Appendix O
Summary of MNA Cleanup Timeframes and Decay Rate Calculations

Constituent Plume & Aquifer	Approximate MNA Cleanup Timeframe (Years)		Overall Estimated MNA Cleanup Timeframe (3)
	Distance Dependent Calculation Method (1)	Time-Dependant calculation Method (2)	
Northern TCE Plume			**25 Years**
Overburden	3.2	20.2	
Bedrock	22.2	NC*	
Southern TCE Plume			**50 Years**
Overburden	41.5	48.1	
Bedrock	25.2	NC*	
RDX Plume			**40 Years**
Overburden	22.3	35.7	
Bedrock	9.8	17.7	

(1) MNA Cleanup time was calculated using the distance-dependant degradation rate constant method as described by Newell et al., (USEPA, 2002)

(2) MNA Cleanup time was calculated using the time-dependant degradation rate constant method as described by Newell et al., (USEPA, 2002)

(3) Overall Estimated MNA Cleanup Timeframes were determined by comparing all timeframes calculated for each plume. The longest calculated timeframe for each plume was rounded up to the nearest five years

* Not Calculated, Insufficient Data for temporal concentration trend.

Appendix O

Distance-Dependent Degradation Rate Constant for TCE

Natural Attenuation Rate Calculation, Distance Rate Constant
Reference: USEPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies
C.J. Newell, H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, M.P. Suarez
Slope of exponential regression versus distance (k/v_x)

Location: Mid-Valley -Southern TCE Plume - Overburden Aquifer - 2003 Data

Monitoring Well	B1038MW-1	B1038MW-3	161MW-1	125MW-1A	125MW-2A	104MW-1	GMW-4	Slope	R^2
Feet	**741**	**1067**	**1705**	**3488**	**3957**	**4507**	**4948**	-0.0006	0.7810
Concentration	**59**	**44**	**94**	**44**	**10.0**	**6.1**	**5.1**		

Hydraulic Conductivity		ft/day
Groundwater Gradient		ft/ft
Total Porosity	**0.20**	porosity
Average groundwater velocity, v_x =	**0.500**	ft/day
	182.5	ft/year

λ = $(v_c/4\alpha_x)$ $([1+2\alpha_x(k/v_x)]^2 - 1)$
α_x = 5 % of flow field (distance separating two furthest wells)
247.4 ft
f_{oc} = **0.01**
K_{oc} = **126** L/kg
K_d = $K_{oc}f_{oc}$
1.26 L/kg
ρ_b = 1.7 kg/L
n = 0.20
R = $1 + (\rho_b K_d/n)$
11.710
v_c = v_x/R
15.5850 ft/year

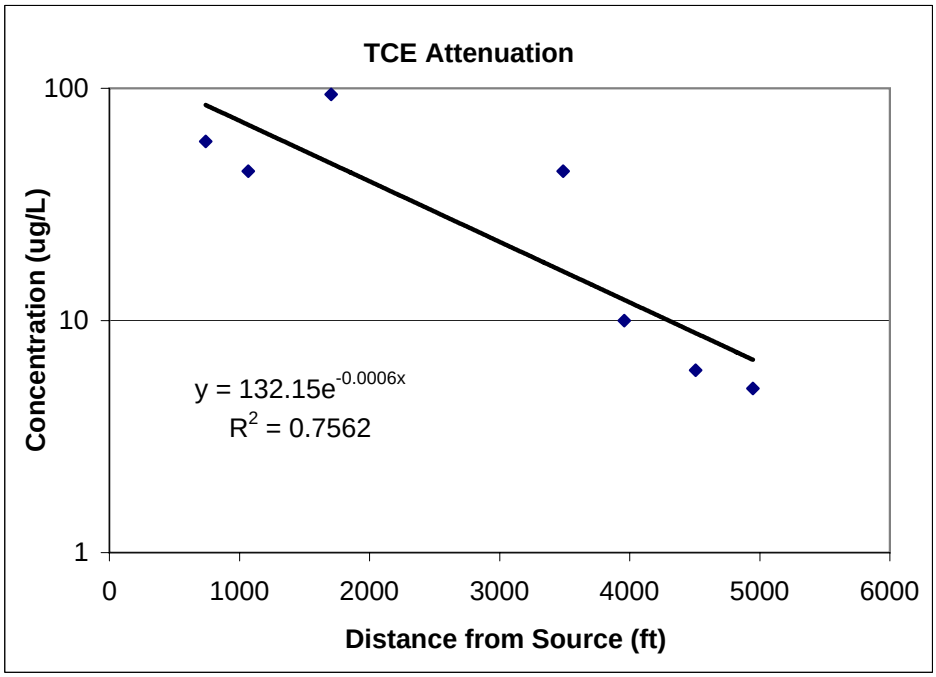
Natural Attenuation Rate

k = **0.1095** /year
half-life = **6.3** years

Estimate of time needed to degrade contaminants at various points:

t= $-\ln[C_{goal}/C_{start}]/k$
C_{goal} = 1.0

Duration at poin	**t (years)**
B1038MW-1	37.2
B1038MW-3	34.6
161MW-1	41.5
125MW-1A	34.6
125MW-2A	21.0
104MW-1	16.5
GMW-4	14.9

