UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF CHEMICAL SAFETY AND POLLUTION PREVENTION

MEMORANDUM

Date: [date placeholder], 2019

SUBJECT: **DRAFT** Review of Agricultural Handler Exposure Task Force (AHETF) Monograph: "Mixing/Loading/Application using Powered Handgun Equipment in Managed Horticultural Facilities (i.e., greenhouses and nurseries)" (AHE1023)

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This memorandum presents EPA's review of the occupational handler exposure scenario monograph "Mixing/Loading/Application using Powered Handgun Equipment in Managed Horticultural Facilities (i.e., greenhouses and nurseries)" (AHE1023) submitted by the Agricultural Handler Exposure Task Force (AHETF). It reflects comments and advice provided by the Human Studies Review Board following its review in April 2019[1]. The AHETF satisfactorily followed the study protocols, sampling design, and data analysis plan. EPA recommends use of the monograph and underlying data in routine regulatory assessment of human health exposure and risk as part of the federal pesticide registration process. Scientific review of the field and analytical reports (AHE600 – Canez and Baugher, 2019) that outline the monitoring data collected to support this scenario can be found in a separate data evaluation review (DER) memorandum (Crowley, 2019; DXXXXXX).

[1] [placeholder for reference to April 2019 HSRB meeting].

1.0 Executive Summary

This document represents EPA's review of the Agricultural Handler Exposure Task Force (AHETF) Study AHE1023: Mixing/Loading/Application using Powered Handgun Equipment in Managed Horticultural Facilities (i.e., greenhouses and nurseries) (Bruce and Holden, 2019). The submission compiles and statistically analyzes dermal and inhalation monitoring for workers who manually open, pour and mix pesticide products in spray solution tanks and apply the solutions using powered handgun equipment in managed horticultural facilities such as greenhouse and nurseries. The AHETF study AHE600 (Canez and Baugher, 2019) provides the underlying exposure monitoring field and analytical results, including laboratory analyses; details can be found in both the submitted study report and corresponding EPA review (Crowley, 2019; DXXXXX).

Overall, the AHETF adequately followed the general study design outlined in the AHETF Governing Document (AHETF, 2008 and 2010) and scenario sampling and data analysis protocol (AHETF, 2012). AHETF efforts represented a well-designed, concerted process to collect reliable, internally-consistent, and contemporary exposure data in a way that takes advantage of and incorporates a more robust statistical design, better analytical methods, and improved data handling techniques. The AHETF data and associated unit exposures are considered superior to the existing data used to assess exposure and risk for this scenario.[2] The data are considered the most reliable data for assessing exposure and risk to individuals mixing/loading/applying (M/L/A) using handgun equipment in greenhouse/nurseries[3] while wearing the following personal protective equipment (PPE): long-sleeved shirts, long pants, shoes, socks, chemical-resistant gloves, and no respirator[4].

The primary quantitative objective was for dermal exposure results (normalized to the amount of active ingredient handled) to be accurate within 3-fold at the geometric mean, arithmetic mean and 95th percentile. This objective was not met: AHETF results showed accuracy of approximately 3.8-fold at the arithmetic mean and 3.3-fold at the 95th percentile. As a result, EPA will incorporate the uncertainty beyond the 3-fold target in the form of a multiplier to the default exposure estimates used in routine handler exposure assessments for this scenario.

The secondary objective to evaluate proportionality versus independence between dermal exposure and the amount of active ingredient handled – a key assumption in the use of exposure data as "unit exposures" – with 80% statistical power was met. However, estimates of the slope of log exposure-log amount of active ingredient handled (AaiH) regression were not consistent with a proportional relationship (confidence intervals exclude a slope of 1). Nevertheless, EPA will continue to use the exposure data normalized by the amount of active ingredient as a default condition for regulatory exposure assessment purposes.

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[2] Pesticide Handlers Exposure Database (PHED) Scenario 35. High Pressure Handwand: liquid, open pour.

[3] The data are not applicable to volatile chemicals (e.g., fumigants). Furthermore, as only liquid and dry flowable formulations were used in the study, EPA plans to evaluate other data for its potential applicability to wettable powders products with similar use patterns.

[4] Adjustments to this dataset would be required to represent alternative personal protective equipment (e.g., applying a protection factor to represent exposure when using a respirator or additional protective clothing). These types of adjustments would be used in risk assessments as appropriate, given the availability of reliable factors, and are not addressed in this review.

Select summary statistics for this scenario are presented in Table 1 below, as well as, for comparison, the value previously used (PHED Scenario 35. High Pressure Handwand: liquid, open pour) to assess pesticide human health exposure/risk for handgun applications in horticultural facilities.

Table 1. Unit Exposures (µg/lb ai handled): M/L/A Powered Handgun in Greenhouses/Nurseries

Exposure Route[b]	PHED Scenario #35	AHETF[a]				
	"Best fit"	Geometric Mean	Arithmetic Mean[d]		95^{th} Percentile[e]	
Dermal[c,d]	2500	392	2850	3610	10380	11418
Inhalation	120	19	448		1186	

[a] Statistics are estimated using a variance component model accounting for correlation between measurements conducted within the same field study (i.e., measurements collected during the same time and at the same location). Additional model estimates (e.g., empirical and simple random sample assumptions) are described in Section 3.0.
[b] Results represent dermal exposure under long-sleeve shirt, pants, shoes/socks, chemical-resistant gloves, and no chemical-resistant headgear. Inhalation exposure is without respiratory protection.
[c] In addition to the modeled estimates of the arithmetic mean and 95^{th} percentile, additional estimates are presented to reflect a to account for uncertainty beyond the 3-fold target for the arithmetic mean and 95^{th} percentile (i.e., "fRA-adjusted").
[d] Arithmetic Mean (AM) = GM * exp{0.5*((lnGSD)^2)}. "fRA-adjusted" value also shown: 2850 * (3.8 ÷ 3) = 3610. See Section 3.3.1.
[e] 95^{th} percentile = GM * GSD^1.645. "fRA-adjusted" value also shown: 10380 * (3.3 ÷ 3) = 11418. See Section 3.3.1.

2.0 Background

The following provides background on the AHETF objectives and review by the Human Studies Review Board (HSRB).

2.1 AHETF Objectives

The AHETF is developing a database (Agricultural Handlers Exposure Database or AHED) which can be used to estimate worker exposures associated with major agricultural and non-agricultural handler scenarios. A scenario is defined as a pesticide handling task based on activity such as mixing/loading or application. Other factors such as formulation (e.g., liquids, granules, etc.) application equipment type (e.g., tractor-mounted boom sprayers, powered handgun sprayers, etc.) are also key criteria for defining some scenarios. AHETF-sponsored studies are typically designed to represent individuals wearing long-sleeved shirts, long pants, shoes, socks, chemical-resistant gloves as appropriate, and no respirators. In some cases, an engineering control (e.g., vehicles with enclosed cabs, closed mixing/loading systems) or additional personal protective equipment/clothing may also be a key element of the scenario.

AHETF studies use dosimetry methods intended to define pesticide handler dermal and inhalation exposures, attempting to represent the chemical exposure "deposited on or to-the-skin" or "in the breathing zone." For the purposes of pesticide handler exposure assessment, dermal and inhalation exposures are expressed as "unit exposures" – exposure per mass of pesticide handled. Mathematically, unit exposures are expressed as exposure normalized by the amount active ingredient handled (AaiH) by participants in scenario-specific exposure studies (e.g., mg exposure/lb ai handled). Scenario-specific unit exposures are then used generically to predict exposure for other chemical and/or application conditions such as different application rates.

