Operator exposure assessment for MON 2139
UK - Case

1. Summary

The purpose of this document is to evaluate the operator exposure when spraying Roundup under UK conditions.
First, exposure was estimated using the UK POEM model considering worst case situations (low spray volumes, high dose). Exposure was calculated for three different types of applicator: tractor mounted with cab, hand-held equipment with hydraulic nozzles, hand-held equipment with rotary disk atomizer

Secondly, exposure field studies related to handheld application of Glyphosate were reviewed and summarized. Measured exposure values were normalized in ml/hr spray solution in order to be compared to the UK-POEM default values.

Finally, several actions are proposed to refine the exposure assessment.

2. Spray volume / dose combination for different applicator type in the UK

Table 1: Spray volume / dose combination for different applicator type in UK

Equipment	Dose (l/ha)		Spray volume (l/ha)				
			Cda 20	Very low 35-70	Low 80	Standard 200	High 250
Tractor mounted sprayer	Standard High	3 6			x x	x x	x x
Knapsack	Standard High	5 10		x	x	x x	x
cda	Standard High	5 10	x x				

3. Label recommendations

MON 2139:

- Wear suitable protective gloves and face protection (face shield) when handling or applying the concentrate.
- Wear suitable protective clothing (coveralls), suitable protective gloves, rubber boots and face protection (face shield and dust mask) when spraying through ultra low volume application and mistblower equipment
- Wear suitable protective clothing (water-proof jacket & trousers) suitable protective gloves and rubber boots when using low volume nozzles in knapsack sprayer, hand held rotary CDA sprayers and hand held weed wiper equipment

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MON 52276:

- Wear suitable protective gloves when handling the concentrate.
- Wear suitable protective clothing (coveralls), suitable protective gloves and rubber boots when using hand-held rotary atomizers, weed wipers, a spot gun or when making stump application
- Wear suitable protective clothing (coveralls), suitable protective gloves, rubber boots and face protection (face shield) when using the stem injection technique
- Wear suitable protective clothing (coveralls), suitable protective gloves, rubber boots and face protection (face shield with disposal filtering face piece) when using mistblowers and making "drift" applications.

4. Estimation of worker exposure using the UK POEM model

Systemic operator exposure was estimated using the UK POEM model, taking into account the label recommendations described in section 2.

The exposure was calculated for three types of applicator, considering a worst-case scenario for each of them (low spray volume, high or standard dose)
The model data entries are summarized in the table below:

Table 2: UK POEM data entries

Formulation	MON 2139 / MON 52276 SL (water based)	
Concentration	360 g a.e./L (a.e. = glyphosate acid)	
Application dose	6 litres/ha (Tractor mounted) 5 litres/ha (hand held)	
Volume of spray solution		
Closed cab application	80 liters/ha	
Hand held outdoors hydraulic nozzles	35 liters/ha	
Hand held outdoors rotary disks atomizers	20 liters/ha	
Workload Tractor:	50 ha /day	
Hand held	1 ha/day	
Application equipment	Tractor mounted equipment (with cab-without cab) Hand held outdoors hydraulic nozzles Hand held outdoors rotary disks atomizers	
Dermal penetration factor	3%	
Bio-availability from inhalation	100%	
Penetration through clothes **Trunk-level/leg-level:**		
Closed cab application	5% / 15%	
Hand held outdoors hydraulic nozzles	20% / 18%	
Hand held outdoors rotary disks atomizers	5% / 20%	
Personal protective equipment	**Reduction factor**	
	Mixing & Loading	**Application**
Gloves	5%	10%
Impermeable clothes (trunk, legs)	5%	5%

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4.1. Tractor mounted with cab: low spray volume (80 l/ha)

A. Product data

1.	Product name:	Roundup (MON 2139)
2a.	Active ingredient (a.i.)	glyphosate
2b.	Concentration	360 mg/mL (acid equivalent)
3.	Formulation type	SL
4a.	Main solvent	water
4b.	Concentration of solvent	not applicable
5.	Maximum in use a.i. concentration	27 mg/mL

B. Exposure during mixing and loading

1a.	Container size	5 liter	
1b.	Hand contamination per operation	0.01 mL/ operation	
2.	Application dose	6 liters product/ha	
3.	Work rate	50 ha/day	
4.	N° operations / day	60/day	
5.	Hand contamination	0.6 mL/day	
6.	Protective clothing	**NONE**	**GLOVES**
7.	Transmission to skin	100 %	5 %
8.	Dermal exposure to formulation	0.6 mL/day	0.03 mL/day
9.	Concentration of a.s.	360 mg/mL	360 mg/mL
10.	Dermal exposure to a.s.	216 mg/day	10.8 mg/day
11.	Percent absorbed	3%	3%
12.	Absorbed dose (mg/person/day)	0.108	0.0054

C. Exposure during spray application

1.	Application technique:	Vehicle mounted (with cab) Hydraulic nozzles			
2.	Application volume	80 liter/ha			
3.	Volume of surface contamination	10 mL/h			
		HANDS	**HANDS**	**TRUNK**	**LEGS**
4.	Exposure distribution	65 %	65 %	10 %	25 %
5.	Clothing	none	gloves	permeable	permeable
6.	Penetration	100 %	10 %	5%	15%
7.	Dermal exposure (mL/h)	6.5	0.65	0.05	0.375
8.	Duration of exposure	6h	6h	6h	6h
		PPE:	**NONE**	**GLOVES**	
9.	Total dermal exposure to spray		41.55 mL/day	6.45 mL/day	
10.	Concentration of a.i.		27 mg/mL	27 mg/mL	
11.	Dermal exposure to a.i.		1121.85 mg/day	174.15 mg/day	
12.	Percent absorbed		3%	3%	
13.	Absorbed dose		33.6555 mg/day	5.2245 mg/day	

