MEMORANDUM

To:	Timothy Leighton, EPA; Alexander Kliminsky, EPA; Shawn Garred, EPA; Kathryn Korthauer, EPA
From:	Jonathan Cohen, ICF
Date:	December 13, 2021
Re:	Statistical Review of the AEATF II Electrostatic Sprayer Study

1. Introduction and Summary

In September 2021, AEATF II submitted the final report for Scenario 2b of their study AEA14 "A Study for Measurement of Potential Dermal and Inhalation Exposure During Pressurized Hand-Wand Spraying of Antimicrobial Products." This study was designed to generate data for six different exposure monitoring scenarios involving the use of pressurized hand-held sprayers. The specific monitoring scenario 2b "Measurement of Potential Dermal and Inhalation Exposure During Indoor Electrostatic Spraying of Sanitizers and Disinfectants," addresses the use of electrostatic sprayers to sanitize indoor surfaces. The Scenario 2b report is titled "Measurement of Potential Dermal and Inhalation Exposure During Indoor Electrostatic Spraying of Sanitizers and Disinfectants," although we will abbreviate this Scenario 2b study as the "Electrostatic Sprayer Study."

ICF was asked by EPA to analyze the electrostatic sprayer study data to investigate the relationship between dermal and inhalation exposures and the pesticide product usage when professionals conduct electrostatic spraying of sanitizers indoors. This was a scripted occupational monitoring study conducted at simulated work sites using three different types of electrostatic sprayers. Eighteen different volunteer test subjects were monitored giving data for 18 monitoring events or MEs. The three types of electrostatic sprayer used in the study were, backpack sprayers (eight subjects), cart-mounted sprayers (seven subjects) and handheld sprayers (three subjects). The sprayers used in the study were of a total of five different brands. The test substance used in this scenario was a quaternary ammonium sanitizer/virucide containing the quaternary ammonium analog ("quat") DDAC that has been used in several AEATF II exposure studies. The total quat concentrations and volumes sprayed were either 215 ppm and 0.5 gallons (group A, six MEs), 430 ppm and 1.0 gallons (group B, five MEs), 860 ppm and 2.0 gallons (group C, six MEs), or 860 ppm and 0.75 gallons (group D, one ME, ME 14), corresponding to DDAC concentrations 36.3 ppm, 72.7 ppm, 145 ppm or 145 ppm, respectively. Except for group D these volumes are the target volumes, and the actual volumes vary a little between MEs in the same group. As explained in the Scenario 2b report, the study design was for 6 MEs in each of the groups A, B and C. For these statistical analyses, we decided to create a new group, D, because the volunteer in group D did not spray their targeted 2 gallons although their amount of active ingredient handled (AaiH) was somewhat similar to those in group B. The volume / concentration groups A, B, C, and D are also referred to more descriptively in this memorandum as Vol Conc Low, Vol Conc Mid, Vol Conc High, and Vol Conc LoHi, respectively.

The monitoring took place at a hotel and conference center in Orlando, Florida using a mixture of hotel guest rooms, conference rooms, and public restrooms. Note that much of the SAS code used for these analyses and some of the following description was adapted from Sarkar's SAS code (which, in turn, was based on code provided by the AHETF) and his June 2010 Statistical Review "Review of Statistical Analyses in Agricultural Handler Exposure Task Force (AHETF) Monographs." The AEATF II Scenario 2b study report describes the experimental study methodology and the measurements in detail.

In this memorandum, the main analyses use data from all 18 MEs and focus on the normalized or unit exposures, which are the exposures divided by the pounds of active ingredient (lb ai). We began the analyses by computing summary statistics of the normalized exposure for each exposure mode using all the data and for each volume / concentration and sprayer type group. We then used an analysis of variance to compare the geometric means of the normalized exposure between the volume / concentration groups and between the sprayer type groups. The geometric means of the normalized exposure for different volume / concentration groups were not statistically significantly different. Furthermore, the concentrations and volumes, and hence the amount of active ingredient, do not vary much within each volume / concentration group. Therefore, we did not fit separate statistical exposure models to each of the volume / concentration groups. However, the analyses of the normalized exposures did show some statistically significant differences between the three sprayer type groups for inhalation exposures and so the main analyses also include separate analyses for each sprayer type. This is despite the warning in the Scenario 2b report that the study was not designed to be stratified by sprayer type. Obviously, the results for the handheld sprayers are of limited value and greater uncertainty due to the fact they are based on only 3 MEs. Because of the smaller sample sizes for the sprayer type groups, leading to increased uncertainty, and to avoid creating a voluminous report, detailed results stratified by sprayer type group are only presented for selected statistical analyses.

Since the data clearly indicated that the dermal exposure data has a potential outlier for ME 17 in the Backpack sprayer group and the Vol Conc High group with unexpected low exposure values, the supplemental memorandum presents the same analyses of the other 17 MEs, for both dermal and inhalation exposures. Although the ME 17 appears to be an outlier for dermal exposure and not for inhalation exposure, it is possible that this ME might also be unrepresentative of inhalation exposures. The supplemental memorandum analysis excluding ME 17 again showed no statistically significant differences between the geometric means for the volume / concentration groups for each exposure mode and showed statistically significant differences between the geometric means for the sprayer type groups for the inhalation exposure modes, but those analyses also showed statistically significant differences between the geometric means for the sprayer type groups for the dermal exposure modes.

For the convenience of the reader the conclusions from the main analysis and from the supplemental analyses are summarized in this section of the statistical review. The supplemental memorandum also includes the threshold analyses to be described below, both using all 18 MEs and using the 17 MEs without the potential outlier.

Each subject was given inner and outer dosimeters. No gloves were worn. To measure head exposures, all subjects wore a white ball cap ("ball cap") and also wore a "hat inner dosimeter" consisting of two gauze pads stapled to the inside of the ball cap. The hat inner dosimeter will be referred to as the "inner hat" to avoid confusion with the six inner dosimeters worn under the outer clothing. Subjects were given a new disposable face mask to wear to protect against COVID-19, although it appears from the study report that the face mask was not used during the ME itself. Subjects also wore a half-face respirator. Each subject also wore eye protection. To measure total inhalable residue, each subject was given a low-volume, personal air-sampling pump attached to an OSHA Versatile Sampler (OVS) sampling tube with glass filter and XAD2 sorbent placed in the subject's breathing zone. To measure respirable particles, each subject was also given a low-volume, personal air-sampling pump attached to a Parallel Particle Impactor (PPI) that contained a PVC filter and a support pad; this PPI was also placed in the subject's breathing zone.

The average percentage recovery of concurrent laboratory samples was calculated and if the percentage was below 100%, the residues from the field samples were corrected by dividing the raw residue by the average concurrent lab percentage recovery. The average percentage recovery of field fortification samples from the set of field fortification samples was also calculated and if the percentage was below 100%, the corrected residues from the field samples were corrected again by dividing the residue corrected for concurrent recovery by the average field fortification recovery. The residues from the hand wash and the face and neck wipes were corrected for removal efficiency using a 90% removal efficiency correction factor for the hand wash residues and an 89% removal efficiency correction factor for the face and neck wipes. In addition, the face and neck residues were corrected for the surface area covered by the protective eyewear and the respirator, by applying a factor of 1.43.

These analyses used the corrected measurements. Excel spreadsheets containing the data in the report were supplied by the Study Director and used for these analyses. Some of the numerical results may differ a little from those in the study report because of rounding conventions; these analyses did not round any intermediate calculations.

The dermal exposure data (mg) were used to develop exposure measurements for the following dermal exposure routes:

- **Long Dermal Hat**. This case represents the dermal exposure to a person wearing long pants, a long-sleeved shirt, and a hat. This is the sum of the DDAC mass from the six inner dosimeters, inner hat, hand wash, and the face/neck wipes. This is referred to as Protected Head in the scenario report.
- **Short Dermal Hat**. This case represents the dermal exposure to a person wearing short pants, a short-sleeved shirt, and a hat. This is the sum of the DDAC mass from the six inner dosimeters, inner hat, hand wash, the face/neck wipes, the lower leg outer dosimeter, and the lower arm outer dosimeter. For consistency with other studies, this case is included in the SAS program, but it is not presented in the statistical memoranda.
- **Long Short Dermal Hat**. This case represents the dermal exposure to a person wearing long pants, a short-sleeved shirt, and a hat. This is the sum of the DDAC mass from the six inner dosimeters, inner hat, hand wash, the face/neck wipes, and the lower arm outer dosimeter.
- **Hands Only**. This case represents the dermal exposure to the hands only and is the DDAC mass from hand wash.
- **Long Dermal No Hat**. This case represents the dermal exposure to a person wearing long pants, a long-sleeved shirt, but no hat. This is the sum of the DDAC mass from the six inner dosimeters, inner hat, hand wash, the face/neck wipes and the ball cap. This is referred to as Unprotected Head in the scenario report.
- **Short Dermal No Hat**. This case represents the dermal exposure to a person wearing short pants, a short-sleeved shirt, but no hat. This is the sum of the DDAC mass from the six inner dosimeters, inner hat, hand wash, the face/neck wipes, the ball cap, the lower leg outer dosimeter, and the lower arm outer dosimeter. For consistency with other studies, this case is included in the SAS program, but it is not presented in the statistical memoranda.
- **Long Short Dermal No Hat**. This case represents the dermal exposure to a person wearing long pants, a short-sleeved shirt, but no hat. This is the sum of the DDAC mass from the six inner dosimeters, inner hat, hand wash, the face/neck wipes, the ball cap, and the lower arm outer dosimeter.

Total inhalable Inhalation exposure was measured by the OVS sampler using the total DDAC residue from the air sampling tube glass fiber filters. Respirable Inhalation exposure was measured by the PPI sampler using the DDAC residue from the PVC filter. The exposure concentrations (mg/m^3) were calculated by dividing the corrected residue mass by the volume of air drawn.

The following inhalation exposure metrics are analyzed in this memorandum:

- **Inhalation (total inhalable) Concentration (mg/m^3).** Abbreviated as **Inhalation (total inhalable) Conc.** DDAC concentration measured by the OVS Sampler.
- **Inhalation (total inhalable) Dose (mg).** Inhalation (total inhalable) Conc (mg/m^3) × Air Sampling Duration (hr) × Breathing Rate for Light Activity (m^3/hr). A breathing rate of 1 m^3/hr is assumed.
- **8-Hour Time Weighted Average Inhalation (total inhalable) Concentration (mg/m^3).** Abbreviated as Inhalation (total inhalable) 8hr TWA. Average total inhalation concentration over eight hours that includes this period of spraying activity. Inhalation (total inhalable) Conc (mg/m^3) × Air Sampling Duration (hr) / 8 (hr).
- **Inhalation (respirable) Concentration (mg/m^3).** Abbreviated as **Inhalation (respirable) Conc.** DDAC concentration measured by the PPI Sampler.
- **Inhalation (respirable) Dose (mg).** Inhalation (respirable) Conc (mg/m^3) × Air Sampling Duration (hr) × Breathing Rate for Light Activity (m^3/hr). A breathing rate of 1 m^3/hr is assumed.
- **8-Hour Time Weighted Average Inhalation (respirable) Concentration (mg/m^3).** Abbreviated as Inhalation (respirable) 8hr TWA. Average inhalation (respirable) concentration over eight hours that includes this period of spraying activity. Inhalation (respirable) Conc (mg/m^3) × Air Sampling Duration (hr) / 8 (hr).

Note that in this memorandum the light activity breathing rate is assumed to be 1 m^3/hr for consistency with other AEATF II studies. In the Scenario 2b report a slightly different light activity breathing rate of 16.7 lpm was assumed.

Some of the measured residue values were below the level of quantitation (LOQ). Such values are called "non-detects." In the Scenario 2b study report, all values below the LOQ were replaced by LOQ/2. In this memorandum we use the LOQ/2 substitution for the primary analyses but also evaluate alternative substitutions and alternative censored statistical models that take into account the fact that the true value is between 0 and the LOQ. All the values for hand, face/neck, and hat exposures as well as the PVC filters were above the LOQ, but there were several other exposure measurements with values below the corresponding LOQ. Note that if the outer dosimeter residue for a body part was found to be below the LOQ, then the inner dosimeter residue for the same body part was not measured and the inner dosimeter residue was treated as being exactly zero. Also note that for the inner and outer dosimeters, the Excel files provided by the study director also reported measured values (below the LOQ) for the non-detects, but those values were not used for these analyses. For the inner dosimeters there were 17 non-detects out of the 93 measured values. For the lower arm outer dosimeters there was only 1 non-detect out of the 18 measured values. For the inner hat there were 8 non-detects out of the 18 measured values. For the OVS tubes there was only 1 non-detect out of the 18 measured values. The alternative statistical analyses of the non-detects showed that they had a minimal impact on the statistical results. In the Supplement, the same finding of a minimal impact of the non-detects is shown for the 17 MEs after excluding ME 17.

In this memorandum we present the analysis of the unit or normalized exposure defined as the dermal or inhalation exposure divided by a normalizing factor. For these analyses the normalizing factor is the amount of active ingredient handled (AaiH) in pounds, i.e., lb ai. Estimates of the arithmetic and geometric means and standard deviations as well as the 95th percentile are computed using the empirical data as well as a lognormal simple random sampling model. Each group is assumed to be a simple random sample of subjects. The empirical model calculates statistics for all the unit exposure measurements assuming the data are statistically independent. The lognormal simple random sampling model calculates statistics for all the unit exposure measurements, assuming the unit exposure measurements are statistically independent with a lognormal distribution.

For each summary statistic we present confidence intervals. We also compute the fold relative accuracies of the summary statistics and compare them with the (primary) study design benchmark of 3-fold accuracy. For all data combined, the study benchmark design value of 3 for the fold relative accuracy was met in every case, with the exception of the empirical 95th percentile using the parametric bootstrap for all the dermal and inhalation exposure routes, together with the empirical and lognormal random sampling 95th percentile and arithmetic mean using the parametric bootstrap for all the inhalation (respirable) exposure routes. For the Cart sprayer type, in all cases all the statistics met the study benchmark for the Cart sprayer type. For the Backpack sprayer type, most of the benchmarks were generally not met. For the Handheld sprayer type, most of the benchmarks were not met for the parametric bootstrap but they were mostly met for the non-parametric bootstrap. This is somewhat surprising since there were only 3 MEs using a Handheld sprayer, which would typically lead to large uncertainty for that group. After excluding ME 17, the analyses in the Supplement show similar results for the fold relative accuracy for all 17 MEs but showed that the study benchmark of 3 for the fold relative accuracy was met for the dermal exposures using the Backpack sprayer.

To evaluate the statistical models, we present quantile-quantile plots of the data and also applied normality tests to determine whether the normalized exposure should be treated as being normally or lognormally distributed. For all the data and for the Backpack sprayer type, the results for dermal exposure generally show stronger evidence for normality than for lognormality, but the results for inhalation exposure generally show stronger evidence for lognormality than for normality. For the Cart sprayer type the results support lognormality over normality. The results for the Handheld sprayer type show no clear preference, primarily because of the limited sample size. A much more detailed discussion is provided in the body of this memorandum.

The analyses in the Supplement repeat the normality analyses after removing the potential outlier, which was in the Backpack sprayer type group. The Supplement's results of the quantile-quantile plots and normality tests are similar for all data combined, but for the Backpack sprayer type the lognormality is preferred over normality for all the exposure modes. Therefore, the results in the Supplement support the use of a lognormal model for each sprayer group after excluding ME 17.

The statistical models for the normalized exposure assume that the mean value of the logarithm of the exposure is equal to an intercept plus the slope times the logarithm of the normalizing factor, where the slope equals 1. To test this "log-log-linearity with a slope of 1" assumption, the lognormal simple random sampling model with a slope term was fitted to the data and a 95% confidence interval for the slope was calculated. A statistical test was used to determine if the slope was 1 or 0, corresponding either to a valid normalized exposure model or to a case where the exposure is independent of the normalizing factor. We applied this test to each exposure metric using the lognormal simple random sampling model. We also present quantile-quantile plots of the residuals from the lognormal simple random sampling model with a slope term to evaluate the fitted models. The fitted regression models are also plotted against the data.

For all 18 MEs, the slopes ranged from 0.49 to 1.13, and the confidence intervals for the slope excluded 0 and included 1, except for the inhalation (respirable) concentration where the interval included both 0 and 1. Thus in all but one case, the assumption of log-log-linearity with slope 1 was supported.

For the Backpack sprayer, the slopes ranged from 0.40 to 1.10 and the confidence intervals either included both 0 or 1 or included 1 but not 0. Thus, the assumption of log-log-linearity was either supported or not rejected. For the Cart sprayer, the slopes ranged from 0.69 to 1.17 and in all cases but one the confidence intervals included 1 but not 0, supporting the assumption of log-log-linearity. As an exception, for inhalation (total inhalable) concentration the confidence interval excluded both 0 and 1, supporting neither proportionality nor independence. For the Handheld sprayer the small sample size of only 3 MEs led to a mixture of results, with slopes that ranged from −0.22 (for the inhalation (total inhalable) concentration) to 1.74 and confidence intervals that sometimes supported and sometimes rejected the proportionality or independence assumptions.

In the Supplement, the same regression models are fitted to data after removing the potential outlier. For all 17 MEs, the slopes ranged from 0.59 to 1.38, and the confidence intervals for the slope excluded 0 and included 1, except for the censored data MLE for Long Dermal Hat, Hands Only, and Long Dermal No Hat that excluded 1 (barely) and excluded 0, and for the inhalation (respirable) concentration where the interval included both 0 and 1. Thus in all but five cases, the assumption of log-log-linearity with slope 1 was supported. For the Backpack sprayer, after removing the potential outlier, the slopes ranged from 0.69 to 1.24 and the confidence intervals included 1 except for Long Dermal Hat, Hands Only, and Long Dermal No Hat (censored data MLE only) where the lower bound was a little larger than 1. The confidence intervals excluded zero for dermal exposures and 4 of the 12 cases for inhalation exposures. Thus, the assumption of log-log-linearity was generally either supported or not rejected.

We also evaluated quadratic regression models where the logarithm of the exposure is regressed against the logarithm of the normalizing factor and the square of the logarithm of the normalizing factor. Using all the data, for all exposure modes, the quadratic coefficient was not statistically significant, so the linear model was preferred over the quadratic model. The analyses on the Supplement also show that after removing ME 17, the quadratic coefficient was not statistically significant.

Finally, we evaluated and compared several alternative statistical model formulations. In addition to the above linear and quadratic models for the logarithm of exposure we considered log-log-logistic and three-parameter logistic models for exposure, and a gamma model for exposure. We used the Akaike Information Criterion to compare the goodness-of-fit, penalizing potentially over-parametrized models with more parameters. Based on the AIC, the best-fitting models using all 18 MEs are the gamma model for the dermal and inhalation (total inhalable) exposure routes and the linear model for the inhalation (respirable) exposure routes. The analyses in the Supplement show that after excluding ME 17, the best-fitting models using the other 17 MEs are also the gamma model for all the exposure routes, with the exception of Long Short Dermal No Hat exposure, for which the quadratic model was the best-fitting (despite the fact that the quadratic coefficient was not statistically significant the 5% significance level).

We will use the following labeling scheme for the tables and figures. Each Table or Figure is labeled as Table Xn or Figure Xn. The letter X is A if the analysis uses all the data as in the main memorandum, either unstratified or stratified by sprayer type or volume / concentration. The letter X is B if the analysis excludes the potential outlier ME 17 as in the Supplement, either unstratified or stratified by sprayer type or volume / concentration. The number n denotes the table or figure number for the data set A or B. The same sequence of analyses applies for each data set. To make it easier to compare results between the different sprayer type or volume / concentration groups, the tables and figures in the Supplement repeat the results for the Cart and Handheld sprayer type groups and for the three other volume / concentration groups (Vol Conc Low, Vol Conc Mid, and Vol Conc LoHi) in the main memorandum that are not affected by removal of the potential outlier in the Backpack sprayer type group.

2. Detailed Results using all 18 MEs.

Summary Statistics of Exposure per Pound of Active Ingredient.

Tables A1 to A11 summarize the normalized exposure data (per pound of active ingredient) with the summary statistics from the 18 MEs (all data), or the 8, 7, and 3 MEs from the three sprayer type groups Backpack, Cart, and Handheld, respectively, and each dermal and inhalation exposure route. Tables A12 to A22 summarize the normalized exposure data (per pound of active ingredient) with the summary statistics from the 18 MEs (all data), or the 6, 5, 6, and 1 MEs from the four volume / concentration groups A = Vol Conc Low, B = Vol Conc Mid, C = Vol Conc High, and D = Vol Conc LoHi, respectively, and each dermal and inhalation exposure route. These analyses assume that the exposure measurements within each sprayer type or volume / concentration group come from some unspecified distribution for that group. Note that for the Vol Conc LoHi group there was only one ME, so the Arithmetic and Geometric Standard Deviations are undefined, and the other statistics are all equal.

Table A1. Summary statistics by sprayer type group for normalized long dermal hat exposure (mg/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	472.284	652.666	315.682	356.671
Arithmetic Standard Deviation	274.125	293.504	115.269	247.645
Geometric Mean	359.642	473.252	300.717	262.587
Geometric Standard Deviation	2.554	3.450	1.385	3.029
Min	22.829	22.829	193.491	73.200
5%	22.829	22.829	193.491	73.200
10%	73.200	22.829	193.491	73.200
25%	285.273	607.815	239.866	73.200
50%	498.406	673.950	293.459	465.830
75%	662.237	790.663	332.308	530.983
90%	812.265	1053.638	555.096	530.983
95%	1053.638	1053.638	555.096	530.983
Max	1053.638	1053.638	555.096	530.983

Table A2. Summary statistics by sprayer type group for normalized long short dermal hat exposure (mg/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	777.125	982.054	541.763	779.824
Arithmetic Standard Deviation	386.688	397.931	217.309	461.754
Geometric Mean	634.791	765.274	507.038	651.393

Statistic	All	Type Backpack	Type Cart	Type Handheld
Geometric Standard Deviation	2.200	2.852	1.485	2.250
Min	58.252	58.252	259.607	256.788
5%	58.252	58.252	259.607	256.788
10%	256.788	58.252	259.607	256.788
25%	453.601	972.517	428.718	256.788
50%	953.816	1019.898	553.865	951.671
75%	1027.080	1260.840	567.028	1131.014
90%	1264.743	1291.668	968.396	1131.014
95%	1291.668	1291.668	968.396	1131.014
Max	1291.668	1291.668	968.396	1131.014

Table A3. Summary statistics by sprayer type group for normalized hands only dermal exposure (mg/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	440.297	619.953	291.585	308.208
Arithmetic Standard Deviation	267.339	281.311	108.706	249.782
Geometric Mean	316.375	439.446	277.498	178.865
Geometric Standard Deviation	2.913	3.674	1.386	4.847
Min	18.183	18.183	191.492	29.120
5%	18.183	18.183	191.492	29.120
10%	29.120	18.183	191.492	29.120
25%	263.458	561.729	204.921	29.120
50%	447.752	643.215	263.585	384.716
75%	608.638	775.010	304.016	510.788
90%	800.855	981.533	518.812	510.788
95%	981.533	981.533	518.812	510.788
Max	981.533	981.533	518.812	510.788

Table A4. Summary statistics by sprayer type group for normalized long dermal no hat exposure (mg/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	549.988	723.654	384.461	473.107
Arithmetic Standard Deviation	293.701	315.753	152.014	299.225

Statistic	All	Type Backpack	Type Cart	Type Handheld
Geometric Mean	439.284	550.229	362.802	376.526
Geometric Standard Deviation	2.297	3.012	1.430	2.544
Min	37.275	37.275	222.280	128.179
5%	37.275	37.275	222.280	128.179
10%	128.179	37.275	222.280	128.179
25%	336.135	661.643	278.569	128.179
50%	624.381	760.046	353.096	628.118
75%	724.890	922.626	429.953	663.023
90%	1012.218	1063.323	693.806	663.023
95%	1063.323	1063.323	693.806	663.023
Max	1063.323	1063.323	693.806	663.023

Table A5. Summary statistics by sprayer type group for normalized long short dermal exposure no hat (mg/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	854.828	1053.042	610.542	896.260
Arithmetic Standard Deviation	426.822	455.133	253.720	511.646
Geometric Mean	705.747	829.091	568.805	759.813
Geometric Standard Deviation	2.131	2.716	1.504	2.168
Min	72.697	72.697	288.396	311.766
5%	72.697	72.697	288.396	311.766
10%	288.396	72.697	288.396	311.766
25%	504.462	995.972	467.421	311.766
50%	995.972	1047.626	596.676	1113.959
75%	1113.959	1310.472	658.774	1263.054
90%	1319.590	1643.497	1107.106	1263.054
95%	1643.497	1643.497	1107.106	1263.054
Max	1643.497	1643.497	1107.106	1263.054

Table A6. Summary statistics by sprayer type group for normalized inhalation (total inhalable) concentration ((mg/m^3)/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	6.537	3.842	11.505	2.130

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Standard Deviation	5.776	3.227	5.754	1.804
Geometric Mean	3.963	2.429	10.257	1.590
Geometric Standard Deviation	3.214	3.067	1.699	2.687
Min	0.477	0.477	4.746	0.571
5%	0.477	0.477	4.746	0.571
10%	0.571	0.477	4.746	0.571
25%	1.391	0.977	6.016	0.571
50%	5.573	3.261	10.061	1.714
75%	9.376	6.656	17.736	4.106
90%	17.736	8.475	20.264	4.106
95%	20.264	8.475	20.264	4.106
Max	20.264	8.475	20.264	4.106

Table A7. Summary statistics by sprayer type group for normalized inhalation (total inhalable) dose (mg/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	5.110	2.879	9.265	1.368
Arithmetic Standard Deviation	4.422	3.069	3.214	0.940
Geometric Mean	3.133	1.923	8.879	1.013
Geometric Standard Deviation	3.132	2.501	1.351	2.996
Min	0.286	0.787	6.784	0.286
5%	0.286	0.787	6.784	0.286
10%	0.787	0.787	6.784	0.286
25%	1.114	0.911	7.040	0.286
50%	3.912	1.424	8.443	1.848
75%	8.443	3.912	10.229	1.971
90%	10.229	9.747	15.939	1.971
95%	15.939	9.747	15.939	1.971
Max	15.939	9.747	15.939	1.971

Table A8. Summary statistics by sprayer type group for normalized inhalation (total inhalable) time-weighted average concentration ((mg/m^3)/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	0.639	0.360	1.158	0.171
Arithmetic Standard Deviation	0.553	0.384	0.402	0.117
Geometric Mean	0.392	0.240	1.110	0.127
Geometric Standard Deviation	3.132	2.501	1.351	2.996
Min	0.036	0.098	0.848	0.036
5%	0.036	0.098	0.848	0.036
10%	0.098	0.098	0.848	0.036
25%	0.139	0.114	0.880	0.036
50%	0.489	0.178	1.055	0.231
75%	1.055	0.489	1.279	0.246
90%	1.279	1.218	1.992	0.246
95%	1.992	1.218	1.992	0.246
Max	1.992	1.218	1.992	0.246

Table A9. Summary statistics by sprayer type group for normalized inhalation (respirable) concentration ((mg/m^3)/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	1.244	0.432	2.607	0.230
Arithmetic Standard Deviation	1.637	0.784	1.818	0.150
Geometric Mean	0.446	0.158	2.149	0.179
Geometric Standard Deviation	5.294	4.141	1.966	2.684
Min	0.023	0.023	0.857	0.057
5%	0.023	0.023	0.857	0.057
10%	0.055	0.023	0.857	0.057
25%	0.101	0.067	1.006	0.057
50%	0.383	0.119	2.476	0.312
75%	2.342	0.358	2.791	0.322
90%	2.791	2.342	6.323	0.322
95%	6.323	2.342	6.323	0.322
Max	6.323	2.342	6.323	0.322

Table A10. Summary statistics by sprayer type group for normalized inhalation (respirable) dose (mg/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	1.030	0.419	2.118	0.122
Arithmetic Standard Deviation	1.280	0.921	1.167	0.050
Geometric Mean	0.352	0.125	1.861	0.114
Geometric Standard Deviation	5.255	3.854	1.742	1.617
Min	0.038	0.038	0.817	0.066
5%	0.038	0.038	0.817	0.066
10%	0.051	0.038	0.817	0.066
25%	0.084	0.055	1.271	0.066
50%	0.189	0.090	1.559	0.141
75%	1.559	0.165	2.805	0.161
90%	2.805	2.693	4.209	0.161
95%	4.209	2.693	4.209	0.161
Max	4.209	2.693	4.209	0.161

Table A11. Summary statistics by sprayer type group for normalized inhalation (respirable) time-weighted average concentration ((mg/m^3)/lb ai) using empirical sampling model

Statistic	All	Type Backpack	Type Cart	Type Handheld
Arithmetic Mean	0.129	0.052	0.265	0.015
Arithmetic Standard Deviation	0.160	0.115	0.146	0.006
Geometric Mean	0.044	0.016	0.233	0.014
Geometric Standard Deviation	5.255	3.854	1.742	1.617
Min	0.005	0.005	0.102	0.008
5%	0.005	0.005	0.102	0.008
10%	0.006	0.005	0.102	0.008
25%	0.011	0.007	0.159	0.008
50%	0.024	0.011	0.195	0.018
75%	0.195	0.021	0.351	0.020
90%	0.351	0.337	0.526	0.020
95%	0.526	0.337	0.526	0.020
Max	0.526	0.337	0.526	0.020

Table A12. Summary statistics by volume / concentration group for normalized long dermal hat exposure (mg/lb ai) using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	472.284	318.374	553.257	531.853	633.464
Arithmetic Standard Deviation	274.125	183.410	140.291	402.083	
Geometric Mean	359.642	264.187	536.565	319.198	633.464
Geometric Standard Deviation	2.554	2.091	1.336	4.148	
Min	22.829	73.200	332.308	22.829	633.464
5%	22.829	73.200	332.308	22.829	633.464
10%	73.200	73.200	332.308	22.829	633.464
25%	285.273	193.491	530.983	239.866	633.464
50%	498.406	297.779	555.096	531.260	633.464
75%	662.237	465.830	662.237	812.265	633.464
90%	812.265	582.166	685.663	1053.638	633.464
95%	1053.638	582.166	685.663	1053.638	633.464
Max	1053.638	582.166	685.663	1053.638	633.464

Table A13. Summary statistics by volume / concentration group for normalized long short dermal hat exposure (mg/lb ai) using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	777.125	583.768	986.039	715.116	1264.743
Arithmetic Standard Deviation	386.688	335.175	262.666	447.414	
Geometric Mean	634.791	503.899	952.088	508.531	1264.743
Geometric Standard Deviation	2.200	1.830	1.367	3.112	
Min	58.252	256.788	561.129	58.252	1264.743
5%	58.252	256.788	561.129	58.252	1264.743
10%	256.788	256.788	561.129	58.252	1264.743
25%	453.601	259.607	968.396	428.718	1264.743
50%	953.816	503.733	1012.717	761.494	1264.743
75%	1027.080	951.671	1131.014	989.073	1264.743
90%	1264.743	1027.080	1256.937	1291.668	1264.743
95%	1291.668	1027.080	1256.937	1291.668	1264.743
Max	1291.668	1027.080	1256.937	1291.668	1264.743

Table A14. Summary statistics by volume / concentration group for normalized hands only exposure (mg/lb ai) using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	440.297	283.131	524.009	503.040	588.267
Arithmetic Standard Deviation	267.339	171.637	140.899	389.750	
Geometric Mean	316.375	211.369	506.198	288.649	588.267
Geometric Standard Deviation	2.913	2.805	1.361	4.472	
Min	18.183	29.120	304.016	18.183	588.267
5%	18.183	29.120	304.016	18.183	588.267
10%	29.120	29.120	304.016	18.183	588.267
25%	263.458	191.492	510.788	204.921	588.267
50%	447.752	279.135	518.812	506.375	588.267
75%	608.638	384.716	608.638	800.855	588.267
90%	800.855	535.191	677.792	981.533	588.267
95%	981.533	535.191	677.792	981.533	588.267
Max	981.533	535.191	677.792	981.533	588.267

Table A15. Summary statistics by volume / concentration group for normalized long dermal no hat exposure (mg/lb ai) using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	549.988	381.409	642.863	564.132	1012.218
Arithmetic Standard Deviation	293.701	205.133	121.073	392.146	
Geometric Mean	439.284	331.132	631.886	374.533	1012.218
Geometric Standard Deviation	2.297	1.843	1.243	3.461	
Min	37.275	128.179	429.953	37.275	1012.218
5%	37.275	128.179	429.953	37.275	1012.218
10%	128.179	128.179	429.953	37.275	1012.218
25%	336.135	222.280	663.023	278.569	1012.218
50%	624.381	344.615	693.806	586.295	1012.218
75%	724.890	620.644	702.642	833.034	1012.218
90%	1012.218	628.118	724.890	1063.323	1012.218
95%	1063.323	628.118	724.890	1063.323	1012.218
Max	1063.323	628.118	724.890	1063.323	1012.218

