 2nd & 3rd site investigation The 2nd & 3rd site investigation The 2nd & 3rd site investigation The 4th & 5th site investigation The 4th & 5th site investigation The 4th, 5th & 6th site investigation The 4th, 5th & 6th site investigation
8. Monitoring system/ Environmental management	Execution & analysis of data collection Execution & analysis of investigation on present situation of monitoring system Study, planning, & determination of suitable monitoring system Study, planning, & determination of air pollution countermeasure Study, planning, & determination of water contamination countermeasure	O JT O JT OJT, meeting OJT, meeting OJT, meeting	The 1st & 2nd site investigation The 2nd & 3rd site investigation The 4th & 5th site investigation The 4th, 5th & 6th site investigation The 4th, 5th & 6th site investigation
9. Civil engineering	Execution & analysis of data collection Study, planning, & determination of air pollution control countermeasure Study, planning,& determination of water contamination countermeasure Estimation of air & water pollution control countermeasure	O JT OJT, meeting OJT, meeting OJT, meeting	The 1st site investigation The 4th, 5th & 6th site investigation The 4th, 5th & 6th site investigation The5th & 6th site investigation
10. Mine pollution control countermeasure	Study, planning, & determination of air pollution control countermeasure Study, planning, & determination of water contamination countermeasure	O JT meeting OJT, meeting	The 4th, 5th & 6th site investigation The 4th, 5th & 6th site investigation
1l. Economic - Financial analysis/ Socio-economical investigation	Hearing investigation technology, arrangement & analysis of data Socio-economical investigation technique, arrangement & analysis of data Estimation of air pollution control countermeasure Estimation of water contamination control countermeasure Economic-' financial analysis technology, arrangement & analysis of data	OJT meeting OJT, meeting Meeting Meeting Meeting	The 3rd, 4th&5th site investigation The3rd, 4th & 5th site investigation The 4th & 5th site investigation The 4th & 5th site investigation The 5th & 6th site investigation

*1 OJT: On the Job Training

Table 12.2 Results of the Counterpart-training Program in Japan

Date	Subject	Place
January 21st (Sun)	Dept. Oman	
January 22nd (Mon)	Arrive. Japan	Tokyo
January 23rd (Tue)	Orientation by JICA at TIC (Tokyo International Center)	Tokyo
January 24th (Wed)	Orientation by JICA at TIC	Tokyo
January 25th (Thu)	Orientation by JICA at TIC	Tokyo
January 26th (Fri)	Orientation by JICA at TIC	Tokyo
January 27th (Sat)	Day off	Tokyo
January 28th (Sun)	Day off	Tokyo
January 29th (Mon)	Environmental Investigation Technology Study at MRC	Tokyo
January 30th (Tue)	Environmental Investigation Technology Study at MRC	Tokyo
January 31st (Wed)	Environmental Investigation Technology Study at MRC	Tokyo
February 1st (Thu)	Make Interim report of the Study with the Study Team at MRC	Tokyo
February 2nd (Fri)	Make Interim report of the Study with the Study Team at MRC	Tokyo
February 3rd (Sat)	Day off	Tokyo
February 4th (Sun)	Day off	Tokyo
February 5th (Mon)	Make Interim report of the Study with the Study Team at MRC	Tokyo
February 6th (Tue)	Make Interim report of the Study with the Study Team at MRC	Tokyo
February 7th (Wed)	Make Interim report of the Study with the Study Team at MRC	Tokyo
February 8th (Thu)	Make Interim report of the Study with the Study Team at MRC	Tokyo
February 9th (Fri)	Make Interim report of the Study with the Study Team at MRC	Tokyo
February 10th (Sat)	Day off	Tokyo
February 11th (Sun)	Day off (National Holiday)	Tokyo
February 12th (Mon)	Day off	Tokyo
February 13th (Tue)	Trip to the active mines	Kyushu
February 14th (Wed)	Trip to the mine pollution control system manufacturer	Kyushu
February 15th (Thu)	Trip to the mine pollution control facilities	Kyushu
February 16th (Fri)	Trip to the closed mine pollution control facilities	Kyushu
February 17th (Sat)	Day off	Tokyo
February 18th (Sun)	Day off	Tokyo
February 19th (Mon)	Final meeting with the JICA Study Team at MRC	Tokyo
February 20th (Tue)	Final meeting with JICA	Tokyo
February 21st (Wed)	Preparation for return to Oman	Tokyo
February 22nd (Thu)	Dept. Japan Arrive. Oman	

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