Appendix J

Sensitivity Analysis

Appendix J
Acetone VCCEP Sensitivity Analysis for Exposure Modeling

Background

A sensitivity analysis was performed for the modeling used in the assessment of .the nail polish remover, spray paint and pure acetone exposure scenarios. This sensitivity analysis was performed in accordance with EPA guidance (USEPA, 2001). According to the EPA, the purpose of a sensitivity analysis is to "identify and rank important sources of variability as well as important sources of uncertainty". In the case of exposure assessment, a sensitivity analysis helps determine which parameters are "driving" the exposure assessment.

The EPA guidance provides two tiers of sensitivity analysis. The EPA Tier 1 sensitivity analysis is appropriate for a deterministic exposure assessment. The results of a Tier 1 sensitivity analysis are transparent and easy to communicate. The EPA Tier 2 sensitivity analysis can only be used in conjunction with probabilistic (i.e. Monte Carlo) models. Since the VCCEP exposure assessment for acetone relies on deterministic estimates of exposure, a Tier 1 sensitivity analysis was performed.

The specific Tier 1 sensitivity analysis method selected for the Acetone VCCEP exposure assessment was the Sensitivity Ratio (SR) method. The SR, also termed elasticity, is the ratio of the change in model output per unit change in an input variable. The equation for the SR is:

$$SR = \frac{\frac{Y_2 - Y_1}{Y_2}}{\frac{X_2 - X_1}{X_2}}$$

where, Y_1 = baseline value of the output variable using baseline values of input variables;
Y_2 = value of the output variable after changing the value of one input variable;
X_1 = baseline point estimate for an input variable; and
X_2 = value of the input variable after changing X_1.

An SR equal to one would indicate that for a one unit increase in the input variable of interest, the model output increases by one unit. An SR equal to zero indicates that changes in the input variable do not change the model output. EPA (2001) notes that for environmental fate and transport models, the ratio method "is likely to be an effective screening tool for identifying potentially influential input variables and assumptions".

There are two types of SR analyses that can be performed – local SR and range SR. For the local SR, the input variable is varied by a small amount (e.g. $\pm$10%), whereas for the range SR, the input variable is varied across the entire range (plausible minimum and maximum).

Since the objective of this work was to determine the relative effect of moderate increases or decreases of the nominal or default value of various parameters, a local SR analysis was performed. EPA notes that the results of a local and range SR are usually the same (USEPA, 2001).

Results

The exposure concentrations for each scenario were estimated using the EPA Multi-Chamber Concentration and Exposure Model Version 1.2 (MCCEM) and the conceptual framework (i.e. base exposure scenario including emissions models and interzonal airflow equation) of the EPA Exposure, Fate Assessment Screening Tool Version 1.1 (E-FAST). A local SR analysis was performed by increasing or decreasing individual parameter values by 10% above or below their nominal value. The 24-hour time weighted average (TWA) was the model output that was used for comparison.

Sensitivity ratios for the three scenarios are presented in Tables S.1 (input parameter increase) and S.2 (input parameter decrease) for both users and non-users. As demonstrated in these tables, the results for each of the three scenarios are similar. Average SRs for each parameter are presented in the last column of each table. Detailed model results and inputs are provided in Tables S.3 (Nail Polish Remover – User), S.4 (Nail Polish Remover– Non User), S.5 (Spray Paint – User), S.6 (Spray Paint – Non User), S.7 (Pure Acetone – User) and S.8 (Pure Acetone – Non User).

Because the parameter SRs for each scenario are similar, it can be concluded that the results are generally applicable to MCCEM and E-FAST within the range of nominal values used in these scenarios. Therefore, sensitivity analysis results will be discussed based on the average SR values, rather than for individual scenarios.

The results indicate that the exposure estimate is most sensitive to:

- Amount of product used per event;
- Total home volume; and
- Whole house air exchange rate.

For these parameters, the average SR close to one indicates a roughly linear relationship between model input and output within the range of the input parameter was varied.

Similarly, these results indicate the exposure estimate is generally not sensitive to:

- Volume of the room of use;
- Exposure time during use; and
- Temperature (vapor pressure).

For these parameters, the SR of less than 0.2 indicates that the relationship between input and output parameters is very weak or zero.