Two major assumptions underlie the use of exposure data in this fashion. First, the expected external exposure is unrelated to the identity of the specific active ingredient in the pesticide formulation. That is, the physical characteristics of a scenario such as the pesticide formulation (e.g., formulation type – granule, liquid concentrate, dry flowable, etc.), packaging (e.g., in a bag or jug), or the equipment type used to apply the pesticide, influence exposure more than the specific pesticide active ingredient (Hackathorn and Eberhart, 1985). Thus, for example, exposure data for mixing/loading/applying one chemical in a greenhouse using a handgun can be used to estimate exposure during mixing/loading/applying of another chemical in a greenhouse using a handgun. Second, dermal and inhalation exposure are assumed proportional to the amount of active ingredient handled. In other words, if one doubles the amount of pesticide handled, exposure is assumed to double.

The AHETF approach for monitoring occupational handler exposure was based on criteria reviewed by EPA and presented to the Human Studies Review Board (HSRB) for determining when a scenario is considered complete and operative. Outlined in the AHETF Governing Document (AHETF, 2008 and 2010), the criteria can be briefly summarized as follows:

- The primary objective of the study design is to be 95% confident that key statistics of dermal exposure (normalized to the amount of active ingredient handled, i.e., dermal "unit exposures") are accurate to within 3-fold. Specifically, the upper and lower 95% confidence limits should be no more than 3-fold higher or lower than the estimates for each of the geometric mean, arithmetic mean, and 95th percentile dermal unit exposures. To meet this primary objective AHETF proposed an experimental design with a sufficient number of monitored individuals across a set of monitoring locations. Note that this "fold relative accuracy" (fRA) objective does not apply to normalized inhalation exposure, though estimates are provided for reference.

- The secondary objective is the ability to evaluate the assumption of proportionality between dermal exposure and amount of active ingredient handled (AaiH) in order to inform use of the AHETF data generically across application conditions. To meet this objective, the AHETF proposed a log-log regression test to distinguish complete proportionality (slope = 1) from complete independence (slope = 0), with 80% statistical power, achieved when the width of the 95th confidence interval of the regression slope is 1.4 or less. Note, again, that this objective does not apply to normalized inhalation exposure; however the tests are performed for informational purposes.

To simultaneously achieve both the primary and secondary objectives described above and maximize logistical/cost efficiency while minimizing the number of participating workers, the AHETF developed a study design employing a 'cluster' strategy. A cluster, from a sample size perspective, is defined as a set of workers monitored in spatial and temporal proximity. For AHETF purposes, clusters are generally defined by a few contiguous counties in a given U.S. state (or states). Importantly, in terms of a sampling strategy, there is assumed to be some level of correlation within clusters. So, while cluster sampling is logistically more efficient and cost effective, within-cluster correlation may result in the need to conduct monitoring for more workers overall than if cluster sampling were not employed.

Though for most handler scenarios the optimal configuration for the AHETF is 5 regional clusters each consisting of 5 participants[5], for AHE600 the AHETF employed a “10 x 3” strategy. To accommodate the analysis for the secondary objective, the AHETF partitions the practical AaiH range handled into strata, and then strives to “place” participants into separate strata so participants within the same cluster are handling different amounts and the overall range is covered. In general, the strata of AaiH for any given scenario is commensurate with typical commercial production agriculture and EPA regulatory assumptions with respect to amount of area that could be treated or amount of dilute solution that could be sprayed in a work day.

2.2 2012 HSRB Protocol Review and Comments

The ability of the EPA to use the AHETF powered handgun exposure monitoring data to support regulatory decisions is contingent upon compliance with the final regulation establishing requirements for the protection of subjects in human research (40 CFR Part 26), including review by the Human Studies Review Board[6]. The protocol and sampling plan for this exposure data and scenario (AHETF, 2012) was presented to the HSRB in January 2012. The meeting report (HSRB, 2012) stated that the proposed approach would “likely generate high quality, reliable and useful data for assessing worker’s pesticide exposures in horticultural settings” if modified in accordance with EPA and HSRB recommendations[7].

However, the Board raised some additional comments/suggestions:

> “… with respect to the use of personal protective equipment (PPE), the potential effect of unanticipated incidental exposures and other variables on proportionality, and the utility of existing European Crop Protection Association (ECPA) data.” (page 1 of HSRB, 2012)

The following table outlines issues raised by the HSRB and how/whether the issue was addressed in the protocol or completed study. HSRB issues/comments are quoted directly or paraphrased from the 2012 meeting report with page numbers included for reference.

Table 2. Summary of 2012 HSRB AHE600 Protocol Review	
2012 HSRB Comment	**Study Outcome**
“One concern that was raised by the Board was that proportionality may not be observed due to unanticipated exposures (e.g., accidentally touching a treated plant or contaminated part of spray equipment), and these sources may contribute substantially to participants’ exposure levels…it will be important for researchers to observe and document all unintentional contacts with treated plants or other events that might	The AHETF altered applicable standard operating procedures (SOP) to further ensure that research staff are attuned to the intent of observing and documenting worker practices and activity. That said, due to the observational (rather than controlled) nature of the work practices, neither the AHETF nor EPA attempted any analysis of potential exposure determinants (outside of the AaiH), as the study was not designed for such evaluations.

[5] Together with the conditions under which the active ingredient is handled, the workers are often referred to as monitoring units (MUs).
[6] http://www2.epa.gov/programs-office-science-advisor-osa/human-studies-review-board
[7] https://archive.epa.gov/osa/hsrb/web/html/jan-26-2012-public-meeting.html

Table 2. Summary of 2012 HSRB AHE600 Protocol Review	
2012 HSRB Comment	**Study Outcome**
contribute to the exposure levels." (HSRB, 2012 page 10)	
"…should chemical-resistant headgear be worn, the use of patches inside the headgear should yield valid estimates of exposure for those participants wearing such a hat. However, this method may underestimate exposures if attempts were made to extrapolate these data to those not wearing such headgear…The effect of the protection afforded by the brim of the chemical-resistant headgear would negatively affect that use. Thus, the Board suggested that the sponsors consider: 1) having study participants use chemical-resistant headgear without a brim (but only if this is allowed by the Worker Protection Standards); or 2) add a third patch dosimeter against the head below the brim, as the density of deposition (µg/cm2) onto this patch could be compared to the deposition onto the rest of the face to estimate the magnitude of protection afforded by such a brim." (HSRB, 2012 page 9)	The study protocol was not altered. First, use of a hat without a brim was not possible. Then, regarding a forehead patch, EPA agreed with the AHETF that, particularly given its likely complications (e.g., sweating), the presence of a patch on the top (exterior) of the chemical-resistant hats should, via extrapolation, provide reasonable estimates of exposure without ("as if" workers were not wearing) chemical-resistant hats.
"The Board also considered issues related to the Agency's recommendation to include wettable powder by at least one participant in each cluster…If both formulations are to be used, the Board recommended that the Agency conduct a separate analysis of each type before combining all of the data for analysis. The sponsor could have 15 MUs use the powder formulation and 15 MUs use the liquid formulation. Alternatively, all MUs could use the wettable powder, as that formulation type is more likely to generate more conservative exposure data." (HSRB, 2012 page 10)	Following the 2012 HSRB, EPA agreed with the AHETF that, due to the logistical recruitment difficulties it would entail, the study protocol did not need to require monitoring of workers who handle wettable powders; the study protocol only encouraged formulation diversity. No workers in the study, however, used a wettable powder pesticide.
"…the Board cautioned the Agency and the sponsors that the justification for the study may be weak. In particular, the Board raised a question about the utility of ECPA data…While there may be other scenario or data quality issues with the ECPA data, the Board recommended that the Agency consider the viability of combining the ECPA application-only exposure data with the Task Force's mixing/loading-only exposure data to satisfy the Agency's registration needs without further human exposure studies." (HSRB, 2012 page 10)	Following the 2012 HSRB, EPA and AHETF further considered the European Crop Protection Association (ECPA) data. The various issues related to conduct of those studies continue to make them incompatible with the intent of the generic AHETF database (e.g., non-standardized levels of PPE, lack of some body part monitoring, etc.).

