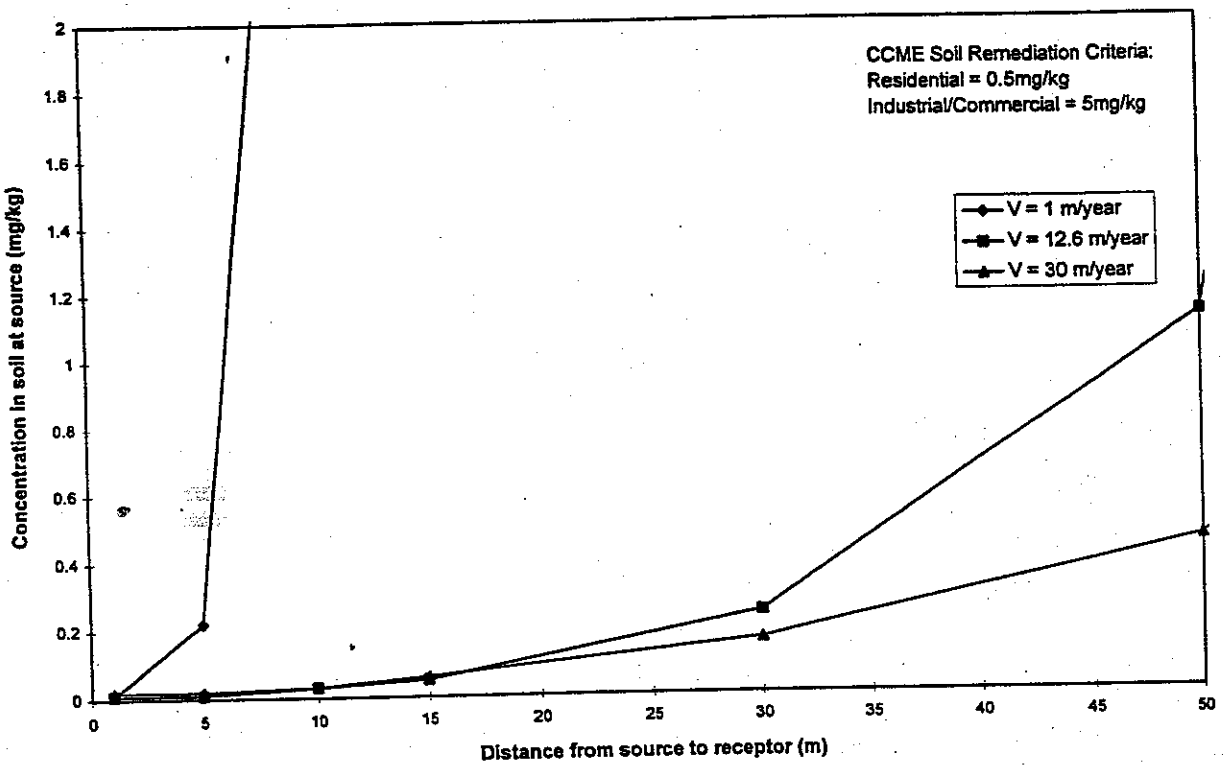
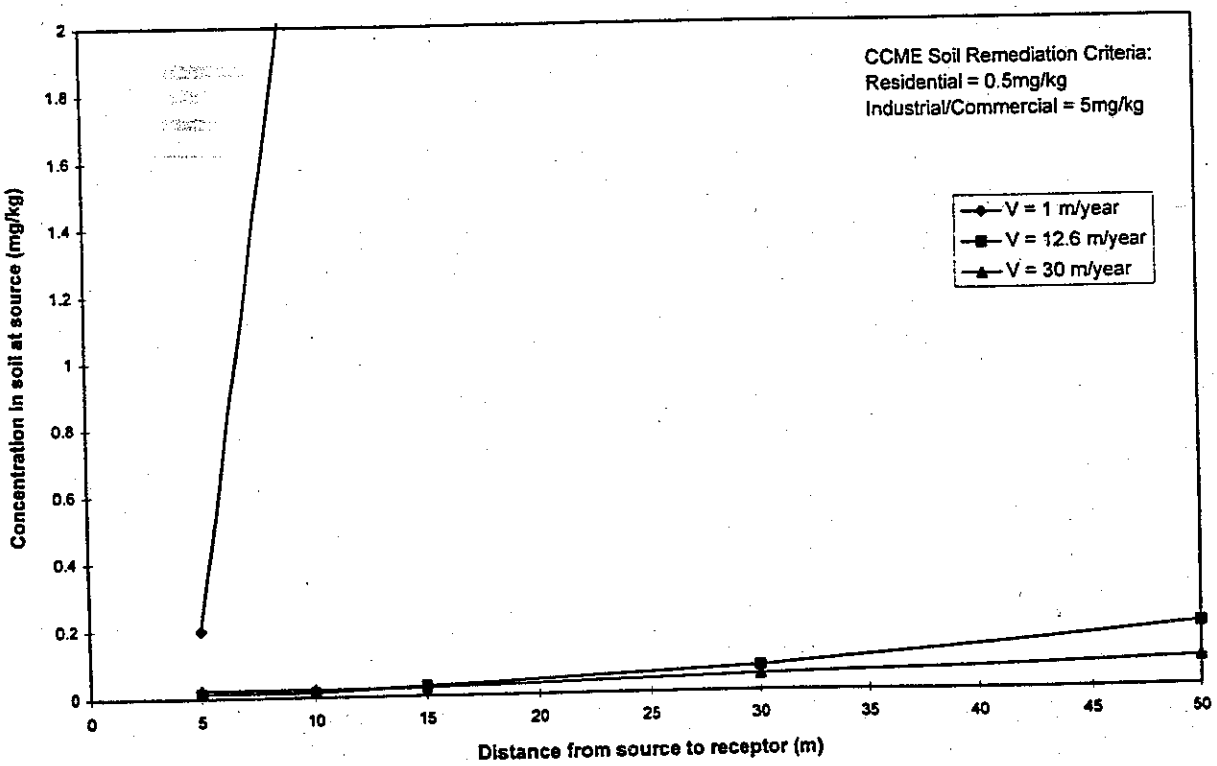
APPENDIX VI-B

Figures of Modelling Results

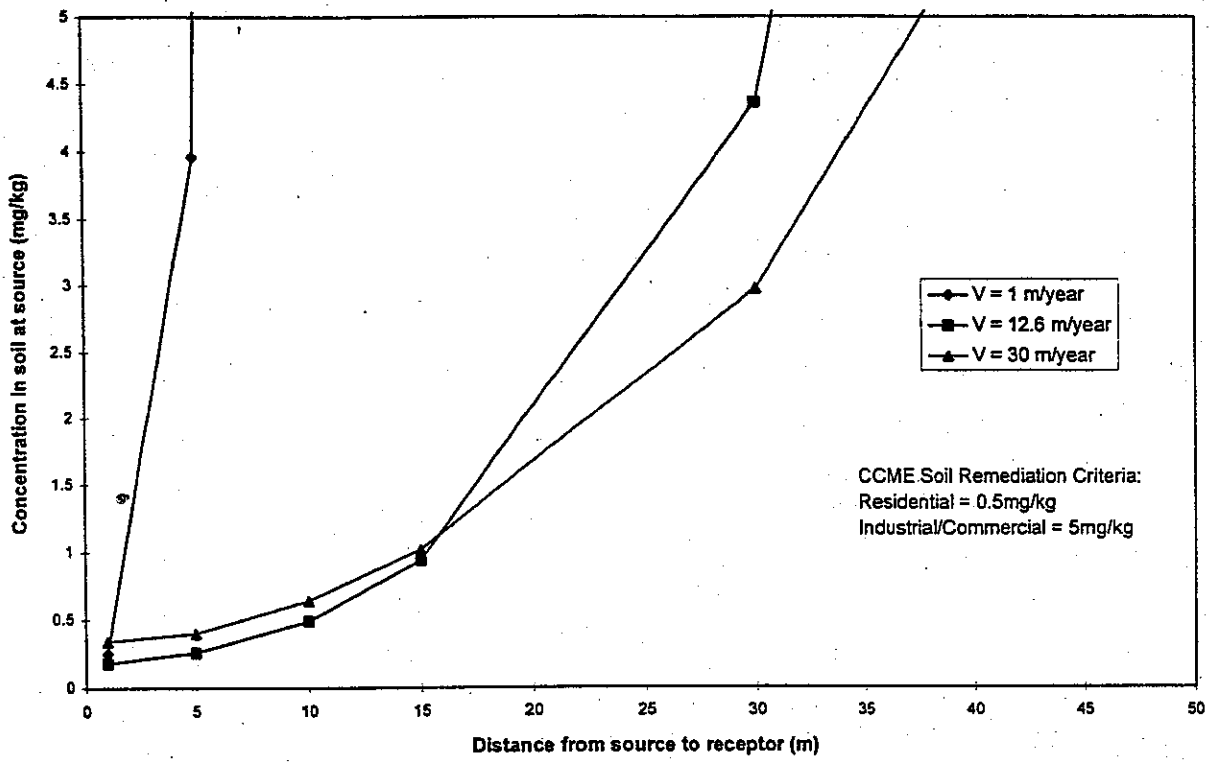
Benzene - Point Source
Protection of Drinking Water (Criterion = 0.005mg/L)
Average Thickness of Unsaturated Zone of Zero metres



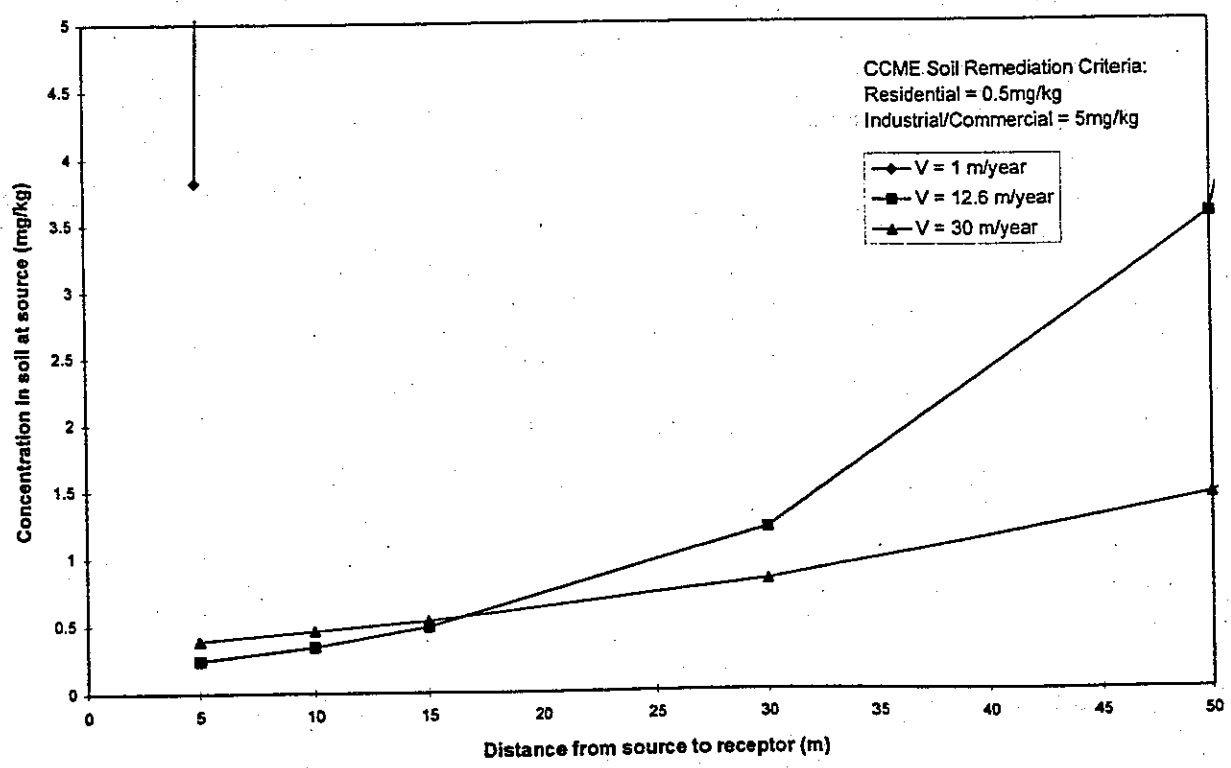
Benzene - Large Source
Protection of Drinking Water (Criterion = 0.005mg/L)
Average Thickness of Unsaturated Zone of Zero metres



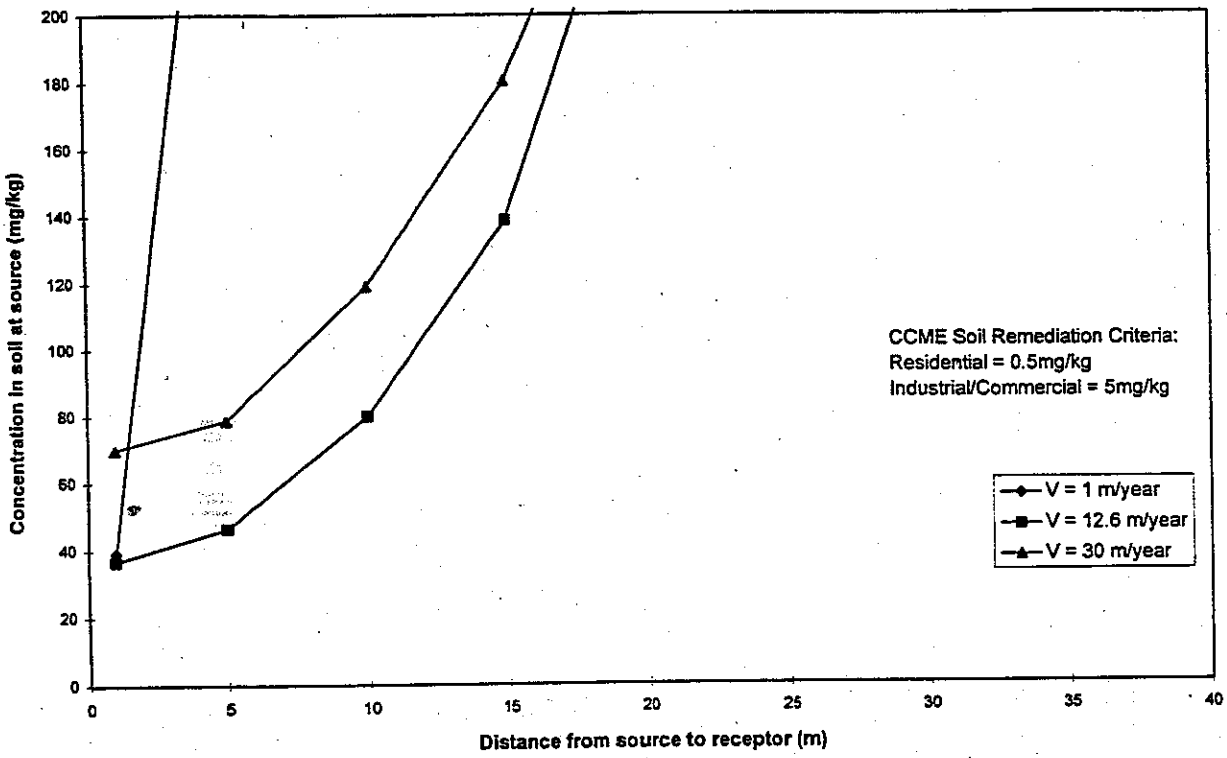
Benzene - Point Source
Protection of Drinking Water (Criterion = 0.005mg/L)
Average Thickness of Unsaturated Zone of 0.5m



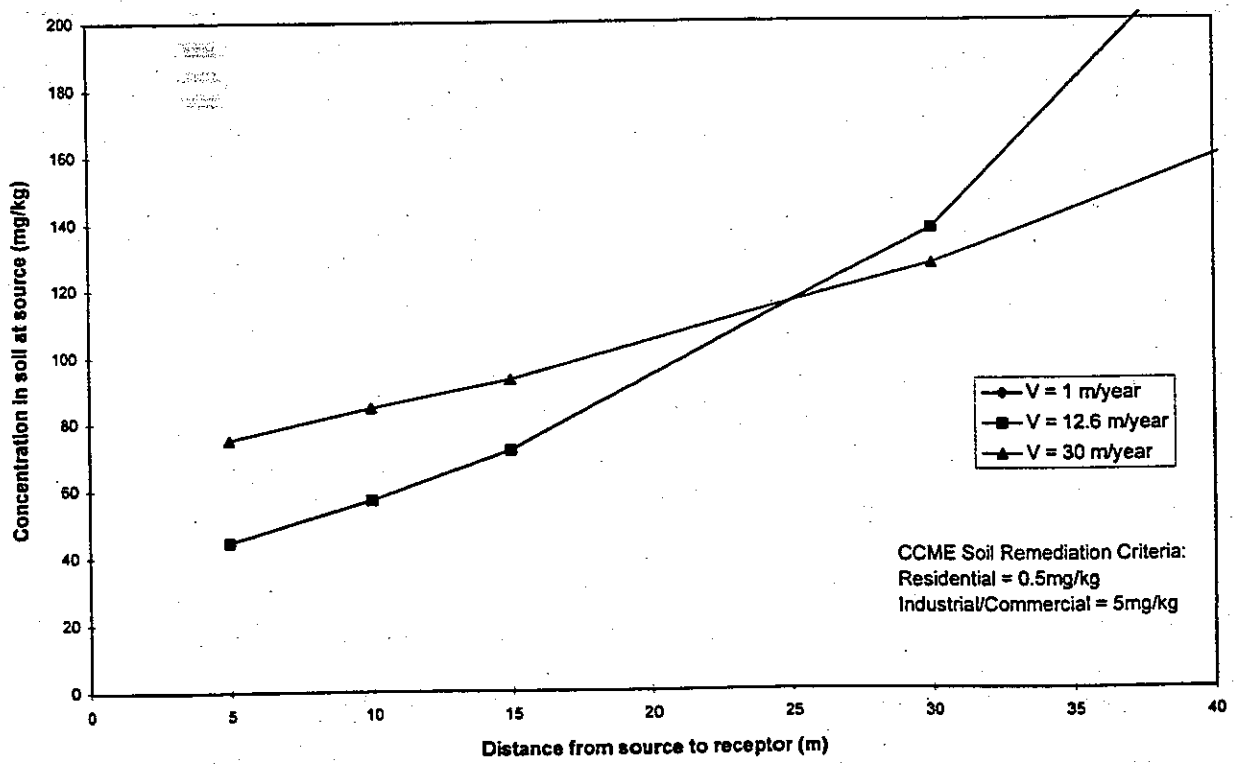
Benzene - Large Source
Protection of Drinking Water (Criterion = 0.005mg/L)
Average Thickness of Unsaturated Zone of 0.5m



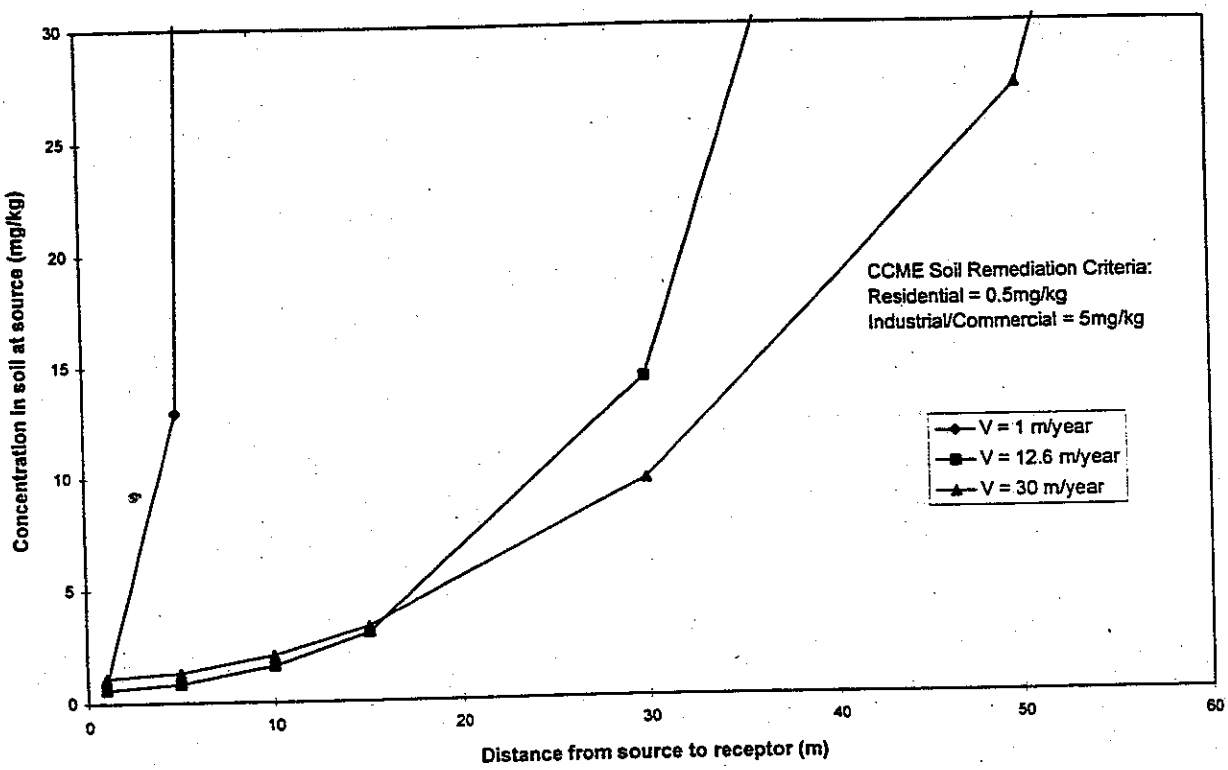
Benzene - Point Source
Protection of Drinking Water (Criterion = 0.005mg/L)
Average Thickness of Unsaturated Zone of 3m