Discussion

Explanation of Results

The strong linear relationship between the modeling results and amount of product used, total home volume and whole house air exchange rate seems reasonable. Based on these results, doubling the air exchange rate or home volume is expected to decrease by about one-half the exposure concentration. Doubling the amount of product used is expected to double the exposure concentration. However, the weak relationship between the modeling results and volume of the room of use, exposure time during use and temperature may seem counterintuitive and will be discussed in detail below.

Volume of the room of use

The model output is relatively insensitive to the volume of the room of use because E-FAST assumes fairly rapid mixing between the room of use and the rest of the home. Concentration profiles indicate that the rest of the home generally reaches equilibrium with the room of use within an hour. In E-FAST, the airflow rate between the room of use and the rest of the home is calculated using an equation from Koontz and Rector (1995). This equation is also used in the EPA Wall Paint Exposure Model Version 3.0.

A recent investigation of air exchange rates confirms that residential structures can reach equilibrium fairly quickly. Howard-Reed et al. (2002) found that a conservative tracer released in a California home with all windows and doors closed was evenly distributed in the home within 45 minutes.

It should be noted that although the rest of the home attains equilibrium with the room of use fairly rapidly after product usage has ended, the exposure of a user located in the room of use will be greater than a non-user located outside the room of use due to the initial higher exposure concentrations in the room of use.

Exposure time during use

The model output that was compared for this analysis was the 24-hour average. Since the nominal exposure times during use were much less than 24-hours, the model output does not appreciably vary with changes in exposure time during use. If the model output were compared for averaging times of the same magnitude as the exposure time during use, then this parameter would have a stronger effect on model output.

Temperature

The vapor pressure and volatility of acetone is related to the ambient temperature. However, because acetone evaporates very rapidly at ambient temperatures, the emission of acetone to the air is limited by application rate rather than vapor pressure. Therefore, the model output is not sensitive to changes in temperature (and vapor pressure).

Other Tier 1 Methods

One variation of the SR analysis is the sensitivity score. The sensitivity score provides more information than the SR by using a normalized measure of variability such as the coefficient of variation (standard deviation divided by the mean). The sensitivity score provides ratios that are independent of the units of the input variable and a more robust comparison among input parameters. Sensitivity scores were not calculated for this sensitivity analysis because the results of the local SR analysis were straightforward. In addition, standard deviations for certain variables such as the volume of the room of use, or the mass of nail polish remover were not available.

Appendix J References

USEPA, 2001. Risk Assessment Guidance for Superfund: Volume III – Part A, Process for Conducting a Probabilistic Risk Assessment. Office of Emergency and Remedial Response. EPA 540-R-02-002. December, 2001.

Howard-Reed, CH, Wallace, LA, and Ott WR, 2002. The Effect of Opening Windows on Air Change Rates in Two Homes. J. Air & Waste Manage. Assoc. 52: 147-159.

Koontz and Rector, 1995. Cited In: EPA Wall Paint Exposure Model Version3.0 User's Guide. Estimation of Distributions for Residential Air Exchange Rates, final report for USEPA Office of Pollution Prevention and Toxics.

Attachment J Tables

Table S.1

Acetone Scenarios Sensitivity Analysis

Sensitivity Ratio[a] - Increase in Parameter Value

Parameter	Sensitivity Ratio - 10% Increase in Nominal Parameter Value						
	Nail Polish Remover		Spray Paint		Pure Acetone		Average
	User	Non User	User	Non User	User	Non User	
Amount of product used per event	1.0	1.1	0.99	0.99	1.00	0.99	1.01
Whole-house air exchange rate	-0.82	-0.92	-0.71	-0.80	-0.75	-0.79	-0.80
Total volume of home	-0.73	-0.77	-0.71	-0.82	-0.78	-0.85	-0.78
Volume of room of use	-0.25	-0.15	-0.21	-0.11	-0.17	-0.11	-0.17
Exposure time during use	0.00	0.00	-0.14	-0.02	-0.01	-0.04	-0.04
Temperature (vapor pressure)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a]The sensitivity ratio, or elasticity, is the ratio of the change in model input per unit change in an input variable. Model output is more sensitive to parameters with larger sensitivity ratios.

