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

OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

MEMORANDUM (DRAFT)

Date: March 24, 2015

SUBJECT: Review of "Determination of Dermal and Inhalation Exposure to Workers during Backpack and Handgun Application of Liquid Sprays in Utilities Rights-of-Way" (AHE400)

PC Code: --
Decision No.: --
Petition No.: --
Risk Assessment Type: --
TXR No.: --
MRID No.: 49472001

DP Barcode: D424153
Registration No.: --
Regulatory Action: --
Case No.: --
CAS No.: --
40 CFR: --

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This memorandum presents EPA's review of the analytical and field phase reports for AHE400 (AHETF, 2014), an Agricultural Handler Exposure Task Force (AHETF) study monitoring dermal and inhalation exposure for workers making backpack or handgun applications of liquid sprays to utility rights-of-way and similar areas. The scenario monographs (Bruce, et al, 2014a and 2014b), which incorporate the monitoring data from AHE400 into single/composite datasets and includes statistical analysis based on pre-defined benchmark accuracy objectives, are reviewed under separate cover (Crowley, 2015a and 2015b).

This study meets EPA standards for occupational pesticide exposure monitoring and are considered acceptable and appropriate for use in occupational exposure assessments for backpack and handgun applicators.

1.0 Executive Summary

The Agricultural Handler Exposure Task Force (AHETF) monitored dermal and inhalation exposure for 21 workers using handgun sprayers and 19 workers using backpack sprayers while applying liquid spray pesticides to undesirable vegetation such as shrubs, vines, and trees in areas such as utility rights-of-way (ROW), parks, roadsides, and wildlife refuges across the eastern half of the United States. Importantly, the pesticide solution was not prepared by the monitored workers; thus, results of monitoring did not include exposures during the pesticide mixing process.

Backpack applications in this study were conducted using a handwand attached to a low-volume tank worn on a worker's back. While walking through the target area, the pesticide solution is sprayed by manually pressurizing the spray tank with a hand-pump attached to the backpack and squeezing the trigger on the wand. Additionally, some of the workers using backpacks also performed "hack-and-squirt" applications (a direct/localized spray following a slice/cut to the base of a tree or bush).

Handgun applications in this study were conducted with a handgun attached to a hose, which is in turn attached, through a mechanical pump, to a vehicle-mounted holding tank. The mechanical pump provides the pressure to spray the pesticide solution. The workers often sprayed the target vegetation from the vehicles, but at times had to drag the hose and walk in and around the targeted areas.

Table 1 presents a high-level summary of all of the exposure monitoring.

Table 1. AHE400 Summary

Equipment	Site	State	No. Monitored Worker-Days	Monitoring Year (for each Worker-day)	Age Range (years)
Backpack	ROW & Park	PA	3	2012/-12/-13	29-53
		NC	1	2011	33
	ROW	GA	1	2011	29
		SC	1	2012	38
	Wildlife Refuge & ROW	FL	3	2011/-12/-12	26-48
	ROW	AR	3	2011/-12/-12	21-31
	Pipeline terminal & ROW	IN	2	2012/-13	24-34
	Park & Drainage ditch	MI	2	2012/-13	33-37
	ROW	TX	3	2011/-12/-12	27-29
Handgun	ROW	PA	2	2012	54-68
		WV	1	2012	49
		NC	2	2011/-13	34-47
		TN	1	2012	48
		FL	3	2011/-13/-13	27-54
		MN	2	2013/-13	20-48
	Fence line & ROW	LA	3	2012/-12/-12	20-48
	Pipeline terminal & ROW	IN	3	2012/-12/-13	19-39
	Roadsides	MI	1	2012	45
	Drainage ditch & ROW	TX	3	2011/-11/-12	25-58

Note: all study subjects were male.

Monitored on actual days of work, backpack applicators handled from 0.03 to 9.65 lbs of active ingredient, spraying 4.5 to 64.5 gallons of solution in 2 to 10.7 hours, covering (when recorded) less than 1 to approximately 6 acres. Handgun applicators handled from 0.077 to 45.95 lbs of active ingredient, spraying 71 to 2900 gallons of solution in 3.3 to 11.4 hours, covering less than 1 to approximately 20 acres. Applicators wore long-sleeved shirts, pants, shoes/socks and chemical-resistant gloves, with a few donning protective leggings and eye protection. No applicator wore a respirator.

Dermal exposure was measured using hand washes, face/neck wipes, and whole body dosimeters (100% cotton union suits) for the remainder of the body (torso, arms, and legs). Inhalation exposure was measured using personal air sampling pumps and OSHA Versatile Samplers (OVS) mounted on the shirt collar.

All studies followed the applicable and most up-to-date AHETF standard operating procedures (SOPs) and their corresponding protocols with deviations appropriately recorded. No protocol deviation is considered to have compromised the overall research. Analytical field and laboratory recovery results were acceptable, generally averaging between 70 and 120% recovery, with coefficients of variation generally lower than 25%. All field samples were appropriately adjusted for the corresponding recovery adjustment factors.

Total dermal exposure[1], calculated by summing the results for inner dosimeters, hand washes and face/neck wipes, as well as dermal exposure normalized to body weight and also normalized to the amount of active ingredient handled are summarized in Table 2 below.

Table 2. Dermal Exposure Summary

Equipment	Statistic[1]	Total Exposure (µg)	Normalized by Body Weight (µg/kg BW)	Normalized by Amount ai Handled (µg/lb ai)[2]
Backpack	Minimum	34	0.48	675
	Maximum	752,379	8,360	241,923
	Mean	73,414	855	31,273
Handgun	Minimum	80	0.88	26
	Maximum	112,258	1,467	12,123
	Mean	12,431	135	1,868

[1] Means are simple averages (i.e., sum of values ÷ n)
[2] Though other exposure metrics are shown in this table, exposure normalized to the amount of active ingredient handled is typically the format used by EPA as an input in standard handler exposure calculations.

Total inhalation exposure, calculated[2] assuming a breathing rate of 16.7 L/min[3], as well as inhalation exposure normalized to body weight and also normalized to amount of active ingredient handled are summarized in Table 3 below.

[1] All dermal exposure values reflect a 2X adjustment on hand rinse and face/neck wipe measurements accounting for assumed 50% residue collection method efficiency (see Section 3.3). Non-adjusted values are available in associated review spreadsheets.
[2] Inhalation exposure (µg) = Residue collected * [Breathing rate (L/min) ÷ Pump rate (L/min)]. Pump rates generally were 2 L/min. Note: AHE400 presented the total active ingredient collected (µg), not results adjusted for breathing rates as shown here. AHETF monograph submissions, reviewed separately, perform the calculation shown here.
[3] NAFTA, 1998. Rate of 16.7 L/min represents light activity.