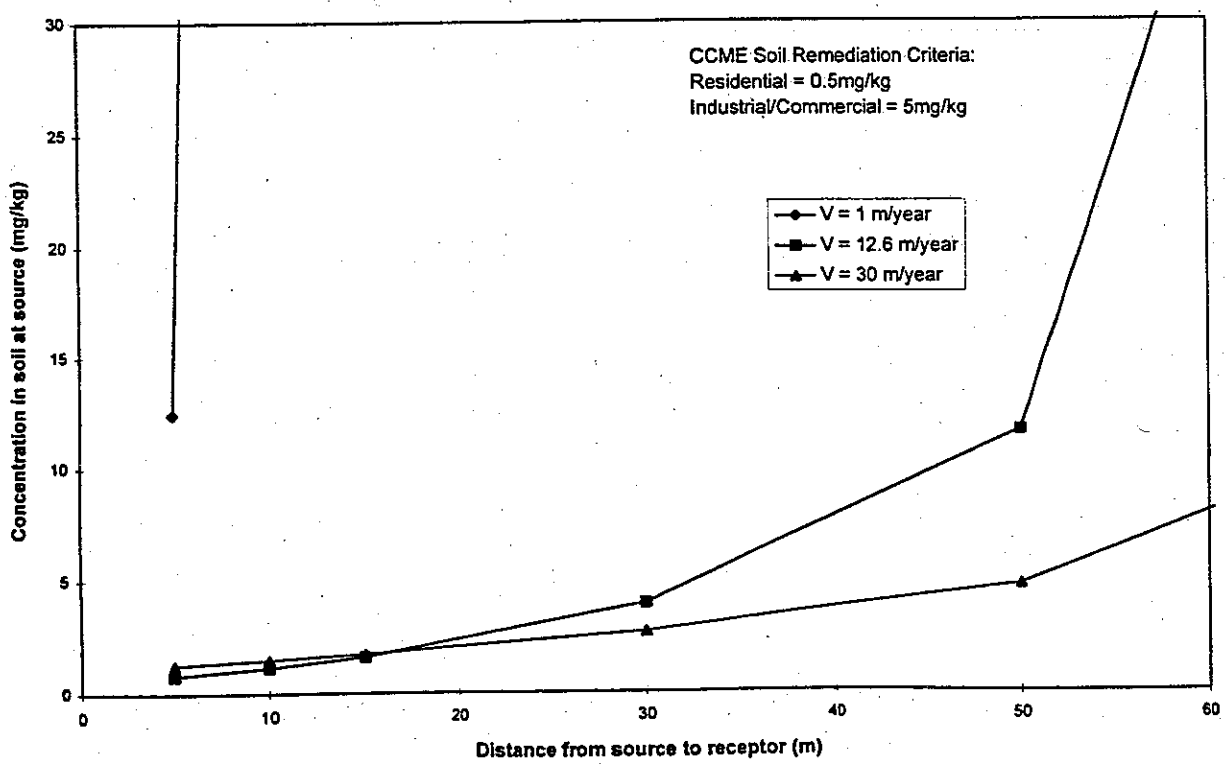
Benzene - Large Source
Protection of Drinking Water (Criterion = 0.005mg/L)
Average Thickness of Unsaturated Zone of 3m



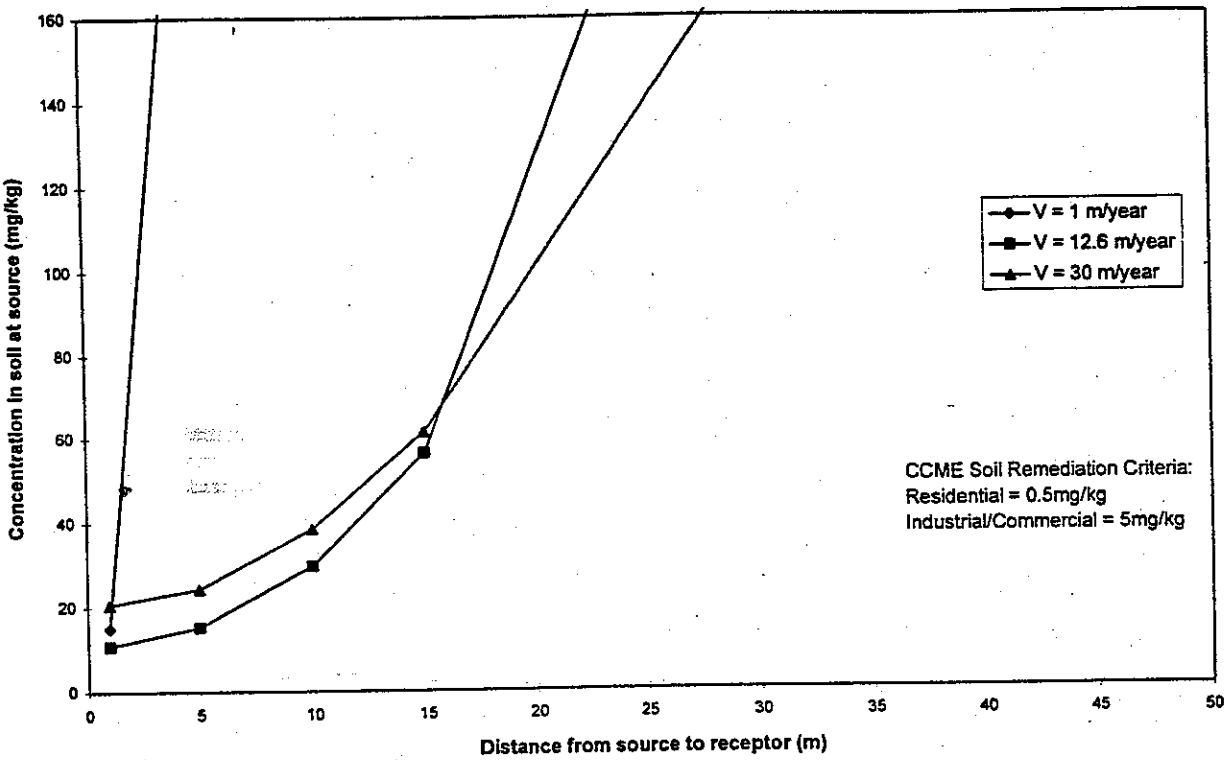
Benzene - Point Source
Protection of Aquatic Life (Criterion = 0.3mg/L)
Average Thickness of Unsaturated Zone of Zero metres



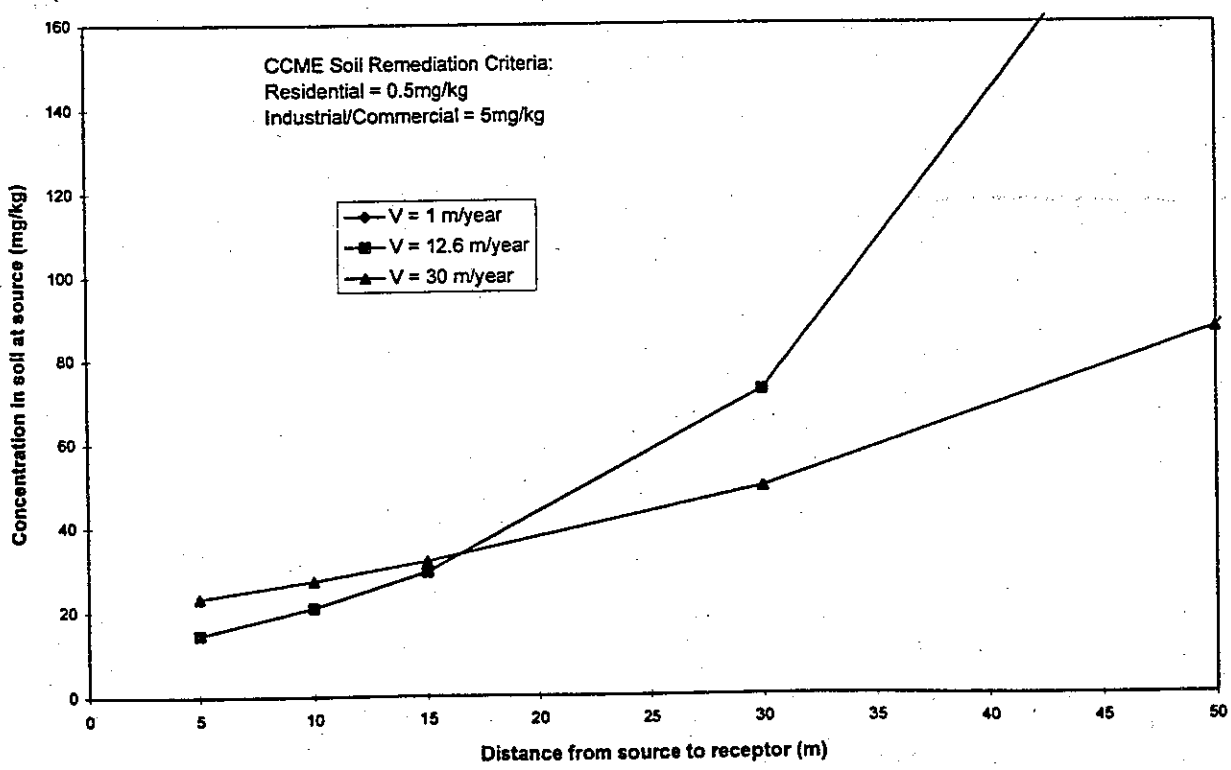
Benzene - Large Source
Protection of Aquatic Life (Criterion = 0.3mg/L)
Average Thickness of Unsaturated Zone of Zero metres



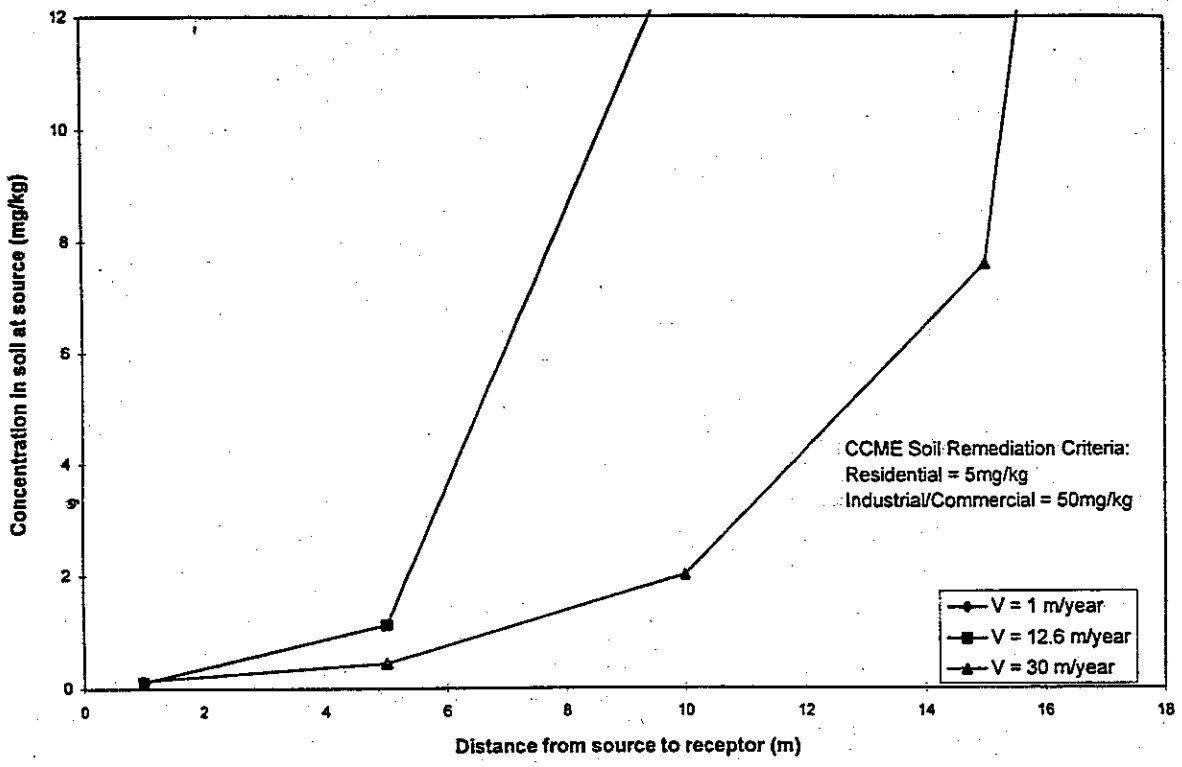
Benzene - Point Source
Protection of Aquatic Life (Criterion = 0.3mg/L)
Average Thickness of Unsaturated Zone of 0.5m



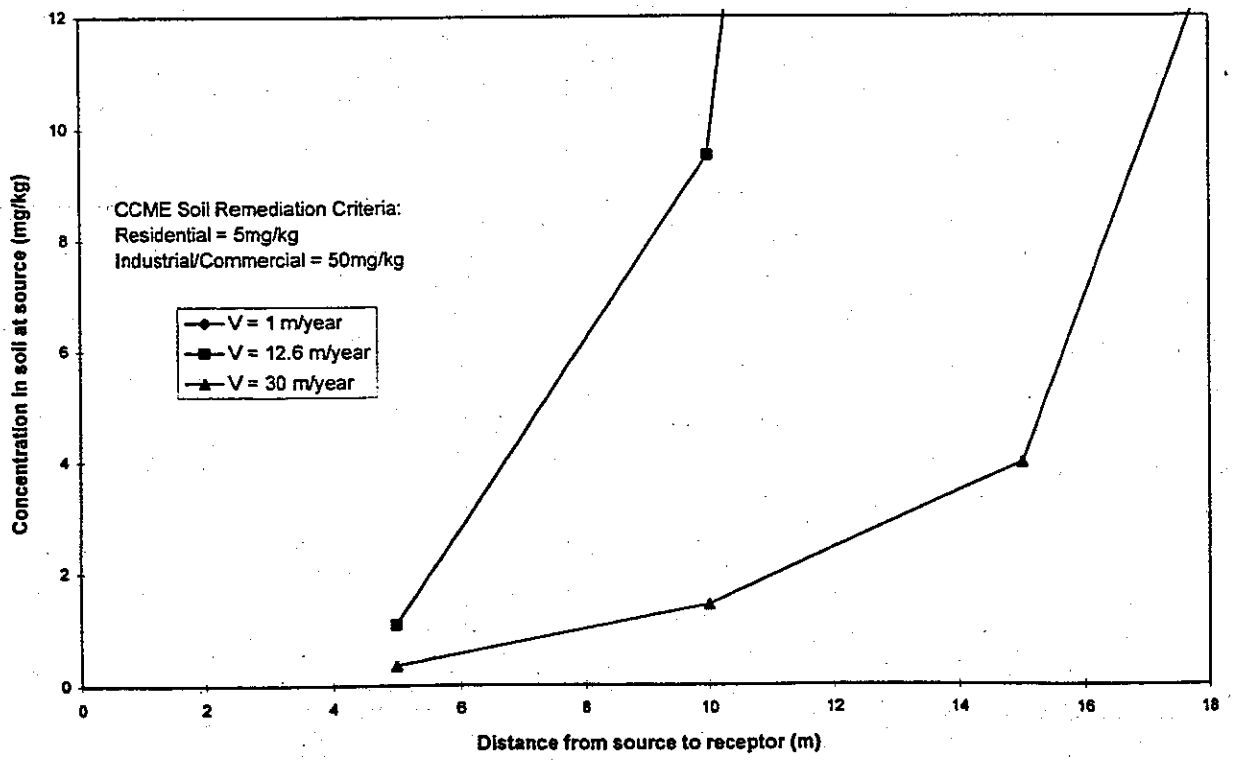
Benzene - Large Source
Protection of Aquatic Life (Criterion = 0.3mg/L)
Average Thickness of Unsaturated Zone of 0.5m



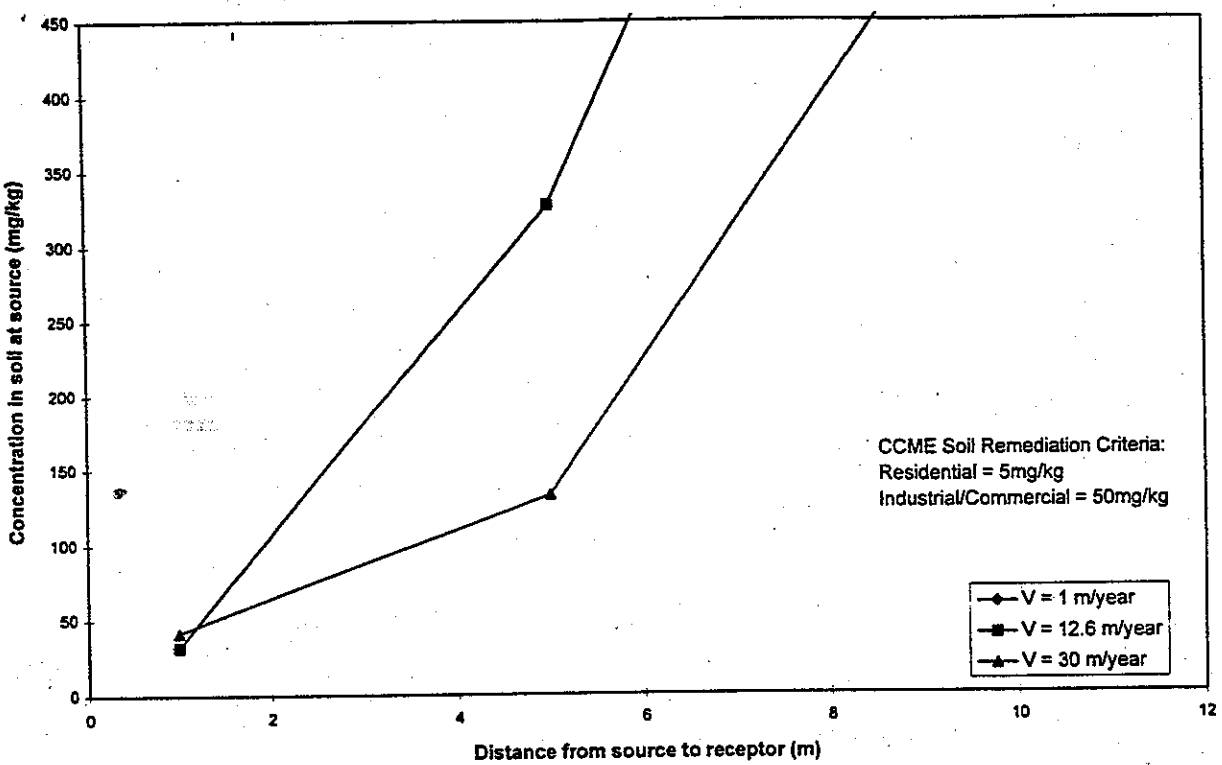
Ethylbenzene - Point Source
Protection of Drinking Water (Criterion = 0.0024mg/L)
Average Thickness of Unsaturated Zone of Zero metres