D. Inhaled exposure during spray application

1.	Inhalation exposure	0.01 mL/h
2.	Duration of exposure	6 h
3.	Concentration of a.i.	27 mg/mL
4.	Inhalation exposure to a.i.	1.62 mg/day
5.	Percent absorbed	100%
6.	Absorbed dose	1.62 mg/day

E. Predicted exposure

1.	No gloves	0.6959 mg/kg bw/day	347 % AOEL
2.	Gloves only when mixing & loading	0.5933 mg/kg bw/day	297 % AOEL
3.	Gloves during M&L and during spray application	0.1195 mg/kg bw/day	60 % AOEL ← OK!

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4.2. Hand-held outdoors hydraulic nozzles: Low level Application: very low spray volume (35 l/ha)

Protective equipment:
Gloves at all time + waterproof jacket and trousers + rubber boots

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A. Product data

1.	Product name:	Roundup (MON 2139)
2a.	Active ingredient (a.i.)	glyphosate
2b.	Concentration	360 mg/mL (acid equivalent)
3.	Formulation type	SL
4a.	Main solvent	water
4b.	Concentration of solvent	not applicable
5.	Maximum in use a.i. concentration	51.43 mg/mL

B. Exposure during mixing and loading

1a.	Container size	5 liter
1b.	Hand contamination per operation	0.01 mL/ operation
2.	Application dose	5 liters product/ha
3.	Work rate	1 ha/day
4.	N° operations / day	2/day
5.	Hand contamination	0.02 mL/day
6.	Protective clothing	**GLOVES**
7.	Transmission to skin	5 %
8.	Dermal exposure to formulation	0.001 mL/day
9.	Concentration of a.s.	360 mg/mL
10.	Dermal exposure to a.s.	0.36 mg/day
11.	Percent absorbed	3%
12.	Absorbed dose	0.0108 mg/day

C. Exposure during spray application

1.	Application technique:	Hand-held Outdoors Hydraulic Nozzles: Low level application		
2.	Application volume	35 liter/ha		
4.	Volume of surface contamination	50 mL/h		
		HANDS	**TRUNK**	**LEGS**
4.	Exposure distribution	25 %	25 %	50 %
5.	Clothing	gloves	impermeable	impermeable
6.	Penetration	10 %	5%	5%
7.	Dermal exposure (mL/h)	1.25	0.625	1.25
8.	Duration of exposure	6h	6h	6h
		PPE:	**GLOVES**	
9.	Total dermal exposure to spray		18.75 mL/day	
10.	Concentration of a.i.		51.43 mg/mL	
11.	Dermal exposure to a.i.		964.31 mg/day	
12.	Percent absorbed		3%	
13.	Absorbed dose		28.92 mg/day	

D. Inhaled exposure during spray application

1.	Inhalation exposure	0.02 mL/h
2.	Duration of exposure	6 h
3.	Concentration of a.i.	51.43 mg/mL
4.	Inhalation exposure to a.i.	6.17 mg/day
5.	Percent absorbed	100%
6.	Absorbed dose	6.17 mg/day

E. Predicted exposure

1.	Gloves during M&L and during spray application	***0.585 mg/kg bw/day***	***293 % AOEL***

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4.3. Hand-held outdoors rotary disk atomizers: Low level Application: Ultra low Spray volume (20 l/ha)

Protective equipment:
Gloves at all time + waterproof jacket and trousers + rubber boots

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A. Product data

1.	Product name:	Roundup (MON 2139)
2a.	Active ingredient (a.i.)	glyphosate
2b.	Concentration	360 mg/mL (acid equivalent)
3.	Formulation type	SL
4a.	Main solvent	water
4b.	Concentration of solvent	not applicable
5.	Maximum in use a.i. concentration	90 mg/mL

B. Exposure during mixing and loading

1a.	Container size	5 liter
1b.	Hand contamination per operation	0.01 mL/ operation
2.	Application dose	5 liters product/ha
3.	Work rate	1 ha/day
4.	N° operations / day	1/day
5.	Hand contamination	0.01 mL/day
6.	Protective clothing	**GLOVES**
7.	Transmission to skin	5 %
8.	Dermal exposure to formulation	0.0005 mL/day
9.	Concentration of a.s.	360 mg/mL
10.	Dermal exposure to a.s.	0.18 mg/day
11.	Percent absorbed	3%
12.	Absorbed dose	0.0054mg/day

C. Exposure during spray application

1.	Application technique:	Hand-held Outdoors Rotary Disc Atomizers: Low level application		
2.	Application volume	20 liter/ha		
5.	Volume of surface contamination	20 mL/h		
		HANDS	**TRUNK**	**LEGS**
4.	Exposure distribution	10 %	5 %	85 %
5.	Clothing	gloves	permeable	impermeable
6.	Penetration	10 %	5%	5%
7.	Dermal exposure (mL/h)	0.2	0.05	0.85
8.	Duration of exposure	6h	6h	6h
		PPE:	**GLOVES**	
9.	Total dermal exposure to spray		6.6 mL/day	
10.	Concentration of a.i.		90 mg/mL	
11.	Dermal exposure to a.i.		594 mg/day	
12.	Percent absorbed		3%	
13.	Absorbed dose		17.82 mg/day	