Table 3. Inhalation Exposure Summary				
Equipment	**Statistic**	**Total Exposure (µg)**	**Normalized by Body Weight (µg/kg BW)**	**Normalized by Amount ai Handled (µg/lb ai)**
Backpack	Minimum	0.54	0.007	1.74
	Maximum	567	7	112
	Mean	100	1.22	35
Handgun	Minimum	0.24	0.003	0.18
	Maximum	670	8.28	35
	Mean	88	1.09	7
Note: Means are simple averages (i.e., sum of values ÷ n)				

2.0 Summary of Field Study Characteristics

This section provides summary characteristics for AHE400. While a summary is provided, the submitted AHE400 report should be consulted for more specific details (applicable sections, tables, and/or page numbers are provided).

2.1 Administrative Summary

AHE400 was sponsored by the AHETF and adequately followed both the protocol and scenario construction plan (AHETF, 2010a), the AHETF Governing Document (AHETF, 2008 and 2010b), and applicable AHETF SOPs.

The study was conducted in compliance with Good Laboratory Practice Standards (GLPS) (40 CFR §160) and met the standards in EPA Test Guidelines Series 875 – Occupational and Residential Exposure (875.1100 – dermal exposure; 875.1300 – inhalation exposure). Deviations from GLPS are noted in AHE400 pages 3-4 – none are considered to have substantially impacted the study conduct or results. Signed copies of acceptable Quality Assurance and Data Confidentiality statements were provided.

Protocol amendments included: adding additional sources for recruitment; allowance for additional clothing such as rubber boots, leggings, and headgear; allowance for sites that are not strictly rights-of-way but are similar in terms of vegetation and terrain and would be subject to similar pesticide applications; increases to field fortification levels; analytical method specifications; and relaxing the "different employer" requirement. The amendments are all considered reasonable accommodations in order to carry out the study and were appropriately documented.

Protocol deviations included: use of analytical methods that were validated but had yet to be specified in the protocol; failure to meet monitoring time and load thresholds; potential lack of sampling test substance lots; failure to perform a hand wash at a break; use of non-AHETF provided gloves; failure to notify potential employers of an introductory letter and phone call; air sampling pump issues; and a change to a principal analytical investigator. None are considered to have negatively impacted the study conduct or results.

For a more detailed summary of amendments and deviations, see Section 4.0 below and refer to AHE400 pages 11-14 as well as Appendix A (pages 454-538).

2.2 Test Materials

Four potential surrogate active ingredients, all herbicides, were specified in the protocol: glyphosate, fosamine, 2,4-D, and imazapyr. Backpack applications utilized 3 of 4 of the surrogates, each one spraying either glyphosate, fosamine, or imazapyr. Handgun applications utilized all four surrogate herbicides, each one spraying either glyphosate, fosamine, 2,4-D, and imazapyr.

Per GLP, AHETF analyzed the test substances for purity. Certificates of Analysis, which formally document analysis of the test substances, are provided in AHE400 Appendix F pages 1400-1430. AHETF determined that analysis of "Pre-Mix" products were suspect due to homogeneity concerns and would instead, where applicable, use the label-specified active ingredient concentrations to calculate amount of active ingredient handled. Additionally, in some cases a sample of the product used was unattainable for analysis, so the nominal concentration listed by the manufacturer on the product was used.

AHE400 pages 65-68 and Table B-2 on pages 92-93 provides more specific details on the products used and methodologies for calculating amount of active ingredient handled. This is also described more in Section 2.7 below.

2.3 Sample Size, Monitored Workers, and Locations

According to the Backpack and Handgun ROW Scenario Construction Plan (AHETF, 2010a) and the AHETF Governing Document (AHETF, 2008 and 2010b), a "7 x 3" configuration was deemed a reasonable approach for these scenarios. That is, for each of the two scenarios, a total of 21 "monitoring units" (MU), obtained by monitoring exposure from 7 spatially distinct study locations across the eastern U.S., each with 3 workers per location would be likely to satisfy pre-defined accuracy benchmarks.

Ultimately, 21 separate workers were monitored conducting handgun applications and 19 were monitored conducting backpack applications. The AHETF decided to terminate the backpack monitoring due to logistical difficulties and because they believed the resulting dataset would be adequate to meet scenario benchmarks. Discussion of the sampling design and related issues is covered under a separate review (Crowley, 2015a and 2015b).

Monitoring locations were all places where undesirable vegetation such as shrubs, vines, or bushes were meant to be controlled. Most of the monitoring was in utility rights-of-ways, such as areas through which electric transmission and distribution lines or pipelines run. These are areas where controlling vegetation is important so as to not only provide easy access to utility personnel and vehicles, but also because the vegetation can damage utility distribution equipment. Other monitoring areas included parks, drainage ditches, wildlife refuges, fence lines, and roadsides where these types of pesticide applications are also conducted. While these are not rights-of-way, both the purpose of the application (i.e., controlling undesirable

vegetation) and location characteristics such as terrain and vegetation type were similar to the right-of-way locations that constituted the bulk of the monitoring.

Table 4 below provides some more detailed characteristics of the workers and locations. The AHE400 study report provides additional backpack applicator details in Table BP-3 on pages 94-97 and handgun applicator details in Table HG-3 on pages 284-287.

Table 4. Worker and Location Summary

Equipment	Age Range (years)	Gender	Weight (lb)	Work Experience (years)	Site/Target	State	Monitoring Years
Backpack	21 -53	All male	137 - 351	< 1 to 15	Distribution line ROW	PA/SC/NC/AR/IN	2011-2013
					Transmission line ROW	PA/GA/FL/AR/TX	2011-2013
					Wildlife refuge	FL	2011
					Pipeline ROW	IN	2012
					Park	PA/MI	2012-2013
					Drainage ditch	MI	2013
Handgun	19 – 68	All male	127 - 251	< 1 to 34	Distribution line ROW	NC/TN/LA/IN/MN/ TX	2011-2013
					Transmission line ROW	PA/WV/NC/FL/LA/ TX	2011-2013
					Dist. and Trans. line ROW	PA	2012
					Drainage ditch	TX	2011
					Roadsides	MI	2012
					Fence line	LA	2012
					Pipeline terminal	IN	2013

2.4 Environmental Conditions

Temperature (including heat index), humidity, wind speed and direction, cloud cover, and rainfall were all reported. The maximum reported temperature was 93° F (Handgun application, TX, 2011 and Backpack application, AR, 2012) and the lowest reported temperature was 45° F (Handgun application, WV, 2012). Rain impacted some of the monitoring. For two handgun applications, monitoring was halted during rain and the applicators took shelter and resumed applications after the rain stopped. Additionally, for each a backpack and handgun application, rain halted monitoring, but in each case in terms of time, amount applied, etc. monitoring was sufficiently complete when halted. Maximum reported wind speed was approximately 20 miles per hour.