Table A16. Summary statistics by volume / concentration group for normalized long short dermal no hat exposure (mg/lb ai) using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	854.828	646.803	1075.644	747.395	1643.497
Arithmetic Standard Deviation	426.822	362.510	260.535	441.302	
Geometric Mean	705.747	563.818	1045.922	552.837	1643.497
Geometric Standard Deviation	2.131	1.787	1.319	2.881	
Min	72.697	288.396	658.774	72.697	1643.497
5%	72.697	288.396	658.774	72.697	1643.497
10%	288.396	288.396	658.774	72.697	1643.497
25%	504.462	311.766	1029.696	467.421	1643.497
50%	995.972	550.569	1107.106	816.528	1643.497
75%	1113.959	1065.557	1263.054	1009.843	1643.497
90%	1319.590	1113.959	1319.590	1301.353	1643.497
95%	1643.497	1113.959	1319.590	1301.353	1643.497
Max	1643.497	1113.959	1319.590	1301.353	1643.497

Table A17. Summary statistics by volume / concentration group for normalized inhalation (total inhalable) concentration ((mg/m^3)/lb ai) using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	6.537	10.324	4.863	4.171	6.377
Arithmetic Standard Deviation	5.776	7.785	3.549	4.000	
Geometric Mean	3.963	6.451	3.749	2.356	6.377
Geometric Standard Deviation	3.214	3.780	2.340	3.587	
Min	0.477	0.571	1.391	0.477	6.377
5%	0.477	0.571	1.391	0.477	6.377
10%	0.571	0.571	1.391	0.477	6.377
25%	1.391	4.106	1.714	0.909	6.377
50%	5.573	9.634	5.130	2.895	6.377
75%	9.376	17.736	6.016	8.475	6.377
90%	17.736	20.264	10.061	9.376	6.377
95%	20.264	20.264	10.061	9.376	6.377
Max	20.264	20.264	10.061	9.376	6.377

Table A18. Summary statistics by volume / concentration group for normalized inhalation (total inhalable) dose (mg/lb ai) using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	5.110	4.365	5.321	5.913	3.720
Arithmetic Standard Deviation	4.422	3.459	4.234	6.188	
Geometric Mean	3.133	2.681	3.760	3.056	3.720
Geometric Standard Deviation	3.132	3.675	2.744	3.902	
Min	0.286	0.286	0.974	0.787	3.720
5%	0.286	0.286	0.974	0.787	3.720
10%	0.787	0.286	0.974	0.787	3.720
25%	1.114	1.734	1.971	0.848	3.720
50%	3.912	4.316	4.104	4.077	3.720
75%	8.443	7.094	9.325	9.747	3.720
90%	10.229	8.443	10.229	15.939	3.720
95%	15.939	8.443	10.229	15.939	3.720
Max	15.939	8.443	10.229	15.939	3.720

Table A19. Summary statistics by volume / concentration group for normalized inhalation (total inhalable) time-weighted average concentration ((mg/m^3)/lb ai) using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	0.639	0.546	0.665	0.739	0.465
Arithmetic Standard Deviation	0.553	0.432	0.529	0.773	
Geometric Mean	0.392	0.335	0.470	0.382	0.465
Geometric Standard Deviation	3.132	3.675	2.744	3.902	
Min	0.036	0.036	0.122	0.098	0.465
5%	0.036	0.036	0.122	0.098	0.465
10%	0.098	0.036	0.122	0.098	0.465
25%	0.139	0.217	0.246	0.106	0.465
50%	0.489	0.539	0.513	0.510	0.465
75%	1.055	0.887	1.166	1.218	0.465
90%	1.279	1.055	1.279	1.992	0.465
95%	1.992	1.055	1.279	1.992	0.465
Max	1.992	1.055	1.279	1.992	0.465

Table A20. Summary statistics by volume / concentration group for normalized inhalation (respirable) concentration ((mg/m^3)/lb ai) using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	1.244	2.039	0.846	0.972	0.101
Arithmetic Standard Deviation	1.637	2.340	1.133	1.157	
Geometric Mean	0.446	1.082	0.359	0.282	0.101
Geometric Standard Deviation	5.294	3.606	4.705	7.753	
Min	0.023	0.312	0.057	0.023	0.101
5%	0.023	0.312	0.057	0.023	0.101
10%	0.055	0.312	0.057	0.023	0.101
25%	0.101	0.322	0.137	0.055	0.101
50%	0.383	1.243	0.273	0.468	0.101
75%	2.342	2.791	1.006	2.342	0.101
90%	2.791	6.323	2.759	2.476	0.101
95%	6.323	6.323	2.759	2.476	0.101
Max	6.323	6.323	2.759	2.476	0.101

Table A21. Summary statistics by volume / concentration group for normalized inhalation (respirable) dose (mg/lb ai) using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	1.030	0.900	0.949	1.391	0.059
Arithmetic Standard Deviation	1.280	1.016	1.210	1.731	
Geometric Mean	0.352	0.450	0.360	0.365	0.059
Geometric Standard Deviation	5.255	3.927	5.350	8.391	
Min	0.038	0.111	0.066	0.038	0.059
5%	0.038	0.111	0.066	0.038	0.059
10%	0.051	0.111	0.066	0.038	0.059
25%	0.084	0.141	0.096	0.051	0.059
50%	0.189	0.489	0.218	0.677	0.059
75%	1.559	1.535	1.559	2.693	0.059
90%	2.805	2.634	2.805	4.209	0.059
95%	4.209	2.634	2.805	4.209	0.059
Max	4.209	2.634	2.805	4.209	0.059

Table A22. Summary statistics by volume / concentration group for normalized inhalation (respirable) time-weighted average concentration ((mg/m^3)/lb ai)using empirical sampling model

Statistic	All	Vol Conc Low	Vol Conc Mid	Vol Conc High	Vol Conc LoHi
Arithmetic Mean	0.129	0.112	0.119	0.174	0.007
Arithmetic Standard Deviation	0.160	0.127	0.151	0.216	
Geometric Mean	0.044	0.056	0.045	0.046	0.007
Geometric Standard Deviation	5.255	3.927	5.350	8.391	
Min	0.005	0.014	0.008	0.005	0.007
5%	0.005	0.014	0.008	0.005	0.007
10%	0.006	0.014	0.008	0.005	0.007
25%	0.011	0.018	0.012	0.006	0.007
50%	0.024	0.061	0.027	0.085	0.007
75%	0.195	0.192	0.195	0.337	0.007
90%	0.351	0.329	0.351	0.526	0.007
95%	0.526	0.329	0.351	0.526	0.007
Max	0.526	0.329	0.351	0.526	0.007

The results for the different sprayer types generally show the highest normalized dermal exposure for the Backpack sprayer and the highest normalized inhalation exposure for the Cart sprayer. The results for the different volume / concentration groups generally show the highest normalized dermal exposure for the LoHi group, although this is based on a single ME, and the second highest normalized dermal exposure for the Mid group. There is no obvious pattern among the different volume / concentration groups for normalized inhalation exposure. Note that although the amount of active ingredient increases from the Low to Mid to High volume / concentration groups, so does the exposure (generally), so the normalized exposure does not necessarily increase.

The results can be used to calculate the proportion of the normalized dermal exposure from hands only. For All MEs, based on the arithmetic means, the overall percentages of normalized exposure from hands only are 93% for Long Dermal Hat, 57% for Long Short Dermal Hat, 80% for Long Dermal No Hat, and 52% for Long Short Dermal No Hat. Among the sprayer type groups and volume / concentration groups, the overall percentages of normalized exposure from hands only range from 86 to 95% for Long Dermal Hat, 40 to 70% for Long Short Dermal Hat, 58 to 89% for Long Dermal No Hat, and 34 to 67% for Long Short Dermal No Hat. Similarly, for the unnormalized dermal exposure, the overall arithmetic mean hands only exposure is 94% of the arithmetic mean Long Dermal Hat exposure, 65% of the arithmetic mean Long Short Dermal No Hat exposure, 85% of the arithmetic mean Long Dermal No Hat exposure, and 60% of the arithmetic mean Long Dermal No Hat exposure.

Compare Sprayer Type Groups

The results in Tables A1 to A11 show some differences between the normalized exposure statistics for the three sprayer type groups "Type Backpack," "Type Cart", and "Type Handheld." To compare these groups, an analysis of variance was performed to test whether the geometric means were statistically significantly different at the 5% significance level. This analysis assumes that that for each group, the normalized exposure is lognormally distributed, an assumption that is evaluated below in the sections "Empirical Quantile Plots" and "Normality Tests." The statistical analysis tests whether the population means of the logarithms of the normalized exposure are the same across the three groups. This is equivalent to testing whether the geometric means of the normalized exposure are the same across the groups. The one-way analysis of variance (ANOVA) test assumes that the geometric standard deviations of the normalized exposure are the same across the groups, which is the same as assuming that the variances of the logarithms of the normalized exposure are the same across the groups. The Welch's ANOVA test avoids this equal variance assumption.

The p-values for these ANOVA tests are shown in Table A23. These analyses show that there were no statistically significant differences (at the 5% significance level) between the three sprayer type groups for any of the dermal exposure modes but there were statistically significant differences (at the 5% significance level) between the three sprayer type groups for all of the inhalation exposure modes.

Table A23. P-values for testing differences in geometric means for different sprayer type groups

Exposure Route	ANOVA	Welch's ANOVA
Long Dermal Hat	0.557	0.657
Long Short Dermal Hat	0.628	0.615
Hands Only	0.451	0.628
Long Dermal No Hat	0.617	0.665
Long Short Dermal No Hat	0.647	0.619
Inhalation (total inhalable) Conc	0.009	0.029
Inhalation (total inhalable) Dose	0.001	0.014
Inhalation (total inhalable) 8hr TWA	0.001	0.014
Inhalation (respirable) Conc	0.001	0.007
Inhalation (respirable) Dose	0.000	0.000
Inhalation (respirable) 8hr TWA	0.000	0.000

Compare Volume / Concentration Groups

The results in Tables A12 to A22 show some differences between the normalized exposure statistics for the four volume / concentration groups "Vol Conc Low," "Vol Conc Mid", "Vol Conc High," and "Vol Conc LoHi." To compare these groups, an analysis of variance was performed to test whether the geometric means were statistically significantly different at the 5% significance level. This analysis assumes that that for each group, the normalized exposure is lognormally distributed. The statistical analysis tests whether the population means of the logarithms of the normalized exposure are the same across the four groups. This is equivalent to testing whether the geometric means of the normalized exposure are the same across the groups. The one-way analysis of variance (ANOVA) test assumes that the geometric standard deviations of the normalized exposure are the same across the groups, which is the same as assuming that the variances of the logarithms of the normalized exposure are the same across the groups. The Welch's ANOVA test avoids this equal variance assumption. Because the group "Vol Conc LoHi" only has one observation, the Welch's ANOVA test does not use the data for that one group.

The p-values for these ANOVA tests are shown in Table A24. These analyses show that there were no statistically significant differences (at the 5% significance level) between the four volume / concentration groups for any of the exposure modes.

Table A24. P-values for testing differences in geometric means for different volume / concentration groups

Exposure Route	ANOVA	Welch's ANOVA
Long Dermal Hat	0.608	0.156
Long Short Dermal Hat	0.409	0.118
Hands Only	0.571	0.194
Long Dermal No Hat	0.443	0.108
Long Short Dermal No Hat	0.307	0.101
Inhalation (total inhalable) Conc	0.529	0.464
Inhalation (total inhalable) Dose	0.973	0.893
Inhalation (total inhalable) 8hr TWA	0.973	0.893
Inhalation (respirable) Conc	0.416	0.339
Inhalation (respirable) Dose	0.765	0.966
Inhalation (respirable) 8hr TWA	0.765	0.966

Statistical Models

The statistical analyses of the normalized exposure use the following two alternative statistical models. Let X be the normalized exposure and X = exp(Y) so that Y = log (X), where log denotes the natural logarithm. LnGM is the log of the geometric mean. Let Z95 be the 95th percentile of a standard normal distribution, approximately 1.645.

- Empirical simple random sampling model. Code "s." Assumes that all the values of X were randomly drawn from an unspecified distribution. Gives empirical estimates such as in Tables A1-A22 above.
  - Y = LnGM + Error. Error is independent and identically distributed with mean 0 and the same variance for every measurement.
  - AMs = Arithmetic mean of X values
  - GMs = Geometric mean of X values = exp(LnGM) (= GMu)
  - GSDs = Geometric standard deviation of X values (= GSDu)
  - P95s = 95th percentile of X values
- Lognormal simple random sampling model. Code "u." Assumes that all the values of X were randomly drawn from a lognormal distribution.
  - Y = LnGM + Error. Error is normally distributed with mean 0, variance Vu, and standard deviation Su = √Vu.

- AMu = Modeled arithmetic mean of X values = exp(LnGM) exp(½ Vu)
- GMu = Modeled geometric mean of X values = exp(LnGM)
- GSDu = Modeled geometric standard deviation of X values = exp(Su)
- P95u = Modeled 95th percentile of X values = exp(LnGM) exp(Z95×Su)

Tables A25 to A28 present the arithmetic mean and 95th percentile estimates from the lognormal simple random sampling model, together with 95% confidence intervals, for each of the exposure routes, for all the data and for each sprayer type group. These are the values of AMu and P95u. The other summary statistics are presented in more detail below.

Table A25. Arithmetic mean and 95th percentile estimates from lognormal simple random sampling model for normalized exposure for All

Commented [KA1]: We have to make a decision on including ME17 (N = 18 as in this table or N=17 as in the supplemental data)

Commented [KA2]: One subsetting was normal verses log-normal (use log for all or parse out on better fit)

Exposure Route	Clothing	Arithmetic Mean (95% Confidence Interval)	95th Percentile (95% Confidence Interval)
Dermal (mg/lb ai)	Long Dermal Hat	558.29 (336.46, 963.20)	1,681.98 (852.84, 3,289.99)
	Long Short Dermal Hat	866.35 (575.78, 1,343.41)	2,322.78 (1,312.13, 4,083.46)
	Hands Only	560.32 (308.25, 1,078.00)	1,836.42 (846.67, 3,945.89)
	Long Dermal No Hat	620.70 (401.70, 992.28)	1,724.78 (944.55, 3,126.56)
	Long Short Dermal No Hat	939.78 (636.87, 1,427.94)	2,450.65 (1,416.65, 4,211.25)
Inhalation (total inhalable) Conc ((mg/m^3)/lb ai)		7.836 (3.997, 16.604)	27.049 (11.612, 62.361)
Inhalation (total inhalable) Dose (mg/lb ai)		6.012 (3.127, 12.401)	20.490 (8.963, 46.371)
Inhalation (total inhalable) 8hr TWA ((mg/m^3)/lb ai)		0.751 (0.391, 1.550)	2.561 (1.120, 5.796)
Inhalation (respirable) Conc ((mg/m^3)/lb ai)		1.787 (0.583, 6.696)	6.911 (2.067, 22.768)
Inhalation (respirable) Dose (mg/lb ai)		1.395 (0.458, 5.175)	5.396 (1.623, 17.681)
Inhalation (respirable) 8hr TWA((mg/m^3)/lb ai)		0.174 (0.057, 0.647)	0.674 (0.203, 2.210)

Table A26. Arithmetic mean and 95th percentile estimates from lognormal simple random sampling model for normalized exposure for Type Backpack

Exposure Route	Clothing	Arithmetic Mean (95% Confidence Interval)	95th Percentile (95% Confidence Interval)
Dermal (mg/lb ai)	Long Dermal Hat	1,018.97 (344.22, 3,540.38)	3,629.16 (913.85, 13,358.38)
	Long Short Dermal Hat	1,325.09 (554.73, 3,475.91)	4,288.96 (1,335.40, 12,917.78)
	Hands Only	1,024.67 (320.89, 3,996.67)	3,736.36 (877.34, 14,691.77)
	Long Dermal No Hat	1,010.52 (398.44, 2,863.57)	3.374.46 (988.55, 10,766.34)

Exposure Route	Clothing	Arithmetic Mean (95% Confidence Interval)	95th Percentile (95% Confidence Interval)
	Long Short Dermal No Hat	1,365.91 (602.03, 3,363.57)	4,289.56 (1,409.87, 12,275,38)
Inhalation (total inhalable) Conc ((mg/m^3)/lb ai)		4.551 (1.761, 13.273)	15.344 (4.406, 49.891)
Inhalation (total inhalable) Dose (mg/lb ai)		2.927 (1.401, 6.545)	8.687 (3.130, 22.792)
Inhalation (total inhalable) 8hr TWA ((mg/m^3)/lb ai)		0.366 (0.175, 0.818)	1.086 (0.391, 2.849)
Inhalation (respirable) Conc ((mg/m^3)/lb ai)		0.434 (0.117, 2.070)	1.638 (0.337, 7.308)
Inhalation (respirable) Dose (mg/lb ai)		0.311 (0.092, 1.309)	1.152 (0.257, 4.764)
Inhalation (respirable) 8hr TWA((mg/m^3)/lb ai)		0.039 (0.011, 0.164)	0.144 (0.032, 0.595)

Table A27. Arithmetic mean and 95th percentile estimates from lognormal simple random sampling model for normalized exposure for Type Cart

Exposure Route	Clothing	Arithmetic Mean (95% Confidence Interval)	95th Percentile (95% Confidence Interval)
Dermal (mg/lb ai)	Long Dermal Hat	317.07 (247.39, 408.26)	513.65 (348.46, 741.52)
	Long Short Dermal Hat	548.26 (404.58, 750.72)	971.58 (606.42, 1,517.70)
	Hands Only	292.66 (228.21, 377.05)	474.54 (321.66, 685.63)
	Long Dermal No Hat	386.75 (294.11, 512.10)	653.27 (426.55, 977.86)
	Long Short Dermal No Hat	618.23 (451.30, 855.67)	1,113.19 (684.26, 1,764.27)
Inhalation (total inhalable) Conc ((mg/m^3)/lb ai)		11.802 (7.761, 18.173)	24.519 (13.037, 44.574)
Inhalation (total inhalable) Dose (mg/lb ai)		9.290 (7.394, 11.725)	14.569 (10.175, 20.462)
Inhalation (total inhalable) 8hr TWA ((mg/m^3)/lb ai)		1.161 (0.924, 1.466)	1.821 (1.272, 2.558)
Inhalation (respirable) Conc ((mg/m^3)/lb ai)		2.701 (1.561, 4.802)	6.533 (2.919, 14.002)
Inhalation (respirable) Dose (mg/lb ai)		2.170 (1.399, 3.423)	4.635 (2.392, 8.666)
Inhalation (respirable) 8hr TWA((mg/m^3)/lb ai)		0.271 (0.175, 0.428)	0.579 (0.299, 1.083)

Table A28. Arithmetic mean and 95th percentile estimates from lognormal simple random sampling model for normalized exposure for Type Handheld

Exposure Route	Clothing	Arithmetic Mean (95% Confidence Interval)	95th Percentile (95% Confidence Interval)
Dermal (mg/lb ai)	Long Dermal Hat	485.23 (103.18, 3,674.49)	1,625.19 (193.41, 12,860.78)
	Long Short Dermal Hat	904.86 (314.91, 3,123.33)	2,471.78 (520.83, 11,227.05)
	Hands Only	621.59 (54.09, 25,378.68)	2,399.09 (115.72. 45,665.72)
	Long Dermal No Hat	582.18 (166.44, 2,692.05)	1,748.65 (291.02, 9,989.20)
	Long Short Dermal No Hat	1,025.19 (378.62, 3,270.78)	2,714,14 (613.70, 11,510.82)
Inhalation (total inhalable) Conc ((mg/m^3)/lb ai)		2.592 (0.678. 13.893)	8.082 (1.210, 51.147)
Inhalation (total inhalable) Dose (mg/lb ai)		1.850 (0.401, 13.531)	6.159 (0.749, 47.756)
Inhalation (total inhalable) 8hr TWA ((mg/m^3)/lb ai)		0.231 (0.050, 1.691)	0.770 (0.094, 5.969)
Inhalation (respirable) Conc ((mg/m^3)/lb ai)		0.292 (0.076, 1.558)	0.909 (0.136, 5.741)
Inhalation (respirable) Dose (mg/lb ai)		0.128 (0.072, 0.239)	0.252 (0.100, 0.617)
Inhalation (respirable) 8hr TWA((mg/m^3)/lb ai)		0.016 (0.009, 0.030)	0.031 (0.013, 0.077)

For each exposure route, the two statistical models were fitted to the observed data and the summary statistics listed above were calculated together with 95% confidence intervals. The 95% confidence intervals in Tables A25 to A28 were computed using a parametric bootstrap. For these calculations, the parametric bootstrap simulations were all generated from the fitted lognormal simple random sampling model, even for the empirical summary statistics, on the basis that the lognormal simple random sampling model is the best choice for modeling the data, even if the summary statistics are developed from a simpler statistical model. For example, in Tables A1 to A11, the empirical arithmetic means are presented, which are the arithmetic means of the 18 measurements for the "All" group, and the 8, 7, or 3 measurements in each of the three sprayer type groups "Type Backpack," "Type Cart," and "Type Handheld." To estimate the uncertainty of those empirical arithmetic means, data are simulated from the lognormal simple random sampling model to calculate the parametric bootstrap confidence intervals. The arithmetic means in Tables A24 to A28 are estimated using the lognormal simple random sampling model, which is also used to estimate the confidence intervals in Tables A24 to A28. The unit exposure estimates (from the lognormal simple random sampling model) displayed in Tables A24 to A28 are recommended over the empirical arithmetic means and 95th percentiles displayed in the Tables A1 to A11.

The algorithm used was as follows:

Step 1:
Assume that there are N subjects in a data subset. (for example, N = 18 for the "All" group).
Simulate N random variables Y, X from the estimated lognormal distribution superimposed upon the observed sampling structure ---;

Y = LnGM + RanNor(Seed)×Sr

X = exp(Y)

where:

LnGM = natural logarithm of fitted geometric mean

Sr = natural logarithm of fitted geometric standard deviation

Step 2:
For Y:

Calculate GMs = exp(EAM)

Calculate GSDs = exp(Su)

Calculate AMu = GMs×exp(0.5×Su×Su)

Calculate P95u = GMs× exp(Z95×Su)

where:

EAM = sample arithmetic mean of Y = AMu

Su = standard deviation of Y

For X:

Calculate arithmetic mean AMs

Calculate 95th percentile P95s

Step 3: Repeat Steps 1 and 2 10,000 times.

Steps 1 to 3 result in 10,000 values each for each of GSDs, GMs, AMs, AMu, P95s, and P95u. 95% confidence intervals can be defined for each parameter by the 2.5th and 97.5th percentiles (lower and upper, respectively) of the bootstrap distribution of that corresponding parameter. Note that by definition, GSDs = GSDu and GMs = GMu.

Non-detects

All the values for hand, face/neck, and hat exposures as well as the PVC filters were above the LOQ but there were several other cases with values below the corresponding LOQ. Note that if the outer dosimeter residue for a body part was found to be below the LOQ, then the inner dosimeter residue for the same body part was not measured and the inner dosimeter residue was treated as being exactly zero. Also note that for the inner and outer dosimeters, the Excel files provided by the study director also reported measured values (below the LOQ) for the non-detects, but those values were not used for these analyses. For the inner dosimeters there were 17 non-detects out of the 96 measured values. For the lower arm outer dosimeters there was only 1 non-detect out of the 18 measured values. For the inner hat there were 8 non-detects out of the 18 measured values. For the OVS tubes there was only 1 non-detect out of the 18 measured values.

For all the analyses presented in this memorandum except for Table A29 and A42, measurements below the LOQ were replaced by the mid-value, the midpoint of the lowest and highest possible value for that measurement. In Tables A29 and A42 we investigated the impact on the summary statistics of the censored values. This analysis in Table A29 is only presented for all 18 MEs.

For each exposure metric, we used the approach in the last paragraph to compute the arithmetic mean and 95th percentiles using the recommended substitution of the midpoint value for values below the LOQ and compared those results to estimates using the alternative substitutions of the minimum and maximum for that non-detect value. For the dermal exposure modes, the exposure values are sums of the measured values for the relevant dosimeter, face, head and neck, hat, and hand wash components, so the minimum exposure is the sum of all the minimum component values, and the maximum exposure is the sum of all the maximum component values. We also investigated a censored maximum likelihood statistical method described in the following paragraph.

The lognormal simple random sampling model assumes that the exposure values are independent and identically lognormally distributed. For uncensored values with a mass m, the mass is between a lower bound of m and an upper bound of m. For censored mass values, the mass value is known to be between a lower bound and an upper bound. The SAS procedure LIFEREG was used to fit the lognormal model to the combined censored and uncensored data using the maximum likelihood method. The procedure produces estimates of the geometric mean and geometric standard deviation for the fitted lognormal distribution.

To calculate confidence intervals for the arithmetic means and 95th percentiles, a parametric bootstrap method was used. This is exactly the same bootstrap method that was used for the original case where the non-detects were replaced by the midpoint value. 10,000 values of the unit exposure were simulated from the fitted lognormal distribution, and for each simulation, the geometric mean and geometric standard deviation were calculated and used to calculate the arithmetic mean (AMu) and 95th percentile (P95u) of the corresponding lognormal distribution. The simulated unit exposures are all uncensored numerical values even though the corresponding residues can be lower than the LOQs. The confidence intervals for the AMu and P95u range from the 2.5th percentile to the 97.5th percentile.

Results for all the exposure metrics are presented in Table A29. The results are compared for the default substitution of the midpoint value ("mid value") the alternative substitutions of the maximum value ("max value") and minimum value ("min value"), and estimates calculated using the maximum likelihood method for censored data, referred to as "Censored data MLE." The "substitute min value" method was not applied for the inhalation exposure data since the lower bound is zero in those cases, producing unrealistic extreme estimates

Table A29. Exposure summary statistics calculated using alternative estimated exposures for values below the LOQ.

Exposure Route	Method for Substituting Values Below the LOQ	Arithmetic Mean	95th Percentile
Long Dermal Hat (mg/lb ai)	Substitute mid value	558.29 (336.46, 963.20)	1,681.98 (852.84, 3,289.99)
	Substitute max value	559.85 (338.17, 963.32)	1,682.02 (855.27, 3,280.90)
	Substitute min value	556.77 (334.50, 963.75)	1,682.31 (850.45, 3,300.41)
	Censored data MLE	544.79 (333.68, 922.14)	1,610.38 (832.30, 3,090.97)
Long Short Dermal Hat (mg/lb ai)	Substitute mid value	866.35 (575.78, 1,343.41)	2,322.78 (1,312.13, 4,083.46)
	Substitute max value	869.95 (583.85, 1,334.85)	2,301.58 (1,314.75, 4,001.80)
	Substitute min value	866.83 (566.52, 1,364.22)	2,369.35 (1,315.16, 4,238.16)
	Censored data MLE	852.21 (573.52, 1,302.60)	2,242.17 (1,286.47, 3,881.58)
Hands Only (mg/lb ai)	Substitute mid value	560.32 (308.25, 1,078.00)	1,836.42 (846.67, 3,945.89)
	Substitute max value	560.32 (308.25, 1,078.00)	1,836.42 (846.67, 3,945.89)
	Substitute min value	560.32 (308.25, 1,078.00)	1,836.42 (846.67, 3,945.89)
	Censored data MLE	542.80 (305.35, 1,014.58)	1,747.64 (823.51, 3,675.09)
Long Dermal No Hat (mg/lb ai)	Substitute mid value	620.70 (401.70, 992.28)	1,724.78 (944.55, 3,126.56)
	Substitute max value	622.50 (403.69, 992.80)	1,725.74 (947.05, 3,121.88)

Exposure Route	Method for Substituting Values Below the LOQ	Arithmetic Mean	95th Percentile
	Substitute min value	618.92 (399.67, 991.86)	1,724.12 (942.09, 3,132.23)
	Censored data MLE	608.88 (399.62, 956.59)	1,659.57 (924.37, 2,958.42)
Long Short Dermal No Hat (mg/lb ai)	Substitute mid value	939.78 (636.87, 1,427.94)	2,450.65 (1,416.65, 4,211.25)
	Substitute max value	943.29 (644.64, 1,418.33)	2,427.79 (1,418.40, 4,128.50)
	Substitute min value	938.94 (628.00, 1,446.24)	2,496.65 (1,420.16, 4,357.45)
	Censored data MLE	925.40 (634.79, 1,384.84)	2,368.34 (1,389.92, 4,009.49)
Inhalation (total inhalable) Conc ((mg/m^3)/lb ai)	Substitute mid value	7.836 (3.997, 16.604)	27.049 (11.612, 62.361)
	Substitute max value	7.626 (4.059, 15,251)	25.568 (11.445, 56.566)
	Censored data MLE	7.549 (3.963, 15.386)	25.566 (11.286, 57.343)
Inhalation (total inhalable) Dose (mg/lb ai)	Substitute mid value	6.012 (3.127, 12.401)	20.490 (8.963, 46.371)
	Substitute max value	5.743 (3.169, 11.011)	18.779 (8.683, 40.239)
	Censored data MLE	5.731 (3.106, 11.210)	18.978 (8.635, 41.314)
Inhalation (total inhalable) 8hr TWA ((mg/m^3)/lb ai))	Substitute mid value	0.751 (0.391, 1.550)	2.561 (1.120, 5.796)
	Substitute max value	0.718 (0.396, 1.376)	2.347 (1.085, 5.030)
	Censored data MLE	0.716 (0.388, 1.401)	2.372 (1.079, 5.164)
Inhalation (respirable) Conc ((mg/m^3)/lb ai)	Substitute mid value	1.787 (0.583, 6.696)	6.911 (2.067, 22.768)
	Substitute max value	1.787 (0.583, 6.696)	6.911 (2.067, 22.768)
	Censored data MLE	1.654 (0.563, 5.844)	6.397 (1.980, 20.379)
Inhalation (respirable) Dose (mg/lb ai)	Substitute mid value	1.395 (0.458, 5.175)	5.396 (1.623, 17.681)
	Substitute max value	1.395 (0.458, 5.175)	5.396 (1.623, 17.681)
	Censored data MLE	1.292 (0.443, 4.519)	4.966 (1.554, 15.834)
Inhalation (respirable) 8hr TWA ((mg/m^3)/lb ai))	Substitute mid value	0.174 (0.057, 0.647)	0.674 (0.203, 2.210)
	Substitute max value	0.174 (0.057, 0.647)	0.674 (0.203, 2.210)
	Censored data MLE	0.162 (0.055, 0.565)	0.625 (0.194, 1.979)

The results in Table A29 for dermal and inhalation exposure show very small impacts of the alternative substitution approaches for treating values below the LOQ on the unit exposure arithmetic mean and 95th percentile.

Fold Relative Accuracy

Fold relative accuracy (fRA_{95}) is a measure that can be used to determine how well a statistic can describe its population parameter. Let us assume θ is a parameter and T is the sample statistic of θ (i.e., an estimate of θ). In this memorandum we will use a more accurate calculation of the fold relative accuracy than the method used for the statistical analyses of several previous studies. The new method can be proven to produce lower values for the fold relative accuracy compared to those previous calculations, although the differences are in most cases quite small. By definition, if T and θ are known, the fold relative accuracy of T is the maximum of T/q and q/T. The fold relative accuracy measure is defined as the 95th percentile of the fold relative accuracy of T where the unknown value of θ is replaced by its estimated value E. Define FRA as the maximum of T/E and E/T. The fold relative accuracy measure (fRA_{95}) is calculated using a parametric or nonparametric bootstrap with N bootstrap replicates by simulating N values for FRA and then finding the 95th percentile of FRA. We used N = 10000 bootstrap replicates for these analysis. If the fRA_{95} of a statistic were equal to 3, and θ was known, then it would be correct to say: "95% of the time the sample statistic will be accurate to within 3-fold of the population value". According to the AHETF Governing Document, the statistical design of the exposure monitoring study should be adequate to produce a fRA_{95} less than or equal to 3. Thus the confidence intervals calculated in the above algorithm can be used to estimate the fold relative accuracy and compare the observed fRA_{95} with the study design benchmark of 3. If the observed fold relative accuracy is greater than 3, this means that the experiment did not meet the benchmark, which would be due to differences between the distributions of the data used to design the study and the experimental data collected in the study. If the fold relative accuracy benchmark is not met, then it might be desirable to collect more data for this scenario in order to meet the benchmark. The fRA_{95} is also referred to as the K-factor.

Following HSRB recommendations, confidence intervals and fold relative accuracy measures were estimated using both a parametric bootstrap approach, as described above, and the following non-parametric bootstrap approach. The non-parametric bootstrap method should be more robust since it does not assume that the fitted parametric model is the correct one. For the non-parametric bootstrap, exactly the same algorithm was used except that Step 1 above was replaced by the following:

Step 1:
Simulate N random variables Y, X by resampling at random with replacement from the original data:
The original exposure data are X(1), X(2), …, X(N), where N is the number of subjects in the data set.
Sample N values at random with replacement from the exposure values X(1), X(2), …, X(N). This gives the N simulated random variables X.
Y = log(X).