D. Inhaled exposure during spray application

1.	Inhalation exposure	0.01 mL/h
2.	Duration of exposure	6 h
3.	Concentration of a.i.	90 mg/mL
4.	Inhalation exposure to a.i.	5.4 mg/day
5.	Percent absorbed	100%
6.	Absorbed dose	5.4 mg/day

E. Predicted exposure

1.	Gloves during M&L and during spray application	***0.3871 mg/kg bw/day***	***194 % AOEL***

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4.4. Conclusions

Based on the UK-POEM model, there is no risk for the operator when applying glyphosate using a tractor mounted with cab equipment and wearing gloves during mixing, loading and application

Systemic operator exposure calculated for hand-held equipment (hydraulic nozzles & RDA) was 2 to 3 times above the AOEL (0.2 mg/kg bw/day), when low spray volumes are applied, and this even when considering that gloves and impermeable clothes are worn during mixing, loading and application.

When spray volumes are higher than 100 l/ha for handheld with hydraulic nozzles and higher than 40l/ha for handheld RDA sprayer, there is no risk for the operator when wearing gloves and impermeable clothes during mixing, loading and application.

In order to refine the UK POEM assessment, field exposure studies are presented hereafter.

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5. Measurement of operator exposure

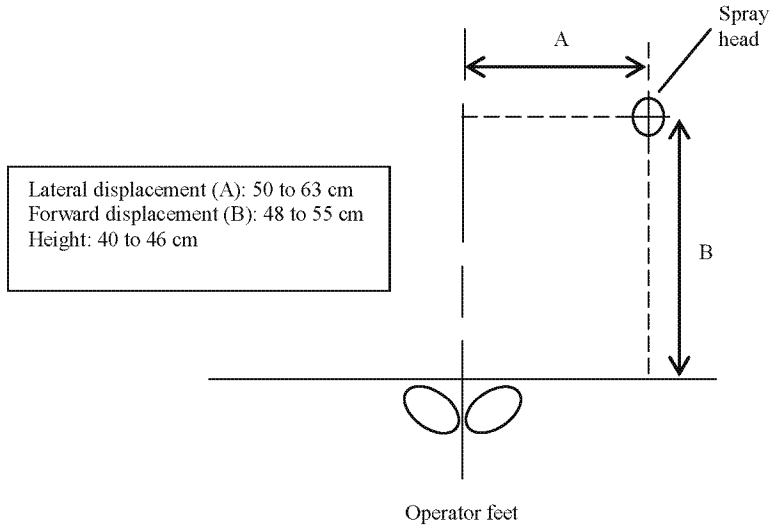
5.1. Measurement during spraying of simulated formulation with a knapsack sprayer

Exposure during spraying with a knapsack sprayer has been estimated in three studies.

(1) Meritt C.R. (1988), A comparison of the potential exposure of spray operators to sprays from the NOMIX system and a conventional lever-operated knapsack sprayer
(2) Meritt C.R. A comparative study of spray exposure: Comparison between the NOMIX system, a conventional lever-operated knapsack sprayer and the micron Herbi using Glyphosate formulations (trial 2), report No 05-270-2
(3) Meritt C.R. A comparative study of spray exposure: Comparison of the NOMIX system and a conventional lever-operated knapsack sprayer using Chipman arsenal formulation, report No 05-270-3

In these studies, a simulated formulation (spray liquid of 0.1% Agral surfactant) was applied using a Cooper Pegler CP15 lever operated knapsack sprayer fitted with a yellow ICI 'Polyjet' anvil nozzle.
Three (study 1) or four replicates (study 2 & 3) were sprayed. Spray time, spray volume and meteorological conditions are summarized in table 3. It should be noted than in studies 2 and 3, wind speeds recorded in the trial were somewhat higher than would be recommended for the application of herbicides by this type of sprayer. Thus in this respect, the data recorded here represent a 'worst case' situation of use.

The position of spray heads/ nozzles in relation with the operator is described here after:



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Sodium fluorescein tracer was included in the formulation to permit volumetric analysis of the amounts of spray material deposited on protective clothing worn by the spray operator.

The operator worn one-piece disposable 'coveralls' (100% polypropylene), gloves (in vinyl), respirators and personal samplers (Casella AFC 123). Wellington boots were worn during spraying but were not extracted. Protective coveralls are worn outside the boot and used to evaluate the contamination down to foot level.

In the field, the contaminated suits are cut and the different sections (head, arms, trunk, thighs and lower legs) are placed in pre-labelled polythen bags. Respirator filters were placed in 25 ml stoppered flasks. Gloves were placed in screw-top jars.

Fluorescein has been extracted from samples using a solution of 0.05 M NaOH. Fluorescein was determined by spectrofluorometry.

Measured exposure in ml spray solution/hour is summarized in table 3.

The general conclusions of these studies are the following:

- The greatest exposure levels were recorded on the lower leg section
- Contamination of the thigh and leg was greater when spraying parallel to the wind than when spraying perpendicular to the wind.
- Levels of respirable spray were extremely low.