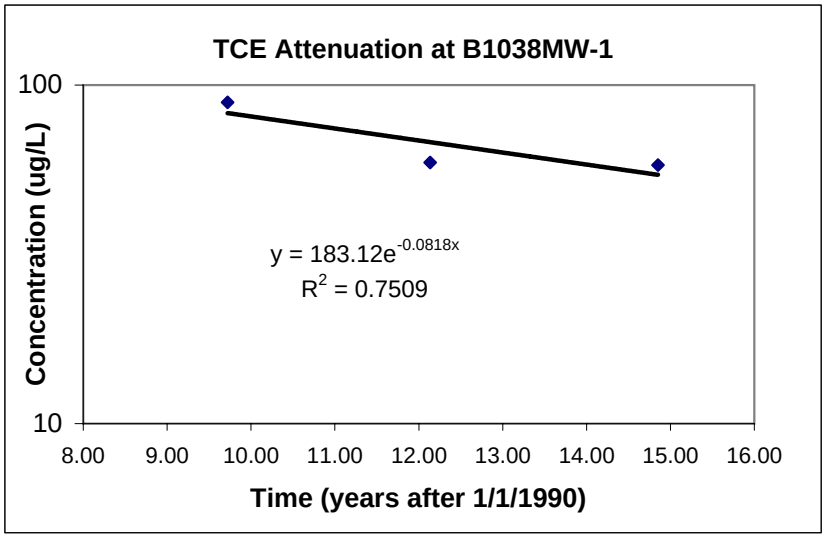


Appendix O

Time-Dependent Degradation Rate Constant for TCE

Natural Attenuation Rate Calculation, Decay Rate Constant
Reference: USEPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies
C.J. Newell, H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, M.P. Suarez
Slope of exponential regression versus time (k)

Location: Mid-Valley - Southern TCE Plume - Overburden Aquifer - Time-Conc. Data



Total Porosity **0.20** porosity
Average groundwater velocity, v_x = **0.130** ft/day
47.5 ft/year

Natural Attenuation Rate

k_{point} = **0.0818** /year
half-life = **8.5** years

Estimate of time needed to degrade contaminants at various points:

$t = -\ln[C_{goal}/C_{start}]/k$ C_{goal} = 1.00

Duration at point:	t (years from 1/1/1990)	MNA Time (from present)
B1038MW-1	63.7	48.1

B1038MW-1				Slope	R^2
Years (from 1/1/1990)	**9.72**	**12.13**	**14.85**	-0.0818	0.7509
Concentration	**89.00**	**59.00**	**58.00**	Y-int	
Date	**9/19/1999**	**2/18/2002**	**11/6/2004**	183.12	
Days (from 1/1/1990)	3548	4429	5421		
Years (from 1/1/1990)	9.7	12.1	14.9		

Appendix O

Distance-Dependent Degradation Rate Constant for TCE

Natural Attenuation Rate Calculation, Distance Rate Constant
Reference: USEPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies
C.J. Newell, H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, M.P. Suarez
Slope of exponential regression versus distance (k/v_x)

Location: Mid-Valley - Southern TCE Plume - Bedrock Aquifer 2003 Data

Monitoring Well	161MW-1B	125MW-1B	125MW-2A	Slope	R^2
Feet	**1650**	**3420**	**3900**	-0.0008	0.8877
Concentration	**83**	**30**	**10.0**		

Hydraulic Conductivity		ft/day
Groundwater Gradient		ft/ft
Total Porosity	**0.05**	porosity
Average groundwater velocity, v_x =	**0.600**	ft/day
	219.0	ft/year

λ =	$(v_c/4\alpha_x)$ $([1+2\alpha_x(k/v_x)]^2 - 1)$	
α_x =	5 % of flow field (distance separating two furthest wells)	
	195	ft
f_{oc} =	**0.01**	
K_{oc} =	**126**	L/kg
K_d =	$K_{oc}f_{oc}$	
	1.26	L/kg
ρ_b =	1.7	kg/L
n =	0.05	
R =	$1 + (\rho_b K_d/n)$	
	43.840	
v_c =	v_x/R	
	4.9954	ft/year