In a few instances monitoring was affected or halted because the ambient temperature exceeded the pre-defined threshold of concern for potential heat-related injury: one backpack application in West Virginia in 2012 (heat index = 106° F) and two handgun applications (both in Texas, heat indices of 105° F in 2011 and 110° F in 2012). However in all cases in terms of time, amount applied, etc. monitoring was sufficiently complete by the time the application was halted.

For more details on environmental conditions see the AHE400 report tables BP-7 (pages 106-109) and HG-7 (pages 296-299).

2.5 Clothing and Personal Protective Equipment (PPE)

Per the stated goals of the AHETF, monitoring of backpack and handgun applications to undesirable vegetation in rights-of-way or similar areas was conducted to represent exposure for workers wearing long-sleeve shirts, pants, shoes/socks, chemical-resistant gloves and no respiratory protection. While this was largely the case, because of the nature of the terrain and environment nearly all workers wore (company-required) hard hats and some wore additional leg coverings (7 backpack applicators, 2 handgun applicators) to protect from thorns or snakes.

So long as the work clothing met the standards of the EPA Worker Protection Standard (WPS), monitoring was conducted with the clothing worn by the worker on the scheduled monitoring day. In three instances, the AHETF supplied workers with replacement shirts or pants prior to study initiation.

Per protocol, new chemical-resistant gloves were supplied by the AHETF to all workers at the beginning of the day and were available throughout the day according to WPS requirements. In one instance a worker (backpack applicator A27) preferred to wear his own chemical-resistant gloves – this was noted as a protocol deviation. Additionally, many workers, either due to company policy or worker preference or required by the pesticide label, wore protective eyewear. In these cases, the exposure measurements were adjusted (according to AHETF SOP 9.K) to extrapolate deposited residue to those portions of the face/head covered by the protective eyewear.

More specific details on work clothing and PPE can be found in the AHE400 study report in Tables BP-4 and BP-5 on pages 98-101 and Tables HG-4 and HG-5 on pages 288-291.

2.6 Application Equipment and Methods

For these studies, as indicated above, only application with either a backpack or handgun was monitored – monitoring was not conducted for those workers responsible for mixing and loading the pesticide.

For backpack applications, the worker used a handheld wand/hose/nozzle apparatus attached to a 3 to 4 gallon spray tank mounted to their backs with shoulder straps. The spray tank solution was pressurized manually using a lever. The spray nozzle typically had a dual set-up where workers could switch between a straight stream or broad/fan stream. In three instances, in addition to the standard backpack applications, workers also conducted "hack-and-squirt" applications, also known as "frill" applications. For these, the trunk of a tree or bush is cut with a knife or machete, and spray solution applied with a small squirt bottle.

For handgun applications, the worker sprayed with a wand/hose/nozzle apparatus attached to vehicle-mounted mechanical pressurizing pump and large spray tank. Vehicle types varied including all-terrain vehicles (ATVs), trucks and tractors. Workers sprayed the target vegetation

from the vehicles, but also at times got off the vehicle dragging the hose behind them while walking through the area. Spray pressures varied, with most less than 100 pounds per square inch (psi), though some others used higher-pressure rigs (e.g., 800 psi) that can spray up to 30 feet.

More details on application equipment and methods can be found in the AHE400 study report for backpack applications on page 70-71 and Table BP-6 on pages 102-105 and for handgun applications on page 259 and Table HG-6 on pages 292-295.

2.7 Application Rates

According to the Backpack and Handgun ROW Scenario Construction Plan (AHETF, 2010a) and the AHETF Governing Document (AHETF, 2008 and 2010b), the total amount of active ingredient applied should be diversified across the scenario and within each study location.

For backpack applications, small volumes of liquid concentrate products (< 1 gallon up to 15 gallons) were mixed with water (7.5 to 400 gallons) according to label specified dilutions in a tank from which workers would load the spray into their backpack. Overall workers sprayed 4.5 to 64.5 gallons of solution in 2 to 11 hours.

In two cases (MUs A27 and A16) ready-to-use products (i.e., packaged as diluted solutions) were used so the amount of product in the spray is the same as the amount of spray prepared. Also, amounts handled reflect the "hack-and-squirt" applications conducted by three workers (MUs A1, A2, and A23) in addition to their backpack applications.

Using the product concentration – determined either by purity analysis or labeled concentration – with the known dilution and amount sprayed, the amount of active ingredient handled can be determined. Backpack applicators handled from 0.03 to 9.65 lbs of active ingredient.

Table 5 below provides more detail on backpack application rates. The submitted AHE400 study report should also be referenced on page 71 and Tables BP-6 (pages 102-105) and BP-13 (page 250).

Table 5. Backpack Application Information

MU ID	Site	Active Ingredient (ai)	Product Conc. (lb ai / gal)	Amt Product in Spray (gal)[a]	Amt Spray Prepared (gal)	Amt Spray Applied (gal)	Loads Sprayed (#)	Area Treated (acres)	Time (hr)	AaiH (lb)[b]
A27[c,d]	Distribution	Glyphosate	0.32	5	5	4.5	2	Not recorded	3.5	1.44
A33[d]	Transmission	Glyphosate	2.67	9.5	160	28.5	10	5.25	9	4.49
A34[d]	Park	Glyphosate	3	2	100	13.5	4	3.5	2	0.81
A8	Distribution	Fosamine	4.3	5.5	275	12.25	4	4	4	2.11[f]
A10	Transmission	Glyphosate	4.28	14	400	64.5	17	6	6.4	9.65
A20[d]	Distribution	Imazapyr	4.19	0.5	210	48	12	0.75	5.1	0.48
A11	Wildlife Refuge	Imazapyr	0.45	1.5	300	22.5	9	3.3	8.2	0.051
A12	Transmission	Glyphosate	4.13	1.35	50	16.5	6	5	5	1.9
A13	Transmission	Glyphosate	4.13	1.35	50	20	7	5	5	2.27