Detailed Summary Statistics with Confidence Intervals and Fold Relative Accuracy

Tables A30 to A40 present the estimates, parametric and non-parametric confidence intervals and fold relative accuracy values for all the summary statistics for the All group and the three sprayer type groups. All these analyses use non-detects substituted by the mid-value.

Table A30. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized long dermal hat exposure (mg/lb ai)

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
All	GSDs	2.55	1.87	3.51	1.37	1.54	3.71	1.61
	GMs	359.64	234.85	561.57	1.55	226.68	522.09	1.51

		Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
	AMs	472.28	326.23	944.03	1.81	350.51	594.41	1.31
	AMu	558.29	336.46	963.20	1.69	403.66	724.20	1.34
	P95s	1,053.64	846.18	5,914.53	4.64	685.66	1,053.64	1.37
	P95u	1,681.98	852.84	3,289.99	1.96	912.41	2,487.61	1.73
Backpack	GSDs	3.45	1.83	6.40	1.87	1.10	6.15	3.08
	GMs	473.25	200.62	1,112.96	2.35	192.90	809.09	2.32
	AMs	652.67	318.47	2,693.09	3.33	447.43	827.10	1.35
	AMu	1,018.97	344.22	3,540.38	3.18	667.98	1300.71	1.49
	P95s	1,053.64	717.40	13,399.04	9.51	769.06	1053.64	1.37
	P95u	3,629.16	913.85	13,358.38	3.86	798.08	5009.72	4.36
Cart	GSDs	1.38	1.16	1.66	1.19	1.10	1.56	1.24
	GMs	300.72	235.89	383.94	1.28	243.74	384.46	1.25
	AMs	315.68	245.97	403.83	1.28	248.46	405.89	1.28
	AMu	317.07	247.39	408.26	1.28	249.22	409.91	1.28
	P95s	555.10	325.08	720.03	1.63	310.28	555.10	1.79
	P95u	513.65	348.46	741.52	1.46	327.17	734.85	1.53
Handheld	GSDs	3.03	1.18	8.49	2.62	1.00	3.14	3.03
	GMs	262.59	73.36	916.41	3.54	73.20	530.98	2.02
	AMs	356.67	94.49	1,652.30	4.20	73.20	530.98	1.75
	AMu	485.23	103.18	3,674.49	5.76	73.20	530.98	2.02
	P95s	530.98	142.33	3,960.00	5.69	73.20	530.98	1.14
	P95u	1,625.19	193.41	12,860.78	8.19	73.20	1800.81	3.49

Table A31. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized long short dermal hat exposure (mg/lb ai)

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
All	GSDs	2.20	1.69	2.88	1.30	1.48	3.04	1.45
	GMs	634.79	443.60	923.38	1.44	431.74	867.80	1.42
	AMs	777.12	563.05	1,323.25	1.58	601.39	945.50	1.26
	AMu	866.35	575.78	1,343.41	1.53	662.20	1,055.90	1.27
	P95s	1,291.67	1,303.50	6,687.02	4.41	1,131.01	1,291.67	1.03

		Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
	P95u	2,322.78	1,312.13	4,083.46	1.76	1,441.89	3,258.69	1.55
Backpack	GSDs	2.85	1.67	4.81	1.70	1.10	4.69	2.56
	GMs	765.27	370.23	1,577.76	2.06	356.89	1172.07	2.04
	AMs	982.05	523.18	2,971.15	2.56	686.82	1179.39	1.32
	AMu	1,325.09	554.73	3,475.91	2.50	1026.88	1481.45	1.26
	P95s	1,291.67	1,088.12	12,951.04	7.84	1256.94	1291.67	1.03
	P95u	4,288.96	1,335.40	12,917.78	3.13	1203.12	5500.92	3.37
Cart	GSDs	1.48	1.20	1.85	1.24	1.12	1.72	1.31
	GMs	507.04	377.53	682.24	1.34	383.64	664.69	1.31
	AMs	541.76	400.29	737.14	1.36	404.36	704.33	1.32
	AMu	548.26	404.58	750.72	1.36	407.50	712.48	1.32
	P95s	968.40	557.37	1,464.42	1.67	561.13	968.40	1.73
	P95u	971.58	606.42	1,517.70	1.59	603.03	1382.42	1.57
Handheld	GSDs	2.25	1.13	4.78	2.02	1.00	2.35	2.25
	GMs	651.39	256.25	1,625.46	2.52	256.79	1131.01	1.74
	AMs	779.82	298.84	2,228.05	2.74	256.79	1131.01	1.60
	AMu	904.86	314.91	3,123.33	3.11	256.79	1131.01	1.71
	P95s	1,131.01	416.15	4,742.34	3.50	256.79	1131.01	1.19
	P95u	2,471.78	520.83	11,227.05	4.66	256.79	2820.43	2.60

Table A32. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized hands only exposure (mg/lb ai)

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
All	GSDs	2.91	2.04	4.19	1.43	1.56	4.27	1.80
	GMs	316.38	194.62	525.83	1.64	185.30	485.11	1.60
	AMs	440.30	294.35	1,049.90	2.10	321.35	560.54	1.32
	AMu	560.32	308.25	1,078.00	1.88	399.85	730.53	1.36
	P95s	981.53	839.13	7,700.92	6.32	677.79	981.53	1.31
	P95u	1,836.42	846.67	3,945.89	2.16	886.32	2,642.33	1.91
Backpack	GSDs	3.67	1.89	7.03	1.93	1.13	6.75	3.20
	GMs	439.45	178.36	1,079.23	2.46	171.23	770.62	2.42
	AMs	619.95	295.32	2,844.51	3.66	423.72	785.81	1.36

		Parametric Bootstrap			Non-parametric Bootstrap			
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
	AMu	1,024.67	320.89	3,996.37	3.49	634.55	1,356.85	1.57
	P95s	981.53	680.35	14,738.75	11.06	749.17	981.53	1.31
	P95u	3,736.36	877.34	14,691.77	4.13	793.59	5,192.88	4.50
Cart	GSDs	1.39	1.16	1.66	1.20	1.14	1.56	1.20
	GMs	277.50	217.56	354.49	1.28	226.04	354.14	1.25
	AMs	291.59	226.89	372.93	1.28	228.75	377.37	1.28
	AMu	292.66	228.21	377.05	1.29	229.26	380.66	1.29
	P95s	518.81	300.03	665.71	1.65	294.81	518.81	1.76
	P95u	474.54	321.66	685.63	1.46	300.11	685.19	1.54
Handheld	GSDs	4.85	1.26	21.05	3.95	1.00	5.23	4.85
	GMs	178.86	29.09	1,060.87	6.06	29.12	510.79	2.86
	AMs	308.21	44.63	3,198.84	8.57	29.12	510.79	2.09
	AMu	621.59	54.09	25,378.68	20.91	29.12	771.78	2.97
	P95s	510.79	74.76	8,530.14	11.59	29.12	510.79	1.33
	P95u	2,399.09	115.72	45,665.72	19.99	29.12	2,985.23	6.24

Table A33. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized long dermal no hat exposure (mg/lb ai)

		Parametric Bootstrap			Non-parametric Bootstrap			
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
All	GSDs	2.30	1.74	3.05	1.32	1.50	3.21	1.49
	GMs	439.28	301.05	652.14	1.47	293.04	611.12	1.45
	AMs	549.99	391.61	974.26	1.64	417.24	680.74	1.28
	AMu	620.70	401.70	992.28	1.57	465.28	773.26	1.29
	P95s	1,063.32	938.00	5,259.09	4.18	795.20	1,063.32	1.28
	P95u	1,724.78	944.55	3,126.56	1.82	1,026.58	2,450.32	1.60
Backpack	GSDs	3.01	1.72	5.22	1.75	1.13	5.04	2.61
	GMs	550.23	256.28	1,178.12	2.14	246.13	889.21	2.09
	AMs	723.65	374.39	2,373.74	2.75	499.65	901.60	1.34
	AMu	1,010.52	398.44	2,863.57	2.67	734.07	1,209.18	1.34
	P95s	1,063.32	796.88	10,795.51	7.83	833.03	1,063.32	1.28
	P95u	3,374.46	988.50	10,766.34	3.33	929.06	4,548.20	3.46

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
Cart	GSDs	1.43	1.18	1.74	1.22	1.13	1.62	1.23
	GMs	362.80	277.86	474.50	1.31	287.41	470.42	1.28
	AMs	384.46	292.05	505.00	1.32	294.85	502.39	1.30
	AMu	386.75	294.11	512.10	1.32	295.74	507.98	1.31
	P95s	693.81	395.22	946.76	1.67	377.39	693.81	1.84
	P95u	653.27	426.55	977.86	1.52	398.89	943.41	1.57
Handheld	GSDs	2.54	1.15	6.06	2.25	1.00	2.58	2.54
	GMs	376.53	128.60	1,079.17	2.90	128.18	663.02	1.76
	AMs	473.11	155.69	1,637.27	3.25	128.18	663.02	1.60
	AMu	582.18	166.44	2,692.05	3.99	128.18	663.02	1.76
	P95s	663.02	224.76	3,703.03	4.41	128.18	663.02	1.06
	P95u	1,748.65	291.02	9,989.20	5.88	128.18	1,825.60	2.78

Table A34. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized long short dermal no hat exposure (mg/lb ai)

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
All	GSDs	2.13	1.66	2.76	1.29	1.47	2.90	1.42
	GMs	705.75	500.37	1,011.18	1.42	487.27	956.42	1.40
	AMs	854.83	624.79	1,404.29	1.54	661.85	1,042.92	1.26
	AMu	939.78	636.87	1,427.94	1.49	722.60	1,144.56	1.27
	P95s	1,643.50	1,407.71	6,760.33	3.53	1,263.05	1,643.50	1.26
	P95u	2,450.65	1,416.65	4,211.25	1.72	1,533.96	3,405.08	1.53
Backpack	GSDs	2.72	1.63	4.47	1.66	1.12	4.30	2.40
	GMs	829.09	414.85	1,652.91	2.00	400.97	1,293.45	1.94
	AMs	1,053.04	571.84	2,930.73	2.39	733.96	1,318.77	1.34
	AMu	1,365.91	602.03	3,363.57	2.37	1,044.51	1,611.86	1.26
	P95s	1,643.50	1,159.77	12,305.51	5.92	1,301.35	1,643.50	1.26
	P95u	4,289.56	1,409.87	12,275.38	2.97	1,312.18	5,761.27	3.11
Cart	GSDs	1.50	1.20	1.89	1.25	1.14	1.75	1.30
	GMs	568.80	419.49	772.76	1.36	426.25	752.96	1.33
	AMs	610.54	446.36	839.06	1.37	450.66	800.42	1.33

Group	Parameter	Estimate	Parametric Bootstrap Lower Bound	Parametric Bootstrap Upper Bound	Parametric Bootstrap Fold Relative Accuracy	Non-parametric Bootstrap Lower Bound	Non-parametric Bootstrap Upper Bound	Non-parametric Bootstrap Fold Relative Accuracy
	AMu	618.23	451.30	855.67	1.38	455.78	813.09	1.34
	P95s	1,107.11	627.19	1,700.37	1.69	650.96	1,107.11	1.70
	P95u	1,113.19	684.26	1,764.27	1.61	680.24	1,599.56	1.58
Handheld	GSDs	2.17	1.12	4.46	1.96	1.00	2.24	2.17
	GMs	759.81	311.81	1,819.05	2.42	311.77	1,263.05	1.66
	AMs	896.26	359.34	2,432.24	2.60	311.77	1,263.05	1.55
	AMu	1,025.19	378.62	3,270.78	2.92	311.77	1,263.05	1.64
	P95s	1,263.05	495.37	5,055.82	3.34	311.77	1,263.05	1.13
	P95u	2,714.14	613.70	11,510.82	4.34	311.77	2,991.55	2.44

Table A35. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized inhalation (total inhalable) concentration ((mg/m^3)/lb ai)

Group	Parameter	Estimate	Parametric Bootstrap Lower Bound	Parametric Bootstrap Upper Bound	Parametric Bootstrap Fold Relative Accuracy	Non-parametric Bootstrap Lower Bound	Non-parametric Bootstrap Upper Bound	Non-parametric Bootstrap Fold Relative Accuracy
All	GSDs	3.214	2.179	4.777	1.48	2.240	3.977	1.35
	GMs	3.963	2.331	6.902	1.72	2.321	6.624	1.69
	AMs	6.537	3.774	15.871	2.13	4.106	9.266	1.51
	AMu	7.836	3.997	16.604	2.04	4.514	11.581	1.62
	P95s	20.264	11.500	129.435	5.04	10.061	20.264	1.64
	P95u	27.049	11.612	62.361	2.32	14.583	40.947	1.70
Backpack	GSDs	3.067	1.731	5.366	1.76	1.979	3.685	1.43
	GMs	2.429	1.117	5.266	2.17	1.192	4.910	2.03
	AMs	3.842	1.649	10.860	2.54	1.775	5.950	1.80
	AMu	4.551	1.761	13.273	2.73	1.678	7.140	2.09
	P95s	8.475	3.539	50.028	4.55	6.377	8.475	1.33
	P95u	15.344	4.406	49.891	3.39	4.538	23.800	2.36
Cart	GSDs	1.699	1.273	2.278	1.34	1.299	1.940	1.26
	GMs	10.257	6.908	15.266	1.49	7.125	14.542	1.43
	AMs	11.505	7.638	17.594	1.52	7.769	15.471	1.42
	AMu	11.802	7.761	18.173	1.53	7.857	15.928	1.44
	P95s	20.264	11.644	42.490	1.92	12.334	20.264	1.64
	P95u	24.519	13.037	44.574	1.85	13.215	33.333	1.68

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
Handheld	GSDs	2.687	1.156	6.741	2.36	1.000	3.123	2.69
	GMs	1.590	0.510	4.848	3.09	0.571	4.106	2.58
	AMs	2.130	0.631	7.760	3.49	0.571	4.106	2.24
	AMu	2.592	0.678	13.893	4.47	0.571	4.106	2.57
	P95s	4.106	0.921	17.886	4.42	0.571	4.106	2.40
	P95u	8.082	1.210	51.147	6.53	0.571	13.849	4.71

Table A36. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized inhalation (total inhalable) dose (mg/lb ai)

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
All	GSDs	3.132	2.142	4.614	1.47	2.263	3.975	1.34
	GMs	3.133	1.865	5.390	1.70	1.842	5.155	1.67
	AMs	5.110	2.963	11.936	2.06	3.212	7.210	1.50
	AMu	6.012	3.127	12.401	1.99	3.363	9.026	1.65
	P95s	15.939	8.878	94.700	4.71	9.325	15.939	1.64
	P95u	20.490	8.963	46.371	2.27	10.559	31.487	1.77
Backpack	GSDs	2.501	1.566	3.953	1.59	1.588	3.133	1.49
	GMs	1.923	1.019	3.621	1.89	1.112	3.545	1.78
	AMs	2.879	1.338	5.832	2.10	1.271	5.045	2.10
	AMu	2.927	1.401	6.545	2.16	1.249	5.823	2.21
	P95s	9.747	2.616	22.843	3.36	3.720	9.747	2.62
	P95u	8.687	3.130	22.792	2.72	2.500	18.834	3.09
Cart	GSDs	1.351	1.147	1.596	1.18	1.113	1.492	1.20
	GMs	8.879	7.093	11.130	1.25	7.403	11.130	1.22
	AMs	9.265	7.352	11.622	1.26	7.447	11.736	1.25
	AMu	9.290	7.394	11.725	1.26	7.452	11.883	1.26
	P95s	15.939	9.542	19.912	1.60	9.325	15.939	1.71
	P95u	14.569	10.175	20.462	1.42	8.995	20.471	1.55
Handheld	GSDs	2.996	1.175	8.316	2.60	1.000	3.051	3.00
	GMs	1.013	0.287	3.493	3.50	0.286	1.971	1.95
	AMs	1.368	0.368	6.235	4.13	0.286	1.971	1.70

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
	AMu	1.850	0.401	13.531	5.61	0.286	1.971	1.94
	P95s	1.971	0.553	14.876	5.71	0.286	1.971	1.07
	P95u	6.159	0.749	47.756	8.02	0.286	6.485	3.33

Table A37. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized inhalation (total inhalable) time-weighted average concentration ((mg/m^3)/lb ai)

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
All	GSDs	3.132	2.142	4.614	1.47	2.263	3.975	1.34
	GMs	0.392	0.233	0.674	1.70	0.230	0.644	1.67
	AMs	0.639	0.370	1.492	2.06	0.401	0.901	1.50
	AMu	0.751	0.391	1.550	1.99	0.420	1.128	1.65
	P95s	1.992	1.110	11.837	4.71	1.166	1.992	1.64
	P95u	2.561	1.120	5.796	2.27	1.320	3.936	1.77
Backpack	GSDs	2.501	1.566	3.953	1.59	1.588	3.133	1.49
	GMs	0.240	0.127	0.453	1.89	0.139	0.443	1.78
	AMs	0.360	0.167	0.729	2.10	0.159	0.631	2.10
	AMu	0.366	0.175	0.818	2.16	0.156	0.728	2.21
	P95s	1.218	0.327	2.855	3.36	0.465	1.218	2.62
	P95u	1.086	0.391	2.849	2.72	0.313	2.354	3.09
Cart	GSDs	1.351	1.147	1.596	1.18	1.113	1.492	1.20
	GMs	1.110	0.887	1.391	1.25	0.925	1.391	1.22
	AMs	1.158	0.919	1.453	1.26	0.931	1.467	1.25
	AMu	1.161	0.924	1.466	1.26	0.931	1.485	1.26
	P95s	1.992	1.193	2.489	1.60	1.166	1.992	1.71
	P95u	1.821	1.272	2.558	1.42	1.124	2.559	1.55
Handheld	GSDs	2.996	1.175	8.316	2.60	1.000	3.051	3.00
	GMs	0.127	0.036	0.437	3.50	0.036	0.246	1.95
	AMs	0.171	0.046	0.779	4.13	0.036	0.246	1.70
	AMu	0.231	0.050	1.691	5.61	0.036	0.246	1.94
	P95s	0.246	0.069	1.860	5.71	0.036	0.246	1.07
	P95u	0.770	0.094	5.969	8.02	0.036	0.811	3.33

Table A38. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized inhalation (respirable) concentration ((mg/m³)/lb ai) using All data

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
All	GSDs	5.294	3.041	9.321	1.75	3.439	7.082	1.46
	GMs	0.446	0.209	0.984	2.17	0.209	0.937	2.11
	AMs	1.244	0.501	5.411	3.48	0.589	2.063	1.89
	AMu	1.787	0.583	6.696	3.36	0.628	3.713	2.49
	P95s	6.323	2.038	64.566	7.36	2.476	6.323	2.29
	P95u	6.911	2.067	22.768	3.32	2.341	14.089	2.54
Backpack	GSDs	4.141	2.005	8.419	2.05	1.771	6.675	2.12
	GMs	0.158	0.059	0.422	2.67	0.068	0.415	2.46
	AMs	0.432	0.106	1.339	3.74	0.092	1.004	4.03
	AMu	0.434	0.117	2.070	4.16	0.094	1.751	4.28
	P95s	2.342	0.255	7.333	7.67	0.273	2.342	8.59
	P95u	1.638	0.337	7.308	4.70	0.223	6.511	5.86
Cart	GSDs	1.966	1.361	2.858	1.45	1.398	2.445	1.37
	GMs	2.149	1.298	3.570	1.66	1.381	3.366	1.56
	AMs	2.607	1.517	4.516	1.73	1.572	4.000	1.61
	AMu	2.701	1.561	4.802	1.76	1.585	4.233	1.63
	P95s	6.323	2.527	13.173	2.36	2.759	6.323	2.29
	P95u	6.533	2.919	14.002	2.20	3.062	11.410	2.00
Handheld	GSDs	2.684	1.156	6.725	2.36	1.000	2.706	2.68
	GMs	0.179	0.058	0.546	3.09	0.057	0.322	1.79
	AMs	0.230	0.071	0.872	3.52	0.057	0.322	1.62
	AMu	0.292	0.076	1.558	4.46	0.057	0.322	1.79
	P95s	0.322	0.104	2.010	4.85	0.057	0.322	1.03
	P95u	0.909	0.136	5.741	6.51	0.057	0.931	2.91

Table A39. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized inhalation (respirable) dose (mg/lb ai) using All data

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
All	GSDs	5.255	3.025	9.227	1.75	3.718	6.371	1.34

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
	GMs	0.352	0.166	0.775	2.16	0.168	0.742	2.10
	AMs	1.030	0.395	4.198	3.32	0.495	1.650	1.83
	AMu	1.395	0.458	5.175	3.33	0.435	2.889	2.63
	P95s	4.209	1.600	49.905	8.48	2.634	4.209	1.56
	P95u	5.396	1.623	17.681	3.30	1.615	11.058	2.70
Backpack	GSDs	3.854	1.936	7.557	1.98	1.369	6.712	2.67
	GMs	0.125	0.049	0.318	2.54	0.062	0.329	2.28
	AMs	0.419	0.084	0.900	4.29	0.067	1.077	5.76
	AMu	0.311	0.092	1.309	3.74	0.067	1.778	5.31
	P95s	2.693	0.197	4.779	11.19	0.111	2.693	24.25
	P95u	1.152	0.257	4.764	4.35	0.115	6.628	9.27
Cart	GSDs	1.742	1.288	2.368	1.35	1.315	2.021	1.29
	GMs	1.861	1.230	2.822	1.52	1.274	2.731	1.46
	AMs	2.118	1.372	3.300	1.55	1.389	2.982	1.47
	AMu	2.170	1.399	3.423	1.57	1.405	3.086	1.49
	P95s	4.209	2.125	8.243	1.97	2.634	4.209	1.60
	P95u	4.635	2.392	8.666	1.91	2.393	6.848	1.79
Handheld	GSDs	1.617	1.073	2.529	1.52	1.000	1.673	1.62
	GMs	0.114	0.066	0.196	1.73	0.066	0.161	1.41
	AMs	0.122	0.070	0.220	1.77	0.066	0.161	1.35
	AMu	0.128	0.072	0.239	1.82	0.066	0.161	1.37
	P95s	0.161	0.088	0.370	2.09	0.066	0.161	1.14
	P95u	0.252	0.100	0.617	2.49	0.066	0.279	1.79

Table A40. Arithmetic mean, geometric mean, geometric standard deviation, and 95th percentiles (with 95% confidence intervals and fold relative accuracy), for different statistical models of the normalized inhalation (respirable) time-weighted average concentration ((mg/m^3)/lb ai)

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
All	GSDs	5.255	3.025	9.227	1.75	3.718	6.371	1.34
	GMs	0.044	0.021	0.097	2.16	0.021	0.093	2.10
	AMs	0.129	0.049	0.525	3.32	0.062	0.206	1.83
	AMu	0.174	0.057	0.647	3.33	0.054	0.361	2.63

			Parametric Bootstrap			Non-parametric Bootstrap		
Group	Parameter	Estimate	Lower Bound	Upper Bound	Fold Relative Accuracy	Lower Bound	Upper Bound	Fold Relative Accuracy
	P95s	0.526	0.200	6.238	8.48	0.329	0.526	1.56
	P95u	0.674	0.203	2.210	3.30	0.202	1.382	2.70
Backpack	GSDs	3.854	1.936	7.557	1.98	1.369	6.712	2.67
	GMs	0.016	0.006	0.040	2.54	0.008	0.041	2.28
	AMs	0.052	0.011	0.112	4.29	0.008	0.135	5.76
	AMu	0.039	0.011	0.164	3.74	0.008	0.222	5.31
	P95s	0.337	0.025	0.597	11.19	0.014	0.337	24.25
	P95u	0.144	0.032	0.595	4.35	0.014	0.829	9.27
Cart	GSDs	1.742	1.288	2.368	1.35	1.315	2.021	1.29
	GMs	0.233	0.154	0.353	1.52	0.159	0.341	1.46
	AMs	0.265	0.172	0.412	1.55	0.174	0.373	1.47
	AMu	0.271	0.175	0.428	1.57	0.176	0.386	1.49
	P95s	0.526	0.266	1.030	1.97	0.329	0.526	1.60
	P95u	0.579	0.299	1.083	1.91	0.299	0.856	1.79
Handheld	GSDs	1.617	1.073	2.529	1.52	1.000	1.673	1.62
	GMs	0.014	0.008	0.025	1.73	0.008	0.020	1.41
	AMs	0.015	0.009	0.028	1.77	0.008	0.020	1.35
	AMu	0.016	0.009	0.030	1.82	0.008	0.020	1.37
	P95s	0.020	0.011	0.046	2.09	0.008	0.020	1.14
	P95u	0.031	0.013	0.077	2.49	0.008	0.035	1.79

Tables A30 to A40 show that for all data combined, the study benchmark design value of 3 for the fold relative accuracy was met in every case, with the exception of the empirical 95th percentile using the parametric bootstrap for all the dermal and inhalation exposure routes and the empirical and lognormal random sampling 95th percentile and arithmetic mean using the parametric bootstrap for all the inhalation (respirable) exposure routes.

Tables A30 to A40 also show that in all cases all the statistics met the study benchmark for the Cart sprayer type. For the Backpack sprayer type, most of the benchmarks were generally not met. For the Handheld sprayer type, most of the benchmarks were not met for the parametric bootstrap but they were mostly met for the non-parametric bootstrap. This is somewhat surprising since there were only 3 MEs using a Handheld sprayer, which would typically lead to large uncertainty for that group.

Empirical Quantile Plots

Quantile-quantile plots of the normalized exposure values were used to evaluate whether the data were lognormally distributed, as implied by the assumed statistical lognormal models. These plots were intended to help determine whether the data supported using untransformed normalized exposure values or log-transformed values or neither. The plots are not intended to evaluate the fitted regression models for the un-normalized exposure to be described below, for which the residual quantile plots were developed.

In each case the quantile-quantile plot compared the observed quantiles of the measured values with the corresponding quantiles of a normal or lognormal distribution. A perfect fit would imply that the plotted values lie in a straight line. The quantile-quantile plots for all exposure routes using all 18 MEs are presented in Figures A1 to A22. Quantile-quantile plots are not presented for the sprayer type groups to avoid having a voluminous memorandum but can be made available. For the dermal exposure routes the plots in Figures A1 to A10 seem to generally show a better fit for the normal distributions, supporting the use of the untransformed dermal exposure values over the log-transformed values. However, it can also be seen that this may well have been due to one unusually low normalized dermal value which is for ME 17, which had normalized dermal exposure for different routes ranging from 18.2 mg/lb ai for hands only to 76.4 mg/lb ai for long short dermal no hat. For this reason, we also analyzed the data after excluding this potential outlier; those results are presented in the Supplement. For the inhalation exposure routes the plots in Figures A11 to A22 seem to generally show a better fit for the lognormal distributions, supporting the use of the log-transformed inhalation exposure values over the untransformed values.

Quantile plot normalized long dermal hat exposure data with a normal distribution
Normalized by Pounds Active Ingredient Handled

Group=All

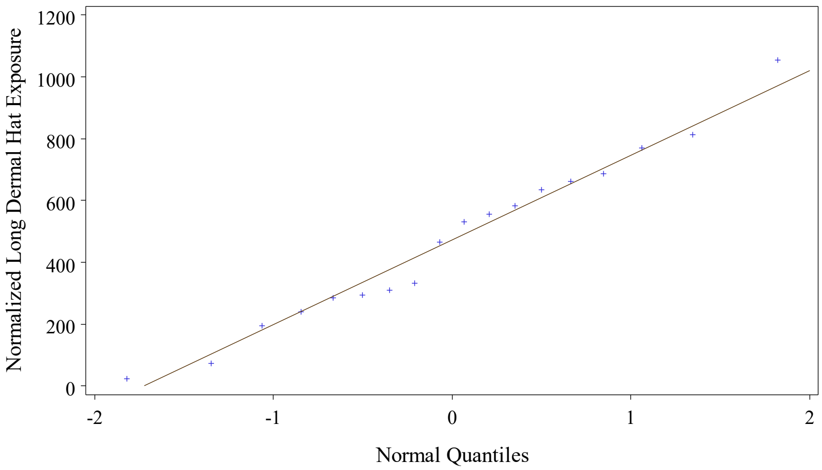


Figure A1. Empirical quantile plot for Long Dermal Hat, with a normal distribution

Quantile plot normalized long dermal hat exposure data with a lognormal distribution
Normalized by Pounds Active Ingredient Handled

Group=All

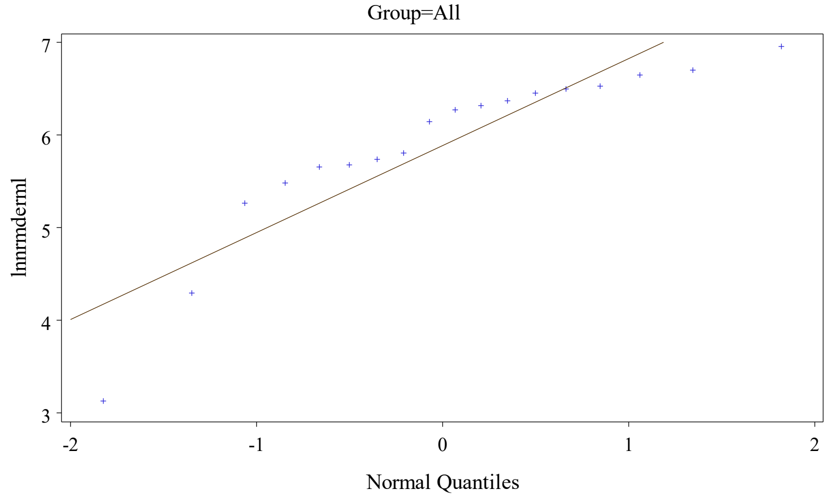


Figure A2. Empirical quantile plot for Long Dermal Hat, with a lognormal distribution

Quantile plot normalized long short dermal hat exposure data with a normal distribution
Normalized by Pounds Active Ingredient Handled
Group=All

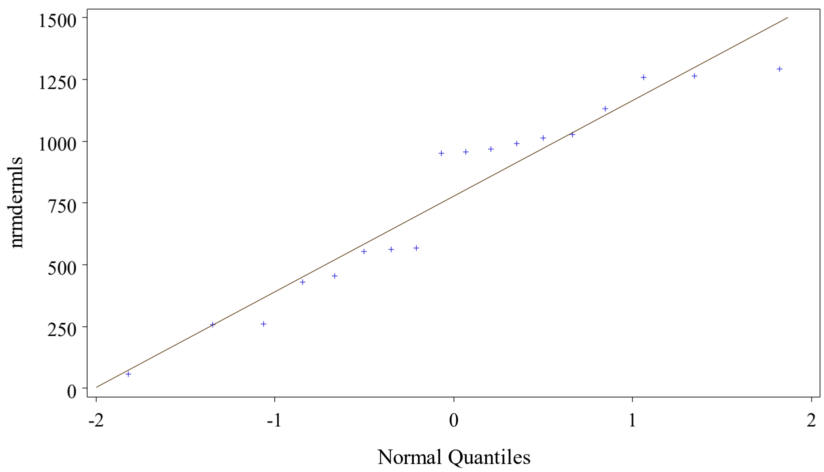


Figure A3. Empirical quantile plot for Long Short Dermal Hat, with a normal distribution

Quantile plot normalized long short dermal hat exposure data with a lognormal distribution
Normalized by Pounds Active Ingredient Handled
Group=All

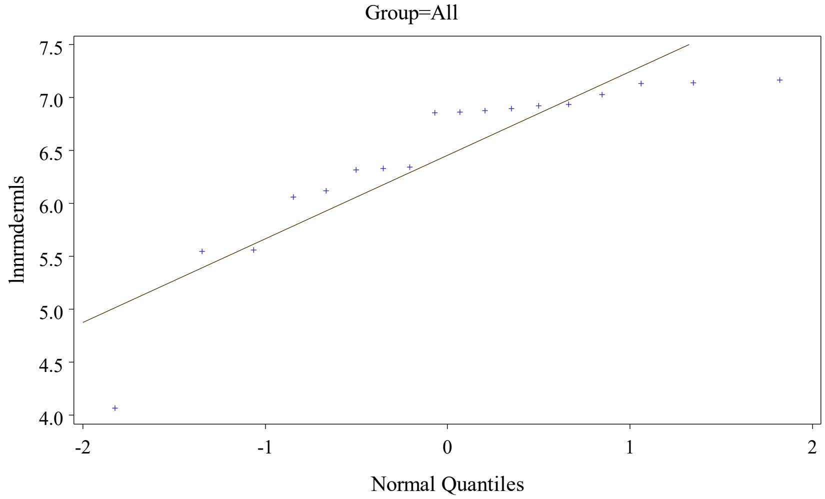


Figure A4. Empirical quantile plot for Long Short Dermal Hat, with a lognormal distribution