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Table 3: Knapsack sprayers:
Potential exposure in ml spray solution/hour

Equipment	Cooper Pegler CP15 lever operated knapsack sprayer [1]			Cooper Pegler CP15 lever operated knapsack sprayer [2]				Cooper Pegler CP15 lever operated knapsack sprayer [3]			
	Rep I	Rep II	Rep III	Rep I[4]	Rep II[4]	Rep III[5]	Rep IV[5]	Rep I[4]	Rep II[4]	Rep III[5]	Rep IV[5]
Test conditions											
Spray volume (l/ha)	182	182	182	179	179	179	179	142	142	142	142
Duration of the test (min)	2.98	3.95	4.23	4.03	4.13	4.12	4.17	4.03	4.13	4.12	4.17
Wind speed at 1.95 m (km/h)	8.4	9.1	11	12.6	14.4	13.3	15.5	16.2	16.9	22.9	16.4
Temperature (°C)	20.1	20.3	19.4	12.8	12.8	12.7	12.5	9.1	8.9	9.5	9.1
Exposure (ml/hour)											
HEAD	0.0046	0.024	0.023	0.0074	0.0029	0.0044	0.0014	0	0	0	0
HANDS	0.06	0.02	0.014	1.676	0.158	0.336	0.012	0.021	0.014	0	0.019
TRUNK (Body + arms)	0.355	0.085	0.534	0.17	0.038	0.12	0.108	0.027	0.04	0.06	0.06
LEGS (Thigh + lower leg)	0.480	1.093	6.535	57.46	34.28	64.74	86.17	0.57	4.92	67.76	73.12
INHALATION	0.0016	0	0	0.0034	0.0009	0.0007	0.0006	0	NA	0	0

(1) Meritt C.R. (1988), A comparison of the potential exposure of spray operators to sprays from the NOMIX system and a conventional lever-operated knapsack sprayer
(2) Meritt C.R. A comparative study of spray exposure: Comparison between the NOMIX system, a conventional lever-operated knapsack sprayer and the micron Herbi using Glyphosate formulations (trial 2), report No 05-270-2
(3) Meritt C.R. A comparative study of spray exposure: Comparison of the NOMIX system and a conventional lever-operated knapsack sprayer using Chipman arsenal formulation, report No 05-270-3
(4) Treatment was sprayed perpendicular to the wind.
(5) Treatment was sprayed parallel to the wind

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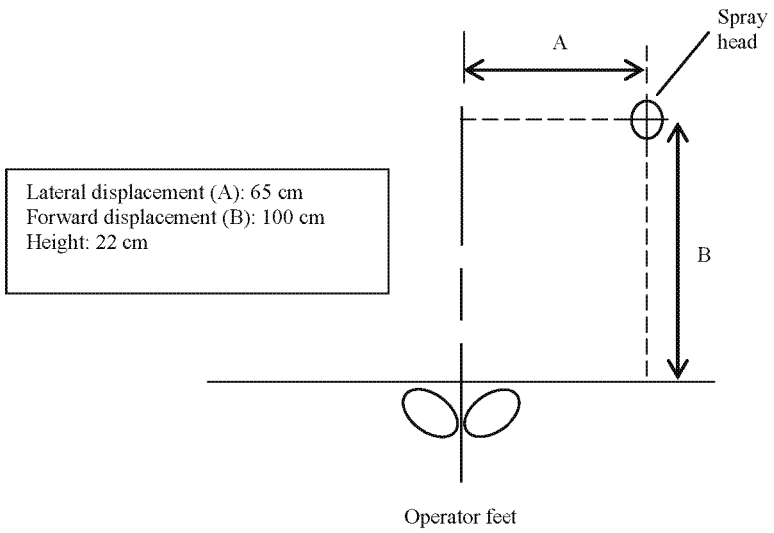
5.2. Measurement of operator exposure during spraying with a Rotary Discs Atomizer sprayer

The operator exposure has been measured during spraying of a Glyphosate formulation ('Roundup') using a RDA sprayer (Meritt C.R. trial 2, report 05-270-2)

In this study, a Glyphosate formulation (Roundup) was applied using Micron Herbi RDA sprayer calibrated to deliver 10 l/ha of spray solution (4 parts roundup + 6 parts water). Spray time and meteorological conditions are summarized in table 4. It should be noted than wind speeds recorded in the trials were somewhat higher than would be recommended for the application of herbicides by this type of sprayer. Thus in this respect, the data recorded here represent a 'worst case' situation of use.

The position of spray heads/ nozzles in relation with the operator is described here after:



Sodium fluorescein tracer was included in the formulation to permit volumetric analysis of the amounts of spray material deposited on protective clothing worn by the spray operator.

The operator worn one-piece disposable 'coveralls' (100% polypropylene), gloves (in vinyl), respirators and personal samplers (Casella AFC 123). Wellington boots were worn during spraying but were not extracted. Protective coveralls are worn outside the boot and used to evaluate the contamination down to foot level.

In the field, the contaminated suits are cut and the different sections (head, arms, trunk, thighs and lower legs) are placed in pre-labelled polythen bags. Respirator filters were placed in 25 ml stoppered flasks. Gloves were placed in screw-top jars.

Fluorescein has been extracted from samples using a solution of 0.05 M NaOH. Fluorescein was determined by spectrofluorometry.

Measured exposure in ml spray solution/hour is summarized in table 4.