2.3 2019 HSRB Review and Comments

[placeholder for April 2019 HSRB review]

3.0 Exposure Study Conduct and Monitoring Results

Field monitoring and analytical results, as well as protocol amendments and deviations, were reported in AHE600 and reviewed by EPA (Crowley, 2019; DXXXXX). No existing studies were deemed acceptable by the AHETF; thus, AHE600 was designed to supplant previously used data. Additionally, no protocol amendments or deviations were considered to adversely affect the study results.

The following sections summarize the conduct of AHE600, the exposure monitoring results and the scenario benchmark statistical analyses presented in the AHETF scenario monograph (Bruce and Holden, 2019).

3.1 Exposure Study Design and Characteristics

As described by the AHETF, this pesticide handler scenario "involves the mixing of dry or liquid formulated product with water which can be accomplished by either preparing a pre-mix and transferring to a spray tank where the mixture is diluted with an appropriate amount of water, or the product can be transferred directly to the spray tank and diluted. Application involves the use of powered handgun equipment in which the liquid spray is applied to the foliage of plants typically grown in commercial horticultural facilities." (AHE1023)

While the AHETF defines the scenario in terms of "dry or liquid formulated product", AHE600 consisted only of monitoring workers who mixed liquids and dry flowables (also known as water-dispersible granules); no worker mixed a wettable powder, another type of dry/solid product formulation. During the protocol phase of the study, following the 2012 HSRB review (see Section 2.2 above), EPA agreed that requiring the AHETF to find participants who would use a wettable powder product would likely result in recruitment difficulties. While this was reasonable, because of the lack of representation of use of wettable powder products in the resulting dataset, EPA plans to evaluate other monitoring data for its applicability to assess exposure of workers who mix and load wettable powders products with a similar use pattern.

With respect to other aspects of the scenario definition, the following provides more details:

Scenario Terminology	AHETF Description from AHE1023
Powered	"…attached to a hose, which is in turn attached, through a pump, to the spray tank. The equipment is powered by a gasoline or electric engine or by battery. Hydraulic pressure forces the liquid spray through an orifice resulting in high volumes of spray…"
Handgun	"…(also referred to as 'spray gun') is a single- or multiple-nozzle device in which the operator squeezes a trigger with his hand to start/stop the flow of liquid spray. The 'hand wand' is a lightweight, long metal extension which ends in a nozzle or cluster of nozzles that again can be turned on and off by the operator by squeezing a trigger or turning a valve. However, for purposes of this scenario, the spray devices attached to the end of the hose, whether they are gun-style or wand-style, are all considered powered handgun equipment."
	"…generally used when needed to treat relatively large areas. The worker makes the application by dragging the hose and dispensing the spray from the nozzle as he walks along rows or walkways. In some situations, the tank may be mounted on a cart and pulled along by hand or with a small vehicle. In other situations, such as in nurseries, the worker might ride on a tractor or other vehicle and operate the gun from the vehicle as he drives along."
Managed horticultural facilities	"…refers to nurseries (N) or greenhouses (GH); furthermore, greenhouses can be engaged in either the production of ornamental crops or in vegetable crops. In broad terms, a nursery is a facility or operation that produces crops in outdoor or open areas while a greenhouse is a facility or operation that produces crops grown

	in indoor or enclosed areas...collectively their structures and/or production areas represent a continuum from completely open facilities to completely enclosed facilities, the plantings are 'managed' (i.e., arranged and maintained) in an organized fashion, and spray practices using powered handgun equipment are similar."

The figures below (from AHE1023 Appendix F; Bruce and Holden, 2019) depict examples of activities for which the exposure data are applicable.

Figure 1: Mixing/Loading (Liquid)

Figure 2: Application (open nursery; handwand; overhead spray)

Figure 3: Application (closed hoop house; handgun; downward spray)

Figure 4: Application (closed greenhouse; handwand; downward spray)

In order to capture the expected range of exposures with a relatively small sample, the monitoring plan/protocol for AHE600 (AHETF, 2012) outlined a strategy to target a diverse set of conditions such as geographic areas (10 locations across the U.S.), types of facilities (e.g., nurseries and greenhouses; open and enclosed; wide and narrow spaces/walkways), plants/crops to be treated (e.g., tall plants, floor plants, hanging baskets), types of equipment (e.g., handgun and handwand; walking or vehicle). At the same time, recruiting procedures were developed to minimize bias in the selection of employers and subjects. As described in detail in the study, there were three recruitment phases. The phases involved winnowing down the initial universe list of employers in the monitoring area who may use powered handgun equipment in greenhouses and nurseries through processes to identify subsequent lists of "qualified employers" and then "potentially eligible" employers. After confirming eligibility, AHETF scheduled and conducted monitoring of workers. Randomization in the process included creation of a Master Grower List (MGL) – typically about 1,500 names – via sampling from the Grower Universe List (GUL) as well as randomization of the Qualified Grower List (QGL) from which to contact during Phase 2 recruitment. Non-response (i.e., inability to contact, interview refusals) was approximately 75% across the monitoring areas and still others contacted were deemed not qualified (e.g., they didn't use certain equipment, or the particular surrogate active ingredient being proposed). In only one instance (recruiting in the Indiana/Michigan area from 2014-2017) was there an opportunity to randomly select from a pool of multiple workers who volunteered.

The sampling plan for this scenario (AHETF, 2012) outlined a '10 x 3' design – monitoring of a total of 30 different workers, 3 workers in each of 10 separate 'clusters' or monitoring areas monitored around approximately the same time – that the protocol demonstrated would simultaneously be cost-effective and satisfy benchmark data analysis objectives. In actuality, this cost-effective approach was not completely achieved. Though 10 geographical locations were monitored, both spatial and temporal differences resulted in (a less cost-effective) configuration of 17 clusters and further "sub-clustering". In three monitoring areas, 4 workers instead of the planned 3 were monitored. These changes to the data configuration followed protocol amendments which relaxed some of the design restrictions due to recruitment difficulties. Finally, monitoring for 3 workers was invalidated due to analytical issues, deviation from protocol, or deviation from normal worker activity. Thus, the final dataset consisted of 27 separate workers monitored in 17 U.S. from 2013-2017.

As monitoring was conducted across 4 years and 17 different U.S. states, both spatial and temporal diversity is represented in the sample. Per protocol, no worker was monitored twice (no "repeat measures") and, to reduce any potential similarities related to training, all workers were associated with different facilities/employers. Other monitoring preferences were unable to be achieved such as the goal to have each worker in a monitored area handle a different formulation or and treat a facility with a different degree of "openness". On the other hand, other conditions such as different hose attachments and spray direction were adequately diverse. The following table provides a summary of monitoring characteristics.

