CHAPTER 6

EFFECT OF VARIOUS FACTORS ON PREDICTED CONCENTRATION OF PRESENT MODEL

To find out the effect of various factors on the predicted ambient concentration of the present CFD model, the following model parameters and inputs: the exponent of the power law, the horizontal dispersion coefficient, the vertical dispersion coefficient, wind direction, and wind speed, are investigated to see their effects on the predicted values of the predicted 45-minute-averaged concentration at various receptors for the case of gas dispersion over an isolated hill.

6.1 Description of the study

In the previous chapter, it was proved that the model is quite valid for the air pollutant dispersion over non-planar terrain. Consequently, the effects of input parameters on the released tracer gas from a continuous point source, which is at 115 meters above the ground and lies upwind of an isolated hill, is studied here by using computer experiments. The isolated hill is modeled after Steptoe Butte hill, Washington State, with the same contour lines as used in the wind tunnel experiments carried out by R. Ohba, et.al. (1990). The contours of the hill, point source position and various receptor positions are shown in Figure 6.1. Each receptor is located 10 m. above the ground. As in the previous wind tunnel experiments, the predicted 45-min-averaged concentration at each receptor point is chosen to indicate the effect of the factors on the gas dispersion over the isolated hill. Ohba et al. used sulfur hexafluoride (SF_6) as inert, nontoxic tracer in their study. First, identification of significant factors is carried out in section 6.2.

6.2 Identification of significant factors for the model

To carry out the computer experiments with efficiency, the factorial design is chosen. Since the number of factors related to the computer experiments is moderately large, say $k \geq 4$, the total number of runs required for the identification becomes large even though the principle of the 2^k factorial experiment is used. Fortunately, the factorial design is useful for this situation. The screening experiments are performed at this early stage in order to identify and discard the factors that have little or no effect.

In this study, we will investigate 5 main factors as follows:

- The exponent of the power law (Pow)
- Horizontal dispersion coefficient (K_H)
- Vertical dispersion coefficient (K_V)
- Wind direction (WD)
- Wind speed (WS)

The ranges of these factors are shown in Table 6.1

At first, the factorial experimental design method is employed to identify the significant factors. Thus, 2^5 treatment combinations or 32 runs, for examples, the cases of *a, b, c, d, e, abc, abd, acd*, etc., are tested. Based on the experimental design principle (Montgomery, 1984), the designation of treatment combinations such as *a, b, c, abc, abcde*, etc. is used to indicate that the corresponding capital letters take on their maxima or high values and the remaining unmentioned factors take on their minima or low values. For example, the case of *a* consists of maximum value of A, but minimum values of factors B, C, D, and E.

Table 6.1 Minimum and maximum values of factors investigated

Range	**Main effect**				
	A = Pow	B = K_H	C = K_V	D = WD	E = WS
Minimum	0.25	20	1	192	2
Maximum	0.55	200	5	226	4

In the identification of the significant factors, the model parameters used are summarized in Table 6.2.

Table 6.2 Simulation conditions used in the simulations to find out the significant factors

Simulation conditions	
Number of grid points in the x, y and z directions	24 x 51 x 26
Grid size ($\Delta x, \Delta y, \Delta z$)	200, 20, 200 m.
Emission Rate	0.631 g/s
Integration step size(Δt)	0.5 sec.
The height of all receptors	10 meter above ground

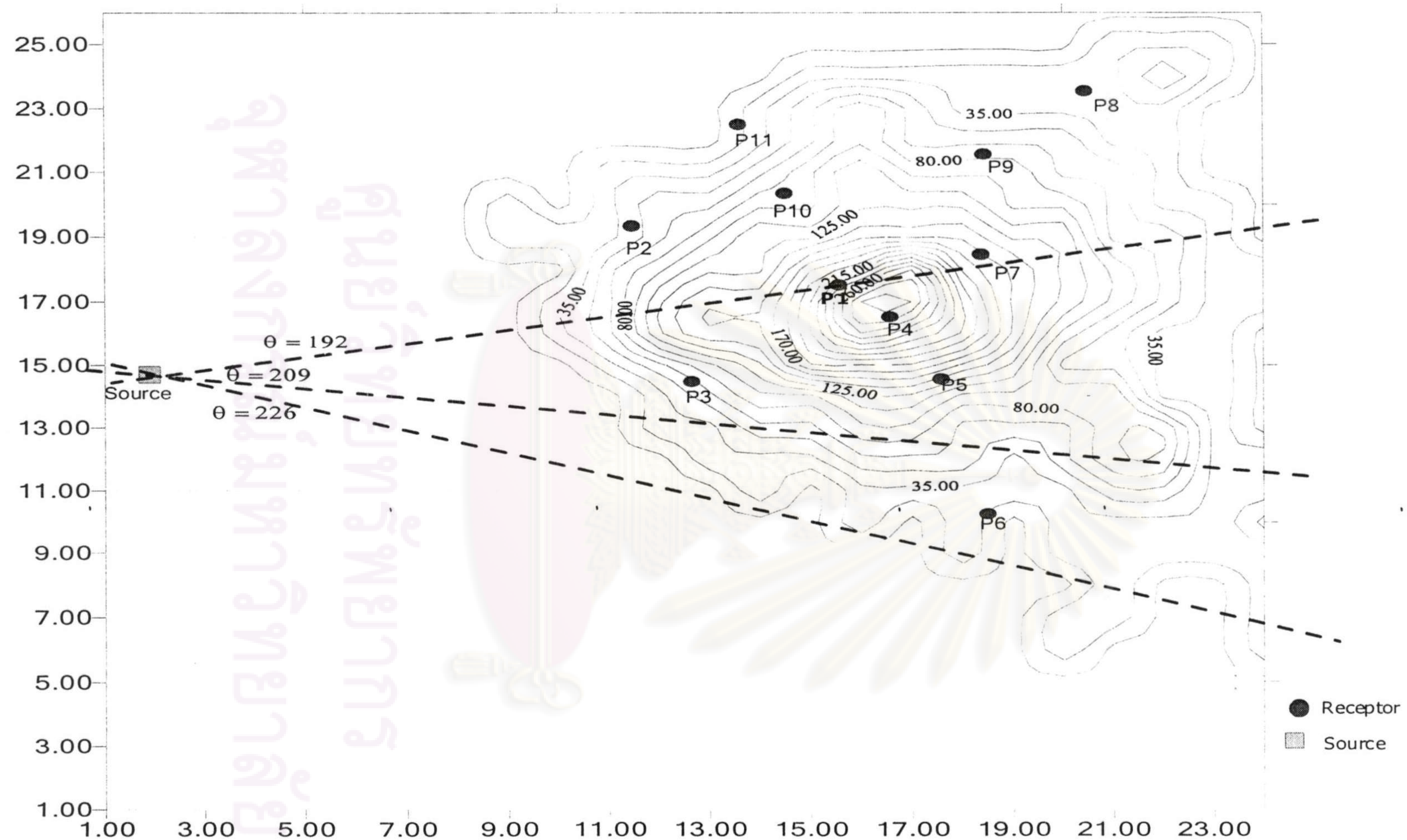

Figure 6.1 A topographical map of Steptoe Butte used in the simulation, [source position (square) and receptor points (circles) with contour lines in meters above the surrounding ground]

From the simulation results, the predicted 45-minute-averaged concentrations at various receptor points in the application of 2^5 factorial design are picked out and listed in Table 6.3. To analyse whether a factor has any significant effect, estimation of the treatment effects on normal probability paper can easily be applied to this study. First, the estimated effects at all receptor points are ordered from the smallest to the largest effects for the 2^5 factorial design of air pollutant dispersion over the isolated hill and presented in Table 6.2 to Table 6.14, respectively. The plot of the estimated effect of each factor on the normal probability paper is illustrated in Figure 6.2 to Figure 6.7. For simplicity the estimated effects can be calculated using Yate's method presented in Appendix C. To study the topographical effect of the relative positions of the receptors around the hill, a receptor point on the upwind slope (P3), on the summit (P4), on the side of hill (P5), on the roughly flat ground (P6), and on the lee side slope (P7 and P9), are chosen. The estimation of the treatment effects on normal probability paper and the effect of various factors at various receptor points are summarized in Appendix D.

Table 6.3 The predicted 45-minute-averaged concentration at various receptor points in the 2^5 factorial design

Number of run	Treatment combinations	predicted 45-min-averaged conc.($\mu g/m^3$) at each receptor point (10 m above ground level)										
		P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**
1	*(1)*	8.432	0.551	0.627	2.025	0.237	0.000	0.174	0.000	0.024	0.902	0.007
2	*a*	8.710	0.574	0.965	2.443	0.467	0.004	0.152	0.000	0.034	1.357	0.014
3	*b*	1.314	0.441	0.277	0.318	0.168	0.032	0.053	0.008	0.086	0.657	0.195
4	*ab*	1.198	0.476	0.302	0.356	0.192	0.032	0.055	0.006	0.093	0.767	0.220
5	*c*	1.994	0.340	0.609	0.809	0.187	0.000	0.140	0.000	0.027	0.336	0.008
6	*ac*	2.249	0.396	0.799	0.938	0.271	0.002	0.147	0.000	0.042	0.509	0.021
7	*bc*	0.725	0.267	0.238	0.144	0.094	0.041	0.033	0.009	0.045	0.259	0.109
8	*abc*	0.826	0.271	0.242	0.171	0.109	0.045	0.038	0.010	0.054	0.306	0.122
9	*d*	12.515	1.203	0.716	0.000	0.000	1.695	0.000	0.000	0.000	0.272	0.000
10	*ad*	12.531	0.969	0.647	0.000	0.000	1.474	0.000	0.000	0.000	0.237	0.000
11	*bd*	6.227	1.701	6.781	0.117	0.000	2.456	0.000	0.000	0.000	0.825	0.000
12	*abd*	1.678	0.519	1.923	0.024	0.000	0.532	0.000	0.000	0.000	0.294	0.000
13	*cd*	12.898	0.514	0.499	0.000	0.000	0.716	0.000	0.000	0.000	0.126	0.000
14	*acd*	11.424	0.460	0.219	0.000	0.000	0.629	0.000	0.000	0.000	0.113	0.000
15	*bcd*	7.881	0.793	4.302	0.000	0.000	1.652	0.000	0.000	0.000	0.330	0.000
16	*abcd*	7.366	0.674	3.858	0.000	0.000	1.721	0.000	0.000	0.000	0.302	0.000

Table 6.3 (Cont.) The predicted 45-minute-averaged concentration at various receptor points in the 2^5 factorial design

Number of run	Treatment combinations	predicted 45-min-averaged conc.($\mu g/m^3$) at each receptor point (10 m above ground level)										
		P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**
17	*e*	41.684	2.406	0.674	6.537	0.421	0.000	0.153	0.036	1.019	11.990	1.085
18	*ae*	41.684	2.406	0.674	6.537	0.421	0.000	0.153	0.036	1.019	11.990	1.085
19	*be*	35.331	2.290	0.166	4.174	0.000	0.000	0.184	0.041	0.880	8.536	1.007
20	*abe*	5.952	1.076	0.412	1.498	0.510	0.055	0.270	0.077	0.658	3.430	0.747
21	*ce*	9.303	1.574	0.925	2.590	0.216	0.000	0.419	0.063	0.557	3.088	0.467
22	*ace*	9.141	1.654	1.651	2.871	0.602	0.000	0.356	0.080	0.627	3.775	0.592
23	*bce*	3.326	0.852	0.626	0.631	0.345	0.109	0.182	0.080	0.305	1.241	0.462
24	*abce*	0.724	0.194	0.100	0.124	0.083	0.034	0.046	0.041	0.133	0.390	0.188
25	*de*	2.758	1.525	0.000	0.000	0.242	0.000	0.000	0.000	0.000	0.134	0.000
26	*ade*	4.014	1.475	0.000	0.000	0.000	1.187	0.000	0.000	0.000	0.097	0.000
27	*bde*	3.670	1.021	3.444	0.560	0.126	6.156	0.000	0.000	0.000	0.373	0.000
28	*abde*	1.255	0.195	1.203	0.418	0.121	4.182	0.026	0.000	0.000	0.109	0.000
29	*cde*	16.255	1.241	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.231	0.000
30	*acde*	15.342	1.110	0.000	0.000	0.000	0.438	0.000	0.000	0.000	0.199	0.000
31	*bcde*	10.586	0.795	5.488	0.000	0.000	5.418	0.000	0.000	0.000	0.248	0.000
32	*abcde*	8.711	0.530	3.870	0.000	0.000	4.702	0.000	0.000	0.000	0.185	0.000

Table 6.4 Ordered effects on the predicted 45-minute-averaged concentration at receptor point P3 for the 2^5 factorial design

Order(q)	Pq	Treatment effect	Estimated effect
1	0.01613	AD	-0.4767
2	0.04839	A	-0.4140
3	0.08065	DE	-0.4076
4	0.11290	E	-0.3346
5	0.14516	ABCE	-0.2955
6	0.17742	ABCDE	-0.1941
7	0.20968	AB	-0.1743
8	0.24194	BCE	-0.1538
9	0.27419	ACDE	-0.0888
10	0.30645	ABE	-0.0713
11	0.33871	ABD	-0.0643
12	0.37097	ABDE	-0.0554
13	0.40323	ACD	-0.0532
14	0.43548	ACE	0.0006
15	0.46774	CD	0.0400
16	0.50000	AC	0.0880
17	0.53226	BC	0.1193
18	0.56452	BE	0.1289
19	0.59677	AE	0.1420
20	0.62903	ADE	0.1490
21	0.66129	BDE	0.1713
22	0.69355	CDE	0.1747
23	0.72581	BCDE	0.1804
24	0.75806	BCD	0.1814
25	0.79032	C	0.2225
26	0.82258	ABC	0.2391
27	0.85484	CE	0.2783
28	0.88710	ABCD	0.3248
29	0.91935	D	0.5227
30	0.95161	B	0.9315
31	0.98387	BD	1.2166

Table 6.5 Ordered effects on the predicted 45-minute-averaged concentration at receptor point P4 for the 2^5 factorial design