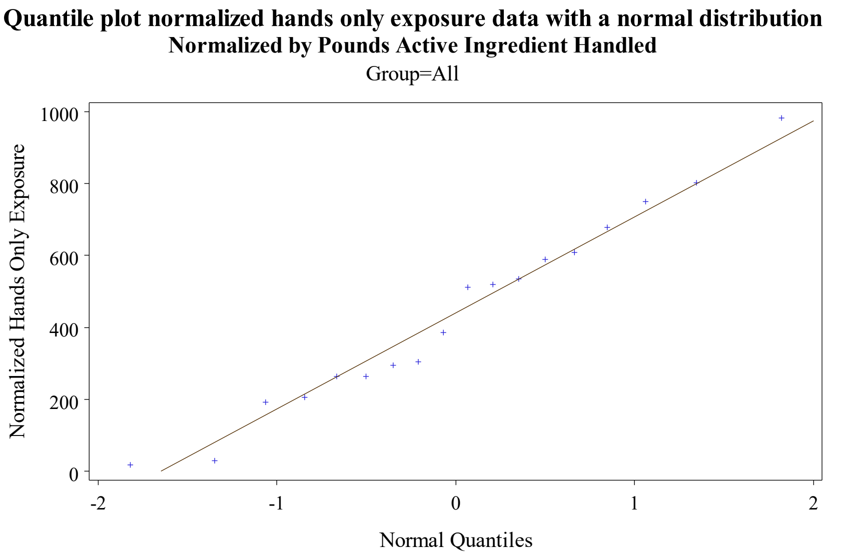


Figure A5. Empirical quantile plot for Hands Only, with a normal distribution

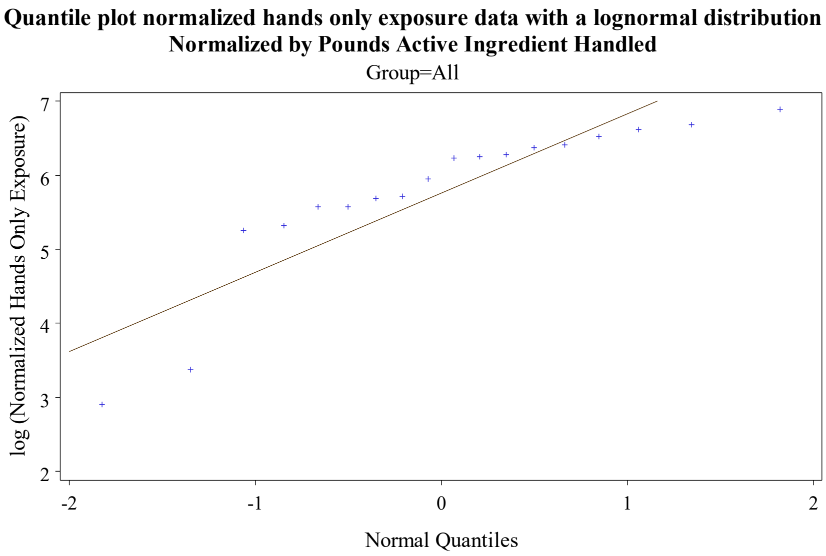


Figure A6. Empirical quantile plot for Hands Only, with a lognormal distribution

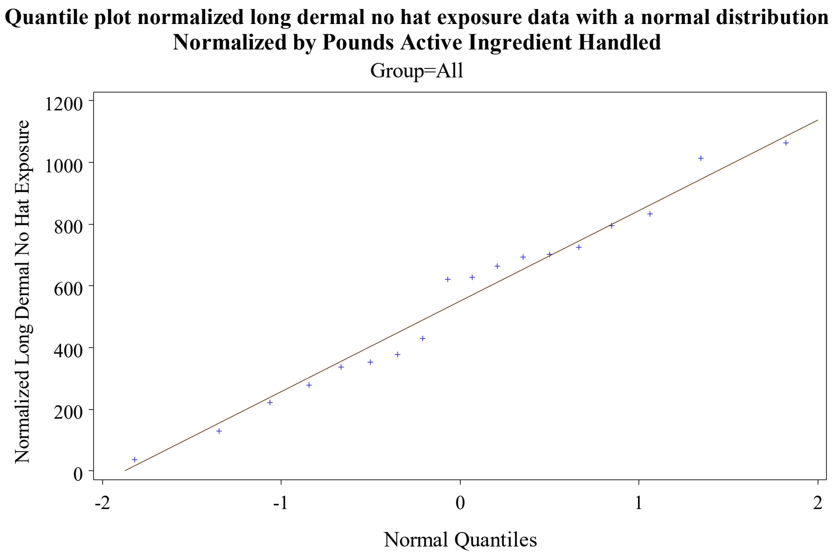


Figure A7. Empirical quantile plot for Long Dermal No Hat, with a normal distribution

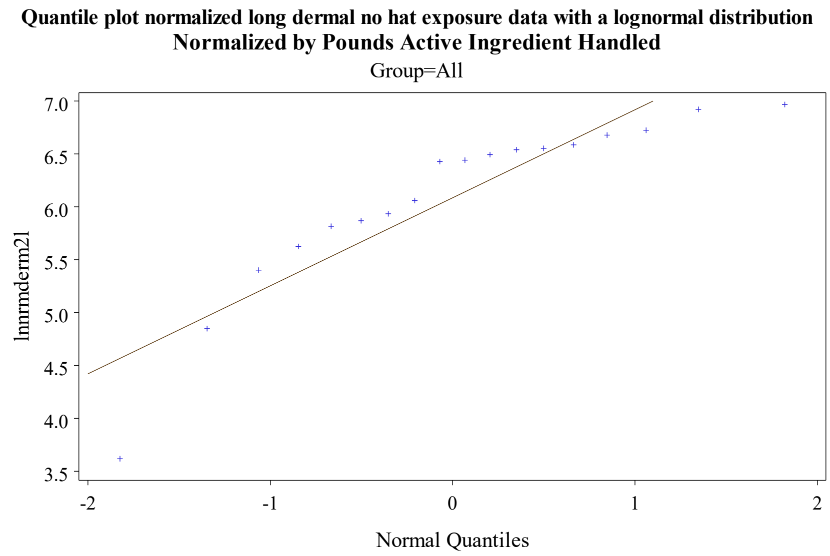


Figure A8. Empirical quantile plot for Long Dermal No Hat, with a lognormal distribution

Quantile plot normalized long short dermal no hat exposure data with a normal distribution
Normalized by Pounds Active Ingredient Handled
Group=All

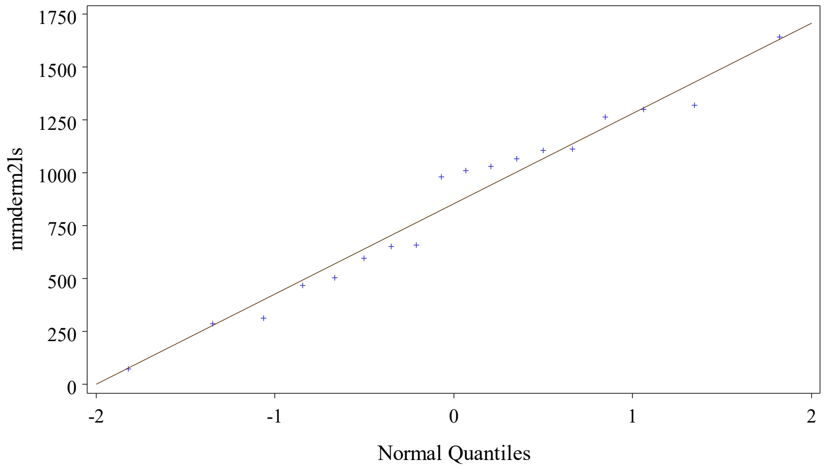


Figure A9. Empirical quantile plot for Long Short Dermal No Hat, with a normal distribution

Quantile plot normalized long short dermal no hat exposure data with a lognormal distribution
Normalized by Pounds Active Ingredient Handled
Group=All

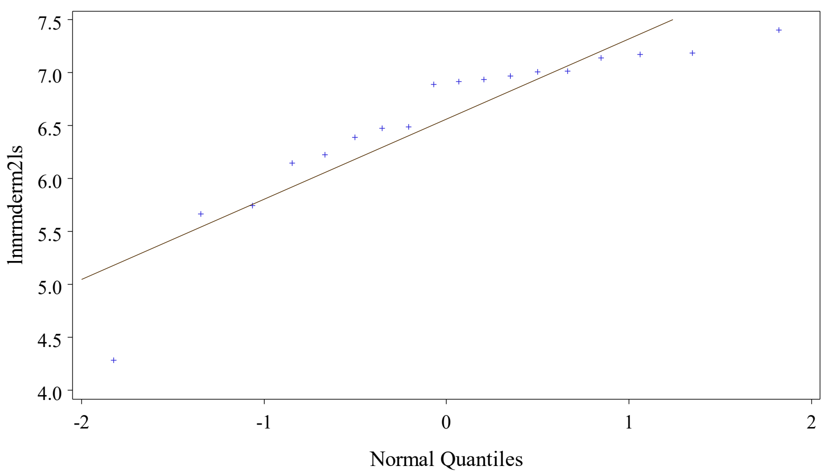


Figure A10. Empirical quantile plot for Long Short Dermal No Hat, with a lognormal distribution

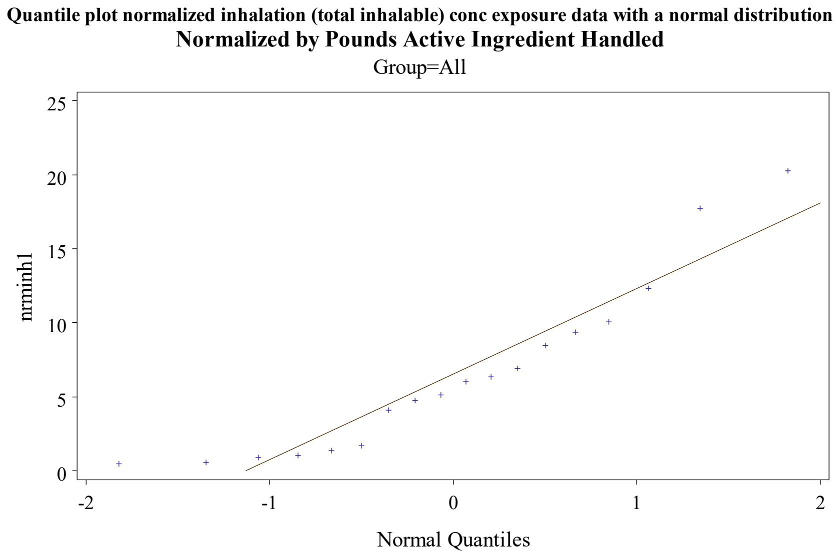


Figure A11. Empirical quantile plot for Inhalation (total inhalable) Conc, with a normal distribution

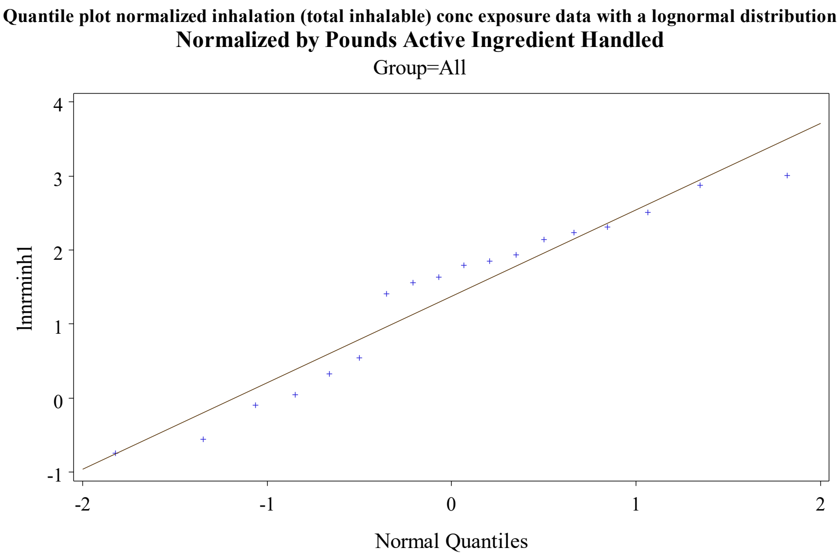


Figure A12. Empirical quantile plot for Inhalation (total inhalable) Conc, with a lognormal distribution

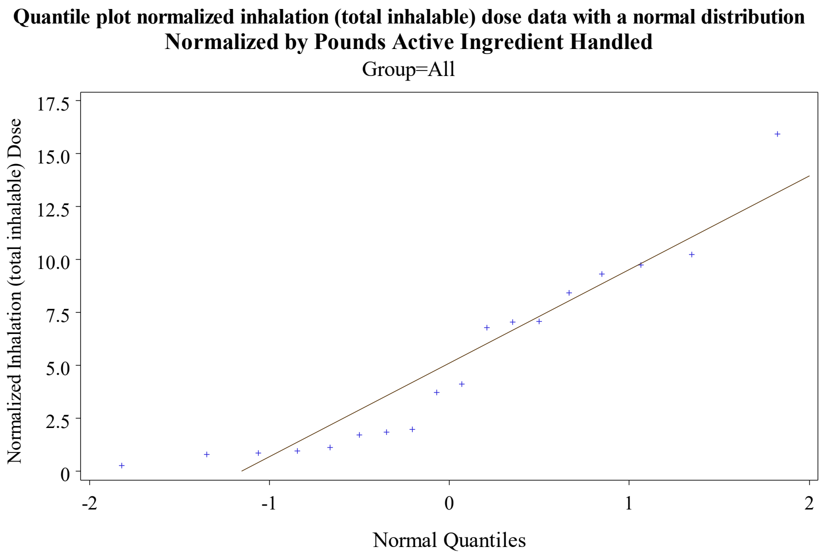


Figure A13. Empirical quantile plot for Inhalation (total inhalable) Dose, with a normal distribution

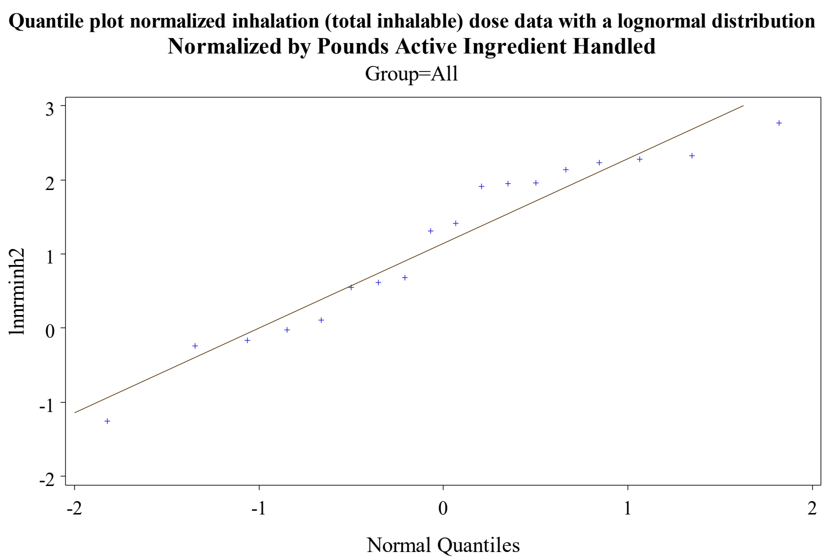


Figure A14. Empirical quantile plot for Inhalation (total inhalable) Dose, with a lognormal distribution

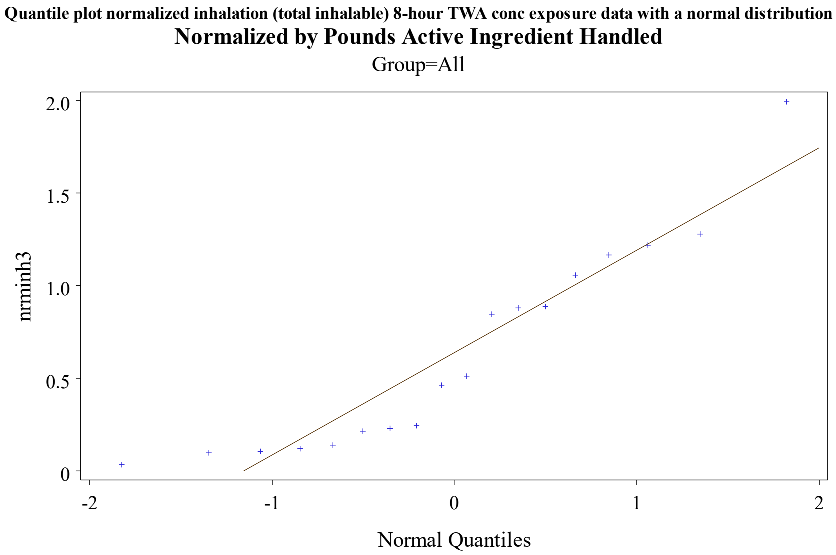


Figure A15. Empirical quantile plot for Inhalation (total inhalable) Time-Weighted Average Conc, with a normal distribution

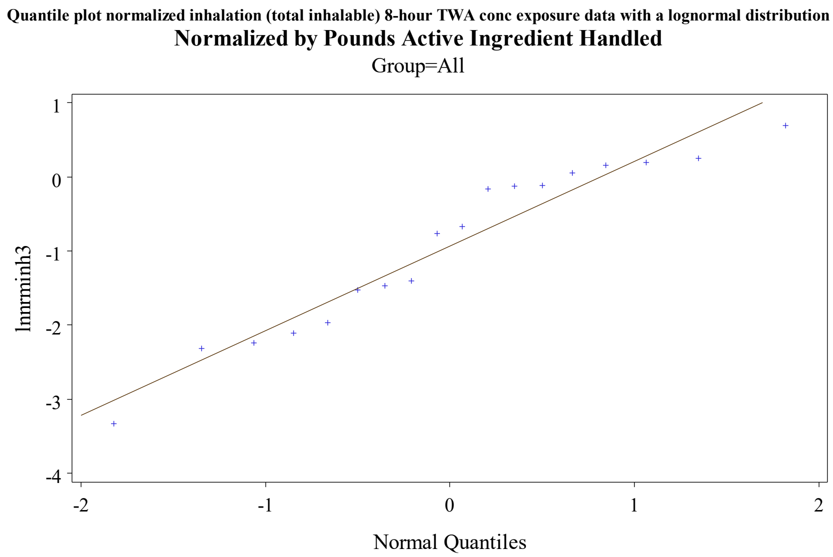


Figure A16. Empirical quantile plot for Inhalation (total inhalable) Time-Weighted Average Conc, with a lognormal distribution

Quantile plot normalized inhalation (respirable) conc exposure data with a normal distribution

Normalized by Pounds Active Ingredient Handled

Group=All

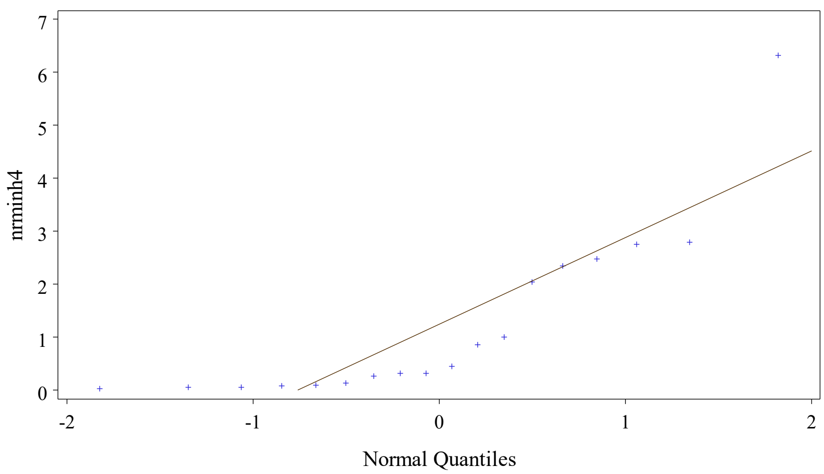


Figure A17. Empirical quantile plot for Inhalation (respirable) Conc, with a normal distribution

Quantile plot normalized inhalation (respirable) conc exposure data with a lognormal distribution

Normalized by Pounds Active Ingredient Handled

Group=All

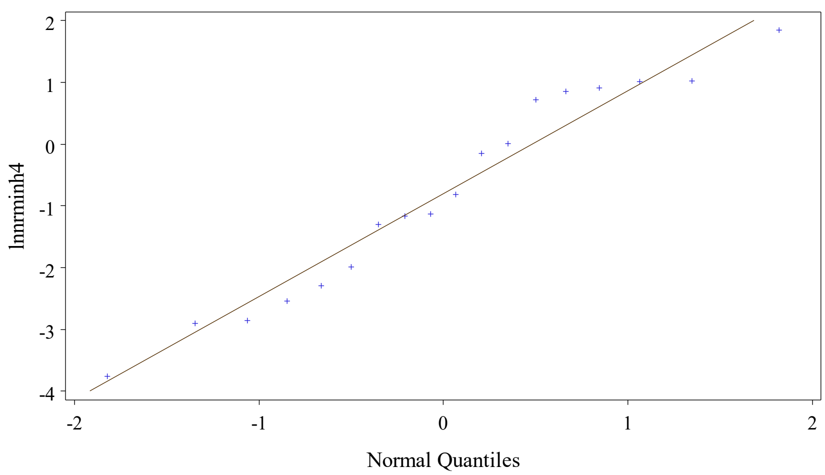


Figure A18. Empirical quantile plot for Inhalation (respirable) Conc, with a lognormal distribution

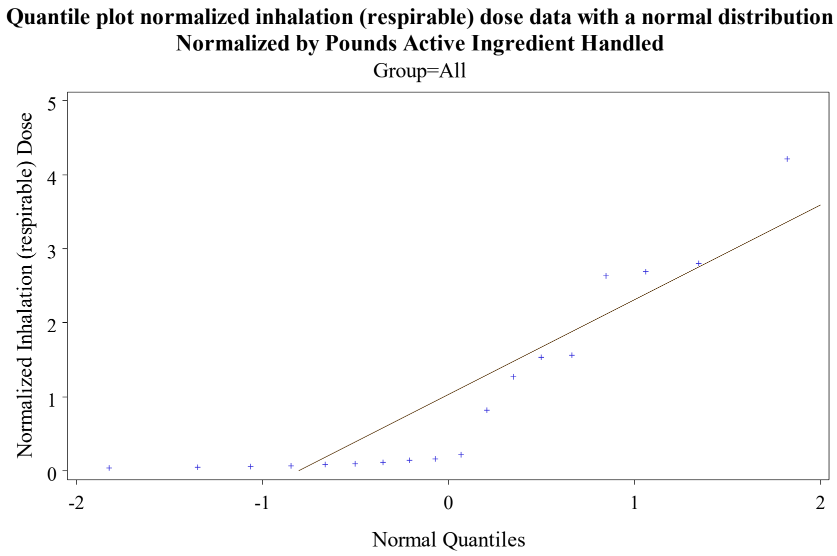


Figure A19. Empirical quantile plot for Inhalation (respirable) Dose, with a normal distribution

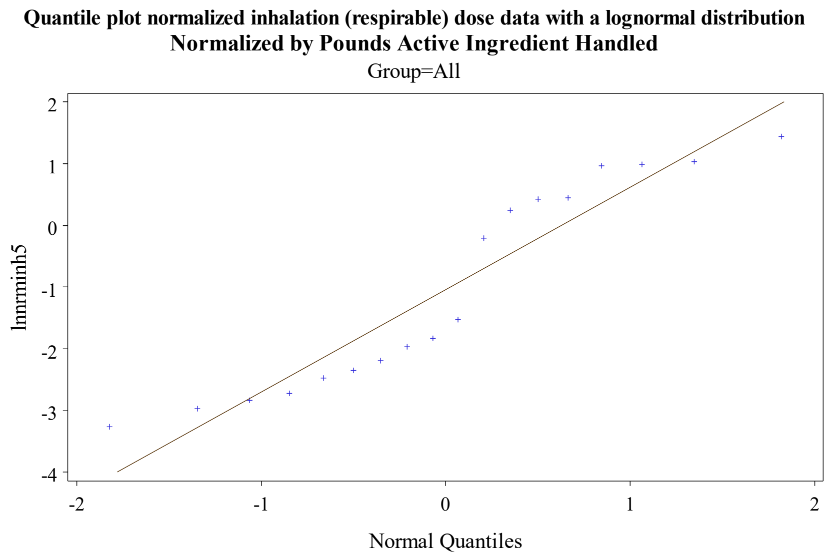


Figure A20. Empirical quantile plot for Inhalation (respirable) Dose, with a lognormal distribution

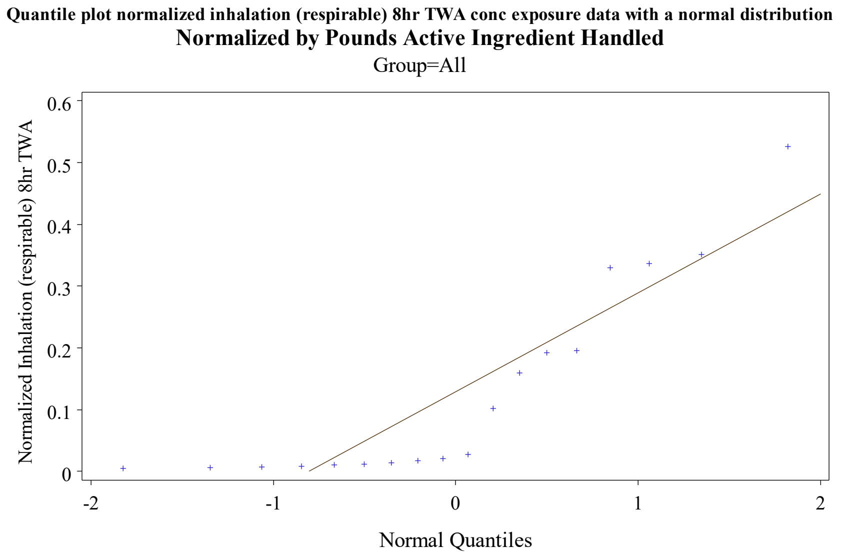


Figure A21. Empirical quantile plot for Inhalation (respirable) Time-Weighted Average Conc, with a normal distribution

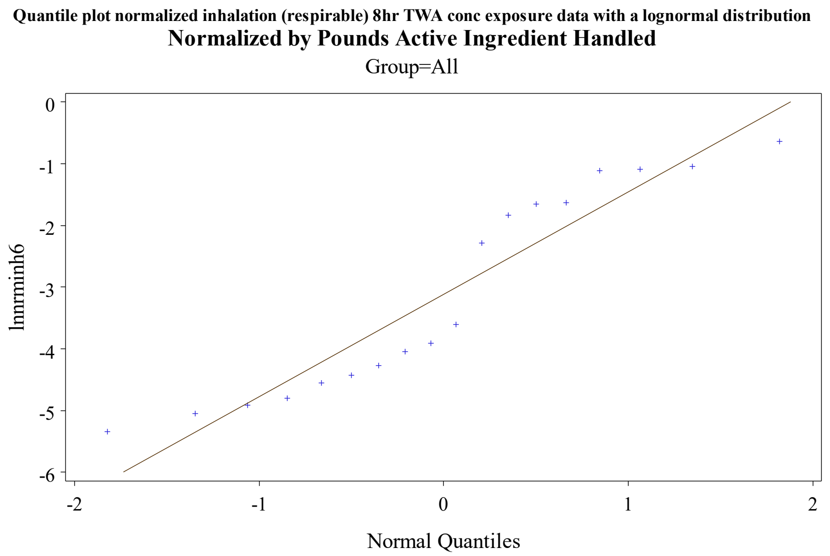


Figure A22. Empirical quantile plot for Inhalation (respirable) Time-Weighted Average Conc, with a lognormal distribution

Normality Tests

Since many of the statistical models used for these analyses assume that the normalized exposure has a lognormal distribution it is important to evaluate this assumption. In the previous section "Empirical Quantile Plots" we evaluated this assumption for all 18 MEs and found that for most dermal exposure modes, a normality assumption was preferred over a lognormality assumption, but for most inhalation exposure modes, a lognormality assumption was preferred over a normality assumption. It should be noted that the true normalized exposure distribution cannot be normal because exposure is non-negative, but it is quite possible that a normal approximation is better than a lognormal approximation for these data.

In this section, for a more quantitative evaluation of the normality or lognormality of the normalized exposure, we also applied Shapiro-Wilk normality tests either to the normalized exposure or to its logarithm. The p-values are shown in Tables A41 to A44 for all the data and separately for each of three sprayer type groups. P-values less than 0.05 for the normalized exposure are evidence against normality of the normalized exposure at the usual 5% level. P-values less than 0.05 for the logarithm of the normalized exposure are evidence against lognormality of the normalized exposure.

For all the data, Table A41 shows the following. For Long Dermal Hat there is stronger evidence for normality although lognormality is not rejected. For Long Short Dermal Hat there is stronger evidence for normality but both normality and lognormality are rejected. For Hands only, Long Dermal No Hat, and Long Short Dermal No Hat, normality is not rejected, and lognormality is rejected. For inhalation (total inhalable) conc exposure, both normality and lognormality are not rejected, but there is stronger evidence for normality. For all other inhalation exposure routes, normality is rejected, and lognormality is not rejected.

For the Backpack sprayer, Table A42 shows that normality is rejected for Long Short Dermal Hat, Long Short Dermal No Hat, and the three Inhalation (respirable) routes, and that lognormality is rejected for all the dermal routes. For the Cart sprayer, Table A43 shows that normality is rejected for Long Short Dermal Hat, Hands Only, and Inhalation (total inhalable) conc exposure, but lognormality was not rejected for any route. For the Handheld sprayer, Table A44 shows that normality and lognormality were both not rejected for every route, but this may be due to the fact that there were only 3 Handheld sprayer MEs.

It is instructive to compare these results with the corresponding Tables B41 to B44 in the Supplement. For the analyses in the Supplement, the potential outlier for ME17 that used the Backpack sprayer was deleted. Similarly to Table A41, Table B41 shows that for all the remaining 17 MEs, normality is again rejected for Long Short Dermal Hat, and Inhalation (respirable) Conc, Dose, and TWA, while lognormality is again rejected for Long Short Dermal Hat, Long Dermal No Hat, and Long Short Dermal No Hat. However, Tables B42 to B44 show that after removing the outlier, lognormality was not rejected for any exposure route. Therefore, the statistical analyses based on a lognormal model are supported if the potential outlier is deleted and separate analyses are applied to each sprayer type group.

Table A41. Shapiro-Wilk Normality tests of the normalized exposure and its logarithm. All data.

Exposure Route	Clothing	P-value for Normality Test of Normalized Exposure	P-value for Normality Test of log Normalized Exposure
Dermal (mg/lb ai)	Long Dermal Hat	> 0.15	0.12
	Long Short Dermal Hat	0.01	< 0.01
	Hands Only	> 0.15	0.04
	Long Dermal No Hat	> 0.15	0.02

Exposure Route	Clothing	P-value for Normality Test of Normalized Exposure	P-value for Normality Test of log Normalized Exposure
	Long Short Dermal No Hat	> 0.15	0.02
Inhalation (total inhalable) Conc ((mg/m^3)/lb ai)		> 0.15	0.13
Inhalation (total inhalable) Dose (mg/lb ai)		0.04	0.07
Inhalation (total inhalable) 8hr TWA ((mg/m^3)/lb ai)		0.04	0.07
Inhalation (respirable) Conc ((mg/m^3)/lb ai)		< 0.01	0.15
Inhalation (respirable) Dose (mg/lb ai)		< 0.01	0.11
Inhalation (respirable) 8hr TWA((mg/m^3)/lb ai)		< 0.01	0.11

Table A42. Shapiro-Wilk Normality tests of the normalized exposure and its logarithm. Backpack sprayer.

Exposure Route	Clothing	P-value for Normality Test of Normalized Exposure	P-value for Normality Test of log Normalized Exposure
Dermal (mg/lb ai)	Long Dermal Hat	0.06	< 0.01
	Long Short Dermal Hat	< 0.01	< 0.01
	Hands Only	0.12	< 0.01
	Long Dermal No Hat	> 0.15	< 0.01
	Long Short Dermal No Hat	0.02	< 0.01
Inhalation (total inhalable) Conc ((mg/m^3)/lb ai)		0.07	> 0.15
Inhalation (total inhalable) Dose (mg/lb ai)		0.08	> 0.15
Inhalation (total inhalable) 8hr TWA ((mg/m^3)/lb ai)		0.08	> 0.15
Inhalation (respirable) Conc ((mg/m^3)/lb ai)		< 0.01	> 0.15
Inhalation (respirable) Dose (mg/lb ai)		< 0.01	0.05
Inhalation (respirable) 8hr TWA((mg/m^3)/lb ai)		< 0.01	0.05

Table A43. Shapiro-Wilk Normality tests of the normalized exposure and its logarithm. Cart sprayer.