Table 3. AHE600 Summary

Monitoring Area	Worker ID	Type of Equipment	Facility	Spray Orientation	Formulation	Monitoring Date
Northeast	20	Hand gun	Nursery and Hoop house (open and enclosed areas)	Horizontal and down	Liquid	10/5/2016
	21	Hand wand	Hoop house (enclosed)	Horizontal and down	Liquid	10/12/2016
Mid-Atlantic	28	Hand wand	Greenhouse (enclosed)	Horizontal, down, and overhead	Liquid	4/5/2017
	30	Hand wand	Greenhouse (enclosed)	Horizontal and down	Dry Flowable	4/21/2017
SC/NC/TN	10	Hand gun	Hoop house (enclosed)	Horizontal and down	Dry Flowable	3/26/2015
	13	Hand gun	Greenhouse (enclosed)	Horizontal and down	Liquid	4/30/2015

Table 3. AHE600 Summary						
Monitoring Area	**Worker ID**	**Type of Equipment**	**Facility**	**Spray Orientation**	**Formulation**	**Monitoring Date**
	26	Hand gun	Nursery (open)	Horizontal and down	Liquid	3/8/2017
	27	Hand wand	Greenhouse (enclosed)	Horizontal, down, and overhead	Liquid	3/25/2017
Northern Florida	4	Hand gun	Greenhouse (enclosed)	Horizontal and down	Dry Flowable	11/20/2013
	5	Hand gun	Hoop house (enclosed) and Greenhouse (open)	Horizontal and down	Liquid	11/22/2013
	6	Hand wand	Hoop house (open and closed)	Horizontal and down	Dry Flowable	12/11/2013
	23	Hand gun	Nursery, Greenhouse, and Hoop house (open and enclosed areas)	Horizontal and down	Liquid	2/1/2017
Southern Florida	14	Hand gun	Nursery and shadehosue (open)	Horizontal, down, and overhead	Dry Flowable	6/5/2015
	17	Hand gun	Shadehouse (enclosed)	Horizontal and down	Liquid	2/10/2016
OH/PA	16	Hand gun	Greenhouse and Nursery (open and closed)	Horizontal, down, and overhead	Liquid	10/7/2015
	22	Hand gun	Greenhouse (enclosed)	Horizontal and down	Dry Flowable	11/2/2016
	29	Hand wand	Greenhouse (enclosed)	Horizontal and down	Liquid	4/13/2017
IN/MI	8	Hand wand	Greenhouse (enclosed)	Horizontal and down	Dry Flowable	3/8/2015
	18	Hand gun	Greenhouse (enclosed)	Horizontal and down	Dry Flowable	9/7/2016
	19	Hand gun	Greenhouse (enclosed)	Down	Liquid	9/8/2016
IL/WI	9	Hand wand	Greenhouse (enclosed)	Horizontal, down, and overhead	Dry Flowable	3/9/2015
	12	Hand wand	Hoop house (enclosed)	Horizontal and down	Liquid	4/25/2015
	24	Hand wand	Greenhouse (enclosed)	Horizontal, down, and overhead	Liquid	2/28/2017
	25	Hand wand	Greenhouse (enclosed)	Down	Liquid	3/3/2017
LA/TX	7	Hand wand	Greenhouse (enclosed)	Horizontal and down	Liquid	1/28/2015
OR/WA	1	Hand wand	Greenhouse (enclosed)	Horizontal and down	Liquid	10/10/2013

Table 3. AHE600 Summary						
Monitoring Area	**Worker ID**	**Type of Equipment**	**Facility**	**Spray Orientation**	**Formulation**	**Monitoring Date**
	2	Hand gun	Hoop house and Shadehouse (open and closed)	Horizontal and down	Liquid	10/30/2013

Also, per protocol, the amount of active ingredient handled by the workers was diversified – mainly to accommodate the secondary (regression analysis) study objective – but also to potentially add indirect variability to the dataset. Within each monitoring areas the study design called for each of 3 workers to represent (or 'occupy') one of three AaiH strata (from 0.5 to 1.6 lbs or 1.6 to 4.8 lbs or 4.8 to 15 lbs). However, it appears the pre-defined active ingredient handled strata were overestimated in the protocol: in actuality only one worker handled an amount in the highest pre-defined strata (worker #14 handled 5.85 lb), and, in many cases, workers handled well below the lower stratum (less than 0.5 lbs). Overall, workers mixed and applied between a few teaspoons to less than a gallon of concentrated liquid product or from less than 1 to 6 pounds of dry flowable formulation, corresponding to a range of 0.0023 to 5.85 lbs of active ingredient (ai) handled. Thus, while the intended strata-based distribution of AaiH across workers was not achieved, ultimately the spread of amount of active ingredient handled was approximately 3 orders of magnitude, an adequate range both for enhancing diversity in the dataset and enabling regression analysis.

For more details on worker characteristics and other monitoring conditions, see the monograph submission (AHE1023), the AHE600 report submission and its corresponding EPA review (Crowley, 2019; DXXXXX).

3.2 Exposure Monitoring and Calculations

This section briefly describes how exposure was measured, the final dermal and inhalation exposure results used in statistical analyses, and how those results were analyzed.

3.2.1 Monitoring Methods

Dermal exposure was measured using 100% cotton "whole body dosimeters" (WBD) underneath normal work clothing (e.g., long-sleeved shirt, long pants, socks and shoes), hand rinses (collected at the end of the day and during restroom and lunch breaks), face/neck wipes, socks, and head patches. Per AHETF goals, monitoring was conducted to represent exposure for workers wearing long-sleeve shirts, pants, shoes/socks, chemical-resistant gloves and no respiratory protection. In order to simulate total head exposure without any eye protection or use of respirators, face/neck wipe samples for those workers who did use eye protection and/or respirators were adjusted to extrapolate to portions of the head covered by protective eyewear and/or hair. For workers who wore chemical-resistant hats, patches were used both underneath the hat attached to the top of the worker's head (a 100 cm^2 patch) and on the outside attached to the top of the hat (a 50 cm^2 patch). Total dermal exposure was then calculated for each worker by summing exposure across all their body part measurements. Dermal exposures in this review represent workers without chemical-resistant hats (via use of results for both head patches for those who wore chemical resistant hats).

Additionally, as presented at a June 2007 HSRB meeting, to account for potential residue collection method inefficiencies[8], EPA follows the rules below to determine whether to adjust the hand and face/neck field study measurements:

- if measured exposures from hands, face and neck constitute less than 20% of total dermal exposure as an average across all workers, no action is required;
- if measured exposure from hands and face/neck constitutes between 20% and 60% of total dermal exposure, the measurements shall be adjusted upward by a factor of 2, or submission of a validation study to support the residue collection method;
- if measured exposure from hands and face/neck constitutes greater than 60% of total dermal exposure, a validation study demonstrating the efficiency of the residue collection methods is required.

For AHE600 the measurements fell in the first category – on average approximately 19% of total dermal exposure consisted of exposure measured using hand washes and face/neck wipes.

Inhalation exposure was measured using a personal air sampling pump and an OSHA Versatile Sampler (OVS) tube. The tube is attached to the worker's shirt collar to continuously sample air from the breathing zone. Total inhalation exposures were calculated by adjusting the measured air concentration (i.e., ug/L) using a breathing rate of 16.7 L/min representing light activities (NAFTA, 1998), and total work/monitoring time[9].

3.2.2 Dermal and Inhalation Exposure Results

Following calculation of total dermal and inhalation exposure as described in Section 3.2.1 above, dermal and inhalation "unit exposures" (i.e., µg/lb ai handled) are then calculated by dividing the summed total exposure by the amount of active ingredient handled. Both dermal and inhalation exposure samples are adjusted as appropriate according to recovery results from field fortification samples and, though alternate methods can be applied by data users (e.g., maximum likelihood estimation), residues with results less than analytical limits use the "½ analytical limit" (either ½ LOD or LOQ) convention. As described in AHE600, this convention would apply to the 7 workers that had all or nearly all non-detects for their dermal exposure samples; no worker had a non-detect inhalation (OVS front section) sample.

