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A System for Rinsing Herbicide Residues from Drums During Highway Right-of-Way Spray Operations

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In Ontario, there are about one million hectares of rights-of-ways (ROW) taken up by highways, road, power lines and pipelines. Approximately 10% of this is treated annually with herbicides (Frank et al. 1983, Anonymous 1979, Table 1).

Table 1. Statistics on rights-of-way spraying in Ontario, Canada, 1983-84.

Herbicide (kg/ha ae)	Municipal Roads	Provincial Highways	Power-Lines	Railways, Pipelines	Total
Total area (10^3 ha)	230	350	200	220	1000
Treated/yr (10^3 ha)	44	22	13	21	100
Herbicide (kg/ha ae)	2.0	2.7	3.3	2.5	-
Formulation (10^3 L)	176	119	86	105	486
Drums (number)[1]	860	680	440	520	2500

[1]Drums 115 and 205 L

Around 2500 drums mainly 205 L, but including some 115 L, are emptied annually to support these operations. This study was undertaken with the Ontario Ministry of Transportation and Communications (OMTC) which annually sprays about 22,000 h of ROW using hormone type herbicides to control undesirable brush and weeds. This requires around 119 kilolitres of formulated product, primarily 2,4-D/dichlorprop, dicamba and picloram dispensed from around 680 drums. In order to perform these operations the OMTC has developed a drum emptying and rinsing

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system utilizing their highway vehicle spray rigs. This study was undertaken to measure the efficiency of this drum rinsing system under field conditions.

MATERIALS AND METHODS

The spray rigs used in the study were owned and operated by the Ontario Ministry of Transportation and Communications. The spray equipment consisted of two tanks, the first for holding water and herbicide solutions (4500 L) and the second for storing herbicide concentrate (900 L). The sprayer's main pump was used to transfer herbicide concentrate from the drums (4 maximum) to the supply tank (Fig. 1a). The general configuration of the spray equipment appears in Fig. 1. Herbicide drums were emptied as completely as possible by inserting the loading hose from the sprayer to the lowest point in the drum while tilting the container on a 45° angle.

The following were the guaranteed herbicide formulations by acid equivalent (ae), their container size and the numbers used in the drum rinsing study.

a) Ten 205 L drums containing 2,4-D amine at 500 and 600 g/L ae
b) Ten 205 L drums containing 2,4-D/dichlorprop at 700 g/L ae
c) Ten 205 L drums containing 2,4-D/picloram at 240+60 g/L ae (Trade name Tordon 101^{R})
d) Five 115 L drums containing dicamba at 400 g/L ae (Trade name Dycleer^{R})

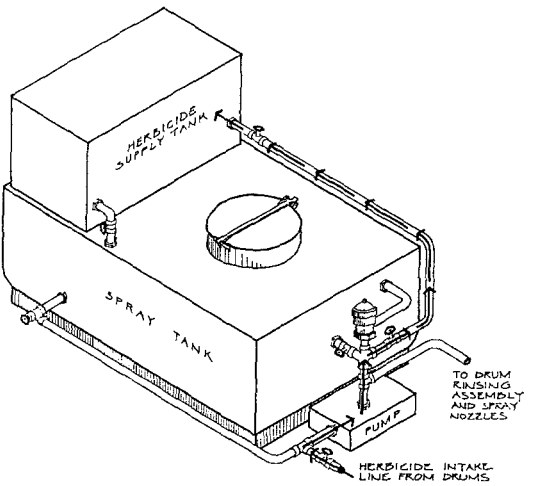
Details on the contents of the 35 drums appears in Table 2.

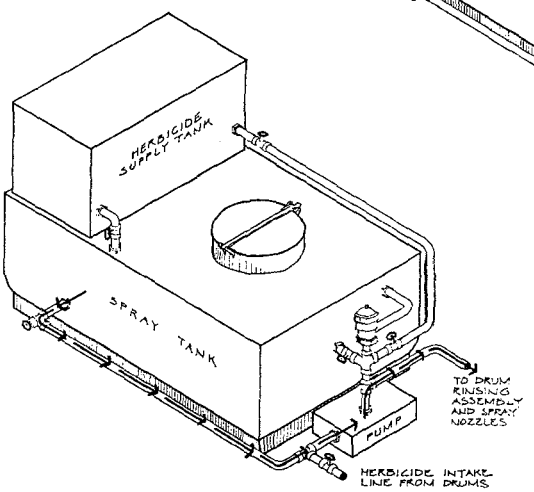
Table 2. Information on contents of 35 drums emptied and rinsed on the highway spraying equipment.

Herbicide	No. of Drums	Concentration (g ae/L)[1]	Volume of Drums (L)	Total Product (L)	Total ae (kg)
2,4-D[2]	6	600	205	2050	1,148
	4	500	205		
Dicamba	5	400	115	575	230
2,4-D[2]	2	385/325	205		
Dichlorprop	4	390/310	205	2050	860/625
	4	400/290	205		
2,4-D	10	240/60	205	2050	499/123
Picloram					

[1]g ae - grams acid equivalent
[2]Significant variations were found in the formulations; 2,4-D should have been 600 g/L and 2,4-D/dichlorprop 250/250 g/L, ae.

a) **LOADING OF HERBICIDE:**
from drums to supply tank.





b) **PATH OF RINSE WATER:**
from spray tank to drums.

c) **PATH OF RINSATE:**
from drums to spray tank.