Natural Attenuation Rate

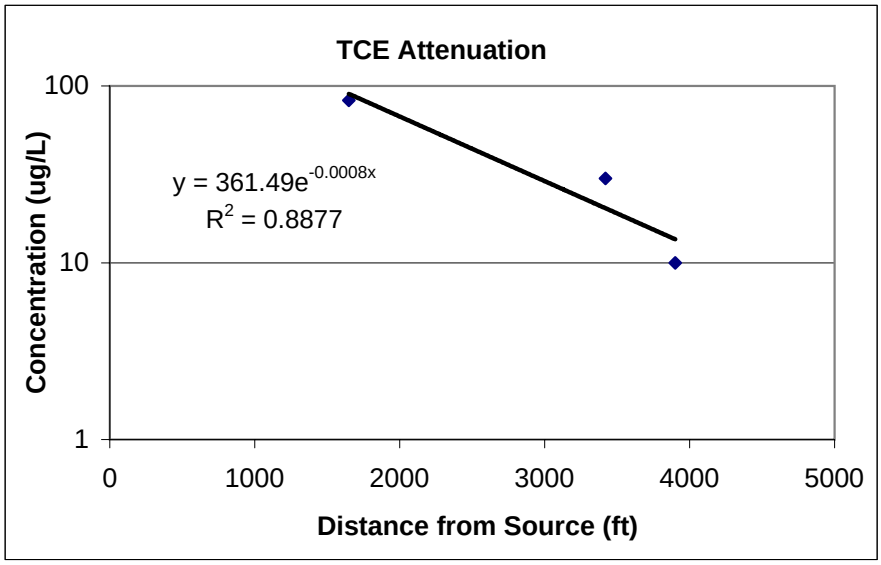
k =	**0.1752** /year
half-life =	**4.0** years

Estimate of time needed to degrade contaminants at various points:

$t = -\ln[C_{goal}/C_{start}]/k$

$C_{goal} = 1.0$

Duration at point:	**t (years)**
161MW-1B	25.2
125MW-1B	19.4
125MW-2A	13.1



Appendix O

Distance-Dependent Degradation Rate Constant for TCE

Natural Attenuation Rate Calculation, Distance Rate Constant
Reference: USEPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies
C.J. Newell, H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, M.P. Suarez
Slope of exponential regression versus distance (k/v_x)

Location: Mid-Valley - Northern TCE Plume - Overburden Aquifer - 2003 Data

Monitoring Well	6MW-4	*Extrap.*	MWF-2A	PW410	Slope	R^2
Feet	**277**	**682**	**1003**	**1544**	-0.0012	0.8905
Concentration	**8**	**7.0**	**5.2**	**1.8**		

Hydraulic Conductivity		ft/day
Groundwater Gradient		ft/ft
Total Porosity	**0.25**	porosity
Average groundwater velocity, v_x =	**1.500**	ft/day
	547.5	ft/year

λ = $(v_c/4\alpha_x)\,([1+2\alpha_x(k/v_x)]^2 - 1)$
α_x = 5 % of flow field (distance separating two furthest wells)
77.2 ft
f_{oc} = **0.01**
K_{oc} = **126** L/kg
K_d = $K_{oc}f_{oc}$
1.26 L/kg
ρ_b = 1.7 kg/L
n = 0.25
R = $1 + (\rho_b K_d/n)$
9.568
v_c = v_x/R
57.2220 ft/year