A summary of the 27 workers is provided in Table 4 below, with data plots shown in Figures 5 and 6. More details on exposure measurements, field fortification sampling, and other laboratory measurements can be found in EPA's study review of AHE600 (Crowley, 2019; DXXXXX).

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[8] The terminology used to describe this are "method efficiency adjusted" (MEA) or "method efficiency corrected" (MEC)

[9] Inhalation exposure (µg) = collected air residue (µg) x [breathing rate (L/min) ÷ average pump flow rate (L/min)]

Table 4. Handgun in Greenhouse/Nurseries Unit Exposure Summary								
Worker ID	Facility	Spray Orientation	Formulation	Solution Sprayed (gallons)	Exposure Time (hrs)	AaiH (lbs)	Unit Exposure (µg/lb ai)	
							Dermal	Inhalation
1	Greenhouse (enclosed)	Horizontal and down	Liquid	80	4.9	0.071	36.6	101
2	Hoop house and Shadehouse (open and closed)	Horizontal and down	Liquid	450	8.5	3.29	1033	0.065
4	Greenhouse (enclosed)	Horizontal and down	Dry Flowable	147.5	3.0	2.94	18.5	54.0
5	Hoop house (enclosed) and Greenhouse (open)	Horizontal and down	Liquid	150	3.1	0.767	1047	1.64
6	Hoop house (open and closed)	Horizontal and down	Dry Flowable	300	2.1	4.20	33.1	1.26
7	Greenhouse (enclosed)	Horizontal and down	Liquid	150	2.4	1.65	225	96.4
8	Greenhouse (enclosed)	Horizontal and down	Dry Flowable	149	2.7	0.158	180	250
9	Greenhouse (enclosed)	Horizontal, down, and overhead	Dry Flowable	100	2.6	0.126	2428	402
10	Hoop house (enclosed)	Horizontal and down	Dry Flowable	472	6.8	0.302	77.3	57
12	Hoop house (enclosed)	Horizontal and down	Liquid	98	3.1	0.975	37.6	5.53
13	Greenhouse (enclosed)	Horizontal and down	Liquid	180	3.2	0.919	208	0.36
14	Nursery and shadehosue (open)	Horizontal, down, and overhead	Dry Flowable	450	3.7	5.85	145	2.58
16	Greenhouse and Nursery (open and closed)	Horizontal, down, and overhead	Liquid	165	4.5	0.044	9075	284
17	Shadehouse (enclosed)	Horizontal and down	Liquid	600	7.6	0.966	155	14.8
18	Greenhouse (enclosed)	Horizontal and down	Dry Flowable	120	2.0	0.183	60.1	65
19	Greenhouse (enclosed)	Down	Liquid	85	1.5	0.445	649	0.523
20	Nursery and Hoop house (open and enclosed areas)	Horizontal and down	Liquid	40	2.1	0.771	311	0.882
21	Hoop house (enclosed)	Horizontal and down	Liquid	100	2.4	0.027	925	368

Table 4. Handgun in Greenhouse/Nurseries Unit Exposure Summary								
Worker ID	**Facility**	**Spray Orientation**	**Formulation**	**Solution Sprayed (gallons)**	**Exposure Time (hrs)**	**AaiH (lbs)**	**Unit Exposure (µg/lb ai)**	
							Dermal	**Inhalation**
22	Greenhouse (enclosed)	Horizontal and down	Dry Flowable	50	1.2	0.068	117	72.0
23	Nursery, Greenhouse, and Hoop house (open and enclosed areas)	Horizontal and down	Liquid	150	2.6	1.54	196	10.2
24	Greenhouse (enclosed)	Horizontal, down, and overhead	Liquid	15	1.2	0.004	2138	508
25	Greenhouse (enclosed)	Down	Liquid	15	2.0	0.002	4500	112
26	Nursery (open)	Horizontal and down	Liquid	190	4.5	3.08	1262	12.7
27	Greenhouse (enclosed)	Horizontal, down, and overhead	Liquid	95	3.6	0.025	8746	14.4
28	Greenhouse (enclosed)	Horizontal, down, and overhead	Liquid	24	2.8	0.007	21198	447
29	Greenhouse (enclosed)	Horizontal and down	Liquid	50	1.3	0.008	3200	61.6
30	Greenhouse (enclosed)	Horizontal and down	Dry Flowable	35	0.6	0.061	19.6	1.6

Figure 5: Dermal Unit Exposures (ug/lb ai)

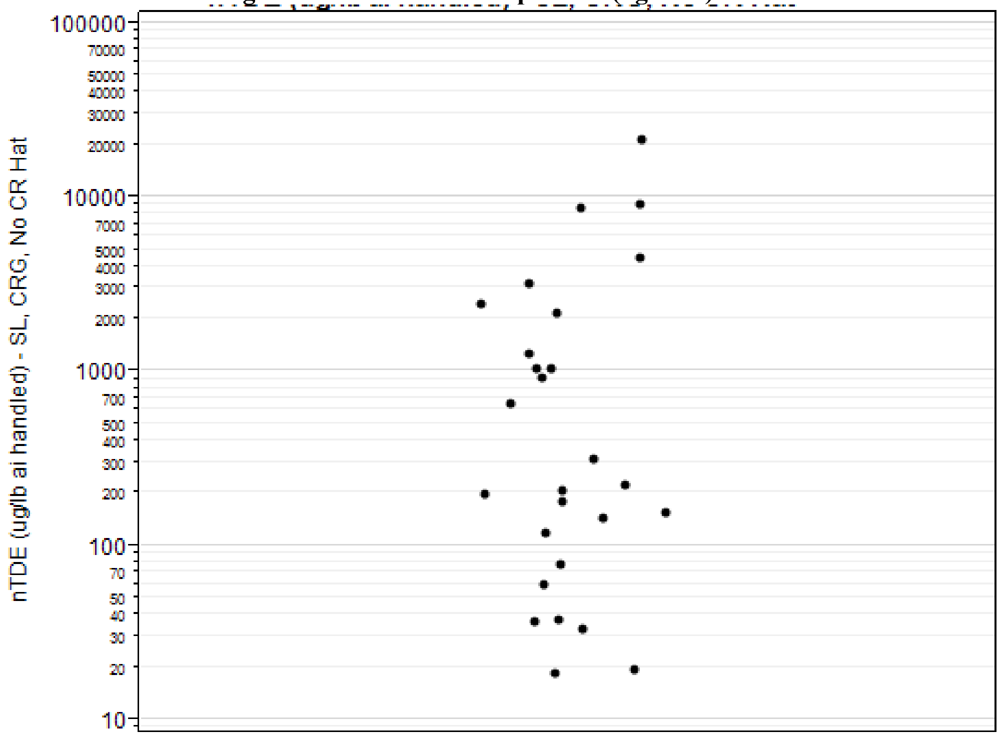
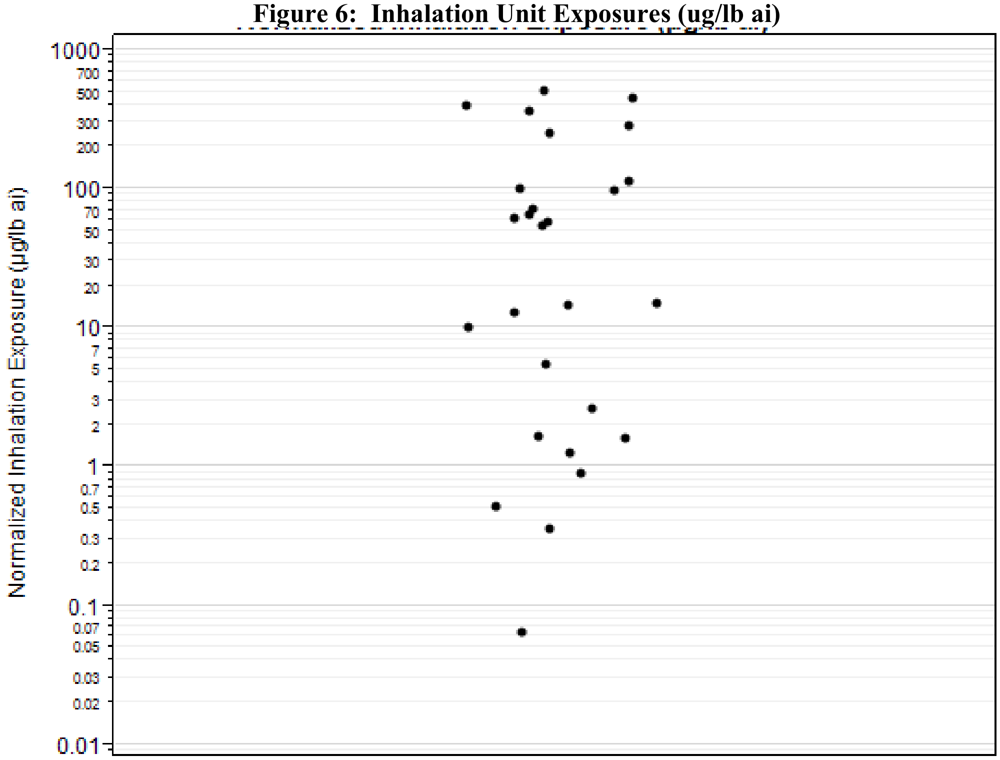