Order(q)	**Pq**	**Treatment effect**	**Estimated effect**
1	0.01613	D	-0.9702
2	0.04839	DE	-0.5287
3	0.08065	C	-0.5227
4	0.11290	E	-0.5067
5	0.14516	CE	-0.3215
6	0.17742	B	-0.1930
7	0.20968	BCD	-0.1889
8	0.24194	BE	-0.1306
9	0.27419	AB	-0.1113
10	0.30645	AE	-0.0947
11	0.33871	ABE	-0.0789
12	0.37097	A	-0.0604
13	0.40323	ABCD	-0.0488
14	0.43548	ABCDE	-0.0366
15	0.46774	BCDE	-0.0052
16	0.50000	ACDE	-0.0047
17	0.53226	AC	-0.0015
18	0.56452	ABDE	0.0083
19	0.59677	ACE	0.0193
20	0.62903	ACD	0.0421
21	0.66129	BCE	0.0518
22	0.69355	ABCE	0.0642
23	0.72581	AD	0.0750
24	0.75806	ABC	0.1082
25	0.79032	ADE	0.1231
26	0.82258	BC	0.2091
27	0.85484	ABD	0.2413
28	0.88710	BDE	0.2692
29	0.91935	CDE	0.4529
30	0.95161	CD	0.5766
31	0.98387	BD	0.5810

Table 6.6 Ordered effects on the predicted 45-minute-averaged concentration at receptor point P5 for the 2^5 factorial design

Order(q)	Pq	Treatment effect	Estimated effect
1	0.01613	D	-0.1198
2	0.04839	AD	-0.0390
3	0.08065	B	-0.0335
4	0.11290	ABCE	-0.0322
5	0.14516	C	-0.0312
6	0.17742	CDE	-0.0247
7	0.20968	ABC	-0.0237
8	0.24194	ADE	-0.0170
9	0.27419	ACDE	-0.0169
10	0.30645	BCE	-0.0138
11	0.33871	DE	-0.0120
12	0.37097	BCD	-0.0087
13	0.40323	ABD	-0.0078
14	0.43548	ACD	-0.0072
15	0.46774	BC	-0.0068
16	0.50000	CE	-0.0060
17	0.53226	AB	-0.0047
18	0.56452	BCDE	-0.0031
19	0.59677	ABDE	0.0000
20	0.62903	CD	0.0006
21	0.66129	BE	0.0039
22	0.69355	AC	0.0072
23	0.72581	BDE	0.0116
24	0.75806	ABE	0.0125
25	0.79032	ACE	0.0169
26	0.82258	AE	0.0170
27	0.85484	ABCD	0.0237
28	0.88710	ABCDE	0.0322
29	0.91935	A	0.0390
30	0.95161	E	0.0426
31	0.98387	BD	0.0490

Table 6.7 Ordered effects on the predicted 45-minute-averaged concentration at receptor point P6 for the 2^5 factorial design

Order(q)	Pq	Treatment effect	Estimated effect
1	0.01613	AB	-0.1546
2	0.04839	ABD	-0.1527
3	0.08065	A	-0.1304
4	0.11290	AD	-0.1297
5	0.14516	ABE	-0.1164
6	0.17742	ABDE	-0.1158
7	0.20968	BCE	-0.0916
8	0.24194	CD	-0.0785
9	0.27419	BCDE	-0.0778
10	0.30645	C	-0.0719
11	0.33871	ACDE	-0.0435
12	0.37097	ABCE	-0.0289
13	0.40323	ABCDE	-0.0203
14	0.43548	ACE	0.0009
15	0.46774	CDE	0.0126
16	0.50000	CE	0.0169
17	0.53226	ACD	0.0309
18	0.56452	BCD	0.0587
19	0.59677	AE	0.0626
20	0.62903	ADE	0.0645
21	0.66129	BC	0.0657
22	0.69355	AC	0.0754
23	0.72581	ABC	0.1462
24	0.75806	ABCD	0.1540
25	0.79032	DE	0.3490
26	0.82258	E	0.3516
27	0.85484	BDE	0.5524
28	0.88710	BE	0.5559
29	0.91935	BD	0.6590
30	0.95161	B	0.6803
31	0.98387	D	1.0188

Table 6.8 Ordered effects on the predicted 45-minute-averaged concentration at receptor point P7 for the 2^5 factorial design

Order(q)	Pq	Treatment effect	Estimated effect
1	0.01613	D	-0.0791
2	0.04839	CD	-0.0295
3	0.08065	B	-0.0252
4	0.11290	BC	-0.0225
5	0.14516	BCE	-0.0217
6	0.17742	CDE	-0.0108
7	0.20968	ACE	-0.0088
8	0.24194	AC	-0.0069
9	0.27419	ABC	-0.0066
10	0.30645	DE	-0.0060
11	0.33871	ABCE	-0.0049
12	0.37097	A	-0.0030
13	0.40323	AE	-0.0024
14	0.43548	BDE	-0.0002
15	0.46774	ABD	-0.0001
16	0.50000	ABE	0.0005
17	0.53226	ABDE	0.0008
18	0.56452	BE	0.0019
19	0.59677	AB	0.0020
20	0.62903	ABCDE	0.0033
21	0.66129	ADE	0.0040
22	0.69355	C	0.0044
23	0.72581	AD	0.0046
24	0.75806	ABCD	0.0050
25	0.79032	ACD	0.0053
26	0.82258	ACDE	0.0072
27	0.85484	CE	0.0092
28	0.88710	BCD	0.0209
29	0.91935	BCDE	0.0210
30	0.95161	BD	0.0268
31	0.98387	E	0.0311

Table 6.9 Ordered effects on the predicted 45-minute-averaged concentration at receptor point P9 for the 2^5 factorial design

Order(q)	Pq	Treatment effect	Estimated effect
1	0.01613	D	-0.1751
2	0.04839	DE	-0.1497
3	0.08065	CE	-0.0589
4	0.11290	C	-0.0505
5	0.14516	BE	-0.0436
6	0.17742	B	-0.0342
7	0.20968	AB	-0.0149
8	0.24194	ABE	-0.0142
9	0.27419	AE	-0.0114
10	0.30645	BC	-0.0106
11	0.33871	A	-0.0089
12	0.37097	BCE	-0.0076
13	0.40323	ACE	-0.0034
14	0.43548	AC	-0.0030
15	0.46774	ABC	-0.0008
16	0.50000	ABCE	-0.0005
17	0.53226	ABDE	0.0000
18	0.56452	ABCDE	0.0005
19	0.59677	ABCD	0.0008
20	0.62903	ACD	0.0030
21	0.66129	ACDE	0.0034
22	0.69355	BCDE	0.0049
23	0.72581	AD	0.0089
24	0.75806	BCD	0.0106
25	0.79032	ADE	0.0114
26	0.82258	ABD	0.0291
27	0.85484	BD	0.0342
28	0.88710	BDE	0.0436
29	0.91935	CDE	0.0589
30	0.95161	CD	0.0632
31	0.98387	E	0.1497

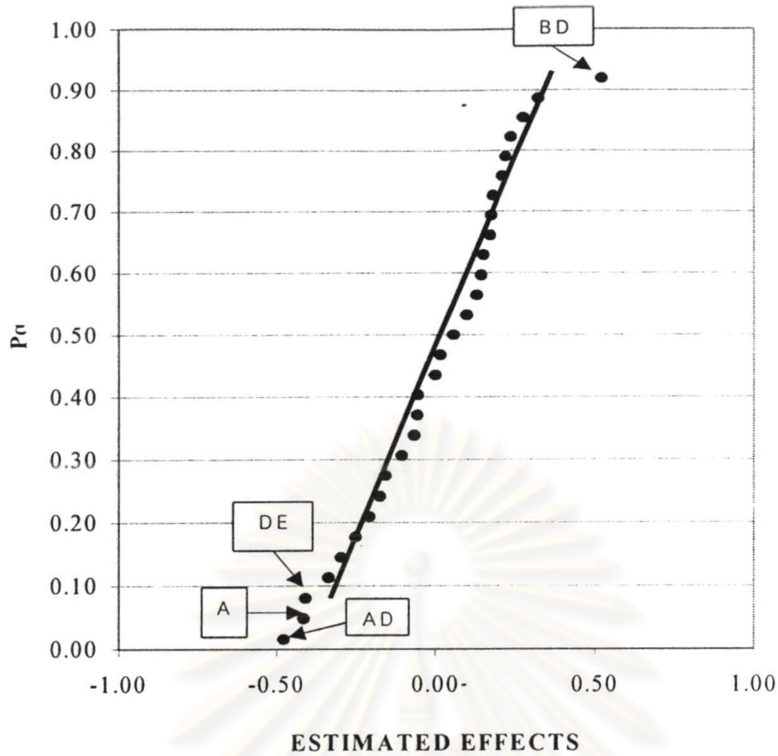

Figure 6.2 Normal probability plot of the ordered effects on the predicted 45-min-averaged concentration at P3 for the 2^5 factorial design

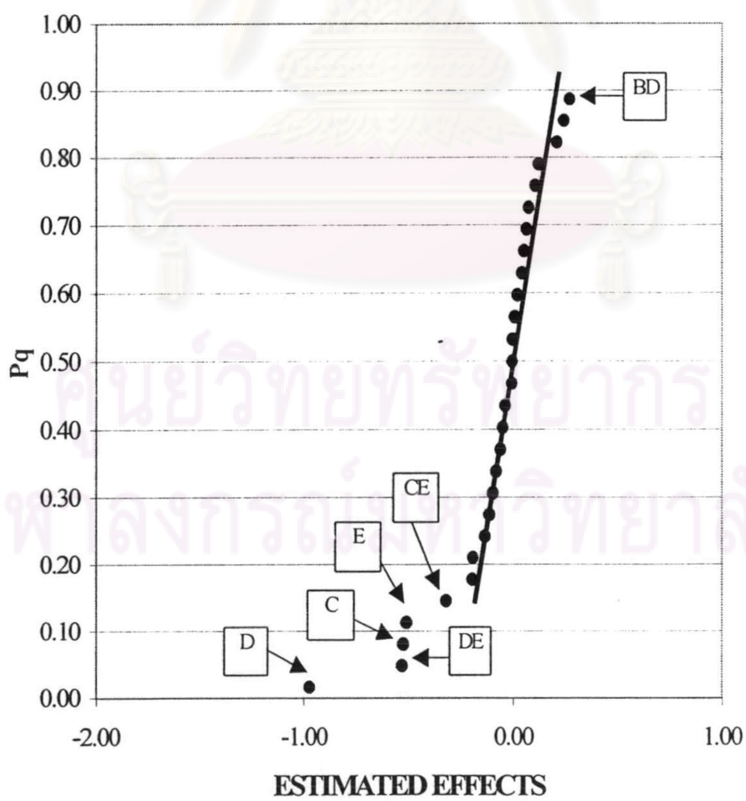

Figure 6.3 Normal probability plot of the ordered effects on the predicted 45-min-averaged concentration at P4 for the 2^5 factorial design

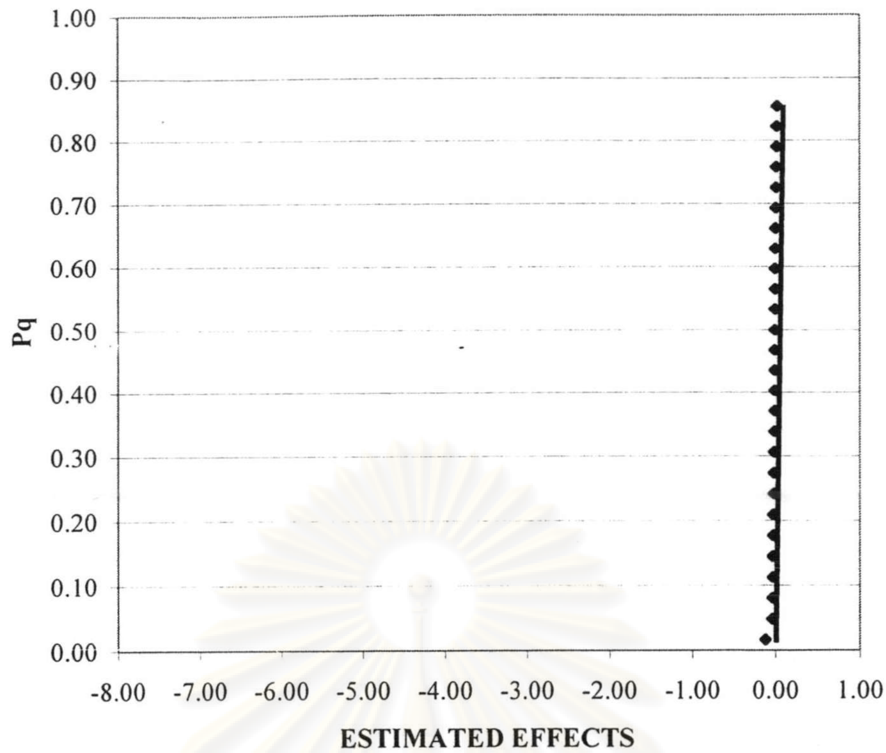

Figure 6.4 Normal probability plot of the ordered effects on the predicted 45-min-averaged concentration at P5 for the 2^5 factorial design

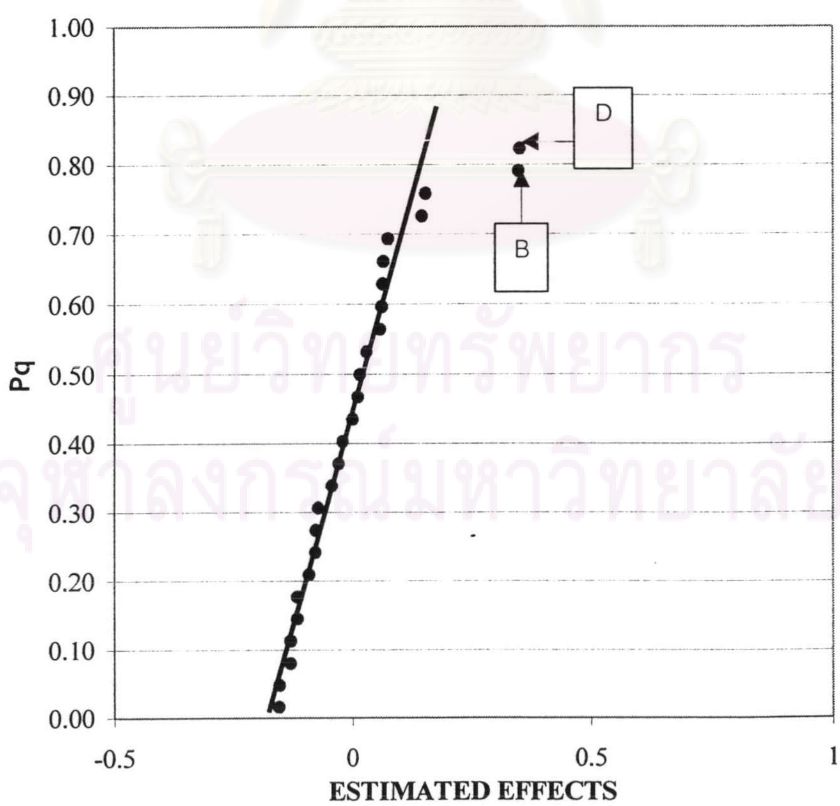

Figure 6.5 Normal probability plot of the ordered effects on the predicted 45-min-averaged concentration at P6 for the 2^5 factorial design