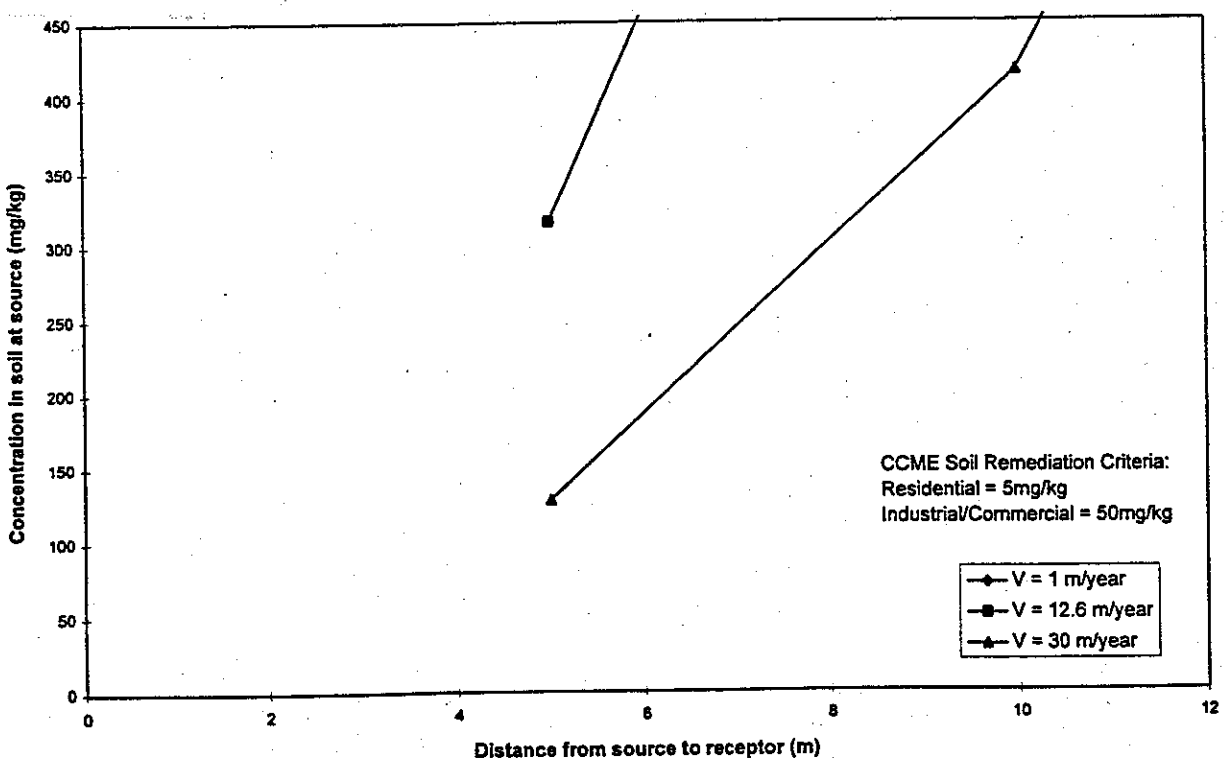
Ethylbenzene - Large Source
Protection of Drinking Water (Criterion = 0.0024mg/L)
Average Thickness of Unsaturated Zone of Zero metres



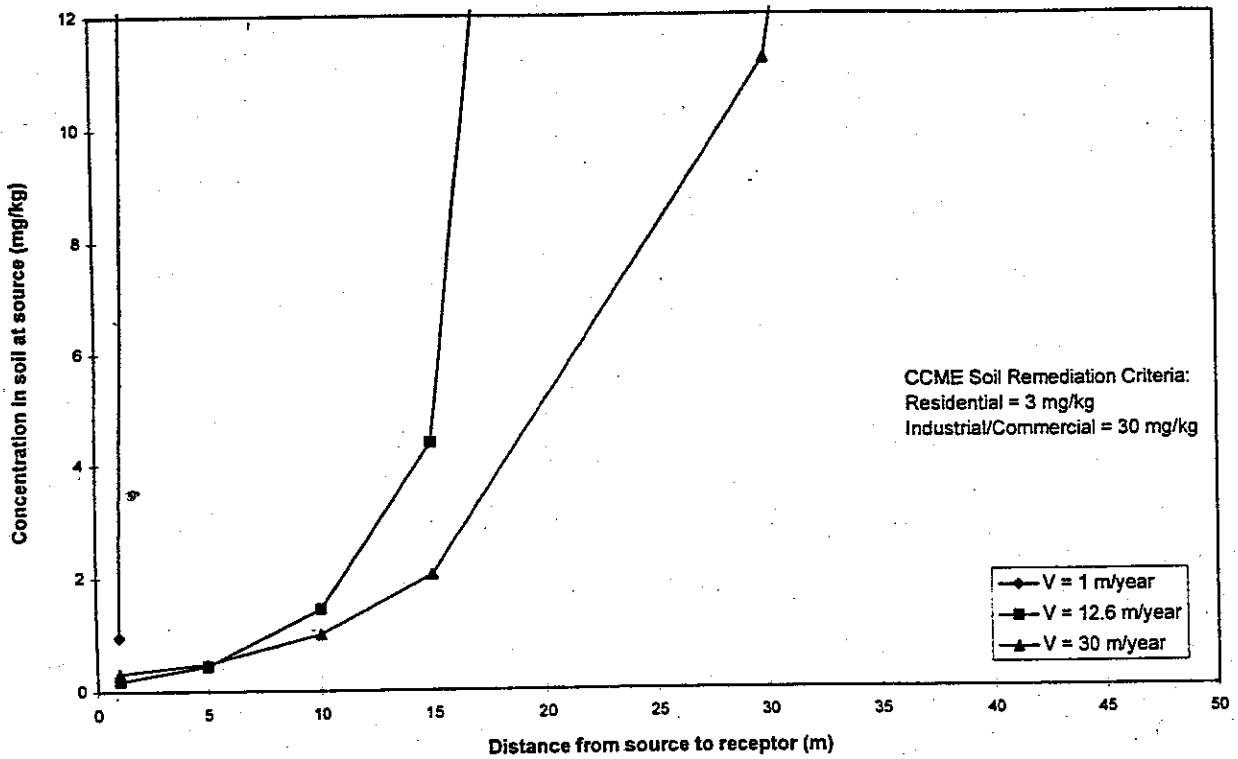
Ethylbenzene - Point Source
Protection of Aquatic Life (Criterion = 0.7mg/L)
Average Thickness of Unsaturated Zone of Zero metres



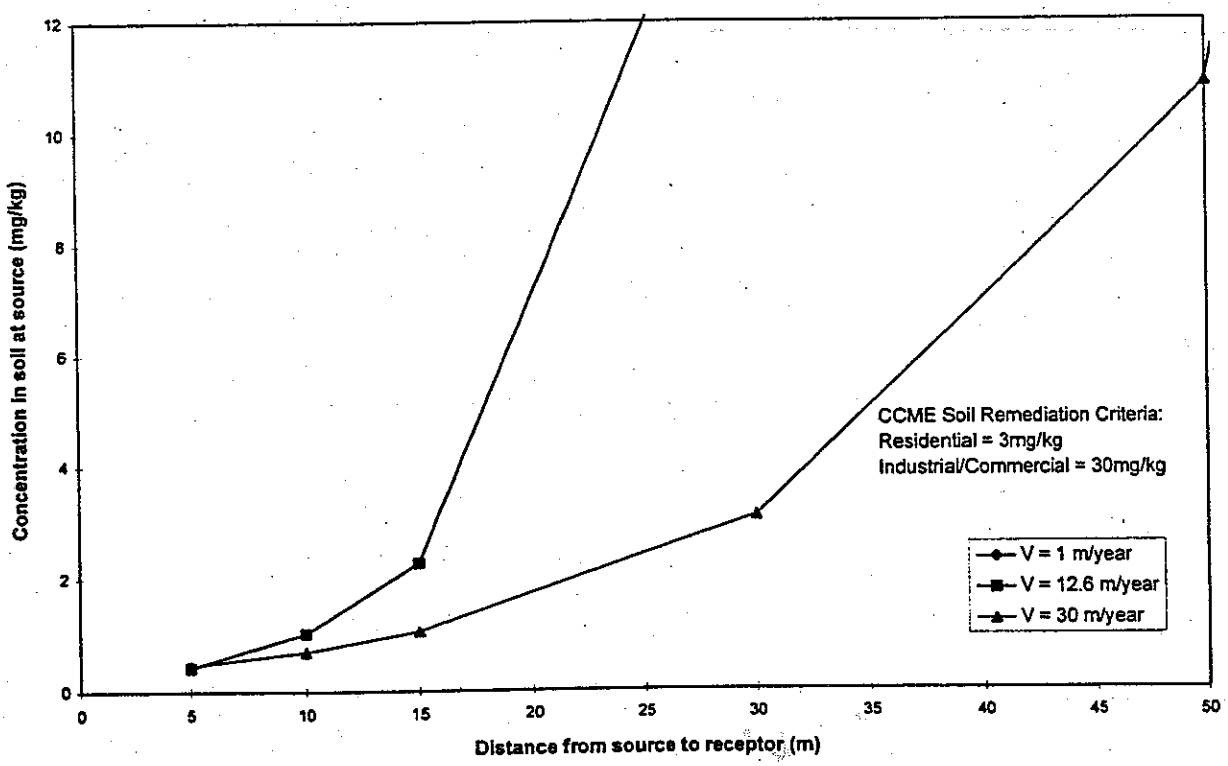
Ethylbenzene - Large Source
Protection of Aquatic Life (Criterion = 0.7mg/L)
Average Thickness of Unsaturated Zone of Zero metres



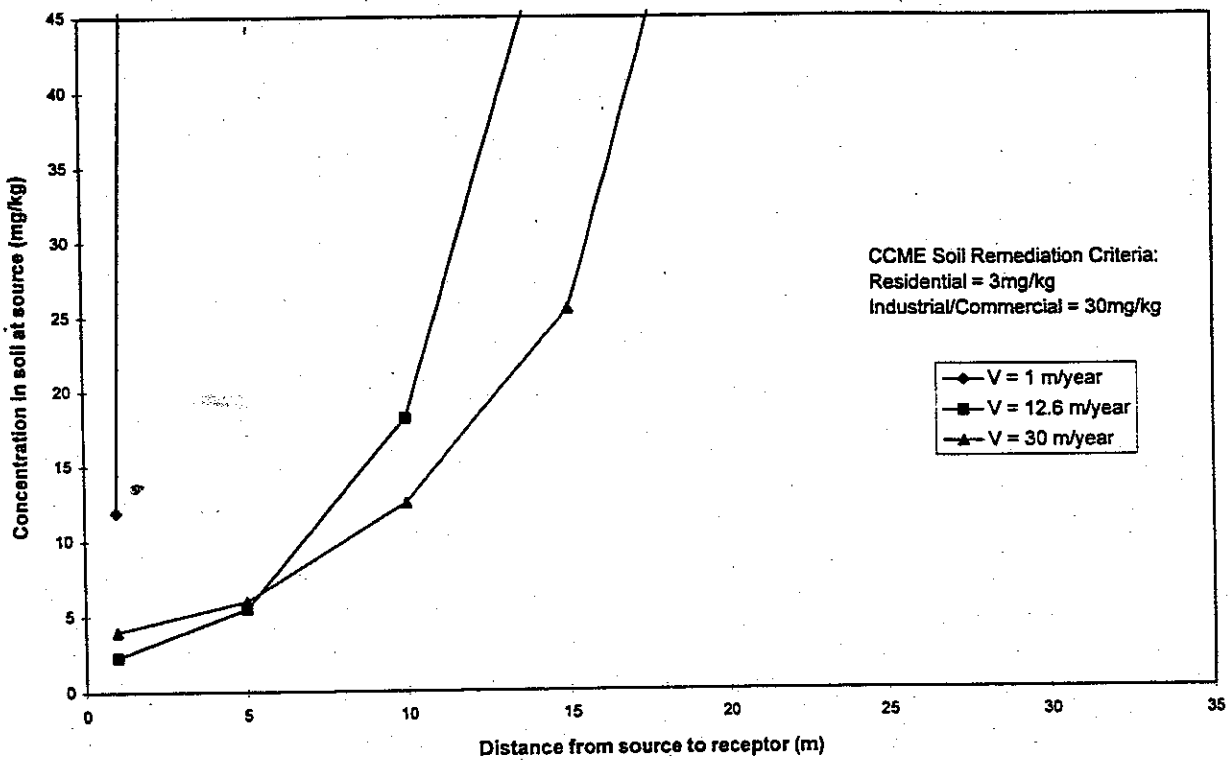
Toluene - Point Source
Protection of Drinking Water (Criterion = 0.024mg/L)
Average Thickness of Unsaturated Zone of Zero metres



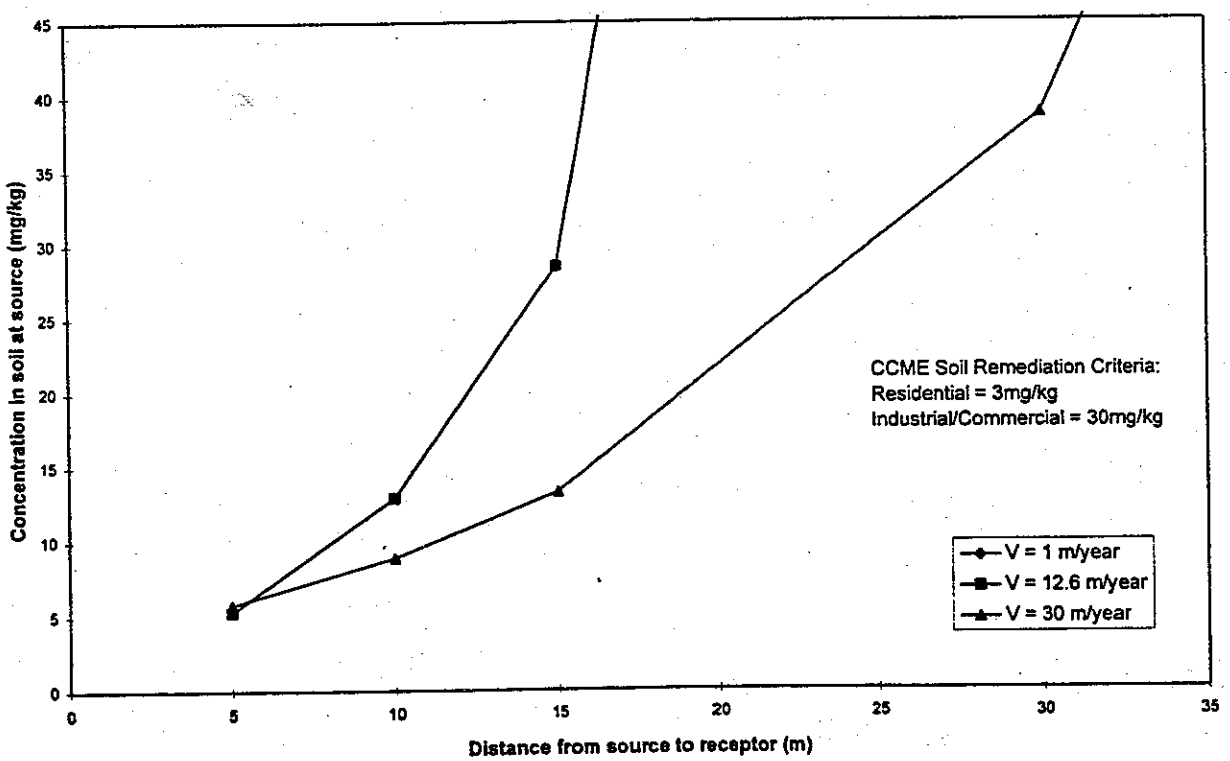
Toluene - Large Source
Protection of Drinking Water (Criterion = 0.024mg/L)
Average Thickness of Unsaturated Zone of Zero metres



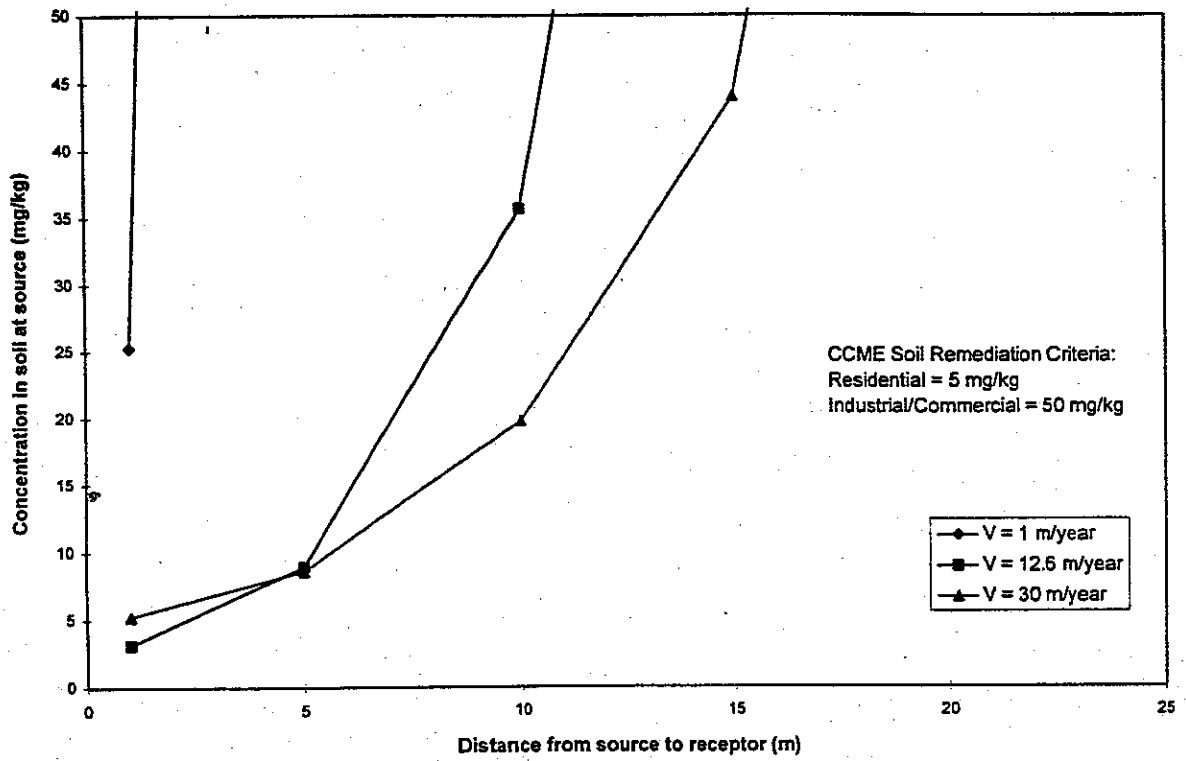
Toluene - Point Source
Protection of Aquatic Life (Criterion = 0.3mg/L)
Average Thickness of Unsaturated Zone of Zero metres



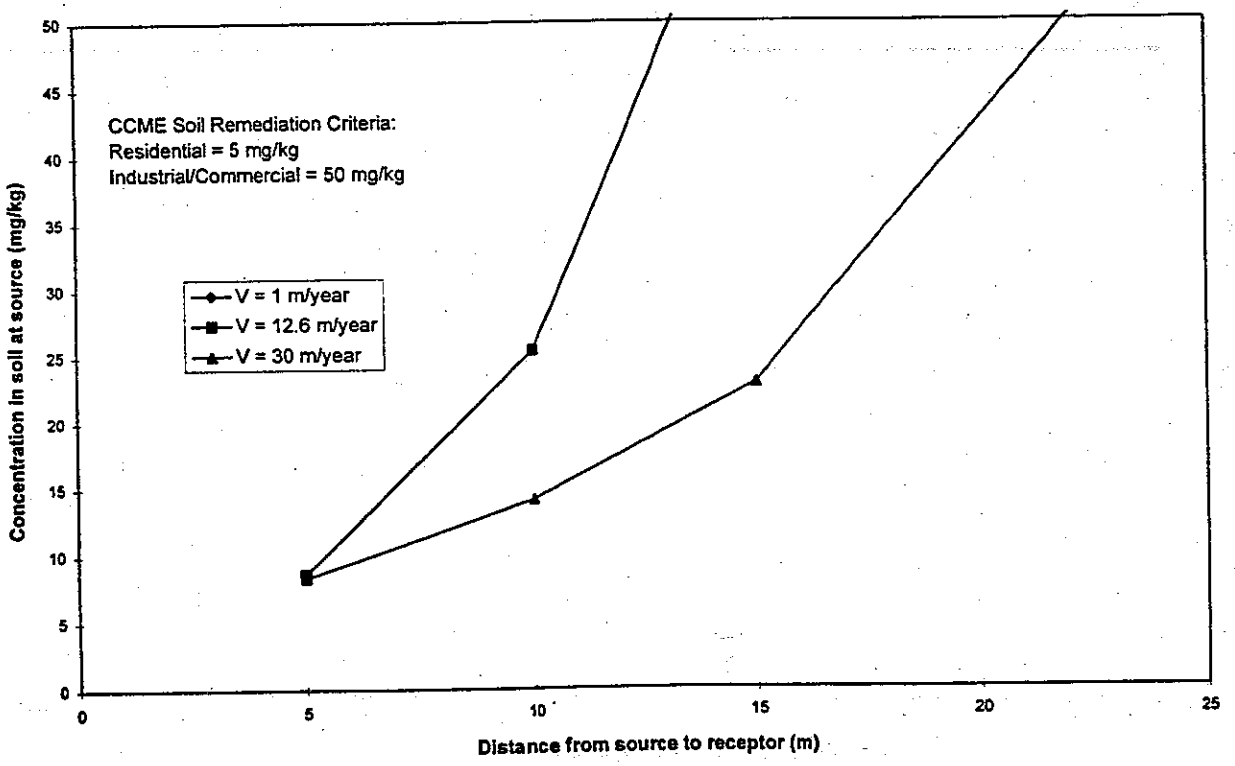
Toluene - Large Source
Protection of Aquatic Life (Criterion = 0.3mg/L)
Average Thickness of Unsaturated Zone of Zero metres