Figure 6: Inhalation Unit Exposures (ug/lb ai)



3.3 Evaluation of Scenario Benchmark Objectives

The AHETF monograph details the extent to which the results of the completed study meet the objectives described in Section 2.1. The monograph states that the primary objective (3-fold accuracy) was not met while the secondary objective (adequate analytical power to evaluate proportionality) was met. EPA agrees with the methodologies used to assess these objectives (Appendix D of Bruce and Holden, 2019) and has independently confirmed the results by re-analyzing the data with the AHETF-supplied statistical programming code (AHE1023 Appendix E).

3.3.1 Primary Objective: fold Relative Accuracy (fRA)

The primary benchmark objective for AHETF scenarios is for select dermal exposure statistics – the geometric mean (GM), the arithmetic mean (AM), and the 95^{th} percentile (P95) – to be accurate within 3-fold with 95% confidence (i.e., "fold relative accuracy" or fRA).

First, the AHETF evaluated the structure of the final dataset in comparison to the intended study design. The initial study design envisioned a (cost- and analytically-efficient) data structure of 10 clusters each with 3 monitored workers, totaling 30 data points. Importantly, as uncertainty can be underestimated if independence is assumed, the AHETF incorporated the potential correlation of monitoring within the same cluster when demonstrating that the planned study design and sample size would satisfy the primary (accuracy) analytical objective. However, when AHE600 was conducted, the AHETF was not able to achieve the intended efficient monitoring configurations due to recruitment difficulties and, from a data analysis perspective resulted in more clusters than intended. While AHE600 utilized the 10 monitoring areas as intended, they expanded some monitoring areas, and, via protocol amendment, allowed for monitoring more than 3 workers per monitoring area to facilitate recruitment and complete the study. Ultimately, data analysis included grouping the data from the 10 monitoring areas into 17 clusters and additional sub-clusters. Figure 7 below (from AHE1023 Appendix D Table 2) illustrates the clustering used for analysis of the primary objective.

Figure 7: AHE1023 Summary of Data 'Clusters'

Monitoring Area	Cluster	SubCluster	Monitoring Unit	Monitoring Date	Nearest Town
601	1	1a	20	10/05/2016	Bridgewater MA
			21	10/12/2016	Newton NH
602	2	2a	28	04/05/2017	Farmville VA
		2b	30	04/21/2017	Pompton Plains NJ
603	3	3a	10	03/26/2015	Greensboro NC
		3b	13	04/30/2015	Nebo NC
	4	4a	26	03/08/2017	Ridgeville SC
		4b	27	03/25/2017	Rockwood TN
604	5	5a	4	11/20/2013	Apopka FL
			5	11/22/2013	Ocala FL
			6	12/11/2013	Dunnellon FL
	6	6a	23	02/01/2017	Dothan AL
605	7	7a	14	06/05/2015	Wellington FL
	8	8a	17	02/10/2016	Miami FL
606	9	9a	16	10/07/2015	Erie PA
	10	10a	22	11/02/2016	Medina OH
	11	11a	29	04/13/2017	Groveport OH
607	12	12a	8	03/08/2015	Kalamazoo MI
	13	13a	18	09/07/2016	Mattawan MI
			19	09/08/2016	Dowagiac MI
608	14	14a	9	03/09/2015	Grant Park IL
		14b	12	04/24/2015	Plano IL
	15	15a	24	02/28/2017	Alma MO
		15b	25	03/03/2017	Reedsville WI
609	16	16a	7	01/28/2015	Troup TX
610	17	17a	1	10/10/2013	Salem OR
			2	10/30/2013	Dayton OR

Next, the AHETF demonstrated both dermal and inhalation unit exposures were shown to fit lognormal distributions reasonably well; lognormal probability plots (and normal probability plots, for comparison) are provided as Attachment 1. Finally, the AHETF calculated estimates of the GM, AM and P95 based on three variations of the data:

- Non-parametric empirical (i.e., ranked) estimates;
- Assuming a lognormal distribution and a simple random sample (SRS); and,
- Hierarchical variance component modeling to account for potential within-cluster correlations, as noted above.

As presented in Appendix C of the AHETF Governing Document (AHETF, 2008 and AHETF, 2010) and Appendix D of the scenario monograph (Bruce and Holden, 2019), the 95% confidence limits for each of these estimates were obtained by generating 10,000 parametric bootstrap samples. Then, the fRA_{95} for each was determined as the maximum of the two ratios of the statistical point estimates with their respective upper and lower 95% confidence limits.

Utilizing both the final datasets and the statistical programming code submitted by the AHETF (in SAS), EPA confirmed the statistical analysis results in the AHETF submission. Results show that both the arithmetic mean and 95th percentile estimates did not meet the accuracy benchmark.

Accuracy results for inhalation exposure, though not formally part of the primary objective, were much higher than those for dermal exposure. In both cases, it appears the variability of both dermal and inhalation exposure for this scenario was underestimated during the study design phase. One of the assumptions in designing the initial '10 x 3' monitoring approach to meet the 3-fold accuracy benchmark was a geometric standard deviation (GSD) of 5, itself a representation of high variability. But the study results show larger GSD estimates – approximately 7 for dermal exposure and 12 for inhalation exposure – that are likely the prime reason behind the less accurate statistics (i.e., > 3-fold accuracy). Results are presented below in Table 5.