Table 5. Backpack Application Information										
MU ID	**Site**	**Active Ingredient (ai)**	**Product Conc. (lb ai / gal)**	**Amt Product in Spray (gal)[a]**	**Amt Spray Prepared (gal)**	**Amt Spray Applied (gal)**	**Loads Sprayed (#)**	**Area Treated (acres)**	**Time (hr)**	**AaiH (lb)[b]**
A1[d,e]	Distribution	Glyphosate	2.67	11	151	33.25	10	2	10.7	6.65
A23[e]	Distribution	Glyphosate	3.9	8	160	14.5	5	0.45	6	3.11
A24	Transmission	Imazapyr	2.04	1.25	225	33	10	Not recorded	4.3	0.37
A16[c,d]	Pipeline	Glyphosate	0.32	30	30	15.875	6	3.25	10.2	5.08
A38[d]	Distribution	Glyphosate	2.07	1.92	32	14.75	5	0.75	8.8	1.83
A31	Park	Glyphosate	3.02	0.4	16.5	16.5	6	0.6	6.3	1.13
A40	Drainage Ditch	Glyphosate	4.07	0.15	7.5	7.5	7	0.9	7.8	0.62
A2[d,e]	Transmission	Glyphosate	2.67	15	200	16.5	7	0.75	7.5	3.62
A4	Transmission	Imazapyr	1.98	0.28	300	16	6	2	6.1	0.03
A25	Transmission	Glyphosate	4	10	221	19.5	7	1.6	3.6	3.51

[a] Amount of product includes any removal of small amounts used for purity analysis.
[b] Amount active ingredient can be approximated by the calculation: product concentration (lb ai/gal product) * amount of product in spray mixture (gal prod) * [amount of spray mixture applied (gallons) ÷ amount of spray mixture prepared (gallons)]. Slight differences with the reported value are due to AHETF calculating and summing the amount ai handled for each load.
[c] Product was a ready-to-use solution, so gallons of product in spray mixture and gallons of spray mixture prepared are the same.
[d] Product was unavailable for sampling or was a "Premix" product – thus, concentration on label was used for calculation purposes.
[e] Worker also made "hack-and-squirt" applications.
[f] Reflects the addition of a total (across 4 backpack loads) of 0.25 gallons (1 lb ai) of the product to the mixture.

For handgun applications, small volumes of liquid concentrate products (< 1 gallon up to 12 gallons) were mixed with large volumes of water (~ 100 to 3100 gallons) according to label specified dilutions. Workers then sprayed from 80 to 2900 gallons in about 3 to 11 hours. Using the product concentration – determined either by purity analysis or labeled concentration – with the known dilution and amount sprayed, the amount of active ingredient handled can be determined. Handgun applicators handled from 0.077 to 45.95 lbs of active ingredient.

Table 6 below provides more detail on backpack application rates. The submitted AHE400 study report should also be referenced for handgun applications on pages 259-260 and Tables HG-6 (on pages 292-295) and HG-13 (page 449).

Table 6. Handgun Application Information										
MU ID	**Site**	**Active Ingredient (ai)**	**Product Conc. (lb ai / gal)**	**Amt Product in Spray (gal)[a]**	**Amt Spray Prepared (gal)**	**Amt Spray Applied (gal)**	**Loads Sprayed (#)**	**Area Treated (acres)**	**Time (hr)**	**AaiH (lb)[b]**
A28[c]	Trans. + Dist. ROW	Glyphosate	4	5	500	485	1	Not recorded	6.8	19.4
A29[c]	Trans. ROW	Glyphosate	2.67	6	600	580	3	6.09	6.7	15.49
A30	Trans. ROW	Glyphosate	4.02	5	600	400	2	3	6.6	13.19
A9	Dist. ROW	Fosamine	4.3	5.5	275	188	1	Not recorded	4.8	16.17
A19	Dist. ROW	Imazapyr	2.13	0.75	900	700	3	4.7	8	1.24
A39	Trans. ROW	Imazapyr	3.88	0.31	260	260	1	6.2	5.5	1.21
A6	Trans. ROW	Imazapyr	1.88	2	250	190	3	40	8.4	2.89
A7	Trans. ROW	Glyphosate	4.27	2.7	295	86.5	2	52	9.7	3.54
A36	Trans. ROW	Imazapyr	2.06	1.5	200	190	2	9.7	5.9	3.09
A14	Fence Line	Imazapyr	1.96	0.46	185	144	4	0.36	7.1	0.71

Table 6. Handgun Application Information										
MU ID	**Site**	**Active Ingredient (ai)**	**Product Conc. (lb ai / gal)**	**Amt Product in Spray (gal)[a]**	**Amt Spray Prepared (gal)**	**Amt Spray Applied (gal)**	**Loads Sprayed (#)**	**Area Treated (acres)**	**Time (hr)**	**AaiH (lb)[b]**
A15	Trans. ROW	Glyphosate	4.18[d]	6	755	671	13	Not recorded	6.4	21.73
A17	Dist. ROW	Glyphosate	4.23	6.3	315	225	2	3	5.2	19.04
A21	Dist. ROW	2,4-D	2.51	1	200	200	4	1.2	6.6	2.51
A22	Dist. ROW	2,4-D	3.76	2.125	635	635	3	2.2	7.4	7.99
A35	Pipeline Terminal	2,4-D	2.32	3.9	107.5	104.5	7	1.5	8.1	8.87
A26	Roadsides	Glyphosate	4.11	12	3100	2900	2	Not recorded	10.4	45.95
A32	Dist. ROW	Fosamine	3.99	3.5	350	338	6	6.7	8.6	13.49
A37	Dist. ROW	Imazapyr	2.06	0.13	275	80	4	Not recorded	11.4	0.077
A3	Trans. ROW	Imazapyr	1.98	0.26	300	281	1	3	6	0.52
A5	Drainage Ditch	Glyphosate	4.10	2.6	140	81[e]	2	1	3.3	6.84
A18	Dist. ROW	Glyphosate	4.24	11	1000	900	2	17	6.9	41.98

[a] Amount of product includes any removal of small amounts used for purity analysis or for backpack applications.
[b] Amount active ingredient can be approximated by the calculation: product concentration (lb ai/gal product) * amount of product in spray mixture (gal prod) * [amount of spray mixture applied (gallons) ÷ amount of spray mixture prepared (gallons)]. Slight differences with the reported value are due to AHETF calculating and summing the amount ai handled for each load.
[c] Product was unavailable for sampling or was a "Premix" product – thus, concentration on label used for calculation purposes.
[d] Represents the average of two product concentrations: 4.16 and 4.19 lb ai/gallon.
[e] AHE400 incorrectly reports this as 71 gallons.

2.8 Exposure Monitoring and Analytical Methods

Per applicable AHETF SOPs, standard passive dosimetry methods recognized by EPA as appropriate for worker exposure monitoring were utilized for all monitoring. No biomonitoring samples were collected. Dermal exposure to the hands was measured using a hand rinse method administered at the end of the workday as well as at lunch, restroom breaks, or other instances where workers would otherwise wash their hands as outlined in AHETF SOP 8.B. Dermal exposure to the face/neck was measured using a wipe technique as outlined in AHETF SOP 8.C and extrapolated to non-wiped portions of the head according to AHETF SOP 9.K. Thus, for those workers who wore eye protection and/or hard hats, the extrapolation to the whole head renders the resulting measurement somewhat representative of face/neck/head exposure without that additional gear. Generally, 1-2 face/neck wipe samples were collected for each worker then analyzed as a composite sample.