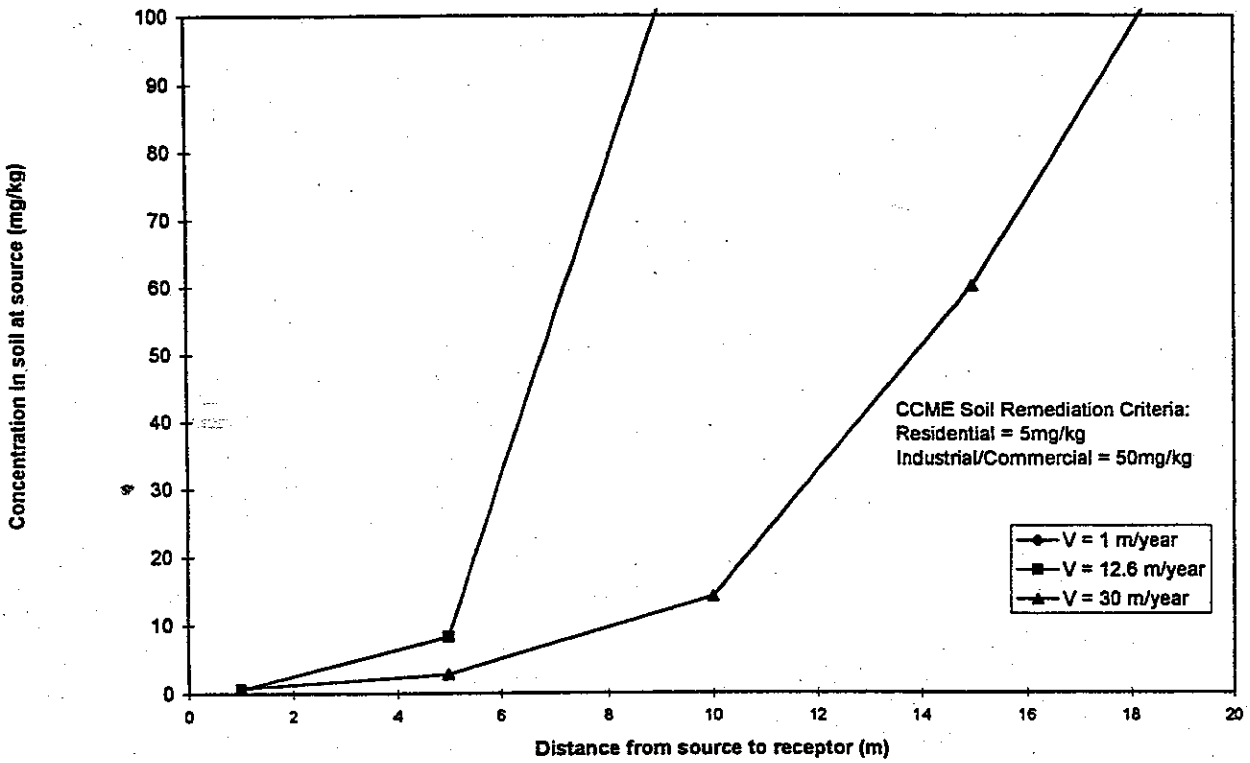
Xylene - Point Source
Protection of Drinking Water (Criterion = 0.3mg/L)
Average Thickness of Unsaturated Zone of Zero metres



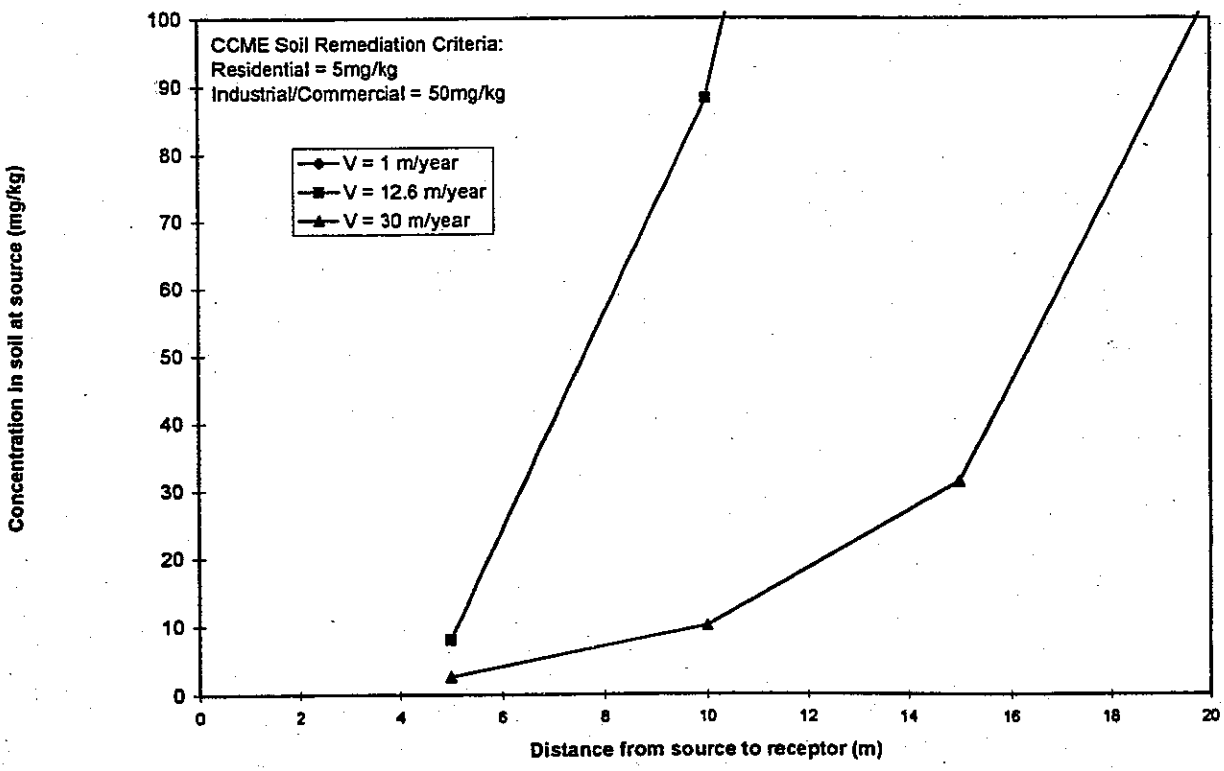
Xylene - Large Source
Protection of Drinking Water (Criterion = 0.3mg/L)
Average Thickness of Unsaturated Zone of Zero metres



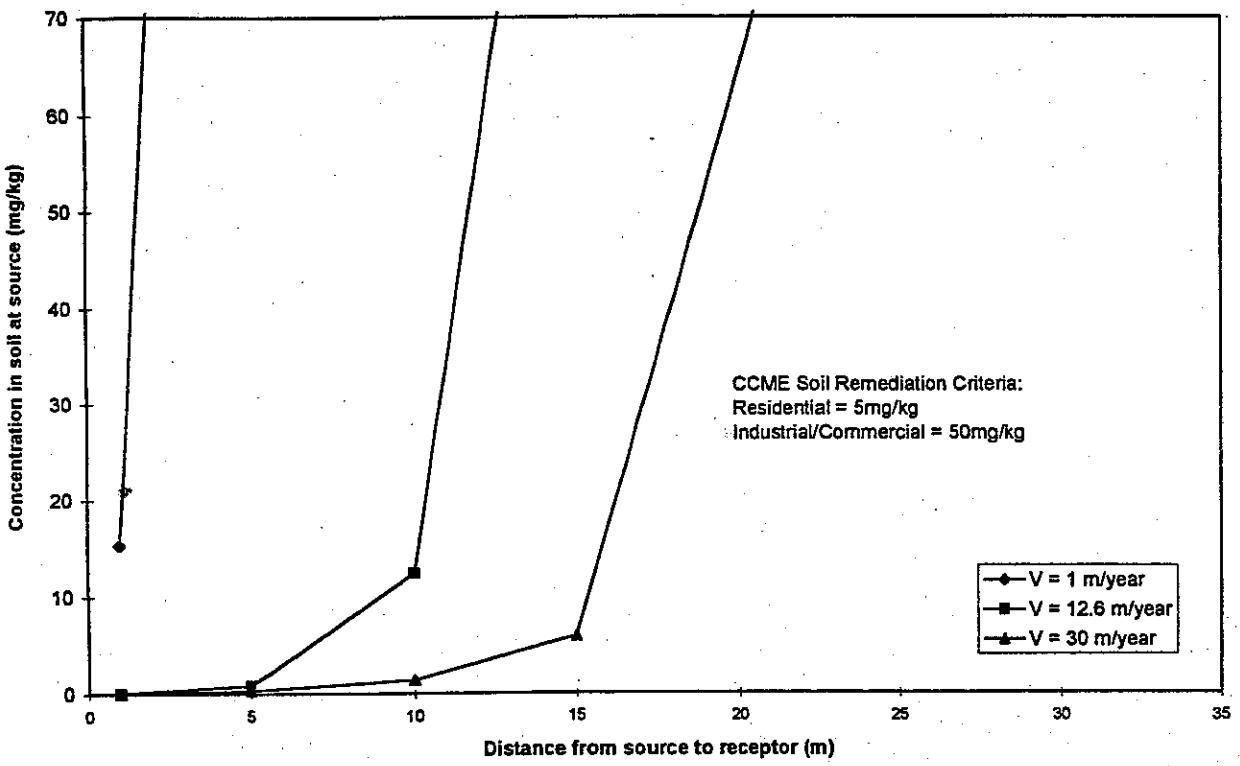
Naphthalene - Point Source
Protection of Drinking Water (Criterion = 0.01mg/L)
Average Thickness of Unsaturated Zone of Zero metres



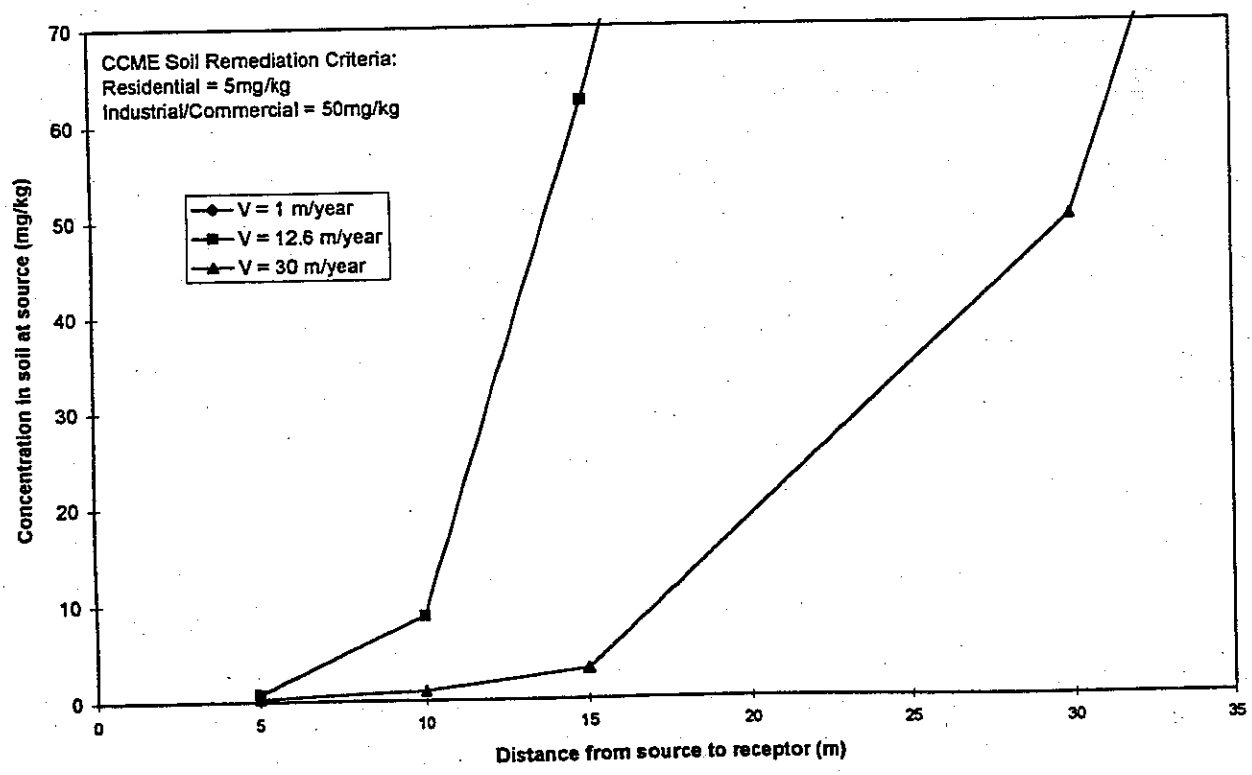
Naphthalene - Large Source
Protection of Drinking Water (Criterion = 0.01mg/L)
Average Thickness of Unsaturated Zone of Zero metres



Naphthalene - Point Source
Protection of Aquatic Life (Criterion = 0.001mg/L)
Average Thickness of Unsaturated Zone of Zero metres



Naphthalene - Large Source
Protection of Aquatic Life (Criterion = 0.001mg/L)
Average Thickness of Unsaturated Zone of Zero metres



APPENDIX VI-C

Tables of Modelling Results

Benzene - Poi ource

Protection of Drinking Water (Criterion = 0.005mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1	0.0123	0.01	0.0054	0.01	0.00516	0.02
Ts = 200 days	5	0.194	0.22	0.00755	0.01	0.00608	0.02
Tus = 60 days	10	3.22	3.58	0.0146	0.03	0.00967	0.03
	15	33.6	37.38	0.0278	0.05	0.0154	0.06
	30		**970.72**	0.129	0.24	0.0447	0.16
	50			0.606	1.12	0.125	0.45
	100			10.4	19.15	0.806	2.91
b = 0.5m	1	0.0123	0.25	0.0054	0.18	0.00516	0.34
Ts = 200 days	5	0.194	3.96	0.00755	0.26	0.00608	0.4
Tus = 60 days	10	3.22	65.74	0.0146	0.49	0.00967	0.64
	15	33.6	685.94	0.0278	0.94	0.0154	1.02
	30		**970.72**	0.129	4.36	0.0447	2.97
	50			0.606	20.47	0.125	8.29
	100			10.4	351.33	0.806	53.47
b = 3m	1	0.00929	39.09	0.00526	36.63	0.00511	69.87
Ts = 300 days	5	0.0705	296.67	0.00667	46.45	0.00576	78.76
Tus = 90 days	10	0.65	**970.72**	0.0115	80.08	0.00871	119.1
	15			0.0199	138.57	0.0132	180.49
	30			0.0718	499.96	0.0336	459.44
	50			0.256	**970.72**	0.00807	**970.72**
	100						
b = 10m	1	0.008	**970.72**	0.0052	**970.72**	0.00508	**970.72**
Ts = 400 days	5						
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

E ene - Large Source

Protection of Drinking Water (Criterion = 0.005mg/L)

Unsaturated depth Half Life - Saturated Half Life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1						
Ts = 200 days	5	0.187	0.2	0.00729	0.01	0.00588	0.02
Tus = 60 days	10	2.29	2.54	0.0103	0.01	0.00688	0.02
	15	17.5	19.48	0.0144	0.03	0.00801	0.02
	30	**1745**	**970.72**	0.0357	0.07	0.0123	0.05
	50			0.105	0.19	0.0218	0.08
	100			1.23	2.26	0.0958	0.34
b = 0.5m	1						
Ts = 200 days	5	0.187	3.82	0.00729	0.24	0.00588	0.39
Tus = 60 days	10	2.29	46.76	0.0103	0.34	0.00688	0.46
	15	17.5	357.26	0.0144	0.49	0.00801	0.53
	30	**1745**	**970.72**	0.0357	1.20	0.0123	0.82
	50			0.105	3.55	0.0218	1.44
	100			1.23	41.56	0.0958	6.36
b = 3m	1						
Ts = 300 days	5	0.068	286.14	0.0064	44.57	0.0055	75.20
Tus = 90 days	10	0.46	**970.72**	0.0082	57.10	0.0062	84.77
	15	2.29	**970.72**	0.0103	71.72	0.0068	92.98
	30			0.0198	137.87	0.0093	127.17
	50			0.0445	309.87	0.014	191.41
	100			0.311	**970.72**	0.044	601.64
b = 10m	1						
Ts = 400 days	5	0.0388	**970.72**	0.00606	**970.72**	0.0054	**970.72**
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Benzene - Point Source
Protection of Aquatic Life (Criterion = 0.3mg/L)

Unsaturated depth Half Life - Saturated Half Life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1	0.74	0.82	0.324	0.60	0.31	1.12
Ts = 200 days	5	11.6	12.9	0.453	0.83	0.365	1.32
Tus = 60 days	10	193	214.72	0.876	1.62	0.58	2.09
	15	**1745**	**970.72**	1.668	3.07	0.923	3.33
	30			7.74	14.24	2.68	9.69
	50			36.36	66.94	7.53	27.22
	100			624	**970.72**	48.4	174.97
b = 0.5m	1	0.74	15.1	0.324	10.95	0.31	20.56
Ts = 200 days	5	11.6	236.82	0.453	15.30	0.365	24.22
Tus = 60 days	10	193	**970.72**	0.876	29.59	0.58	38.47
	15			1.668	56.35	0.923	61.23
	30			7.74	261.46	2.68	177.79
	50			36.36	**970.72**	7.53	499.51
	100			624	**970.72**	48.4	**970.72**
b = 3m	1	0.557	**970.72**	0.316	**970.72**	0.306	**970.72**
Ts = 300 days	5						
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1	0.48	**970.72**	0.311	**970.72**	0.304	**970.72**
Ts = 400 days	5						
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

Benzene - Large Source
Protection of Aquatic Life (Criterion = 0.3mg/L)

Unsaturated depth Half Life - Saturated Half Life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1						
Ts = 200 days	5	11.2	12.46	0.437	0.80	0.352	1.28
Tus = 60 days	10	137	152.42	0.623	1.15	0.412	1.49
	15	1050	**970.72**	0.868	1.60	0.48	1.74
	30	**1745**	**970.72**	2.14	3.94	0.742	2.68
	50			6.32	11.64	1.31	4.74
	100			74.2	136.61	5.74	20.75
b = 0.5m	1						
Ts = 200 days	5	11.2	228.64	0.437	14.76	0.352	23.35
Tus = 60 days	10	137	**970.72**	0.623	21.05	0.412	27.34
	15			0.868	29.32	0.48	31.84
	30			2.14	72.29	0.742	49.22
	50			6.32	213.50	1.31	86.90
	100			74.2	**970.72**	5.74	380.77
b = 3m	1						
Ts = 300 days	5	4.08	**970.72**	0.387	**970.72**	0.334	**970.72**
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1						
Ts = 400 days	5	2.33	**970.72**	0.363	**970.72**	0.325	**970.72**
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Ethylbenzene int Source
Protection of Drinking Water (Criterion = 0.0024mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1	1.13	15	0.005	0.11	0.0033	0.14
Ts = 200 days	5	**152**	**1008.7**	0.0514	1.13	0.0105	0.45
Tus = 60 days	10			0.609	13.37	0.0466	2.01
	15			4.93	108.28	0.176	7.59
	30			**152**	**1008.7**	4.09	176.39
	50					95.9	**1008.7**
	100					**152**	**1008.7**
b = 0.5m	1	1.13	**1008.7**	0.005	**1008.7**	0.0033	**1008.7**
Ts = 200 days	5	**152**	**1008.7**	0.0514	**1008.7**	0.0105	**1008.7**
Tus = 60 days	10			0.609	**1008.7**	0.0466	**1008.7**
	15			4.93	**1008.7**	0.176	**1008.7**
	30			**152**	**1008.7**	4.09	**1008.7**
	50					95.9	**1008.7**
	100					**152**	**1008.7**
b = 3m	1	0.228	**1008.7**	0.00396	**1008.7**	0.00298	**1008.7**
Ts = 300 days	5						
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1	0.0918	**1008.7**	0.00351	**1008.7**	0.00282	**1008.7**
Ts = 400 days	5						
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

ylbenzene - Large Source
Protection of Drinking Water (Criterion = 0.0024mg/L)

Unsaturated depth Half Life - Saturated Half Life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1						
Ts = 200 days	5	**152**	**1008.7**	0.0496	1.09	0.0102	0.35
Tus = 60 days	10			0.433	9.52	0.0331	1.43
	15			2.56	56.22	0.0918	3.96
	30			**152**	**1008.7**	1.13	48.73
	50					16.6	715.90
	100					**152**	**1008.7**
b = 0.5m	1						
Ts = 200 days	5	**152**	**1008.7**	0.0496	**1008.7**	0.0102	**1008.7**
Tus = 60 days	10			0.433	**1008.7**	0.0331	**1008.7**
	15			2.56	**1008.7**	0.0918	**1008.7**
	30			**152**	**1008.7**	1.13	**1008.7**
	50					16.6	**1008.7**
	100					**152**	**1008.7**
b = 3m	1						
Ts = 300 days	5	**152**	**1008.7**	0.0208	**1008.7**	0.00655	**1008.7**
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1						
Ts = 400 days	5	**152**	**1008.7**	0.0129	**1008.7**	0.00518	**1008.7**
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Ethylbenzene - Point Source
Protection of Aquatic Life (Criterion = 0.7mg/L)