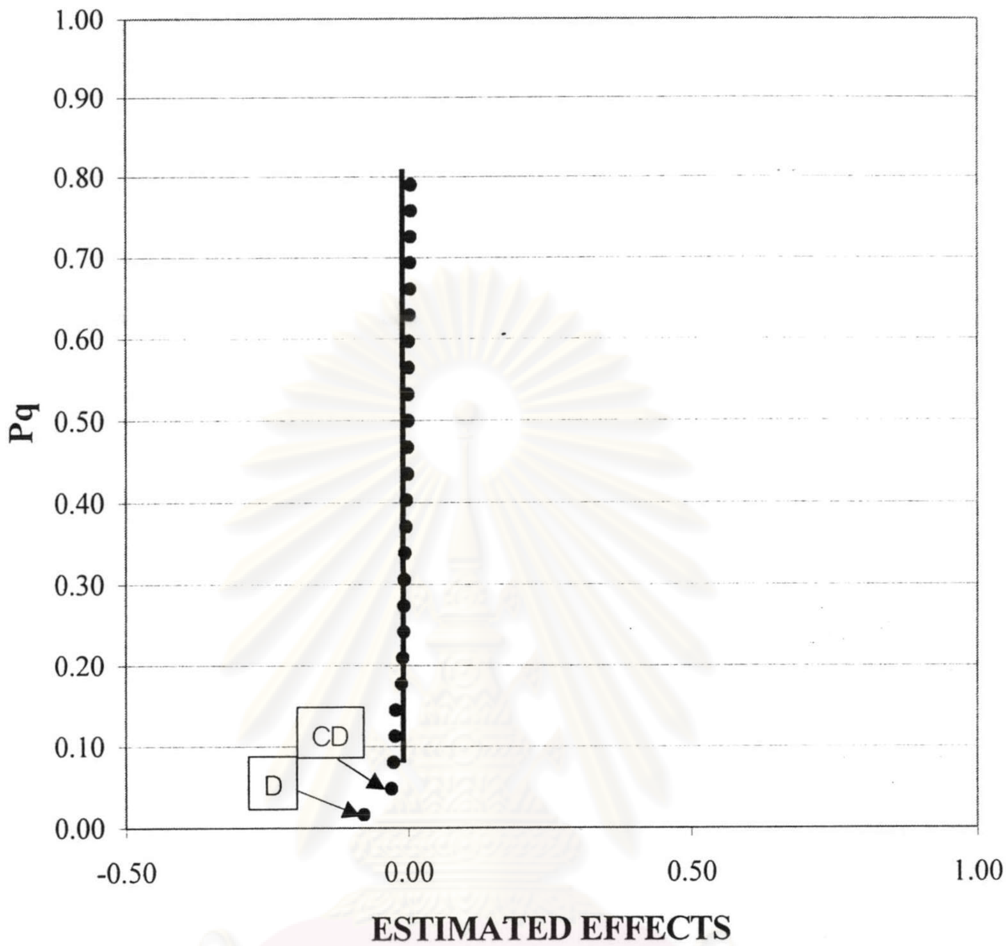

Figure 6.6 Normal probability plot of the ordered effects on the predicted 45-min-averaged concentration at P7 for the 2^5 factorial design

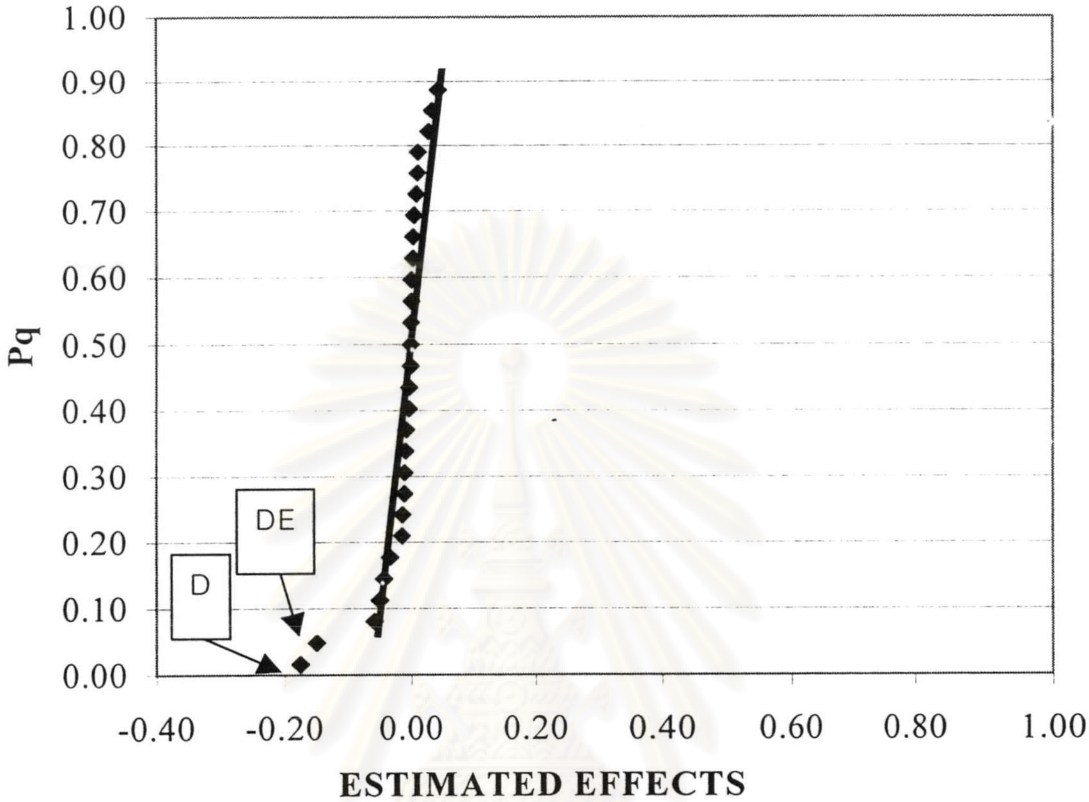

Figure 6.7 Normal probability plot of the ordered effects on the predicted 45-min-averaged concentration at P9 for the 2^5 factorial design

Based on Figures 6.2-6.7 and Tables 6.4-6.9, the following conclusions have been obtained.

1) The exponent of the power law, horizontal dispersion coefficient, wind direction, wind speed and the binary interaction of the exponent of the power law and wind direction, the horizontal dispersion coefficient and wind direction, and the wind direction and wind speed have significant effects on the predicted 45-min-averaged concentration at receptor point P3 located in an upwind area.

2) At receptor P4 the vertical dispersion coefficient, wind direction, wind speed and the binary interaction of the horizontal dispersion coefficient and wind direction, the vertical dispersion coefficient and wind speed, and the wind direction and wind speeds have significant effects.

3) No factors have significant effects at receptor P5.

4) As for receptor P6, only the horizontal dispersion coefficient and wind direction affect the predicted 45-min-averaged concentration.

5) For the lee-side receptors, P7 and P9, the vertical dispersion coefficient, wind speed and their interaction have significant effects at receptor

P7, whereas at P9 the wind direction, wind speed and their interaction have significant effects.

6.3 Effects of significant factors

The effect of the significant factors at different types of receptor points namely on the upwind slope (P3), the summit (P4), the side of the hill (P5), the roughly flat terrain (P6), and the leeside slope (P7 and P9) are investigated in this section. The simulation conditions for all cases are listed in Table 6.10.

Table 6.10 Simulation conditions used to investigate the effect of the significant factors on the predicted 45-min. average concentration at various receptor points.

Case	**The exponent of the power law**	**Horizontal dispersion coefficient (m^2/s)**	**Vertical dispersion coefficient (m^2/s)**	**Wind direction (degrees)**	**Wind speed (m/s)**
Exp-Effect	0.25	200	1	192	4
	0.3	200	1	192	4
	0.35	200	1	192	4
	0.55	200	1	192	4
K_H-Effect	0.55	20	1	192	4
	0.55	50	1	192	4
	0.55	100	1	192	4
	0.55	150	1	192	4
	0.55	200	1	192	4
K_V-Effect	0.55	200	1	192	4
	0.55	200	2	192	4
	0.55	200	3	192	4
	0.55	200	4	192	4
	0.55	200	5	192	4
WD-Effect	0.55	200	1	192	4
	0.55	200	1	200	4
	0.55	200	1	209	4
	0.55	200	1	226	4
WS-Effect	0.55	200	1	192	2
	0.55	200	1	192	3
	0.55	200	1	192	3.5
	0.55	200	1	192	4

Case	The exponent of the power law	Horizontal dispersion coefficient (m^2/s)	Vertical dispersion coefficient (m^2/s)	Wind direction (degrees)	Wind speed (m/s)
Exp&WD -Effect	0.25	200	1	192	4
	0.3	200	1	192	4
	0.35	200	1	192	4
	0.55	200	1	192	4
	0.25	200	1	209	4
	0.3	200	1	209	4
	0.35	200	1	209	4
	0.55	200	1	209	4
Exp&WD -Effect	0.25	200	1	226	4
	0.3	200	1	226	4
	0.35	200	1	226	4
	0.55	200	1	226	4
WD&WS -Effect	0.55	200	1	192	2.5
	0.55	200	1	192	3
	0.55	200	1	192	3.5
	0.55	200	1	192	4
	0.55	200	1	209	2.5
	0.55	200	1	209	3
	0.55	200	1	209	3.5
	0.55	200	1	209	4
	0.55	200	1	226	2.5
	0.55	200	1	226	3
	0.55	200	1	226	3.5
	0.55	200	1	226	4
WD&K_H-Effect	0.55	20	1	192	4
	0.55	50	1	192	4
	0.55	100	1	192	4
	0.55	150	1	192	4
	0.55	200	1	192	4
	0.55	20	1	209	4
	0.55	50	1	209	4
	0.55	100	1	209	4
	0.55	150	1	209	4
	0.55	200	1	209	4

Case	The exponent of the power law	Horizontal dispersion coefficient (m^2/s)	Vertical dispersion coefficient (m^2/s)	Wind direction (degrees)	Wind speed (m/s)
WD&K_H-Effect	0.55	20	1	226	4
	0.55	50	1	226	4
	0.55	100	1	226	4
	0.55	150	1	226	4
	0.55	200	1	226	4
WD&K_V-Effect	0.55	200	1	192	4
	0.55	200	2	192	4
	0.55	200	3	192	4
	0.55	200	4	192	4
	0.55	200	5	192	4
	0.55	200	1	209	4
	0.55	200	2	209	4
	0.55	200	3	209	4
	0.55	200	4	209	4
	0.55	200	5	209	4
	0.55	200	1	226	4
	0.55	200	2	226	4
	0.55	200	3	226	4
	0.55	200	4	226	4
	0.55	200	5	226	4
WS&K_H-Effect	0.55	20	1	192	4
	0.55	50	1	192	4
	0.55	100	1	192	4
	0.55	150	1	192	4
	0.55	200	1	192	4
	0.55		1	192	4
	0.55	20	1	192	3
	0.55	50	1	192	3
	0.55	100	1	192	3
	0.55	150	1	192	3
	0.55	200	1	192	3
	0.55		1	192	3
	0.55	20	1	192	2
	0.55	50	1	192	2
	0.55	100	1	192	2
	0.55	150	1	192	2
	0.55	200	1	192	2
	0.55		1	192	2
WS&K_V-Effect	0.55	200	1	192	2
	0.55	200	2	192	2
	0.55	200	3	192	2
	0.55	200	4	192	2
	0.55	200	5	192	2

Case	The Exponent of the power law	Horizontal dispersion coefficient (m^2/s)	Vertical dispersion coefficient (m^2/s)	Wind direction (degrees)	Wind speed (m/s)
WS&K_V-Effect	0.55	200	1	192	3
	0.55	200	2	192	3
	0.55	200	3	192	3
	0.55	200	4	192	3
	0.55	200	5	192	3
	0.55	200	1	192	4
	0.55	200	2	192	4
	0.55	200	3	192	4
	0.55	200	4	192	4
	0.55	200	5	192	4

6.3.1 Effect of horizontal dispersion coefficient

The predicted 45-minute-averaged concentration at receptors P3 and P6 are under the influence of the horizontal dispersion coefficient. Figure 6.8 shows that increasing the horizontal dispersion coefficient, K_H, from 20 to 200 m^2/s decreases the predicted average concentration at receptor P3 from about 0.7 to 0.4 $\mu g/m^3$ because of the horizontal expansion of the plume width with increasing horizontal dispersion coefficient. It is seen that as the horizontal dispersion coefficient decreases to 20 m^2/s, its influence on the predicted average concentration at receptor P3 is more obvious. As expected, increasing the horizontal dispersion coefficient, K_H, from 20 to 200 m^2/s slightly increases the predicted average concentration at receptor P6 as shown in Figure 6.9, since receptor P6 lies too far from the direction of 192 degrees to get the effect of plume dispersion when the horizontal dispersion coefficient is small. Since increasing the horizontal dispersion coefficient increases the plume width, the predicted average concentration at receptor P6 becomes slightly greater.