Exposure Route	Clothing	P-value for Normality Test of Normalized Exposure	P-value for Normality Test of log Normalized Exposure
Dermal (mg/lb ai)	Long Dermal Hat	0.06	> 0.15
	Long Short Dermal Hat	0.04	> 0.15
	Hands Only	0.04	> 0.15
	Long Dermal No Hat	> 0.15	> 0.15
	Long Short Dermal No Hat	0.09	> 0.15
Inhalation (total inhalable) Conc ((mg/m^3)/lb ai)		> 0.15	> 0.15
Inhalation (total inhalable) Dose (mg/lb ai)		> 0.15	> 0.15
Inhalation (total inhalable) 8hr TWA ((mg/m^3)/lb ai)		> 0.15	> 0.15
Inhalation (respirable) Conc ((mg/m^3)/lb ai)		0.03	> 0.15
Inhalation (respirable) Dose (mg/lb ai)		> 0.15	> 0.15
Inhalation (respirable) 8hr TWA((mg/m^3)/lb ai)		> 0.15	> 0.15

Table A44. Shapiro-Wilk Normality tests of the normalized exposure and its logarithm. Handheld sprayer.

Exposure Route	Clothing	P-value for Normality Test of Normalized Exposure	P-value for Normality Test of log Normalized Exposure
Dermal (mg/lb ai)	Long Dermal Hat	> 0.15	0.11
	Long Short Dermal Hat	> 0.15	> 0.15
	Hands Only	> 0.15	0.14
	Long Dermal No Hat	0.11	0.09
	Long Short Dermal No Hat	> 0.15	0.14
Inhalation (total inhalable) Conc ((mg/m^3)/lb ai)		> 0.15	> 0.15
Inhalation (total inhalable) Dose (mg/lb ai)		0.12	0.09
Inhalation (total inhalable) 8hr TWA ((mg/m^3)/lb ai)		0.12	0.09
Inhalation (respirable) Conc ((mg/m^3)/lb ai)		0.09	0.09
Inhalation (respirable) Dose (mg/lb ai)		> 0.15	> 0.15

Exposure Route	Clothing	P-value for Normality Test of Normalized Exposure	P-value for Normality Test of log Normalized Exposure
Inhalation (respirable) 8hr TWA((mg/m^3)/lb ai)		> 0.15	> 0.15

Log-log-Linearity Analyses and Estimated Log-log Intercepts and Slopes

The statistical analyses in this section are mainly based on the distributional assumption that the normalized exposure has a lognormal distribution. While this assumption has been generally supported for most of the previous AEATF II studies, the results of the quantile-quantile plots and normality tests presented in the last two sections for all 18 MEs tend to support a lognormal distribution for normalized inhalation exposure but not for normalized dermal exposure. As shown in the Supplement, this is generally true even after the potential outlier for ME 17 is excluded. As discussed in the last section, the normality tests in the Supplement support the assumption of lognormality for each sprayer type group after removing the potential outlier.

The use of the normalized or unit exposure is based on the assumption that the exposure is proportional to the normalizing factor. The normalizing factor for Scenario 2b is the pounds of active ingredient handled, abbreviated as AaiH or ai. Exact proportionality is defined as

Exposure = K × Normalizing Factor,

where K is the proportionality constant. Exact proportionality implies that

Normalized Exposure = Exposure / Normalizing Factor = K,

so that if the normalizing factor is doubled, then the exposure is exactly doubled, which is not a reasonable assumption due to the variability of exposure for any given value of the normalizing factor. Instead of exact proportionality we allow for random multiplicative error terms, which do not depend on the value of the normalizing factor so that

Exposure = K × Normalizing Factor × Multiplicative Errors, or

Normalized Exposure = K × Multiplicative Errors.

Since the above quantile plots generally support the assumption that the normalized exposure is lognormally distributed, we can take natural logarithms of both sides to get a log-log-linear model of the form

Log (Exposure) = Intercept + 1 × Log (Normalizing Factor) + Error Terms.

The statistical analyses of log-log-linearity, previously referred to as proportionality, is based on the following more general log-log-linear statistical model:

Linear Model

Log (Exposure) = Intercept + Slope × Log (Normalizing Factor) + Random Error.

The Random Error terms are assumed to be normally distributed with a mean of zero and a variance of Varerror. The error terms are also assumed to be independent of the Normalizing Factor, which is the explanatory variable in this regression model. The values of Intercept, Slope, and Varerror are parameters of the fitted model. This linear model is for the Exposure rather than the Normalized Exposure (Exposure / Normalizing Factor).

Using this model, taking exponentials of both sides gives

Exposure = $e^{\text{Intercept}} \times (\text{Normalizing Factor})^{\text{Slope}} \times e^{\text{Random Error}}$, so that

E{Exposure | Normalizing Factor} = Expected Exposure Given the Normalizing Factor

= C × $(\text{Normalizing Factor})^{\text{Slope}}$, where

C = Expected Value $\{e^{\text{Intercept}} \times e^{\text{Random Error}}\} = e^{\text{Intercept}} \times e^{\text{Varerror}/2}$

The value of E{Exposure | Normalizing Factor} is the arithmetic mean of the distribution of exposures for a future set of randomly selected workers that have the same value of the normalizing factor, i.e., for Scenario 2b, the same amount of active ingredient handled. The parameters Intercept and Varerror are unknown, but are estimated by fitting the linear model to the data.

Therefore, the expected exposure given the value of the Normalizing Factor will be proportional to the value of the Normalizing Factor if and only if the Slope in the linear model equals 1. Note that the proportionality constant is C, which is very different to the estimated value of Slope.

Lognormal Model

If the value of Slope in the linear model is 1, then

Log (Exposure) = Intercept + 1 × Log (Normalizing Factor) + Random Error,

so that

Log (Normalized Exposure) = Log(Exposure / Normalizing Factor)

= Intercept + Random Error,

This statistical model is exactly the same as the lognormal simple random sampling model that was defined above.

The same calculations that we used for the linear model give

E{Exposure | Normalizing Factor} = Expected Exposure Given the Normalizing Factor

= C* × (Normalizing Factor), where

C* = Expected Value $\{e^{\text{Intercept*} \times \text{Random Error}}\} = e^{\text{Intercept*}} \times e^{\text{Varerror*}/2}$

These parameters are shown with asterisks to emphasize that they will in general be different from the ones for the model with a slope parameter not necessarily equal to 1.

Test for log-log-linearity with slope 1

Proportionality, or log-log-linearity with slope 1, of exposure to the Normalizing Factor is statistically modeled by assuming a Slope equal to 1 in the linear model.

Possible alternative models include the same formulation with a slope of zero, implying that the exposure does not depend upon the value of the normalizing factor, even though the normalizing factor varied between the subjects as part of the study design. Other possible models include the same model with a slope not equal to zero or one, the quadratic models discussed below, or models with more complicated relationships between the exposure and the experimental conditions. To evaluate and test whether the slope is zero, one, or other possible values, we fitted the above linear model and computed confidence intervals for the intercept and slope.

Table A45 (all MEs) and Tables A46 to A48 (by sprayer type) show the 95% confidence intervals for the slope calculated from the above linear model. Table A49 (all MEs) and Tables A50 to A52 (by sprayer type) show the 95% confidence intervals for the intercept calculated from the above linear model. The confidence intervals for the Handheld sprayers are very wide because they were based on only 3 MEs but have been included for completeness. A confidence interval for the slope that includes one but not zero supports the use of unit exposures. A confidence interval for the slope that includes zero but not one suggests that the exposure does not depend on the normalizing factor. A confidence interval for the slope that includes both zero and one suggests that either the basic statistical model is incorrect or there are not enough data to statistically infer whether the slope is zero or one. The table also shows the values of the threshold ai and the corresponding estimated exposure, to be described and discussed In the Supplement. Threshold values were not computed for the censored data models.

There were several non-detects reported in the data for both dermal and inhalation exposure. The rows marked "Substitute mid value" calculate the slope estimates after replacing each non-detect residue by the midpoint of the lowest and highest possible value for that residue. The rows marked "Censored data MLE" calculate the slope estimates for the linear model using a censored maximum likelihood statistical method and the lower and upper bounds for each non-detect. This procedure was implemented using the LIFEREG SAS procedure.

Table A45. 95 percent confidence intervals for the slope of log exposure versus the log of the normalizing factor. All data.

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper	Threshold	Exposure
Long Dermal Hat (mg)	Substitute mid value	1.08	0.65	1.51	0.00046	0.25630
	Censored data MLE	1.08	0.71	1.45		
Long Short Dermal Hat (mg)	Substitute mid value	1.02	0.66	1.38	0.00018	0.15749
	Censored data MLE	1.02	0.70	1.33		
Hands Only (mg)	Substitute mid value	1.13	0.64	1.61	0.00050	0.28191
	Censored data MLE	1.13	0.71	1.55		
Long Dermal No Hat (mg)	Substitute mid value	1.06	0.68	1.44	0.00044	0.27387
	Censored data MLE	1.06	0.73	1.39		

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper	Threshold	Exposure
Long Short Dermal No Hat (mg)	Substitute mid value	1.01	0.66	1.35	0.00005	0.04513
	Censored data MLE	1.01	0.70	1.31		
Inhalation (total inhalable) Conc (mg/m^3)	Substitute mid value	0.64	0.14	1.14	0.00053	0.00415
	Censored data MLE	0.62	0.20	1.05		
Inhalation (total inhalable) Dose (mg)	Substitute mid value	1.05	0.53	1.57	0.00028	0.00168
	Censored data MLE	1.04	0.59	1.49		
Inhalation (total inhalable) 8hr TWA (mg/m^3)	Substitute mid value	1.05	0.53	1.57	0.00028	0.00021
	Censored data MLE	1.04	0.59	1.49		
Inhalation (respirable) Conc (mg/m^3)	Substitute mid value	0.49	−0.22	1.21	0.00050	0.00090
	Censored data MLE	0.49	−0.13	1.11		
Inhalation (respirable) Dose (mg)	Substitute mid value	0.90	0.14	1.66	0.00136	0.00189
	Censored data MLE	0.90	0.24	1.56		
Inhalation respirable) 8hr TWA (mg/m^3)	Substitute mid value	0.90	0.14	1.66	0.00136	0.00024
	Censored data MLE	0.90	0.24	1.56		

Table A46. 95 percent confidence intervals for the slope of log exposure versus the log of the normalizing factor. Type Backpack.

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper	Threshold	Exposure
Long Dermal Hat (mg)	Substitute mid value	0.75	−0.45	1.95	0.00148	1.50991
	Censored data MLE	0.75	−0.09	1.58		
Long Short Dermal Hat (mg)	Substitute mid value	0.66	−0.32	1.65	0.00112	1.48250
	Censored data MLE	0.66	−0.02	1.35		
Hands Only (mg)	Substitute mid value	0.74	−0.52	2.00	0.00154	1.57503
	Censored data MLE	0.74	−0.13	1.62		

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper	Threshold	Exposure
Long Dermal No Hat (mg)	Substitute mid value	0.77	−0.30	1.83	0.00139	1.40591
	Censored data MLE	0.77	0.03	1.50		
Long Short Dermal No Hat (mg)	Substitute mid value	0.67	−0.26	1.60	0.00110	1.50258
	Censored data MLE	0.67	0.02	1.32		
Inhalation (total inhalable) Conc (mg/m^3)	Substitute mid value	0.40	−0.53	1.33	0.00086	0.00394
	Censored data MLE	0.40	−0.25	1.04		
Inhalation (total inhalable) Dose (mg)	Substitute mid value	0.91	0.01	1.82	0.00223	0.00652
	Censored data MLE	0.91	0.29	1.54		
Inhalation (total inhalable) 8hr TWA (mg/m^3)	Substitute mid value	0.91	0.01	1.82	0.00223	0.00081
	Censored data MLE	0.91	0.29	1.54		
Inhalation (respirable) Conc (mg/m^3)	Substitute mid value	0.58	−0.76	1.93	0.00122	0.00053
	Censored data MLE	0.58	−0.35	1.52		
Inhalation (respirable) Dose (mg)	Substitute mid value	1.10	−0.23	2.43	0.00024	0.00007
	Censored data MLE	1.10	0.18	2.02		
Inhalation respirable) 8hr TWA (mg/m^3)	Substitute mid value	1.10	−0.23	2.43	0.00024	0.00001
	Censored data MLE	1.10	0.18	2.02		

Table A47. 95 percent confidence intervals for the slope of log exposure versus the log of the normalizing factor. Type Cart.

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper	Threshold	Exposure
Long Dermal Hat (mg)	Substitute mid value	1.03	0.73	1.34	0.00037	0.11748
	Censored data MLE	1.03	0.84	1.23		
Long Short Dermal Hat (mg)	Substitute mid value	1.10	0.75	1.45	0.00046	0.25113
	Censored data MLE	1.09	0.87	1.31		
Hands Only (mg)	Substitute mid value	1.00	0.70	1.31	0.00002	0.00604

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper	Threshold	Exposure
	Censored data MLE	1.00	0.81	1.20		
Long Dermal No Hat (mg)	Substitute mid value	1.06	0.73	1.39	0.00042	0.16072
	Censored data MLE	1.06	0.85	1.27		
Long Short Dermal No Hat (mg)	Substitute mid value	1.11	0.75	1.47	0.00046	0.28617
	Censored data MLE	1.10	0.87	1.33		
Inhalation (total inhalable) Conc (mg/m^3)	Substitute mid value	0.66	0.36	0.96	0.00086	0.00394
	Censored data MLE	0.66	0.46	0.86		
Inhalation (total inhalable) Dose (mg)	Substitute mid value	1.14	0.91	1.37	0.00052	0.00485
	Censored data MLE	1.14	0.99	1.29		
Inhalation (total inhalable) 8hr TWA (mg/m^3)	Substitute mid value	1.14	0.91	1.37	0.00052	0.00061
	Censored data MLE	1.14	0.99	1.29		
Inhalation (respirable) Conc (mg/m^3)	Substitute mid value	0.69	0.17	1.22	0.00043	0.00116
	Censored data MLE	0.69	0.36	1.03		
Inhalation (respirable) Dose (mg)	Substitute mid value	1.17	0.69	1.65	0.00048	0.00104
	Censored data MLE	1.17	0.86	1.48		
Inhalation respirable) 8hr TWA (mg/m^3)	Substitute mid value	1.17	0.69	1.65	0.00048	0.00013
	Censored data MLE	1.17	0.86	1.48		

Table A48. 95 percent confidence intervals for the slope of log exposure versus the log of the normalizing factor. Type Handheld.

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper	Threshold	Exposure
Long Dermal Hat (mg)	Substitute mid value	1.78	−12.50	16.05	0.00018	0.08719
	Censored data MLE	1.78	0.50	3.05		
Long Short Dermal Hat (mg)	Substitute mid value	1.61	−8.48	11.70	0.00021	0.18650

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper	Threshold	Exposure
	Censored data MLE	1.61	0.71	2.50		
Hands Only (mg)	Substitute mid value	2.15	−17.74	22.05	0.00017	0.10742
	Censored data MLE	2.15	0.38	3.93		
Long Dermal No Hat (mg)	Substitute mid value	1.63	−10.65	13.90	0.00018	0.10403
	Censored data MLE	1.63	0.53	2.72		
Long Short Dermal No Hat (mg)	Substitute mid value	1.56	−8.26	11.38	0.00020	0.20621
	Censored data MLE	1.56	0.69	2.43		
Inhalation (total inhalable) Conc (mg/m^3)	Substitute mid value	1.11	−14.31	16.52	0.00000	0.00001
	Censored data MLE	1.03	−0.32	2.37		
Inhalation (total inhalable) Dose (mg)	Substitute mid value	1.74	−12.68	16.15	0.00017	0.00031
	Censored data MLE	1.64	0.43	2.85		
Inhalation (total inhalable) 8hr TWA (mg/m^3)	Substitute mid value	1.74	−12.68	16.15	0.00017	0.00004
	Censored data MLE	1.64	0.43	2.85		
Inhalation (respirable) Conc (mg/m^3)	Substitute mid value	−0.22	−0.33	−0.11	0.00016	0.00005
	Censored data MLE	−0.22	−0.23	−0.21		
Inhalation (respirable) Dose (mg)	Substitute mid value	0.41	−0.48	1.30	0.00020	0.00003
	Censored data MLE	0.41	0.33	0.49		
Inhalation respirable) 8hr TWA (mg/m^3)	Substitute mid value	0.41	−0.48	1.30	0.00020	0.00000
	Censored data MLE	0.41	0.33	0.49		

Table A49. 95 percent confidence intervals for the intercept of the regression model for log exposure versus the log of the normalizing factor. All data.

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper
Long Dermal Hat (mg)	Substitute mid value	6.49	3.29	9.69
	Censored data MLE	6.49	3.70	9.28

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper
Long Short Dermal Hat (mg)	Substitute mid value	6.57	3.87	9.27
	Censored data MLE	6.57	4.21	8.93
Hands Only (mg)	Substitute mid value	6.70	3.07	10.33
	Censored data MLE	6.70	3.54	9.87
Long Dermal No Hat (mg)	Substitute mid value	6.53	3.69	9.37
	Censored data MLE	6.53	4.05	9.00
Long Short Dermal No Hat (mg)	Substitute mid value	6.61	4.02	9.21
	Censored data MLE	6.61	4.35	8.88
Inhalation (total inhalable) Conc (mg/m^3)	Substitute mid value	−1.28	−5.02	2.46
	Censored data MLE	−1.39	−4.58	1.79
Inhalation (total inhalable) Dose (mg)	Substitute mid value	1.51	-2.39	5.42
	Censored data MLE	1.42	−1.94	4.79
Inhalation (total inhalable) 8hr TWA (mg/m^3)	Substitute mid value	−0.56	−4.47	3.34
	Censored data MLE	−0.65	−4.02	2.71
Inhalation (respirable) Conc (mg/m^3)	Substitute mid value	−4.57	−9.91	0.78
	Censored data MLE	−4.57	-9.23	0.09
Inhalation (respirable) Dose (mg)	Substitute mid value	−1.77	−7.45	3.90
	Censored data MLE	−1.77	−6.72	3.17
Inhalation respirable) 8hr TWA (mg/m^3)	Substitute mid value	−3.85	−9.53	1.82
	Censored data MLE	−3.85	−8.80	1.09

Table A50. 95 percent confidence intervals for the intercept of the regression model for log exposure versus the log of the normalizing factor. Type Backpack.

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper
Long Dermal Hat (mg)	Substitute mid value	4.42	-3.89	12.74
	Censored data MLE	4.42	−1.35	10.19
Long Short Dermal Hat (mg)	Substitute mid value	4.34	−2.47	11.14
	Censored data MLE	4.34	−0.38	9.06
Hands Only (mg)	Substitute mid value	4.31	−4.44	13.06
	Censored data MLE	4.31	−1.76	10.38
Long Dermal No Hat (mg)	Substitute mid value	4.70	−2.69	12.09
	Censored data MLE	4.70	−0.43	9.82
Long Short Dermal No Hat (mg)	Substitute mid value	4.46	−2.01	10.92
	Censored data MLE	4.46	−0.03	8.94
Inhalation (total inhalable) Conc (mg/m^3)	Substitute mid value	−3.25	−9.71	3.21
	Censored data MLE	−3.25	−7.73	1.23
Inhalation (total inhalable) Dose (mg)	Substitute mid value	0.06	−6.20	6.32
	Censored data MLE	0.06	−4.28	4.41
Inhalation (total inhalable) 8hr TWA (mg/m^3)	Substitute mid value	−2.02	−8.28	4.25
	Censored data MLE	−2.02	−6.36	2.33
Inhalation (respirable) Conc (mg/m^3)	Substitute mid value	−4.70	−14.02	4.61
	Censored data MLE	−4.70	−11.16	1.76
Inhalation (respirable) Dose (mg)	Substitute mid value	−1.39	−10.62	7.84
	Censored data MLE	−1.39	−7.80	5.01
Inhalation respirable) 8hr TWA (mg/m^3)	Substitute mid value	−3.47	−12.70	5.76
	Censored data MLE	−3.47	−9.88	2.93

Table A51. 95 percent confidence intervals for the intercept of the regression model for log exposure versus the log of the normalizing factor. Type Cart.

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper
Long Dermal Hat (mg)	Substitute mid value	5.96	3.64	8.28
	Censored data MLE	5.97	4.47	7.46
Long Short Dermal Hat (mg)	Substitute mid value	6.98	4.27	9.68
	Censored data MLE	6.92	5.22	8.62
Hands Only (mg)	Substitute mid value	5.65	3.31	8.00
	Censored data MLE	5.65	4.14	7.16
Long Dermal No Hat (mg)	Substitute mid value	6.34	3.82	8.85
	Censored data MLE	6.34	4.71	7.96
Long Short Dermal No Hat (mg)	Substitute mid value	7.15	4.37	9.93
	Censored data MLE	7.11	5.35	8.87
Inhalation (total inhalable) Conc (mg/m^3)	Substitute mid value	−0.26	−2.60	2.08
	Censored data MLE	−0.26	−1.77	1.25
Inhalation (total inhalable) Dose (mg)	Substitute mid value	3.24	1.45	5.02
	Censored data MLE	3.24	2.09	4.39
Inhalation (total inhalable) 8hr TWA (mg/m^3)	Substitute mid value	1.16	-0.63	2.94
	Censored data MLE	1.16	0.01	2.31
Inhalation (respirable) Conc (mg/m^3)	Substitute mid value	−1.57	−5.60	2.46
	Censored data MLE	−1.57	−4.17	1.02
Inhalation (respirable) Dose (mg)	Substitute mid value	1.93	−1.76	5.62
	Censored data MLE	1.93	−0.45	4.30
Inhalation respirable) 8hr TWA (mg/m^3)	Substitute mid value	−0.15	−3.84	3.54
	Censored data MLE	−0.15	−2.53	2.22

Table A52. 95 percent confidence intervals for the intercept of the regression model for log exposure versus the log of the normalizing factor. Type Handheld.

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper
Long Dermal Hat (mg)	Substitute mid value	12.05	−07.46	131.55
	Censored data MLE	12.05	1.41	22.69
Long Short Dermal Hat (mg)	Substitute mid value	11.54	−72.92	96.00
	Censored data MLE	11.54	4.02	19.06
Hands Only (mg)	Substitute mid value	14.82	−151.69	181.33
	Censored data MLE	14.82	−0.01	29.65
Long Dermal No Hat (mg)	Substitute mid value	11.15	−91.58	113.87
	Censored data MLE	11.15	2.00	20.30
Long Short Dermal No Hat (mg)	Substitute mid value	11.30	−70.87	93.47
	Censored data MLE	11.30	3.98	18.62
Inhalation (total inhalable) Conc (mg/m^3)	Substitute mid value	1.36	−127.70	130.41
	Censored data MLE	0.76	−10.39	11.92
Inhalation (total inhalable) Dose (mg)	Substitute mid value	6.15	−114.54	126.84
	Censored data MLE	5.43	−4.62	15.47
Inhalation (total inhalable) 8hr TWA (mg/m^3)	Substitute mid value	4.07	−116.62	124.76
	Censored data MLE	3.35	−6.70	13.40
Inhalation (respirable) Conc (mg/m^3)	Substitute mid value	−11.87	−12.79	−10.95
	Censored data MLE	−11.87	−11.95	−11.79
Inhalation (respirable) Dose (mg)	Substitute mid value	−7.08	−14.53	0.37
	Censored data MLE	−7.08	−7.74	−6.41
Inhalation respirable) 8hr TWA (mg/m^3)	Substitute mid value	−9.16	−16.61	−1.70

Exposure Route	Treatment of Non-detects	Estimate	Lower	Upper
	Censored data MLE	−9.16	−9.82	−8.49

For all 18 MEs, the slopes ranged from 0.49 to 1.13, and the confidence intervals for the slope excluded 0 and included 1, except for the inhalation (respirable) concentration where the interval included both 0 and 1. Thus in all but one case, the assumption of log-log-linearity with slope 1 was supported.

For the Backpack sprayer, the slopes ranged from 0.40 to 1.10 and the confidence intervals either included both 0 and 1 or included 1 but not 0. Thus, the assumption of log-log-linearity was either supported or not rejected.

For the Cart sprayer, the slopes ranged from 0.69 to 1.17 and in all cases but one the confidence intervals included 1 but not 0, supporting the assumption of log-log-linearity. As an exception, for inhalation (total inhalable) concentration the confidence interval excluded both 0 and 1, supporting neither proportionality nor independence.

For the Handheld sprayer the small sample size of only 3 MEs led to a mixture of results, with slopes that ranged from −0.22 (for the inhalation (total inhalable) concentration) to 1.74 and confidence intervals that sometimes supported and sometimes rejected the proportionality or independence assumptions.

Quantile plots for residuals

To evaluate the fitted linear regression models we created quantile-quantile[1] plots of the studentized residuals for each fitted model. To avoid a voluminous report, these plots are only presented for the models fitted to all the data. The residual is the observed value of log exposure minus the predicted value. The studentized residual is the residual divided by its standard error. For these analyses we used the internally studentized residual where the estimated standard error is calculated using all the data. An alternative approach that is sometimes preferred when checking for outliers in small samples is to use the externally studentized residual where the estimated standard error is calculated after excluding the data point. If the plotted points lie close to the straight line, then the model assumptions for the linear model are supported. Furthermore, a standard rule of thumb identifies statistical outliers as cases where the studentized residual is above +3 or below −3 (a stricter criterion of ±2 is sometimes used, and more complex statistical outlier tests taking into account the sample size are also available). These quantile-quantile plots are for the Linear Model. Quantile-quantile plots for the Lognormal Model were presented in the even-numbered Figures A1 to A22 above, since in that case both the predicted values and the standard errors are the same for every ME. The quantile-quantile plots of the studentized residuals for the models fitted to all the data for each exposure route are shown below in Figures A23 to A33.

[1] These quantile plots compare the distribution of the studentized residuals to a standard normal distribution. Some authors prefer a more exact approach where the distribution of the studentized residuals is compared to a t distribution. That method is not easily available using current SAS software.

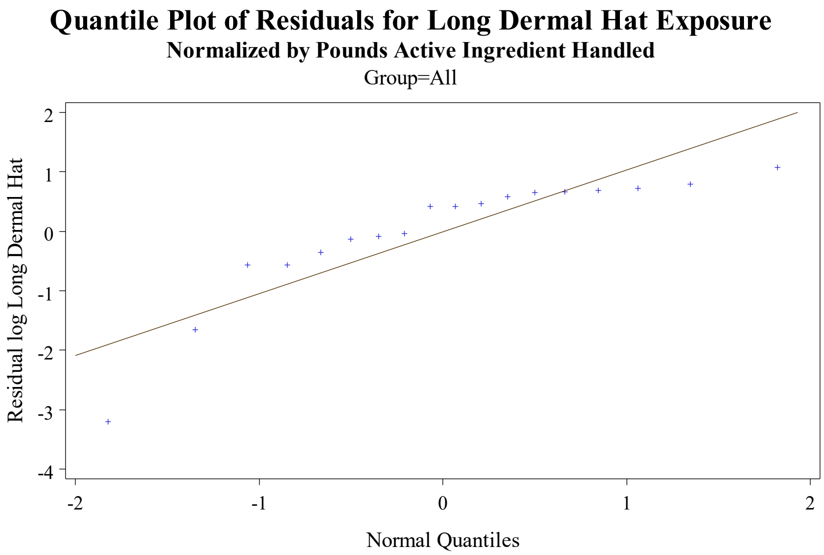


Figure A23. Quantile plot of residuals from linear model for Long Dermal Hat

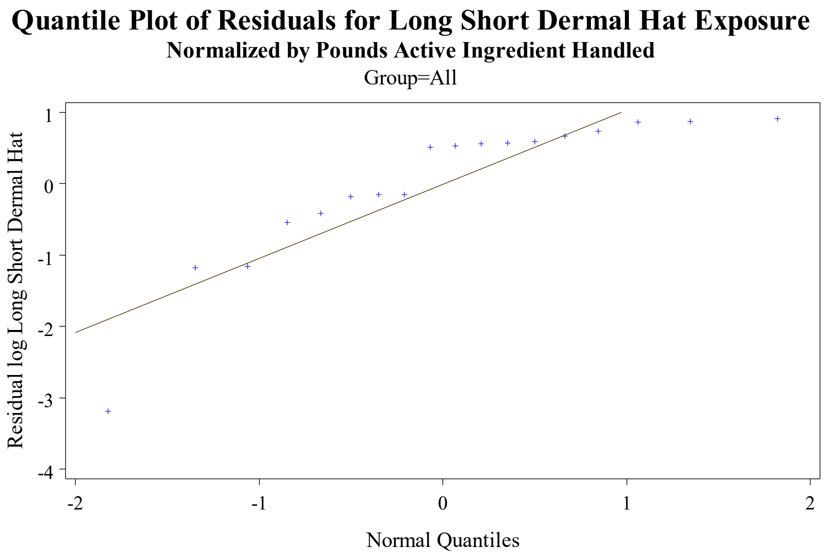


Figure A24. Quantile plot of residuals from linear model for Long Short Dermal Hat

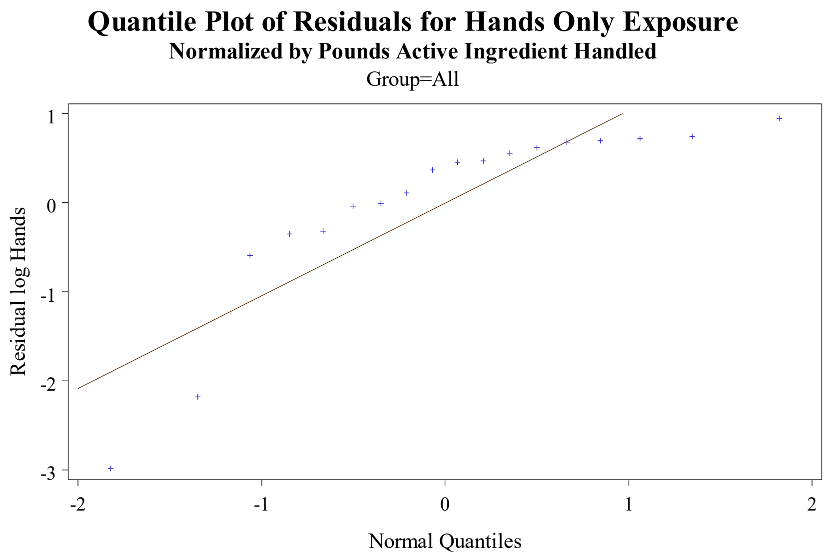


Figure A25. Quantile plot of residuals from linear model for Hands Only

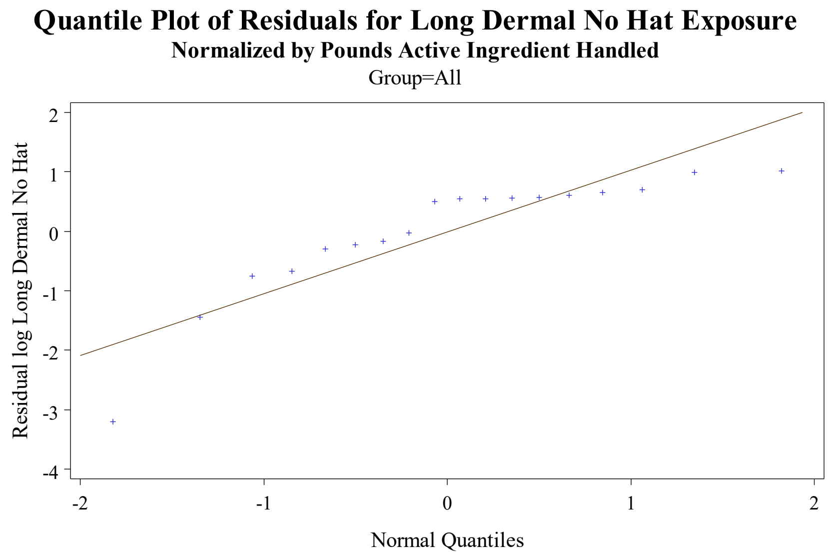


Figure A26. Quantile plot of residuals from linear model for Long Dermal No Hat

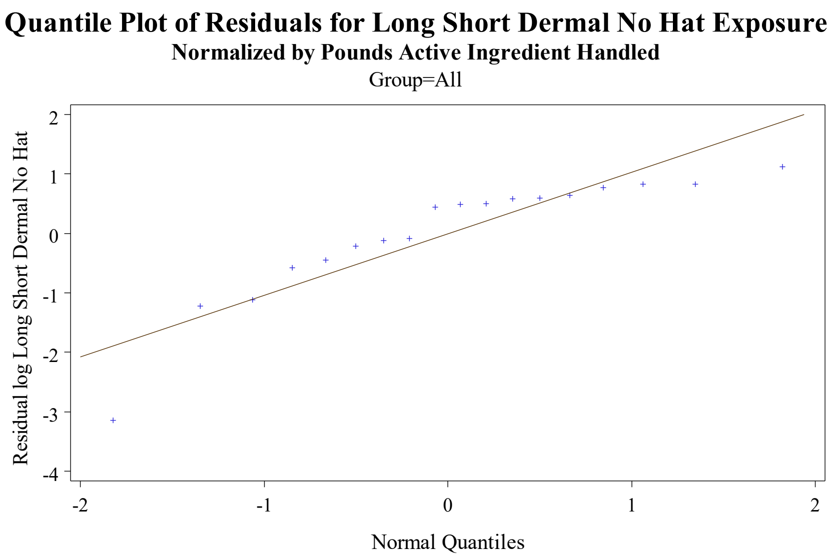


Figure A27. Quantile plot of residuals from linear model for Long Short Dermal No Hat