Unsaturated depth Half Life - Saturated Half Life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1	**152**	**1008.7**	1.46	32.07	0.965	41.613
Ts = 200 days	5			14.9	327.24	3.08	132.83
Tus = 60 days	10			**152**	**1008.7**	13.6	586.52
	15					51.4	**1008.7**
	30						
	50						
	100						
b = 0.5m	1	**152**	**1008.7**	1.46	**1008.7**	0.965	**1008.7**
Ts = 200 days	5			14.9	**1008.7**	3.08	**1008.7**
Tus = 60 days	10			**152**	**1008.7**	13.6	**1008.7**
	15					51.4	**1008.7**
	30						
	50						
	100						
b = 3m	1	66.6	**1008.7**	1.15	**1008.7**	0.869	**1008.7**
Ts = 300 days	5						
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1	26.7	**1008.7**	1.02	**1008.7**	0.824	**1008.7**
Ts = 400 days	5						
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

Ethylbenzene - Large Source
Protection of Aquatic Life (Criterion = 0.7mg/L)

Unsaturated depth Half Life - Saturated Half Life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1						
Ts = 200 days	5	**152**	**1008.7**	14.4	316.26	2.97	126.09
Tus = 60 days	10			126	**1008.7**	9.67	417.03
	15			**152**	**1008.7**	26.7	**1008.7**
	30					**152**	**1008.7**
	50						
	100						
b = 0.5m	1						
Ts = 200 days	5	**152**	**1008.7**	14.4	**1008.7**	2.97	**1008.7**
Tus = 60 days	10			126	**1008.7**	9.67	**1008.7**
	15			**152**	**1008.7**	26.7	**1008.7**
	30					**152**	**1008.7**
	50						
	100						
b = 3m	1						
Ts = 300 days	5	**152**	**1008.7**	6.09	**1008.7**	1.91	**1008.7**
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1						
Ts = 400 days	5	**152**	**1008.7**	3.78	**1008.7**	1.51	**1008.7**
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Toluene - Large Source
Protection of Drinking Water (Criterion = 0.024mg/L)

Unsaturated depth Half Life - Saturated Half Life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1						
Ts = 200 days	5	77.6	290.1	0.0685	0.43	0.0382	0.46
Tus = 60 days	10	**515**	**962.64**	0.167	1.03	0.0586	0.71
	15			0.369	2.28	0.0875	1.06
	30			2.7	16.62	0.255	3.10
	50			24	148.47	0.896	10.88
	100			**515**	**962.64**	14.5	176.14
b = 0.5m	1						
Ts = 200 days	5	77.6	**962.64**	0.0685	625.30	0.0382	684.76
Tus = 60 days	10	**515**	**962.64**	0.167	**962.64**	0.0586	**962.64**
	15			0.369	**962.64**	0.0875	**962.64**
	30			2.7	**962.64**	0.255	**962.64**
	50			24	**962.64**	0.896	**962.64**
	100			**515**	**962.64**	14.5	**962.64**
b = 3m	1						
Ts = 300 days	5	10.3	**962.64**	0.0493	**962.64**	0.0328	**962.64**
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1						
Ts = 400 days	5	3.23	**962.64**	0.0415	**962.64**	0.0304	**962.64**
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Toluene - Point Source
Protection of Drinking Water (Criterion = 0.024mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1	0.255	0.96	0.0301	0.19	0.0264	0.32
Ts = 200 days	5	80.4	300.56	0.0709	0.44	0.0395	0.48
Tus = 60 days	10	**515**	**962.64**	0.235	1.45	0.0825	1.00
	15			0.709	4.38	0.168	2.04
	30			9.8	60.63	0.923	11.22
	50			138	853.68	5.15	62.56
	100			**515**	**962.64**	122	**962.64**
b = 0.5m	1	0.255	**962.64**	0.0301	274.76	0.0264	473.24
Ts = 200 days	5	80.4	**962.64**	0.0709	647.21	0.0395	708.06
Tus = 60 days	10	**515**	**962.64**	0.235	**962.64**	0.0825	**962.64**
	15			0.709	**962.64**	0.168	**962.64**
	30			9.8	**962.64**	0.923	**962.64**
	50			138	**962.64**	5.15	**962.64**
	100			**515**	**962.64**	122	**962.64**
b = 3m	1	0.127	**962.64**	0.279	**962.64**	0.0256	**962.64**
Ts = 300 days	5						
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1	0.0875	**962.64**	0.0269	**962.64**	0.0251	**962.64**
Ts = 400 days	5						
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

Toluene - Point Source
Protection of Aquatic Life (Criterion = 0.3mg/L)

Unsaturated depth Half Life - Saturated Half Life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1	3.19	11.92	0.376	2.32	0.33	4.01
Ts = 200 days	5	**515**	**962.64**	0.887	5.49	0.494	6.00
Tus = 60 days	10			2.94	18.18	1.03	12.52
	15			8.86	54.81	2.1	25.50
	30			122	754.70	11.5	139.70
	50			**515**	**962.64**	64.4	782.31
	100					**515**	**962.64**
b = 0.5m	1	3.19	**962.64**	0.376	**962.64**	0.33	**962.64**
Ts = 200 days	5	**515**	**962.64**	0.887	**962.64**	0.494	**962.64**
Tus = 60 days	10			2.94	**962.64**	1.03	**962.64**
	15			8.86	**962.64**	2.1	**962.64**
	30			122	**962.64**	11.5	**962.64**
	50			**515**	**962.64**	64.4	**962.64**
	100					515	**962.64**
b = 3m	1	1.59	**962.64**	0.349	**962.64**	0.32	**962.64**
Ts = 300 days	5						
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1	1.09	**962.64**	0.336	**962.64**	0.314	**962.64**
Ts = 400 days	5						
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

Toluene - Large Source
Protection of Aquatic Life (Criterion = 0.3mg/L)

Unsaturated depth Half Life - Saturated Half Life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1						
Ts = 200 days	5	**515**	**962.64**	0.857	5.30	0.477	5.79
Tus = 60 days	10			2.09	12.93	0.733	8.90
	15			4.61	28.52	1.09	13.24
	30			33.8	209.09	3.19	38.75
	50			300	**962.64**	11.2	136.06
	100			**515**	**962.64**	181	**962.64**
b = 0.5m	1						
Ts = 200 days	5	**515**	**962.64**	0.857	**962.64**	0.477	**962.64**
Tus = 60 days	10			2.09	**962.64**	0.733	**962.64**
	15			4.61	**962.64**	1.09	**962.64**
	30			33.8	**962.64**	3.19	**962.64**
	50			300	**962.64**	11.2	**962.64**
	100			**515**	**962.64**	181	**962.64**
b = 3m	1						
Ts = 300 days	5	129	**962.64**	0.617	**962.64**	0.411	**962.64**
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1						
Ts = 400 days	5	40.4	**962.64**	0.519	**962.64**	0.38	**962.64**
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Xylene - Point Source
Protection of Drinking Water (Criterion = 0.3mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1	5.28	25.26	0.398	3.15	0.338	5.2474
Ts = 200 days	5	**170**	**406.55**	1.13	8.94	0.555	8.6276
Tus = 60 days	10			4.5	35.61	1.27	19.737
	15			15.6	123.47	2.83	43.989
	30			**170**	**406.55**	19.1	296.85
	50					131	**406.55**
	100						
b = 0.5m	1	5.28	**406.55**	0.398	**406.55**	0.338	**406.55**
Ts = 200 days	5	**170**	**406.55**	1.13	**406.55**	0.555	**406.55**
Tus = 60 days	10			4.5	**406.55**	1.27	**406.55**
	15			15.6	**406.55**	2.83	**406.55**
	30			**170**	**406.55**	19.1	**406.55**
	50					131	**406.55**
	100						
b = 3m	1	2.31	**406.55**	0.363	**406.55**	0.325	**406.55**
Ts = 300 days	5						
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1	1.47	**406.55**	0.346	**406.55**	0.318	**406.55**
Ts = 400 days	5						
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

Xylene - Large Source
Protection of Drinking Water (Criterion = 0.3mg/L)

Unsaturated depth Half Life - Saturated Half Life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1						
Ts = 200 days	5	**170**	**406.55**	1.09	8.63	0.536	8.33
Tus = 60 days	10			3.2	25.32	0.908	14.11
	15			8.16	64.59	1.47	22.85
	30			83.3	**406.55**	5.28	82.06
	50			**170**	**406.55**	22.9	355.90
	100					**170**	**406.55**
b = 0.5m	1						
Ts = 200 days	5	**170**	**406.55**	1.09	**406.55**	0.536	**406.55**
Tus = 60 days	10			3.2	**406.55**	0.908	**406.55**
	15			8.16	**406.55**	1.47	**406.55**
	30			83.3	**406.55**	5.28	**406.55**
	50			**170**	**406.55**	22.9	**406.55**
	100					**170**	**406.55**
b = 3m	1						
Ts = 300 days	5	170	**406.55**	0.735	**406.55**	0.445	**406.55**
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1						
Ts = 400 days	5	102	**406.55**	0.595	**406.55**	0.404	**406.55**
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

1,3,5-Trimethylbenzene - Point Source
Protection of Aquatic Life (Criterion = 0.052mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance m	V = 1 m/year Cgw mg/L	 Cs mg/kg	V = 12.6 m/year Cgw mg/L	 Cs mg/kg	V = 30 m/year Cgw mg/L	 Cs mg/kg
b = 0m	1	**75**	**2208.3**	0.788	76.77	0.188	36.01
Ts = 200 days	5			**75**	**2208.3**	7.08	1354.20
Tus = 60 days	10					**75**	**2208.3**
	15						
	30						
	50						
	100						
b = 0.5m	1	**75**	**2208.3**	0.788	2208.3	0.188	**2208.3**
Ts = 200 days	5			**75**	2208.3	7.08	**2208.3**
Tus = 60 days	10					**75**	**2208.3**
	15						
	30						
	50						
	100						
b = 3m	1	**75**	**2208.3**	0.359	2208.3	0.126	**2208.3**
Ts = 300 days	5						
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1	**75**	**2208.3**	0.234	2208.3	0.103	**2208.3**
Ts = 400 days	5						
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

1,3,5-Trimethylbenzene - Large Source
Protection of Aquatic Life (Criterion = 0.052mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance m	V = 1 m/year Cgw mg/L	 Cs mg/kg	V = 12.6 m/year Cgw mg/L	 Cs mg/kg	V = 30 m/year Cgw mg/L	 Cs mg/kg
b = 0m	1						
Ts = 200 days	5	**75**	**2208.3**	**75**	**2208.3**	6.84	1308.3
Tus = 60 days	10					**75**	**2208.3**
	15						
	30						
	50						
	100						
b = 0.5m	1						
Ts = 200 days	5	**75**	**2208.3**	**75**	**2208.3**	6.84	**2208.3**
Tus = 60 days	10					**75**	**2208.3**
	15						
	30						
	50						
	100						
b = 3m	1						
Ts = 300 days	5	**75**	**2208.3**	48.7	**2208.3**	1.84	**2208.3**
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1						
Ts = 400 days	5	**75**	**2208.3**	13.5	**2208.3**	0.88	**2208.3**
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Naphthalene Point Source
Protection of Drinking Water (Criterion = 0.01mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1	9.85	153.34	0.0234	0.60	0.0145	0.74
Ts = 200 days	5	**32**	**249.18**	0.322	8.30	0.0546	2.76
Tus = 100 days	10			4.81	123.98	0.279	14.12
	15			**32**	**249.18**	1.19	59.98
	30					**32**	**249.18**
	50						
	100						
b = 0.5m	1	9.85	**249.18**	0.0234	**249.18**	0.0145	**249.18**
Ts = 200 days	5	**32**	**249.18**	0.322	**249.18**	0.0546	**249.18**
Tus = 100 days	10			4.81	**249.18**	0.279	**249.18**
	15			**32**	**249.18**	1.19	**249.18**
	30					**32**	**249.18**
	50						
	100						
b = 3m	1	1.69	**249.18**	0.0179	**249.18**	0.0129	**249.18**
Ts = 300 days	5						
Tus = 150 days	10						
	15						
	30						
	50						
	100						
b = 10m	1	0.617	**249.18**	0.0156	**249.18**	0.0121	**249.18**
Ts = 400 days	5						
Tus = 200 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

Naphthalene - Large Source
Protection of Drinking Water (Criterion = 0.01mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1						
Ts = 200 days	5	**32**	**249.18**	0.311	8.02	0.0528	2.67
Tus = 100 days	10			3.42	88.17	0.198	10.04
	15			24.2	**249.18**	0.617	31.22
	30			**32**	**249.18**	9.85	**249.18**
	50					**32**	**249.18**
	100						
b = 0.5m	1						
Ts = 200 days	5	**32**	**249.18**	0.311	**249.18**	0.0528	**249.18**
Tus = 100 days	10			3.42	**249.18**	0.198	**249.18**
	15			24.2	**249.18**	0.617	**249.18**
	30			**32**	**249.18**	9.85	**249.18**
	50					**32**	**249.18**
	100						
b = 3m	1						
Ts = 300 days	5	**32**	**249.18**	0.118	**249.18**	0.0319	**249.18**
Tus = 150 days	10						
	15						
	30						
	50						
	100						
b = 10m	1						
Ts = 400 days	5	**32**	**249.18**	0.0693	**249.18**	0.0244	**249.18**
Tus = 200 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Naphthalene - Point Source
Protection of Aquatic Life (Criterion = 0.001mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1	0.985	15.33	0.00234	0.06	0.00145	0.07
Ts = 200 days	5	**32**	**249.18**	0.0322	0.83	0.00546	0.28
Tus = 100 days	10			0.481	12.40	0.0279	1.41
	15			4.65	119.72	0.118	5.97
	30			**32**	**249.18**	3.56	180.32
	50					**32**	**249.18**
	100						
b = 0.5m	1	0.985	**249.18**	0.00234	**249.18**	0.00145	**249.18**
Ts = 200 days	5	**32**	**249.18**	0.0322	**249.18**	0.00546	**249.18**
Tus = 100 days	10			0.481	**249.18**	0.0279	**249.18**
	15			4.65	**249.18**	0.118	**249.18**
	30			**32**	**249.18**	3.56	**249.18**
	50					**32**	**249.18**
	100						
b = 3m	1	0.169	**249.18**	0.00179	**249.18**	0.00128	**249.18**
Ts = 300 days	5						
Tus = 150 days	10						
	15						
	30						
	50						
	100						
b = 10m	1	0.0617	**249.18**	0.00155	**249.18**	0.00121	**249.18**
Ts = 400 days	5						
Tus = 200 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

Napthalene - Large Source
Protection of Aquatic Life (Criterion = 0.001mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m	1						
Ts = 200 days	5	**32**	**249.18**	0.0311	0.80	0.00528	0.27
Tus = 100 days	10			0.342	8.82	0.0198	1.00
	15			2.42	62.31	0.0617	3.12
	30			**32**	**249.18**	0.985	49.85
	50					18.7	**249.18**
	100					**32**	**249.18**
b = 0.5m	1						
Ts = 200 days	5	**32**	**249.18**	0.0311	**249.18**	0.00528	**249.18**
Tus = 100 days	10			0.342	**249.18**	0.0198	**249.18**
	15			2.42	**249.18**	0.0617	**249.18**
	30			**32**	**249.18**	0.985	**249.18**
	50					18.7	**249.18**
	100					**32**	**249.18**
b = 3m	1						
Ts = 300 days	5	**32**	**249.18**	0.0118	**249.18**	0.00319	**249.18**
Tus = 150 days	10						
	15						
	30						
	50						
	100						
b = 10m	1						
Ts = 400 days	5	**32**	**249.18**	0.00693	**249.18**	0.00244	**249.18**
Tus = 200 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Benzo(a)pyrei Point Source

Protection of Drinking Water and Aquatic Life (Criterion = 0.00001mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m Ts = 2000 days Tus = 1000 days	1	0.004	21.39	0.004	21.39	0.004	21.39
	5						
	10						
	15						
	30						
	50						
	100						
b = 0.5m Ts = 2000 days Tus = 1000 days	1	0.004	21.39	0.004	21.39	0.004	21.39
	5						
	10						
	15						
	30						
	50						
	100						
b = 3m Ts = 3000 days Tus = 1500 days	1	0.004	21.39	0.004	21.39	0.004	21.39
	5						
	10						
	15						
	30						
	50						
	100						
b = 10m Ts = 4000 days Tus = 2000 days	1	0.004	21.39	0.004	21.39	0.004	21.39
	5						
	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

(:o(a)pyrene - Large Source

Protection of Drinking Water and Aquatic Life (Criterion = 0.00001mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m Ts = 2000 days Tus = 1000 days	1						
	5	0.004	21.39	0.004	21.39	0.004	21.39
	10						
	15						
	30						
	50						
	100						
b = 0.5m Ts = 2000 days Tus = 1000 days	1						
	5	0.004	21.39	0.004	21.39	0.004	21.39
	10						
	15						
	30						
	50						
	100						
b = 3m Ts = 3000 days Tus = 1500 days	1						
	5	0.004	21.39	0.004	21.39	0.004	21.39
	10						
	15						
	30						
	50						
	100						
b = 10m Ts = 4000 days Tus = 2000 days	1						
	5	0.004	21.39	0.004	21.39	0.004	21.39
	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

Pyrene - Point Source
Protection of Drinking Water (Criterion = 0.39mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance m	V = 1 m/year Cgw mg/L	 Cs mg/kg	V = 12.6 m/year Cgw mg/L	 Cs mg/kg	V = 30 m/year Cgw mg/L	 Cs mg/kg
b = 0m Ts = 6000 days Tus = 3000 days	1	0.17	73.9	0.17	73.9	0.17	73.9
	5						
	10						
	15						
	30						
	50						
	100						
b = 0.5m Ts = 6000 days Tus = 3000 days	1	0.17	73.9	0.17	73.9	0.17	73.9
	5						
	10						
	15						
	30						
	50						
	100						
b = 3m Ts = 9000 days Tus = 4500 days	1	0.17	73.9	0.17	73.9	0.17	73.9
	5						
	10						
	15						
	30						
	50						
	100						
b = 10m Ts = 12000 days Tus = 6000 days	1	0.17	73.9	0.17	73.9	0.17	73.9
	5						
	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

Pyrene - Large Source
Protection of Drinking Water (Criterion = 0.39mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance m	V = 1 m/year Cgw mg/L	 Cs mg/kg	V = 12.6 m/year Cgw mg/L	 Cs mg/kg	V = 30 m/year Cgw mg/L	 Cs mg/kg
b = 0m Ts = 6000 days Tus = 3000 days	1						
	5	0.17	73.9	0.17	73.9	0.17	73.9
	10						
	15						
	30						
	50						
	100						
b = 0.5m Ts = 6000 days Tus = 3000 days	1						
	5	0.17	73.9	0.17	73.9	0.17	73.9
	10						
	15						
	30						
	50						
	100						
b = 3m Ts = 9000 days Tus = 4500 days	1						
	5	0.17	73.9	0.17	73.9	0.17	73.9
	10						
	15						
	30						
	50						
	100						
b = 10m Ts = 12000 days Tus = 6000 days	1						
	5	0.17	73.9	0.17	73.9	0.17	73.9
	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

n-Hexane - P Source

Protection of Drinking Water (Criterion = 0.78mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance m	V = 1 m/year Cgw mg/L	 Cs mg/kg	V = 12.6 m/year Cgw mg/L	 Cs mg/kg	V = 30 m/year Cgw mg/L	 Cs mg/kg
b = 0m	1	**13**	**439.37**	**13**	**439.37**	**3.33**	**439.37**
Ts = 200 days	5					**13**	**439.37**
Tus = 60 days	10						
	15						
	30						
	50						
	100						
b = 0.5m	1	**13**	**439.37**	**13**	**439.37**	**3.33**	**439.37**
Ts = 200 days	5					**13**	**439.37**
Tus = 60 days	10						
	15						
	30						
	50						
	100						
b = 3m	1	**13**	**439.37**	**13**	**439.37**	**2.13**	**439.37**
Ts = 300 days	5					**13**	**439.37**
Tus = 90 days	10						
	15						
	30						
	50						
	100						
b = 10m	1	**13**	**439.37**	**4.25**	**439.37**	**1.68**	**439.37**
Ts = 400 days	5			**13**	**439.37**	**13**	**439.37**
Tus = 120 days	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

t xane - Large Source

Protection of Drinking Water (Criterion = 0.78mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance m	V = 1 m/year Cgw mg/L	 Cs mg/kg	V = 12.6 m/year Cgw mg/L	 Cs mg/kg	V = 30 m/year Cgw mg/L	 Cs mg/kg
b = 0m	1						
Ts = 200 days	5	**13**	**439.37**	**13**	**439.37**	**13**	**439.37**
Tus = 60 days	10						
	15						
	30						
	50						
	100						
b = 0.5m	1						
Ts = 200 days	5	**13**	**439.37**	**13**	**439.37**	**13**	**439.37**
Tus = 60 days	10						
	15						
	30						
	50						
	100						
b = 3m	1						
Ts = 300 days	5	**13**	**439.37**	**13**	**439.37**	**12.4**	**439.37**
Tus = 90 days	10					**13**	**439.37**
	15						
	30						
	50						
	100						
b = 10m	1						
Ts = 400 days	5	**13**	**439.37**	**13**	**439.37**	**5.53**	**439.37**
Tus = 120 days	10					**13**	**439.37**
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Decane - Point Source
Protection of Drinking Water (Criterion = 17.3mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m Ts = 200 days Tus = 60 days	1	0.02	218.37	0.02	218.37	0.02	218.37
	5						
	10						
	15						
	30						
	50						
	100						
b = 0.5m Ts = 200 days Tus = 60 days	1	0.02	218.37	0.02	218.37	0.02	218.37
	5						
	10						
	15						
	30						
	50						
	100						
b = 3m Ts = 300 days Tus = 90 days	1	0.02	218.37	0.02	218.37	0.02	218.37
	5						
	10						
	15						
	30						
	50						
	100						
b = 10m Ts = 400 days Tus = 120 days	1	0.02	218.37	0.02	218.37	0.02	218.37
	5						
	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