Dermal exposure to the remainder of the body (torso, arms, and legs) was measured using whole body dosimeters (100% cotton union suits), sectioned into six pieces and analyzed separately according to AHETF SOP 8.A. All these measurements combine to reflect dermal exposure underneath a single layer of work clothing (long-sleeve shirt, pants, shoes/socks) and chemical-resistant gloves. Inhalation exposure was measured using OVS tubes mounted on the worker's collar and personal sampling pumps (set at 2 liters per minute) according to AHETF SOP 8.D. The concentrations measured represent the chemical available in each worker's breathing zone. The submitted AHE400 study report outlines the passive dosimetry procedures in more details on pages 14-18.

Validated analytical methods specific to each type of monitoring matrix (i.e., inner dosimeters, hand rinses, etc.) were used to extract residues. The analytical methods are outlined in the analytical reports:

- 2.4-D – AHE400 Appendix B, pages 539-647
- Fosamine – AHE400 Appendix C, pages 648-760
- Glyphosate – AHE400 Appendix D, pages 761-1176
- Imazapyr – AHE400 Appendix E, pages 1177-1399.

Limits of quantification and detection (as defined in AHETF SOP 9.A) are presented in Table 7 below.

Table 7. Analytical Limits (µg/sample) for AHE400

Monitoring Matrix	Limit of Detection				Limit of Quantification			
	2,4-D	Fosamine	Glyphosate	Imazapyr	2,4-D	Fosamine	Glyphosate	Imazapyr
Inner Dosimeter	0.30	0.1701	0.139	0.041	1.0			
Socks	0.060	0.0285	0.011	0.0355	0.25			
Hand Rinse	0.30	0.1278	0.179	0.167	1.0			
OVS air sampler (per section)	0.0015	0.0008	0.0016	0.0005	0.005			
Face/Neck Wipe	0.30	0.3123	0.143	0.317	1.0			

3.0 Results

This section provides a discussion of quality assurance and quality control sampling and the actual field monitoring measurements of workers.

3.1 Quality Assurance

All phases of each study were subject to appropriate quality assurance processes according to EPA's GLPs which included an audit by the AHETF Quality Assurance Unit (QAU) per AHETF SOPs (AHETF SOP Chapter 5: A-K). The inspected phases were: Protocol, Field Phase, Field Data, Draft Report, Analytical Data, Final Report, and Post-Audit Report. The study contains a signed quality assurance compliance statement as required by GLPs. Protocol amendments or deviations were addressed appropriately under GLP guidance and are described further in Section 4.0.

3.2 Quality Control

AHETF instituted various quality control measures to ensure proper field conduct including calibration of sprayers, preparation and handling of exposure measurement matrices, evaluation of test material, and field observations (AHETF SOP Chapter 10: A-G). Analytical methods were validated appropriately ensuring that all exposure matrices could be measured for the surrogate active ingredients proposed. Analytical quality control measures for ensuring the

integrity of measurements captured in the research were also instituted according to AHETF SOP 9.J.

Exposure monitoring matrices (inner whole body dosimeters, hand washes, face/neck wipes, OVS tubes) were fortified with known amounts of active ingredient to assess their stability during field, transit, and storage conditions according to AHETF SOP 8.E. Laboratory control samples were also fortified at the level of quantification and at levels capturing the range of expected field exposures for each matrix. Generally, field fortification samples were collected in triplicate at each of 3 levels (high, middle, and low) on each sampling day. Travel fortifications were generally conducted on each day of sampling in duplicate only at the high fortification level. Untreated control samples – included to determine if there are significant background sources or contamination during sample processing – were generally conducted in duplicate on each day of sampling.

The following sections provide results for all quality control sampling across all exposure measurement matrices for all chemicals used. The identified supplemental tables should be referenced for chemical-specific results.

3.2.1 Field and Laboratory Control Samples

As expected, most non-fortified (blank) laboratory and field control samples contained no detectable residues. For field controls, detectable residues (imazapyr, fosamine, and glyphosate) were infrequent and found mostly in OVS tubes. For laboratory controls, imazapyr was detected in a few inner dosimeter and OVS tubes. Detections in the OVS tube control samples are not surprising given the sensitivity of the method – the LOD $\leq$ 0.0016 ug/sample, and many were close to that residue level. For other dosimeters, the detections were all lower than the lowest field fortification level tested. In all cases, both the frequency and magnitude of these detections did not indicate systematic contamination; thus, per standard AHETF procedure, no correction was made to any field monitoring samples based on results of control samples.

More detailed results can be found in AHE400: Appendix B (2,4-D) Tables 7-11 on pages 578-582; Appendix C (Fosamine) Tables 7-11 on pages 689-694; Appendix D (Glyphosate) Tables 11-16 on pages 844-860; Appendix E (Imazapyr) Tables 11-16 on pages 1241-1252.

3.2.2 Field Fortification Recoveries – Applicable to Both Backpack and Handgun Exposure Monitoring

Field fortification sampling matrices are spiked with known amounts of chemical, then placed under similar conditions and duration as the actual sampling matrices used on the workers (including drawing air through OVS samplers). The intent of these samples is to quantify potential residue losses due to the sampling methods used under actual field conditions. Additional samples are also fortified to assess degradation of the sample during transit from the field to the lab and during sample storage. However, per AHETF protocol, these are only analyzed if anomalous field fortification recoveries indicate potential degradation during transport and sample storage. No storage or transport fortification samples were analyzed since

field fortification results did not indicate any problems related to excessive degradation of residues.

Field fortifications are conducted at 3 levels to capture the expected range of results, with triplicate samples taken on each day at each fortification level[4]. Once analyzed, the average recovery results (expressed as a percentage of known amount applied) are used as multipliers to adjust, or correct, all measured field samples to 100%. As the fortification samples are conducted at levels to capture the range of expected field sample results, adjustments are done using the average percent recovery for the fortification level closest to the measured field sample[5]. The mid-point between each fortification level is used as the threshold in determining the average recovery percentage for use in adjusting the field sample.

With some exceptions, field fortification averages for each fortification level and each monitoring matrix were in the range of 70-120% with coefficients of variation generally less than 25%. A summary of field fortification results for each matrix is provided below in Sections 3.2.3.1 – 3.2.3.4.

3.2.2.1 Inner Dosimeters and Socks

Results for inner whole body dosimeter (WBD) and sock field fortification samples were acceptable, with average recoveries ranging from 70% to 120% and coefficients of variation less than 25%.