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Table 4: RDAsprayer + Glyphosate formulation:
Potential exposure in ml spray solution/hour

Equipment	Micron Herbi RDA sprayer (ml/hr)			
	Rep I [1]	Rep II [1]	Rep III [2]	Rep IV [2]
Test conditions				
Spray volume (l/ha)	8.8	8.8	8.8	8.8
Duration of the test (s)	190	189	179	183
Wind speed at 1.95 m (km/h)	14.4	15.8	13.3	13.0
Temperature (°C)				
Exposure (ml/hour)				
HEAD	0.002	0	0.004	0.030
HANDS	0.031	0.032	0.012	0.013
TRUNK (Body + arms)	0.054	0.04	0.024	0.124
LEGS (Thigh + lower legs)	1.57	0.061	9.47	9.93
INHALATION	0.0002	0.002	0.0	0.0004
TOTAL	***1.66***	***0.14***	***9.51***	***10.1***

(1) Treatment was sprayed perpendicular to the wind.
(2) Treatment was sprayed parallel to the wind

The general conclusions of this study are the following:

- The greatest exposure levels were recorded on the lower leg section
- Contamination of the thigh and leg was greater when spraying parallel to the wind than when spraying perpendicular to the wind.
- Levels of respirable spray were extremely low.

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5.3. Measurement of operator exposure during spraying with a backpack sprayer

Three studies assessed the operator exposure to Roundup when applied using a backpack sprayer:

(1) Kramer R.M. (1978), Herbicide applicator exposure to N-Nitroso-glyphosate during application of Roundup herbicide and field re-entry. Monsanto report No MSL-0288.

(2) Cowell J.E., Steinmetz J.R. (1990), Assessment of forestry Nursery Workers Exposure to Glyphosate During Normal Operations. Monsanto report No MSL-9665.

(3) Cowell J.E., Steinmetz J.R. (1990), Assessment of forest worker exposures to Glyphosate during backpack foliar application of roundup herbicide. Monsanto report No MSL-9656.

Each study has been deeply reviewed and exposure data ($\mu g/cm^2$) have been normalized and expressed in ml/hr of spray solution.

The $\mu g/cm^2$ of glyphosate measured on pads was expressed in µg based on the surface area of each body part. The surface areas used in this assessment are summarized in table 5.

Table 5: Surface areas

Body part	Surface area (cm^2)
Hands	820
Lower leg	2380
Thigh	3820
Forearm	1210
Upper arm	2910
Chest/stomach	3550
Back	3550
Front of neck	150
Back of neck	110
Head	1300

The inhalation exposure of the operator to glyphosate was calculated based on the concentration of Glyphosate measured in air during application ($\mu g/m^3$) and on the human breathing rate (1.8 m^3/hour)

The exposure in ml/hr was then calculated considering the exposure expressed in µg, concentration of the spray solution, and the time of exposition

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5.3.1 MSL-0288

Inhalation and dermal exposure to Glyphosate and N-Nitrosoglyphosate was determined during outdoors application of Roundup. The test was conducted in Florida in area that provides various weed conditions. Specifically, the area provided plots where three applications each of boom treatment, handgun treatment and backpack spot treatment could be made. Only the results of backpack application are reported here.

The backpack applications were made using a hand-pumped backpack sprayer. The sprayer was filled with 11.36 liters of water and 147 ml of Roundup (360 g a.e./L) was added. The concentration of the spray solution was therefore 4.6 g a.e./L.
Approximately 45 minutes were necessary to apply the 11.5 liters in each treatment.

Sampling techniques were designed to determine operator exposure to herbicide contact through air he breathes, the amount that may deposit on exposed skin surfaces and the amount that may deposit on covered skin.

Air samples were collected using a Bendix High volume Air samples model 500 fitted with a ten centimeters diameter reeve Angel glass fiber/organic binder filter pad. The pump and filter combination was designed to draw about 24 m^3/hr, a volume representing 15 to 20 times the amount a person normally inhales.
The air sampler was run for the entire time it took to make the Roundup application (45 to 60 minutes), providing an accurate time weighted average exposure assessment.

The deposition of herbicide on skin and on covered skin surfaces was estimated by attaching 10 by 10 cm surgical pads at strategic locations on the applicator's body. A total of eleven pads were used for each test, located as follows:

Exposed	Under Clothing
Top of head	Right forearm
Forehead	Left bicep
Chest	Ankle
Shoulder	
Back	
Right bicep	
Left forearm	
Thigh	

In addition, separate estimates of amount of Glyphosate that may get on the operator's hands was measured by having the operator wear cotton gloves. This technique would yield maximum exposure levels as the glove would absorb any spills which could be wiped or washed off the hand.

Three replicate measurements were made during filling and spraying.

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- *Inhalation exposure*

Calculation and results of inhalation exposure are presented in table 6.

Table 6: MSL 0288: Normalized inhalation exposure (ml/hr)

Operation	Calculated air concentration (CA) ($\mu g/m^3$)	Inhalation ($\mu g/hr$) = CA*1.8 m^3/hr	***Inhalation (ml/hr)****
Backpack 1	1.19	2.14	***0.00047***
Backpack 2	0.3	0.54	***0.00012***
Backpack 3	< 0.05	< 0.09	***< 2 10^{-5}***

* Inhalation ($\mu g/hr$) = inhalation ($\mu g/hr$) / concentration of spray solution (4600 $\mu g/ml$)

- *Potential exposure (Glyphosate found on operator clothing + unprotected skin)*

Measured exposure ($\mu g/cm^2$) is given for each body part in table 7.

Table 7: MSL-0288 exposure ($\mu g/cm^2$)

Clothing type	Quantity of Glyphosate found ($\mu g/cm^2$)		
	Test 1	Test 2	Test 3
Gloves			
Left	0.014	1.98	6.56
Right	0.006	2.00	3.22
Exposed Gauze pads			
Head	--	--	--
Forehead	--	0.033	0.012
Shoulder	0.033	0.116	0.235
Chest	0.017	0.083	0.245
Back *	6.38	5.96	3.99
Thigh	0.96	0.18	1.39
Right bicep	0.090	0.058	0.253
Left forearm	0.051	0.098	0.377

* Highest exposure values were observed on this pad. This was expected as the sprayer is resting on this pad allowing pickup of any spillage.