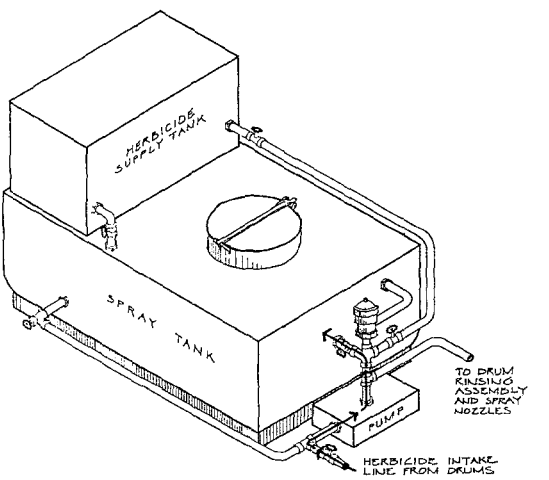
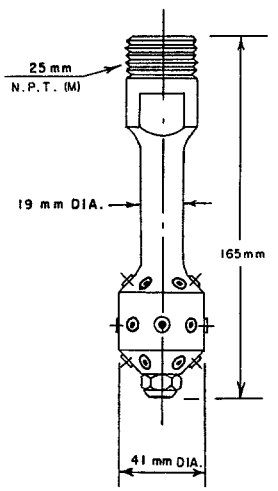
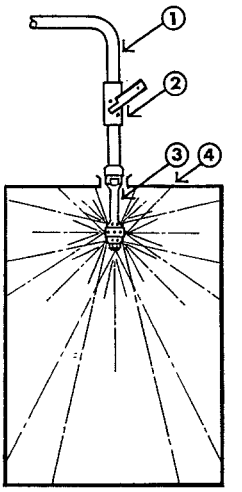


FIGURE 1: GENERAL CONFIGURATION OF SPRAY EQUIPMENT



a) DRUM WASHING NOZZLE



b) DRUM RINSING ASSEMBLY:
1: from sprayer; 2: shut-off valve;
3: drum washing nozzle; 4: drum.

FIGURE 2: DRUM RINSING ASSEMBLY AND NOZZLE DETAIL

The main (4500 L) spray tank was filled with clean water from the most convenient source available, e.g. surface water or hydrant. Existing herbicide solutions were flushed from sprayer lines by circulating the clean water from the main tank throughout the system, but did not include herbicide concentrate trapped in the loading line (approximately 3 L every 2 to 4 drums emptied). These lines usually raised the concentration by between 3 and 110 mg/L of each herbicide to the water reservoir. The rinse water was then pumped to the drums through a 2.5 cm discharge line from the main pump to give a pressure of 550 kPa at the nozzle (Fig. 2). The brass drum washing nozzle (Fig. 2a) was inserted into each drum through the large bung hole to the depth illustrated in Figure 2b and operated for 20-30 seconds for each rinsing of a 205 L drum and 10-15 seconds for a 115 L drum. This time span generated 20 to 25 L and 12 to 15 L of rinsate in the 205 and 115 L drums respectively. The drum washing nozzle's 21 orifices projected a spray pattern that thoroughly covered all inside surfaces of the drums. Each drum was rinsed three times. After each washing the rinsate was pumped back into the spray tank (Fig. 1c). Drums were emptied as completely as possible using the same technique employed in loading herbicide concentrate into the sprayer. On average 0.25 L of rinsate remained in each drum using this procedure. In

most cases a fourth rinsing was undertaken to determine what residual herbicide still remained in the drums.

The following 100 ml samples were collected for analyses:

i) The four herbicide concentrates employed;
ii) Rinse water from the main tank prior to rinsing;
iii) Rinsate from the drums after each rinsing cycle;
iv) Rinse water from main tank after the third and fourth rinse cycles were completed.

The following measurements or determinations were also made:

i) Total volume of rinse water in main tank;
ii) Volume of herbicide concentrate remaining in each drum after emptying;
iii) Volume of residual rinsate in drums after each rinse cycle completed.

Samples of solution (100 ml) were extracted and esterified according to a procedure described by Yip (1971). Gas liquid chromatographic determinations were made using the electrolytic conductivity detection system (halogen mode) with a column packing of 5% Dexsil on Varaport 30 as described by Frank and Sirons (1980) and Frank, Sirons and Ripley (1979).