Table 5. Handgun in Greenhouse/Nursery – Results of Primary Benchmark Analysis

Statistic	Dermal			Inhalation[a]		
	Unit Exposure (µg/lb ai)		fRA_{95}	Unit Exposure (µg/lb ai)		fRA_{95}
	Estimate	95% CI		Estimate	95% CI	
GM_S	392	183-831	2.1	19.0	7.3-49.0	2.6
GSD_S	7.33	4.31-12.61	--	12.36	6.32-24.52	--
GM_M	392	181-841	2.2	19.0	7.1-49.7	2.6
GSD_M	7.33	4.33-12.85	--	12.36	6.3-25.13	--
ICC_1	0.00	0.00-0.58	--	0.00	0.00-0.58	--
ICC_2	0.00	0.00-0.82	--	0.00	0.00-0.82	--
GM_S = geometric mean assuming SRS = "exp(average of 27 ln(UE)) values". GSD_S = geometric standard deviation assuming SRS = "exp(standard deviation of 27 ln(UE)) values" GM_M = variance component model-based geometric mean GSD_M = variance component model-based geometric standard deviation ICC_1 = intra-class correlation for data in the same cluster but different sub-clusters ICC_2 = intra-class correlation for data in the same cluster and sub-cluster						
AM_S	2149	648-9939	4.1	109	46-2193	8.4
AM_U	2850	832-11689	3.7	448	73-3730	7.1
AM_M	2850	834-12397	3.8	448	74-4148	7.4
AM_S = simple average of 27 unit exposures AM_U = arithmetic mean based on GM_S = GM_S*exp{0.5*((lnGSD_S)^2} AM_M = variance component model-based arithmetic mean = GM_M* exp{0.5*((lnGSD_M)^2}						
$P95_S$	9075	2287-42244	4.3	447	176-6980	6.3
$P95_U$	10380	3149-33018	3.2	1186	263-5114	4.4
$P95_M$	10380	3173-34262	3.3	1186	266-5358	4.5
$P95_S$ = 95th percentile (i.e., the 26th unit exposure out of 27 ranked in ascending order) $P95_U$ = 95th percentile based on GM_S = GM_S * GSD_S^1.645 $P95_M$ = variance component model-based 95th percentile = GM_M* GSD_M^1.645						
[a] Accuracy results for inhalation exposure are presented but, unlike dermal exposure, are not subject to the 3-fold threshold study objective.						

As the primary objective was not met – AHETF results showed accuracy of approximately 3.8-fold at the arithmetic mean and 3.3-fold at the 95th percentile – EPA will quantitatively incorporate the uncertainty beyond the 3-fold target in the form of a multiplier to the default exposure estimates used in routine handler exposure assessments (see Table 1).

3.3.2 Secondary Objective: Evaluating Proportionality

The secondary objective of the study design is to evaluate whether characteristics of the resulting data (i.e., the variability and correlation structure, the range of AaiH, etc.) are consistent assumptions used when designing the study to have 80% statistical power to distinguish between complete proportionality from complete independence between dermal exposure and amount of active ingredient handled. Upon completion of the study, the data can be analyzed to determine if it provides a level of precision consistent with that benchmark.

To evaluate the relationship for this scenario, the AHETF performed regression analysis of ln(exposure) and ln(AaiH) to determine if the slope is not significantly different than 1 – providing support for a proportional relationship – or if the slope is not significantly different than 0 – providing support for an independent relationship. A proportional relationship would mean that doubling the amount of active ingredient handled would double exposure. Both simple linear regression and mixed-effect regression were performed to evaluate the relationship between dermal exposure and AaiH. A confidence interval width of 1.4 (or less) indicates at least 80% statistical power. For the dermal exposure results, the width of the regression confidence interval for dermal exposure was less than 1.4, demonstrating that the study was adequately powered to detect complete independence from complete proportionality.

The resulting regression slopes and confidence intervals for dermal exposure and inhalation exposure are summarized in Table 6. As mentioned previously, the conduct of the monitoring resulted in no detectable effects of cluster or sub-cluster, resulting in identical results for the simple linear regression and mixed-effects model.

Table 6. Summary Results of log-log Regression Slopes

Model	**Dermal Exposure**			**Inhalation Exposure**		
	Est.	**95% CI**	**CI Width**	**Est.**	**95% CI**	**CI Width**
Mixed-Effects	0.52	0.22-0.82	0.60	0.32	-0.04-0.67	0.71

Note: results shown using the Kenward-Rogers denominator degrees of freedom method. AHETF statistical analysis (AHE1023 Appendices D and E) provides results using the Containment method as well. Results were not substantially different.

For dermal exposure the 95% confidence interval slope excludes 0 and 1, suggesting a positive relationship but perhaps not a proportional relationship; for inhalation exposure the 95% confidence interval slope includes 0 and excludes 1, a result that doesn't exclude the possibility that amount of active ingredient handled has little effect on exposure. See Figures 8 and 9 below (from AHE1023 Appendix D).

Figure 8: Dermal vs AaiH Log-log Regression

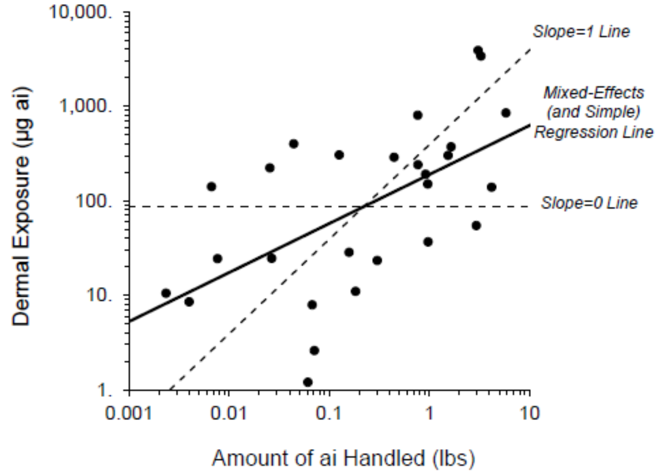
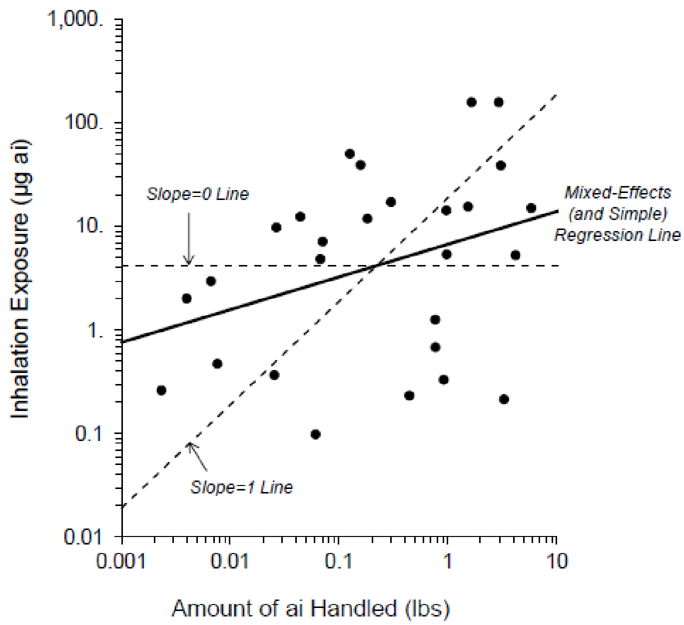


Figure 9: Inhalation vs AaiH Log-log Regression



4.0 Data Generalizations and Limitations

The need for an upgraded generic pesticide handler exposure database has been publicly discussed and established (Christian, 2007). While existing exposure data for mixing/loading/applying with handgun equipment in greenhouse/nurseries was identified, the AHETF did not consider any to be of sufficient quality for their database. Therefore, AHE600 was conducted to develop all new data to supplant the existing data used in regulatory risk assessments. The data will be used generically for current and future pesticide products to assess exposure and risk for workers mixing/loading/applying with handgun equipment in greenhouse/nurseries while wearing a long-sleeved shirt, long pants, shoes, socks, chemical-resistant gloves, and no respirator. However, certain limitations need to be recognized with respect to collection, use, and interpretation of the exposure data.