Trunk, legs and hands exposures were calculated in order to be compared with default value given in the UK POEM model.

Exposure were calculated according to the following formulas:

Trunk:

1. Clothing area

Exposure (μg) =
[($\mu g/cm^2$ shoulder + $\mu g/cm^2$ r. bicep) / 2] x 2910 cm^2 (upper arm area)
+ $\mu g/cm^2$ forearm x 1210 cm^2 (forearm area) + $\mu g/cm^2$ chest x 3550 cm^2 (chest area) + $\mu g/cm^2$ back x 3550 cm^2 (back area)

2. Unprotected skin

Exposure (μg) = [($\mu g/cm^2$ forehead + $\mu g/cm^2$ shoulder) / 2] x 1300 cm^2 (head area)

3. Total exposure (μg) = Clothing + Unprotected

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***Legs**:*

Exposure (µg) =
(µg/cm^2 thigh) x [3820 cm^2(thigh area) + 2380 cm^2 (lower leg area)]

***Hands**:*

Exposure (µg) = (µg/cm^2 left glove + µg/cm^2 right glove) x 820 cm^2 (hands area)

The calculation of the exposure in ml/hr was done considering the time of exposure and the concentration of the spray solution:

Exposure (ml/hr) =
[Exposure (µg) / time (min)] x [60 (min) / concentration of spray solution (µg/ml)]

Results are presented in table 8.

Table 8 : MSL 0288: potential exposure (ml/hr)

Body part	Exposure (ml/hr)*		
	Test 1 (exposure time = 46 min)	Test 2 (exposure time = 45 min)	Test 3 (exposure time = 33 min)
Trunk**	6.43	6.29	6.40
Legs	1.67	0.32	3.37
Hands	0.002	0.47	1.57
TOTAL	8.1	7.1	11.3

* Concentration of spray solution = 4600 µg/ml. Complete calculations can be found in the excel sheet in annex.

** The exposure value on the trunk is due principally to the back exposure.

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5.3.2. MSL 9655:

The purpose of this study was to monitor the exposure resulting from the use of glyphosate herbicide in forestry nursery operations. The percent clothing penetration was also estimated in this study.
Three types of worker functions were investigated.
"Tractor applicators" mixed and loaded Glyphosate into the spray tank and applied the mixture to various roadsides, ditch banks and fallow nursery beds.
"Weeders" used hand-held sprayers with shielded nozzles to selectively apply Glyphosate to weeds in and around pine seedling beds.
"Scouts" scanned pine seedling nursery beds to estimate the pest populations/damage.
In this study, exposure of applicators, weeders and scouts while performing their duties under normal-use conditions was biologically monitored by analysis of collected composite urine specimens. Additionally, dermal/clothing deposition exposure was monitored by passive dosimetry with cotton gauze pads and hand rinses.

Only the weeders exposure is presented here below in order to illustrate hand-held application of glyphosate.

Weeders worked for 8 hours and applied 1,89 L of a 9 g a.e./L solution per trip. Four trips were made each day for a total of 68.04 g glyphosate applied each day. One of the weeders (weeders # 4) also mixed and filled the sprayers for all the other weeders. Applications were made with hand-held sprayers with shielded nozzles using a directed spray, spot treatment application technique. Weeders worn what they normally wear or whatever protective clothing specified on the label (cotton clothes? + rubber boots + rubber gloves?).

Only the exposure measured using the passive dosimetry method is reported here.

Gauze pads were placed on the subjects in the following locations:

Location of Patches	Body region represented
Ankle pads combined left and right	Lower leg
Thigh pads combined left and right	Thigh
Forearm pads on outside of shirt combined left and right	Forearm
Forearm pads on inside of shirt combined left and right	Used in calculation of % of clothing penetration
Chest pad	Chest/stomach/ front of neck
Back pad	Back/back of neck
Head pad	Head

Some single location were analysed for each type of worker but the majority of the pads were combined for a single analysis for the worker work period. Specific pads analysis were conducted for two weeders (#4 and #5). Results of these analyses are presented hereafter.

Exposure on hands was measured by analyzing hand rinses.

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- *Potential Exposure (clothing + exposed skin)*

Measured exposure (µg/cm^2) on the gauze pads is presented in table 9.

Table 9: MSL-9655 exposure (µg/cm^2) measured by the passive dosimetry method

Exposed gauze pads	Quantity of Glyphosate found (µg/cm^2)	
	Weeder #4	Weeder #5
Ankle	39.7	98.3
Thigh	60.4	0.649
Forearm	0.0756	0.236
Chest	< 0.018	0.037
Back	< 0.018	< 0.018
Head	0.171	0.547

Exposure (µg/day) were calculated using the following formulas:

Trunk:

1. Clothing area
Exposure (µg/day) =
µg/cm^2 forearm x [1210 cm^2 (forearm area) + 2910 cm^2 (upper arm area)]
+ µg/cm^2 chest x 3550 cm^2 (chest area) + µg/cm^2 back x 3550 cm^2(back area)

2. Unprotected skin
Exposure (µg/day) =
µg/cm^2 head x 1300 cm^2 (head area)
+ µg/cm^2 chest x 150 cm^2 (front of neck area)
+ µg/cm^2 back x 150 cm^2 (back of neck area)

3. Total exposure (µg/day) = Clothing area + Unprotected skin

Legs

Exposure (µg/day) =
µg/cm^2 ankle x 2380 cm^2 (lower leg area) + µg/cm^2 thigh x 3820 cm^2 (thigh area)

The calculation of the exposure in ml/hr was done considering the time of exposure (8 hr/day) and the concentration of the spray solution:

Exposure (ml/hr) =
Exposure (µg/day) / (time (hr) x concentration of spray solution (µg/ml))

Results are presented in table 10.