Some atypically high and low average recoveries (~ 9% of all inner dosimeter and sock fortifications) were observed (48-66% and 121-153%), mostly for glyphosate fortifications in sock dosimeters. However, except for one fortification with a CV=31% (which did not end up being applicable to any field sample) all other CVs for these atypical results were less than 25%. For more details on field fortification results for inner dosimeters and socks see AHE400 Table BP-11 on pages 216-232 and Table HG-11 on pages 413-430.

Adjustments based on results for each surrogate active ingredient at each fortification level were applied to field samples falling into the following ranges[6]. Specific adjustment factors associated with each of these ranges can be found in AHE400 in Tables BP-12 on pages 233-249 and HG-12 pages 431-448.

- Imazapyr/Glyphosate/Fosamine
    - WBD
        - Before 2012: $\leq$ 52.5 µg, > 52.5 to $\leq$ 2,050 µg, and > 2,050 µg

[4] In 2012 fortification levels for dermal dosimetry were increased to accommodate field samples that exceeded the highest fortification level.

[5] Per AHETF standard procedure, if average recovery is > 120% the maximum ("downward") adjustment value applied is 1.2.

[6] During review, EPA identified minor errors in the values used for recovery adjustments for WBD for backpack applicators: MU A10 – a value of 1.00 was used instead of 0.784 for the upper leg sample; MU A23 – a value of 1.00 was used instead of 0.997 for most of the WBD samples; MU A25 – a value of 1.00 was used instead of 0.997 for some of the WBD samples. EPA decided to note these corrections but, because of the insignificant effect on overall results, not require any changes or re-submissions.

        - After 2012: ≤ 252.5 µg, > 252.5 to ≤ 25,250 µg, and > 25,250 µg
    - Socks:
        - Before 2012: ≤ 5.5 µg, > 5.5 to ≤ 55 µg, and > 55 µg
        - After 2012: ≤ 50.5 µg, > 50.5 to ≤ 2,550 µg, and > 2,550 µg
- 2,4-D
    - WBD: ≤ 252.5 µg, > 252.5 to ≤ 25,250 µg, and > 25,250 µg
    - Socks: ≤ 50.5 µg, > 50.5 to ≤ 2,550 µg, and > 2,550 µg

3.2.2.2 Face/Neck Wipes

Results for face/neck wipe field fortification samples were acceptable, with average recoveries ranging from approximately 70% to 120% and coefficients of variation less than 25%. Very few (~ 6%) atypical recoveries (63-68% and 125-149%) were observed, all with CVs less than 25%. For more details on field fortification results for face/neck wipes see AHE400 Table BP-11 on pages 216-232 and Table HG-11 on pages 413-430.

Adjustments based on results for each surrogate active ingredient at each fortification level were applied to field samples falling into the following ranges. Specific adjustment factors associated with each of these ranges can be found in AHE400 in Tables BP-12 on pages 233-249 and HG-12 pages 431-448.

- Glyphosate/Fosamine/2,4-D/Imazapyr
    - Before 2012: ≤ 52.5 µg, > 52.5 to ≤ 1,050 µg, and > 1,050 µg
    - After 2012: ≤ 52.5 µg, > 52.5 to ≤ 2,550 µg, and > 2,550 µg

3.2.2.3 Hand Washes

Results for hand wash field fortification samples were acceptable, with average recoveries ranging from approximately 70% to 120% and coefficients of variation less than 25%. Very few (~ 5%) atypical recoveries (43-64% and 121-124%) were observed (mostly for glyphosate), all with CVs less than 25%. For more details on field fortification results for face/neck wipes see AHE400 Table BP-11 on pages 216-232 and Table HG-11 on pages 413-430.

Adjustments based on results for each surrogate active ingredient at each fortification level were applied to field samples falling into the following ranges. Specific adjustment factors associated with each of these ranges can be found in AHE400 in Tables BP-12 on pages 233-249 and HG-12 pages 431-448.

- Glyphosate/Fosamine/2,4-D/Imazapyr
    - Before 2012: ≤ 52.5 µg, > 52.5 to ≤ 1,050 µg, and > 1,050 µg
    - After 2012: ≤ 252.5 µg, > 252.5 to ≤ 5,250 µg, and > 5,250 µg

3.2.2.4 OVS Air Samplers

Results for OVS field fortification samples were acceptable, with average recoveries ranging from approximately 70% to 120% and coefficients of variation less than 25%. Very few (~ 5%)

atypical recoveries (59% and 124-138%) were observed (mostly for glyphosate), all with CVs less than 25%. For more details on field fortification results for face/neck wipes see AHE400 Table BP-11 on pages 216-232 and Table HG-11 on pages 413-430.

Adjustments based on results for each surrogate active ingredient at each fortification level were applied to field samples falling into the following ranges. Specific adjustment factors associated with each of these ranges can be found in AHE400 in Tables BP-12 on pages 233-249 and HG-12 pages 431-448.

- Glyphosate/Fosamine/2,4-D/Imazapyr: $\leq$ 2.525 µg, > 2.525 to $\leq$ 252.5 µg, and > 252 µg

3.3 Field Measurements

The following sections summarize the exposure monitoring results, conducted as described in Section 2.8. Exposure values reflect total exposure for workers across their monitoring periods, not normalized by any exposure metric. All measurements were appropriately adjusted for field fortification recoveries (see Section 3.2.2). Face/neck wipe measurements were extrapolated to un-wiped portions of the face and head according to AHETF SOP 9.K. For samples below the LOQ or LOD, ½ LOQ or ½ LOD was used.

Additionally, in order to account for potential residue collection method inefficiencies, EPA makes adjustments to hand and face/neck field study measurements as follows[7]:

- if measured exposures from hands, face and neck contribute less than 20% as an average across all workers, no action is required;
- if measured exposure contribution from hands and face/neck represents between 20% and 60% of total, 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 contribution from hands and face/neck represents is greater than 60%, a validation study demonstrating the efficiency of the residue collection methods is required.

For handgun applicators, the contribution of hands and face/neck exposures averaged 30% while for backpack applicators, the contribution averaged 27%. Therefore the results for exposures to the hands and head and total dermal exposures outlined in the following sections present the aforementioned additional 2x adjustment for hand and face/neck measurements.