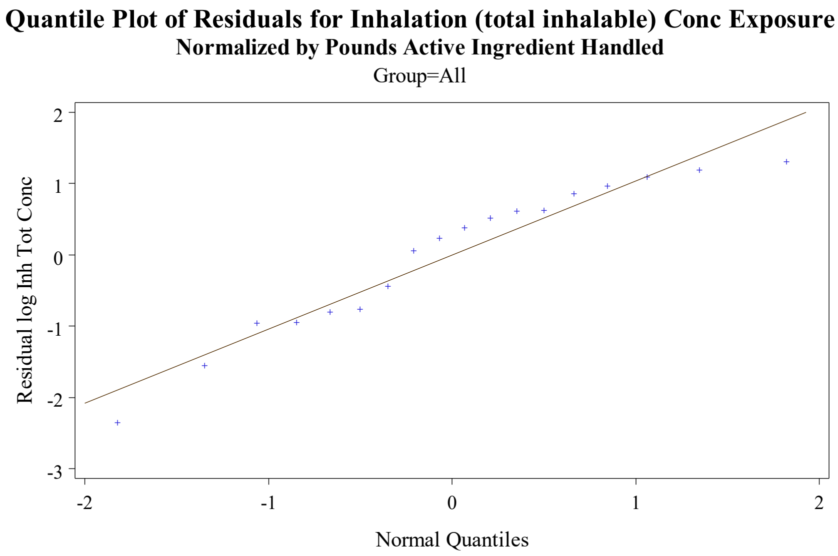


Figure A28. Quantile plot of residuals from linear model for Inhalation (total inhalable) Conc

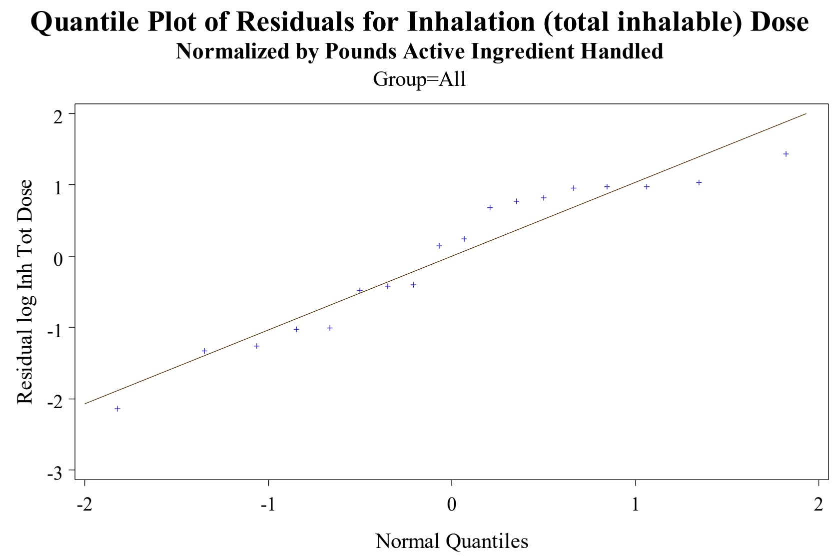


Figure A29. Quantile plot of residuals from linear model for Inhalation (total inhalable) Dose

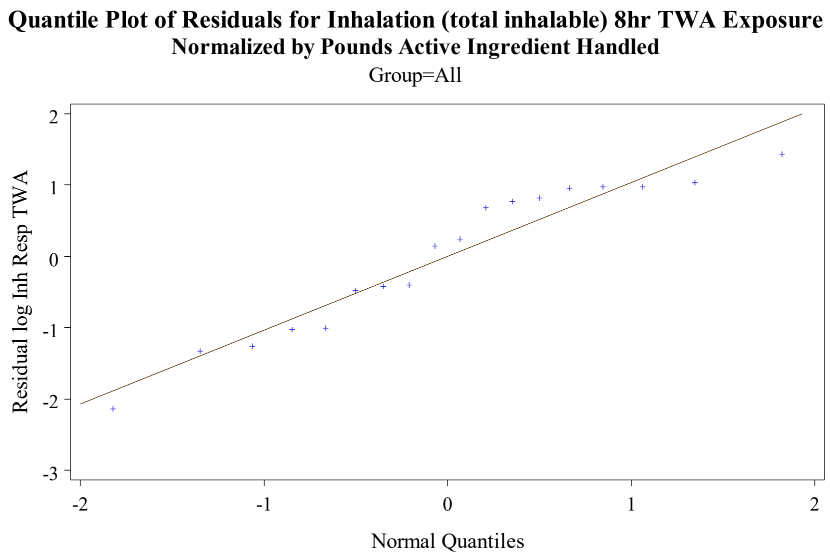


Figure A30. Quantile plot of residuals from linear model for Inhalation (total inhalable) Time-Weighted Average Conc

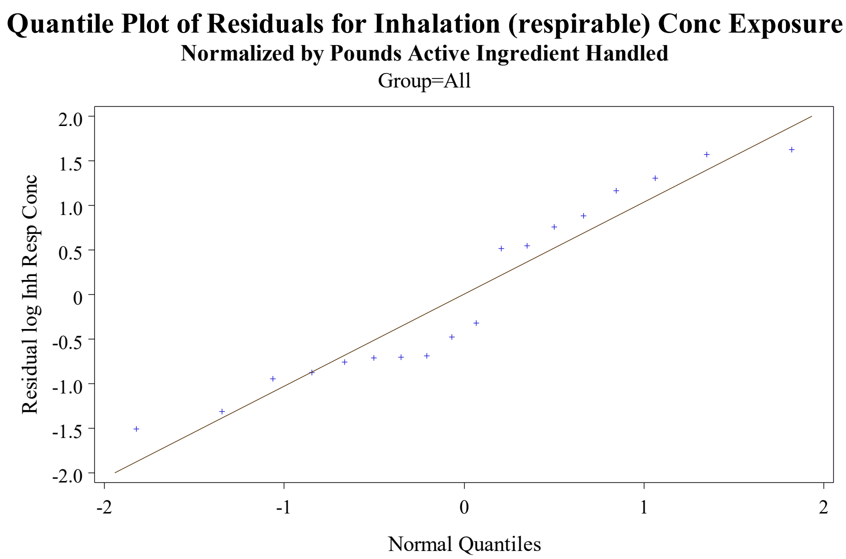


Figure A31. Quantile plot of residuals from linear model for Inhalation (respirable) Conc

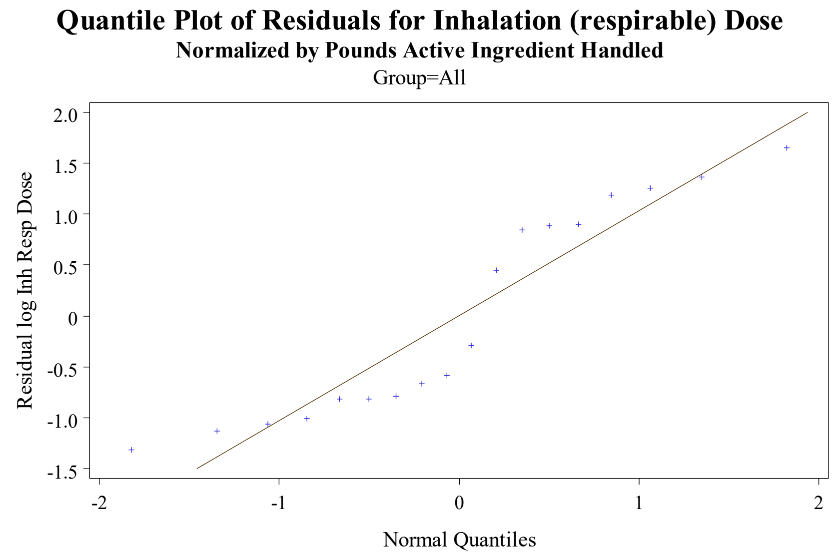


Figure A32. Quantile plot of residuals from linear model for Inhalation (respirable) Dose

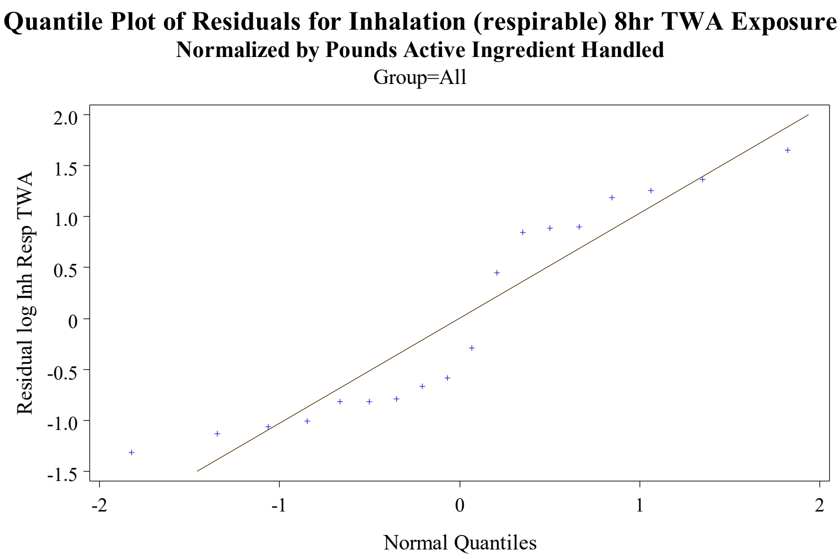


Figure A33. Quantile plot of residuals from linear model for Inhalation (respirable) Time-Weighted Average Conc

The quantile-quantile plots of the studentized residuals for dermal exposure are reasonably close to the straight line except for the lowest value with studentized residuals below −3 which appears to be a potential outlier. This value is for ME 17. In the Supplement we investigate the effect of excluding this ME. For inhalation exposure the studentized residuals are all reasonably close to the straight line, although the models for inhalation (respirable) appear to fit more poorly than the models for inhalation (total inhalable). None of the other studentized residuals exceeded the standard rule of thumb outlier cutoff of ±3.

Using the provided SAS code, we also created scatter plots of the studentized residuals for All the data and by sprayer type against potential explanatory variables to investigate whether it would be useful to incorporate additional variables in the regression models. The plots also showed the ME numbers. The explanatory variables of interest were: sprayer type, nozzle type (80 μm, 40 μm, or Not Available), spray direction (To, Away, Other), spray distance (≤ 2 ft or Other), and the use of an extension wand (Yes or No). Those plots did not show any interesting patterns beyond the previously discussed sprayer type differences and the outlier for ME 17. For this reason, those plots are not presented here.

Regression plots

The lognormal linear regression results for all the exposure routes are shown below in Figures A34 to A66 using the mid value substitution method for non-detect values. In this case we present the results for the Backpack and Cart sprayer type groups as well as the models fitted to all the data. Note that the potential outlier identified in the last section was in the Backpack sprayer group and in the highest volume / concentration group C. Results for the Handheld sprayer type were only based on 3 MEs, with only one degree of freedom, and are not presented here. The data points are labeled to show the targeted volumes and concentrations for the four volume / concentration groups. (As an exception, we show the volume for ME 14 in group D as (approximately) 0.75 gallons although the initial target volume for that ME was 2 gallons).

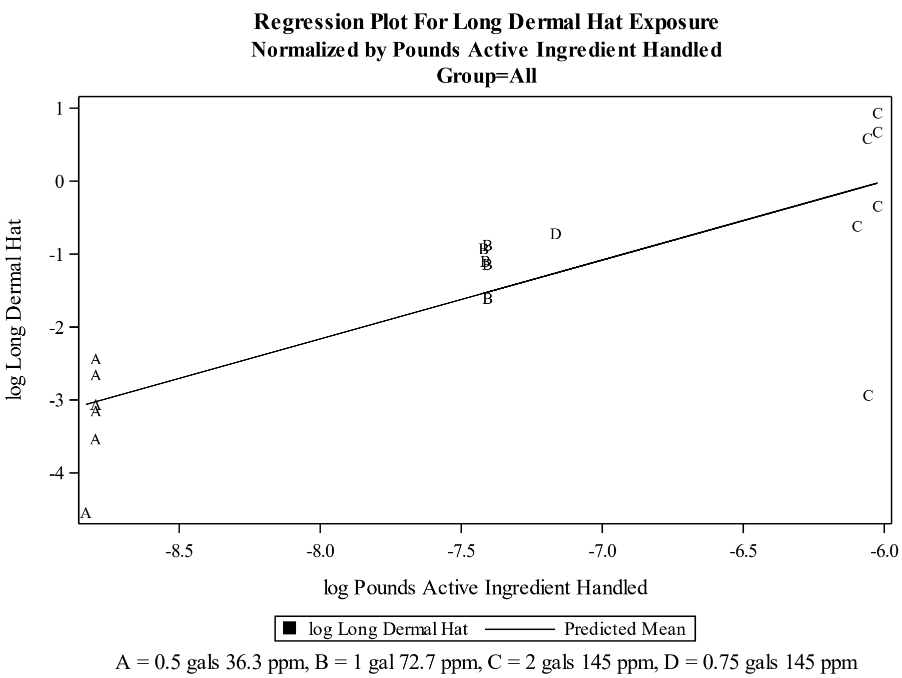


Figure A34. Regression plot for Long Dermal Hat Exposure (mg). Group = All.

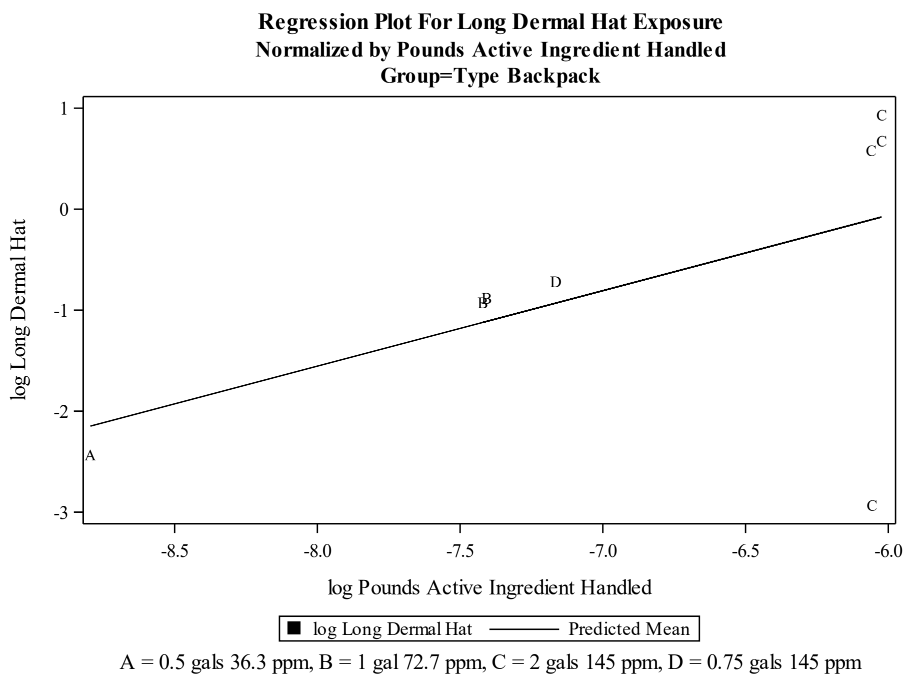


Figure A35. Regression plot for Long Dermal Hat Exposure (mg). Group = Type Backpack.

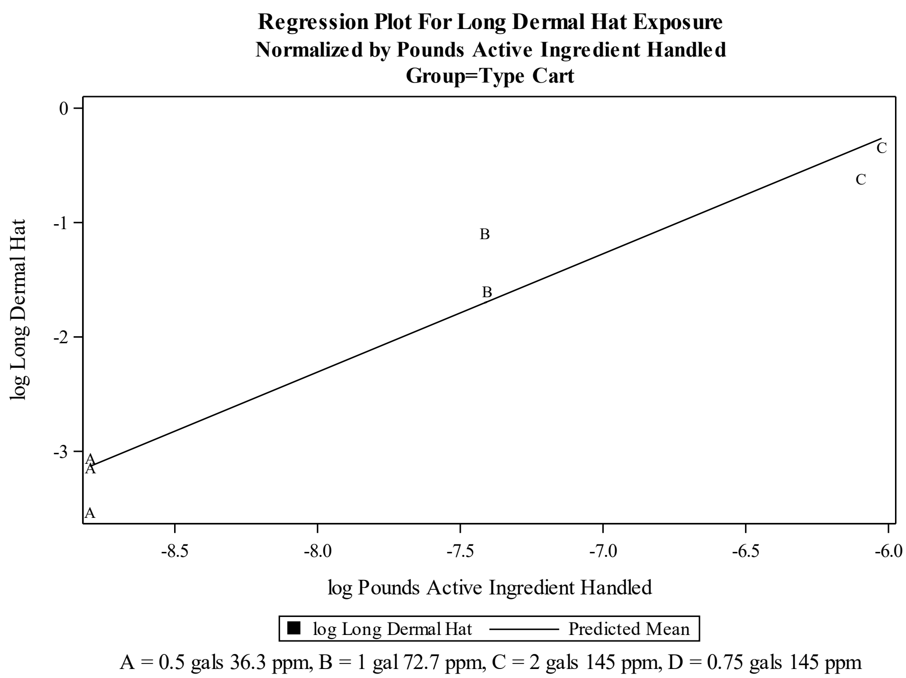


Figure A36. Regression plot for Long Dermal Hat Exposure (mg). Group = Type Cart.

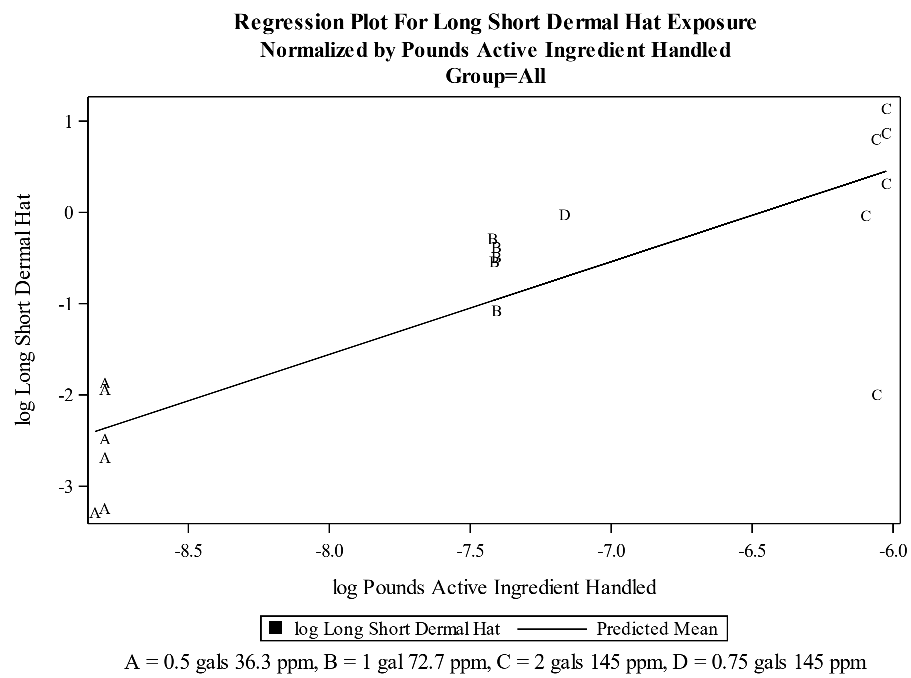
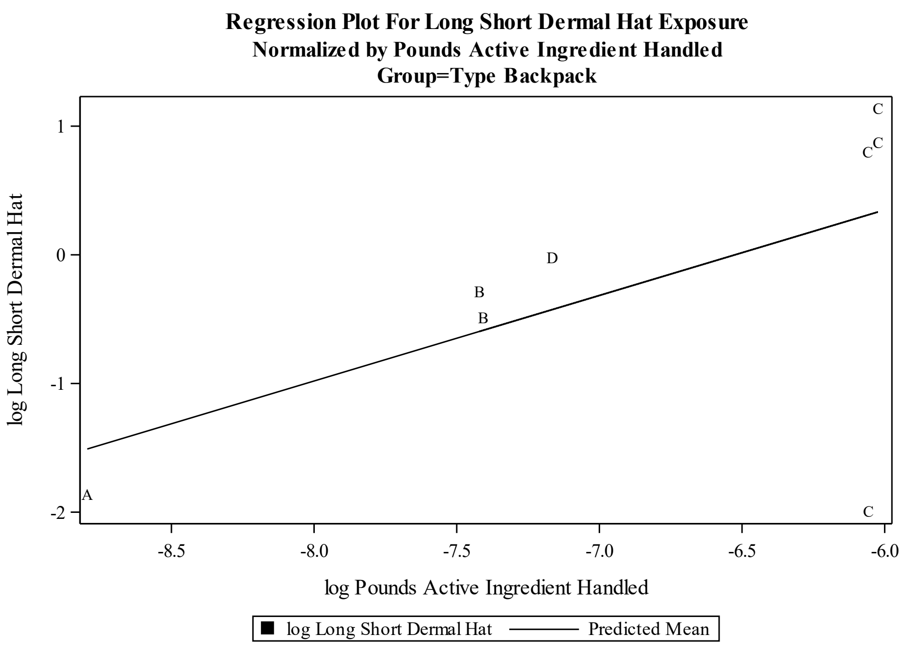


Figure A37. Regression plot for Long Short Dermal Hat Exposure (mg). Group = All.



A = 0.5 gals 36.3 ppm, B = 1 gal 72.7 ppm, C = 2 gals 145 ppm, D = 0.75 gals 145 ppm

Figure A38. Regression plot for Long Short Dermal Hat Exposure (mg). Group = Type Backpack.

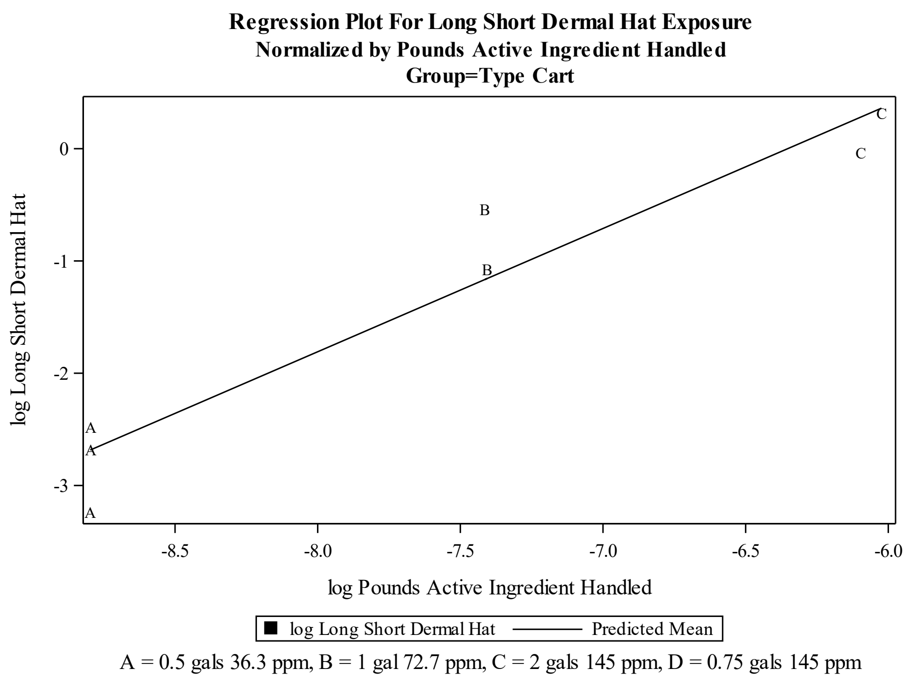


Figure A39. Regression plot for Long Short Dermal Hat Exposure (mg). Group = Type Cart.

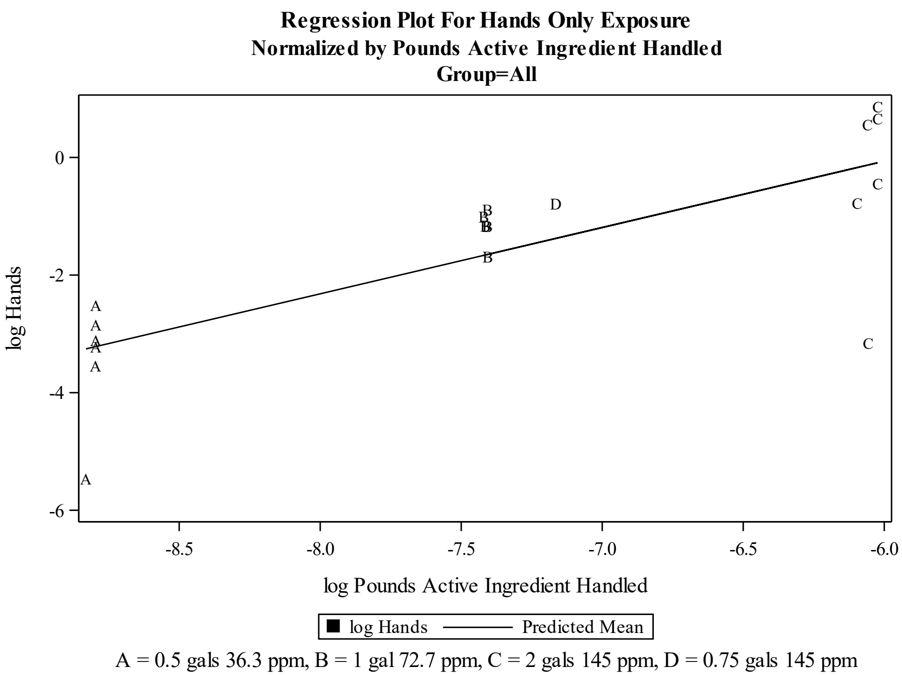
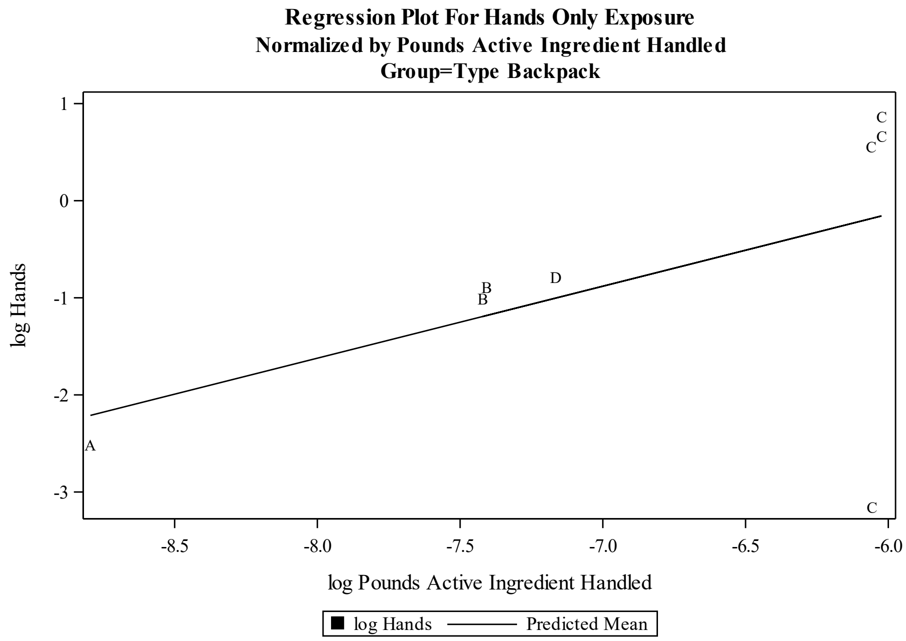


Figure A40. Regression plot for Hands Only Exposure (mg). Group = All.



A = 0.5 gals 36.3 ppm, B = 1 gal 72.7 ppm, C = 2 gals 145 ppm, D = 0.75 gals 145 ppm

Figure A41. Regression plot for Hands Only Exposure (mg). Group = Type Backpack.

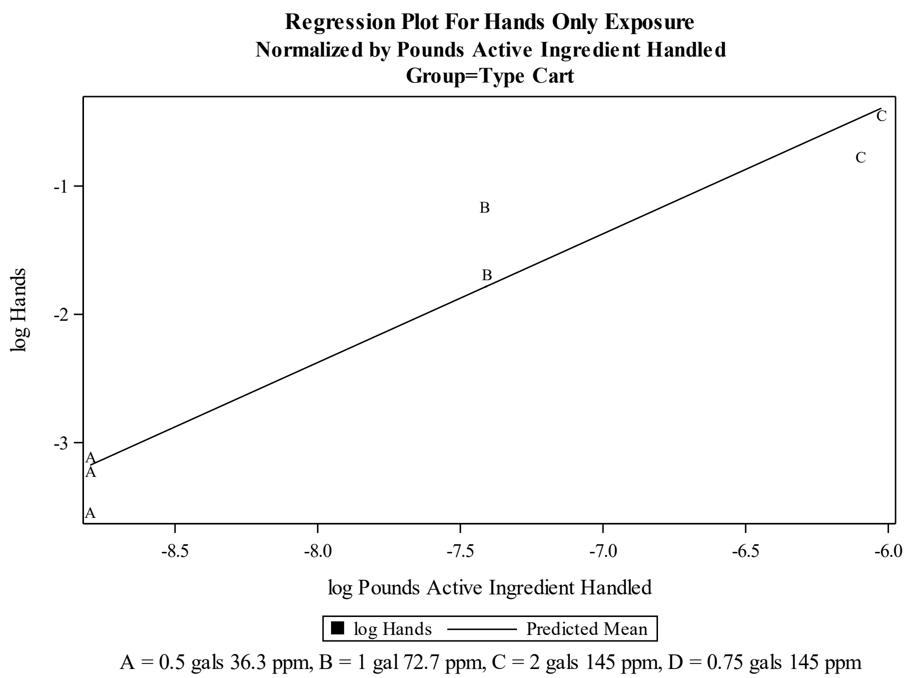
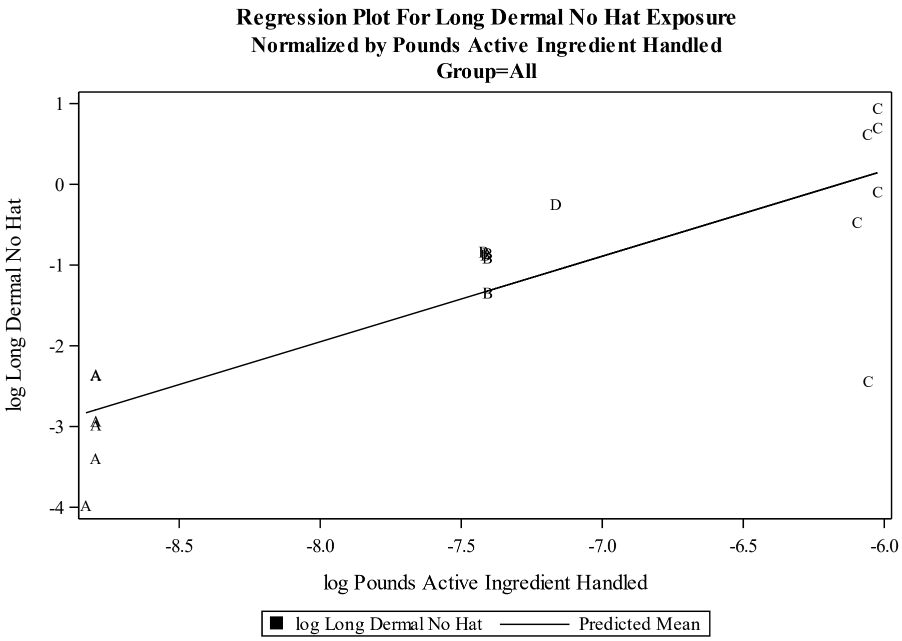


Figure A42. Regression plot for Hands Only Exposure (mg). Group = Type Cart.



A = 0.5 gals 36.3 ppm, B = 1 gal 72.7 ppm, C = 2 gals 145 ppm, D = 0.75 gals 145 ppm

Figure A43. Regression plot for Long Dermal No Hat Exposure (mg). Group = All.