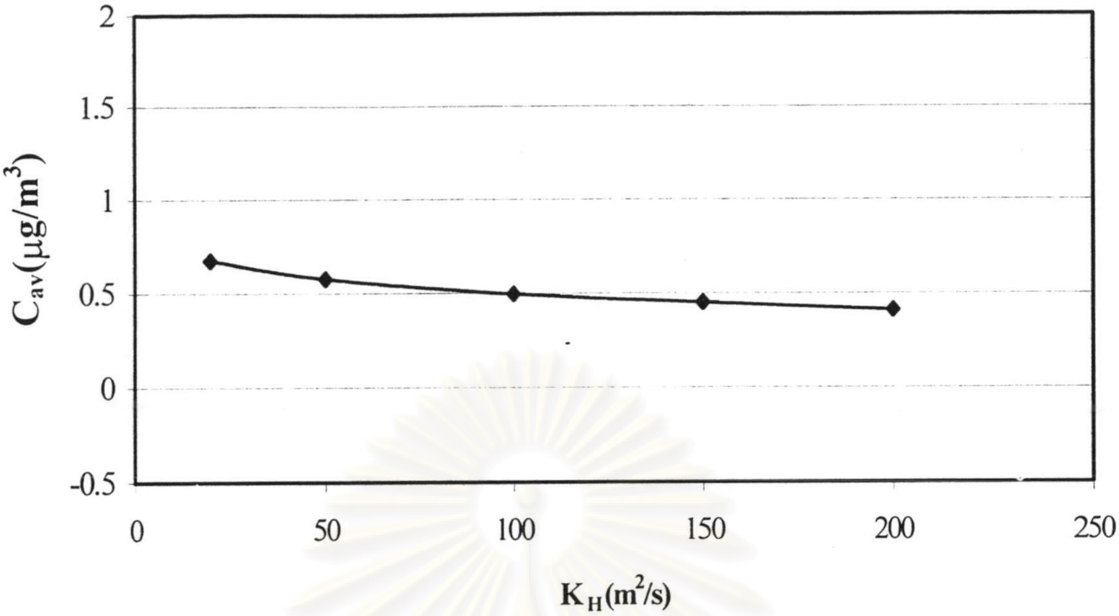

Figure 6.8 Effect of horizontal dispersion coefficient (K_H) on predicted 45-min-averaged concentration at receptor P3

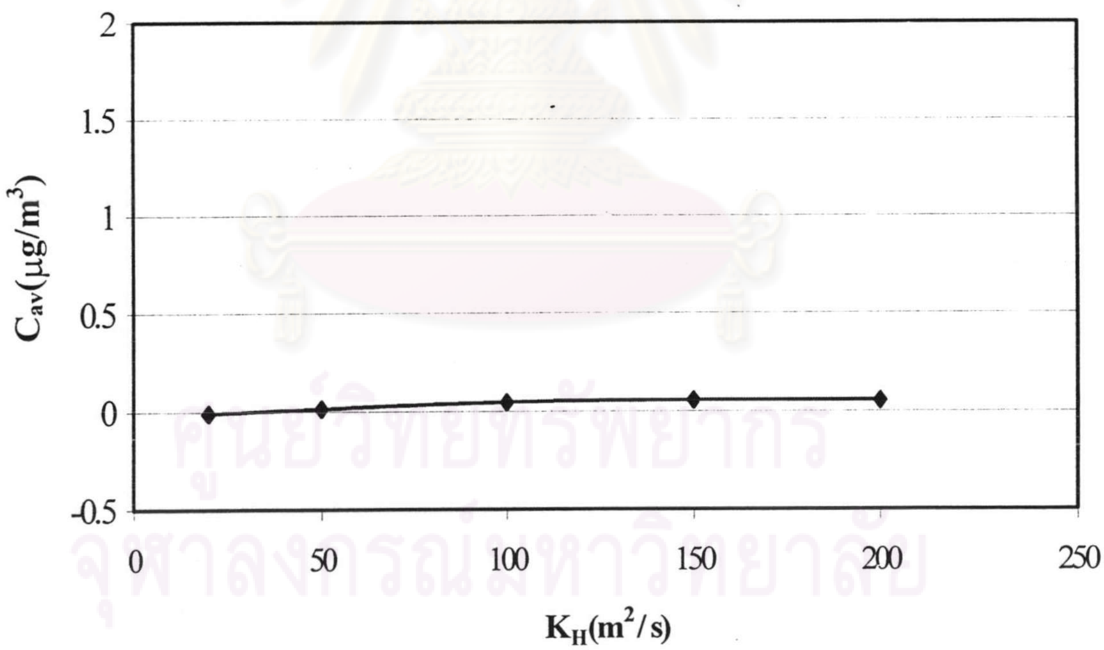

Figure 6.9 Effect of horizontal dispersion coefficient (K_H) on predicted 45-min-averaged concentration at receptor P6

6.3.2 Effect of vertical dispersion coefficient

The effect of the vertical dispersion coefficient, K_V, on the predicted 45-minute-averaged concentration are significant at receptors P4 and P7. Figures 6.10 and 6.11 show the same trend that increasing the vertical dispersion coefficient from 1 to 5 m^2/s halves the predicted average concentration from 1.5 to about 0.7 $\mu g/m^3$ at receptor P4 and from 0.27 to 0.17 $\mu g/m^3$ at receptor P7. Since the concentrations at P4 are several times greater than those at P7, it means that the probability of plume release reaching receptor P4 is higher than receptor P7 which is located on the lee side.

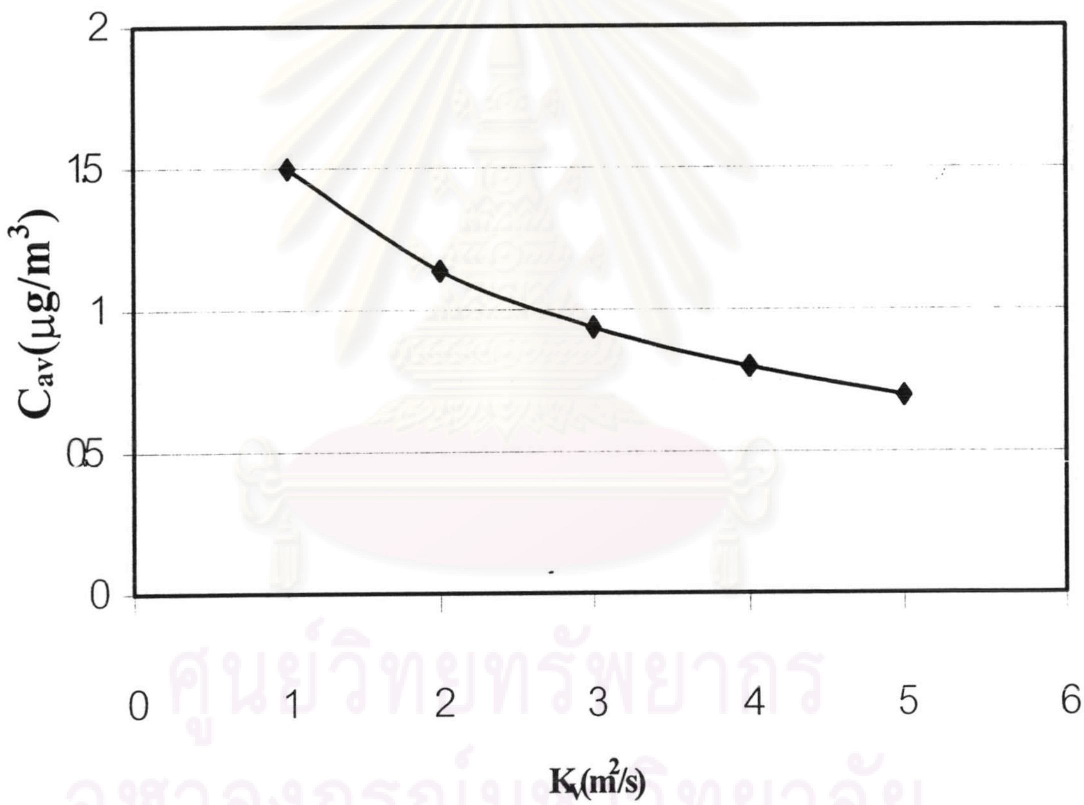

Figure 6.10 Effect of vertical dispersion coefficient (K_V) on predicted 45-min-averaged concentration at receptor P4

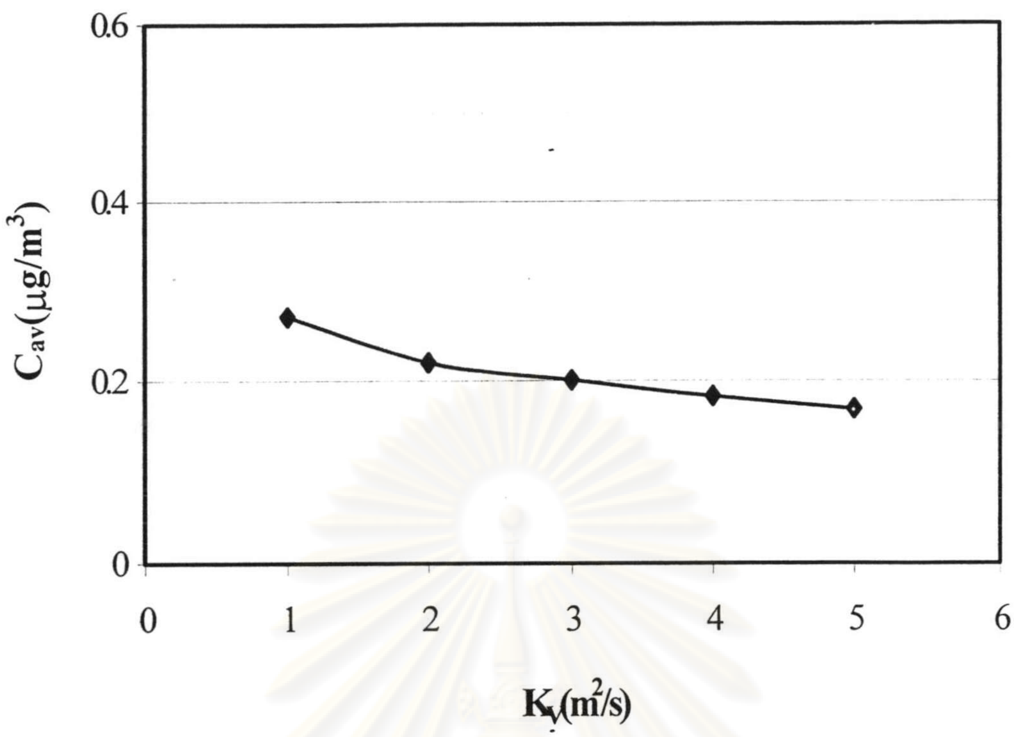

Figure 6.11 Effect of vertical dispersion coefficient (K_V) on predicted 45-min-averaged concentration at receptor P7

6.3.3 Effect of wind direction

The receptors P3, P4, P6 and P7 show significant impact of wind direction, WD, on the predicted average concentration. As is well known, the nearer the receptor is to the centerline of the plume, the higher the observed concentration becomes. The receptor P3 is located in between the paths of the dispersing plume of wind directions of 200 and 209 degrees from the north, and the exact wind direction should lie between 200 and 209 degrees. In Figure 6.12, it is seen that the predicted average concentration at receptor P3 in the case of wind direction of 200 degrees from the north is higher than that of 209 degrees from the north simply because the location of the receptor is closer to the centerline of the plume from wind direction of 200 than 209 degrees from the north. As for receptor P4, Figure 6.13 shows that the predicted average concentration increases as the wind direction shifts from 192 to 200 degrees and then decreases as the wind direction further shifts from 200 to 226 degrees because of its particular location. In contrast, the predicted average concentration at receptor P6 rises from nearly zero to about 4 ($\mu g/m^3$) as the wind direction shifts from 192 to 226 degrees, as shown in Figure 6.16, since the receptor is located near the path of the plume dispersing from wind direction of 226 degrees from the north. Interestingly, although receptor P7 is located near the path of the plume dispersing from the wind direction of 192 degrees, shifting the wind direction from 192 to 209 degrees neither increases nor decreases the predicted average concentration shown in Figure 6.15. This clearly implies that the effect of terrain on the observed concentration can be much greater than the effect of wind direction when the receptor is located on the lee side of a hill. However, upon further shifting the wind direction to 226 degrees, the predicted average concentration at receptor P7 decreases significantly to an unrealistic negative value because the path of the dispersing plume from the wind direction of 226 degrees is so far off that the plume body can not reach the receptor. On the other hand, receptor P9 is located on the path of a wind direction less than 192 degrees from the north, whereas the paths of wind directions of 209 and 226 degrees lie on the opposite side of the hill. Consequently, the highest average concentration at receptor P9 is observed for the wind direction of 192. The effect of wind direction in this case appears to be small, though.