Decane - Large Source
Protection of Drinking Water (Criterion = 17.3mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m Ts = 200 days Tus = 60 days	1						
	5	0.02	218.37	0.02	218.37	0.02	218.37
	10						
	15						
	30						
	50						
	100						
b = 0.5m Ts = 200 days Tus = 60 days	1						
	5	0.02	218.37	0.02	218.37	0.02	218.37
	10						
	15						
	30						
	50						
	100						
b = 3m Ts = 300 days Tus = 90 days	1						
	5	0.02	218.37	0.02	218.37	0.02	218.37
	10						
	15						
	30						
	50						
	100						
b = 10m Ts = 400 days Tus = 120 days	1						
	5	0.02	218.37	0.02	218.37	0.02	218.37
	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances

Eicosane - Poi ource
Protection of Drinking Water (Criterion = 7.8mg/L)

Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m Ts = 200 days Tus = 60 days	1	3.11E-07	1	3.11E-07	1	3.11E-07	1
	5						
	10						
	15						
	30						
	50						
	100						
b = 0.5m Ts = 200 days Tus = 60 days	1	3.11E-07	1	3.11E-07	1	3.11E-07	1
	5						
	10						
	15						
	30						
	50						
	100						
b = 3m Ts = 300 days Tus = 90 days	1	3.11E-07	1	3.11E-07	1	3.11E-07	1
	5						
	10						
	15						
	30						
	50						
	100						
b = 10m Ts = 400 days Tus = 120 days	1			3.11E-07	1	3.11E-07	1
	5						
	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached

osane - Large Source
rotection of Drinking Water (Criterion = 7.8mg/L)

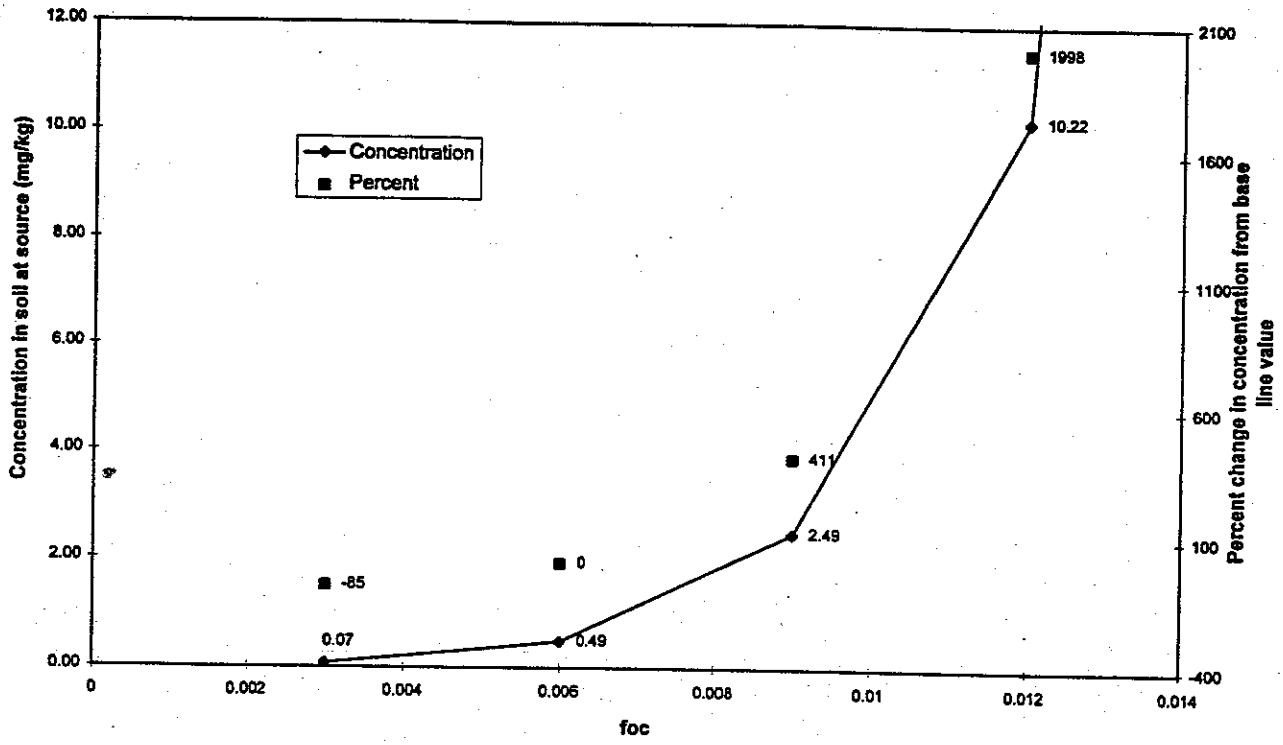
Unsaturated depth Half life - Saturated Half life - Unsaturated	Distance	V = 1 m/year		V = 12.6 m/year		V = 30 m/year	
		Cgw	Cs	Cgw	Cs	Cgw	Cs
	m	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg
b = 0m Ts = 200 days Tus = 60 days	1						
	5			3.11E-07	1	3.11E-07	1
	10						
	15						
	30						
	50						
	100						
b = 0.5m Ts = 200 days Tus = 60 days	1						
	5			3.11E-07	1	3.11E-07	1
	10						
	15						
	30						
	50						
	100						
b = 3m Ts = 300 days Tus = 90 days	1						
	5			3.11E-07	1	3.11E-07	1
	10						
	15						
	30						
	50						
	100						
b = 10m Ts = 400 days Tus = 120 days	1						
	5			3.11E-07	1	3.11E-07	1
	10						
	15						
	30						
	50						
	100						

V: Darcy Velocity
Cgw: Groundwater concentration
Cs: Soil concentration
Hi-lighted values indicate the saturation limit is reached
The model could not predict concentrations at 1m distances and Darcy velocity of 1m/year

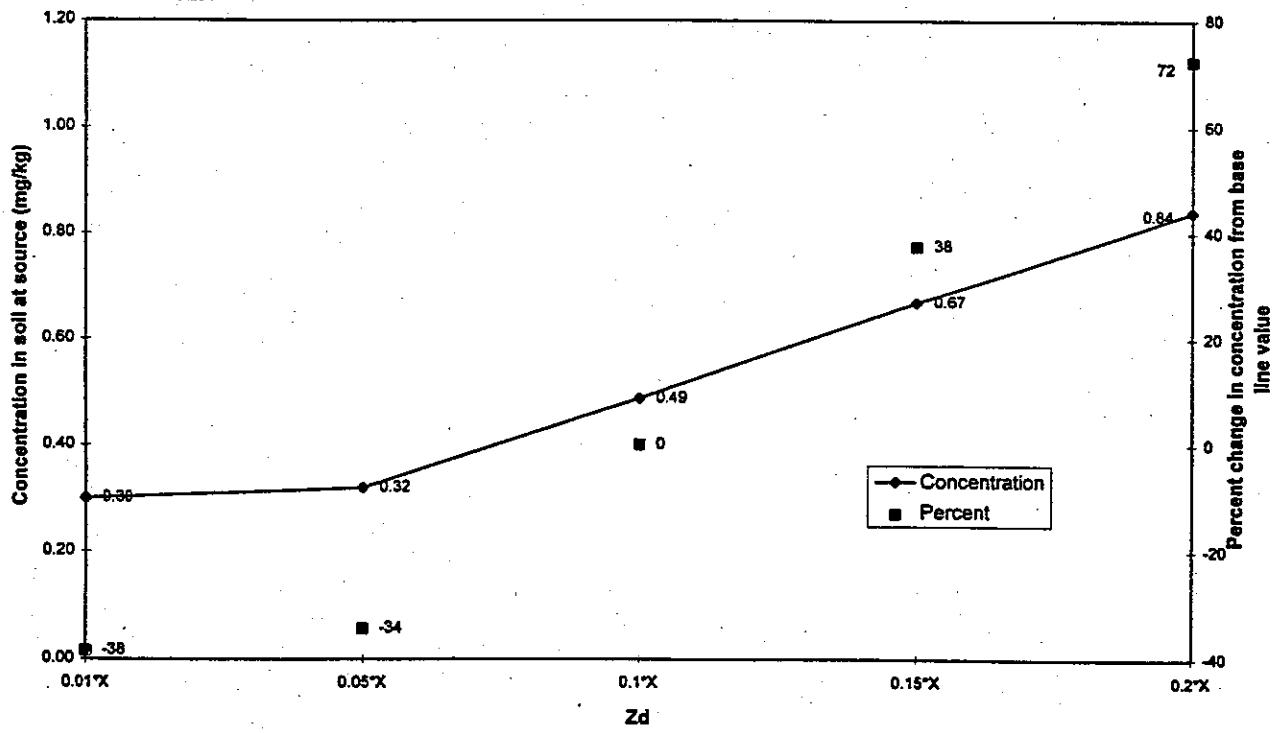
APPENDIX VI-D

Sensitivity Analyses

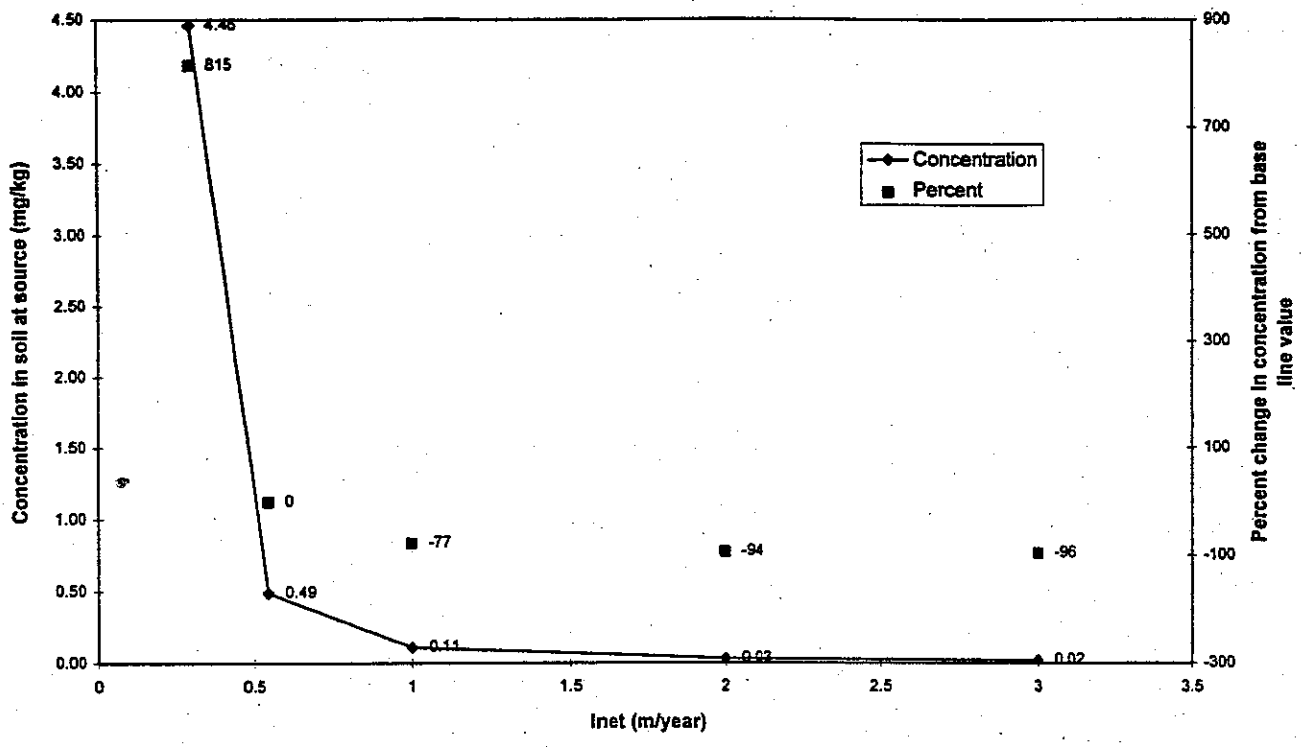
Sensitivity Analysis - foc
Benzene, Point Source, Darcy Velocity = 12.6 m/year,
Unsaturated Depth = 0.5 m, Distance from source to receptor = 10 m,
Protection of Drinking Water (Criterion = 0.005mg/L)



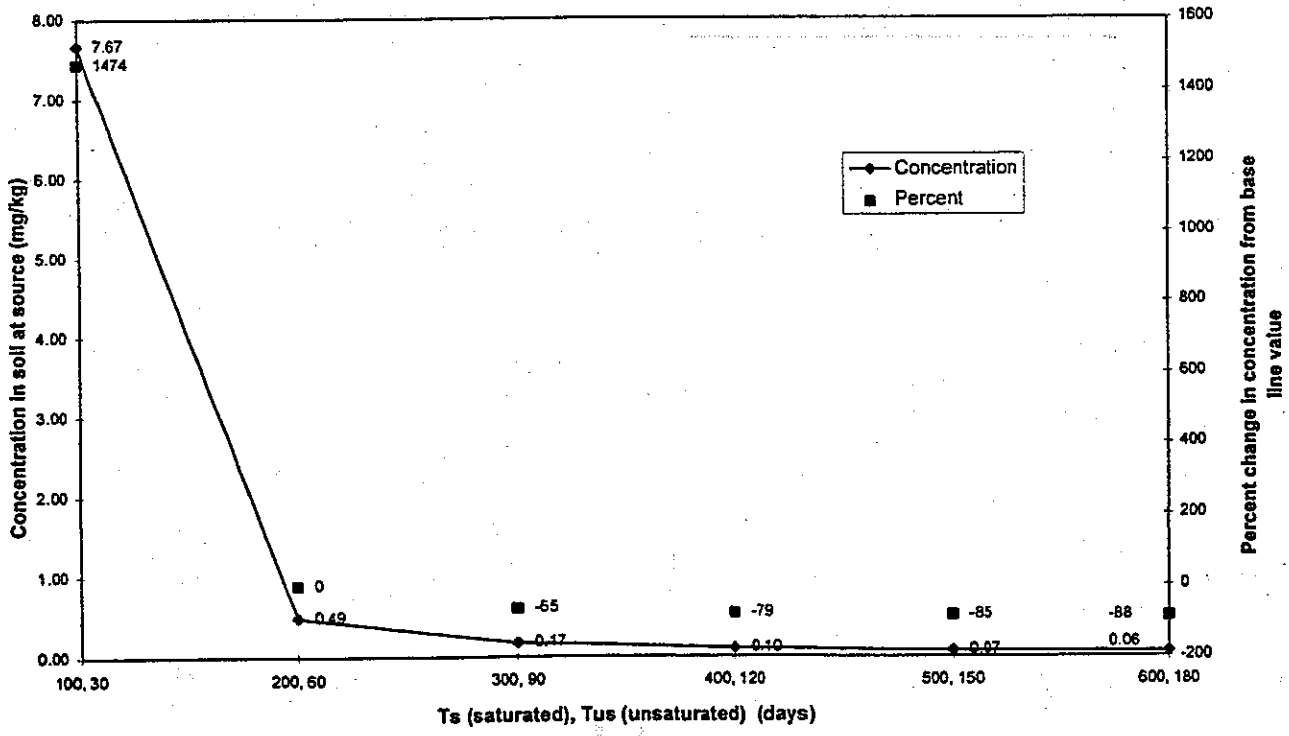
Sensitivity Analysis - Zd
Benzene, Point Source, Darcy Velocity = 12.6 m/year,
Unsaturated Depth = 0.5 m, Distance from source to receptor = 10 m,
Protection of Drinking Water (Criterion = 0.005mg/L)



Sensitivity Analysis - Net Infiltration Rate (Inet)
Benzene, Point Source, Darcy Velocity = 12.6 m/year,
Unsaturated Depth = 0.5 m, Distance from source to recepter = 10 m,
Protection of Drinking Water (Criterion = 0.005mg/L)

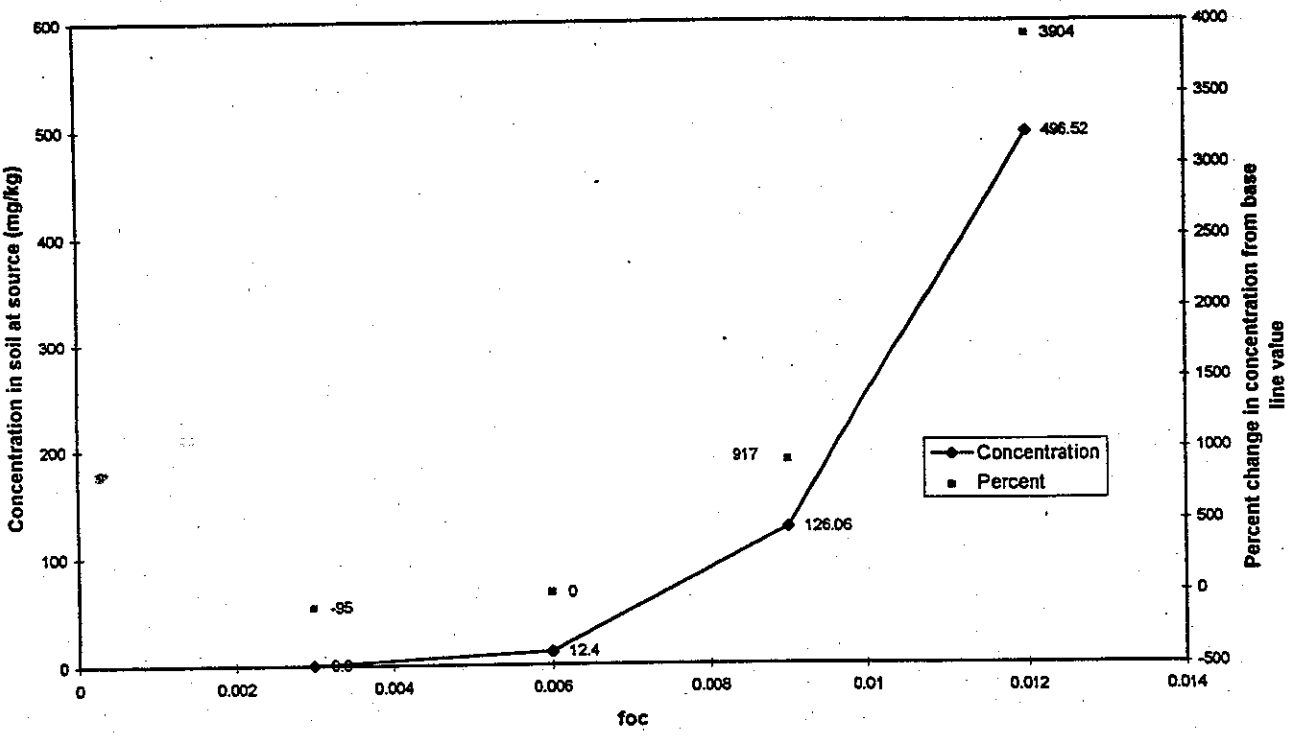


Sensitivity Analysis - Half lives (Ts,Tus)
Benzene, Point Source, Darcy Velocity = 12.6 m/year,
Unsaturated Depth = 0.5 m, Distance from source to receptor = 10 m,
Protection of Drinking Water (Criterion = 0.005mg/L)