Table S.2

Acetone Scenarios Sensitivity Analysis

Sensitivity Ratio[a] - Decrease in Parameter Value

Parameter	Sensitivity Ratio - 10% Decrease in Nominal Parameter Value						
	Nail Polish Remover		Spray Paint		Pure Acetone		Average
	User	Non User	User	Non User	User	Non User	
Amount of product used per event	1.00	1.0	0.99	1.01	1.00	1.03	1.00
Whole-house air exchange rate	-0.96	-1.17	-0.78	-0.95	-0.86	-0.97	-0.95
Total volume of home	-0.82	-0.97	-0.85	-0.99	-0.90	-0.99	-0.92
Volume of room of use	-0.24	-0.15	-0.21	-0.11	-0.16	-0.07	-0.16
Exposure time during use	0.00	0.00	-0.07	-0.02	0.00	0.00	-0.02
Temperature (vapor pressure)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a]The sensitivity ratio, or elasticity, is the ratio of the change in model input per unit change in an input variable. Model output is more sensitive to parameters with larger sensitivity ratios.

Table S.3

Sensitivity Analysis - Nail Polish Remover Scenario

Adult or Child User

Parameter	Input Values				1-Day TWA Exposure Concentration					
	Baseline	10% Decrease in Baseline	10% Increase in Baseline	Unit	Baseline	10% Decrease in Baseline	(Percent Change)	10% Increase in Baseline	(Percent Change)	Unit
Amount of product used per event	3.06	2.75	3.37	g	0.551	0.496	(-10%)	0.607	(10%)	ppm
Total volume of home	369	332	406	m^3	0.551	0.596	(8.2%)	0.511	(-7.3%)	ppm
Whole-house air exchange rate	0.450	0.405	0.495	hr^{-1}	0.551	0.604	(9.6%)	0.506	(-8.2%)	ppm
Volume of room of use	40.0	36.0	44.0	m^3	0.551	0.564	(2.4%)	0.537	(-2.5%)	ppm
Exposure time during use	10.0	9.0	11.0	min	0.551	0.551	(0.0%)	0.551	(0.0%)	ppm
Temperature (vapor pressure)	25.0	22.5	27.5	°C	0.551	0.551	(0.0%)	0.551	(0.0%)	ppm

Table S.4

Sensitivity Analysis - Nail Polish Remover Scenario

Infant or Child Non User (Does Not Enter Room of Use)

Parameter	Input Values				1-Day TWA Exposure Concentration					
	Baseline	10% Decrease in Baseline	10% Increase in Baseline	Unit	Baseline	10% Decrease in Baseline	(Percent Change)	10% Increase in Baseline	(Percent Change)	Unit
Amount of product used per event	3.06	2.75	3.37	g	0.196	0.177	(-10%)	0.217	(11%)	ppm
Total volume of home	369	332	406	m^3	0.196	0.215	(9.7%)	0.181	(-7.7%)	ppm
Whole-house air exchange rate	0.450	0.405	0.495	hr^{-1}	0.196	0.219	(12%)	0.178	(-9.2%)	ppm
Volume of room of use	40.0	36.0	44.0	m^3	0.196	0.199	(1.5%)	0.193	(-1.5%)	ppm
Exposure time during use	10.0	9.0	11.0	min	0.196	0.196	(0.0%)	0.196	(0.0%)	ppm
Temperature (vapor pressure)	25.0	22.5	27.5	°C	0.196	0.196	(0.0%)	0.196	(0.0%)	ppm

Table S.5

Sensitivity Analysis - Spray Paint Scenario

Teenager or Adult Product User

Parameter	Input Values				1-Day TWA Exposure Concentration					
	Baseline	10% Decrease in Baseline	10% Increase in Baseline	Unit	Baseline	10% Decrease in Baseline	(Percent Change)	10% Increase in Baseline	(Percent Change)	Unit
Amount of product used per event[a]	186	167	205	g	14.1	12.7	(-10%)	15.5	(10%)	ppm
Total volume of home	369	332	406	m^3	14.1	15.3	(8.5%)	13.1	(-7.1%)	ppm
Whole-house air exchange rate	0.450	0.405	0.495	hr^{-1}	14.1	15.2	(7.8%)	13.1	(-7.1%)	ppm
Volume of room of use	20.0	18.0	22.0	m^3	14.1	14.4	(2.1%)	13.8	(-2.1%)	ppm
Exposure time during use	40.0	36.0	44.0	min	14.1	14.2	(0.71%)	13.9	(-1.4%)	ppm
Temperature (vapor pressure)	25.0	22.5	27.5	°C	14.1	14.1	(0.0%)	14.1	(0.0%)	ppm

[a]For this analysis, the acetone content was assumed to be 29.3% by weight.