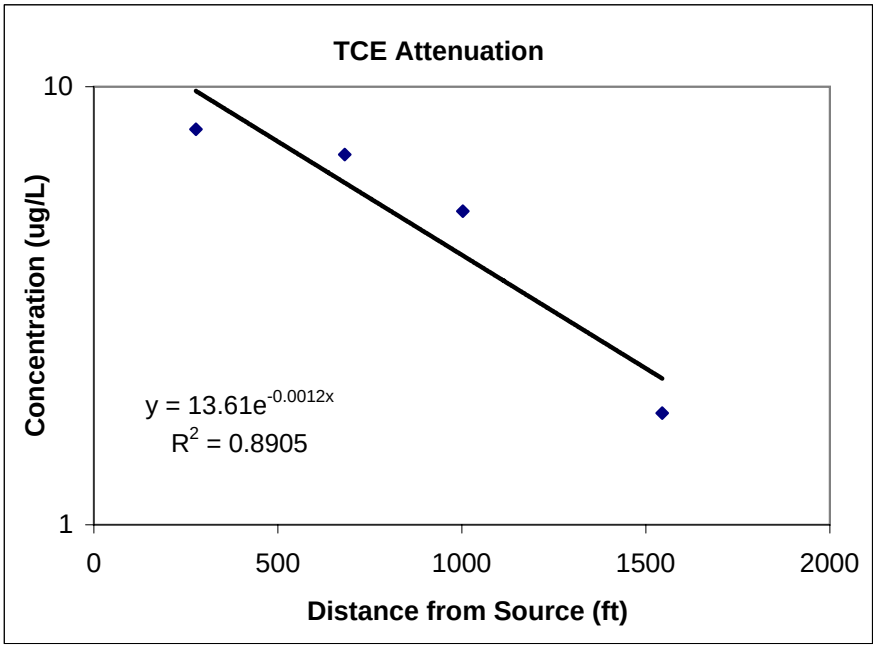
Natural Attenuation Rate

k = **0.6570** /year
half-life = **1.1** years

Estimate of time needed to degrade contaminants at various points:

$t = -\ln[C_{goal}/C_{start}]/k$
C_{goal} = 1.0

Duration at point:	**t (years)**
6MW-4	3.2
MWF-2A	2.5
PW410	0.9

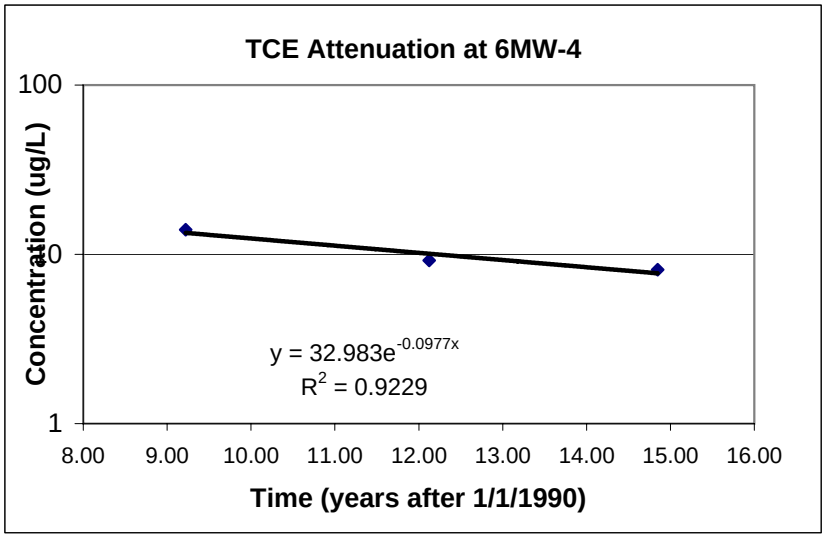


Appendix O

Time-Dependent Degradation Rate Constant for TCE

Natural Attenuation Rate Calculation, Decay Rate Constant
Reference: USEPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies
C.J. Newell, H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, M.P. Suarez
Slope of exponential regression versus time (k)

Location: Mid-Valley - Northern TCE Plume - Overburden Aquifer - Time-Conc. Data



Total Porosity **0.25** porosity
Average groundwater velocity, v_x = **1.500** ft/day
547.5 ft/year

Natural Attenuation Rate

k_{point} = **0.0977** /year
half-life = **7.1** years

Estimate of time needed to degrade contaminants at various points:

$t = -\ln[C_{goal}/C_{start}]/k$ C_{goal} = 1.00

Duration at point:	t (years from 1/1/1990)	MNA Time (from present)
6MW-4	35.8	20.2

6MW-4				Slope	R^2
Years (from 1/1/1990)	**9.22**	**12.12**	**14.85**	-0.0977	0.9229
Concentration	**14.00**	**9.20**	**8.10**	Y-int	
Date	**3/21/1999**	**2/14/2002**	**11/5/2003**	32.983	
Days (from 1/1/1990)	3366	4425	5420		
Years (from 1/1/1990)	9.2	12.1	14.8		

Appendix O

Distance-Dependent Degradation Rate Constant for TCE

Natural Attenuation Rate Calculation, Distance Rate Constant
Reference: USEPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies
C.J. Newell, H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, M.P. Suarez
Slope of exponential regression versus distance (k/v_x)