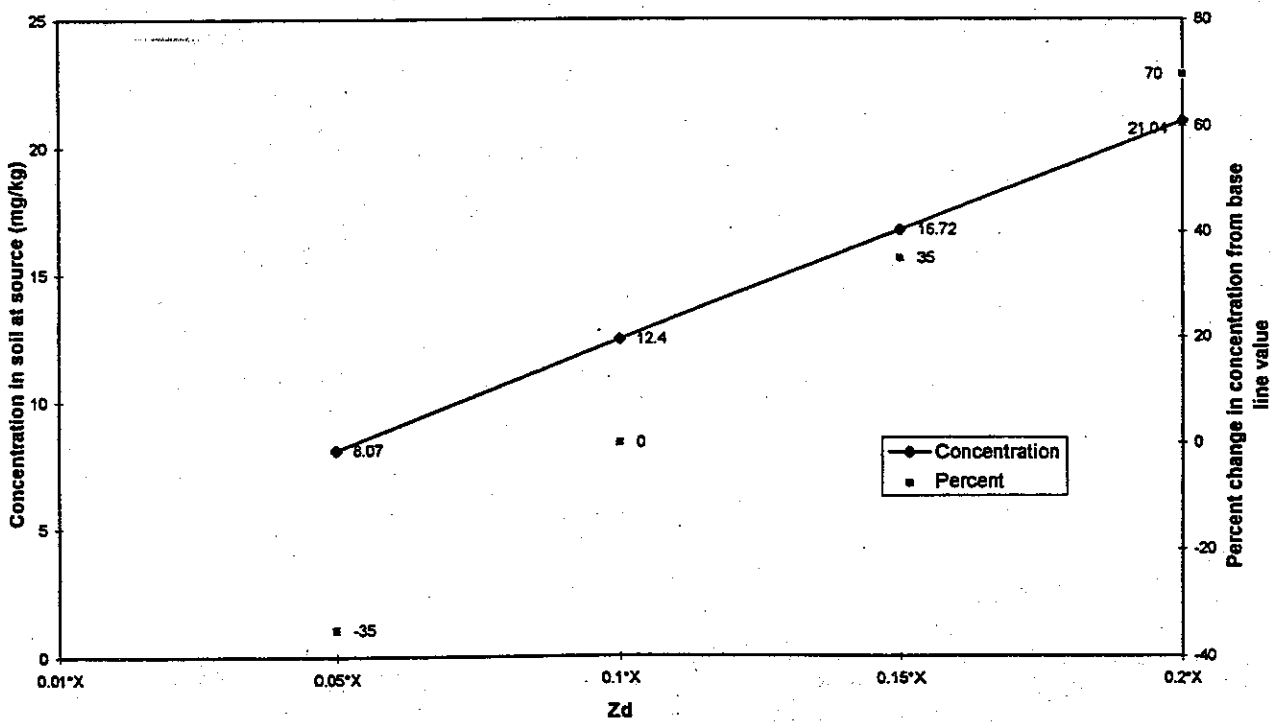
Sensitivity Analysis - foc

Naphthalene, Point Source, Darcy Velocity = 12.6 m/year,
Unsaturated Depth = 0 m, Distance from source to receptor = 10 m
Protection of Aquatic Life (Criterion = 0.001 mg/L)

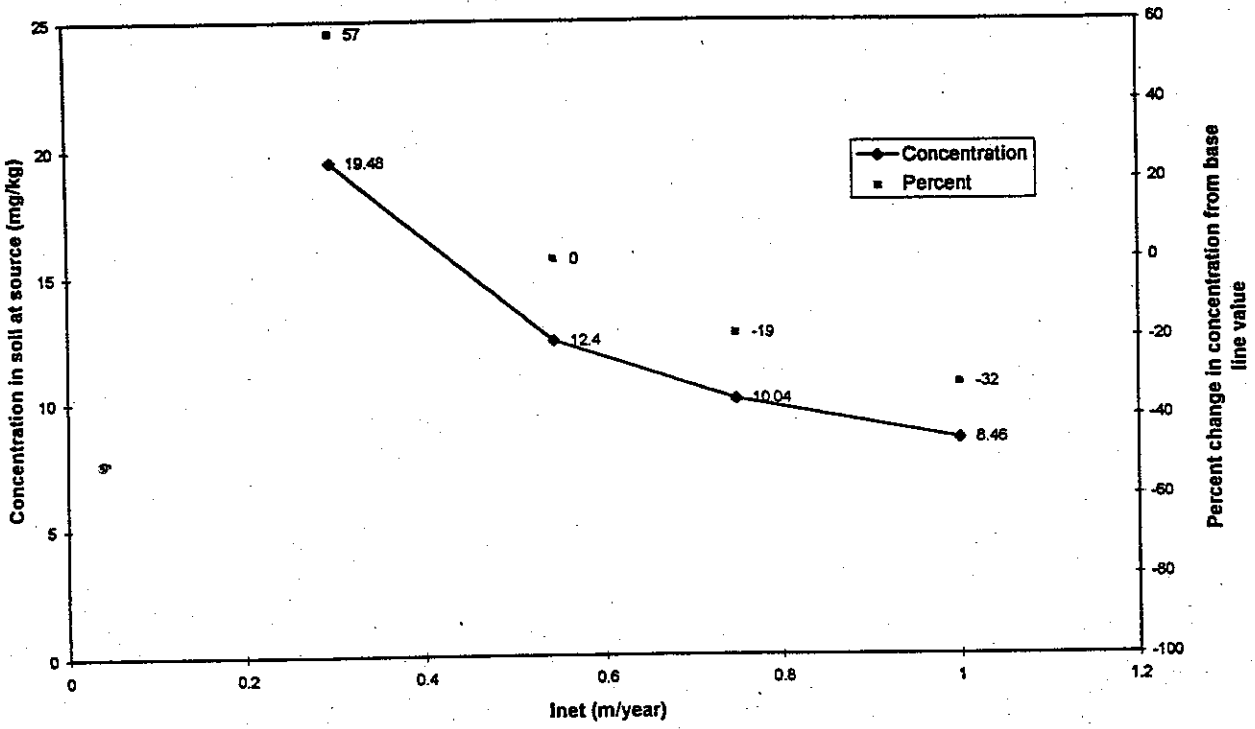


Sensitivity Analysis - Zd

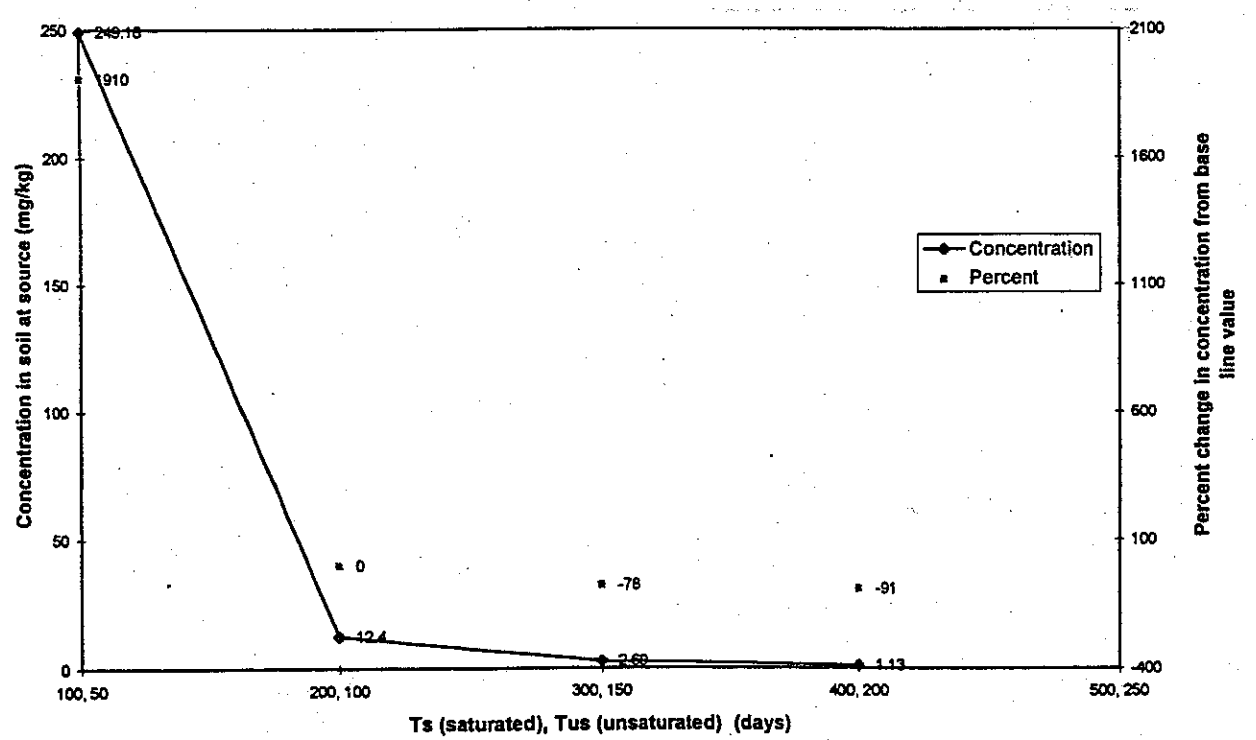
Naphthalene, Point Source, Darcy Velocity = 12.6 m/year,
Unsaturated Depth = 0 m, Distance from source to receptor = 10 m
Protection of Aquatic Life (Criterion = 0.001 mg/L)



Sensitivity Analysis - Net Infiltration Rate (Inet)
Naphthalene, Point Source, Darcy Velocity = 12.6 m/year,
Unsaturated Depth = 0 m, Distance from source to receptor = 10 m
Protection of Aquatic Life (Criterion = 0.001 mg/L)



Sensitivity Analysis - Half lives (Ts, Tus)
Naphthalene, Point Source, Darcy Velocity = 12.6 m/year,
Unsaturated Depth = 0 m, Distance from source to receptor = 10 m
Protection of Aquatic Life (Criterion = 0.001 mg/L)



APPENDIX VI-E

Determination of Remediation Criteria Protective of Drinking Water

APPENDIX VI-E

DETERMINATION OF REMEDIATION CRITERIA PROTECTIVE OF DRINKING WATER

1.0 SOIL CONCENTRATION

Acceptable soil concentrations for petroleum hydrocarbon indicator parameters are determined by equating the proportions of the acceptable concentration to the target hazard index (0.1) and an arbitrary concentration (1 mg/kg) to its calculated hazard index (see Exhibit VI-E.1). The hazard index, given a petroleum hydrocarbon soil concentration of 1 mg/kg, is determined by combining the calculated hazard quotients of the appropriate surrogates. The concentration of each surrogate at the receptor for a petroleum hydrocarbon soil concentration of 1 mg/kg is required in order to determine the intake which, in turn, is needed to calculate the hazard quotients of each surrogate. This is predicted using the groundwater model given the surrogate soil concentrations calculated according to their composition in 1 mg/kg of petroleum hydrocarbon in soil.

1.1 Groundwater Concentration at the Source

The groundwater model predicts the groundwater concentration at the source for each surrogate given their soil concentrations calculated according to their composition in 1 mg/kg of petroleum hydrocarbon in soil. Since the groundwater concentration at the source is directly proportional to the soil concentration, the acceptable groundwater concentration of each surrogate at the source is the product of the calculated acceptable petroleum hydrocarbon soil concentration and the predicted surrogate groundwater concentration at the source for a petroleum hydrocarbon soil concentration of 1 mg/kg. The acceptable surrogate groundwater concentrations at the source are then combined according to their composition in the petroleum hydrocarbon parameters to give the acceptable groundwater concentration at the source for each indicator.

1.2 Drinking Water Concentration

The method used to calculate acceptable drinking water concentrations is similar to the one outlined in Exhibit VI-E.1. A petroleum hydrocarbon water concentration of 1 mg/L

is the arbitrary value chosen and the surrogate concentrations in water are calculated according to their composition in each indicator.

1.3 Drinking Water Concentration of Surrogates

The risk based concentrations (RBC) were based on the most sensitive residential receptor for drinking water (7 month to 45 year old). A target exposure ratio of 1 was used as a risk estimate, as this is an acceptable level. The oral reference dose (RfD) for each of these chemicals was used to determine the RBC. The RfD's were compiled from several sources, including the Massachusetts Department of Environmental Protection (1994), Staats Creative Sciences (1994), U.S. EPA (1992) Health Effects Assessment Summary Tables and U.S. EPA (1993) Integrated Risk Information System.

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EXHIBIT VI-E.1
Illustration of the Calculations to Determine the VPH Criterion for the Protection of Drinking Water

① Relationship used to determine VPH soil criterion

$$\frac{C_{VPH}}{HI} = \frac{C'_{VPH}}{HI'}$$

② Fate & Transport Modelling (Unsaturated thickness = 0 m, small source = 1 m x 5 m, distance to receptor = 10 m)

$$C^S_{hexane} = C'_{VPH} \times F_{alk} \times f_{hexane}$$

$$C^S_{toluene} = C'_{VPH} \times F_{alk} \times f_{toluene}$$

③ Estimation of Hazard Quotients (Receptor = 13 kg child drinking 1 litre/day)

$$\text{Intake of hexane} = \frac{C^R_{hexane} \times 1 \text{ litre / day}}{13 \text{ kg}} = 2.2 \times 10^{-12} \text{ mg/kg/day}$$

$$\text{Intake of toluene} = \frac{C^R_{toluene} \times 1 \text{ litre / day}}{13 \text{ kg}} = 2.2 \times 10^{-4} \text{ mg/kg/day}$$

$$HQ_{hexane} = \frac{\text{Intake of Hexane}}{\text{Reference Dose}} = \frac{2.2 \times 10^{-12}}{0.06} = 3.67 \times 10^{-11} \text{ mg/kg/day}$$

$$HQ_{toluene} = \frac{\text{Intake of Toluene}}{\text{Reference Dose}} = \frac{2.2 \times 10^{-4}}{0.2} = 1.1 \times 10^{-3} \text{ mg/kg/day}$$

$$HI' = HQ_{hexane} + HQ_{toluene} = 1.1 \times 10^{-3} \text{ mg/kg/day}$$

④ Risk-based Remediation Criterion for VPH

$$C_{VPH} = \frac{C'_{VPH} \times HI}{HI'} = \frac{1 \text{ mg / kg} \times 0.1}{1.1 \times 10^{-3}} = 91 \text{ mg/kg}$$

Parameter	Definition	Default
C_{VPH}	Risk-based remediation criterion to be derived for VPH in soil.	--
HI	Hazard index adjusted to include toxicity for presence of other similarly acting chemicals	0.1
C'_{VPH}	Arbitrary value of VPH concentration in soil.	1 mg/kg
HI'	Calculated hazard index based on ingestion of drinking water containing VPH concentrations determined by the groundwater model for an assumed soil concentration of 1 mg/kg.	--
C^s_{hexane} $C^s_{toluene}$	Soil concentration of surrogates based on the assumed VPH concentration of 1 mg/kg	0.018 mg/kg, 0.12 mg/kg
F_{alk}	Proportion of alkanes	0.6
F_{aro}	Proportion of aromatics	0.4
f_{hexane}	Proportion of hexane in alkane chemical class	0.03
$f_{toluene}$	Proportion of toluene in aromatic chemical class	0.3
C^R_{hexane} $C^R_{toluene}$	Concentration at receptor determined by the groundwater model for the assumed soil concentrations of C^s_{hexane} and $C^s_{toluene}$	2.9×10^{-4} mg/L, 2.8×10^{-3} mg/L

Tables VI-E

Table 1 : Surrogate concentrations based on an assumed petroleum hydrocarbon indicator parameter soil concentration of 1 mg/kg

Scenario	Depth m	Toluene		Hexane		Naphthalene		Decane		Pyrene		Eicosane	
		C^S mg/kg	C^R mg/L	C^S mg/kg	C^R mg/L	C^S mg/kg	C^R mg/L	C^S mg/kg	C^R mg/L	C^S mg/kg	C^R mg/L	C^S mg/kg	C^R mg/L
1. Small Source (1m x 3m)													
V = 12.6 m/year	0	0.12	2.8E-03	0.018	2.9E-11	0.006	7.0E-07	0.08	2.1E-159	0.002	2.0E-10	0.024	0
	0.5	0.12	2.0E-06	0.018	6.0E-30	0.006	1.0E-12	0.08	0	0.002	5.0E-19	0.024	0
V = 30 m/year	0	0.12	3.4E-03	0.018	1.0E-08	0.006	5.0E-06	0.08	3.6E-105	0.002	4.8E-09	0.024	0
	0.5	0.12	2.3E-06	0.018	2.0E-27	0.006	7.2E-12	0.08	0	0.002	1.3E-17	0.024	0
2. Large Source (5m x 30m)													
V = 12.6 m/year	0	0.12	2.8E-03	0.018	2.9E-11	0.006	6.8E-07	0.08	2.1E-159	0.002	1.8E-10	0.024	0
	0.5	0.12	1.9E-06	0.018	5.9E-30	0.006	9.8E-13	0.08	0	0.002	4.8E-19	0.024	0
V = 30 m/year	0	0.12	4.0E-03	0.018	1.2E-08	0.006	6.0E-06	0.08	4.2E-105	0.002	5.8E-09	0.024	0
	0.5	0.12	2.7E-06	0.018	2.4E-27	0.006	8.6E-12	0.08	0	0.002	1.6E-17	0.024	0

Table 2 : Remediation criteria protective of drinking water 10m from the source for petroleum hydrocarbon indicator parameters

Scenario	Depth m	VPH		LEPH		HEPH		TPH	
		Cs mg/kg	Cgw mg/L	Cs mg/kg	Cgw mg/L	Cs mg/kg	Cgw mg/L	Cs mg/kg	Cgw mg/L
1. Small Source (1m x 3m)									
V = 12.6 m/year	0	93	22	7400	420	2.0E+08	2.0E+05	2.0E+08	2.0E+05
	0.5	1.3E+05	22	5.2E+09	420	7.8E+16	2.0E+05	7.8E+16	2.0E+05
V = 30 m/year	0	76	7	1000	24	8.1E+06	3.3E+03	8.1E+06	3.3E+03
	0.5	1.1E+05	7	7.2E+08	24	3.0E+15	3.3E+03	3.0E+15	3.3E+03
2. Large Source (5m x 30m)									
V = 12.6 m/year	0	93	15	7600	290	2.2E+08	1.5E+05	2.2E+08	1.5E+05
	0.5	1.4E+05	15	5.3E+09	290	8.1E+16	1.5E+05	8.1E+16	1.5E+05
V = 30 m/year	0	65	5	870	17	6.7E+06	2300	6.7E+06	2.3E+03
	0.5	9.6E+04	5	6.0E+08	17	2.4E+15	2300	2.4E+15	2.3E+03

Table 3 : Surrogate Parameters

Parameter	Toluene	Hexane	Naphthalene	Decane	Pyrene	Eicosane
Rfd (mg/kg/day)	0.2	0.06	0.004	1.33	0.03	0.6
Percent	12	1.8	0.6	8	0.2	2.4
Cdw (mg/L)	2.6	0.78	0.052	17.3	0.39	7.8

Table 4 : Acceptable drinking water concentrations for petroleum hydrocarbon indicator parameters

Parameter	VPH	LEPH	HEPH	TPH
Concentration (mg/L)	1.4	0.83	12	14.2

C^S: Soil concentration (see Exhibit VI-E.1, step 2).
C^R: Groundwater concentration at the receptor 10m away from the source. Determined by the groundwater model.
Cs: Soil concentration at source, refer to Exhibit VI-E.1.
Cgw: Groundwater concentration at source, based on Cs and the composition of the surrogates.
Rfd: Reference Dose
Percent: Average percentage of surrogate in petroleum hydrocarbon products based on composition given in Tables 5.3, 5.4 and 5.5.
Cdw: Risk based acceptable drinking water concentration based on HQ of 1 and body weight (13 kg) and ingestion rate (1 L/day) for a seven month to four year old child.
Acceptable drinking water concentrations for petroleum hydrocarbon parameters were calculated in a similar way to the methodology described in Exhibit VI-E.1.

APPENDIX VII

CALCULATION OF RISK-BASED REMEDIATION CRITERIA FOR LIVESTOCK

APPENDIX VII

CALCULATION OF RISK BASED REMEDIATION CRITERIA FOR LIVESTOCK

This simple analysis outlines how livestock watering objectives were derived using exposure to cattle from ingestion of contaminants via drinking water. *It should be noted that the livestock watering objectives were derived in consideration of long-term survival for cattle. They do not consider the health implications of contaminant transfer to humans consuming livestock or by-products of livestock.*

1.0 RISK-BASED CONCENTRATION OF CONTAMINANTS FOR CATTLE BASED ON WATER CONSUMPTION

The total contaminant dose associated with drinking contaminated water can be estimated according to:

$$EDI = C \times IR_{ing} \times BA \times FI \times BW^{-1} \quad (1)$$

where: EDI = estimated daily intake from drinking water (mg/kg-BW/d)

C = contaminant concentrations in water (mg/L)

IR_{ing} = water ingestion rate (L/d)

BA = oral availability of contaminant (unitless)

BW = body weight (kg)

FI = fraction of water ingested from site, conservatively assumed to be 1.0 for this analysis

The maximum acceptable concentration that could be safely consumed is easily derived by rearranging the equation and solving for the contaminant concentration:

$$C = EDI \times BW \times IR_{ing}^{-1} \times BA^{-1} \quad (2)$$

where EDI is set to equal the chemical exposure limit (i.e., equivalent to setting the hazard quotient equal to 1.0).

An example of the maximum acceptable concentration for contaminants in drinking water supplies used by cattle is based on the following input values.

1.1 Body Weight (BW)

The average live weight for grazing steer has been reported to be approximately 319 kg (Hyer et al., 1991).

1.2 Water Intake Rates (IR_{ing})

Calder and Braun (1983) calculated water intake rates for mammals (in litres per day) as:

$$IR_{ing} = 0.099BW^{0.90}$$

where the body weight (BW) is given in kilograms. Based on a 319 kg grazing steer, one individual would be expected to ingest approximately 17.7 litres of water per day.

1.3 Exposure Limit (EDI) and Bioavailability

1.3.1 Benzene

Risk assessment of the oral toxicity of benzene is currently under review by the U.S. EPA (1995). An **oral RfD of 1.26E-2 mg/kg body weight/day** has been suggested by Health Canada for benzene (BCE, personal communication).