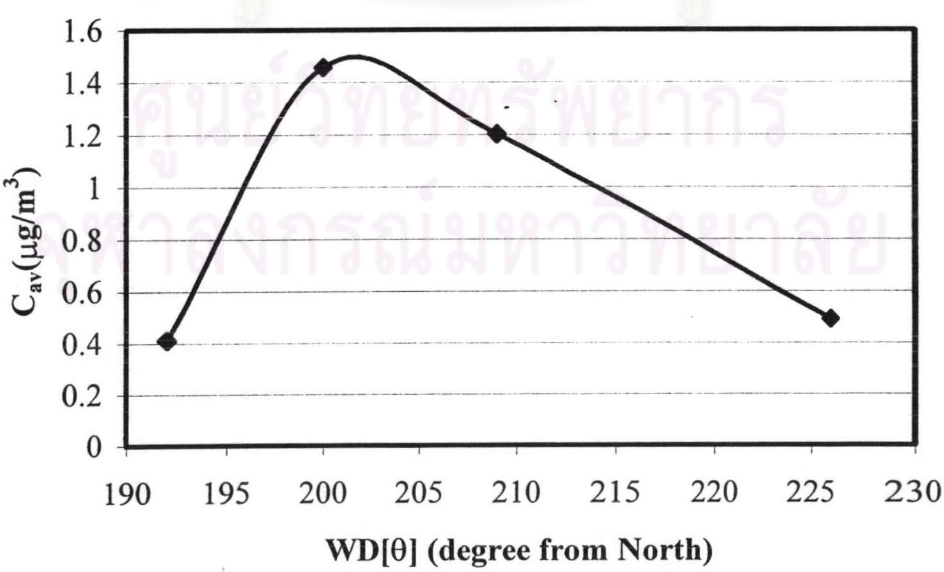

Figure 6.12 Effect of wind direction (WD) on predicted 45-min-averaged concentration at receptor P3

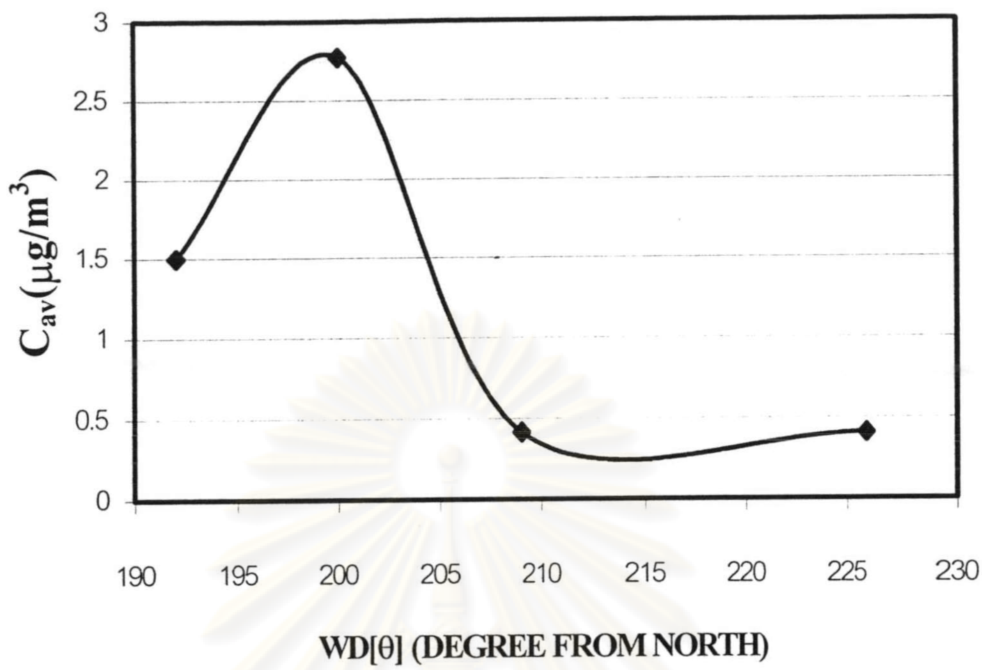

Figure 6.13 Effect of wind direction (WD) on predicted 45-min-averaged concentration at receptor P4

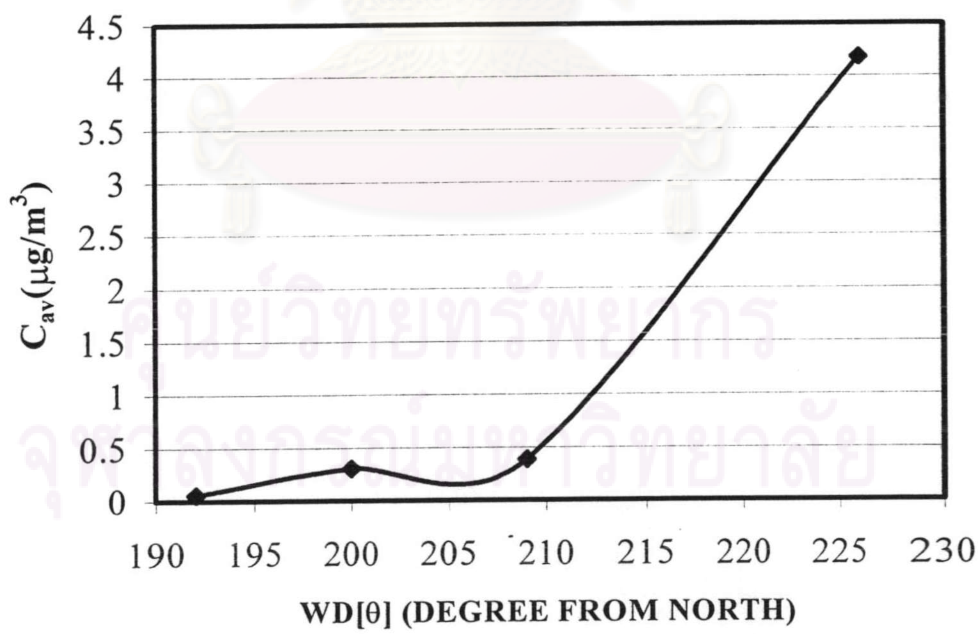

Figure 6.14 Effect of wind direction (WD) on predicted 45-min-averaged concentration at receptor P6

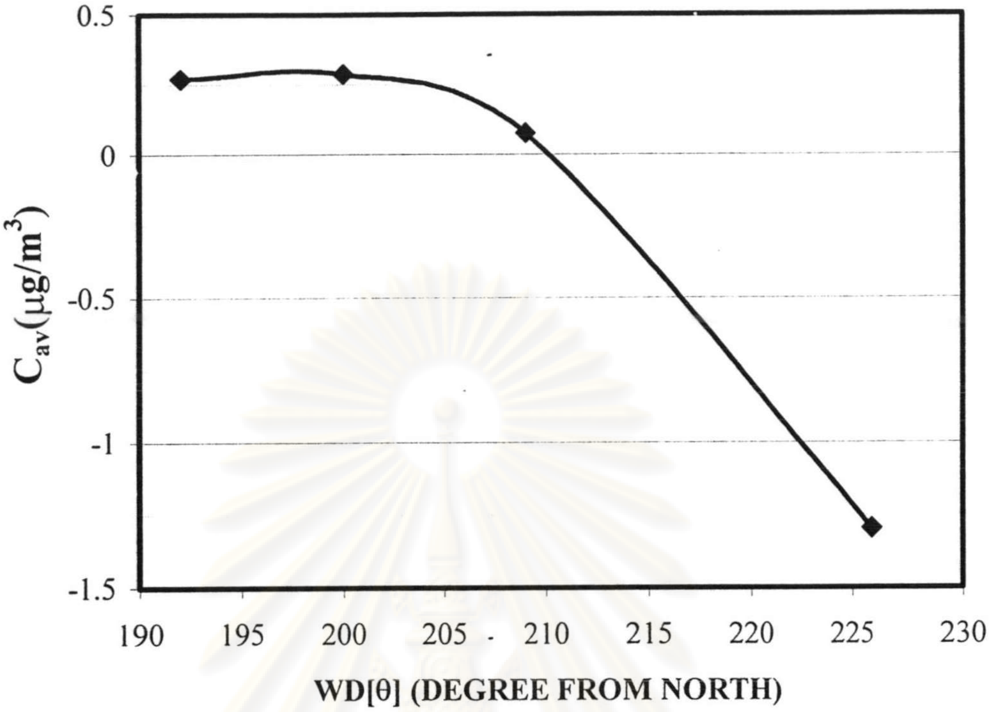

Figure 6.15 Effect of wind direction (WD) on predicted 45-min-averaged concentration at receptor P7

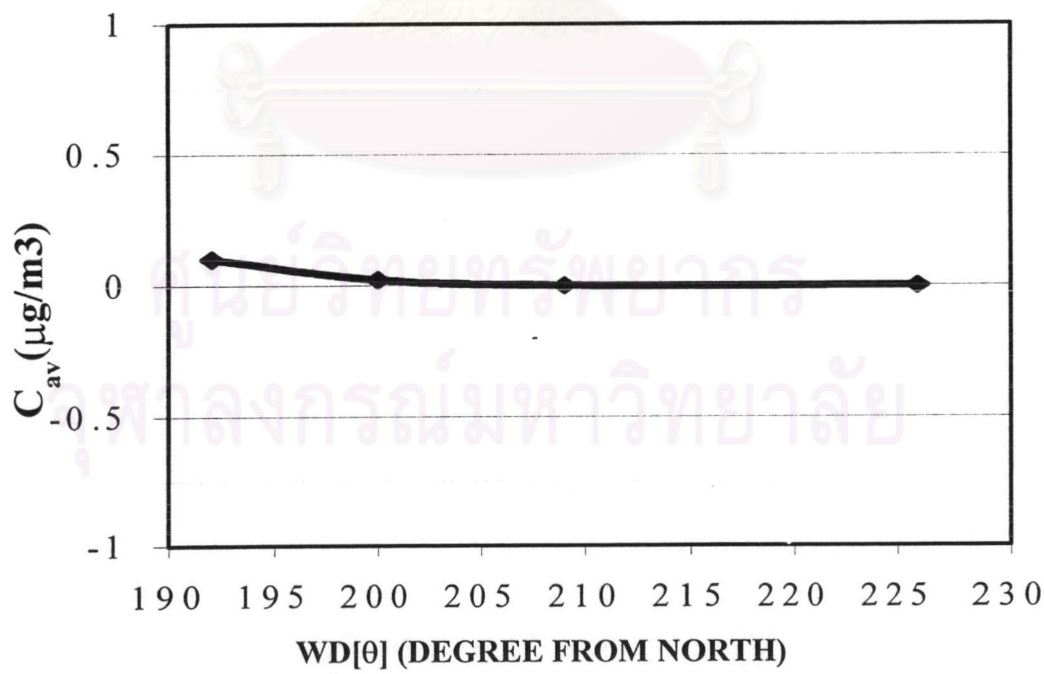

Figure 6.16 Effect of wind direction (WD) on predicted 45-min-averaged concentration at receptor P9

6.3.4 Effect of wind speed

The effect of wind speed, WS, on the predicted 45-minute-averaged concentration is significant at receptors P3, P4, and P9. In Figure 6.17, the predicted average concentration at receptor P3 decreases as wind speed increases from 2 to 4 m/s, because increasing the wind speed generally reduces the angle of the plume width, so receptor P3 detects less amount of the tracer gas under higher wind speed condition. On the other hand, increasing the wind speed increases the predicted average concentration from 0.6 to 1.5 $\mu g/m^3$ at receptor P4 and from 0.02 to 0.08 $\mu g/m^3$ at receptor P9 because receptor P4 is located near the centerline of the dispersing plume and receptor P9 is located farther downwind where the effect of smaller plume angle is higher. In other words, the plume angle decreases as the wind speed increases, and so does the predicted average concentration at receptor P9.

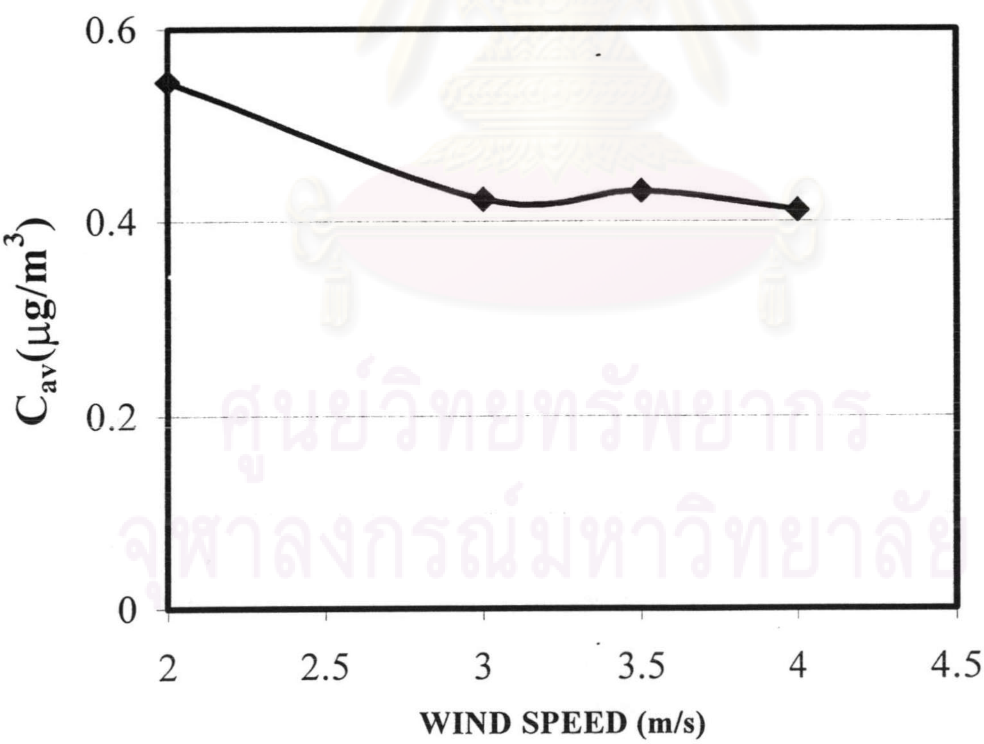

Figure 6.17 Effect of wind speed (WS) on the predicted 45-min-averaged concentration at receptor P3

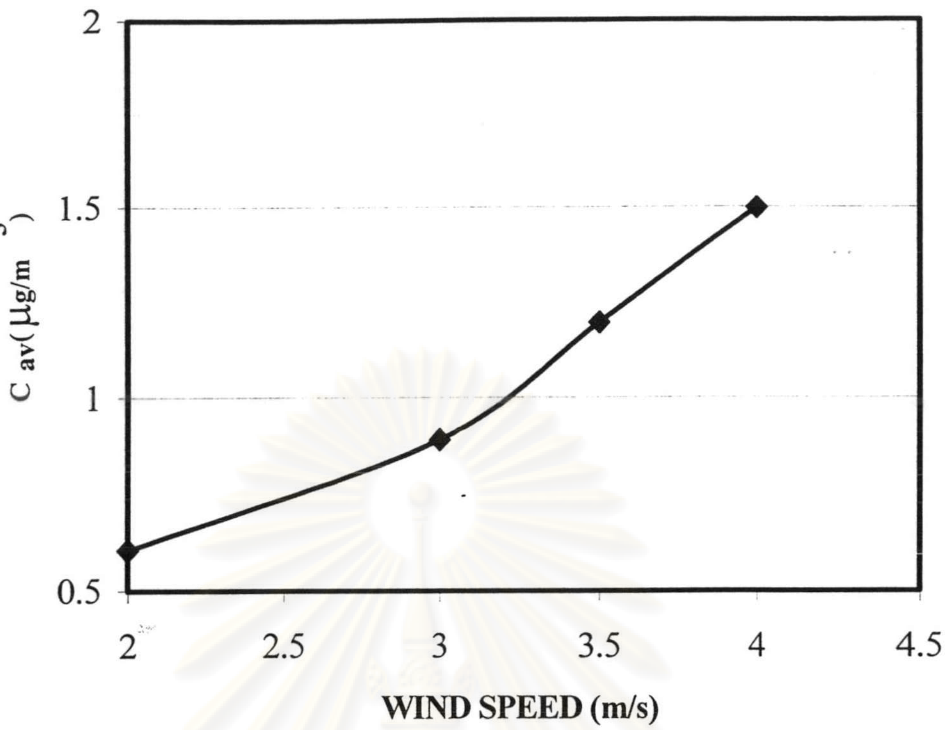

Figure 6.18 Effect of wind speed (WS) on the predicted 45-min-averaged concentration at receptor P4