Location: Mid-Valley - Northern TCE Plume - Bedrock Aquifer - 2003 Data

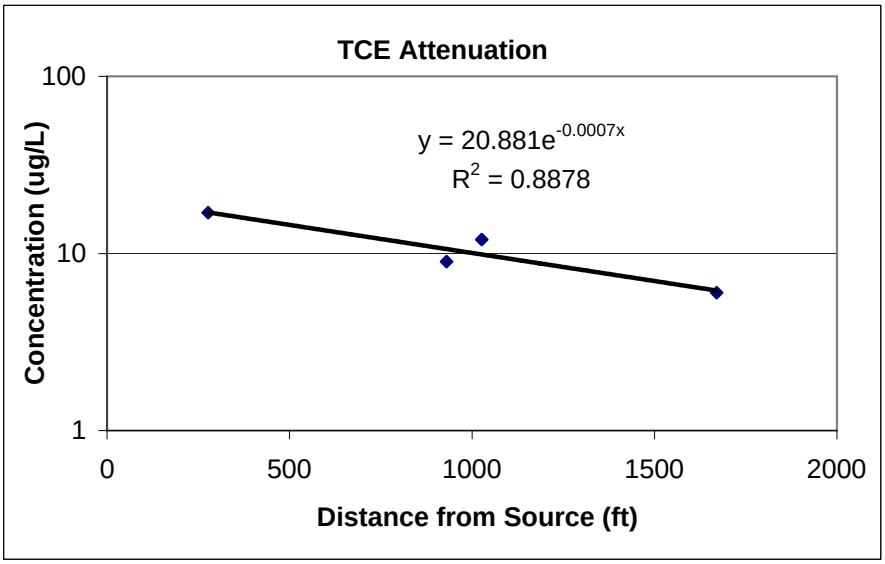
Monitoring Well	6MW-4D	DM17-2	DM17-3	*Extrap.*	Slope	R^2
Feet	**277**	**930**	**1027**	**1670**	-0.0007	0.8878
Concentration	**17**	**9**	**12**	**6.0**		

Hydraulic Conductivity		ft/day
Groundwater Gradient		ft/ft
Total Porosity	**0.05**	porosity
Average groundwater velocity, v_x =	**0.500**	ft/day
	182.5	ft/year

λ = $(v_c/4\alpha_x)$ $([1+2\alpha_x(k/v_x)]^2 - 1)$
α_x = 5 % of flow field (distance separating two furthest wells)
83.5 ft
f_{oc} = **0.01**
K_{oc} = **126** L/kg
K_d = $K_{oc}f_{oc}$
1.26 L/kg
ρ_b = 1.7 kg/L
n = 0.05
R = $1 + (\rho_b K_d/n)$
43.840
v_c = v_x/R
4.1629 ft/year

Natural Attenuation Rate

k = **0.1278** /year
half-life = **5.4** years



Estimate of time needed to degrade contaminants at various points:

$t = -\ln[C_{goal}/C_{start}]/k$
C_{goal} = 1.0

Duration at point:	**t (years)**
6MW-4D	22.2
DM17-2	17.2
DM17-3	19.5

Appendix O

Distance-Dependent Degradation Rate Constant for RDX

Natural Attenuation Rate Calculation, Distance Rate Constant
Reference: USEPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies
C.J. Newell, H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, M.P. Suarez
Slope of exponential regression versus distance (k/v_x)

Location: Mid-Valley - RDX Plume - Overburden Aquifer - 2003 Data

Monitoring Well	114MW-1A	*Extrap.*	162MW-1	161MW-1	Slope	R^2
Feet	**95**	**207**	**394**	**565**	-0.0088	0.9873
Concentration	**22**	**5.0**	**1.3**	**0.3**		

Hydraulic Conductivity		ft/day
Groundwater Gradient		ft/ft
Total Porosity	**0.25**	porosity
Average groundwater velocity, v_x =	**0.050**	ft/day
	18.3	ft/year

λ = $(v_c/4\alpha_x)\,([1+2\alpha_x(k/v_x)]^2 - 1)$
α_x = 5 % of flow field (distance separating two furthest wells)
28.25 ft
f_{oc} = **0.01**
K_{oc} = **100** L/kg
K_d = $K_{oc}f_{oc}$
1 L/kg
ρ_b = 1.7 kg/L
n = 0.25
R = $1 + (\rho_b K_d/n)$
7.800
v_c = v_x/R
2.3397 ft/year