3.3.1 Inner Dosimeters and Socks

For backpack applicators, without field fortification adjustments, individual WBD sections ranged from < 0.3 (non-detectable) – 259,830 µg. Out of a total of 120 inner dosimeter samples, 3 were below the LOQ and 1 below the LOD. Sock samples without field fortification

[7] This approach was discussed and presented at a meeting of the Human Studies Review Board (June 2007). The terminology used to describe this are "method efficiency adjusted" (MEA) or "method efficiency corrected" (MEC). Previous AHETF submissions included these adjustments but they have indicated that they will no longer continue to do so. Thus these adjustments are instead made by EPA.

adjustments ranged from 0.95 – 3,959 µg. No sock dosimeter sample was below the LOQ or LOD. AHE400 Tables BP-14 and BP-15 on pages 251-252 provide more details on these samples. After adjusting for field fortification recoveries and summing the six separate body sections, the total dermal exposure underneath the long-sleeve shirt and pants ranged from 6 – 730,551 µg with an average of 66,760 µg. Sock dosimeters with field fortification adjustments ranged from 1 – 3,884 µg with an average of 679 µg.

For handgun applicators, AHE400 presents results for WBD and sock samples without field fortification adjustments. Individual WBD sections ranged from < 1.0 (non-detectable) – 49,165 µg. Out of a total of 126 inner dosimeter samples, 1 was below the LOQ. Sock samples ranged from 0.25 – 6,117 µg. Only 1 sock dosimeter sample out of 21 was below the LOQ. AHE400 Tables HG-14 and HG-15 on pages 450-451 provide more details on these samples. After adjusting for field fortification recoveries and summing the six separate body sections, the total dermal exposure underneath the long-sleeve shirt and pants ranged from 44 – 98,905 µg with an average of 8,497 µg. Sock dosimeters ranged from 0.13 – 6,185 µg with an average of 548 µg.

3.3.2 Face/Neck Wipes

For backpack applicators face/neck wipe samples ranged from < 0.3 (non-detectable) – 549 µg without field fortification adjustments. Out of 19 face/neck wipe samples, 1 was below the LOQ. AHE400 Table BP-15 on page 252 provides more details on these samples. For handgun applicators these ranged from 1.6 – 2,160 µg without field fortification adjustments. No face/neck wipe sample was below the LOQ or LOD. AHE400 Table HG-15 on pages 451 provides more details on these samples.

Because some workers wore eye protection and because measurements cannot be easily conducted on hair, extrapolations from those portions of the face/neck that are wiped need to be made to portions of the head that are not measured. Specifics on these adjustment factors can be found in AHETF SOP 9.K. Additionally, as previously described, the measurements are further adjusted upward by EPA by a factor of 2 to account for potential inefficiencies in residue collection by the wipe technique.

For backpack applicators, after adjusting for field fortification recoveries and extrapolating to non-wiped portions of the head described above, total head exposure ranged from 0.8 – 943 µg with an average of 200 µg. Including the 2X adjustment by EPA for potential method collection inefficiencies, total head exposure ranged from 1.6 – 1,886 µg with an average of 399 µg.

For handgun applicators, after adjusting for field fortification recoveries and extrapolating to non-wiped portions of the head described above, total head exposure ranged from 3 – 4,347 µg with an average of 500 µg. Including the 2X adjustment by EPA for potential method collection inefficiencies, total head exposure ranged from 6 – 8,694 µg with an average of 999 µg.

3.3.3 Hand Washes

Per protocol, hand washes were collected at the end of each work day and at points where workers would normally wash their hands such as during restroom or lunch breaks. Most

workers had 2 hand wash samples taken; one handgun applicator had 4 hand washes and one backpack applicator had 5 hand washes. A few workers, despite having relatively long work days (i.e., 4-8 hours) did not take any breaks and thus only had the 1 hand wash sample conducted at the end of their workday. The following table outlines the number of hand wash samples broken down by the work duration.

		Table 8. Hand Wash Summary			
		Work Duration (hours)			
		< 4	**4-6**	**6-8**	**≥ 8**
Backpack	Percentage of Workers	16%	26%	32%	26%
	# of Hand Washes	1-2	1-3	1-2	2-5
Handgun	Percentage of Workers	5%	19%	43%	33%
	# of Hand Washes	1	1-2	1-4	2-3

For backpack applicators, individual hand wash samples ranged from 3.5 – 8,404 µg without field fortification adjustments. No hand wash sample was below the LOQ or LOD. AHE400 Table BP-15 on page 252 provides more details on these samples. For handgun applicators, individual hand wash samples ranged from < 1.0 – 3,042 µg without field fortification adjustments. Out of a total of 43 hand wash samples, 1 was below the LOQ. AHE400 Table HG-15 on page 451 provides more details on these samples.

For backpack applicators, after adjusting for field fortification recoveries and summing hand washes for each worker, the total hand exposure ranged from 13 – 10,776 µg with an average of 2,788 µg. Including the 2X adjustment by EPA for potential method collection inefficiencies, total hand exposure ranged from 26 – 21,552 µg with an average of 5,575 µg.

For handgun applicators, after adjusting for field fortification recoveries and summing each hand wash, the total hand exposure ranged from 4 – 4,473 µg with an average of 1,194 µg. Including the 2X adjustment by EPA for potential method collection inefficiencies, total hand exposure ranged from 8 – 8,946 µg with an average of 2,387 µg.

3.3.4 OVS Air Samplers/Inhalation Exposure

Front and back sections of the OVS tube were analyzed separately. Most back section samples were less than the LOD, with a few less than the LOQ. All front section samples had detected residues. Inhalation exposure results were invalidated for two backpack applicators due to sampling pump failure (MU A27) and lack of remaining sample for analysis (MU A1 – sample extract was used up from previous analysis with an improper analytical method).

For backpack applicators, OVS front sections ranged from 0.0466 – 59.66 µg without field fortification adjustments. AHE400 Table BP-16 on page 253 has more details on these results. After adjusting for field fortification recoveries, the total (front section + back section) collected active ingredient amounts ranged from 0.07 – 67 µg with an average of 12 µg.

For handgun applicators, OVS front sections ranged from 0.0219 – 77.79 µg without field fortification adjustments. AHE400 Table HG-16 page 452 has more details on these results. After adjusting for field fortification recoveries, the total (front section + back section) collected active ingredient amounts ranged from 0.03 – 80 µg with an average of 11 µg.

The above described results for the amount of active ingredient collected by the air sampling units. The AHE400 report – as it is mainly a presentation of field and analytical results – presents only total active ingredient collected by the air sampling units. Separate AHETF monograph submissions (under separate EPA reviews) present worker inhalation exposures applying an assumed breathing rate. To calculate worker inhalation exposures, the measured amounts are adjusted based on the pump flow rate (in liters per minute) and a typical worker's breathing rate for this type of activity. For these studies a breathing rate of 16.7 liters per minute was used, representing light activities (NAFTA, 1998). The calculation is as follows:

*Inhalation exposure = Adjusted residue (µg) * [Breathing rate (LPM) ÷ Pump flow rate (LPM)]*

For backpack applicators, worker exposures ranged from 0.54 – 567 µg with an average of 100 µg. For handgun applicators, worker exposures ranged from 0.24 – 670 µg with an average of 88 µg.