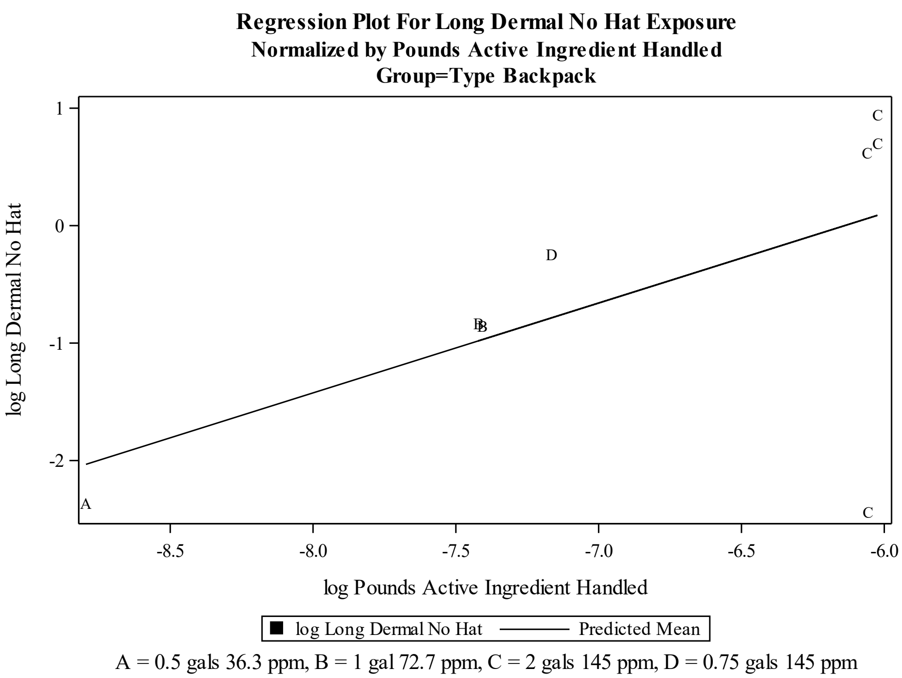


Figure A44. Regression plot for Long Dermal No Hat Exposure (mg). Group = Type Backpack.

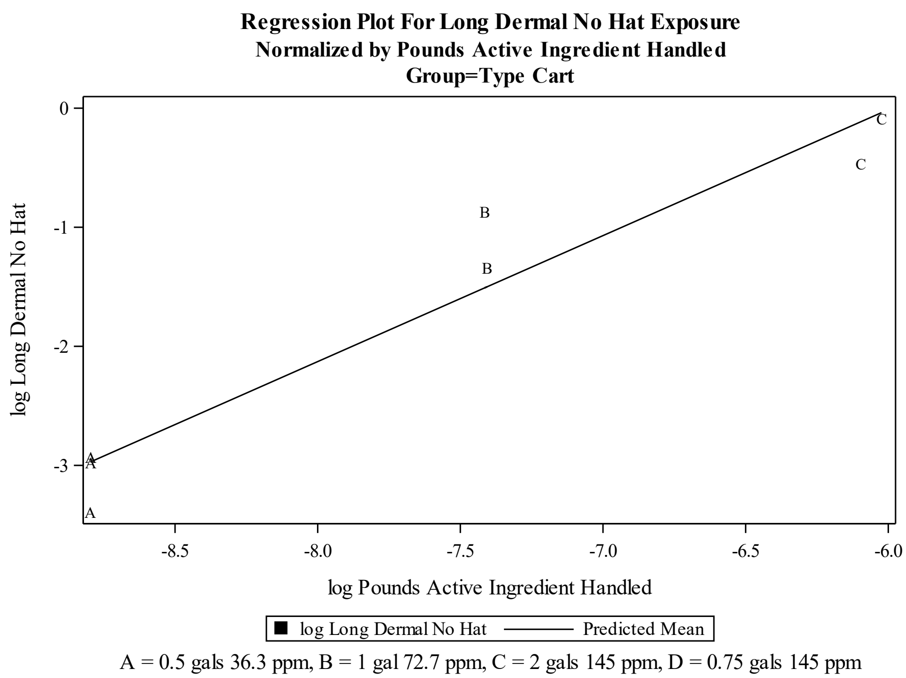


Figure A45. Regression plot for Long Dermal No Hat Exposure (mg). Group = Type Cart.

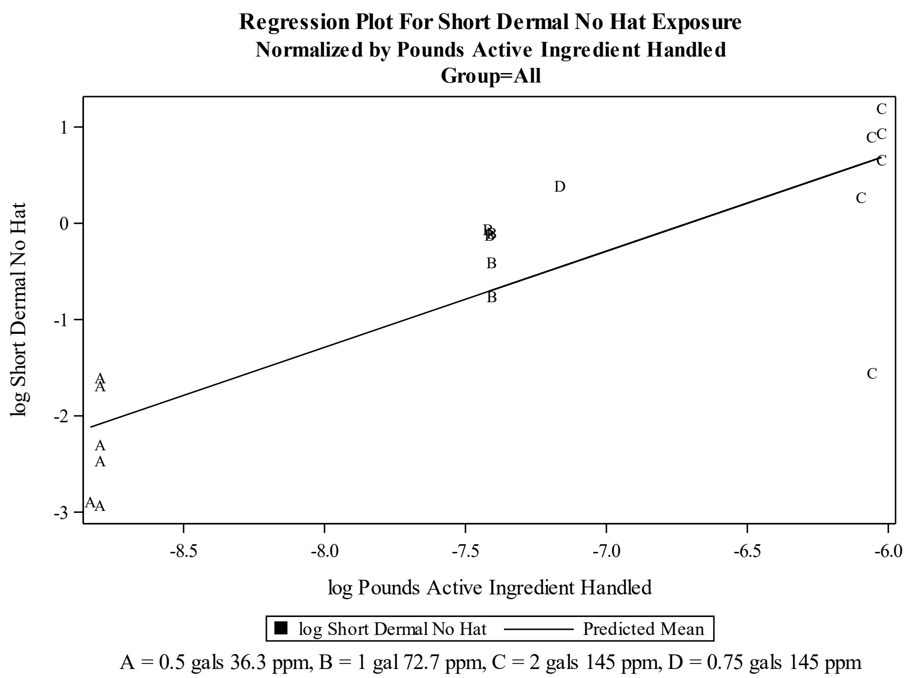


Figure A46. Regression plot for Long Short Dermal No Hat Exposure (mg). Group = All.

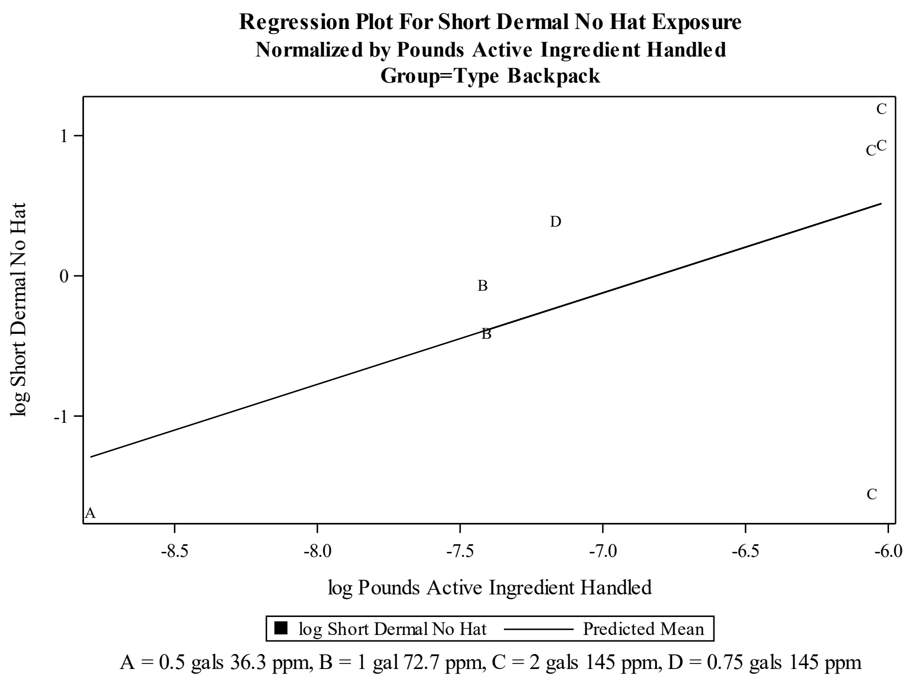


Figure A47. Regression plot for Long Short Dermal No Hat Exposure (mg). Group = Type Backpack.

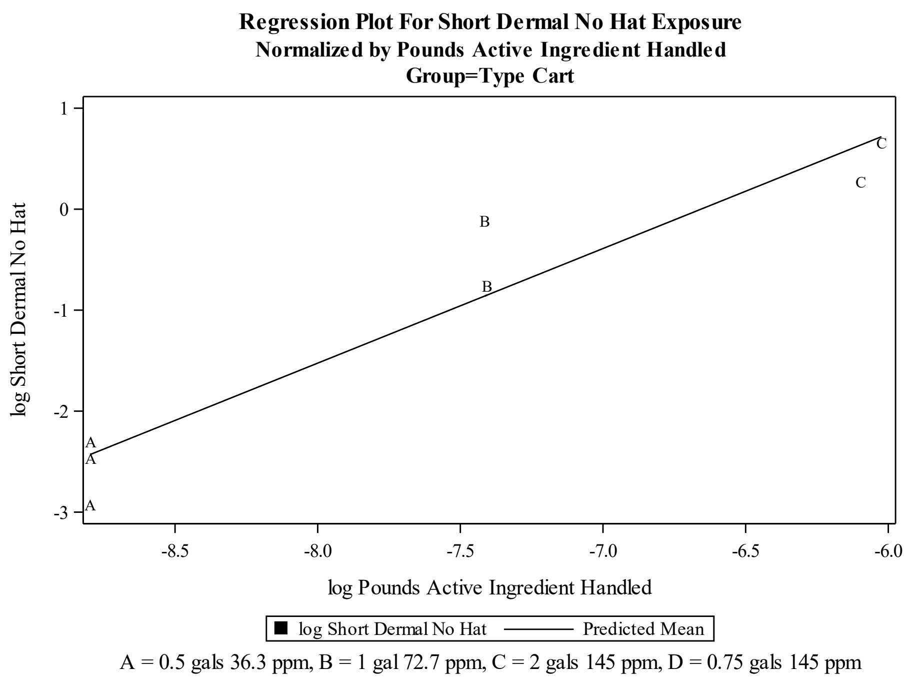


Figure A48. Regression plot for Long Short Dermal No Hat Exposure (mg). Group = Type Cart.

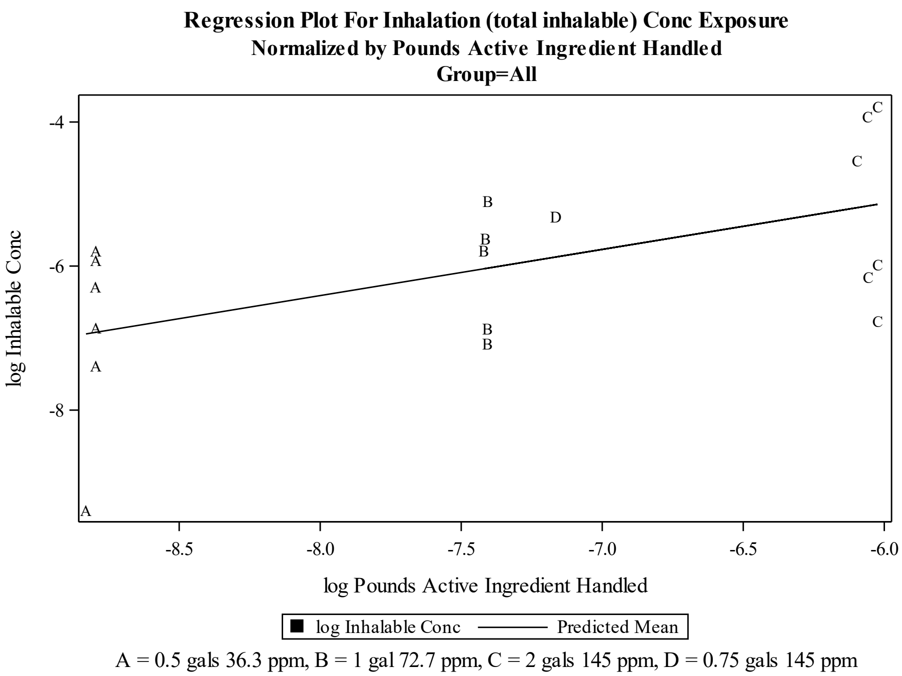


Figure A49. Regression plot for Inhalation (total inhalable) Conc Exposure (mg/m^3). Group = All.

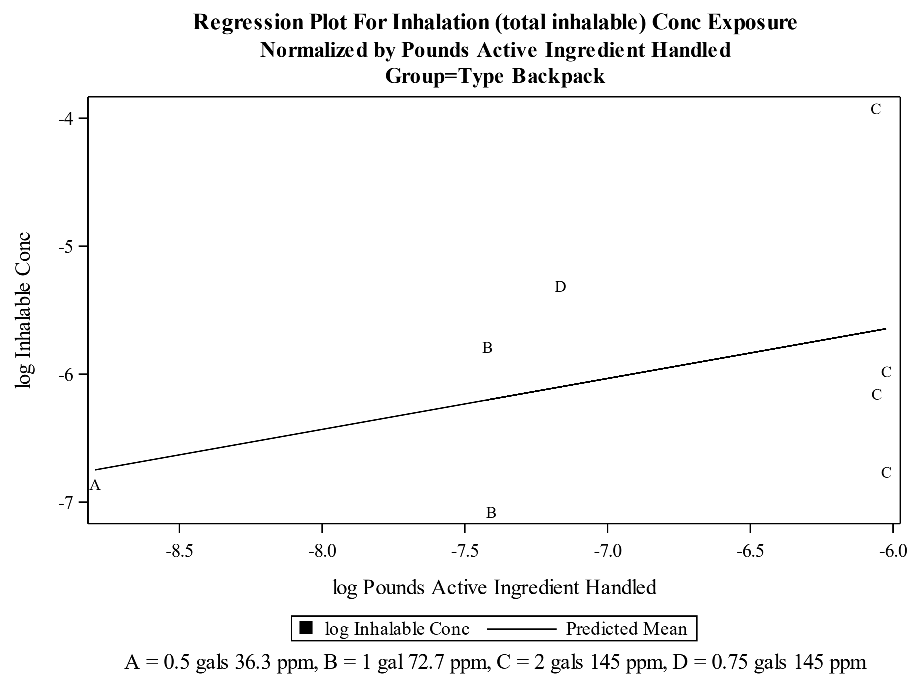


Figure A50. Regression plot for Inhalation (total inhalable) Conc Exposure (mg/m^3). Group = Type Backpack.

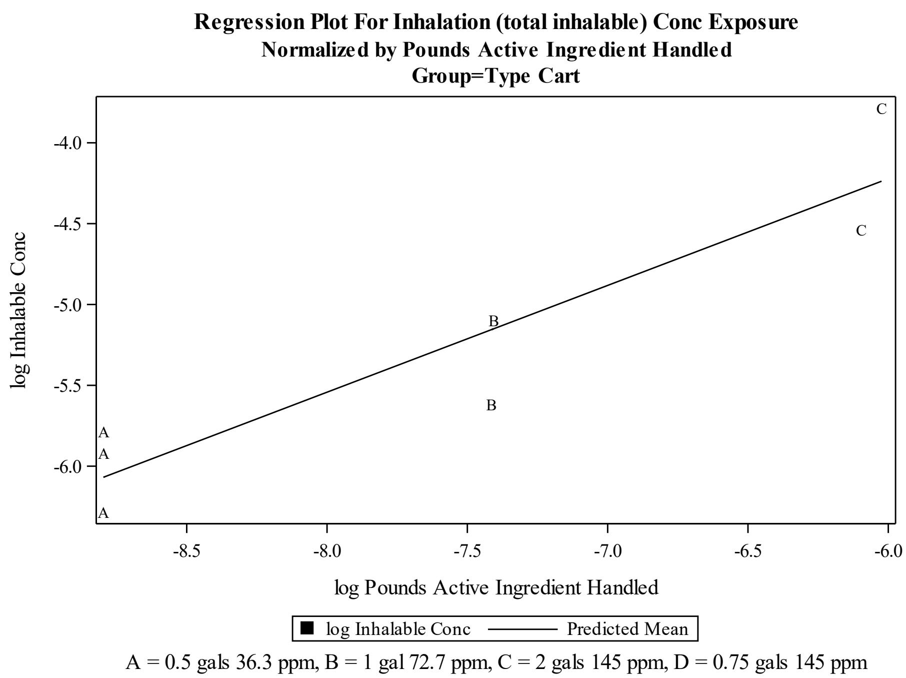


Figure A51. Regression plot for Inhalation (total inhalable) Conc Exposure (mg/m^3). Group = Type Cart.

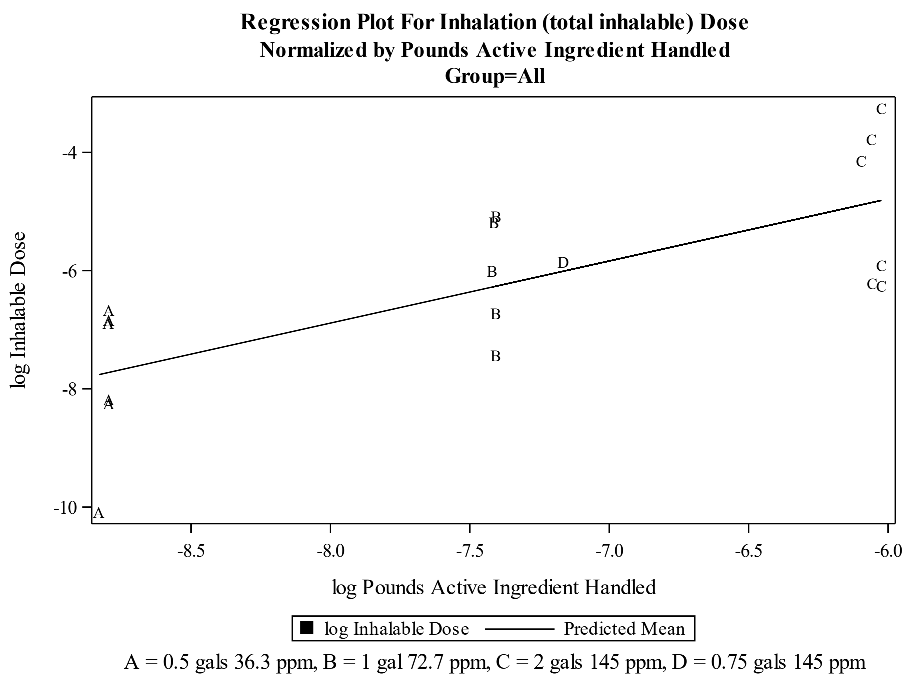


Figure A52. Regression plot for Inhalation (total inhalable) Dose Exposure (mg). Group = All.

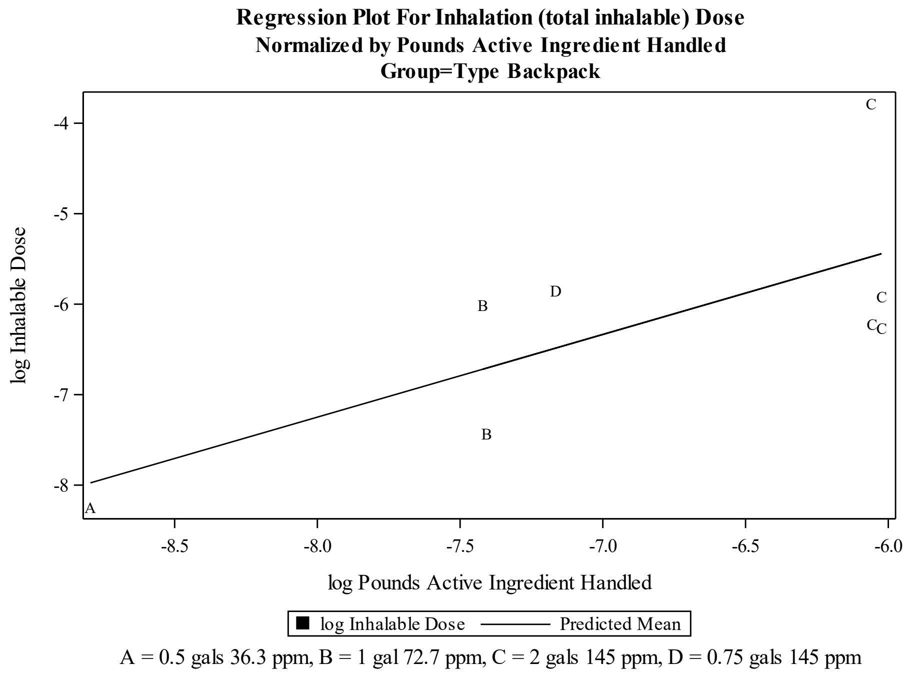
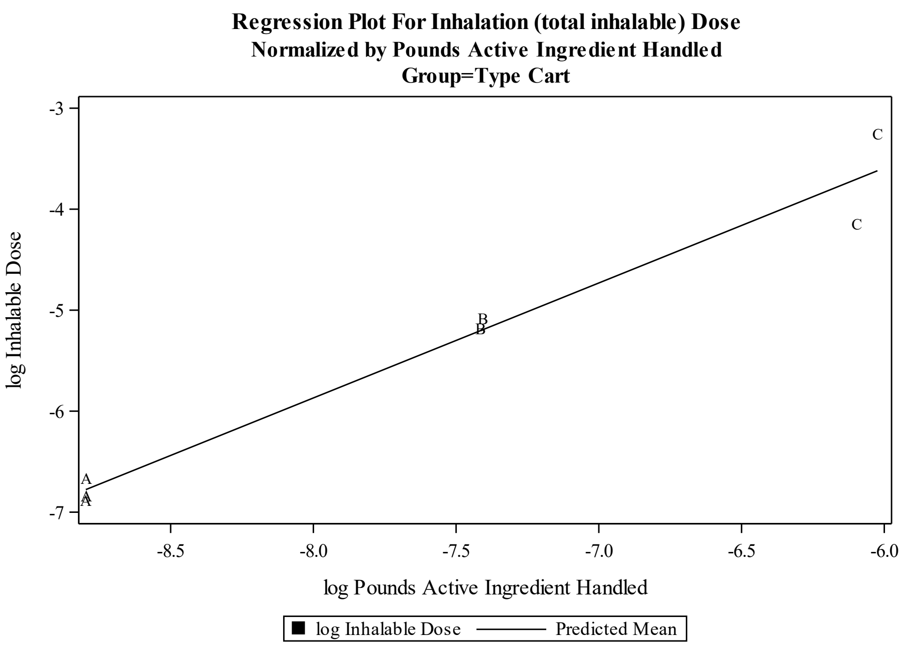


Figure A53. Regression plot for Inhalation (total inhalable) Dose Exposure (mg). Group = Type Backpack.



A = 0.5 gals 36.3 ppm, B = 1 gal 72.7 ppm, C = 2 gals 145 ppm, D = 0.75 gals 145 ppm

Figure A54. Regression plot for Inhalation (total inhalable) Dose Exposure (mg). Group = Type Cart.

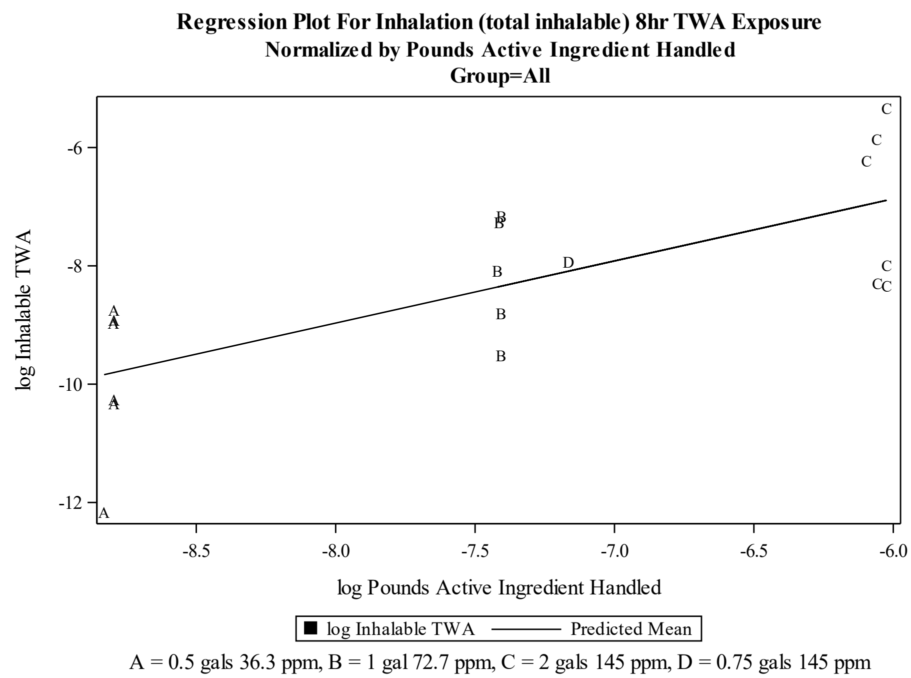


Figure A55. Regression plot for Inhalation (total inhalable) Time-Weighted Average Conc Exposure (mg). Group = All.

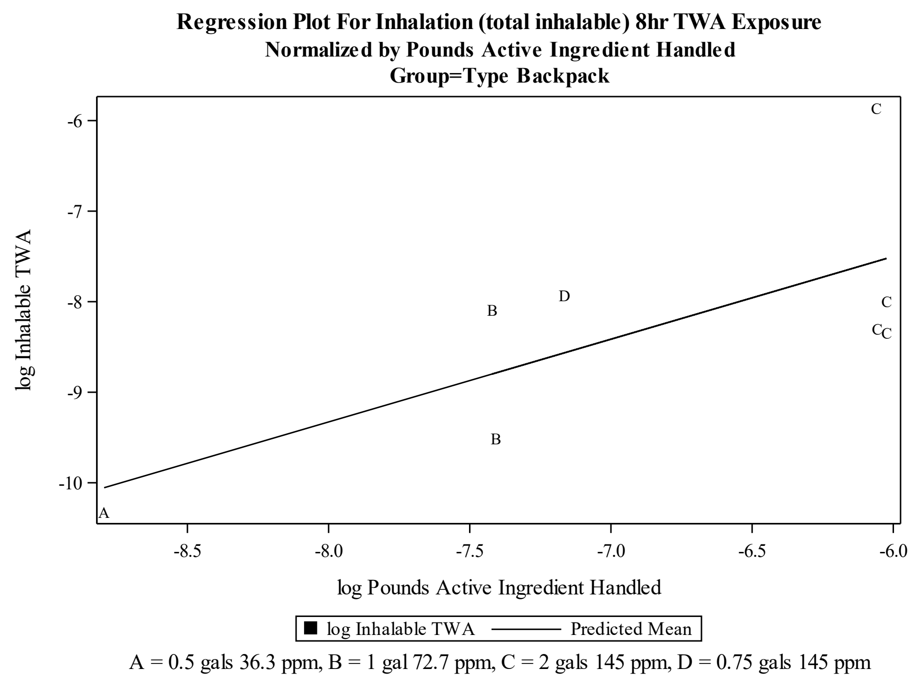


Figure A56. Regression plot for Inhalation (total inhalable) Time-Weighted Average Conc Exposure (mg). Group = Type Backpack.

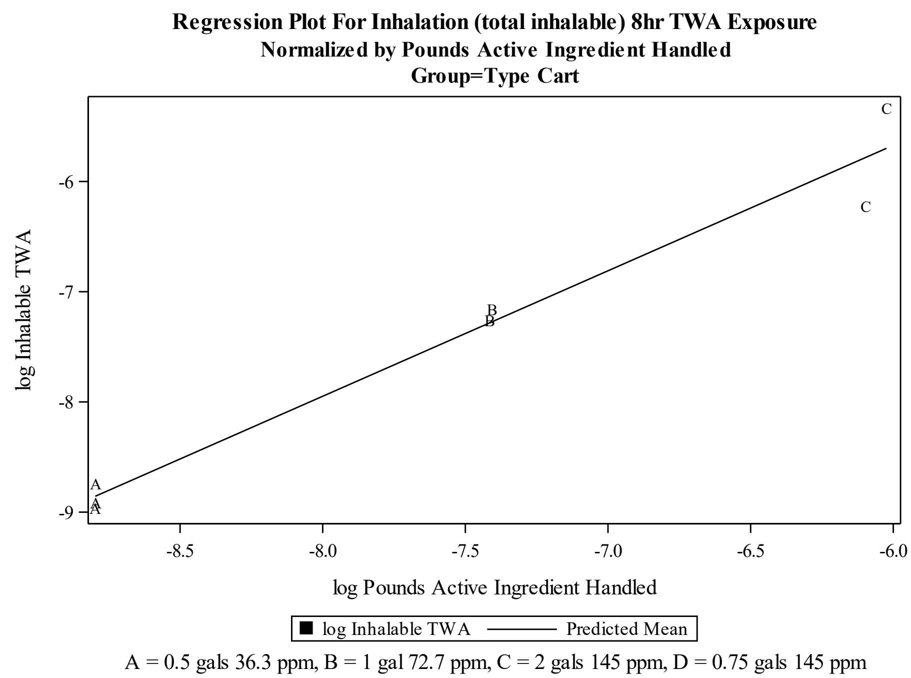


Figure A57. Regression plot for Inhalation (total inhalable) Time-Weighted Average Conc Exposure (mg). Group = Type Cart.

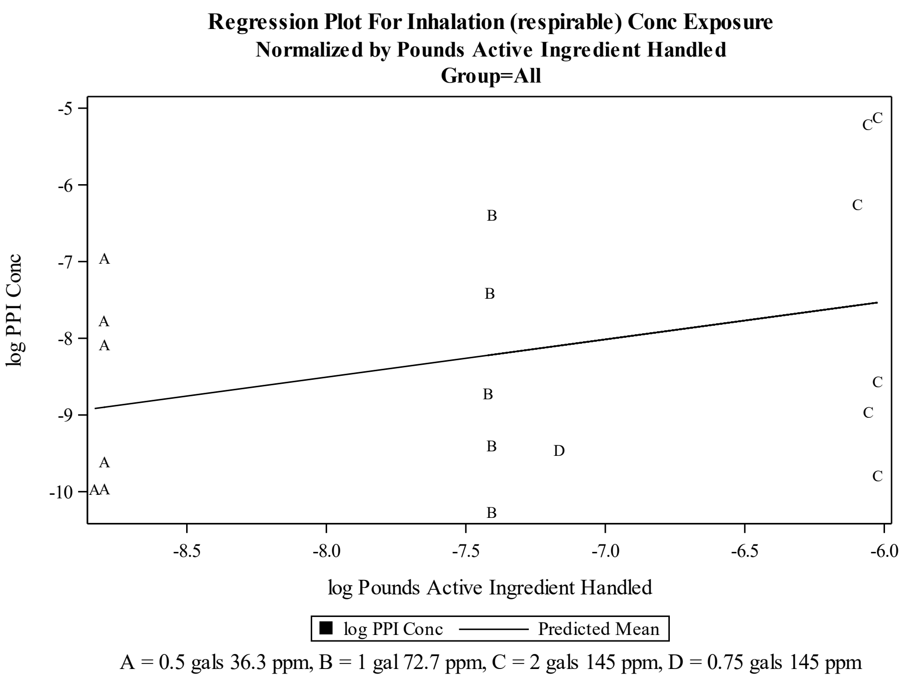


Figure A58. Regression plot for Inhalation (respirable) Conc Exposure (mg/m^3). Group = All.

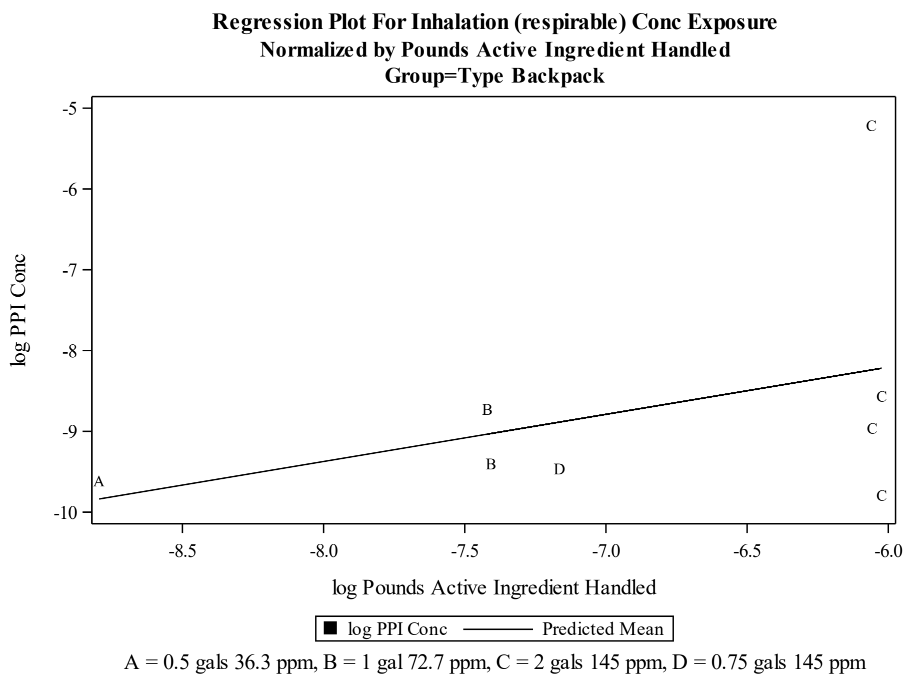


Figure A59. Regression plot for Inhalation (respirable) Conc Exposure (mg/m³). Group = Type Backpack.