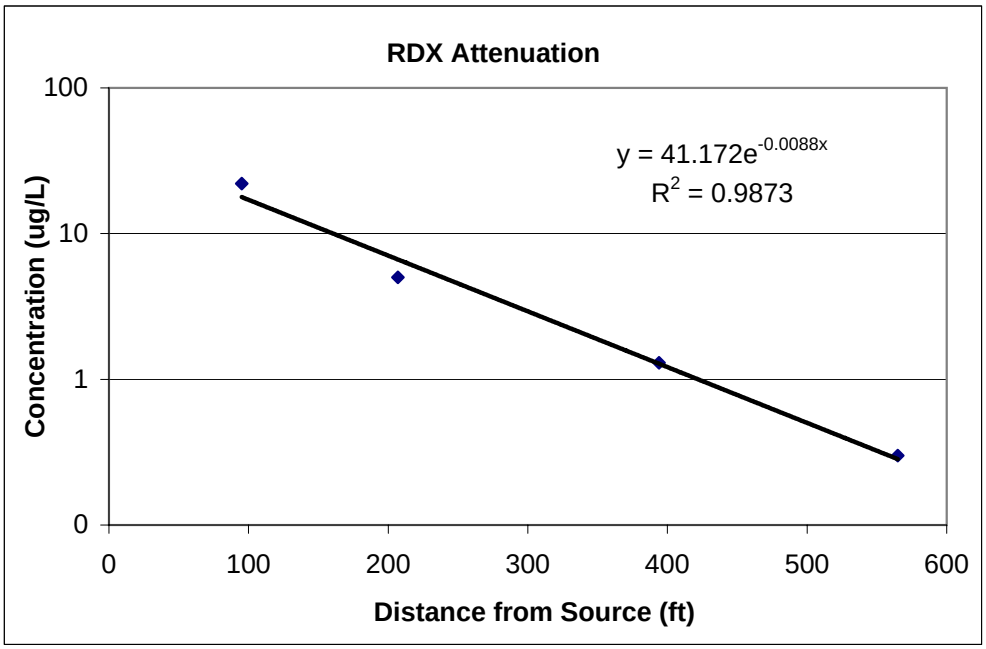
Natural Attenuation Rate

k = **0.1606** /year
half-life = **4.3** years

Estimate of time needed to degrade contaminants at various points:

$t = -\ln[C_{goal}/C_{start}]/k$
C_{goal} = 0.61

Duration at point:	**t (years)**
114MW-1A	22.3
162MW-1	4.7
161MW-1	-4.4

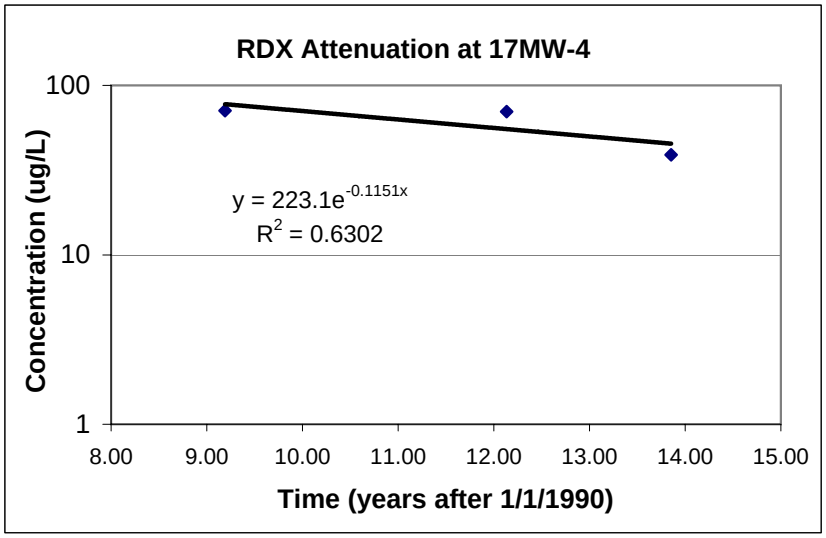


Appendix O

Time-Dependent Degradation Rate Constant for RDX

Natural Attenuation Rate Calculation, Decay Rate Constant
Reference: USEPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies
C.J. Newell, H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, M.P. Suarez
Slope of exponential regression versus time (k)

Location: Mid-Valley - RDX Plume - Overburden Aquifer - Time-Conc. Data



Total Porosity **0.25** porosity
Average groundwater velocity, v_x = **0.050** ft/day
18.3 ft/year

Natural Attenuation Rate

k_{point} = **0.1151** /year
half-life = **6.0** years

Estimate of time needed to degrade contaminants at various points:

$t = -\ln[C_{goal}/C_{start}]/k$ C_{goal} = 0.61

Duration at point:	t (years from 1/1/1990)	MNA Time (from present)
17MW-4	51.3	35.7

17MW-4				Slope	R^2
Years (from 1/1/1990)	**9.19**	**12.13**	**13.85**	-0.1151	0.6302
Concentration	**71.00**	**70.00**	**39.00**	Y-int	
Date	**3/9/1999**	**2/18/2002**	**11/6/2003**	223.1	
Days (from 1/1/1990)	3354	4429	5056		
Years (from 1/1/1990)	9.2	12.1	13.9		

Appendix O

Distance-Dependent Degradation Rate Constant for RDX

Natural Attenuation Rate Calculation, Distance Rate Constant
Reference: USEPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies
C.J. Newell, H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, M.P. Suarez
Slope of exponential regression versus distance (k/v_x)