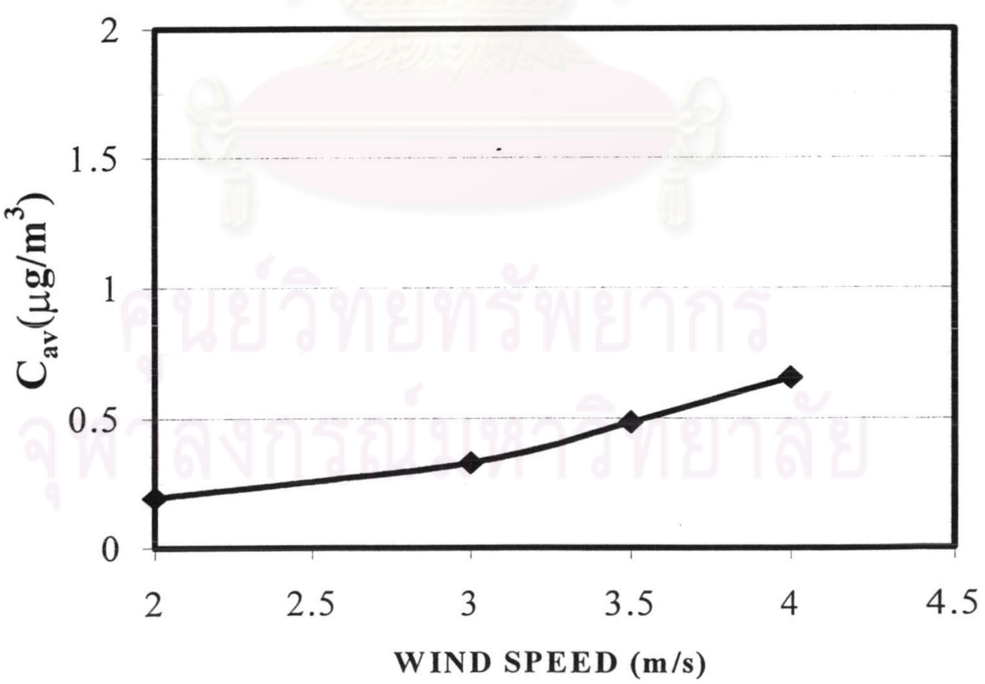

Figure 6.19 Effect of wind speed (WS) on the predicted 45-min-averaged concentration at receptor P9

6.3.5 Interactive effect of wind direction and horizontal dispersion coefficient

From the plot of ordered effects on the predicted 45-min-averaged concentration, it has been found that the interactive effect of wind direction and horizontal dispersion coefficient exerts significant influence on the predicted concentration at receptors P3, P4 and P6. Figure 6.20 illustrates that the predicted average concentration at receptor P3 in the case of wind direction of 226 degrees is significantly influenced by the horizontal dispersion coefficient, whereas for the other two wind directions, changes in the horizontal dispersion coefficient hardly affect the average concentration. This is particularly true for wind direction of 192 degrees because P3 is at the farthest distance from the path of the dispersing plume along that wind direction. In Figure 6.21, the predicted average concentration at P4 rapidly drops as K_H increases for the wind direction of 192 degrees because the receptor is located near the centerline of the plume. So, increasing the horizontal dispersion coefficient, which increases the plume width, will drops the concentration at P4. In contrast, for wind directions of 209 ad 226 degrees the predicted average concentration tends to increase as the horizontal dispersion coefficient increases, since the plume becomes wider, thus increasing the possibility that P4 lies within the widened influence of the plume. As for receptor P6 which is located between the paths of wind directions of 209 and 226 degrees, it seems that the strongest effect of the horizontal dispersion coefficient for both wind directions occurs in the range of 100-150 m^2/s. In fact the predicted average concentration for wind direction of 226 degrees increases and decreases rapidly as the horizontal dispersion coefficient varies within the above range, as shown in Figure 6.22. But for the wind direction of 192 degrees, there is little effect of the horizontal dispersion coefficient.

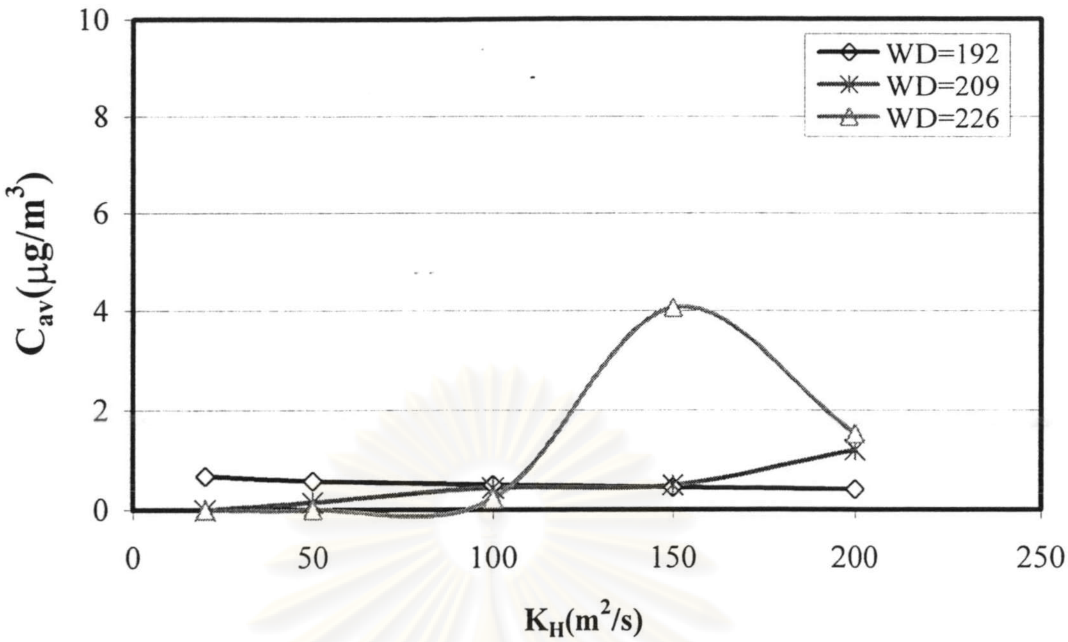

Figure 6.20 Interactive effect of horizontal dispersion coefficient (K_H) on predicted 45-min-averaged concentration at receptor P3 for various wind directions

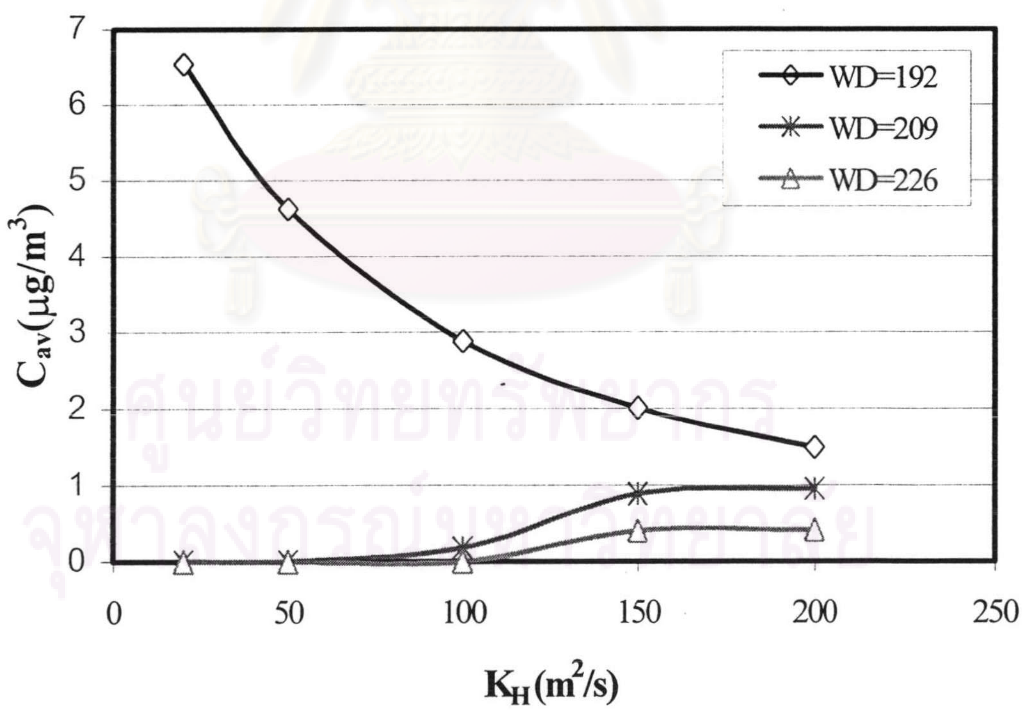

Figure 6.21 Interactive effect of horizontal dispersion coefficient (K_H) on predicted 45-min-averaged concentration at receptor P4 for various wind directions

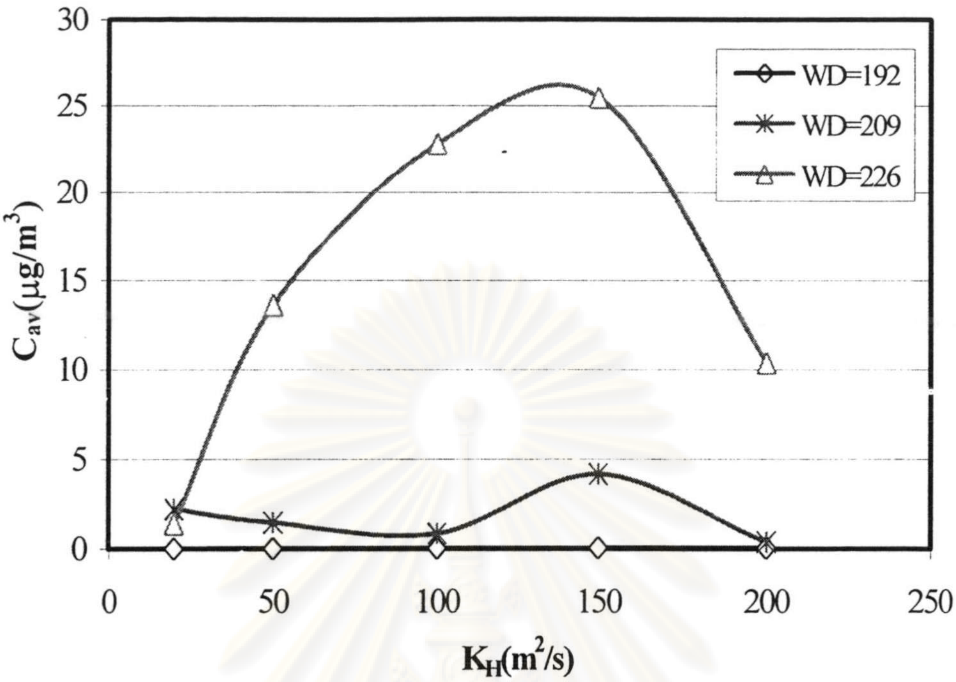

Figure 6.22 Interactive effect of horizontal dispersion coefficient (K_H) on predicted 45-min-averaged concentration at receptor P6 for various wind directions

6.3.6 Interactive effect of wind direction and vertical dispersion coefficient

The effect of this interaction on the predicted average concentration at receptors P4 and P7 is discussed. Figure 6.23 illustrates that increasing the vertical dispersion coefficient significantly decreases the predicted average concentration at P4 in the wind direction of 192 degrees. In Figure 6.26, the predicted average concentration at receptor P7 dramatically decreases with K_V for the wind direction of 192 degrees, but slightly increases for the wind direction of 209 degrees. However, for the wind direction of 226 degrees, there is little effect of the vertical dispersion coefficient. The results may be attributed to the fact that the distance from the path of the dispersing plume to receptors P4 and P7 are quite far and both receptors are located beyond the envelope of the dispersed plume.