Table S.6

Sensitivity Analysis - Spray Paint Scenario

Infant or Child Non User (Does Not Enter Room of Use)

Parameter	Input Values				1-Day TWA Exposure Concentration					
	Baseline	10% Decrease in Baseline	10% Increase in Baseline	Unit	Baseline	10% Decrease in Baseline	(Percent Change)	10% Increase in Baseline	(Percent Change)	Unit
Amount of product used per event[a]	186	167	205	g	4.74	4.26	(-10%)	5.21	(10%)	ppm
Total volume of home	369	332	406	m^3	4.74	5.21	(9.9%)	4.35	(-8.2%)	ppm
Whole-house air exchange rate	0.450	0.405	0.495	hr^{-1}	4.74	5.19	(9.5%)	4.36	(-8.0%)	ppm
Volume of room of use	20.0	18.0	22.0	m^3	4.74	4.79	(1.1%)	4.69	(-1.1%)	ppm
Exposure time during use	40.0	36.0	44.0	min	4.74	4.75	(0.21%)	4.73	(-0.21%)	ppm
Temperature (vapor pressure)	25.0	22.5	27.5	°C	4.74	4.74	(0.0%)	4.74	(0.0%)	ppm

[a]For this analysis, the acetone content was assumed to be 29.3% by weight.

Table S.7

Sensitivity Analysis - Spot Remover Scenario (Pure Acetone)

Teenager or Adult Product User

Parameter	Input Values				1-Day TWA Exposure Concentration					
	Baseline	10% Decrease in Baseline	10% Increase in Baseline	Unit	Baseline	10% Decrease in Baseline	(Percent Change)	10% Increase in Baseline	(Percent Change)	Unit
Amount of product used per event	30.8	27.7	33.9	g	8.30	7.47	(-10%)	9.13	(10%)	ppm
Total volume of home	369	332	406	m^3	8.30	9.05	(9.0%)	7.65	(-7.8%)	ppm
Whole-house air exchange rate	0.450	0.405	0.495	hr^{-1}	8.30	9.01	(8.6%)	7.68	(-7.5%)	ppm
Volume of room of use	20.0	18.0	22.0	m^3	8.30	8.43	(1.6%)	8.16	(-1.7%)	ppm
Exposure time during use[a]	11	10	12	min	8.30	8.30	(0.0%)	8.29	(-0.12%)	ppm
Temperature (vapor pressure)	25.0	22.5	27.5	°C	8.30	8.30	(0.0%)	8.30	(0.0%)	ppm

[a]MCCEM requires an integer value for this parameter.

Table S.8

Sensitivity Analysis - Spot Remover Scenario (Pure Acetone)

Infant or Child Non User (Does Not Enter Room of Use)

Parameter	Input Values				1-Day TWA Exposure Concentration					
	Baseline	10% Decrease in Baseline	10% Increase in Baseline	Unit	Baseline	10% Decrease in Baseline	(Percent Change)	10% Increase in Baseline	(Percent Change)	Unit
Amount of product used per event	30.8	27.7	33.9	g	2.72	2.44	(-10%)	2.99	(10%)	ppm
Total volume of home	369	332	406	m^3	2.72	2.99	(10%)	2.49	(-8.5%)	ppm
Whole-house air exchange rate	0.450	0.405	0.495	hr^{-1}	2.72	2.98	(9.7%)	2.50	(-7.9%)	ppm
Volume of room of use	20.0	18.0	22.0	m^3	2.72	2.74	(0.74%)	2.69	(-1.1%)	ppm
Exposure time during use[a]	11	10	12	min	2.72	2.72	(0.0%)	2.71	(-0.37%)	ppm
Temperature (vapor pressure)	25.0	22.5	27.5	°C	2.72	2.72	(0.0%)	2.72	(0.0%)	ppm

[a]MCCEM requires an integer value for this parameter.