3.4 Exposure Calculations

This section provides total exposures (expressed as mass active ingredient), as well as exposures normalized to (i.e., dividing by) body weight and amount of active ingredient handled (AaiH).

3.4.1 Dermal Exposures

Total dermal exposure, calculated by summing the results for inner dosimeters, hand washes and face/neck wipes, are presented below as well as normalized to body weight and amount of active ingredient handled. Results are presented both with and without adjustments for potential inefficiencies of the hand wash and face/neck wipe methods (MEA = method efficiency adjustment).

Table 9. Dermal Exposure Summary

Equipment	Statistic	Total Exposure (µg)		Normalized by Body Weight (µg/kg BW)		Normalized by Amount ai Handled (µg/lb ai)	
		MEA	Non-MEA	MEA	Non-MEA	MEA	Non-MEA
Backpack	Minimum	34	20	0.48	0.28	675	400
	Maximum	752,379	742,664	8,360	8,252	241,923	238,799
	Mean	73,414	70,426	855	819	31,273	30,110
Handgun	Minimum	80	66	1.06	0.88	26	17
	Maximum	112,258	108,674	1515	1,467	12,123	11,365
	Mean	12,431	10,738	156	135	1,868	1,654

Note: Means are simple averages (i.e., sum of values ÷ n)

3.4.2 Inhalation Exposures

As shown in Section 3.3.4, inhalation exposure is calculated based on the chemical in air over the monitoring period, the pump flow rate, and the worker's breathing rate. Results are presented below.

Table 10. Inhalation Exposure Summary				
Equipment	**Statistic**	**Total Exposure (µg)**	**Normalized by Body Weight (µg/kg BW)**	**Normalized by Amount ai Handled (µg/lb ai)**
Backpack	Minimum	0.54	0.007	1.74
	Maximum	567	7	112
	Mean	100	1.22	35
Handgun	Minimum	0.24	0.003	0.18
	Maximum	670	8.28	35
	Mean	88	1.09	7
Note: Means are simple averages (i.e., sum of values ÷ n)				

3.5 Field Observations

Field researchers observed each worker and recorded their behavior throughout the work day. These can be found in the AHE400 report in Table BP-9 on pages 112-174 and HG-9 on pages 302-369.

Much of the observations detailed routine application procedures (e.g., MU A27 @ 0815: "Sprayed a ~20 ft. section of high brush along side of road."). Other observations may potentially provide clues as to determinants of exposure – examples of these types of observations include:

- Overhead spraying – e.g., MU A33 @ 0902: "Sprays a birch tree (~5 ft. tall) on hillside, which requires overhead spraying. Large visible plume, moderate contact with A33";
- Contact with treated foliage – e.g., MU A10 @ 1102: "A10 observed walking directly into just sprayed foliage (below waist high)";
- Getting off truck to walk and spray target area (handgun) – e.g., MU A22 @ 0918: "A22 down from truck, walking along ROW area, spraying into ROW."

EPA reviewed the field observations for potential clues as to determinants of exposure or potential reasons for high exposures. Though difficult to quantify in this fashion, some additional analysis where field observations were reviewed in a quantitative fashion, refer to the scenario monograph reviews (Crowley, 2015a and Crowley, 2015b). Data users are recommended to review the field observations to get a sense of the extent of activities within these exposure scenarios.

4.0 Protocol Amendments and Deviations

Amendments to and deviations from the study protocol are detailed below. For additional details, see the AHE400 study report on pages 11-14 as well as Appendix A on pages 504-538. The study amendments were reasonable accommodations to accomplish the research and deviations did not adversely impact the study conduct or the exposure monitoring results.

Protocol Amendments:

- To increase likelihood of finding workers to monitor, additional employer sources were added: the same employer can be used in multiple monitoring areas; referrals from other employers; and, employers/companies the AHETF is aware of but not on the "Employer Universe List".
- Because recruitment revealed that workers commonly wear chaps and leggings for physical protection, this was removed as an exclusion criterion.
- Because recruitment revealed that workers commonly wear (or are required by their employers to wear) hard hats and boots that rise above mid-calf, those were removed as exclusion criteria.
- Because recruitment specifically for electric and pipeline utility rights-of-way proved limiting, additional areas of similar brush/shrubs, foliage density/height, and terrain such as roadsides and wildlife refuges were added as possible sites.
- Amended contact information for Principal Analytical Investigator and Analytical Facility
- Amended fosamine and imazapyr analytical methods sections to more accurately identify the methods following their complete development and validation.
- Recruitment in the originally specified US states proved limiting, other states will be acceptable.
- Field fortification levels for dermal exposure monitoring methods were increased.
- Recruitment proved difficult, so the "same employer" restriction was relaxed – but with additional restrictions that if they had the same employer monitoring must occur in a separate year, a different job site, and a different application crew.
- Changed glyphosate analytical methods following addition of a derivatization step and added additional text specifying how this revised method was validated.

Protocol Deviations

- Field samples for MUs A8 and A9 as well as associated field fortification levels were analyzed for fosamine using analytical methods not fully identified in the protocol or by a protocol amendment. Though not identified in the protocol or amendment, at the time of analysis the method had been validated and finalized.
- Unavailability of test substances for purity analysis. Amount of active ingredient handled determined from product label and dilution rates.
- Instances of less than 4 hours of monitoring time. Other application characteristics (tank loads, gallons sprayed, etc.) were still adequate and representative of typical workdays.
- Lack of hand wash collection preceding a cigarette break.
- Use of applicator's own chemical-resistant gloves rather than AHETF-supplied chemical-resistant gloves.
- Failure to inform application company representative that they would receive an AHETF introductory letter.
- Inhalation exposure pump off for extended periods of (non-exposure) time such as lunch breaks or rain events.
- Lack of documentation of changes to analytical laboratory facilities.

5.0 Conclusion

As the studies followed their corresponding protocols as well as EPA guidelines for occupational pesticide exposure monitoring, the results are reliable for assessment of exposure and risk for backpack and handgun applications in utility rights-of-ways and other areas where chemical control of similar undesirable vegetation is conducted.

Since these exposure data were collected with the intention to populate a generic pesticide exposure database, reviewers are directed to the additional information and statistical analyses in the AHETF Handgun ROW Scenario Monograph (Bruce, et al, 2014a) and the AHETF Backpack ROW Scenario Monograph (Bruce, et al, 2014b).

Review of those monographs as well as recommendations for use of the data by EPA exposure assessors are in a separate review memorandum (Crowley, 2015a and 2015b).

6.0 References

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