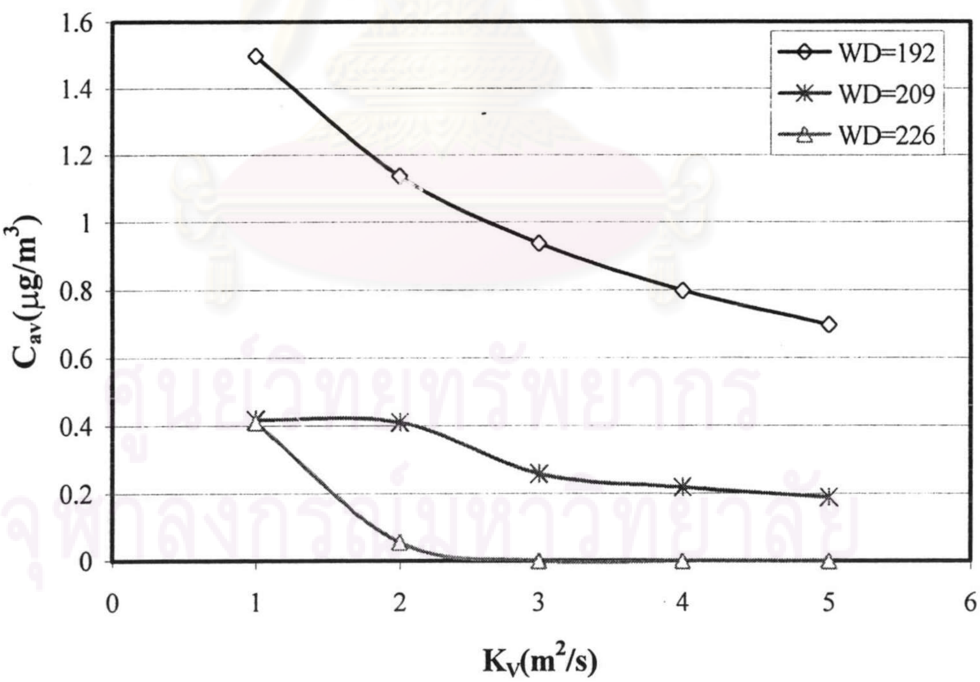

Figure 6.23 Effect of vertical dispersion coefficient (K_V) on the predicted 45-min-averaged concentration at receptor P4 for various wind directions

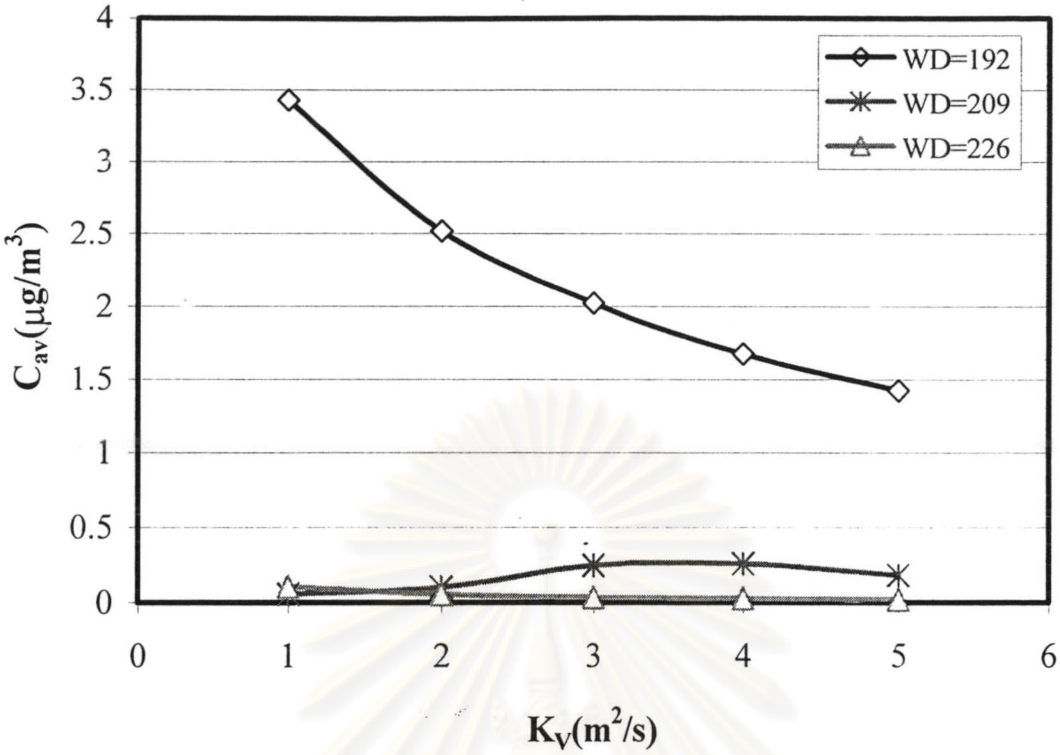

Figure 6.24 Effect of vertical dispersion coefficient (K_V) on the predicted 45-min-averaged concentration at receptor P7 for various wind directions

6.3.7 Interactive effect of wind direction and wind speed

To investigate this interactive effect, receptors P3, P4 and P9 are chosen. In Figure 6.25, wind directions of 192 and 209 degrees have the most significant effect on the predicted average concentration at P3 when the wind speed is about 3.5 m/s. So has the wind direction of 226 degrees at wind speed of 2.5 m/s. However, in the case of receptor P4, the predicted average concentration significantly increases with wind speed for wind direction of 192 degrees and slightly decreases for wind directions of 209 and 226 degrees as shown in Figure 6.26. Meantime, Figure 6.27 illustrates that increasing the wind speed significantly increases the predicted average concentration at receptor P9 in the wind direction of 192 degrees. Any way, it can be concluded that even the most significant wind speed takes a relatively low value when the receptor is located far from the path of the dispersed plume. In contrast, the most significant wind speed takes a high value when the receptor is located close to the path of the dispersed plume.

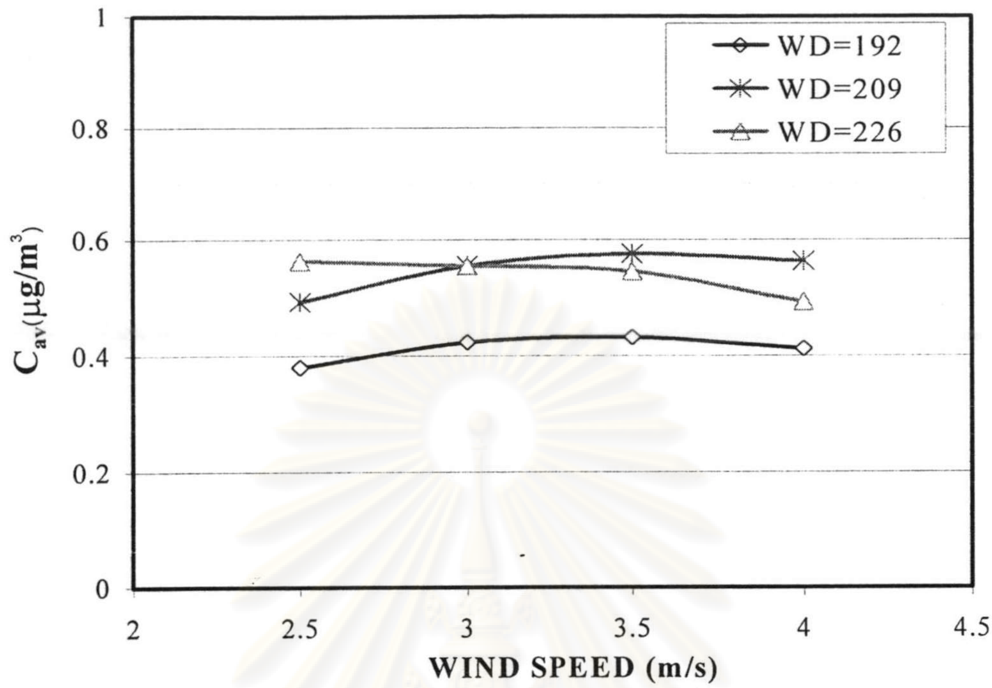

Figure 6.25 Effect of wind speed (WS) on the predicted 45-min-averaged concentration at receptor P3 for various wind directions

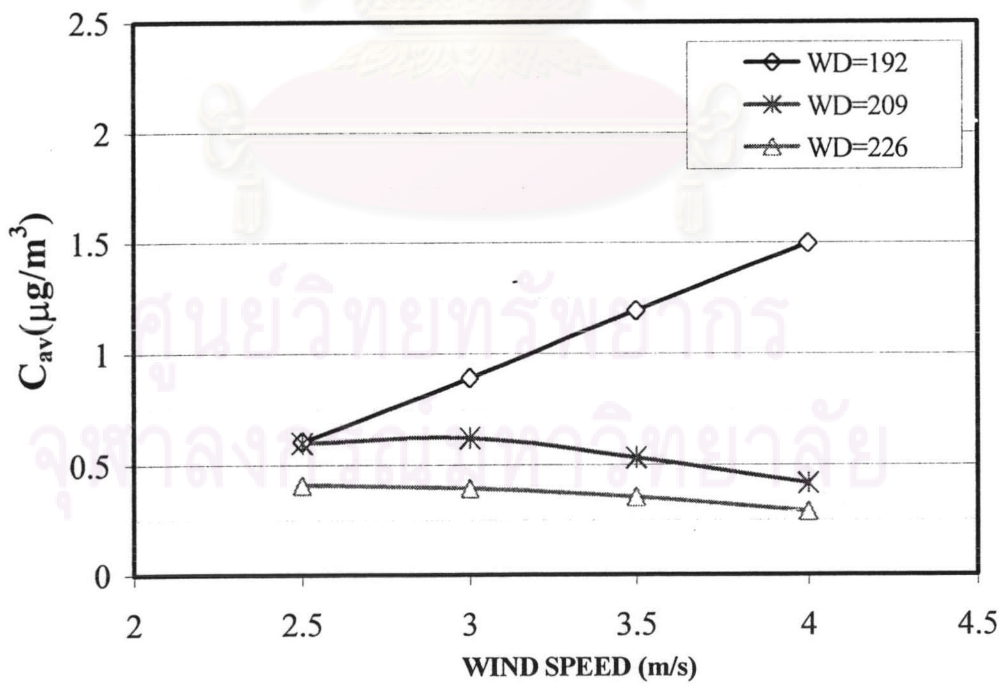

Figure 6.26 Effect of wind speed (WS) on the predicted 45-min-averaged concentration at receptor P4 for various wind directions

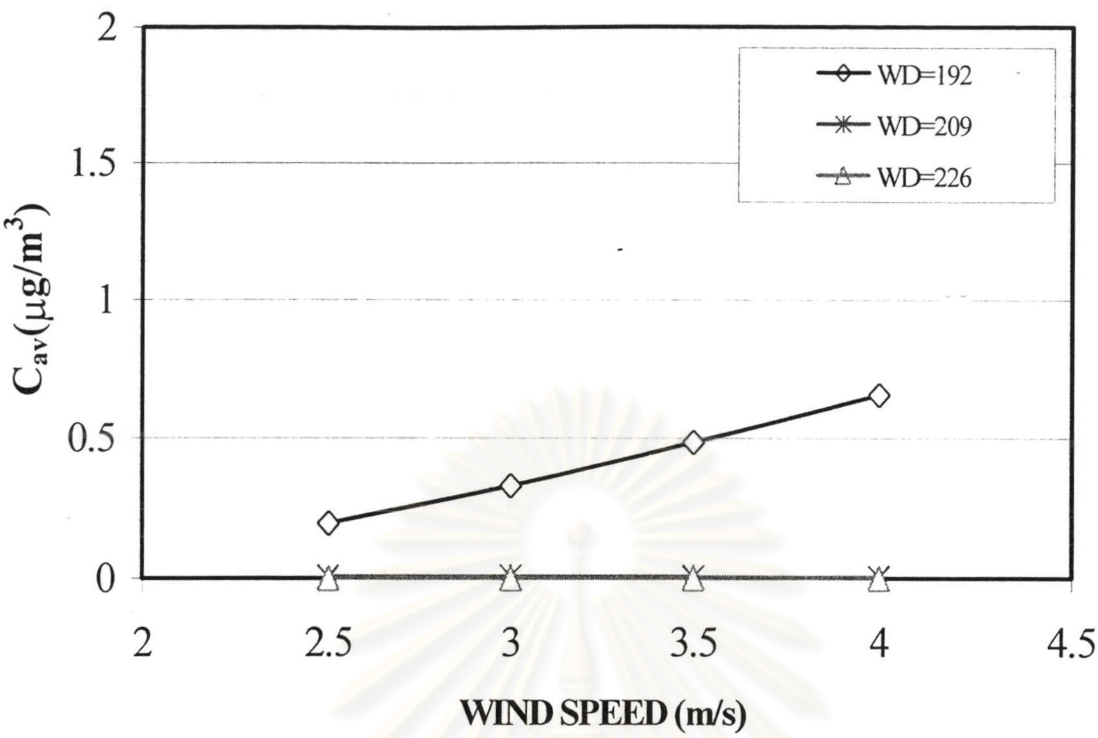

Figure 6.27 Effect of wind speed (WS) on the predicted 45-min-averaged concentration at receptor P9 for various wind directions

6.3.8 Interactive effect of vertical dispersion coefficient and wind speed

Receptors P4 and P10 are chosen for discussion. Figures 6.28 and 6.29 illustrate a similar trend that the predicted average concentration at both receptors at different wind speeds drops as the vertical dispersion coefficient increases. Under the high wind speed condition, the predicted average concentration decreases from 1.5 to 0.75 $\mu g/m^3$ at receptor P4 and from 3.5 to 1.5 $\mu g/m^3$ at receptor P10 as K_V increases. However, the concentration decreases from 0.3 to 0.125 $\mu g/m^3$ at receptor P4 and from 0.75 to 0.25 $\mu g/m^3$ at receptor P10 under low wind speed condition. In conclusion, the vertical dispersion coefficient has significant negative effect on the predicted average concentration when wind speed is high.