RESULTS AND DISCUSSION

Emptying the 205 L drums of herbicide concentrate for spraying purposes resulted in the removal of 99.4 to 99.5% of the formulation. Residual herbicide concentrate remaining in these drums range from 0.98 $\pm$ 0.38 L to 1.23 $\pm$ 0.79 L (Table 3,4). With the 115 L drums 98.7% of the formulation was removed and the amounts of Dycleer^{R} remaining in the drums was 1.45 $\pm$ 2.18 L (Table 3). The actual amounts of herbicide by a.e. residual in the drums varied from a low of 308 $\pm$ 198 g 2,4-D plus 77 $\pm$ 49 g picloram to a high of 686 $\pm$ 180 g of 2,4-D when alone.

The volume of water in the spray tanks used for rinsing varied from 4100 to 4320 L. On average the first rinsing of drums removed 85% of the residual 2,4-D and 89% of the 2,4-D plus dichlorprop mixture, 91 and 87% of the 2,4-D plus picloram mixture and 74% of the dicamba. The second rinsings removed a further 4.1 to 18.4% of the residue and the third rinsing 2.2 to 7.3% of the four herbicides. Normally three rinsings are recommended and preferred as a maximum in commercial operations. The fourth rinsing was designed to help determine what residual amounts still remained in the drums after the triple rinsing procedure. In the case of 2,4-D alone an average of 8 $\pm$ 6 g ae remained in the 10 drums, or 1.2% of the residual herbicide left after emptying. With the 2,4-D plus dichlorprop mixtures the mean amount remaining was 5 $\pm$ 3 g ae for each of the two components per drum. With the 2,4-D plus picloram mixture the mean amount remaining was 8 and 2 g respectively per drum and

Table 3. Residual 2,4-D and dicamba remaining in 205 and 115 L drums respectively following emptying and efficiency of subsequent removal of these residues through each of 3 or 4 rinsings.

Item	Remainder in Drum & Line Formulation a.e. (L)	(g)	Rinsings (g a.e.)[1] 1	2	3	4	Remainder in Drum After Rinsing (g.a.e.)
2,4-D (10 Drums)							
Total	12.25	6855	5835	636	302	NA	83
Mean/Drum	1.23	686	584	64	30	NA	8
SD	0.32	180	64	34	27	NA	6
%	0.60	0.60	85.1[3]	9.3	4.4	NA	1.2
Dicamba (5 Drums)							
Total	7.24	2896	2143	532	191	22	8
Mean/Drum	1.45	579	429	106	32	4	2
SD	2.18	873	741	105	40	9	3
%	1.3 [2]	1.3	74.0[3]	18.4	6.6	0.8	0.3

[1]g a.e. - grams acid equivalent.
[2]Percent remaining in drums calculated from Table 2.
[3]Percent removed of residual active by each rinsing.

Table 4. Residual 2,4-D/dichlorprop and 2,4-D/picloram remaining in 205 L drums following emptying and efficiency of subsequent removal of these residues through each four rinsings.

Item	Remainder in Drum & Line Formulation a.e. (L)	(g)	Rinsings (g a.e.)[1] 1	2	3	4	Remainder in Drum After Rinsing (g a.e.)
2,4-D/Dichlorprop (10 Drums)							
Total	9.83	4422/ 3011	3508/ 2684	226/ 115	97/ 61	33/ 32	18/ 19
Mean/Drum	0.98	442/ 301	351/ 268	23/ 12	10/ 6	3/ 3	2/ 2
SD	0.38	75/ 124	126/ 103	15/ 15	9/ 11	4/ 5	2/ 2
%	0.48[2]	0.55/ 0.48	79.3/[3] 89.1	5.1/ 5.8	2.2/ 2.2	0.7/ 1.1	0.4/ 0.6
2,4-D/Picloram (10 Drums)							
Total	12.34	3079/ 765	2800/ 663	127/ 47	74/ 36	48/ 14	30/ 5
Mean/Drum	1.23	308/ 77	280/ 66	13/ 5	7/ 4	5/ 1	3/ 1
SD	0.79	198/ 49	195/ 44	3/ 2	2/ 2	2/ 1	2/ 1
%	0.60[2]	0.63/ 0.62	90.9/[3] 86.7	4.1 6.1	2.4/ 4.7	1.6/ 1.8	1.0/ 0.7

[1]g a.e. - grams of acid equivalent
[2]Percent remaining in drums calculated from Table 2
[3]Percent removed of residual active by each rinsing

with dicamba the mean amount remaining was 6 g. Archer and Hisich (1973) detoxified metal drums of emulsifiable concentrate parathion with water and solvents and found a triple rinse of water removed between 94 and 99% (mean 97%) of residual insecticide. The first wash removed 88.2%, the second 6.7% and the third 2.3% of the residue left in the drums. In this study the first rinse removed between 74 and 91%, the second 4 to 18%, and the third 2 to 7% of each of the four components left after the drums had been emptied.

It was concluded that this emptying and rinsing system worked efficiently. Firstly, drums were emptied of between 98.7 to 99.6% of their contents. Secondly, the triple rinsing technique efficiently removed 97.4 to 98.8% of the residual herbicide. Collectively the emptying and rinsing procedures removed 99.99% of all four herbicides.

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