Table 10: MSL-9655 normalized exposure in ml/hr spray solution

Body part	Potential exposure (ml/hr)*	
	Weeder #4	Weeder #5
Trunk	0.007	0.02
Legs	3.8	2.7

* Concentration of spray solution was 9000 µg/ml

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- *Hands: dermal exposure (ml/hr)*

Weeders worn gloves during spraying. Dermal exposure on hands was evaluated by analysing hand rinses of 9 weeders. Hands dermal exposure (µg/day) for each weeder is summarized in table 11.

Table 11: MSL-9655 hands dermal exposure (µg/day)

Weeder	Exposure (µg/day)
Weeder #4	103.3
Weeder #5	618.9
Weeder #6	38.4
Weeder #7	199.5
Weeder #8	53.8
Weeder #9	306.2
Weeder #10	138.6
Weeder #11	55.3
Weeder #91	103.4
Average	179.8

The calculation of the exposure in ml/hr was done considering the mean exposure value, the time of exposure and the concentration of the spray solution (9000 µg/ml)

Exposure (ml/hr) =
Exposure (µg/day) / (time (hr) x concentration of spray solution (µg/ml))
= 179.8/ (8 x 9000)
= ***0.0021 ml/hr of spray solution***

- *Percent clothing penetration*

The percent clothing penetration has been calculated by dividing the micrograms found in pads underneath clothes by the micrograms found on the pads outside of the clothes in areas adjacent to the underneath pads and averaging for the number of workers. This was done six times in this study. ***The percent clothing penetration was calculated to be 40%***.

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5.3.3. MSL-9656

The purpose of this study was to determine the exposure of forest workers to glyphosate while performing backpack foliar application of Roundup herbicide. The percent clothing penetration was also estimated in this study.
Workers at three sites were monitored biologically by analysis of collected urine specimens and by passive dosimetry using cloth patches, hand washes, and air filter samples.

Roundup herbicide has been applied using a backpack sprayer (solo model 475 diaphragm pump backpack with a spraying system model 30 Gunjet, or a wand and tip No TP2503).
Workers worn normal protective clothing: cotton clothing (long pants and long sleeved shirt), rubber boots and gloves (natural rubber).
They worked for 8 hours/day. The concentration of the spray solution was 10.8 g a.e./L.
16 workers were monitored during this study.

In order to be compared with the default values proposed by the UK POEM model, only the exposure measured using the passive dosimetry method is reported here.

Gauze pads were placed on the subjects in the following locations:

Location of Patches	Body region represented
Mean of Shin and calf (left and right)	Lower leg
Mean of Thigh (left and right)	Thigh
Mean of Forearm (left and right)	Forearm
Right forearm, chest and left thigh patches, all underneath clothing	Used in calculation of % clothing penetration
Shoulder (left and right)	Upper arm
Chest	Chest/stomach/ front of neck
Back	Back/back of neck
Mean of shoulder, back and chest	Head

- *Potential Exposure (clothing + exposed skin)*

Exposure was calculated according the following formulas:

Trunk:

1. Clothing area
Exposure (µg/day) =
[(µg/cm^2 right shoulder + µg/cm^2 left shoulder)/2] x 2910 cm^2 (upper arm area)
+ µg/cm^2 chest x 3550 cm^2 (chest area) + µg/cm^2 back x 3550 cm^2(back area)
+ [(µg/cm^2 right forearm + µg/cm^2 left forearm)/2] x 1210 cm^2 (forearm area)

2. Unprotected skin
Exposure (µg/day) =
[(µg/cm^2 r. shoulder + µg/cm^2 chest + µg/cm^2 l. shoulder + µg/cm^2 back)/4] x 1300 cm^2 (head area)

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3. Total exposure (µg/day) = Clothing area + Unprotected skin

Legs

Exposure (µg/day) =
[(µg/cm^2 r. thigh + µg/cm^2 l. thigh)/2] x 3820 cm^2 (thigh area)
+ [(µg/cm^2 r. shin + µg/cm^2 l. shin + µg/cm^2 calf)/3] x 2380 cm^2 (lower leg area)

The calculation of the exposure in ml/hr was done considering the time of exposure (8 hr/day) and the concentration of the spray solution:

Exposure (ml/hr) =
Exposure (µg/day) / (time (hr) x concentration of spray solution (µg/ml))

Measured exposure (µg/cm^2) and calculated exposure in ml/hr of spray solution are presented for each worker in the excel sheet given in annex of this document.
Mean exposure was calculated to be ***0.35 ml/hr*** and ***2.8 ml/hr*** for ***trunk*** and ***legs*** respectively.

- *Hands: Dermal exposure*

Workers worn gloves during spraying. Dermal exposure on hands was evaluated by analysing hand rinses from each of the 16 workers. Hands dermal exposure (µg/day) and calculated exposure in ml/hr of spray solution for each worker is presented in annex.
The calculation of the exposure in ml/hr was done considering the exposure value, the time of exposure and the concentration of the spray solution (10800 µg/ml).