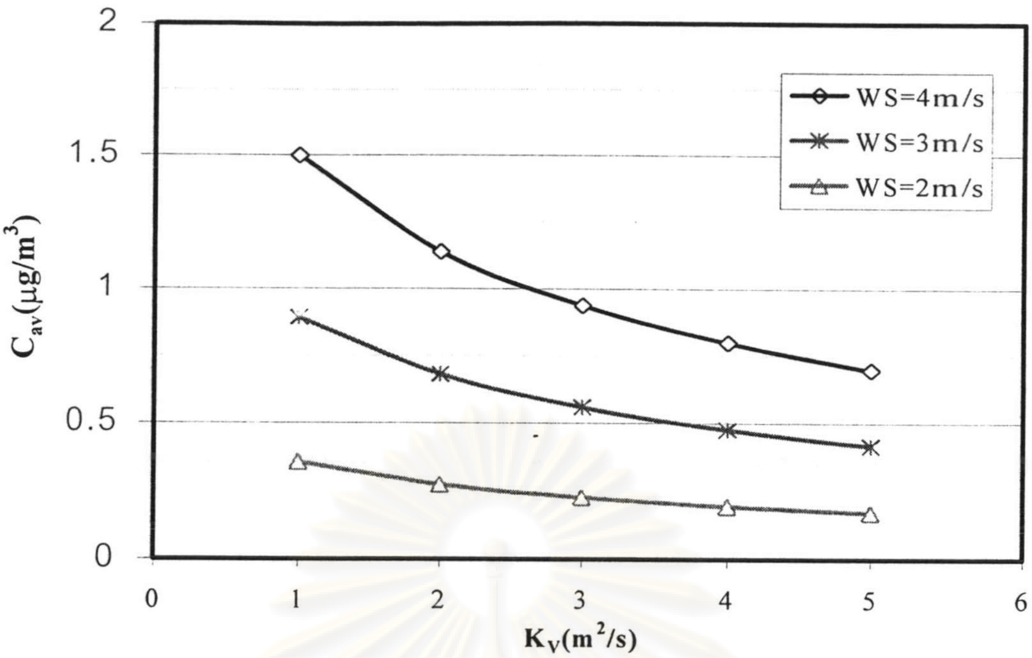

Figure 6.28 Effect of vertical dispersion coefficient (K_V) on the predicted 45-min-averaged concentration at receptor P4 for various wind speeds

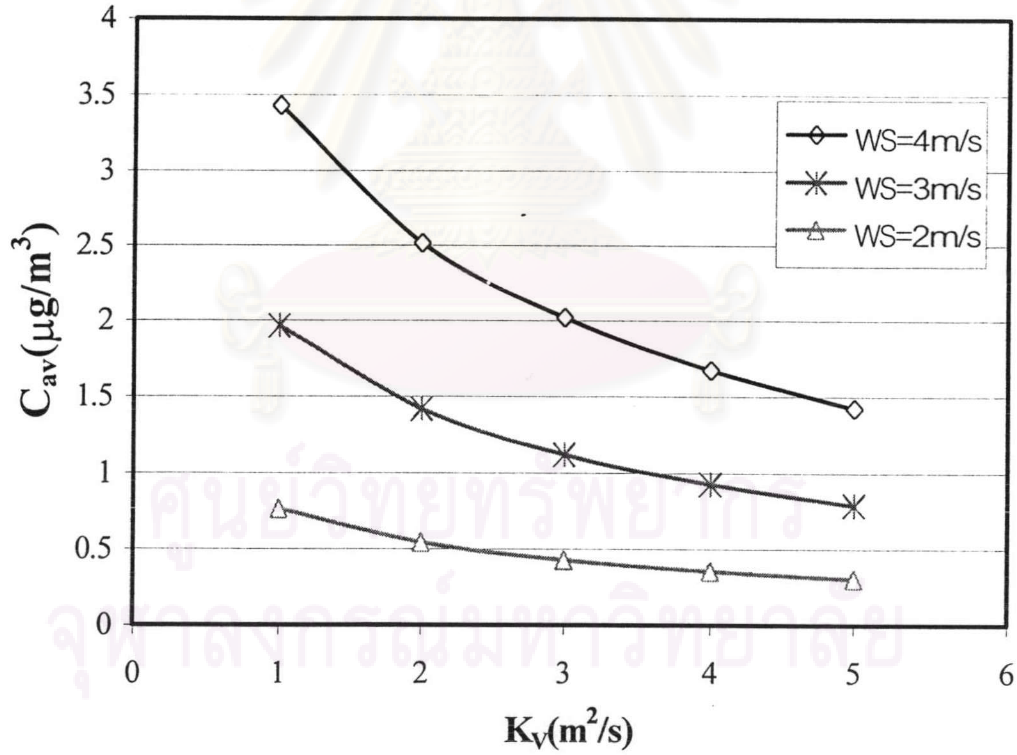

Figure 6.29 Effect of vertical dispersion coefficient (K_V) on the predicted 45-min-averaged concentration at receptor P10 for various wind speeds

6.3.9 Interactive effect of the exponent of the power law and wind direction

Receptors P3, P4 and P6 are chosen to enhance the understanding of the interactive effect of the exponent of the power law and wind direction. In Figure 6.30, the predicted average concentration at P3 for wind directions of 209 and 192 degrees slightly increases as the exponent increases. Similar to the case of receptor P3, increasing the exponent also increases the predicted average concentration at P4 in case of wind direction of 192 degrees. As shown in Figure 6.31, the effect of the exponent at P4 is insignificant for the other two wind directions. Similarly, the predicted average concentration at P6 also increases as the exponent increases as shown in Figure 6.32. It may be concluded that for all three receptors increasing the exponent generally increases the average concentration, especially when a receptor is located near the path of the dispersed plume. Figure 6.33 shows that increasing the exponent shifts the wind profile farther from the flat profile. As expected, the flatter the wind profile, the better the mixing in the vertical direction. So, decreasing the exponent significantly dilutes the observed ground-level average concentration.

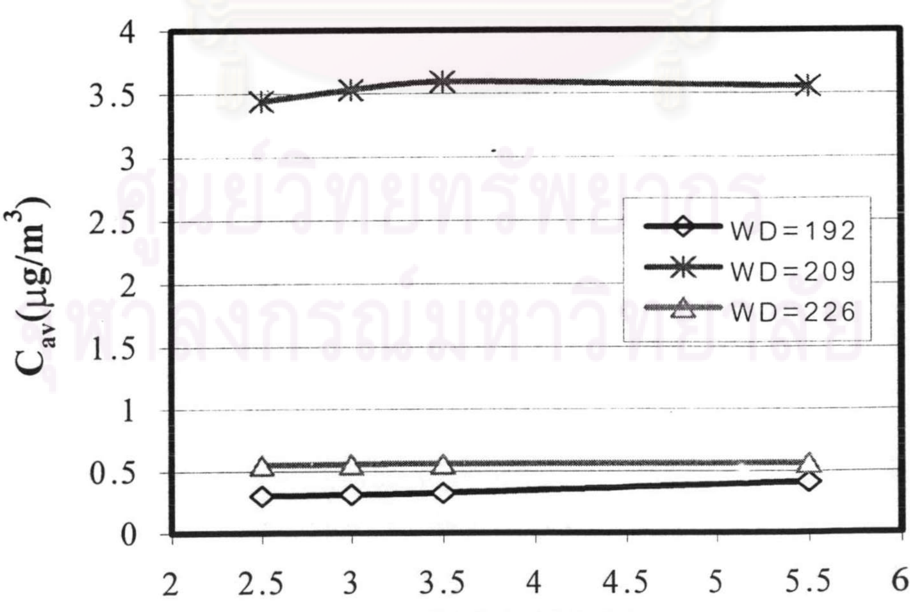

Figure 6.30 Effect of the exponent of the power law (Pow) on the predicted 45-min-averaged concentration at receptor P3 for various wind direction

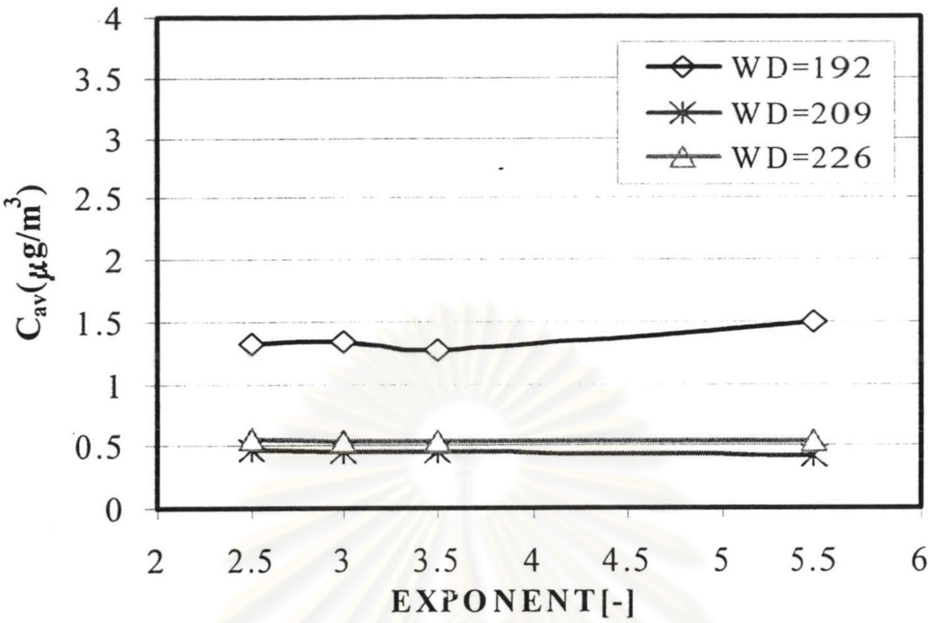

Figure 6.31 Effect of the exponent of the power law (Pow) on predicted 45-min-averaged concentration at receptor P4 for various wind direction

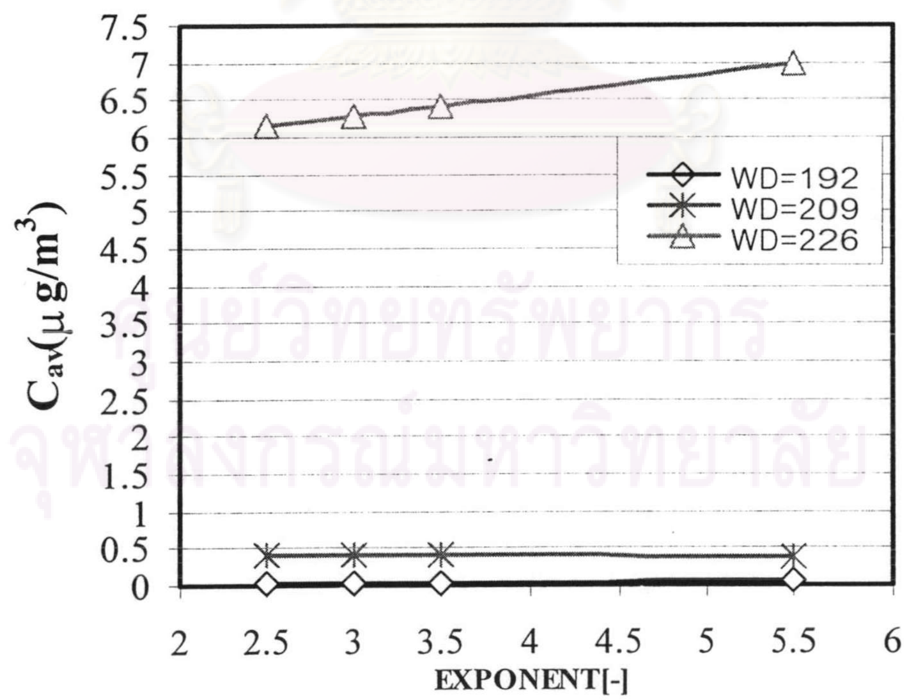

Figure 6.32 Effect of the exponent of the power law (Pow) on the predicted 45-min-averaged concentration at receptor P6 for various wind direction

In conclusion, the following factors, namely wind direction, wind speed, and horizontal and vertical dispersion coefficients have significant effects on the predicted average concentration at a majority of the receptors investigated. However, the exponent of the power law has a significant effect only at some receptors, e.g. receptor P6.

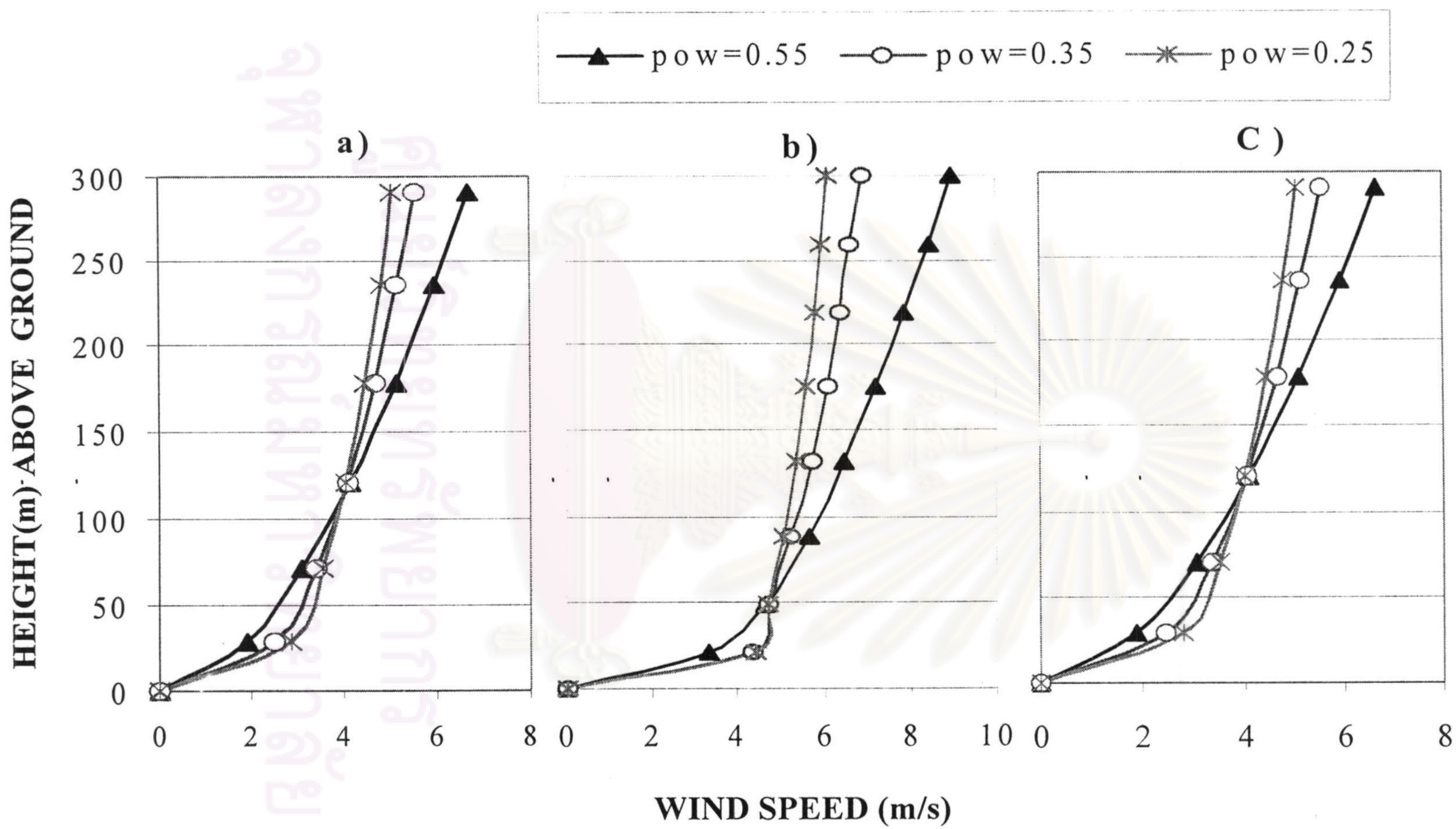

Figure 6.33 Effect of the exponent of the power law (Pow) on wind profile (a) at upwind (b) at summit (c) at downwind