4.1 Generic Use in Exposure Assessment

Though specific active ingredients were monitored in AHE600, the data is considered reliable for use in a generic fashion (i.e., for any pesticide active ingredient). Importantly, use of the data generically in a regulatory context implies that the pesticide active ingredient being reviewed has a use pattern consistent with the activities and conditions represented by the data for this scenario. While the AHETF defines the scenario in terms of "dry or liquid formulated product", AHE600 monitoring consisted only of workers who mixed liquids and dry flowables (also known as water-dispersible granules); no worker mixed a wettable powder, another type of dry/solid product formulation. While EPA agreed that requiring the AHETF to find participants who would use a wettable powder product would likely result in recruitment difficulties, because no workers used wettable powders, EPA plans to evaluate other monitoring data for its applicability to assess exposure of workers who mix and load wettable powders products with a similar use pattern.

Additionally, the availability of this data does not preclude additional consideration or use of acceptable available chemical- and scenario-specific studies, biomonitoring studies, or other circumstances in which exposure data can be acceptably used in lieu of these data.

4.2 Applicability of AHETF Data for Volatile Chemicals

The data generated in this study are acceptable to use as surrogate data for assessing mixer/loader/applicator exposure to other conventional pesticides used in handgun sprayers, which are generally chemicals of low volatility. Since they are not typically used in handgun sprayers, it is not expected that this dataset would be used to support regulatory decisions for high volatility pesticides (e.g., fumigants).

4.3 Use of "Unit Exposures"

As previously described, for the purposes of pesticide handler exposure assessment, dermal and inhalation exposures are expressed as "unit exposures" – exposure per mass of pesticide handled. This format provides a very simple exposure model from which to extrapolate data generically to other chemicals with different application rates. Underlying use of the data in that format is the assumption that exposure is proportional to the amount of active ingredient handled. In other words, if one doubles the amount of pesticide handled, exposure is assumed to double.

For this handgun sprayer data submitted by the AHETF scenario, results of the analysis of the relationship between dermal and inhalation exposure and the amount of active ingredient handled were mixed. On the one hand, in both cases there appears to be a positive upward trend, which makes intuitive sense. However, a formal look at the confidence intervals around the regression slope suggest a weaker relationship than proportionality. Despite this outcome, to remain consistent with how other handler exposure data are used, EPA will continue to use the unit exposure format that assumes proportionality. However, the outcome of this study suggests that a more thorough look at this assumption should occur in the future.

4.4 Representativeness and Extrapolation to Exposed Population

Targeting and selecting specific monitoring characteristics (i.e., "purposive sampling" or "diversity selection") as well as certain restrictions necessary for logistical purposes (e.g., selection of certain monitoring areas known to contain greenhouses to ensure a large pool of potential participants, requiring potential participants to use certain pesticides to ensure laboratory analysis of exposure monitoring matrices, and requiring selection of workers who normally wear the scenario-defined minimal PPE), render the data neither purely observational nor random to allow for characterization of the dataset as representative of the population of workers making applications in horticultural facilities with powered handguns. It is important to recognize this as a limitation when making use of the data.

It appears however, that the final dataset has captured routine behavior as well as limiting the likelihood of "low-end" or non-detect exposures via certain scripting aspects (e.g., adequate application durations), both of which are valuable for regulatory assessment purposes. And, as outlined in the AHE600 study submission and EPA's review of AHE600, an informal survey of local experts did not suggest that the monitoring was atypical for each monitoring area. Also, construction and use of master lists of potential growers/employers/companies likely mitigated selection bias on the part of participants or recruiters. Thus, with respect to costs, feasibility, and utility, the resulting dataset is considered a reasonable approximation of expected exposure for this population.

5.0 Conclusions

EPA has reviewed the AHETF Mixing/Loading/Application using Powered Handgun Equipment in Managed Horticultural Facilities scenario monograph and concurs with the technical analysis of the data as well as the evaluation of the statistical benchmark objectives. Conclusions are as follows:

- Deficiencies in the data EPA currently uses to estimate dermal and inhalation exposure for mixing/loading/application using powered handgun equipment in managed horticultural facilities have been recognized and the need for new data established.
- The primary (quantitative) objective was not met: estimates of the arithmetic mean and 95^{th} dermal exposures were not shown to be accurate within 3-fold with 95% confidence. As a result, EPA will incorporate a multiplier to the dermal exposure data to incorporate the additional uncertainty beyond the target 3-fold level.
- The secondary (quantitative) objective was met: results of the log-log regression analysis demonstrate that the study was adequately powered to distinguish proportionality from independence between dermal exposure and AaiH.
- With respect to EPA's default assumption of proportionality, results of the analysis evaluating the relationship between both dermal and inhalation exposure and the amount of active ingredient handled were mixed. However, EPA will continue to recommend using exposures normalized by AaiH as a default condition for exposure assessment purposes. Future evaluation of the relationship between exposure and AaiH are warranted.

- The AHETF data developed and outlined in the monograph and this review represent the most reliable data for assessing exposure during mixing/loading/application using powered handgun equipment in managed horticultural facilities. However, the applicability of this data in assessing exposure when using wettable powders, or only for liquid and dry flowable products will require further internal EPA discussion.

6.0 References

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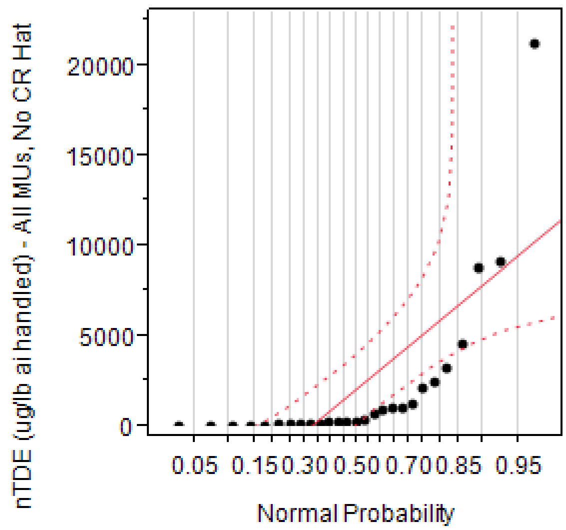
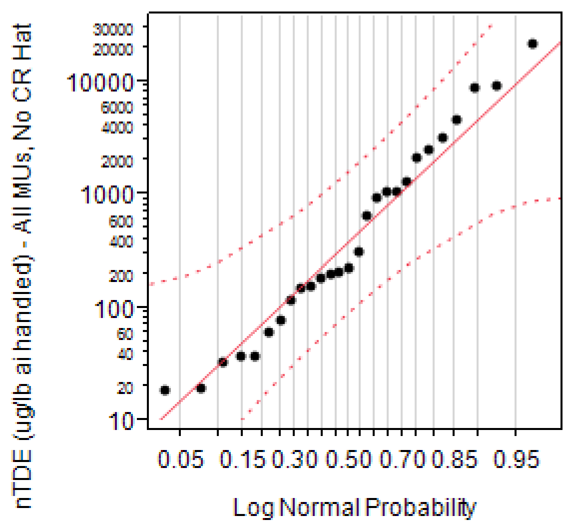
Attachment 1
Normal and Lognormal Probability Plots of Dermal Unit Exposures





Normal and Lognormal Probability Plots of Inhalation Unit Exposures