No data were located regarding the oral bioavailability of benzene. In the absence of data, a conservative estimate of bioavailability of 100% was used for the ingestion of benzene.

1.3.2 Ethylbenzene

No specific data were located on the oral toxicity of ethylbenzene to cattle. In the absence of receptor specific data, **an oral RfD of 1.9 mg/kg body weight/day** was derived based on a subchronic rat oral bioassay conducted by Wolf *et. al.* (1956). The U.S. EPA (1995) reported a NOAEL of 97.1 mg/kg body weight/day for liver and kidney toxicity in rats for the above study. Assuming an uncertainty factor of 10 to account for

the subchronic length of the study and 5 to account for interspecies extrapolation, an oral RfD of 1.9 mg/kg body weight/day was estimated (RfD = 97.1 mg/kg body weight/day/50) for cattle.

No data were located regarding the bioavailability of ethylbenzene. In the absence of data, a conservative estimate of bioavailability of 100% was used for ingestion of ethylbenzene.

1.3.3 Toluene

No specific data were located on the oral toxicity of toluene to cattle. In the absence of receptor specific data, **an oral RfD of 2.2 mg/kg body weight/day for cattle** was derived based on a 13-week rat gavage study conducted by the NTP (1989). The U.S. EPA (1995) reported a NOAEL of 223 mg/kg body weight/day for changes in liver and kidney weights in rats for the above study. Assuming an uncertainty factor of 10 to account for the subchronic length of the study, 5 for interspecies extrapolation and 2 to account for the limited data available (lack of reproductive and developmental toxicity studies), an oral RfD of 2.2 mg/kg body weight/day was estimated (RfD = 223 mg/kg body weight/day/100) for cattle.

No data were located regarding the bioavailability of toluene. In the absence of data, a conservative estimate of bioavailability of 100% was used for the ingestion of toluene.

1.3.4 Xylene

No specific data were located on the oral toxicity of xylene to cattle. In the absence of receptor specific data, **an oral RfD of 50 mg/kg body weight/day for cattle** was derived based on a chronic oral gavage study in laboratory rats conducted by the NTP (1986). The U.S. EPA (1995) reported a NOAEL of 250 mg/kg body weight/day for hyperactivity, decreased body weight and increased mortality in rats for the above study. Assuming an uncertainty factor of 5 to account for interspecies extrapolation, an oral RfD of 50 mg/kg body weight/day was estimated (RfD = 250 mg/kg body weight/day/5) for cattle.

No data were located regarding the bioavailability of xylene. In the absence of data, a conservative estimate of bioavailability of 100% was used for ingestion of xylene.

1.3.5 Naphthalene

No specific data were located on the toxicity of naphthalene to cattle. In the absence of receptor specific data, **an oral RfD of 2.7 mg/kg body weight/day** was derived based on a 90-day laboratory mouse study by Shopp et al. (1984). Using the NOAEL of 133 mg/kg body weight/day established by Shopp et al. (1984), and an uncertainty factor of 50 (5 for extrapolation between species and 10 to account for the subchronic length of the study), an RfD of 2.7 mg/kg body weight/day is recommended for livestock watering.

A bioavailability factor of 75% for ingestion was assumed based on a study by Rahman *et. al.* (1986).

1.3.6 Benzo(a)pyrene

No specific data were located on the oral toxicity of benzo(a)pyrene to cattle; however, benzo(a)pyrene is known to induce carcinogenic effects in laboratory animals (U.S. EPA, 1995). In the absence of receptor specific data, **an RsD of 0.001 mg/kg body weight/day for cattle** was derived based on carcinogenicity studies in mice and rats conducted by Neal and Rigdon (1967), Rabstein *et .al.* (1973) and Brune *et. al.* (1981). In these studies, increases in forestomach, squamous cell, larynx and esophagus papillomas and carcinomas were observed in mice and rats. The U.S. EPA (1995) calculated an oral slope factor of 7.3 mg/kg body weight/day based on a geometric mean of four slope factors obtained by differing modeling procedures combining multiple data sets from the above studies. Based on an oral slope factor of 7.3 mg/kg body weight/day, a dose of 0.001 mg/kg body weight/day would produce a risk of one in a hundred of developing cancer based on increased tumor incidence as a result of exposure through the diet (RsD = 1×10^{-2}/7.3 mg/kg body weight/day) for cattle.

A bioavailability factor of 25% for ingestion of benzo(a)pyrene was assumed based on a study by Rahman *et. al.* (1986).

2.0 RECOMMENDED LIVESTOCK WATERING OBJECTIVES

Using equation 2 and the above input variables, acceptable ground water or surface water concentrations were calculated for cattle, and are listed in the table below as "Livestock Watering."

Chemical	RfD Cattle (mg/kg-d)	Oral Bioavailability	Livestock Watering (mg/L)
benzene	0.013	1	0.23
toluene	2.2	1	40
ethylbenzene	1.9	1	34
xylene	50	1	900
naphthalene	2.66	0.75	65
benzo(a)pyrene	0.001 (RsD)	0.25	0.07

3.0 REFERENCES

Brune *et. al* 1981. Cited In: U.S. EPA, 1995. (full reference cite not available).

Calder, W.A. and E.J. Braun. 1983. Scaling of osmotic regulation in mammals and birds. Am. J. Physiol. 43:301-322.

Hyer, J.C., Oltjen, J.W. and Galyean, M.L. 1991. Evaluation of a feed intake model for the grazing beef steer. J Anim Sci 69(2):827-835.

Neal, J. and Rigdon, R.H. 1967. Gastric tumours in mice fed benzo(a)pyrene: A quantitative study. Tex Rep Biol Med 25:553-557. Cited In: U.S. EPA, 1995.

NTP (National Toxicology Program). 1989. Toxicology and carcinogenesis studies of toluene in F344/N rats and B6C3F1 mice. Technical Report Series No. 371. Research Triangle Park, NC. Cited In: U.S. EPA, 1995.

NTP (National Toxicology Program). 1986. NTP Technical Report on the Toxicology and carcinogenesis studies of xylenes (mixed) (60.2% m-xylene, 13.6% p-xylene, 17.0% ethylbenzene and 9.1% o-xylene) (CAS No. 1330-20-7) in F344/N rats and B6C3F1 mice (gavage studies). NTP-TR-327. Cited In: U.S. EPA, 1995.

Ott, M.G., Townsend, J.C., Fishveck,W.A. and Langner, R.A. 1978. Mortality among individuals occupationally exposed to benzene. Arch Environ Health 33:3-10. Cited In: U.S. EPA, 1995.

Rabstein *et al.* 1973. Cited In: U.S. EPA, 1995. (full reference cite not available).

Rahman, A., Barrowman, J.A. and Rahimtula, A. 1986. The influence of bile on the bioavailability of polynuclear aromatic hydrocarbons from the rat intestine. Can J Physiol Pharmacol 64:1214-1218.

Rinsky, R.A., Young, R.J. and Smith, A.B. 1981. Leukemia in benzene workers. Am J Ind Med 2:217-245. Cited In: U.S. EPA, 1995.

Shopp, G.M., White, K.L., Holsapple, M.P., Barnes, D.W., Duke, S.S., Anderson, A.C., Condie, L.W., Hayes, J. and Borzelleca, J.F. 1984. Naphthalene toxicity in CD-1 mice: General toxicology and immunotoxicology. Fund Appl Toxicol 4:406-419.

U.S. EPA. 1995. Integrated Risk Information System (IRIS). On-line database. Benzene.

U.S. EPA. 1995. Integrated Risk Information System (IRIS). On-line database. Benzo(a)pyrene.

U.S. EPA. 1995. Integrated Risk Information System (IRIS). On-line database. Ethylbenzene.

U.S. EPA. 1995. Integrated Risk Information System (IRIS). On-line database. Toluene.

U.S. EPA. 1995. Integrated Risk Information System (IRIS). On-line database. Xylenes.

Wolf, M.A., Rowe, V.K., McCollister, D.D., Hollingsworth, R.L. and Oyen, F. 1956. Toxicological studies of certain alkylated benzenes and benzene. Arch Ind Health 14:387-398. Cited In: U.S. EPA, 1995.

Wong, O., Morgan,R.W. and Whorton, M.D. 1983. Comments on the NIOSH study of leukemia in benzene workers. Technical report submitted to Gulf Canada, Ltd. by Environmental Health Associates. Cited In: U.S. EPA, 1995.

APPENDIX VIII

RISK CALCULATIONS FOR OUTDOOR SOIL INGESTION AND INHALATION PATHWAY

APPENDIX VIII

RISK CALCULATIONS FOR OUTDOOR SOIL INGESTION AND INHALATION PATHWAY

1.0 SOIL INGESTION PATHWAY RISK ESTIMATES

The unadjusted risk-based acceptable soil concentrations, obtained using the methodology described in Section 6.2 are presented in Table VIII.1. As shown, for non-carcinogens, the acceptable soil concentrations are back-calculated using the maximum HQ based on the doses calculated for each age category representing the composite receptor (residential case). The maximum HQ was obtained for the infant receptor (0-6 months) with a slightly lower HQ obtained for the young child (7 months to 4 years).

Relatively high acceptable soil concentrations were obtained for most chemicals. The lowest acceptable soil concentration was obtained for the residential scenario for benzo(a)pyrene (2.6 mg/kg) followed by benzene (662 mg/kg).

All risk-based soil concentrations exceed the soil saturation limits presented in Table 8.4 with the exception of benzo(a)pyrene and benzene for residential case. Although not a requirement for the ingestion model, it is recommended that the risk-based criteria exceeding the soil saturation limits be replaced with the soil saturation limits for consistency with other pathways.

2.0 OUTDOOR INHALATION PATHWAY RISK ESTIMATES

The unadjusted risk-based acceptable soils concentrations and soil saturation concentrations, obtained using the methodology described in Section 6.3, are presented in Table VIII.2. The risk-based criteria are not replaced with the soil saturation concentrations in Table VIII.2 in order to illustrate the magnitude of the calculated risk-based values. To fulfill the model assumptions, risk-based concentrations that exceed the soil saturation limit should be replaced with the soil saturation limit.

As shown, acceptable soil concentrations are back-calculated using the maximum HQ based on doses calculated for the composite receptor (residential case). The maximum HQ was obtained for the infant receptor (0-6 months).

The lowest acceptable soil concentrations were obtained for the carcinogens, benzene and benzo(a)pyrene. For the residential case, the acceptable soil concentrations are 23 mg/kg for benzene and 1.5 mg/kg for benzo(a)pyrene.

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TABLE VIII.1
Risk-Based Soil Criteria for Outdoor Ingestion Pathway
(Based on EPA RAGS, Part B)

ICLR = 7E-06
HQ = 1

Chemical	Soil Saturation C_{sat} (mg/kg)	Residential		Commercial	
		Carcinogens (mg/kg)	Non-carcinogens (Max HQ) (mg/kg)	Carcinogens (mg/kg)	Non-carcinogens (Max HQ) (mg/kg)
Benzene	1124	662	--	8880	--
Toluene	1011	--	48000	--	2450000
Ethylbenzene	1024	--	24000	--	1230000
Xylenes	417	--	480000	--	24500000
Naphthalene	251	--	960	--	49100
B(a)P	21	2.63	--	35.3	--
n-Hexane	517	--	14400	--	736000
n-Nonane		--	24000	--	1230000
Eicosane	36	--	1000000	--	5000000
Pyrene	73	--	7200	--	368000
Decane	218	--	320000	--	16300000

TABLE VIII.2
Risk-Based Soil Criteria for Outdoor Inhalation Pathway
(Based on EPA RAGS, Part B)

ICLR = 7E-06
HQ=1

Chemical	Soil Saturation C_{sat} (mg/kg)	(Volatilization/Particulate Emissions)			
		Residential		Commercial	
		Carcinogens (mg/kg)	Non-carcinogens (Max HQ) (mg/kg)	Carcinogens (mg/kg)	Non-carcinogens (Max HQ) (mg/kg)
Benzene	1124	23.1	--	38.2	--
Toluene	1011	--	5910	--	9720
Ethylbenzene	1024	--	31300	--	51500
Xylenes	417	--	158000	--	260000
Naphthalene	251	--	1800	--	2970
B(a)P	21	1.54	--	2.56	--
n-Hexane	517	--	927	--	1520
n-Nonane	11	--	794	--	1310
Eicosane	36	--	56000000	--	92000000
Pyrene	73	--	576000	--	949000
Decane	218	--	1380000	--	2280000

SUPPLEMENT I

CONSIDERATIONS FOR ALTERNATE CALCULATIONS FOR VPH AND LEPH

SUPPLEMENT I
Considerations for Alternative Calculations for VPH and LEPH

1.0 BACKGROUND

This supplement was developed in response to comments and concerns respecting the applicability of VPH and LEPH-based remediation criteria when the surrogates n-hexane and naphthalene, respectively, are demonstrated to be absent (i.e., not detectable). n-Hexane is considered the most toxic alkane of the VPH fraction (RfD = 0.06 mg/kg•day), and as such may needlessly bias a VPH remediation criterion in a conservative manner if it is, in fact, absent from the VPH fraction found at a contaminated site. Similarly, naphthalene may also be absent. To accomodate this concern, an alternative approach of using n-nonane as the VPH alkane surrogate and 1-methlnaphthalene as the LEPH aromatic surrogate, are considered in the criteria derivation process. Finally, consideration is given to the degree of conservatism used for the target hazard index.

2.0 TOXICITY OF n-NONANE

n-Nonane is the longest carbon-chain member of the VPH fraction (C_5 to C_9) and has fate and transport properties similar to n-hexane. However, unlike n-hexane, n-nonane does not demonstrate the peripheral neuropathies, giant axonal swelling or nasal turbinate lesions observed with n-hexane. n-Nonane has been reviewed by both the Massachussets Department of Environmental Protection (MDEP, 1994) and Staats Creative Sciences (SCS, 1994) and ascribed an equivalent oral reference dose (based on the same rat inhalation study conducted by Carpenter, et al., 1978) of 0.6 and 1.017 mg/kg-d, respectively.

Examination of the rationale in the derivation of the RfD suggests both reviews should ascribe a greater degree of conservatism to the RfD. In the case of the SCS review, a NOAEL was assigned to an exposure regime which was associated with reduction in growth rate (1,600 ppm). The MDH review considered the NOAEL to be the next lowest exposure regime (590 ppm) and noted this to be approximately 10-fold less toxic than the NOAEL for n-hexane observed in a subchronic mouse inhalation study (Dunnick, et al., 1989). Consequently, they adopted an RfD for n-nonane 10-fold greater (i.e., less toxic) than n-hexane. This, however, does not correspond to the dose rate observed in the

original n-nonane study, nor does it address the observation that the subchronic study was only 62 days rather than the preferred 90 day duration.

For the purposes of the present report, it is noted that the NOAEL exposure roughly equates to a dose rate of 375 mg/kg-day. Applying a 1,000-fold uncertainty factor consistent with the SCS (1994) review yields 0.375 mg/kg-d. In light of the short duration of the subchronic study and its uncertainty, respecting further effects, this value was marginally adjusted to yield an RfD of 0.1 mg/kg-d.

3.0 ALTERNATE VPH CRITERIA

Using the above-noted RfD for n-nonane, a series of transport/fate simulations were conducted using the indoor air/soil gas transport model described in the main report. The following tables provide the VPH concentration predicted in soil and groundwater, using n-nonane as the VPH-alkane surrogate. The results indicate that a VPH concentration of about 10 mg/kg in soil based on nonane and toluene surrogates, and using a conservative HQ of 0.1. Using a conservative RfD for n-nonane of 0.1 mg/kg-day, as compared to 0.6 mg/kg-day, had only a 30% effect on the calculated VPH concentration in soil (Case 5 and 8), because of toluene's greater contribution to the overall toxicity. For a non-conservative HQ of 0.5, the VPH concentration in soil would be about 50 mg/kg.

4.0 ALTERNATE LEPH CRITERION

For naphthalene, a somewhat different approach was employed. The toxicity (i.e., RfD) of naphthalene was retained but the transport characteristics of 1-methylnaphthalene was used as the surrogate. The effect on the calculated value is shown in Table SI-2. Using a HQ of 0.5 would bring the LEPH criterion from 275 mg/kg (for naphthalene + decane) to about 1,400 mg/kg.

5.0 RESULTS OF SENSITIVITY ANALYSIS – VPH AND LEPH

The method used to derive criteria for VPH and LEPH, in the context of the surrogate approach (see Chapter 5.0), requires consideration of the following information:

1) Petroleum hydrocarbon composition (i.e., proportion of surrogates and hydrocarbon classes).

2) Surrogate toxicity.

3) Surrogate environmental fate and transport.

The derived soil criteria will vary depending on surrogates chosen for composition, toxicity and environmental fate and transport. The surrogates chosen to represent the toxicity and environmental fate and transport for the generic VPH and LEPH criteria presented in Section 3.0 were considered to be somewhat conservative both in terms of toxicty and mobility. The effect of surrogate selection on the derived soil and groundwater criteria was evaluated for several combinations of surrogates as presented in Tables SI-1 and SI-2. As shown, for VPH the derived soil criteria ranged from 3.8 mg/kg to 15 mg/kg for a target hazard index of 0.1. The criteria varied over a relatively narrow range primarily due to the relatively small differences in surrogate RfDs (e.g., RfD_{hexane} equal to 0.06, RfD_{nonane} equal to 0.1. A somewhat higher VPH criteria was derived using a nonane RfD of 0.6 (52 mg/kg). In addition, the differences in physical/chemical parameter values between hexane and nonane are relatively small.

The use of the proportion of the surrogate alone to derive total petroleum hydrocarbon criteria is potentially non-conservative due to the possible presence of other compounds of similar toxicity within each hydrocarbon class. For this reason, the target hazard index was adjusted to account for other compounds present. However, the proportion of the surrogate (f) to chemical class (F) represents an upper bound for the target hazard index.

For surrogates chosen for this study, the maximum f value was 0.3 for toluene followed by 0.1 for decane. Therefore, in particular the hazard index chosen (0.1) for these chemicals is likely too conservative. To this end it may be of interest to BCE to consider a less conservative adjustment of the target hazard index such as a value on the order of 0.3 to 0.5. This would have the effect of raising permissible risk-based criteria up to 5-fold, and still be reasonably conservative in light of the proportion of surrogate in the hydrocarbon mixture.

REFERENCES FOR SUPPLEMENT I

Carpenter, C.P.; Geary, D.L.; Myers, R.C.; Nachreiner, D.J.; Sullivan, L.J.; and King, J.M., 1978. *Petroleum hydrocarbons toxicity studies XVII: Animal responses to n-Nonane Vapour.* Toxicol. Appl. Pharmocol. 44:53-61.

Dunnick, J.K.; Graham, D.G.; Yong, R.S.; Haber, S.B.; and Brown, H.R., 1989. *Thirteen-week toxicity study on n-hexane in B6C3FI mice after inhalation exposure.* Toxicol 57(2)163-172.

MDEP, 1994. *Interim Final Petroleum Report: Development of Health-Based Alternative to the Total Petroleum Hydrocarbon (TPH) Parameter..* Massachusetts Dept. of Env'l Protection, Boston, MA.

SCS, 1994. *Staats Creative Sciences Final Report on Development of a Human Health Dual Risk Factor for Long Chain Petroleum Hydrocarbons* conducted for U.S. Dept. of Defense, Dept. of AirForce. F41624-94-C-9009.

TABLE SI-1
Results of Sensitivity Analysis for VPH
Indoor Residential Inhalation Scenario

Case	Toxicity Surrogates	Fate & Transport Surrogates	HQ	Soil (mg/kg)	Groundwater (mg/L)
1	hexane & toluene	hexane & toluene	0.1	3.8	0.22
2	hexane & toluene	heptane & toluene	0.1	6.0	--
3	hexane & toluene	nonane & toluene	0.1	4.3	--
4	nonane [4] & toluene	hexane & toluene	0.1	7.6	0.6
5	nonane [4] & toluene	nonane & toluene	0.1	7.2	--
6	nonane [4] & toluene/ethylbenzene [1]	nonane & toluene	0.1	9.8	--
7	nonane [4] & toluene/ethylbenzene [1]	nonane & toluene/ethylbenzene [2]	0.1	15.2	--
8	nonane [5] & toluene	nonane & toluene	0.1	10.7	--
9	nonane [5] & toluene/ethylbenzene [1]	nonane & toluene/ethylbenzene [2]	0.1	52	--

Notes:
1) Average RfD for toluene and ethylbenzene.
2) Average physical/chemical parameters used for toluene and ethylbenzene.
3) Composition data used for risk calculations were estimated proportions for toxicity surrogates listed.
4) Nonane RfD = 0.1.
5) Nonane RfD = 0.6.

TABLE SI-2
Results of Sensitivity Analysis for LEPH
Indoor Residential Inhalation Scenario

Toxicity Surrogates	Fate & Transport Surrogates	Residential VPH		
		HQ	Soil (mg/kg)	Groundwater (mg/L)
naphthalene & decane	naphthalene & decane	0.1	275	--
naphthalene & decane	1-methylnaphthalene & decane	0.1	700	--

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