Exposure (ml/hr) =
Exposure (µg/day) / (time (hr) x concentration of spray solution (µg/ml))

Mean exposure value was calculated to be ***0.018 ml/hr of spray solution***.

- *Inhalation exposure*

Air filters attached in the breathing zone of the test subjects were analysed for glyphosate residues. Exposure value (µg/day) and calculated value in ml/hr of spray solution are given in annex.
The calculation of the exposure in ml/hr was done considering the exposure value, the time of exposure and the concentration of the spray solution (10800 µg/ml).

Exposure (ml/hr) =
Exposure (µg/day) / (time (hr) x concentration of spray solution (µg/ml))

Mean exposure was calculated to be ***0.0008 ml/hr of spray solution***.

- *Percent clothing penetration*

The percent clothing penetration was calculated by dividing the micrograms found in the pads worn underneath clothes by the micrograms found on the pads worn outside the clothes in the areas adjacent to the underneath pads. An average was then calculated from the numbers of workers for which this penetration was measured (n = 7). ***The average clothing penetration was calculated to be 3.84%.***

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6. General conclusions and proposed actions

- Measured exposure when applying Glyphosate with a RDA sprayer was normalized in ml/hr in order to be compared to the UK POEM default values. Measured exposure was lower than default values proposed for potential exposition in the UK POEM model. Values are compared in the table below:

Body part	Measured exposure (ml/hr) - RDA sprayer				UK POEM value – RDA sprayer
	Rep 1	Rep 2	Rep 3[(1)]	Rep 4[(1)]	
HANDS	0.031	0.032	0.012	0.013	2 ml/hr
TRUNK	0.054	0.04	0.024	0.124	1 ml/hr
LEGS	1.57	0.061	9.47	9.93	17 ml/hr
INHALATION	0.0002	0.002	0	0.0004	0.01 ml/hr

[(1)] Treatment was sprayed parallel to the wind

- Hand contamination is low when spraying glyphosate using a RDA sprayer. It should be taken into account when calculating the operator exposure with the UK POEM.

- Measured exposure values when applying Glyphosate with backpack sprayer were normalized in ml/hr in order to be compared to the UK POEM default values. Measured exposure values were lower than default values proposed by UK – POEM. Values are summarized in the table below.

Body part	Measured exposure (ml/hr)						UK POEM value Hand-held
	MSL0288			MSL9655		MSL9656	
	Test 1	Test 2	Test 3	Weeder #4	Weeder #5	Mean (n=16)	
HANDS Potential Dermal	0.002	0.47	1.57	0.0021 (mean, n=8)		0.018	12.5 ml/hr 1.25 ml/hr
TRUNK	6.43	6.29	6.40	0.007	0.02	0.35	12.5 ml/hr
LEGS	1.67	0.32	3.37	3.8	2.7	2.8	25 ml/hr
INHAL.	NA	NA	NA	NA	NA	0.0008	0.02 ml/hr

NA= Not applicable

- Exposure to Glyphosate through inhalation is very low. This is line which the results of the droplet spectra analysis.
  This should be taken into account when calculating the exposure using the UK POEM model. Default value should be replaced by a value specific for Glyphosate. This can be based on the field studies.
  Highest value measured for RDA sprayer is 0.002 ml/hr. (5 x less than default value).
  Highest value measured for backpack sprayer is 0.002 ml/hr (see excel sheet). This is 10 times less than the UK POEM default value.
  Proposal: replace default values in the model by highest measured values in field studies. This will reduce the calculated exposure.

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- Hand contamination is low when wearing gloves and is far below the default value recommended in UK POEM. This shows that gloves protect hands effectively against glyphosate.
  → Would be good if we could ***evaluate the gloves penetration.*** Based on the above results, penetration is certainly lower than the 10% recommended by the UK POEM model

- All studies (even those with simulated formulations) except one (Kramer R.M., 1978) showed that contamination on legs represents the major part of the exposure.
  → Mitigation measures should be proposed to reduce this contamination (???). Does it exist special sprayer capable to reduce the legs contamination?

  → Field studies (Meritt C.R) shown that highest contamination of legs occurred when spraying parallel to the wind. A mitigation measure could be to recommend spraying perpendicular to the wind.

  → It would be helpful to know ***the % penetration factor for Glyphosate through clothes (permeable and impermeable) and boots***, in order to see what clothing we should recommend.

- Percent clothing penetration has been measured in two different studies (Cowell, 1990).
  Each operator worn clean standard cotton clothing including long pants and long sleeved shirt, leather or rubber boots, appropriate clean gloves (rubber) and hard hat while handling and applying the Roundup herbicide.
  Percent clothing penetration was calculated by dividing the micrograms found in the pads underneath clothes by the micrograms found on the pads outside clothes in the area adjacent to the underneath pads and averaging for the number of workers.
  In MSL9655, percent penetration was calculated from forearm pads (left and right) placed inside the shirt.
  In MSL 9656, percent penetration was calculated from right forearm, chest and left thigh patches, all underneath clothing.

  Studies give different results. ***A percent clothing factor was calculated to be 40% in MSL9655 and 4 % in MSL9656.***

  Based on the reports, it was not possible to understand how such different results were obtained. According to report MSL-9656, it could be due to cross contamination of the inside patches during their removal and preparation for analysis.

  Moreover, default penetration factor (5%) proposed by PSD for impermeable clothes are certainly overestimated. It would be good if we can have data to show that this factor can be reduced in the case of Glyphosate.

  It would be interesting to conduct a ***study to better estimate the clothing penetration factor.***

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