Location: Mid-Valley - RDX Plume - Bedrock Aquifer - 2003 Data

Monitoring Well	17MW-5	*Extrap.*	125MW-1B	125MW-2B	Slope	R^2
Feet	**95**	**933**	**1770**	**2250**	-0.0022	0.7067
Concentration	**69**	**43.0**	**17.0**	**0.3**		

Hydraulic Conductivity		ft/day
Groundwater Gradient		ft/ft
Total Porosity	**0.18**	porosity
Average groundwater velocity, v_x =	**0.600**	ft/day
	219.0	ft/year

λ =	$(v_c/4\alpha_x)\,([1+2\alpha_x(k/v_x)]^2 - 1)$	
α_x =	5 % of flow field (distance separating two furthest wells)	
	112.5	ft
f_{oc} =	**0.01**	
K_{oc} =	**100**	L/kg
K_d =	$K_{oc}f_{oc}$	
	1	L/kg
ρ_b =	1.7	kg/L
n =	0.18	
R =	$1 + (\rho_b K_d/n)$	
	10.444	
v_c =	v_x/R	
	20.9681	ft/year

Natural Attenuation Rate

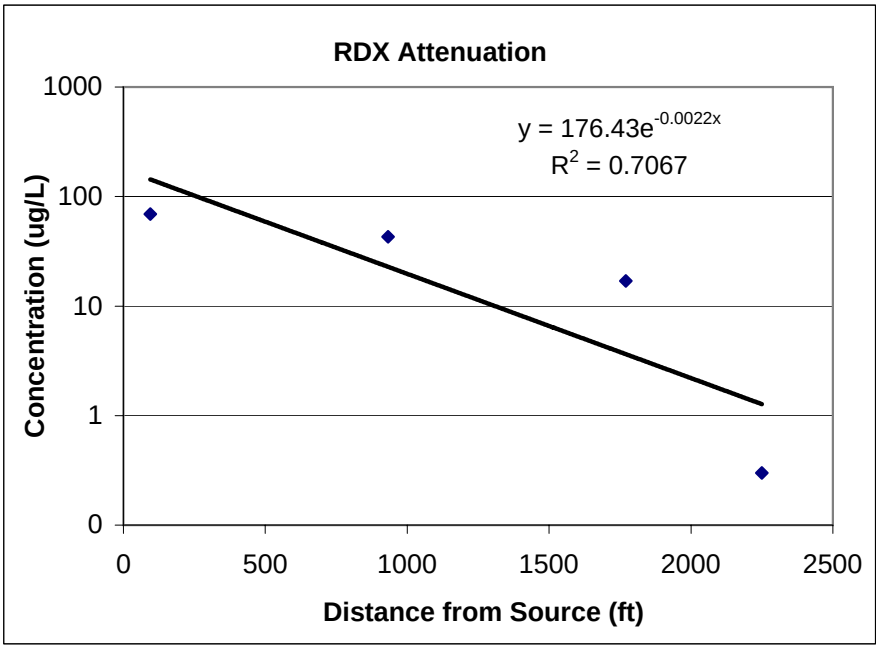
k =	**0.4818** /year
half-life =	**1.4** years

Estimate of time needed to degrade contaminants at various points:

$t = -\ln[C_{goal}/C_{start}]/k$

$C_{goal} = 0.61$

Duration at point:	**t (years)**
17MW-5	9.8
125MW-1B	6.9
125MW-2B	-1.5

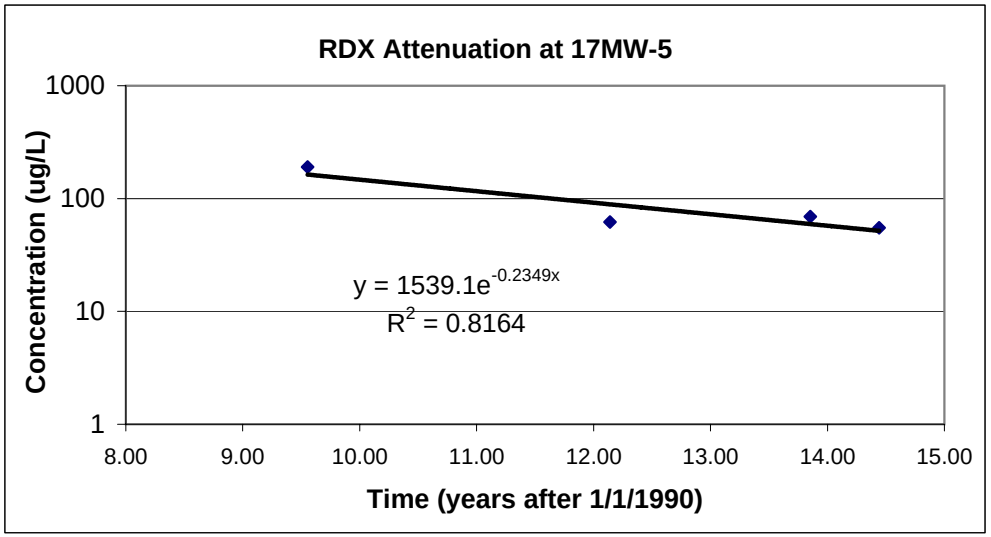


Appendix O

Time-Dependent Degradation Rate Constant for RDX

Natural Attenuation Rate Calculation, Decay Rate Constant
Reference: USEPA, 2002, Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies
C.J. Newell, H.S. Rifai, J.T. Wilson, J.A. Connor, J.A. Aziz, M.P. Suarez
Slope of exponential regression versus time (k)

Location: Mid-Valley - RDX Plume - Bedrock Aquifer - Time-Conc. Data



Total Porosity **0.05** porosity
Average groundwater velocity, v_x = **0.600** ft/day
219.0 ft/year

Natural Attenuation Rate

k_{point} = **0.2349** /year
half-life = **3.0** years

Estimate of time needed to degrade contaminants at various points:

$t = -\ln[C_{goal}/C_{start}]/k$ C_{goal} = 0.61

Duration at point:	t (years from 1/1/1990)	MNA Time (from present)
17MW-5	33.3	17.7

17MW-5					Slope	R^2
Years (from 1/1/1990)	**9.55**	**12.14**	**13.85**	**14.44**	-0.2349	0.8164
Concentration	**190.00**	**62.00**	**69.00**	**55.00**	Y-int	
Date	**7/20/1999**	**2/20/2002**	**11/6/2003**	**6/9/2004**	1539.1	
Days (from 1/1/1990)	3487	4431	5056	5271		
Years (from 1/1/1990)	9.6	12.1	13.9	14.4		

Appendix O

Hydrogeologic Parameters Used for Degradation Rate Calculation

Area L Bedrock		Hydraulic Conductivity	Gradient*	Porosity	Groundwater Velocity=K*i/n		
		K (Ft/Min)	i (Ft/Ft)	n	Velocity (Ft/Min)	Velocity (Ft/Day)	Velocity (Ft/Yr)
114MW-1B	Rising Head	0.000024	0.04427	0.05	2.09E-05	0.0301	10.99
161MW-1B	Rising Head	0.0004215	0.04427	0.05	3.73E-04	0.5374	196.15
6MW-4D	Average	0.000167	0.084**	0.05	2.80E-04	0.4032	147.17
171MW-4	Rising Head	0.0019	0.04427	0.05	1.68E-03	2.4225	884.20
171MW-4	Falling Head	0.001816	0.04427	0.05	1.61E-03	2.3154	845.11

***Gradient measured from 161MW-1B and 125MW-1B**
****Gradient measured from 6MW-4D and DM17-3**

Robinson Run Area, Overburden		Hydraulic Conductivity	Gradient*	Porosity	Groundwater Velocity=K*i/n		
		K (Ft/Min)	i (Ft/Ft)	n	Velocity (Ft/Min)	Velocity (Ft/Day)	Velocity (Ft/Yr)
B1038MW-1	Rising Head	0.000530	0.0433	0.25	9.18E-05	0.1322	48.26
161MW-1	Avg	0.003952083	0.0433	0.25	6.85E-04	0.9857	359.77

***Gradient measured from 161MW-1 and 125MW-1**

Northwest Area L, Overburden		Hydraulic Conductivity	Gradient*	Porosity	Groundwater Velocity=K*i/n		
		K (Ft/Min)	i (Ft/Ft)	n	Velocity (Ft/Min)	Velocity (Ft/Day)	Velocity (Ft/Yr)
6MW-4	Average	0.003270833	0.087	0.25	1.14E-03	1.6391	598.26
17MW-2	Average	0.008444444	0.087	0.25	2.94E-03	4.2317	1544.56

***Gradient measured from 6MW-4 and MW138-2**

1000 Area, Overburden		Hydraulic Conductivity	Gradient*	Porosity	Groundwater Velocity=K*i/n		
		K (Ft/Min)	i (Ft/Ft)	n	Velocity (Ft/Min)	Velocity (Ft/Day)	Velocity (Ft/Yr)
162MW-1	Rising Head	0.004811	0.002	0.25	3.85E-05	0.0554	20.23
162MW-1	Falling Head	0.004632	0.002	0.25	3.71E-05	0.0534	19.48
161MW-1	Avg	0.003952083	0.002	0.25	3.16E-05	0.0455	16.62

***Gradient measured from 114MW-1A and 162MW-1**