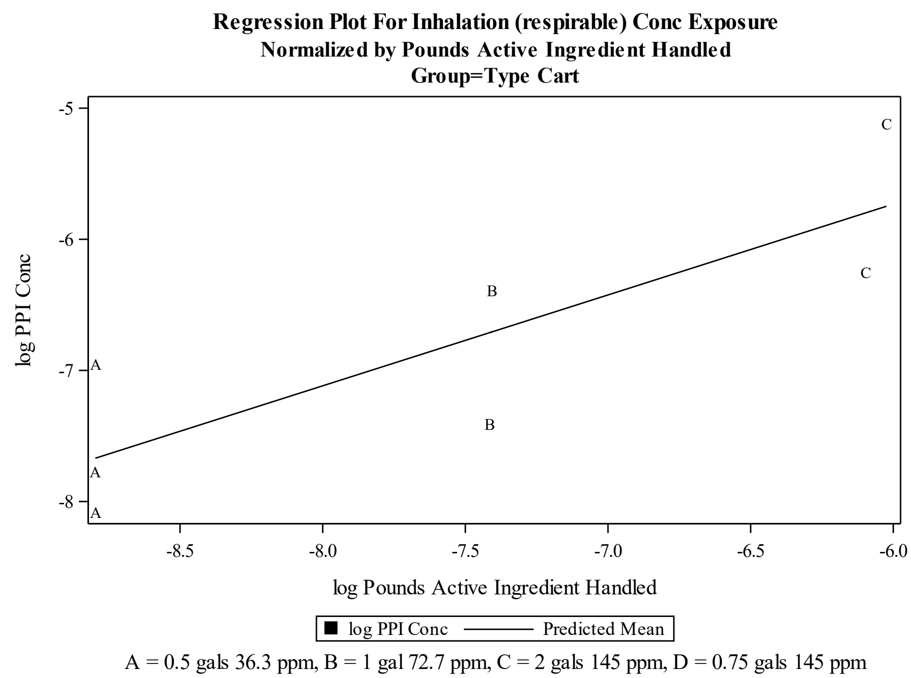


Figure A60. Regression plot for Inhalation (respirable) Conc Exposure (mg/m^3). Group = Type Cart.

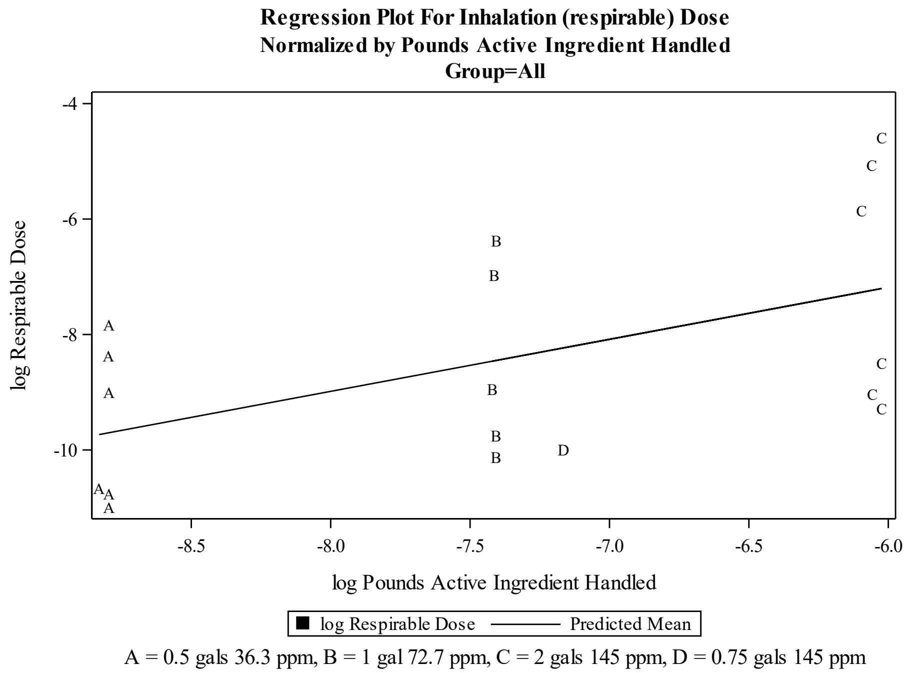


Figure A61. Regression plot for Inhalation (respirable) Dose Exposure (mg). Group = All.

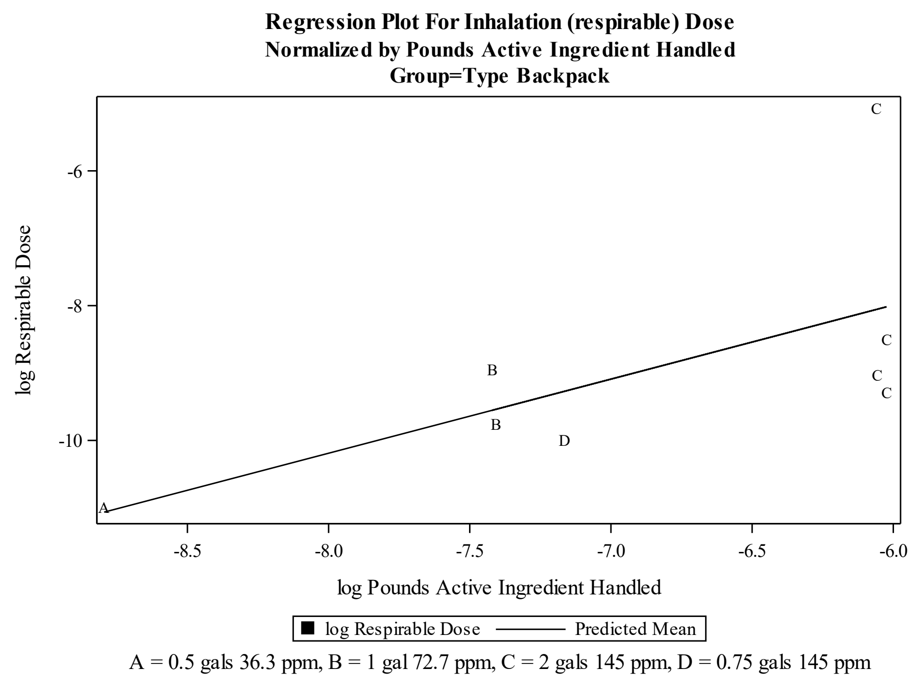
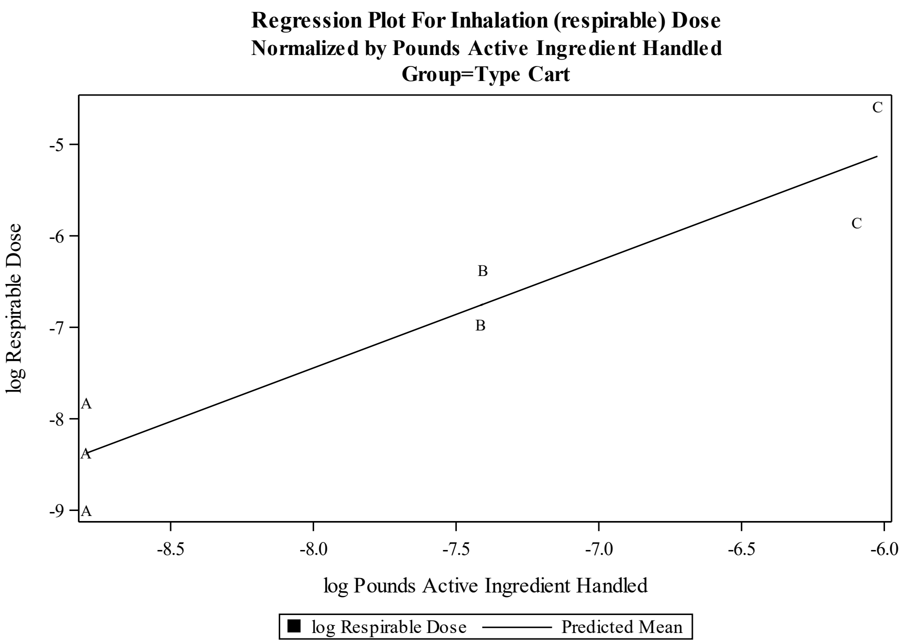


Figure A62. Regression plot for Inhalation (respirable) Dose Exposure (mg). Group = Type Backpack.



A = 0.5 gals 36.3 ppm, B = 1 gal 72.7 ppm, C = 2 gals 145 ppm, D = 0.75 gals 145 ppm

Figure A63. Regression plot for Inhalation (respirable) Dose Exposure (mg). Group = Type Cart.

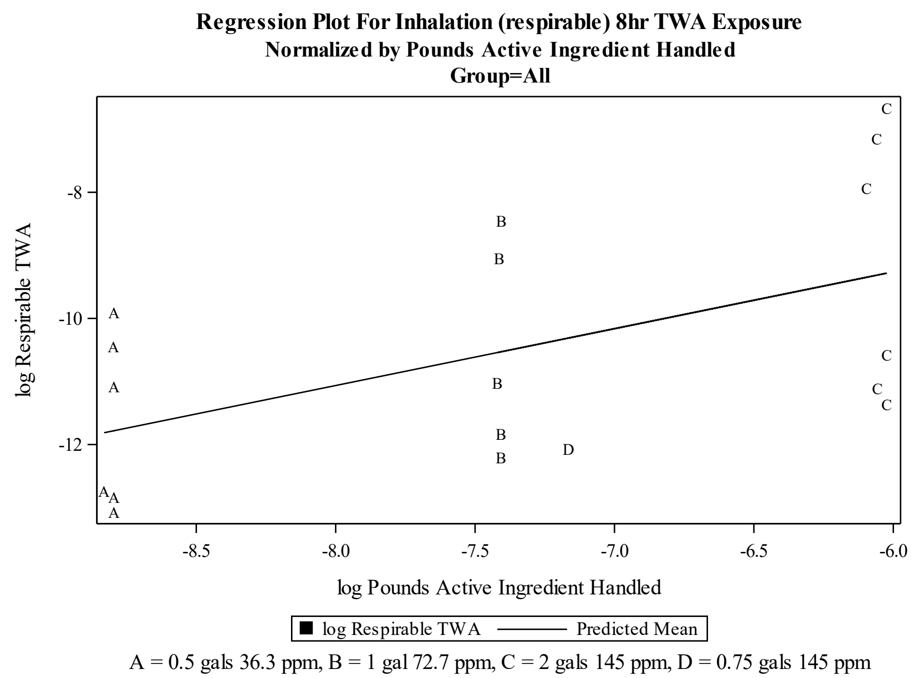


Figure A64. Regression plot for Inhalation (respirable) Time-Weighted Average Conc Exposure (mg). Group = All.

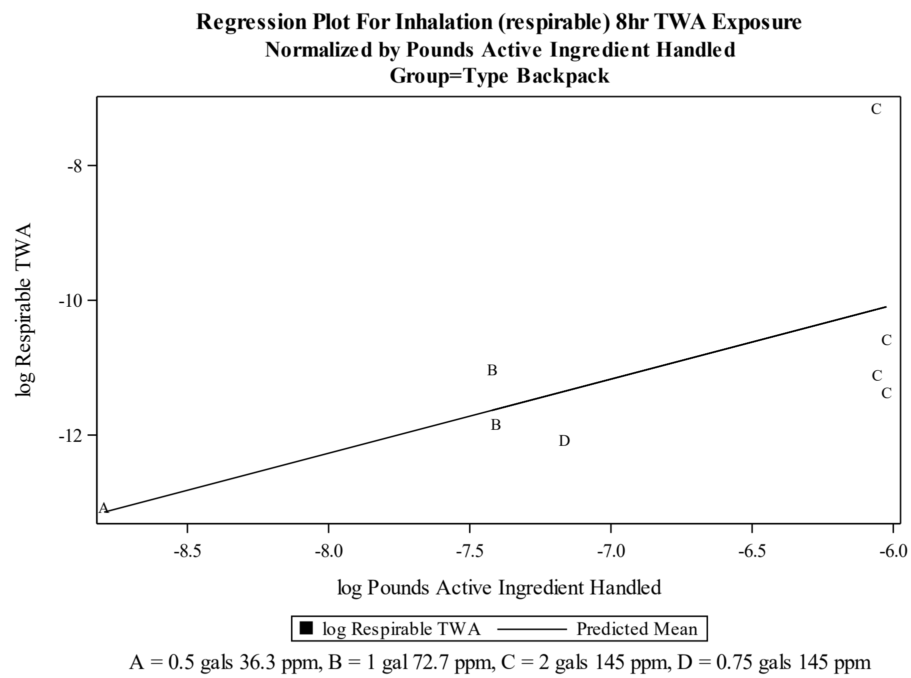


Figure A65. Regression plot for Inhalation (respirable) Time-Weighted Average Conc Exposure (mg). Group = Type Backpack.

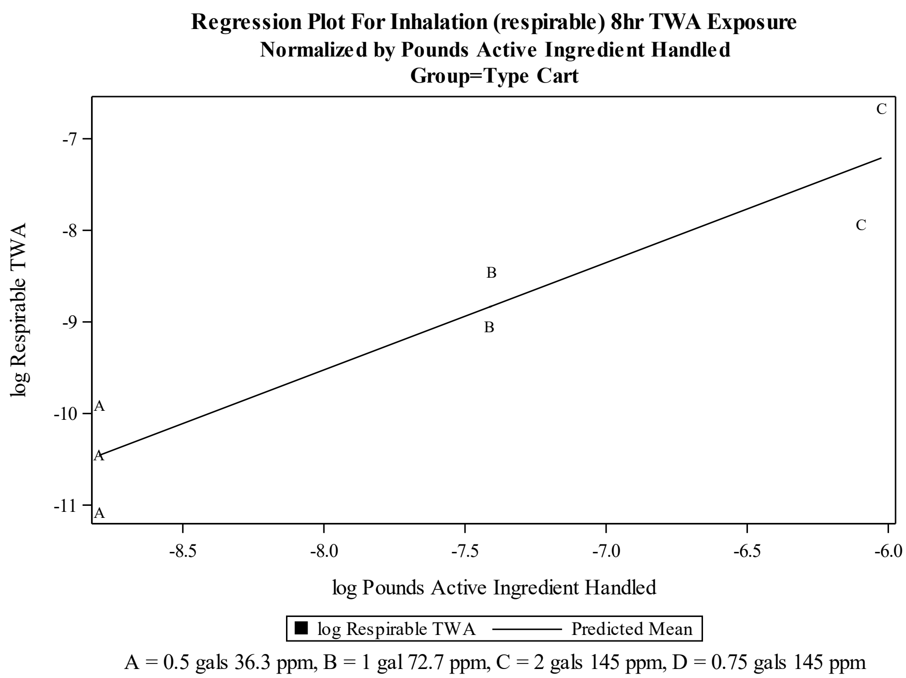


Figure A66. Regression plot for Inhalation (respirable) Time-Weighted Average Conc Exposure (mg). Group = Type Cart.

Quadratic models

The log-log-linearity test was based on a linear model for log exposure versus log (Normalizing Factor). The normalizing factor for Scenario 2b is the amount of active ingredient handled. The HSRB has suggested that a quadratic model should also be considered.

There are two quadratic models that could be considered. Since the original linear model is of the form

Log (Exposure) = Intercept + Slope × Log (Normalizing Factor) + Error Terms,

the main quadratic model is of the form

Log (Exposure) = Intercept + Slope × Log (Normalizing Factor) + Quad × {Log (Normalizing Factor)}^{2}

+ Error Terms.

Note that the quadratic term is the square of the logarithm of the Normalizing Factor rather than the logarithm of the square; the latter approach produces an ill-defined model with two multiples of the logarithm of the Normalizing Factor).

Another approach might be to consider a quadratic model for exposure:

$$\text{Exposure} = \text{Intercept} + \text{Slope} \times (\text{Normalizing Factor}) + \text{Quad} \times (\text{Normalizing Factor})^2 + \text{Error Terms.}$$

We do not recommend this second approach for these data since the exposures are known to be non-negative and the quantile plots showed that the exposure data are better modeled using a log-normal distribution than using a normal distribution.

The parsimony principle suggests that the appropriate statistical procedure for this study is to first fit the quadratic regression model for the logarithm of the exposure

$$\text{Log (Exposure)} = \text{Intercept} + \text{Slope} \times \text{Log (Normalizing Factor)} + \text{Quad} \times \{\text{Log (Normalizing Factor)}\}^2 + \text{Error Terms.}$$

If the coefficient Quad is statistically significant at the 5% level, which is equivalent to requiring that the 95% confidence interval does not include zero, then the quadratic model is supported. Otherwise, the linear model should be used.

Table A53 presents the quadratic coefficient Quad from the fitted quadratic regression models for all the exposure routes using All data. Results for the sprayer type groups are not presented here. Coefficients for the Intercept and Slope are shown under model 2 in Tables A54 to A64 below.

Table A53. Quadratic coefficients with 95% confidence intervals for quadratic regression models for the log exposure versus log (Normalizing Factor). All data.

Exposure Route	Estimate	Lower Bound	Upper Bound
Long Dermal Hat	−0.331	−0.861	0.200
Long Short Dermal Hat	−0.351	−0.784	0.082
Hands Only	−0.387	−0.987	0.213
Long Dermal No Hat	−0.340	−0.802	0.121
Long Short Dermal No Hat	−0.363	−0.772	0.046
Inhalation (total inhalable) Concentration	−0.063	−0.718	0.592
Inhalation (total inhalable) Dose	−0.169	−0.848	0.511

Exposure Route	Estimate	Lower Bound	Upper Bound
Inhalation (total inhalable) Time Weighted Average Concentration	−0.169	−0.848	0.511
Inhalation (respirable) Concentration	0.294	−0.630	1.217
Inhalation (respirable) Dose	0.188	−0.802	1.178
Inhalation (respirable) Time Weighted Average Concentration	0.188	−0.802	1.178

Since all the 95% confidence intervals for Quad include zero, the quadratic coefficient is not statistically significant, and the quadratic models are not supported.

Alternative Statistical Approaches

In this section we present and compare some alternative statistical approaches to the linear and quadratic models. These results are presented for All the data but not by sprayer type.

For estimating the 95th percentile of the normalized or unit exposure, our preferred approach is to fit a lognormal statistical model. HSRB has previously recommended consideration of a quantile regression approach, which would provide confidence intervals for the 95th percentile assuming a simple random sample from an unspecified distribution. This is exactly the same as the above calculations of the confidence intervals for P95s calculated using the non-parametric bootstrap approach. The quantile regression approach could also be applied to the exposure to estimate the 95th percentile of the exposure as a linear or non-linear function of the amount of active ingredient. We chose not to apply the latter approach due to its complexity and because it would not be consistent with the modeling approaches used for estimating the arithmetic mean.

For estimating the dependence of exposure on the amount of active ingredient, our main model was the linear model described above, where the mean log(exposure) is a linear function of the log(Normalizing Factor). All logarithms in this memorandum are natural logarithms. For convenience let NF denote the Normalizing Factor, which is the pounds of active ingredient for Scenario 2b.

This model is described by the equation:

Model 1: Log(Exposure) $= \mu + \beta \log(NF) + \text{Error}$

We also considered a quadratic model, although we found above that the quadratic term was not significant for the main analyses. This model is described by the equation:

Model 2: Log(Exposure) = μ + β log(NF) + γ {log(NF}^{2} + Error

The HSRB has previously suggested including non-linear functions of the log-log-logistic or logistic forms:

Model 3. Log-log-logistic: Exposure = $\delta + \frac{\alpha-\delta}{1+\gamma\, exp\{\beta\, log(NF)\}}$ + Error.

Model 4. 3-parameter logistic: Exposure = $\frac{C}{1+exp\{\alpha+\beta\times NF\}}$ + Error.

Since there is no background exposure in this scenario, we will assume δ = 0 for the log-log-logistic model. A major problem with using the log-log-logistic model is that the mean exposure is bounded above, which is possibly unrealistic.

For each of the above models, the errors are assumed to be normally distributed.

Another HRSB suggestion was to fit a gamma model instead of a log-normal model. We chose to assume a log link, so that the exposure has a gamma distribution with a mean exp(μ + β log(NF)) and variance = (mean)^2/ϕ. This is model 5.

The fitted model parameters and confidence intervals are presented in Tables A54 to A64 below. Note that the nonlinear models 4 and 5 were fitted using SAS's iterative procedure NLIN and it is possible that better estimates of the parameters could have been obtained using different starting points for the estimated parameters. Furthermore, in several cases the iterative methods failed to converge or some of the confidence bounds were not calculated and in those cases the model was not tabulated. In rare cases a model might converge for the inhalation dose but not for the inhalation time-weighted average, or vice versa, which is theoretically impossible (since the exposure values differ by a factor of 8), but this can happen due to computer overflow issues. For the same reason, for these two models, the calculated AIC values described in the next sub-section below might not be identical.

Model Parameters

Table A54. Alternative fitted statistical models for Long Dermal Hat Exposure (mg). All Data.

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	6.488	3.289	9.686
	β	1.081	0.654	1.508
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	−11.366	−40.187	17.455
	β	−3.835	−11.736	4.066
	γ	−0.331	−0.861	0.200

Model	Parameter	Estimate	Lower Bound	Upper Bound
3. Log-log logistic regression of exposure on NF	α			
	γ			
	β			
4. 3-parameter logistic regression of exposure on NF	α	5.233	−373.788	384.255
	c	31.297	−11,827.858	11,890.452
	β	−832.966	−6,996.033	5,330.101
5. Gamma model for exposure	μ	7.574	5.357	9.790
	β	1.194	0.898	1.490
	ϕ	2.142	1.165	3.939

Table A55. Alternative fitted statistical models for Long Short Dermal Hat Exposure (mg). All data.

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	6.572	3.869	9.274
	β	1.016	0.655	1.377
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	−12.358	−35.873	11.158
	β	−4.197	−10.644	2.250
	γ	−0.351	−0.784	0.082
3. Log-log logistic regression of exposure on NF	α	0.00577	−0.08716	0.09870
	γ	0.00006	-0.00242	0.00253
	β	−0.99621	−4.48683	2.49442
4. 3-parameter logistic regression of exposure on NF	α	4.943	-287.298	297.185
	c	40.137	−11,663.858	11,744.133
	β	−758.705	−5,821.736	4,304.327

Model	Parameter	Estimate	Lower Bound	Upper Bound
5. Gamma model for exposure	**μ**	7.284	5.238	9.331
	β	1.085	0.812	1.359
	ϕ	2.675	1.443	4.957

Table A56. Alternative fitted statistical models for Hands Only Exposure (mg). All data.

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	6.704	3.075	10.333
	β	1.128	0.643	1.612
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	−14.167	−46.755	18.420
	β	−4.620	−13.554	4.314
	γ	−0.387	−0.987	0.213
3. Log-log logistic regression of exposure on NF	**α**			
	γ			
	β			
4. 3-parameter logistic regression of exposure on NF	**α**	5.127	−372.680	382.933
	C	25.433	−9,579.770	9,630.636
	β	−830.033	−7,602.177	5,942.111
5. Gamma model for exposure	**μ**	7.667	5.229	10.105
	β	1.217	0.891	1.543
	ϕ	1.791	0.981	3.272

Table A57. Alternative fitted statistical models for Long Dermal No Hat Exposure (mg). All data.

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	6.527	3.687	9.367

Model	Parameter	Estimate	Lower Bound	Upper Bound
	β	1.060	0.681	1.439
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	−11.845	−36.918	13.228
	β	−4.000	−10.873	2.874
	γ	−0.340	−0.802	0.121
3. Log-log logistic regression of exposure on NF	**α**			
	γ			
	β			
4. 3-parameter logistic regression of exposure on NF	**α**	5.667	−538.508	549.842
	c	57.670	−31,310.059	31,425.400
	β	−808.150	−6,133.757	4,517.458
5. Gamma model for exposure	**μ**	7.454	5.371	9.538
	β	1.156	0.878	1.435
	ϕ	2.518	1.362	4.658

Table A58. Alternative fitted statistical models for Long Short Dermal No Hat Exposure (mg). All data.

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	6.611	4.018	9.205
	β	1.007	0.661	1.353
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	−12.981	−35.184	9.222
	β	−4.389	−10.475	1.698
	γ	−0.363	−0.772	0.046
3. Log-log logistic regression of exposure on NF	**α**	2.36E−03	−2.53E−03	7.26E−03
	γ	3.81E−07	−1.18E-05	1.25E−05

Model	Parameter	Estimate	Lower Bound	Upper Bound
	β	−1.49E+00	−5.39E+00	2.41E+00
4. 3-parameter logistic regression of exposure on NF	α	4.751	−225.067	234.568
	c	35.773	−8,163.346	8,234.892
	β	−758.108	−5,571.417	4,055.200
5. Gamma model for exposure	μ	7.255	5.232	9.279
	β	1.068	0.798	1.339
	ϕ	2.798	1.508	5.193

Table A59. Alternative fitted statistical models for Inhalation (total inhalable) Concentration (mg/m³)

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	−1.281	−5.021	2.458
	β	0.641	0.142	1.140
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	−4.681	−40.259	30.897
	β	−0.295	−10.049	9.458
	γ	−0.063	−0.718	0.592
3. Log-log logistic regression of exposure on NF	α			
	γ			
	β			
4. 3-parameter logistic regression of exposure on NF	α	2.232	−2.658	7.123
	c	0.010	0.003	0.018
	β	−2,465.249	−12,103.350	7,172.853
5. Gamma model for exposure	μ	-0.629	−3.234	1.975
	β	0.671	0.324	1.019
	ϕ	1.309	0.727	2.357

Table A60. Alternative fitted statistical models for Inhalation (total inhalable) Dose (mg). All data.

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	1.515	-2.393	5.423
	β	1.050	0.529	1.572
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	−7.595	−44.484	29.293
	β	−1.458	−11.571	8.654
	γ	−0.169	−0.848	0.511
3. Log-log logistic regression of exposure on NF	**α**			
	γ			
	β			
4. 3-parameter logistic regression of exposure on NF	**α**	3.212	−7.326	13.750
	C	0.014	0.002	0.027
	β	−3,001.365	−21,264.140	15,261.411
5. Gamma model for exposure	**μ**	2.426	-0.412	5.265
	β	1.108	0.729	1.487
	ϕ	1.176	0.656	2.108

Table A61. Alternative fitted statistical models for Inhalation (total inhalable) Time-weighted Average Concentration (mg/m³). All data.

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	−0.565	−4.473	3.343
	β	1.050	0.529	1.572
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	−9.674	−46.563	27.214
	β	−1.458	−11.571	8.654

Model	Parameter	Estimate	Lower Bound	Upper Bound
	γ	−0.169	−0.848	0.511
3. Log-log logistic regression of exposure on NF	**α**			
	γ			
	β			
4. 3-parameter logistic regression of exposure on NF	**α**	3.2121	−7.3276	13.7517
	c	0.0018	0.0002	0.0034
	β	−3,001.7722	−21,266.6549	15,263.1104
5. Gamma model for exposure	**μ**	0.347	−2.491	3.185
	β	1.108	0.729	1.487
	ϕ	1.176	0.656	2.108

Table A62. Alternative fitted statistical models for Inhalation (respirable) Concentration (mg/m³)

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	−4.569	−9.914	0.775
	β	0.492	−0.221	1.206
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	11.280	−38.877	61.438
	β	4.857	−8.893	18.607
	γ	0.294	−0.630	1.217
3. Log-log logistic regression of exposure on NF	**α**			
	γ			
	β			
4. 3-parameter logistic regression of exposure on NF	**α**	6.724	−165,632.706	165,646.153
	c	0.382	−3,189.924	63,190.687

Model	Parameter	Estimate	Lower Bound	Upper Bound
	β	−198.525	−52,206.132	51,809.082
5. Gamma model for exposure	μ	−1.898	−5.459	1.663
	β	0.722	0.248	1.196
	ϕ	0.632	0.364	1.097

Table A63. Alternative fitted statistical models for Inhalation (respirable) Dose (mg). All data.

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	−1.773	−7.446	3.900
	β	0.901	0.144	1.659
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	8.367	−45.388	62.121
	β	3.694	−11.043	18.430
	γ	0.188	−0.802	1.178
3. Log-log logistic regression of exposure on NF	α			
	γ			
	β			
4. 3-parameter logistic regression of exposure on NF	α	6.496	−32,777.270	32,790.261
	c	0.511	−16,723.422	16,724.443
	β	−323.770	−25,703.374	25,055.834
5. Gamma model for exposure	μ	1.127	−2.707	4.961
	β	1.150	0.639	1.661
	ϕ	0.586	0.339	1.013

Table A64. Alternative fitted statistical models for Inhalation (respirable) Time-weighted Average Concentration (mg/m^3). All data.

Model	Parameter	Estimate	Lower Bound	Upper Bound
1. Linear regression of Ln(exposure) on Ln(NF)	μ	−3.853	−9.526	1.821
	β	0.901	0.144	1.659
2. Quadratic regression of Ln(exposure) on Ln(NF)	μ	6.287	−47.468	60.042
	β	3.694	−11.043	18.430
	γ	0.188	−0.802	1.178
3. Log-log logistic regression of exposure on NF	**α**			
	γ			
	β			
4. 3-parameter logistic regression of exposure on NF	**α**			
	C			
	β			
5. Gamma model for exposure	**μ**	−0.953	−4.787	2.881
	β	1.150	0.639	1.661
	ϕ	0.586	0.339	1.013

Model Comparisons

One way to compare the fit of the 5 models presented above is to use the Akaike Information Criterion (AIC), which takes minus twice the log-likelihood and then makes an adjustment or penalty for the number of parameters in the model. To properly apply this approach to the seven models it was first necessary to re-express all of them using the same dependent variable, ln(exposure), since models 1 and 2 were specified using ln(exposure) but models 3 to 5 were specified using exposure. The following two tables compare the AIC values for the various Dermal and Inhalation exposure measures. The smaller values of the AIC suggest a better-fitting model. AIC values for models that failed to converge are not shown.

Table A65. Akaike Information Criteria values for alternative models for Dermal Exposure. All data.

Model	Long Dermal Hat	Long Short Dermal Hat	Hands Only	Long Dermal No Hat	Long Short Dermal No Hat
1. Linear regression of Ln(exposure) on Ln(NF)	53.6	47.5	58.1	49.3	46.0
2. Quadratic regression of Ln(exposure) on Ln(NF)	53.6	46.2	58.0	48.5	44.2
3. Log-log logistic regression of exposure on NF		73.3			69.5
4. 3-parameter logistic regression of exposure on NF	89.7	74.2	93.6	81.9	70.9
5. Gamma model for exposure	46.1	41.6	49.9	42.8	40.7

Table A66 Akaike Information Criteria values for alternative models for Inhalation Exposure. All data.

Model	Inhalation (total inhalable) Concentration	Inhalation (total inhalable) Dose	Inhalation (total inhalable) Time-Weighted Average Concentration	Inhalation (respirable) Concentration	Inhalation (respirable) Dose	Inhalation (respirable) Time-Weighted Average Concentration
1. Linear regression of Ln(exposure) on Ln(NF)	59.2	60.8	60.8	72.0	74.2	74.2
2. Quadratic regression of Ln(exposure) on Ln(NF)	61.1	62.4	62.4	73.5	76.0	76.0
3. Log-log logistic regression of exposure on NF						
4. 3-parameter logistic regression of exposure on NF	86.6	110.5	110.5	126.4	147.0	

Model	Inhalation (total inhalable) Concentration	Inhalation (total inhalable) Dose	Inhalation (total inhalable) Time-Weighted Average Concentration	Inhalation (respirable) Concentration	Inhalation (respirable) Dose	Inhalation (respirable) Time-Weighted Average Concentration
5. Gamma model for exposure	56.7	59.1	59.1	73.9	75.8	75.8

Based on the AIC, the best-fitting models are the gamma model for the dermal and inhalation (total inhalable) exposure routes and the linear model for the inhalation (respirable) exposure routes.